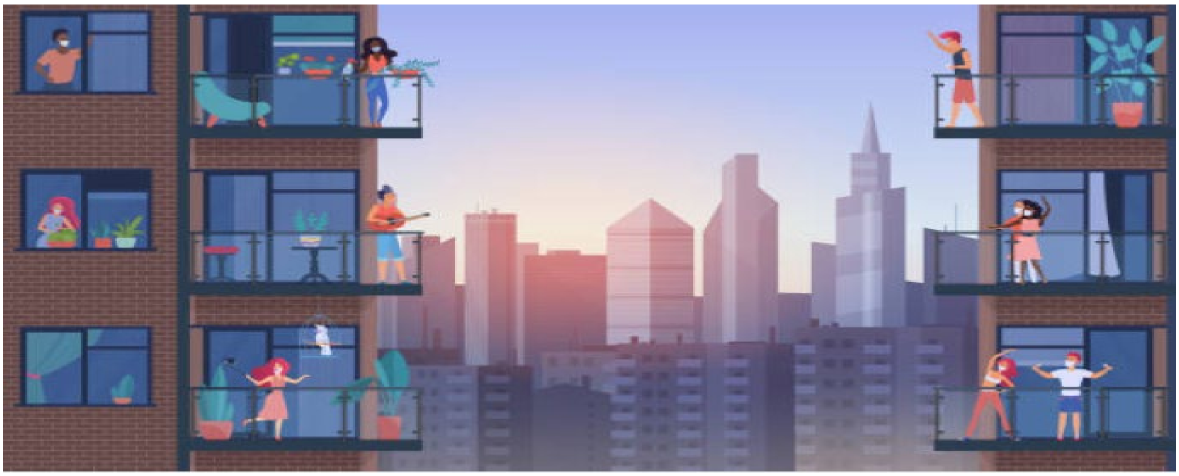
An investigation into water leakage of concrete balconies in residential apartment buildings



August 2024

Preface and acknowledgements

Swinburne University of Technology (SUT) has, with the support of the Housing Industry Association (HIA), conducted a research project to identify the causes of water leakage through concrete balconies in Class 2 buildings.[1]

Water leakage in balconies is both prevalent and costly in Victoria. This research aims to reduce the frequency of water ingress in concrete balconies in apartment buildings by identifying opportunities for improvement to concrete balcony design and construction practices, the National Construction Code (NCC) and/or relevant Australian Standards, the consideration of risk associated with balcony type and use, and the consideration of a holistic approach to balcony construction.

Project team

Prof. Shan Kumar (SUT), Chief Investigator and Lead Author
Simon Croft (HIA)
Prof. Jay Sanjayan (SUT)
Dr Scott Menegon (SUT)
Prof. Emad Gad (SUT)

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> The research team is aware of concurrent work being undertaken by the Australian Building Codes Board (ABCB). Current National Construction Code (NCC) 2025 draft content strengthens waterproofing and weatherproofing provisions.
>
> Given that NCC 2025 provisions are not yet finalised, reference to draft content is not referenced in this research. However, it is noted some matters identified within this report are already under consideration by the ABCB during the drafting of NCC 2025.
>
> Insights delivered by this research, including feedback received through consultations and interviews, have been shared with the ABCB and Standards Australia as part of their participation in the Research Advisory Group.

[1] A Class 2 building is a building containing two or more sole-occupancy units where people live above, besides, or below each other. This class may also include single storey attached dwellings with a common space below such as a carpark.

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Acronyms

- ABCB: Australian Building Code Board
- Act: *Building Act* 1993
- AS: Australian Standard
- AIW: Australian Institute of Waterproofing
- BMF: Building Minister's Forum
- BCA: Building Code of Australia
- CI: Chief Investigator
- CSV: Cladding Safety Victoria
- CRP: Cladding Rectification Program
- DtS: Deemed-to-Satisfy
- HIA: Housing Industry Association
- JASANZ: Joint Accreditation System of Australia and New Zealand
- MBS: Municipal Building Surveyor
- NCC: National Construction Code
- NATA: National Association of Testing Authorities
- PBS: Private Building Surveyor
- RNS: Relevant Building Surveyor
- SBS: State Building Surveyor
- SUT: Swinburne University of Technology
- VBA: Victorian Building Authority
- VCAT: Victorian Civil and Administrative Tribunal
- VMIA: Victorian Managed Insurance Agency

Definitions

- Defects: lack of something necessary for completeness; shortcoming.
- Building defect: any fault or deviation from the intended condition of a material, assembly or component.[2]
- Defective building: a building that is not fit for purpose due to a failing or shortcoming in the function, performance, statutory or user requirements of the building, where the failing or shortcoming has existed since construction or been triggered later 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 moisture barrier, which can be a sheet or applied as a liquid.
- Waterproof: property of a material that does not allow moisture to penetrate through when tested in accordance with AS 4564.1.

[2] This definition is obtained from the *National Dictionary of Building and Plumbing Terms*, an online dictionary published by Standards Australia in partnership with the Australian Building Codes Board. Available at https://www.constructiondictionary.com.au/, the definition of 'Building Defect' is sourced from HB 50-2004: *Glossary of building terms* (Standards Australia, 2004).

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1 Executive Summary

Water ingress and resulting building damage, particularly associated with external balconies of mid to high-rise apartments, is cited as one of the most common defects in Class 2 buildings, both nationally and in Victoria.

This research delivers insights about the processes, parties and practices involved in the design and building of concrete balconies in apartment buildings, and how the introduction of recommended reforms can minimise water leakage.

The research also analyses academic and grey literature, and relevant content from current Australian building standards and codes. This analysis is supported by feedback from key stakeholders and industry experts gathered by surveys, interviews, and observations of apartment buildings for case studies.

Given the significant economic and health impacts of leaky concrete balconies, addressing the knowledge gap to drive targeted improvements in concrete balcony planning, design, and construction will improve the built environment and deliver positive outcomes for the Victorian community.

1.1 Key findings

This research comprehensively examines five key issues that cause water ingress in concrete balconies:

- design, detailing, coordination and planning
- roles and accountabilities
- construction systems, practices and materials
- post-construction repair and maintenance
- guidance, education and training.

Across these five issues, sixteen recommendations for reform to regulation and/or practice are identified (see section 9). These reforms would significantly reduce the current problem of water ingress issues in concrete balconies of Victorian apartment buildings. Additional recommendations are also provided about the direction of future research to encourage increases in knowledge and the identification of potential solutions to the issue of water leakage.

Key themes identified across the research and in associated stakeholder interviews are:

- a current heavy reliance on waterproofing membranes during the design and construction of concrete balconies of as a primary protection measure, as opposed to a more holistic approach to balcony design and construction; and
- the need for unified and accessible building codes and standards for balcony design and construction, reducing the need to interpret numerous different components of codes and standards across issues such as structure, drainage, waterproofing, falls, material standards, windows and doors, balconies, hobs and finishing materials.

A holistic perspective that identifies the concrete slab as the primary protection against concrete balcony water ingress is recommended. Adoption of this perspective by all relevant parties to concrete balcony construction and design must by definition include consideration of the interrelationship between materials, site characteristics, falls, drainage, membranes, toppings and finishing materials.

Complementing this holistic perspective, a coordination and simplification of content about balconies is recommended across the National Construction Code (NCC) and relevant standards. The provision of a central source of information, incorporating design and construction requirements as well as generic detailing specifications, would increase the capacity and efficiency with which a wide range of building practitioners engage with this content.

In addition, the research identifies the following opportunities for reform:

- the adoption of a risk-based approach to design and construction that requires greater reinforcement of concrete balconies in higher-risk structures (particularly those with habitable spaces beneath them, and for buildings located near to coastal areas)
- changes to guidelines and standards regarding load limits and crack control
- increases in levels of detail in drawings of certified designs of concrete balconies
- improvements to the clarification of accountabilities and coordination of information between parties at the design stage, including an elevation to the role of the structural engineer as a leader in the design phase
- mandatory inspections of concrete balconies to ensure compliance of construction
- increased opportunities for education and training for practitioners, including the development and release of a freely available technical reference document
- promotion within industry of the use of approved products.

Figure 1 summarises the key issues identified by this research, and the associated recommendations for change.

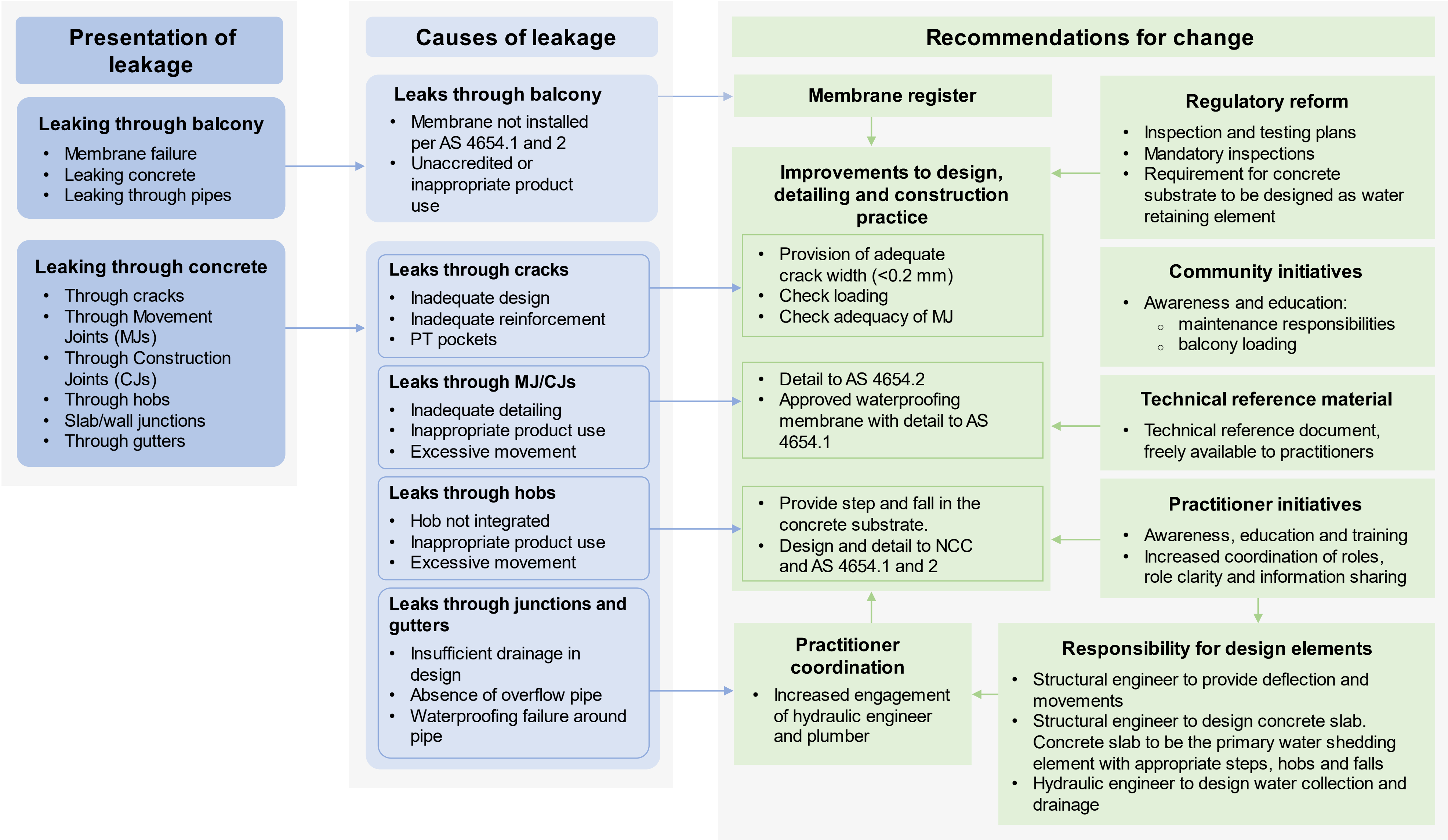

Figure 1: Presentation and causes of water ingress to concrete balconies, and a summary of proposals to minimise the occurrence of leaks.

2 Introduction

2.1 Background and research context

Water leakage due to inadequate water shedding and waterproofing/weather tightness, particularly of external balconies of mid to high-rise apartments, is often cited as one of the most common defects (Artibus Innovation, 2021) in Class 2 buildings, both nationally and in Victoria. Defects associated with balconies can lead to structural issues and can be costly to repair.

Through its work on the Victorian Government's Cladding Rectification Program, Cladding Safety Victoria (CSV) identified defective building work associated with balconies in a high percentage of the Class 2 buildings undergoing cladding rectification (Victorian State Government (Cladding Safety Victoria), 2023). Of the 270 buildings that received rectification funding in the program (as of October 2022), nearly one-third of Class 2 buildings were identified as having balcony defects:

- 84 buildings featured leaking balconies, balustrades, and terraces causing structural damage
- more than 550 defective balconies were identified, with these defects left unaddressed by the owners or builders during the defects liability period. Of these defective balconies:
    - 19 per cent have waterproofing issues due to lack or insufficient waterproofing
    - 52 per cent of defects were caused by water ingress
    - the balcony defects of seven buildings were likely to be related to poor design
- 64 per cent of impacted buildings were constructed more than 10 years ago.

The costs to rectify the defective balconies identified under the A$600m Cladding Rectification Program comprised approximately 38 per cent of the total value of cladding rectification contracts initiated through the scheme (A$228m as calculated (Victorian State Government (Cladding Safety Victoria), 2023)).

Further, a macro-economic analysis prepared for the Australian Building Codes Board (ABCB) (Centre for International Economics, 2021) found that repair costs associated with building defects amounted to approximately A$2.5 billion per year. Class 2 buildings contributed more than half of these costs overall ($1.3 billion, or 52%), and a staggering 38 per cent (around $500 million) of the rectification costs associated with Class 2 buildings are estimated to be spent on waterproofing/weatherproofing defects. However, it must be emphasised that this analysis, which provided a broad grouping of waterproofing and weatherproofing defects, did not provide detail about individual buildings. For example, the analysis did not provide information about the circumstances in which these defects occurred, nor did it provide profiles of the Class 2 buildings examined (e.g. the age of the buildings). For this reason, the extent to which these findings can be applied to other buildings may be limited.

The economic impact associated with defective balconies is not limited to owners and occupiers, who may claim rectification costs through strata insurance policies. As noted by Johnston, et al. (2021):

> Insurance statistics have shown that one of the topmost costliest claims are for water damage including water leakage in high-rise dwellings and commercial buildings. Approximately 30% of the total insurance spent on repairing water damage including water leakage defects.

A 2022 research report on defects assessment and the cost associated with insurance claims in Victoria between 2011-2018 (Sandanayake, Yang, Chhibba, & Vrcelj, 2022) revealed that 85 per cent of the total defects were caused by poorly executed work. This examination of Victorian Managed Insurance Authority[3] data found that, in terms of defect expenditure, waterproofing and water penetration in balcony construction topped the list.

This issue is not limited to Victoria. Recent research from New South Wales (NSW) about defects in apartment buildings, which surveyed strata managers, found that the common property of approximately 39 per cent of apartment (Class 2) buildings were reported to have serious defects. Of these, waterproofing was the most common serious defect (see Table 1) (New South Wales State Government (NSW Fair Trading), 2021).

Table 1: Proportions of serious defects found in a sample of NSW apartment buildings

Serious defects reported in common property	Proportion of all buildings surveyed	Proportion of buildings with a serious defect
Waterproofing	23%	63%
Fire safety systems	14%	38%
Structure	27%	27%
Enclosure	26%	26%
Key services	17%	17%
Non-compliant cladding	16%	16%

The consequences of water ingress to apartment balconies are not limited to economic concerns; the ramifications of water ingress can include serious consequences to the health and safety of occupants. Condensation and mould formation caused by water penetration/ingress through porous material can have a negative impact on human health and amenity (Dewsbury, et al., 2016). The impact of water leakage on porous or corrodible materials can also weaken integrity of structural elements, such as through balustrade failure (Wittocx, et al., 2022), which can then present life-threatening issues. Such findings reinforce the need to improve building practices, which would in turn reduce associated negative health, amenity, and structural integrity impacts from water leakage and water damage in apartment buildings.

2.1.1 Establishing root causes of water ingress to concrete balconies

While the potential impacts of water leakage and water damage in apartment buildings are well understood, the reasons for why and how this occurs in buildings, and effective solutions to help prevent this from occurring, are more complex to establish. In many cases, past research does not adequately identify the root cause of why leakage occurs, focusing instead on the ways that leakage can present within balcony structures (see section 7.1).

The presentation of water leakage in balconies is often termed a 'waterproofing defect,' but defects associated with waterproofing can include a very broad range of issues such as roof or window flashings failures, issues with parapet cuppings, rising damp, problematic cladding installations, aesthetic considerations, shower pooling, and condensation and/or mould growth. This research does

[3] The Victorian Managed Insurance Authority is the Victorian State Government's insurer and risk adviser. VMIA carries out functions as conferred by the *Victorian Management Insurance Act* 1996, including management of domestic building insurance (DBI) in Victoria, which provides cover to homeowners for incomplete or defective building work.

not dismiss the significance of these matters, or the importance of resolution to building owners and occupiers, rather it seeks to note and avoid such generalisations or groupings. This is an important step in identifying and preventing issues that are specifically related to balconies (and in particular, concrete balconies), to the exclusion of broader waterproofing issues (see also Figure 1).

Water ingress issues associated with balconies

Balconies may display a range of different issues that are causative to water ingress, including:

- inappropriate falls incorporated in the design
- a design that does not incorporate wind driven rain associated with the building's location
- interactions between different cladding systems
- lack of, or insufficient, drainage
- the installation of balcony balustrades
- the installation of windows and doors on balconies and level thresholds
- a hob installation that results in water pooling
- the lack of overhead protection for the balcony
- overloading of the structure
- the overloading or overwatering of planter boxes
- a lack of maintenance of drainage channels
- post occupation building work, and installations that compromise the waterproofing of the structure.

Underlying the diversity of the issues above is a smaller range of factors such as manufacturer and practitioner quality control, regulatory activity, the adequacy of maintenance, and the quality of installation. Any regulatory response must consider the underlying causative factors in order to truly address the varied causes of water ingress.

Caution should be taken in addressing these issues without considering the range of balconies to which a regulatory response may be applied, and the differences in their design, function and use. For example, different solutions are likely to be required for water ingress to a single apartment balcony, as compared to a high traffic building podium above a habitable space.

This research considers issues related to water ingress in balconies in a holistic fashion and provides insights that can be applied to address these issues. To achieve this, this research thoroughly investigates the causes of concrete balcony failure per a wide literature review, engages industry experts to leverage their expertise, and examines real-world case studies from design through to occupation. From this approach, this research considers the suitability of the provisions in the NCC and existing standards, and identifies opportunities for reform.

2.2 Objectives and scope

2.2.1 Objectives

The key objectives of this research 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 to reduce or eliminate water ingress/leakage in concrete balconies in Class 2 buildings, and

- make evidence-based recommendations for improvements to current regulations, standards, and work practice, and establish areas of focus for practitioner education and training.

2.2.2 Scope and exclusions

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

Issues associated with balconies of other forms of construction (such as timber and steel balconies) are not within the scope of this work.

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

Notwithstanding these exclusions, some of the items 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 fashion.

2.3 Methodology

A mixed-methods approach was adopted to investigate the causes of water leakage through concrete balconies for apartment buildings in the Australian building industry. This approach involved a systematic literature review, collection of practitioner expertise via an online survey and interviews, and an examination of practical application of balcony construction methods via case studies.

The research method is illustrated in Figure 2 and described below.

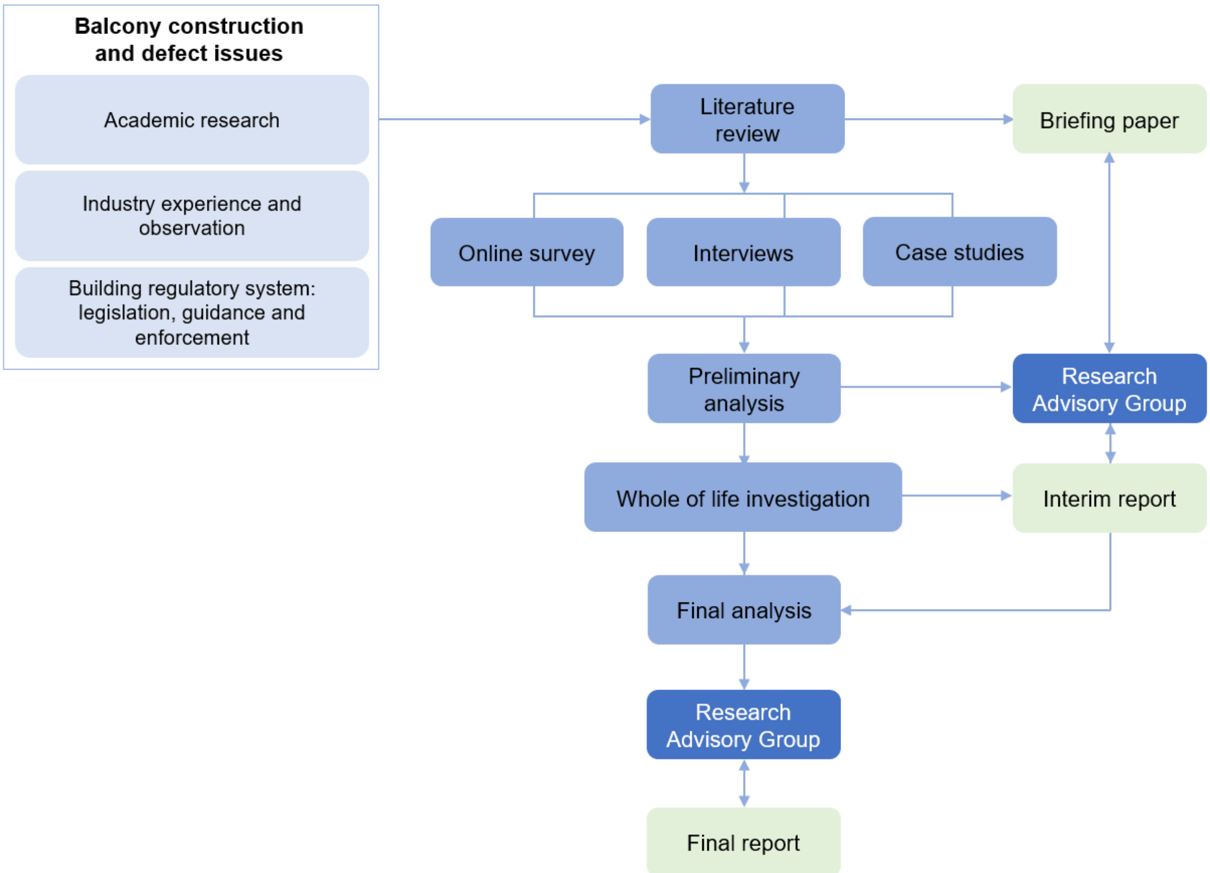

Figure 2: Research methodology

2.3.1 Literature review

The primary focus of this phase of research was to examine existing defects reports, practitioner guidance (e.g. Codes and Standards), academic literature and documented industry knowledge relating to water leakage through concrete balconies, and to investigate potential solutions to address the issue. This step served as the groundwork for the project, providing a comprehensive understanding of the issues involved, and enabled the preparation of a briefing paper to set the agenda for subsequent phases of research.

2.3.2 Research Advisory Group

A Research Advisory Group (RAG) has provided strategic direction and provide feedback and guidance to the research project so that it could best achieve its objectives. The RAG included members from the following organisations, as well as other industry experts:

- Swinburne University of Technology
- Housing Industry Association
- Victorian Building Authority
- Department of Transport and Planning (Victoria)
- Australian Building Codes Board (ABCB)
- Standards Australia, and
- Engineers Australia.

2.3.3 Online survey

Based upon the briefing paper established following the literature review, survey questions were devised by the research team. An online survey was published on the Housing Industry Association's website for one month, from 7 July 2023 until 7 August 2023. The survey was advertised through the HIA's July member newsletter, as well as through direct messaging to industry associations (including engineering and architectural consultants), universities, builders and subcontractors, suppliers, and government bodies.

To promote awareness of the importance and the seriousness of the concrete balcony leakage issue and raise interest in participation with online survey and stakeholder interviews, between August 2023 and March 2024 the Chief Investigator (CI) delivered presentations to engineers, architects and builders at number of webinars and seminars, including at the Concrete Institute of Australia's *Biennial National Conference* 2023.

The survey results have been summarised in Appendix A: Online survey.

2.3.4 Interviews with stakeholders

A selection of professionals across multiple disciplines were interviewed to obtain information and opinions from different perspectives (*n*=33, including structural engineers, architects, builders, waterproofing experts, waterproofing product suppliers, building surveyors, owners corporations, project managers and government agencies).[4]

[4] Interviewees included a diverse range of Australian participants, as well as the head of a well-respected international concreting institution.

Stakeholder interviews were conducted between August 2023 and February 2024. The research team is indebted to the interviewees for providing their valuable time, advice, and encouragement with the interviews. Their enthusiasm and willingness to participate in this interview process highlights the seriousness of the water leakage in apartment buildings concrete balconies.

Interview responses are summarised in Appendix B: Stakeholder interviews.

2.3.5 Case studies

An examination of case studies is key to research where evidence-based recommendations are expected. Case studies, representing the design and construction of concrete balconies in apartment buildings, were examined through workshops with engineers, architects, builders and waterproofing contractors. Eight stakeholder workshops were conducted across August 2023 and February 2024.

Most of the case studies are reported in anonymity at the request of practitioners, consultants, and consumers who provided them. Where drawings were not made available to the project, the CI has prepared illustrations of his understanding of the details.

Case study findings are presented in Appendix C: Case studies.

2.3.6 Whole of Life investigation

A whole of life (WOL) investigation, with the inclusion of estimated repair and replacement costs, was conducted to study the efficacy of various method of construction, repair, retrofit and maintenance during the service life of the balcony structure.

The results are presented in section 6.

3 Australian Practice

3.1 Current regulatory requirements

In Australia, all forms of building construction are subject to regulations, and have regard to planning and building administrative frameworks in place nationally, as well as additional requirements specific to each State and Territory.

This section of the research provides an outline of Australian practice regarding construction and guidance. It additionally identifies potential opportunities for improvements to these controls to mitigate some of the identified issues related to water leakage in concrete balconies.

3.2 National Construction Code

3.2.1 Overview

The National Construction Code (NCC) (Australian Building Codes Board, 2022) is Australia's primary set of technical design and construction provisions for buildings.

The NCC sets out the requirements for the design and construction of new buildings (and new building work in existing buildings) in Australia, including plumbing and drainage work.

The NCC is maintained and developed by the Australian Building Codes Board (ABCB) on behalf of the Australian and State and Territory Governments. The primary users of the NCC are architects, builders, plumbers, building surveyors, hydraulic consultants, engineers, and other building and plumbing-related professions and trades.

Each Australian State and Territory gives legal effect to the NCC via building and plumbing legislation.[5] Accordingly, each State/Territory has special requirements, which are included as separate schedules of the NCC for each State/Territory. States and Territories may vary the application of certain provisions of the NCC, and these are identified within specific provisions throughout the NCC and are also listed in the schedules.

Within the NCC, other relevant guidance documents are referenced, such as selected Australian Standards (AS). As referenced documents, these standards external to the NCC also become requirements for the materials, design, and construction of buildings. Referenced documents are listed in Schedule 2 of the NCC, and become part of the NCC when relevantly applied to meet a Performance Requirement.

Structure of the NCC

The NCC series is produced in three volumes. Volume One and Two are the Building Code of Australia (BCA) and Volume Three is the Plumbing Code of Australia (PCA):

[5] See *Governing requirements* of NCC 2022 (Australian Building Codes Board, 2022).

- NCC Volume One contains the requirements for Class 2 to 9 buildings.[6]
- NCC Volume Two contains the requirements for Class 1 and 10 buildings. Volume Two also comprises the ABCB Housing Provisions which contain the Deemed-to-Satisfy (DtS) Provisions that are considered to be acceptable forms of construction that meet the requirements for complying with Parts H1 to H8 of NCC Volume Two (i.e. they comply with the Performance Requirements listed those Parts of the NCC).
- NCC Volume Three relates to plumbing and drainage work associated with all classes of buildings.

In a similar manner to other countries that have adopted regulatory frameworks comparable to those in Australia, the NCC is performance-based code (Figure 3) that sets the minimum technical requirements for the safety, health, amenity, accessibility and sustainability of buildings.

The NCC's mandatory Performance Requirements set out the minimum performance level that the building or element of the building must achieve. Practitioners may choose to achieve these over-arching Performance Requirements via:

- a prescriptive DtS solution,
- a tailored or unique solution for the building by formulating a Performance Solution, or
- a combination of the two.

Historically, most solutions for building compliance follow the DtS compliance pathway. However, over time, as buildings have become more complex and bespoke, and as technology has advanced, the use of performance-based solutions within Class 2-9 buildings has increased.

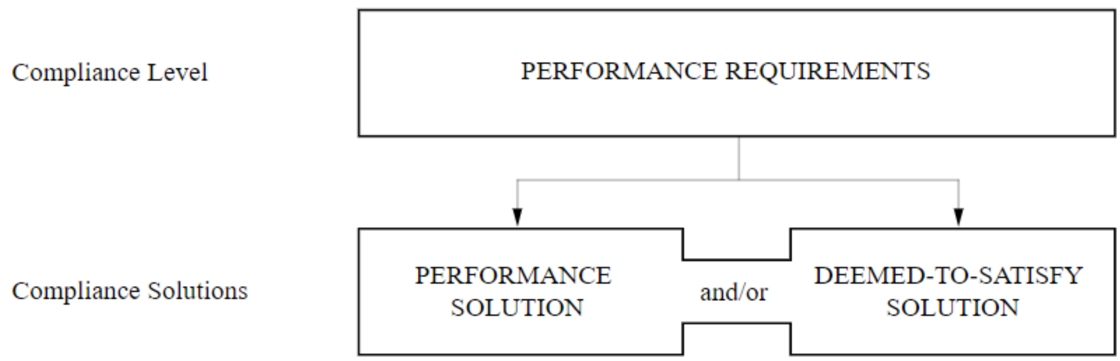

Figure 3: NCC compliance structure (see A2G1 per Australian Building Codes Board, 2022)

3.2.2 NCC requirements relevant to balconies

NCC Volume One contains provisions applicable to Class 2 – 9 buildings, and in general, balcony waterproofing is addressed under *Section F: Health and Amenity* (*Part F1: Surface water management, rising damp, and external waterproofing*, as well as *Part F3: Roof and wall cladding*). The relevant NCC provisions for design (from a structural perspective), materials and resistance to action are found within *Section B: Structure (Part B1: Structural Provisions).*

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[6] The NCC groups buildings by function and use. These groups of buildings are assigned a classification; some classifications also have sub classifications, referred to by a letter after the number (e.g. Class 1a). A building may have multiple parts, which have different uses. In most cases, each of these parts must be classified separately. A building (or part of a building) may also have multiple uses and therefore be assigned more than one classification. See *Part A6* of NCC 2022 and https://www.vba.vic.gov.au/building/regulatory-framework/building-classes.

NCC Performance Requirements relevant to balconies

Under *Section F* of the NCC 2022, there are a number of Performance Requirements that prescribe the intended performance level of buildings in relation to water and moisture management. These requirements are intended to protect not only building elements, but also the health and amenity of building occupants. These Performance Requirements include:

- F1P1 – managing rainwater impact on adjoining properties
- F1P2 – preventing rainwater from entering buildings
- F1P3 – rainwater drainage systems
- F1P4 – rising damp
- F3P1 – weatherproofing.

Other Performance Requirements within the NCC also hold relevance to concrete balconies, and are more focused on structural performance (as opposed to the water and moisture provisions listed above). Practitioners should also have regard to:

- B1P1 – structural reliability
- B1P2 – structural resistance
- B1P3 – glass installations at risk of human impact
- B1P4 – building in flood hazard areas.

Observations from this research about NCC Performance Requirements

In interviews conducted for this research, approximately 70 per cent of stakeholders highlighted the difficulty of interpreting and applying these Performance Requirements to development of Performance Solutions, or mapping comparative DtS solutions to these Performance Requirements. This observation is possibly linked to the fact that the Performance Requirements do not specifically refer to balconies and the waterproofing of balconies, as the same drainage and surface water components also relate to roofing, gutters and drainage around building structures as well as drainage/falls for balconies.

> If you go along the path of [a Performance Solution], you can do whatever you want and get it signed off by an expert. Who is checking that expert has [the] credentials to do so? No one.
>
> - Construction Director 1

> Sustainability [as an] issue sits above all these building defect issues. Code and Standards committees are giving importance to the sustainability, and in this process some of the other pertaining issues, such as water leakage, are sidelined.
>
> - Policy Advisor 1

Further, a lack of tangible and measurable targets in a number of these Performance Requirements increases the difficulty of devising a Performance Solution that suitably addresses performance requirements. This then leads to the potential for variable interpretation of the Performance Requirements and DtS provisions by practitioners, which may cause non-compliant design and building works.

> I was asked to sign off for a [Performance Solution] on a balcony waterproofing as an expert. Currently there is no specific guidelines to verify the credential of the expert… we advise on how to go about achieving the [Performance Solution] but there is no checking process that the builder has followed the advice. And other thing is: how do I confirm that the construction has not been changed since my signoff?
>
> \- Waterproofing Specialist 2

NCC Deemed-to-Satisfy provisions relevant to balconies

The DtS provisions for concrete balcony design and waterproofing for Class 2 buildings are provided in Part F1 of the NCC 2022. The primary DtS provisions for balconies design and waterproofing and mitigation against water ingress into the building are:

- F1D3 – Stormwater drainage
- F1D4 – Exposed joints
- F1D5 – External waterproofing membranes
- F1D6 – Damp-proofing.

From a weatherproofing, waterproofing, and prevention of water ingress perspective, two key NCC 2022 references for the design and construction of balconies are F1D5 (for external waterproofing) and F1D4 (for exposed joints in balcony and podium substrates and for planter boxes on balconies, podiums or occupiable roofs).

For example, exposed joints[7] in the drainage surface of a balcony must not be located beneath or run through a planter box or water feature. They should be located at a ridge or high point of the structural substrate and be protected from any anticipated excessive movement (e.g. through the use of hobs, and membrane design as detailed in Section 2.9 of AS 4654.2[8]). Balconies must also have a waterproofing membrane constructed from materials complying with AS 4654.1,[9] and be of a design and installation complying with AS 4654.2.

Other DtS provisions within the NCC also hold relevance to concrete balconies. Practitioners should also have regard to:

- F3D2 – Roof coverings
- F3D4 – Glazed assemblies
- F3D5 – Wall cladding
- B1D2 – Resistance to actions
- B1D3 – Determination of individual actions
- B1D4 – Determination of structural resistance of materials and forms of construction
- B1D6 – Construction of buildings in flood hazard areas.

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[7] Exposed joints include construction joints, control joints, expansion joints, contraction joints and movement joints, including those directly below drainage surfaces.

[8] Standards Australia. (2012). Waterproofing membranes for external above-ground use, Part 2: Design and installation. (AS Standard No. 4654.2-2012).

[9] Standards Australia. (2012). Waterproofing membranes for external above-ground use, Part 1: Materials. (AS Standard No. 4654.1-2012).

Observations from this research about NCC DtS provisions

In interviews conducted for this research, approximately 70 per cent of stakeholders highlighted the difficulty of interpreting and applying DtS provisions. Specifically, stakeholders communicated a perceived lack of holistic focus of the NCC and pointed out the lack of a central repository of requirements for concrete balconies. Specifically, stakeholders highlighted the significant number of provisions related to balconies that have a shared relevance to waterproofing, drainage, surface water, structural designs, materials and membranes, falls, designs, hobs, balcony barriers (balustrades), claddings, installation of doors and windows, and wind-driven rain design parameters.

> The NCC and standards are written in a way that allow people to interpret it in a particular manner and [then] not take responsibility when the error comes back to them, arguing that they have followed what the codes have told them to follow and they are not liable for the fault. The codes are also written as a legal document - written in a way that the codes themselves can't be held liable for a fault also. At the end, it becomes a legal battle and who can argue to the point that was a requirement was followed or not?
>
> \- Waterproofing Specialist 1

Another issue cited by stakeholders in interviews was that all balconies are essentially treated the same in terms of NCC DtS provisions. However, there is a wide variety of applications for balconies, with different risk profiles. For example, cantilevered balconies and balconies over habitable spaces have a different risk profile to balconies associated with a ground level walk up apartment. This issue of variable risk associated with different balcony types is considered further in section 7.4.4 of this research.

Heavy reliance on referenced Australian Standards and other related wall cladding standards was cited as an issue that increases complexity of, and decreases coordination across, a large number of compliance materials. Approximately half of the stakeholders interviewed indicated a preference for first-principle design standards, rather than standard construction detailing and installation standards.

> Standards and codes are fairly robust and good most of the time, but they do not cover all the details and there are gaps and it's left to the engineer and architect to figure it out. It [would be] good to identify the gaps and address solutions to make it a complete document. This will help addressing some water leakage issues in balconies.
>
> \- Policy Advisor 3

3.3 Australian Standards

There are numerous Australian Standards (AS) that are relevant to the design of concrete balconies (see Figure 4).

Of central relevance are the AS that set out requirements about:

- material specification and design (AS 4654.1), and the installation of membranes (AS 4654.2). Such membranes often require compliance with additional AS, such as to meet slip resistance and heat aging requirements, and to be detailed to deal with wind issues

- the substrate design requirement for concrete slabs according to AS 4654.2 (Clause 2.5.1, Note (a)) refers to AS 3600[10] for reinforced concrete design.
- the substrate design requirement for screed and tiles according to AS 3958[11] (Clause 3.2.4)
- loading requirements as given in AS/NZS 1170.1[12] for floors and barriers including balustrades. Balustrades, which can be made from a variety of materials are subject to a range of standards depending on material type. Wind loading requirements is as given in AS/NZS 1170.2[13] and the Earthquake Loading requirements to as given in AS 1170.4.
- the geometry of the balcony and its compliance with access and mobility requirements (AS 1428.1)[14]
- the drainage and plumbing requirements of the balcony (AS 3500.3).[15]

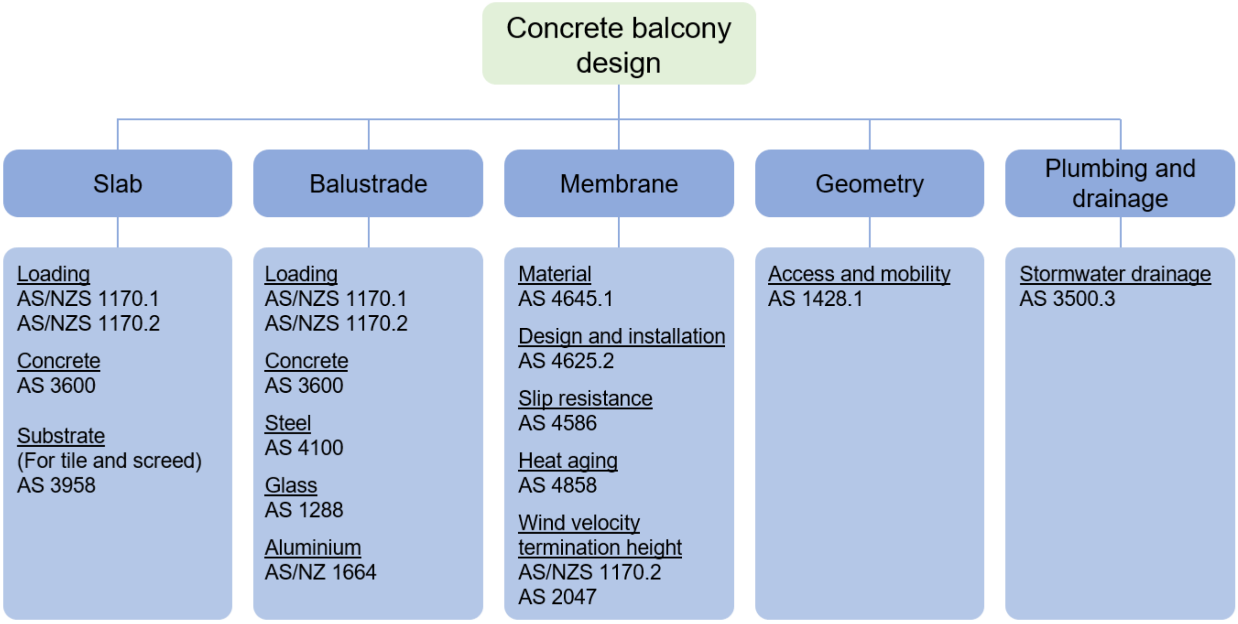


Figure 4: Australian Standards relevant to concrete balcony construction

3.3.1 AS 4654.1 Waterproofing membranes for above ground use - Part 1: Materials

The objective of AS 4654 (parts 1 and 2) is to provide a consistent and reliable approach to both the materials used, and the design and installation of external waterproofing membrane systems.

AS 4654.1 sets out the requirements for materials used within waterproofing systems, and describes the material properties of the waterproofing membrane used. The guidance provided within AS 4654.1 is intended to ensure that the material properties of membranes are waterproof (impervious

[10] Standards Australia. (2018). Concrete Structures (AS/NZ Standard No. 3600:2018).
[11] Standards Australia. (2023). Concrete Structures (AS/NZ Standard No. 3958:2023).
[12] Standards Australia. (2002). Structural design actions, Part 1: Permanent, imposed and other actions. (AS/NZ Standard No. 1170.1:2002).
[13] Standards Australia. (2021). Structural design actions, Part 2: Wind action. (AS/NZ Standard No. 1170.2:2021).
[14] Standards Australia. (2021). Design for access and mobility, Part 1: General requirements for access — New building work. (AS Standard No. 1428.1).
[15] Standards Australia. (2021). Plumbing and Drainage, Part 3: Stormwater Drainage. (AS/NZS Standard No. 3500.3).

to moisture), and that membranes remain waterproof under a variety of situations, exposures and conditions.

There are five main types of waterproofing membranes. These are differentiated by the way they are attached to the substrate and held in position (ballasted, fully bonded, inverted roofs, mechanically fastened, and partially bonded).

Waterproofing membrane systems may be either *exposed* to the elements of weather (e.g. UV radiation) or *protected* from these elements with finishes/coverings installed over them. It is therefore important to know the requirements of the intended waterproofing area, and to ensure the materials are fit for the purpose for which they are being installed.

AS 4654.1 sets out requirements of the material properties of different types of waterproofing membranes, as determined by scientific testing. Some of the waterproofing membrane material properties that are assessed in AS 4654.1 are:

- thickness
- tensile strength
- puncture resistance
- elongation at break
- root resistance
- temperature resistance
- resistance to ultraviolet radiation (UV).

Observations from this research about AS 4654

One broad issue with AS 4654, in parallel to that identified regarding NCC content, is that it primarily relates to the waterproofing membranes as opposed to taking a more holistic approach to balcony design and construction.

A narrow focus within AS 4654 on waterproofing elements and the membranes, rather than on the waterproofing system as a whole, increases the likelihood that designers or practitioners also adopt this narrow focus. As emphasised elsewhere in this report (see section 6), a holistic perspective is recommended to reduce the likelihood of defects, such as those that allow water ingress into concrete balconies.

Further, there is a perceived lack of clarity within AS 4654 about where and how its provisions are to be applied. This means that it may also be difficult for some practitioners to link the policy intent of NCC provisions with the direct application of the standard's provisions in a real-world construction environment. For example, a practitioner designing a balcony may apply all components of AS 4654, or they may apply only the components relevant to waterproofing membranes; likewise, they may be unclear whether there are parts of AS 4654 that are relevant to all balconies and podiums, or restricted to certain types of these structures.

> With respect to waterproofing in open balconies, podium rooftop terraces are not well understood in general. NCC 2022 and AS 4654.1 1 and 2 are very difficult to follow and are not clear enough in certain aspect of compliance requirements. Diagrams in AS are difficult interpret and some information's are [sic] informative too (termination height of membrane). For example, overflow pipe size locations are not specified for all types of balconies.
>
> - Construction Director 1

3.3.2 AS 4654.2 Waterproofing membranes for above ground use - Part 2: Design and installation

AS 4654.2 sets out the requirements for the design and installation of waterproofing membranes for above ground use. These are associated with external waterproofing membrane systems applied to roofs, decks, balconies, and planter boxes in buildings.

AS 4654.2 contains two sections:

- Section 1 – the scope and definitions that apply to the AS
- Section 2 – sixteen parts that address the design and installation of external waterproofing membrane systems, including service conditions, substrate requirements, membrane placement and location, curing, treatment at door and window openings, movement control, drainage, and overflows.

AS 4654.2 also contains two appendices:

- Appendix A – information about vertical upward termination heights, including the minimum vertical termination height of the membrane where a membrane is to prevent water entry
- Appendix B – information about maintenance, including specifying that where visible a waterproofing system should be inspected on a regular basis for evidence of deterioration.

The primary users of AS 4654.2 are builders, waterproofing contractors, designers, building certifiers, building surveyors, and tilers.

3.4 Product conformity

Alongside the technical design and construction provisions in the NCC and related standards, there are additional building product conformity requirements, which include processes for building product testing, certification, and approval.

The NCC contains building product conformity requirements under its evidence of suitability provisions (Australian Building Codes Board, 2021), which lists product evidentiary requirements and the means by which a material, product, design, or form of construction should take to demonstrate compliance with the NCC.

In Victoria, building product accreditation is granted by the Building Regulations Advisory Committee (BRAC). Product accreditation includes the construction methods, design components, and systems connected with building products.

Many of the AS referenced in the NCC contain testing requirements for products to show compliance with those AS. Under these provisions, the NCC provides several ways to demonstrate compliance:

- certificate of Conformity from WaterMark, a mandatory certification scheme for plumbing and drainage products
- certificate of Conformity from CodeMark, a voluntary third-party building product certification scheme
- certificate of Accreditation from a State or Territory Accreditation authority
- certificate from an appropriately qualified person such as an engineer
- certificate from a product certification body accredited by the Joint Accreditation System of Australia and New Zealand (JASANZ)
- report registered by a registered testing authority, or
- other documentary evidence, for example, a certificate through an industry scheme.

Observations from this research about product conformity

Not all waterproofing materials available for purchase have CodeMark certification or BRAC accreditation. While unaccredited materials used in waterproofing membranes have been tested by an Accredited Testing Laboratory or have equivalent product evidentiary requirements, this testing may have been conducted on a prototype in a factory or testing environment, rather than as in-situ testing on sites. This means that onsite practitioners must install the product per the tested specimen in order to achieve the stated performance. Where this does not happen during concrete balcony construction, defects may occur that leave the balcony vulnerable to water ingress.

The correct application of membranes is also dependent on the correct preparation of the substrate. Often, a membrane needs to be installed in conjunction with a compliant system of products rather than an ad-hoc mix of similar products. If this occurs during concrete balcony construction, defects may occur that leave the balcony vulnerable to water ingress.

4 Victorian Regulatory Framework

The Victorian *Building Act 1993* (the Act) sets out the framework for the regulation of building construction, building standards and the maintenance of specified building safety features (Figure 5).

The *Building Regulations 2018* are a subordinate legislation of the Building Act and contain, among other content, requirements relating to building permits, building inspections, occupancy permits, enforcement, and the maintenance of buildings.

The *Building Regulations 2018* adopt the Building Code of Australia (BCA), which is part of the NCC. The ABCB, on behalf of the Australian Government and each State and Territory government, produces and maintains the NCC.

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

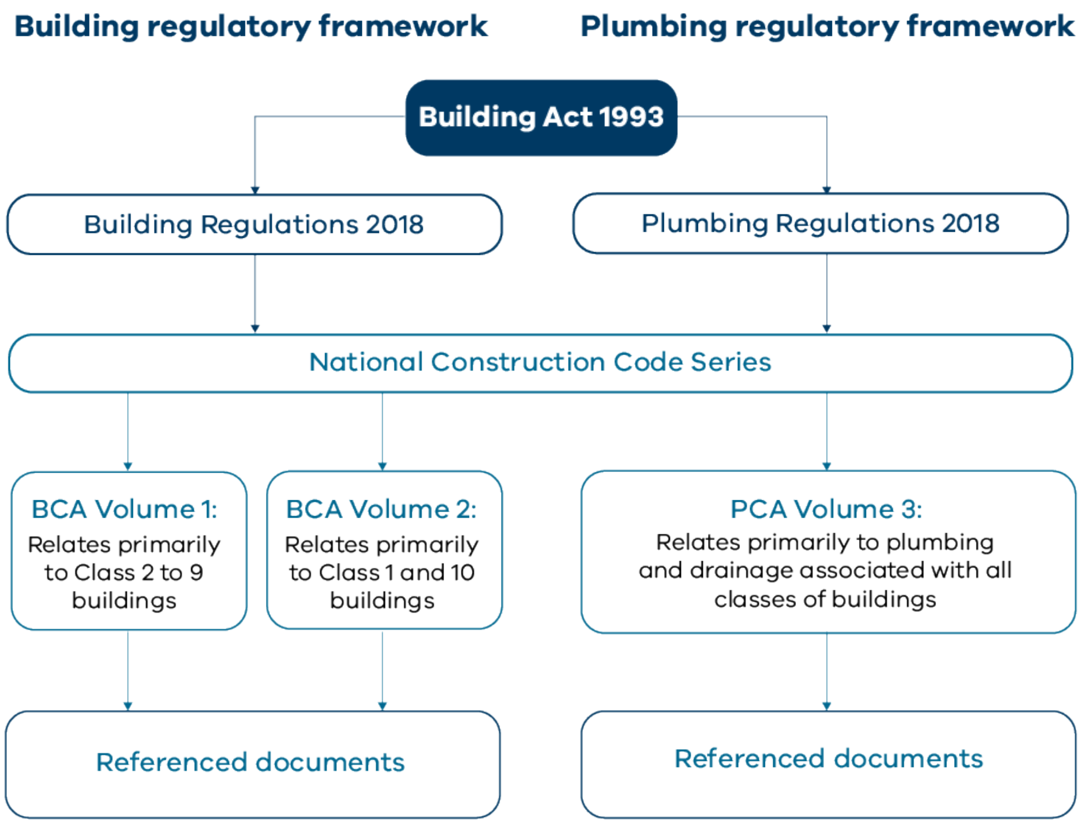


Figure 5: Victorian Regulatory Framework (Victorian Building Authority, 2024)

4.1 Planning in Victoria

The Victorian Planning Provisions (VPP), established under the *Planning and Environment Act* 1987 (PE Act), are template and reference documents on which planning schemes, and their provisions, must be based (Victorian State Government (Department of Transport and Planning), 2024). The VPP is applied to all planning schemes in Victoria per guidance within the Ministerial Direction s7(5) *The Form and Content of Planning Schemes* (Victorian State Government (Department of Transport and Planning), 2017 (amdt 2023)).

There are provisions within the VPP for private and open spaces, which for apartment buildings are interpreted as the inclusion of balconies (see Clause 58-05-3).

4.2 Consumer protections under the Victorian regulatory framework

There are a series of regulatory requirements set in place to protect consumers from the consequences of engaging persons who work outside of the regulatory framework.

The VBA advises consumers that constructing or replacing a balcony must be done legally, which "... usually means: applying for a building permit [and] having the balcony appropriately designed and documented" (Victorian Building Authority, n.d.).[16]

Further, a building permit levy is payable if the cost of building work is $10,000 or more. This means that residential works over $10,000 will always require a building permit, as a building permit is required for levy payment. A building permit is issued by a building surveyor, and cannot be issued unless all building practitioners listed on the building permit as responsible for the project are appropriately licenced or registered.

Additionally, a practitioner must be registered with the VBA if they carry out work worth more than $10,000, or use a combination of skills (such as plastering and painting) for the works, or if they perform structural building work.

Under the *Domestic Building Contracts Act 1995*, consumers are required to enter into a major domestic building contract for building and renovating when the value of works is over $10,000. This contract provides protections for consumers under both the *Domestic Building Contracts Act 1995* and the Australian Consumer Law (Consumer Affairs Victoria, 2021).

Further, under the *Building Act 1993*, in order for a building practitioner to enter into a major domestic building contract, they must hold a current registration as a building practitioner with the VBA.

Taken together, these obligations mean that in general, there is a $10,000 threshold over which consumers are afforded legislated rights and protections. However, this threshold will not appear to be met if a practitioner issues invoices to consumers in smaller amounts over time. Indeed, Consumer Affairs Victoria (CAV) warns consumers against persons engaging in contract splitting practices in order to avoid entering into a major domestic building contract (Consumer Affairs Victoria, 2023). Such a warning evidences this practice (though it does not speak to its frequency); it also highlights

[16] There are a number of exceptions to this requirement (see Victorian Building Authority, 2023).

the impact on consumers who commission costly works but are then unable to rely on their legislated rights as they could have, had a contract been in place. In these cases, a builder, who may not be registered, works largely outside the regulatory scheme, and may not build per requirements for compliance under the NCC and relevant AS. This could be in order to be able to underbid (and be more likely to be awarded work, such as subcontracting for waterproofing membrane installation), or be due to insufficient skills or knowledge about regulations.

4.3 Registration of waterproofing installers in Victoria

4.3.1 Requirements for registration

In Victoria, there is no universal requirement for a person performing waterproofing works to hold registration as a building practitioner. Rather, the value of works and the contractual arrangements between the parties will guide any registration requirements.

As discussed above in section 4.2, under the *Domestic Building Contracts Act 1995*, a major domestic building contract is required for most domestic work valued at more than $10,000. In order for a building practitioner to enter into a major domestic building contract, they must be registered with the VBA under the *Building Act 1993*.

This means that any owner seeking total domestic building works valued at more than $10,000 will be required to establish a contracted arrangement with a practitioner registered by the VBA. This might include a contract with a Domestic Builder - Unlimited (DBU) for the construction of the building and/or the waterproofing, or a Domestic Builder - Limited (Waterproofing) (DBL-W)[17] for the waterproofing alone.

Further increasing the complexity of these arrangements, any DB-U may choose to sub-contract the waterproofing works to a third party. Any party they hire to perform the waterproofing is not required to hold any kind of registration. This is due to the fact that under this subcontracting arrangement, the warranty and responsibility of the waterproofing remains with the DB-U, who should oversee the works and ensure that they are fully satisfied with the works and their compliance with regulations.

There is presently no national or Victorian strategy to impose regulations about the registration status of subcontracted parties, and that doing so is likely to impose a significant regulatory burden upon both industry and the State (Shergold & Weir, 2018).

4.3.2 Proposed changes to registration of tradespersons in Victoria

The Building Confidence Report made a recommendation for national extensions to the number and scope of categories for building practitioners involved in the design, construction and maintenance of buildings (Recommendation 1; Shergold & Weir, 2018).

The Victoria State Government made amendments to the *Building Act 1993* in late 2018 to introduce a registration and licensing scheme for tradespersons. This scheme aims to reduce non-compliant

[17]The *Building Regulations* 2018 provides for the registration category of builder (see Schedule 9, item 30 for the class of commercial builder limited to waterproofing, and Schedule 9, item 46 in for the class of domestic builder limited to waterproofing). However, the registration category of builder does not incorporate all waterproofing tradespersons.

building work, enhance industry accountability, and encourage consistency of industry skill. Changes are proposed be implemented for carpentry practitioners in the first stage of change, and other trades will follow in subsequent implementation stages. Waterproofers are included in the proposed second stage of change.

The Victoria State Government has stated its intent to release a Regulatory Impact Statement and draft regulations for public consultation via Engage Victoria, the Victorian Government's online consultation platform (Victorian State Government, 2022).

5 Introduction to balconies

5.1 Context

In the modern era, a balcony is broadly defined as a platform enclosed by a wall or barrier on the outside of a building, with access from an upper-floor window or door. This definition applies to apartment building balconies (specifically, Class 2 buildings as defined within the NCC).

Balconies can be utilised for enjoying the view, growing plants, relaxing or entertaining guests, and Australians love their balconies for these reasons. Apartment Design Guidelines for Victoria (Victorian State Government (Department of Transport and Planning), 2021) explains the importance of a balcony:

> Access to functional and usable private open spaces - outdoor spaces such as balconies, courtyards and terraces accessible only to the particular apartment - allows occupants to extend their living spaces outdoors to enjoy a range of recreations.

Figure 6: Balconies
(Victorian State Government (Department of Transport and Planning), 2017)

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

5.2 Common balcony types

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

- cantilevered or spanning (i.e. supported by load-bearing elements such as walls and columns)
- stacked
- false, and
- hung.

Figure 7: Common balcony designs incorporated into modern Australian buildings
From left to right (top) cantilevered and stacked; (bottom) false and hung.

The scope of this research includes four cantilevered and spanning concrete balcony types (Figure 8Figure 8: Balcony Types):

1. Projecting open balconies. This type of balcony projects outward from the structure's exterior wall, but has no roof or windows.
2. Projecting enclosed balconies. This type of balcony projects outward from the structure's exterior wall, and has a roof and windows (which can be closed or openable).
3. Recessed/inset open balconies. This type of balcony is inserted into the structure's exterior wall. It has a roof, but no windows.
4. Recessed/inset enclosed balconies. This type of balcony has a roof and windows (which can be closed or openable).

Figure 8: Balcony Types within the scope of this research

Ribeiro, Ramos, and Flores-Colen (2020) note the evolutionary importance of balcony usage, and explain the increased prevalence of balconies:

> Balconies are an ancient architectural archetype that are being increasingly considered in multi-family buildings of high-density cities… Developing compact and high-density cities is becoming a strategy to promote sustainable development, accommodating population growth, and mitigating human impacts on the local and global environment. During this increasing urbanization, balconies of multi-family buildings are replacing courtyards and gardens as a desired private outdoor space.

Furthermore, Ribeiro et al. observed that open balconies are particularly popular in high-density cities, especially in warm regions such as those with tropical and sub-tropical climates. This is true across Australia, and in Victoria are recognised within the state's Apartment Design Guidelines for Victoria (Victorian State Government (Department of Transport and Planning), 2021), which includes provisions for private, open spaces such as balconies.

5.3 Concrete balconies: key components

The main components of the balconies within the scope of this investigation include:

- concrete slab
- barriers including balustrades and handrails
- waterproofing membrane
- floor drainage, and
- final floor finish.

Descriptions of each of these elements are provided below in section 5.3.1 to section 5.3.6. Construction of these elements, and compliance with NCC 2022 Deemed to Satisfy (DTS) provisions, are discussed below in section 5.3.7 and illustrated in Figure 9 and Figure 10.

5.3.1 Concrete slab

A concrete slab is a load bearing element defined as a concrete substrate.[18] Concrete slabs are either cantilevered or spans between beams, walls or columns. Reinforced or post-tensioned concrete[19] are the most preferred methods of construction in Australia and in some instances, this can be precast rather than poured in situ.

The concrete slab constitutes the primary line of defence in terms of water ingress when designed and detailed appropriately. Current practice indicates that an upstand hob or surface set down, integrated surface fall and adequate drainage will be sufficient to minimise water leakage.

Concrete is a versatile material if it is designed, constructed, and maintained to appropriate codes and standards. Concrete is strong in compression and weak in tension, so reinforcement and/or post-tensioning may be added to enhance its tensile strength. While this performance enhancement makes concrete a versatile material, contact with water will cause corrosion to the reinforcement.

Therefore, as cracking in concrete and subsequent water penetration can weaken the reinforcement, it is essential to keep cracking under control for structures exposed to weather,[20] such as balconies and roof terraces.

For exposed concrete and water retaining structures, a mixed design is normally specified by structural engineers, incorporating requirements for low shrinkage and low permeability (watertightness). Otherwise, water ingress through shrinkage cracks and permeable concrete, resulting in subsequent corrosion of reinforcement, is likely. Adequate cover to the reinforcement will also extend durability of the concrete structure.[21] However excessive cover may increase the tendency for cracking and hence an optimum cover selection based on the exposure condition complying to AS is critical.

5.3.2 Concrete quality

A number of academic literature reviews have identified inferior quality of concrete as an issue that can lead to water leakage in concrete balcony slabs (Campion & Cannella, 2019 and Chew & De Silva, 2020). This finding is supported by observations from the online survey and stakeholder interviews conducted for this research:

> The concreter will just say: "Oh, it doesn't matter, it's full of concrete, no one will ever see it." They have to work it out, and you know, they are on site… they are just trying to finish the job so they can get on to do the next project, and the fact that suddenly something gets 5 [mm] cover, they are not worried about it. So, your steel will end up having around 5 [mm] cover. That's just a classic example of what goes wrong in these sorts of balconies.
>
> - Structural Engineer 3

The project structural engineer and the contractor are responsible for ensuring that a balcony's slab is designed and constructed with concrete that has adequate strength, impermeability, and cover to

[18] AS 4654.2 (Standards Australia, 2012).
[19] AS 3600:2018 (Standards Australia, 2018), *Definition*: cl 1.6.3.73 (reinforced) and cl 1.6.3.67 (post-tensioned).
[20] AS 3600:2018 (Standards Australia, 2018), cl 2.33 (cracking) and cl 4.3 (exposure).
[21] AS 3600:2018 (Standards Australia, 2018), *Section 4 - Design for durability:* cl 4.10 (adequate cover) and cl 4.1 (length of durability).

limit water ingress and avoid corrosion of steel reinforcements across the balcony's intended life. The following measures are recommended for achieving concrete quality:

- The contractor must ensure the correct bar chairs are securely fixed to maintain adequate cover during concrete placement.
- Weather conditions (rain, wind, temperature, and humidity) at the time of concrete placement can substantially affect the quality of the hardened concrete. The contractor must have adequate control measures to ensure the weather conditions will not adversely affect the concrete placement.
- Cold joints, construction joints and post-tension pockets should not be permitted on the balcony slab with a habitable space below.
- The following measures must be used to achieve acceptable permeability as a water-retaining concrete slab:
    - A suitable concrete mix is to be specified and used.
    - Adequate crack control reinforcement shall be used to limit crack width to the relevant standards (0.2 mm for AS 3600 and 0.15 mm for AS 3735).
    - Concrete must be cured as per guidelines set out in Australian standards (AS 3600 and AS 3799).

5.3.3 Barriers (including balustrades) and handrails

Barriers, such as balustrades and parapets, are safety elements that prevent people from accidentally falling from a balcony edge, while handrails assist people with circulation and continuous movement. Commonly used materials are steel, glass, aluminium, timber or concrete (precast or in situ). The design and construction of barriers and handrails should conform to BCA and AS requirements as well as relevant material design standards (according to the material type chosen). Base fixings of balustrades and the waterproofing around it are critically important.

The design loads (live and wind) on the barrier, the design actions imposed on the concrete slab, and the base fixing of the balustrade are the responsibility of the project structural engineer.

5.3.4 Waterproofing membrane

The material used as an impervious moisture membrane must comply with AS 4654.1 and can be sheet or liquid applied. The use of the membranes as part of a waterproofing membrane system must be designed and installed according with AS 4654.2 (Standards Australia, 2012). The interface of such membranes with upstands, doors, façade elements, movement joints and drainage points require special attention at design to ensure that the membrane has appropriate strength, compatible to concrete substrate, capable of withstanding concrete substrate and associated building movements, coverage, and at construction to ensure that the integrity of the membrane is preserved. Without this attention, water ingress may result.

5.3.5 Floor drainage

Floor gullies with drainpipes that securely dispose of water are typically incorporated within exposed/open balcony designs. Overflow flood outlets are installed as a safety mechanism for disposing of water in case of a blocked drainpipe. In some cases, the floor slopes to the edge, and water is collected via a gutter, or is allowed to shed freely from the building on the ground below.

For balconies and terraces plumbing, drainage and overflow pipe must be installed according to AS 3500.3.

5.3.6 Final floor finish

In situ screed to falls is sometimes provided, with tiling, pavers or decking on legs/pods to achieve desired levels and surface finish/appearance.

5.3.7 Typical balcony design and construction

A typical method of construction (which demonstrates compliance to AS 4654.2) has been interpreted by the authors shown in Figure 9 and Figure 10. For a successful waterproofing system, an integral set down and fall in the concrete substrate must be formed, and the waterproofing membrane should be applied on the fall and inside the drain outlet (not the outside). Further, the overflow level must be below the waterproofing line.

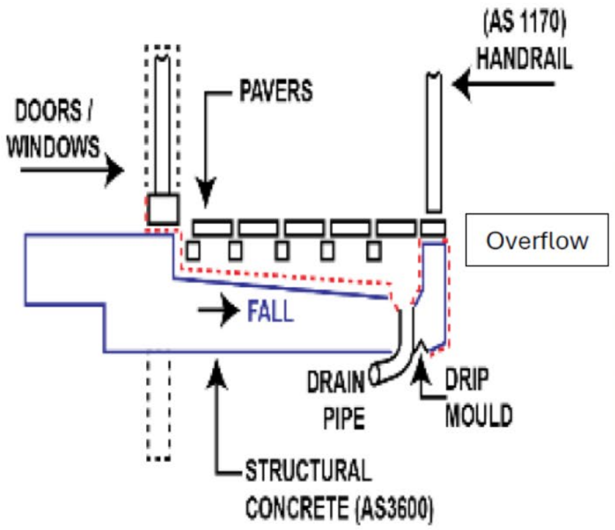
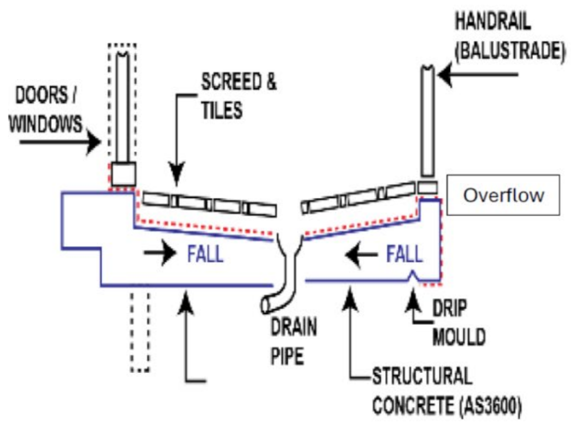


Figure 9: Typical concrete balcony construction details (pods and pavers installation).
The waterproofing membrane is per AS 4654.1, and indicated by a dotted red line (- - - - -).



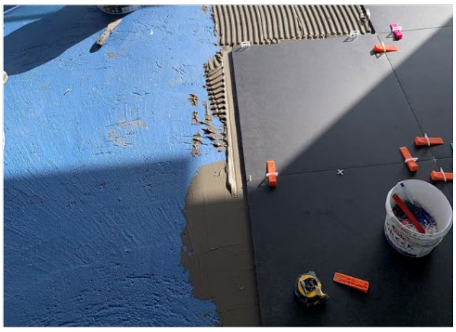


Figure 10: Typical concrete balcony construction details (screed and tile installation).
The waterproofing membrane is per AS 4654.1, and indicated by a dotted red line (- - - - -).

The preferred method of construction for many builders has no set down (in order to minimise the cost of building), avoiding a folded concrete slab, and maximising ceiling height. This method of construction has been graphically interpreted by the authors in Figure 11 and Figure 12. However, builders are able to choose to use performance-based solutions as described within the NCC (see section A2G2) to obtain acceptance by the relevant building surveyor (RBS). It is the role of a design practitioner to prepare performance solutions (in coordination with the relevant stakeholders, including the builder) and follow the relevant process. When followed, these steps allow for a holistic compliance assessment in lieu of ad-hoc or 'on the go' performance solutions that seek to address non-compliances on site.

The method of construction as described in in Figure 11 and Figure 12 generally does not demonstrate compliance to the NCC per AS 4654.2 (Standards Australia, 2012), and if constructed as shown would require a Performance Solution as approved by a building surveyor per section A2G2 of the NCC 2022.

In Figure 11, non-compliant construction is observable due to the membrane termination height, the member termination at the drainpipe, the membrane as applied to a flat substrate, the lack of an overflow pipe, and a potential trip hazard.

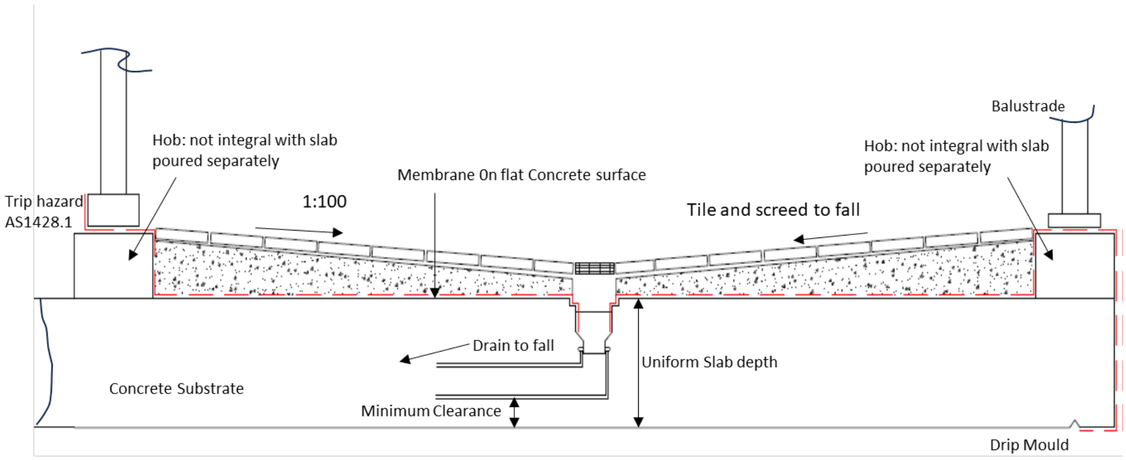


Figure 11: Preferred construction by builders (screed to falls and no set down)
The waterproofing membrane is indicated by a dotted red line (- - - - -).
The method of construction for the tile and screed complies with AS 3958:2023 (clause 3.2.4).

In Figure 12, non-compliant construction is observable due to the membrane termination height and the absence of a step-down, the membrane as applied to a flat substrate, the lack of an overflow pipe, and a potential trip hazard.

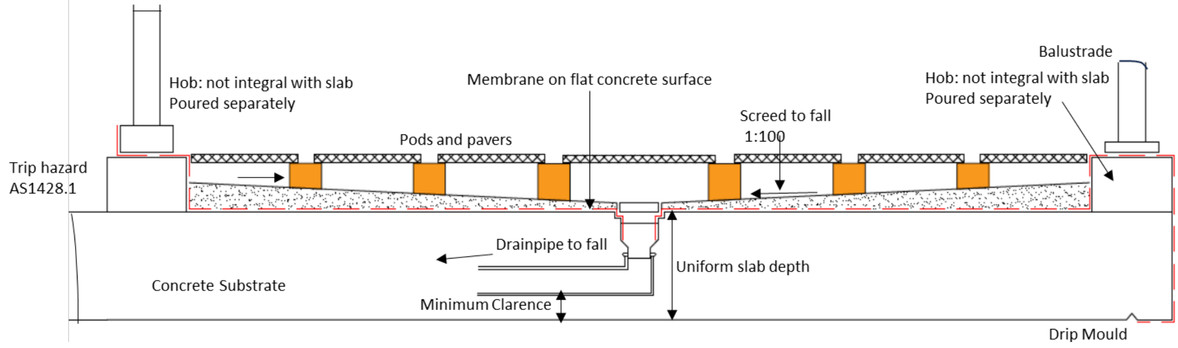


Figure 12: Preferred construction by builders (screed to falls with tiles/pavers and no set down)
The waterproofing membrane is indicated by a dotted red line (- - - - -).
The method of construction for the concrete floor complies with AS 3958: 2023 (clause 3.2.4).

Typically, when a concrete substrate is formed flat, a hob is installed to create the required fall in the screed, and a waterproofing membrane is applied on the concrete substrate or on the screed. Figure 13 shows a standard detail adopted by architects, where the membrane is laid on screed with a fall, but there is no integral fall to the concrete.[22] This is a more satisfactory detail than one with a membrane laid on the flat substrate, where water would otherwise accumulate. However, when the membrane reaches the end of its product life cycle, water will be able to penetrate through the screed, and will accumulate on the flat surface of the concrete substrate. Water ingress may then occur through the porous concrete and/or any cracks present in the concrete.

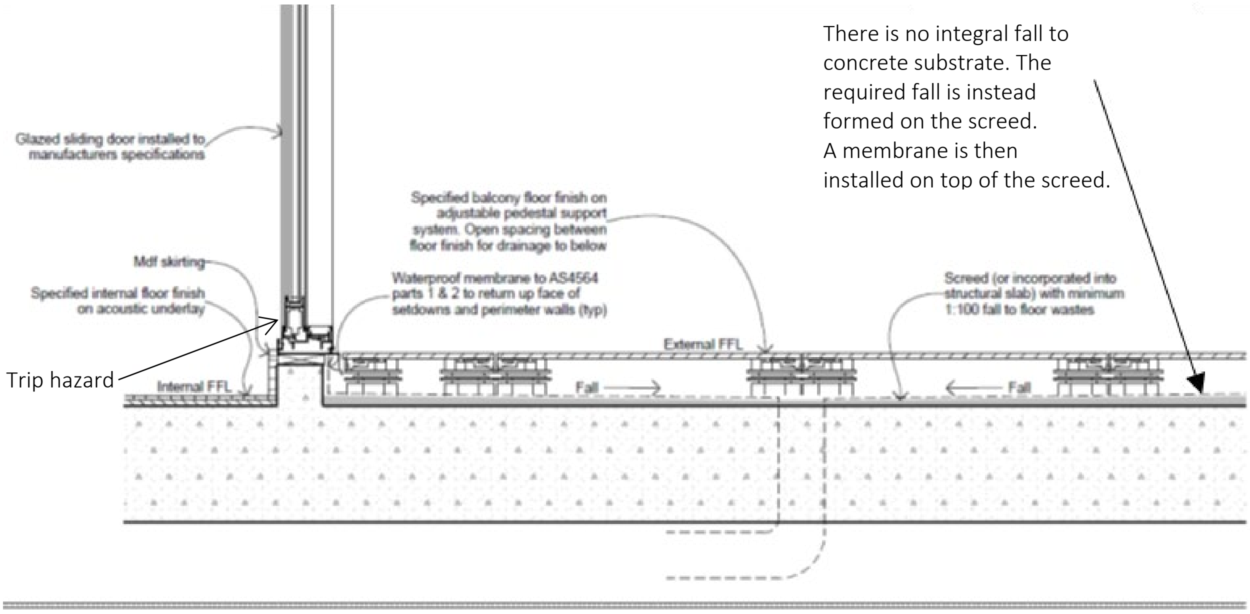


Figure 13: Typical concrete balcony architectural construction details (flat slab, fall on screed and no set down)

Anecdotally, inexperienced structural engineers are prone to focus less on balcony details, and may simply include a general note that one should refer to the architect’s drawings for waterproofing details. This accords the responsibility to specify the levels, slope, and finishes to the architects of the structure. In contrast, experienced structural engineers produce more detailed concrete balcony

[22] Characteristics of Figure 13 were supplied anonymously by an architect for this research, who indicated this design is popular among builders (see Case Study - Project E).

details to ensure that a set down is created. The end result of this degree of specificity is the prevention of water ingress to the habitable space.

> The balcony section does need to be drawn. But I suspect that for a lot of these second and third and fourth tier consultants out there are just cutting this off. Just saying: "Oh, it's a typical detail, don't worry about it, and well, the guys on site will work it out". If in doubt, draw a section. We work on projects that our fees are big enough that enables us to do that. But there's company out there that won't draw that section because you know, why should I spend an extra two hours of my time just to save someone's ten-years-away problem anyway.
>
> - Structural Engineer 3

A typical section-through of a concrete balcony (extracted from structural drawings) is shown in Figure 14.[23] In this drawing, a structural engineer has noted that the balustrade is to be designed and detailed by others. While this responsibility for balustrade construction may be delegated, the fixing to concrete and the calculation of load imposed by the balustrade are the responsibility of the project structural engineer. Additional loads from balustrades can increase balcony deflection by 27 per cent and reinforcement by 10 per cent (see Table 2 in section 6.2.1).

Another important detail in Figure 14 to note is that there is no screed or tile noted, and this may result in the design structural engineer failing to allow for additional superimposed dead load (SDL) from screed and tiles. The additional dead load can increase the deflection by 54 per cent and reinforcement by 17 per cent (see Table 2 in section 6.2.1).

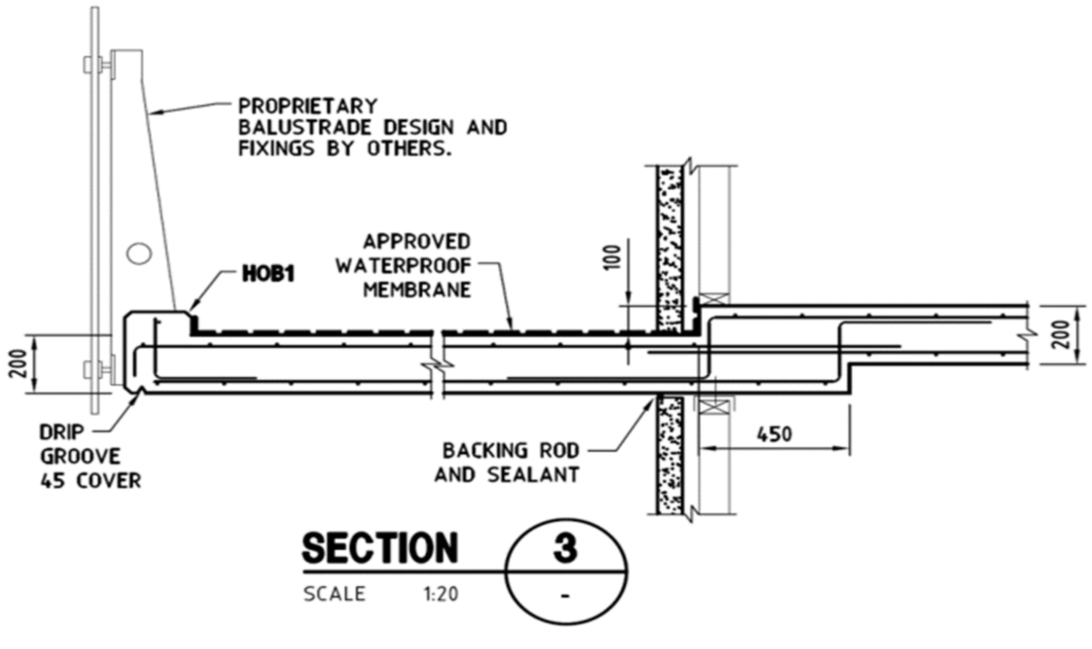


Figure 14: Typical concrete balcony structural construction details (flat slab with set down and no fall)

[23] Supplied anonymously by an engineer for this research, who indicated this is the standard structural drawing (see Case Study - Project E).

A number of interviews (see Appendix B: Stakeholder interviews) have highlighted that not having a set down and fall in the balcony construction is a major cause for water leakage in concrete balconies, for example:

> Flat concrete and screed to fall will never work, it will create several issues with water drainage. I always insist on a set down and fall and the membrane must be on the fall surface. The membrane must be an approved one and allowing for the correct movements is critical for successful application and this must be installed by a certified tiler. I have seen enough balconies constructed with screed and tiles failed with water leakage issues and the repair cost associated with this is huge compared to the cost saving with construction not having falls. After starting to construct concrete balconies with integrated set down and correct fall I have now no issues with water leakage.
>
> - Builder 2/Architect 3

> …probably 3-4 years ago… what was generally on a building permit document, the builder would go off and build. [The] building surveyor would not necessarily scrutinize those documents to that level of degree, and the builder certainly would just sign off and say 'I have done in accordance with the documents' and leave it at that. What's been happening, certainly in the last two to three years because of the shake up in the industry because building surveyors are now closely regulated, they have to sign off in triplicate. They are now very much whatever document you issue for the permit is the document that needs to be built at the end of the day by the builder and there is no deviation unless it gets approved by the building surveyor along the process.
>
> - Architect 4

While Figure 11 and Figure 12 do not comply with AS requirements as noted above, Figure 15 and Figure 16 below were drawn to highlight how those construction methods can be amended or redesigned to comply with NCC 2022 and AS requirements. However, this type of construction is also ultimately not suitable for concrete balcony construction, especially for open balconies with habitable space underneath them, due to the capacity for water to pool on the flat concrete substrate if the membrane fails (or *when* it fails at the end of its product life cycle). The performance of this type of construction is discussed further in Appendix C: Case studies.

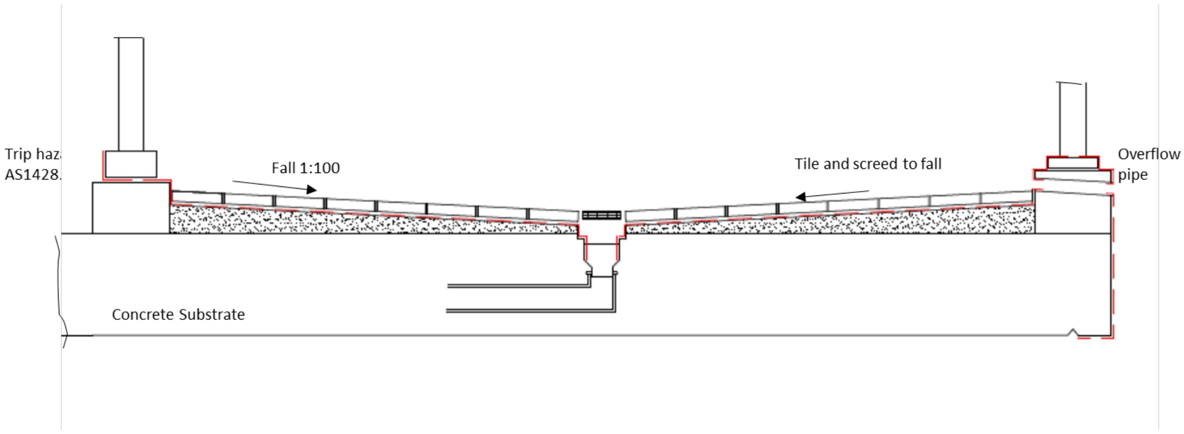


Figure 15: Typical concrete balcony construction details (screed to falls and no set down)
The waterproofing membrane is indicated by a dotted red line (- - - - -).
The method of construction for the tile and screed complies with AS 3958: 2023 (clause 3.2.4).

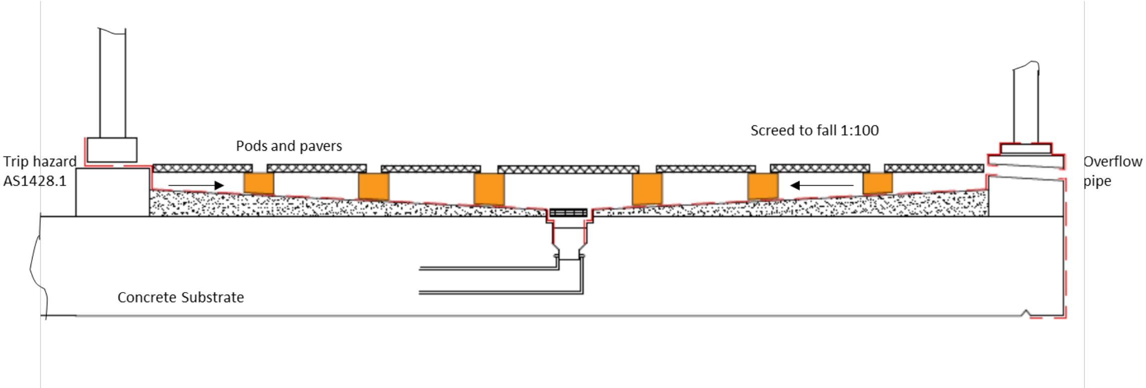


Figure 16: Typical concrete balcony construction details (screed to fall with tiles/pavers and no set down) The waterproofing membrane is indicated by a dotted red line (- - - - -).

> Ninety per cent of water leakage issues are related to [a] lack of fall, integral steps, and hobs. It's all to do with money. Under the design and construct contract agreement builder is always choose path to cut cost [sic]. Constructing integral steps, falls and hobs are costly with respect to material labour and time. [If a] builder's concrete subcontractor constructs a flat slab, and leaves it to the tiler to get the required fall and hob… [they will have] a membrane laid on the screed with a flat concrete substrate. Over a period, [the] tile and screed cracks, and water penetrates to the membrane, and the water can flow to the drain. However, when the membrane fails, the water penetrates through the screed and gets accumulated on the concrete surface as there is no fall on the concrete. Over a period, the accumulated water can penetrate through the normal concrete, or leak through the crack, or leak through joints such as MJs and CJs. This is why a membrane on the concrete with a fall is a much better option than the option of having it on falling screed.
>
> - Structural Engineer 12

6 Whole of life considerations

6.1 The journey of water

This research provides an overview of current practice during the design and construction of concrete balconies, and recommends broad corrective actions to reduce the prevalence of water ingress from balconies into adjacent building elements. The research also reviews key problematic elements of structural design of concrete balconies (see section 6.2.1).

It is important that readers contextualise this information by considering matters relevant to concrete balconies that exist outside typical structural design. These include:

1. the need to adopt whole-of-life cost considerations for concrete balconies, which incorporate both initial costs as well as long-term costs associated with maintenance and repair (see section 6.2), and
2. the need for clearly defined pathways for water along and through the balcony to collection and drainage destinations. This maximises the likelihood that the structure will remain protected from water ingress across its expected design life.

This second lens is of particular importance during the design and construction of balconies. While water's journey on and within any structure is guided by good design and construction, ultimately even well-designed and properly installed elements may fail, or function contrary to design intent. For example, a structural engineer may take all necessary steps to ensure that an architect includes falls and sufficient space for hydrophilic rolls in construction and movement joints, so that they may swell and block water ingress under wet conditions. However, water ingress may not effectively be controlled if a builder substitutes the specified product with another or alters the specified dimensions and design. Ultimately, this will impact the performance of not just the altered elements, but more importantly the available pathway that guides water away from ingress into the building or through building elements.

This perspective is best adopted across the whole-of-life of the balcony, and as such no one element of the balcony should be viewed as a singular waterproofing solution. Falls, flashing and in-joint waterproofing are essential tiers of protection that support waterproofing membranes. Currently available membranes have an estimated life of approximately 15 years or less, which is well below the length of building design life. Further, membranes are known to be vulnerable to separation and cracking due to movements of building elements (e.g. due to moving loads, wind, and thermal expansion and contraction). Therefore, concrete balcony designs must incorporate other pathways that are available for water to travel (e.g. in draining and collecting to defined points), as the balcony must continue to drain and shed water even when one element of the structure fails. This multi-tiered perspective of waterproofing measures is illustrated in Figure 17.

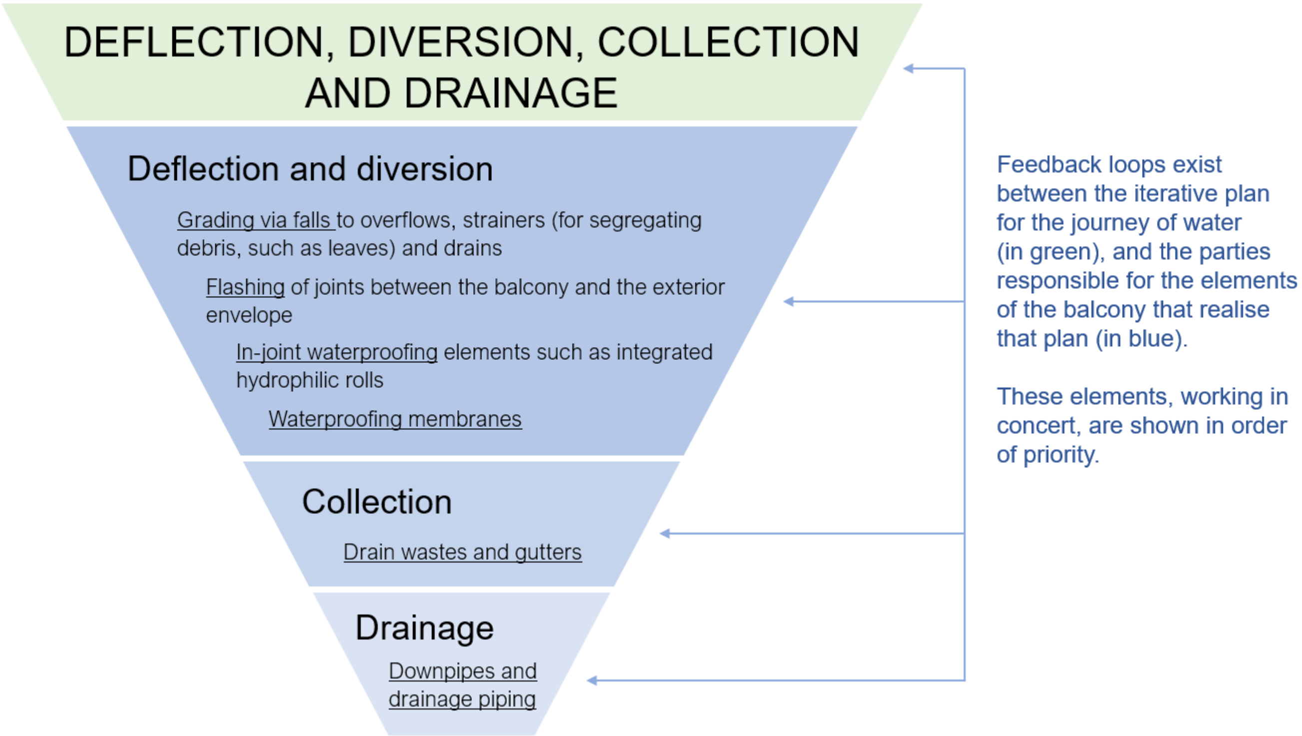


Figure 17: A clearly defined pathway for water to follow is imperative for concrete balconies

In conclusion, there is a need for understanding of the hierarchical nature of a well-designed pathway for water, where a clear plan incorporating deflection, diversion, collection and drainage supersedes the physical elements of the balcony itself. Those physical elements, designed to exclude water, should always be addressed as if they are part of the broader plan for the journey of water, with a designated pathway made available for water to follow. Through this perspective, if an overflow of water sheds from the balcony to the street or gutter in an inappropriate manner, the issue to be addressed is not simply the remediation of an existing stormwater solution, but rather the modification of the already existing pathway available to water. For this reason, the addition to the design of redundant pathways and collection points for water to follow is ideal.

6.2 Whole of life costs

For built environment projects (bridges, buildings, highways, ports, airports, etc.), many parties carry the burden of not only the initial investment, but also the cost of maintenance and operation. Across the lifetime of the structure, many decisions are made that will impact the duration and performance of the structure. These decisions are likely to be made by many parties with disparate technical knowledge, from developers and practitioners to consumers as end users of structures.

To support the long-term consequences of decision making is in the interest of all parties. Therefore, it is important to examine the economics of structures – including concrete balconies – as more than purely the cost of design and construction, and instead to adopt a holistic system-based view.

This view serves to preserve the financial sustainability and promote better management of structures. Ultimately, this will support and encourage practitioners to make design and construction choices that result in safer structures for longer, and the longevity of outcomes for consumers. Within this context, life cycle cost analysis (LCCA) plays a significant role in modern engineering project management (Matos, et al., 2019).

LCAA serves to demonstrate that the predicted design life of each of a balcony's elements will be reduced if they are not designed and built per relevant AS and other relevant guidelines, and/or not well maintained. This is true for each element within a balcony structure; although each element does have different durability spans and warranty periods, predicted design life will proportionally reduce for each element.

> The challenges in ensuring the quality and structural integrity of apartments include owners' expectations for defect-free homes, the burden of additional inspection costs, a lack of ongoing structural assessments, varying inspection scopes and quality, and the need for qualified inspectors to provide holistic assessments throughout a building's life cycle.
>
> - Academic 2/Owners Corporation 1

The 2006 ABCB guideline document *Durability in buildings*, which has now been withdrawn from publication, presents the theory of life cycle performance (LCP) (reproduced in Figure 18) (Australian Building Codes Board, 2006; see also National Association of Steel-framed Housing, 2009). As part of an LCCA, the LCP emphasises that routine inspections, repair and restorations and maintenance are key for successful achievement of the design life. Three strategies are presented in the LCP:

Strategy 1 No maintenance is performed on a well-designed and documented concrete balcony, where the performance level at the start of the design life is much better than expected. Due to this, the balcony's performance is largely not impacted by the absence of maintenance. Such balconies will have integrated steps and falls, with an approved membrane laid on a concrete substrate (i.e. in compliance with AS 4654.1 and 2) by suitably trained installers. This balcony will have an expected design life of approximately 50 years.

Strategy 2 The starting performance level is lower than as outlined for Strategy 1, and no regular maintenance is undertaken. However, when failure is noticed, inspection and repair will be carried out. For example, if inspection detected cracking and corrosion, an appropriate repair and restoration would then prolong the design life greater than per Strategy 1. If the identification of a need for repair was after the expiry of the warranty period, then the cost of replacement of elements would be borne by the owner. However, the cost of repairs and other associated costs will be substantially higher than balconies that do receive regular maintenance.

Strategy 3 The starting performance level is lower than both Strategy 1 and Strategy 2. Design life is achieved through regular maintenance. This includes the replacement of the membrane. Unlike Strategy 2, any membrane failure would likely be identified before the warranty period, and if so, the cost will be borne by the supplier instead of the owner.

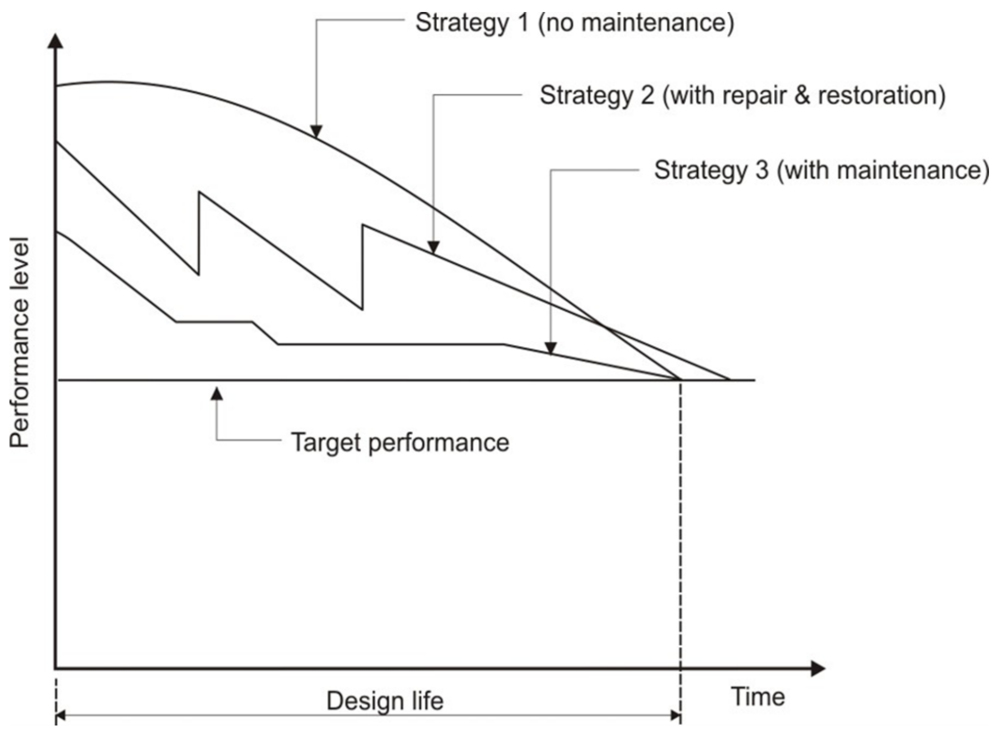


Figure 18: Life Cycle Performance

For the purpose of demonstrating the LCCA in the context of concrete balconies, and the benefits of its usage in decision making during design and construction, the authors have re-interpreted the LCP to show the impact of these three strategies as applied to well- and poorly-constructed balconies (Figure 19).

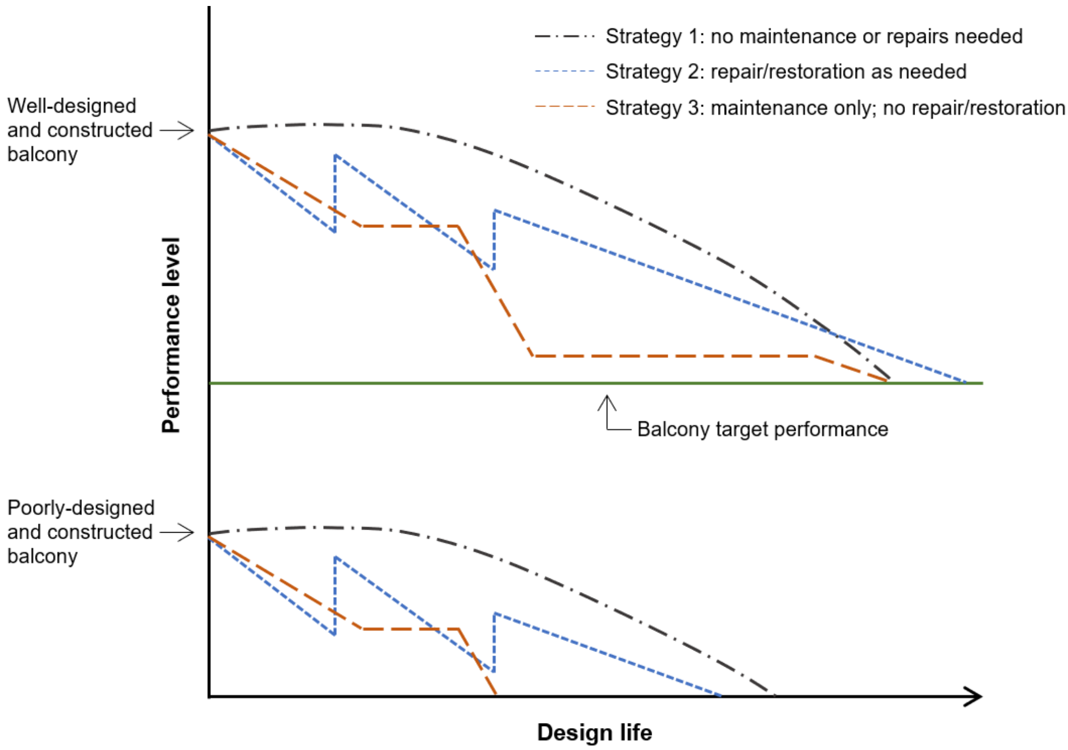


Figure 19: Life Cycle Performance: Authors' interpretation for concrete balconies

For both these balcony types, the three strategies are applied with identical starting performance levels. From this comparison, it can be seen that if a completed balcony begins its life below the targeted performance level, in all cases its design life will be reduced in comparison to a balcony constructed at a high performance level. While this finding seems intuitive, holding the starting performance levels constant also allows a comparison to be made between the likely design life for each strategy for both balcony types.

It should be noted that, where a balcony was poorly designed and/or constructed, Strategy 3 no longer delivers the longevity of Strategy 1, as the impact of the absence of repair is manifest more rapidly due to the short, rapid decreases in performance at each event requiring remediation. Further, Strategy 2 no longer outperforms Strategy 1, as the truncated life of the balcony affords fewer opportunities for repair to occur. In short, good design and construction is likely to afford balconies a degree of passive protection.

Taken together, this demonstrates that concrete balconies should not only be well designed and constructed but should also be regularly maintained by owners/occupiers, and have repairs carried out promptly as required. The following two sections of this report build on this LCP through an investigation of the predictable duration of performance, and the production of an LCCA of concrete balconies.

> We design buildings that are designed to last for at least 50 years. The maximum warranty you're probably going to get on the waterproofing membrane is probably 20 years. And you know that someone will do something in 10 years to damage it anyway.
>
> - Structural Engineer 3

6.2.1 Concrete cover

A demonstration of the benefits afforded by a consideration of whole of life costs is possible though the examination of costs associated with concrete balcony cover. The life span of concrete is based on two elements: the properties of concrete cover, and the quality of the concrete used. For concrete balconies, the concrete cover must be selected for the exposed surface, ignoring the presence of waterproofing membrane. A fulsome definition of concrete cover is provided by Barreto, Passuello, Dal Molin, & Masuero (2021):

> Concrete cover is a protective mechanism in reinforced concrete structures that maintains the high alkalinity and the passive film over the reinforcement. If the passive film breaks down (depassivation), corrosion can initiate, which occurs when the cover degrades (chemically, physically, or mechanically), chlorides penetrate to the reinforcement or cover concrete carbonates (American Concrete Institute, 2016).

Barreto et al. also noted that cover thickness plays a key role in informing structural performance of reinforced concrete structure. The authors associated an increase in the cover thickness of reinforced concrete slabs (from 15 mm to 30 mm) with an up to 400 per cent increase in service life. For the nominal increase in costs associated with cover thickness, a cost reduction in repair and maintenance costs of up to 75 per cent was predicted.

The above research found that the increased costs of the cover, per exposure classification, are likely to be justified because they will ultimately increase the service life of the structure, as well as reduce costs across its service life. Further, a concrete slab with an appropriate cover need not rely on waterproofing membranes, which are a frequently reported point of failure in balcony structures.[24]

In general, structural engineers prefer to minimise cover in order to achieve better balcony structural performance, where greater effective depth is achieved by the use of membrane as a protection against exposed conditions. However, exposed cracks in concrete surfaces such as concrete balconies, terraces and rooftops will be subjected to greater levels of water penetration where lesser cover exists, which leads to faster corrosion, a reduction in service life, and may result in total failure of the balcony structure if left unattended with no maintenance and repair. Indeed, a number of survey respondents and stakeholder interviewees cited inadequate concrete cover as an issue that causes concrete reinforcement corrosion, and associated water leakage issues.

To examine the impact of a reduction of cover on concrete balcony performance, a comparison was performed between cover of 20 mm and 30 mm (Table 2). This comparison examines differing construction types, loadings, and the effects of these on reinforcement and deflection.

Table 2: Concrete cover and loading analysis for a cantilevered balcony

Note: Approximate values are provided for comparison purposes only.

				*Concrete cover = 20 mm			*Concrete cover = 30 mm		
Construction		Loading		Reinforcement (mm^2/m)		Deflection (mm)	Reinforcement (mm^2/m)		Deflection (mm)
				ULS ±	SLS #		ULS ±	SLS #	
A	200 mm thick cantilevered balcony slab	E	A, plus: SDL$^{\mho}$ = 1.3KPa LL$^{\phi}$ = 2.0KPa	1** (665)***	1.5 (1000)	1 (20.3)	1.08 (735)	1.62 (1050)	1.27 (25.8)
B	A, plus added balustrade loadings	F	E, plus balustrade loadings: Vertical 0.75KN/m Horizontal 0.75KN/m	1.10 (715)	1.65 (1090)	1.35 (27.4)	1.15 (761)	1.72 (1145)	1.59 (32.2)
C	B, plus added screed and tile finish	G	F, plus tile and screed load: 1.25KPa	1.3 (826)	1.75 (1160)	1.54 (31.3)	1.30 (866)	1.83 (1217)	1.9 (38.5)
D	C, plus added planters	H	G, plus 4KN point load (1m width slab)	1.6 (1062)	2.05 (1365)	3.45 (70)	1.7 (1127)	2.15 (1431)	4 (81)

Concrete cover: * Based on the exposure condition (AS 3600) ** Datum ***Actual

± ULS: Ultimate Limit State.

SLS: Serviceability Limit State (Based on 0.2mm crack width as per AS 3600).

$^{\mho}$ SDL: Superimposed dead loading.

$^{\phi}$ LL: live loading.

The above comparison shows that a balcony designed to comply with NCC and relevant AS may increase the reinforcement quantity by 215 per cent and deflection by 400 per cent in comparison to

[24] Membranes as a common point of failure are discussed further in section 5.3.4 of this report.

a balcony that is not.[25] The approximate cost associated with these works (the increase in reinforcement, the required step and falls, and the increase in slab thickness) is estimated to be around $4500 per balcony.[26] If this cost is less than the cost associated with repair and maintenance of balconies without these protections, then the argument to adopt greater cover for concrete balconies would become persuasive. Such a comparison is considered within the next section of this report.

6.2.2 Concrete balcony Life Cycle Cost Analysis

For concrete balconies, the minimum cover requirement must be selected with no regard to any protection from a waterproofing membrane, as the design life of the concrete slab (50 years) is generally more than the warranty period (10-15 years) of the membrane. However, membranes remain important to consider, as they play a key role at locations such as construction joints, movement joints, slab/wall junctions and balustrade base fixings.

In the following LCCA for a concrete balcony (presented in Table 3), a number of design strategies and their associated life cycle costs are explored to shed light on the importance of providing adequate cover for concrete balcony structures, carrying out regular maintenance and conducting routine inspections where early detection of water ingress can reduce the repair rectification and other associated cost substantially.

In this LCCA, a concrete balcony of moderate size is used for the calculations (8m x 3m, or 24m^2).[27] The example balcony has 20 mm of concrete cover (assumed protection from a waterproofing membrane), and 15 mm of as-built cover (from concrete scanning). Note that the cover required due to exposed concrete (i.e., no membrane protection) is 30 mm.

This LCCA demonstrates three insights:

1. Buildings that benefit from excellent design and construction result in lower occupancy costs associated with maintaining the structure when compared to buildings that must rely upon maintenance, repair and restoration
2. Even where excellent design and construction is not achieved, the early identification of warning signs of balcony failure (e.g. small cracks) through regular maintenance will result in lower occupancy costs associated with maintaining the structure when compared to repair and restoration identified only at the point of failure.
3. Buildings that have reasonably-designed and constructed concrete balconies, if regularly maintained, can have a similar expected balcony life to balconies that have excellent design and construction.

---

[25] The 215% increase in reinforcement is observed within Table 2 by comparing the A/E values for ULS (which represents a value of initial design strength) with D/H value for SLS (which incorporates exposure conditions, deflection, crack control and durability). The 400% increase in deflection is observed within Table 2 by comparing the A/E and D/H values for deflection.
[26] This estimation was provided by a quantity surveyor, and the calculation for the additional works includes increases in formwork, concrete and labour.
[27] This balcony design is based on the balcony in Case Study D (see Appendix C: Case studies).

Table 3: Approximate lifecycle cost comparison for a 24m² concrete balcony

Item	Strategy 1 No maintenance required due to a well-designed and constructed concrete balcony.	Strategy 2 No maintenance on a reasonably-designed and constructed concrete balcony. Inspection and repair undertaken after observing failure.	Strategy 3 Proper maintenance on a reasonably designed and constructed concrete balcony. Inspection and repair undertaken early.
Concrete	Appropriate cover for an exposed concrete surface	Less cover, due to the assumption of protection from a membrane (or due to construction error)	Less cover, due to the assumption of protection from a membrane (or due to construction error)
Membrane failure	N/A; balcony capable of draining water in the event of membrane failure	Failure noticed at or after point of failure	Early detection of failure
Maintenance costs	Nil; none required	Nil; none conducted	$2,000* annually
Replacement of membrane	Nil	$30,000 per replacement (replacement after warranty period due to late detection of failure)	$0 (replacement within the warranty period due to early failure detection)
Major concrete repair or replacement	Nil	$45,000± per replacement (replacement and repair, due to late identification of failure)	$15,000± per repair (repair only, due to early failure detection)
Occupant relocation	Nil	$9,000 [ʊ] per floor during concrete replacement	Nil; not required
Expected balcony life	**50** years	**25** years	**50** years
Total expected costs across entire balcony life	Nil	**$231,000** Includes: • two membrane replacements, as the average life of a membrane is 10-15 years ($30,000 x 2) • two major concrete repairs and replacements ($45,000 x 3) • two dual-floor occupant relocations (($9,000 x 2) x 2)	**$130,000** Includes: • maintenance costs ($2,000 x 50), and • two major concrete repairs ($15,000 x 2).

* Maintenance cost estimation:

- Cleaning drainage outlets and keeping the balcony free of debris and blockages ($500 at each 6-month interval)
- Routine yearly inspection by approved inspectors/Engineers/Architects ($500 at each 6-month interval)

± Concrete replacement estimation (Wittocx, et al., 2022):

- Replacement of waterproofing membrane and the associated waterproofing elements for joints and flashing ($30,000)
- Repair:
  - screed and tiling ($10,000)
  - grout injection of cracks for concrete substrate ($5,000).

ʊ Relocation cost estimation:

- Median duration for total replacement of a concrete balcony is estimated to be 15 weeks. This duration does not include any time associated with negotiation/dispute with responsible parties, lodgement of insurance claims, or time spent awaiting practitioner availability for repair. It is assumed for the purposes of this estimate that habitable spaces below the balcony do not require occupant relocation until the repair of the balcony. Note that the estimate of 15 weeks is on a per floor basis (e.g. if three floors were to be impacted by the water leakage, then three households would require temporary relocation, and the cost would triple). These figures therefore represent a conservative estimate of costs for relocation duration.
- Median rent for a two-bedroom apartment in metropolitan Melbourne is $600 per week (Victorian State Government (Department of Families, Fairness and Housing), 2024).

7 Causes and prevalence of water ingress in concrete balconies

7.1 Overview

A number of defect reports, best practice guidelines, and grey literature about causes of water leakage are available for review and analysis. However, peer reviewed research papers about water leakage in apartment building concrete balconies are scarce (Denman, Ullah, Qayyum, & Olatunji, 2024). This is somewhat surprising, given that water leakage is identified as the most common building defect in apartment buildings (Johnston, et al., 2021).

A review of a representative mix of research and defects reports (including both academic and grey literature) related to water ingress issues in concrete balconies in apartment buildings identified a number of key causes. These are outlined in Table 4, and can be summarised as:

- All nine sources identified water ingress caused by:
  - Waterproofing membrane failure
  - Little or no maintenance
  - Insufficient or no slope, no hob, no overflow pipe
  - Lack of planning and design coordination
  - Lack of supervision, inspection, and certification.
- A moderate number of sources identified water ingress caused by:
  - Cracked tiles cracked concrete / mould formation / corrosion
  - Pipe penetration and floor trap
  - Inadequate or poorly designed / detailed movement joints
  - Poorly treated construction joints
  - Porous internal walls and slabs.
- The least commonly reported cause of water ingress was poorly treated construction joints.

Table 4: Causes of water ingress identified by a representative sample of academic literature, grey literature, and stakeholder interviews

	Literature reviewed									Stakeholder Interviews
Causes of water ingress	Prudential Investment Company of Australia, n.d.	Johnston & Reid, 2019	Chung, et al., 2020	Zurbriggen & Herwegh, 2020	Rutland, 2017	Ross, 2018	Donnan, 2010	Sriravindrarajah & Tran, 2018	Khan, 2019	
Waterproofing membrane failure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ 100%
Little or no maintenance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ 100%
Insufficient or no slope, no hob, no overflow pipe	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ 80%
Cracked tiles cracked concrete / mould formation / corrosion	✓	-	-	-	✓	✓	-	-	-	✓ 50%
Pipe penetration and floor trap	✓	✓	-	-	-	✓	✓	-	✓	✓ 30%
Inadequate or poorly designed / detailed movement joints	✓	✓	-	-	-	✓	-	-	✓	✓ 80%
Poorly treated construction joints	✓	-	-	-	-	-	-	-	-	✓ 50%
Porous internal walls and slabs	✓	✓	-	-	-	-	✓	-	✓	✓ 50%
Lack of planning and design coordination	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ 90%
Lack of supervision, inspection, and certification	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ 90%

However, a common limitation to these reports is that many causes identified cannot be interpreted as *root* causes. An example of this is the common finding within the literature that water ingress is caused by a failure of a waterproofing membrane. Understandably, this can contribute to water ingress through concrete cracks, joints and slab wall junctions; the moisture then corrodes the reinforcement in the slab, and the slab/wall junction, rendering the habitable space under the balcony unusable. However, the cause of the failure of the waterproofing membrane must be explored further to identify its source (e.g. as a design issue, a construction fault, or an incident caused by an occupant (e.g. post-construction of services such as air conditioners).

In the following sections, this report makes a more comprehensive study by examining five key issues causing water ingress in balconies (Figure 20):

- design, detailing, coordination and planning
- roles and accountabilities
- construction systems, practices and materials
- post-construction repair and maintenance
- guidance, education and training.

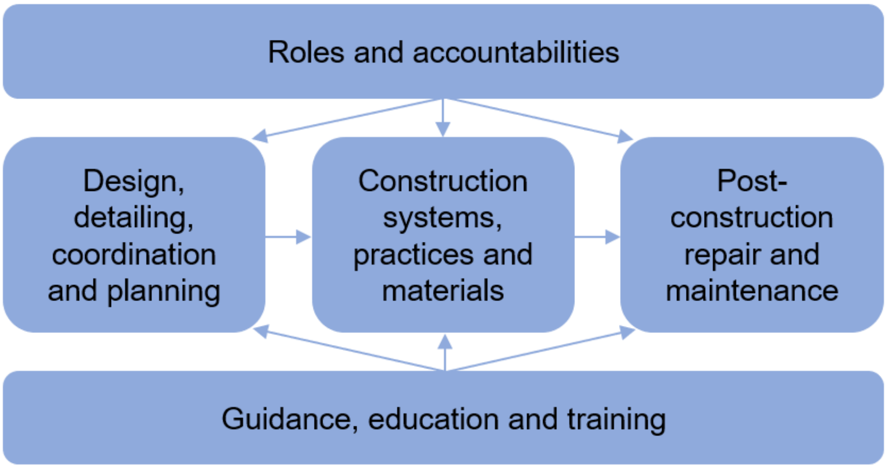


Figure 20: Five key issues causing water ingress in balconies

7.2 Design, detailing, coordination and planning

7.2.1 The importance of design coordination

For any construction to be successful, initial design coordination is paramount. The opportunity for construction defects to arise is reduced by the presence of a detailed construction drawing that makes clear how it achieves compliance with the NCC and relevant Australian Standards. A lack of such planning increases the potential for defects in concrete balcony construction, potentially leading to water leakage and resultant costs to consumers and industry.

Coordination, collaboration and effective communication from the beginning is vital to avoid issues in the waterproofing system even if standards are followed by the engineer. Due to most of the decision-making and design of the concrete substrate for the concrete balcony being conducted by the engineer, all parties (architects, hydraulic engineer, and the waterproofing consultant) must inform the engineer of any relevant requirements in a timely fashion and be consulted to inform final design decisions (Taylor, 2020).

> There is a lack of coordination between all the parties regarding to the design and construction of a building. There is coordination typically between the engineer and architects and the services engineers. But when you're talking about the subtle details required for balconies and these types of areas, then that's often missed out. It will be just assumed that everyone will do it correctly, but it is not coordinated the same as what you will find with other parts of the build.
>
> - Structural Engineer 11

> We find that the leaks are almost always on the drawings. Only in five or ten per cent of the cases the drawing is fine and the installation wrong.
>
> - Waterproofing Specialist 3

The design of exposed concrete structures and features can be complex given the number of individual components that will impact overall performance and coordination between professionals, including architects, structural engineers, and building owners. In section 5 of this report, it was shown that the design of concrete balconies requires the consideration of not only the NCC, but also a number of AS relating to different construction disciplines.

> No one person can design a building anymore, particularly [a] Class 2 building. Everyone's got their own expertise and so many elements, particularly when it comes to external waterproofing, interact. So the team as a whole have to get their heads together and understand the solution, how it works and how it interacts with surrounding elements… How is that facade designed and does it actually allow drainage of any required moisture drainage within the facade as well? How does it interact with any drainage solution that might be applied to the balcony? ... You sit around as a project team and agree on how it all interacts together. And I think that's a critical part.
>
> - Builder 2/Architect 3

Many of the design considerations are directly related to, and may impact, other design components such as concrete mix, design and weatherproofing. Performance problems that can result from poor system design, and a failure to adequately consider the interaction between design elements, include water leakage, and the results can range from aesthetic deterioration to partial or complete structural failure (Regan & O'Brien, 2022).

The results of research conducted by prominent researchers Law et. al (2021), on a sample of accepted water-related domestic building insurance claims for residential buildings (mostly houses), identified inadequate detailing of waterproofing design on structural drawings and architectural drawings that was likely to have been a contributing factor to water ingress in those buildings. These findings are supported by the interviews and surveys conducted during the present research. A quarter of survey respondents (25%) identified detailed design coordination as the second most important issue with respect to minimising leakage of water in concrete balconies.[28]

Within the stakeholder interviews, all most all interviewees stressed the importance of planning, design detailing and coordination.

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[28] See Figure 24 (Most important activities to minimise water leakage) in Appendix A: Online survey.

> Poor design creates a problem for the builder/installer/applicator for them to have to redesign to try and make it work on the run. And then they get blamed for changing the design and for the leakage when the thing never had a chance to be buildable in the first place.
>
> - Waterproofing Specialist 2

> For me, it really is a design thing, you can't get your engineer and architects to agree on the same thing. The architect has a concept they want to achieve, and engineer has constraints. That's where the real issue starts. [The] waterproofing membrane is the final line of defence, if you are relying on a final finish as your primary defence, you are already losing the battle.
>
> - Builder 1/Construction Director 1

> Whatever we [architects] do that might get changed during construction and will be approved by the RBS via performance solutions which will not be supplied to us for approval. As architects, we know very well the correct way of designing waterproofing for a balcony or bathroom is with set down. But these are not in our hands. During the [design and development] stage, I would design all as per AS 4654.1 and 2 but these will be changed during the construction stage.
>
> - Architect 2

Design elements attributed to water leakage issues

In a concrete balcony design, there are two key components: a) concrete and b) the waterproofing membrane. With respect to water ingress/leakage, the authors' opinion is that many practitioners (builders, architects and waterproofing contractors) consider that the primary line of defence is the water proofing membrane, and the substrate (in this research, a concrete slab) is treated as the second line of defence.

Conversely, in an interview conducted for the present research, a waterproofing specialist stressed his view that the concrete slab is the primary waterproofing element. He said:

> When it comes to the waterproofing of an element, the structural engineer is the most important person. And the industry should not rely on waterproofing membranes and sealant to do all the waterproofing work. Another important aspect of the design of a balcony area is having fall across the surface that can successfully divert water away from the balcony area. Rather than relying on the waterproofing materials to hold and prevent water from intruding into the structure of the building, the process of "water shedding" can be used. This includes using strategies such as weep holes to carry water away from brick work and other exterior elements of the building. Ensuring that balcony areas are designed to cater for this idea is important, rather than only creating falls on surfaces after the concrete is poured or adding other measures during the construction process. When factoring in fall for a concrete surface it is important to consider movement of the structure, foundations, and slab rather than just the as per construction plans.
>
> - Waterproofing Specialist 3

Indeed, 77 per cent of the interviewees shared their views that the key element most likely to prevent water leakage across the life of a concrete balcony was the design:

> If you design the balcony correctly, provide enough falls, etc, you can virtually say that you don't even need the waterproofing products. Because if it's designed right, the water will get away so quickly, you don't need to worry about ponding water or anything else like that. We are over-reliant on the waterproofing membrane when we mention waterproofing, and waterproofing membranes are expected to solve all the problems and it doesn't work since it is specifically fragile. So, it will depend on the structural integrity of the balcony to perform to expectation.
>
> \- Waterproofing Specialist 2

> A lot of the problems come from the very first design. The issue of the design of the balcony is only handled from the structural engineer's point of view in terms of strength, and there is no detailing to help the builder determine how to manage the water shedding, so we've got a structural issue before we start.
>
> \- Structural Engineer 7

Even where concrete balcony design drawings do contain the required level of detail, a degree of assurance regarding this important issue should be provided. Only a quarter of the stakeholders interviewed for this research indicated that a structural design (including associated deflection and movements) is supplied to the RBS as part of the package of documents that accompanies a building permit application. This view was held across a diverse range of interviewee roles (seven structural engineers, one waterproofing specialist, one architect, two construction managers and one building practitioner). Further, of the stakeholders interviewed, 57 per cent believed that stringent design and material specifications are required, while 26 per cent said this might be so. Only 18 per cent of interviewees disagreed that stringent design and material specifications are required.[29]

Ideally, the supply of detailed drawings would be more common, and where an RBS finds no details about the waterproofing of a balcony, they should request this via a request for information. The availability of details about the structural performance of the concrete substrate to parties during construction would serve to facilitate the selection and application of an appropriate waterproofing membrane.

[29] See Figure 34: Stringent requirements for concrete balconies in Appendix A: online survey

Recommendation 1: Concrete balcony design drawings must contain suitable levels of detail.

Building permits must include a certified design that provides detail about concrete balcony construction. This should include information about deflections and movements, and any other necessary information to facilitate the construction of the waterproofing design (e.g. product requirements).

This could be achieved by:

1. The production of a concrete balcony construction detail (showing compliance to NCC and relevant AS), along with the waterproofing specifications, in collaboration by the structural engineer, the project architect, the hydraulics engineer and or licensed plumber.
2. The inclusion of the concrete balcony construction detail (per point 1 above) within the building permit application package is supplied for the building surveyor's approval as part of the issuance of a building permit.

Detailing contribution attributed to water leakage issues

A common occurrence of non-compliance can be seen in the architectural and structural design documentation provided by design practitioners not complying with the minimum performance standards set by the NCC. In research conducted by Law et al (2021), the researchers shortlisted a small number of cases to be examined as case studies. In these cases, inadequate detailing of waterproofing design on the structural and architectural drawings was observed as a common issue.

This then places the burden of balcony waterproofing on the builders without supporting detailing and documentation if unnoticed by the RBS during the building permit approval stage. A non-compliant design or inadequate design detailing must be recognised and issued for re-evaluation before reaching the construction phase. The NSW *Building Stronger Foundations* discussion paper suggests that in order to promote increased conformality and accountability, all design practitioners, not just architect and engineers, should give a signed declaration that plans and drawings comply with the BCA (New South Wales State Government, 2019). A further emphasis was placed on building practitioners to declare that buildings are constructed in accordance with the provided plans to allow detecting the origins of issues along with boosting accountability and responsibility.

> The client wasn't aware of the compliance requirements of the concrete balcony. He was under the impression it was just a concrete slab with tiles laid over. With coordination meetings with engineers, architects and waterproofing specialists, the client appreciated the efforts taken by us as a proactive builder. This coordination meeting won the job for us.
>
> - Builder 2/Architect 3

> You can have the problem solved in ten minutes by putting everyone in the same room.
>
> - Structural Engineer 3

Inadequate/missing information was sighted by several interviewees (some of the case studies also highlighted this):

> When VBA did a desktop audit of RBS approved work [in 2021 (Victorian Building Authority, 2021)], they found that the largest area where there wasn't enough information is weather and waterproofing, 82 per cent of the work did not have enough information.
>
> \- Academic 1/Architect 1

> I would say across the board what I've seen is a real lack of attention to detail when it comes to design issues. And I know that that's a real challenge for building surveyors.
>
> \- Policy Advisor 4

While waterproofing is an important measure to take to protect a building from water ingress, predicting where water will coalesce on the exterior is equally important. This can be difficult in practice when only following relevant standards, since every building is different in how water will access areas of the balcony. For the design of building envelopes, it is important to treat every building differently and be able to recognise that every building design may not fit perfectly into the pre-determined designs represented in AS and other guidance.

Recommendation 2: Design to be coordinated between relevant parties at the outset of the design process. An initial coordination workshop should be held by key players to develop and document an agreed concept sketch for concrete balcony detail.
Planning, clear communication and coordination among all players must be established from the beginning of the project. This particularly applies to structural engineers, architects, hydraulic engineers, the RBS, the quantity surveyor and waterproofing consultants. An initial coordination workshop should be held by key players to develop and document an agreed concept sketch for concrete balcony detail. This will facilitate producing a certified balcony construction detail (which, as outlined in recommendation 1, could be required for permit application). For their own benefit, the developer/builder should initiate this coordination workshop. In the request for tender (RFT), requirement of this workshop should be included.

7.2.2 Verification, certification, and as built drawings.

It is noted that the process of verification and certification of design documentation is iterative with multiple reviews and revisions (Stakeholder interviewee Academic 1/Architect 1). The interviewee further states the key role played by the RBS in ensuring a non-compliant design or inadequate detailing is found at the point of certification before issuing a building permit approval.

The importance of this role is also emphasised in a case study conducted for the present research (see Project D in Appendix C: Case studies), where defects occurred during the construction phase as the RBS was unsuccessful in noticing a non-compliant design during the certification phase leading to defects being transferred and constructed on site.

This iterative approach to documentation can create a complex chain reaction wherein the origin of non-compliance and subsequent accountability become difficult to determine. This highlights the importance of the role of RBS as any oversight on incomplete/insufficient design detailing on behalf of the architect and engineers has the potential to lead to non-compliant construction.

During the collection of case studies for the present research, our research team noted that there were few or no as-built balcony drawings for completed buildings available to view. This makes any comparison between the design and final construction more challenging, particularly for building inspectors. It also means that most defect reports are prepared without the as-built drawings, which hampers any capacity to identify causes for building defects.

The main reason provided by participants (architects, construction managers and builders) to the present research for a lack of as-built drawings was that these are prepared by waterproofing contractors (commonly known as 'tilers,' who are unlikely to be registered practitioners), and are not provided to other parties during construction.

7.3 Roles and accountabilities

7.3.1 Establishing responsibility and accountability

A defined chain of responsibility with respect to concrete balcony construction was generally not found within the literature review for the present research. Observations of structural drawings during interviews identified number of occasions where waterproofing was referred to the architect's details by structural engineer, while architects exhibited similar behaviour in referring to waterproofing within the engineers' details.

Even if a compliant design has been detailed by the structural engineer and architect, the builder may choose to ignore elements of the design and adopt their preferred details. Currently, there is no mechanism to assign responsibility for identifying and resolving water leakage issues in concrete balconies.

> Accountability makes people more responsible for their actions, without accountability anyone can put up anything and just walk away.
>
> - Architect 2

> There is a general lack of understanding of who is responsible for waterproofing and where that responsibility lies. Is it the architect, the structural engineer, the hydraulics engineer or the builder/contractor and who is responsible? I suggest they are all responsible.
>
> - Structural Engineer 9

7.3.2 Evidencing a chain of responsibility

A task-based analysis of responsibility was carried out on the interviewee responses to identify the chain of responsibility. Within concrete balcony waterproofing design and construction, there are various stages of construction, and across these stages, responsibilities may be allocated as follows:

- overall, the builder, building structural engineer and architect are equally responsible for the final product, with the licensed plumber or hydraulic engineer responsible for the design and construction of drainage for the balcony

- design engineers, concrete suppliers, concrete subcontractors, membrane suppliers, and waterproofing contractors are responsible for construction of the concrete balcony slab to NCC requirements
- it is unclear who is ultimately responsible for the selection of an appropriate approved waterproofing membrane, but generally this 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 the on-site installation and testing of the membrane
- the owner is responsible for maintenance. The builder holds the as-built drawings, warranties, and a maintenance manual and hands these over to the owner post-construction. In 2023, a requirement was introduced for a building manual, as approved by the RBS, to be supplied to the building owner.[30] However, as yet no regulations set out the documents required for inclusion in the manual.

Most interviewees agreed that everyone involved in the process must share the responsibility for the balcony overall.

Several interviewees (70%) observed that accountability has been noticed as missing regarding who is responsible for the waterproofing. This imposes a risk of individuals or entities making decisions or taking actions without being held responsible for the consequences:

> There is a general lack of understanding of who is responsible for waterproofing and where that responsibility lies.
>
> \- Structural Engineer 5

> When things go wrong and you try to get a forensic assessment of what went wrong, all too clearly the line of responsibility is not there, and whether that's due to poor record keeping or due to legal advice is unsure.
>
> \- Building Surveyor 2

> There is coordination typically between the engineer and the architect and the services engineer. But when you're talking about the subtle details required for the balconies and these types of areas, that's often missed out. It will be just assumed that everyone will do it correctly, but it is not coordinated on the same level as what you will find with other parts of the building.
>
> \- Structural Engineer 9

[30] This requirement was made by way of amendment to the Building Act 1993 (see s41A, s41B, and s44A).

> Balconies are a problem area that comes across all practitioners. Looking at the drawings, the drawings were incorrect, did not have a drop in level, did not have a drainage grate etc. There are two ways to go about designing your balcony, one is with a drop in level, drop in level is determined by your wind class because it affects your upper termination of your membrane, the other way if you have a drop in level is to have a grate and your balcony must drain away from your grate towards the balustrade, so you need two grates one at the end and one at the door, neither of which were in the drawings, so the only solution is a performance solution which I think they didn't go through. When I checked the permits there was no special provision for a performance solution for the balcony, so this is a clear non-compliance issue all the way through.
>
> - Academic 1/Architect 1

Recommendation 3: The builder should submit a signed Inspection and Testing Plan to the RBS prior to the issuance of an occupancy permit. This will identify the chain of responsibility and clarify accountabilities. Accordingly, parties will be able to readily identify which practitioner is required to act to ensure compliance.
An Inspection and Testing Plan (ITP) for the design and construction of the concrete balcony must be prepared by the project team (consisting of project structural engineer, hydraulics engineer, project architect, builder's project manager, and waterproofing contractor). The ITP must address all necessary requirements for the design, construction and waterproofing of the concrete balcony, and identify the hold points and accountable persons. A final copy of the ITP (signed by all project team members) must be submitted by the builder to the RBS prior to issue of an occupancy certificate.

In further exploring the theme of roles and accountabilities during balcony design and construction, the authors have noted that industry would benefit from the use of a detailed checklist to record acceptance of concrete balcony detailing (illustrated in Figure 21). Only seven per cent of the key stakeholders interviewed for this research were aware of the availability of an approved design checklist for design. About thirty-nine per cent believed that no approved design checklist is available, while 54 per cent were unsure.[31]

Under a builder's coordination, this checklist could be used by all key players and could be submitted to the RBS as supporting documentation.

> At the tender stage we can sit down with the architect and say look, this is the design, there should be mandatory inspections has to be carried out. Mandatory testing has to be carried out, mandatory sign off procedure has to be carried out. There is a combined liability has to be established.
>
> -Structural Engineer 4

[31] See Figure 37: Availability of approved design checklist) in Appendix A: Online survey.

Recommendation 4: A detailed checklist should be available to practitioners to record acceptance of concrete balcony detailing. This will identify the chain of responsibility and clarify accountabilities, as parties will be able to readily identify which practitioner is required to act to ensure compliance.
A detailed checklist that identifies the chain of responsibility and associated accountabilities during design and construction should be freely available to practitioners. This would ideally be provided in tandem with dedicated guidance about the design and construction of concrete balconies (see also 7.6.1).

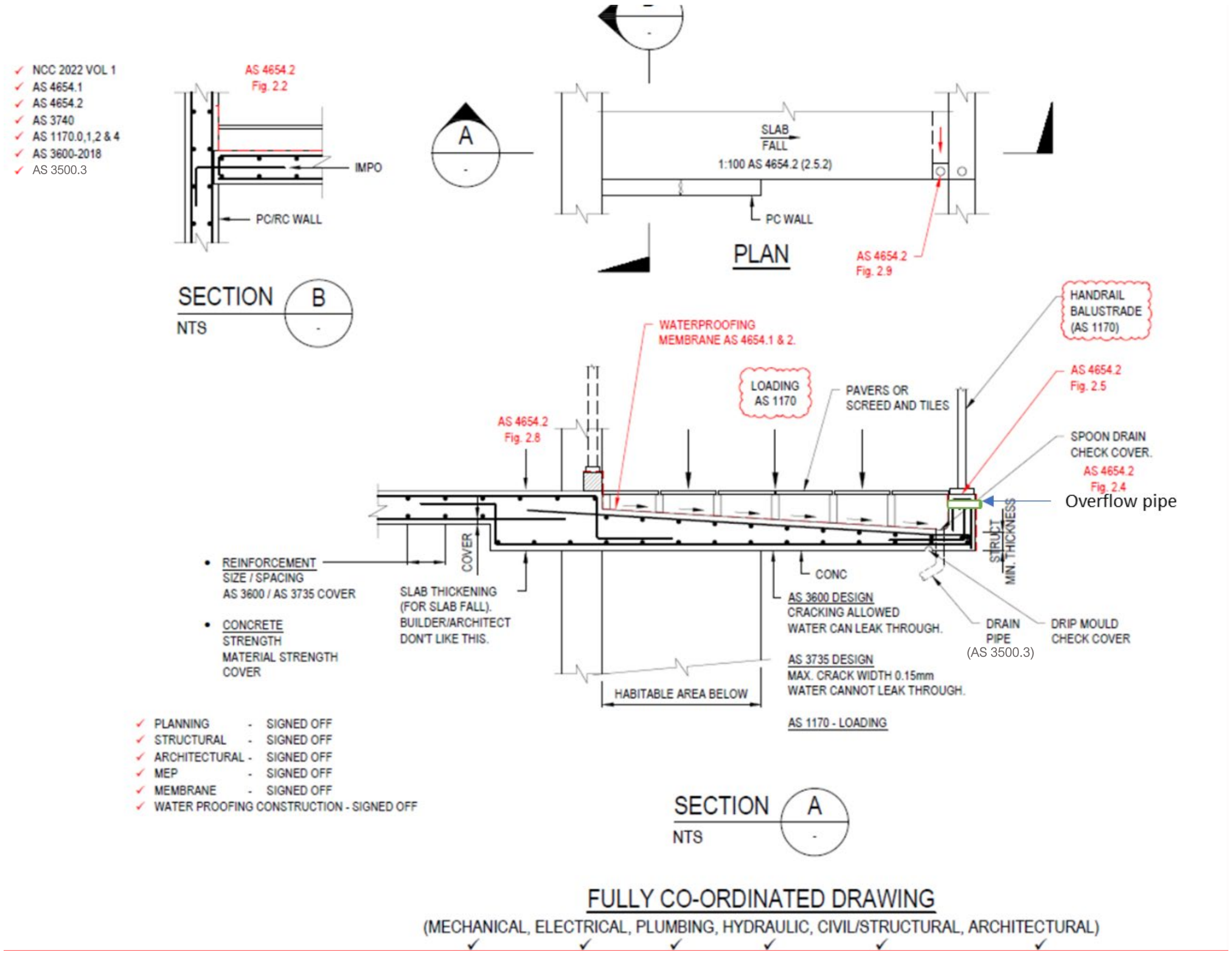

Figure 21: Apartment concrete balcony design and construction: Suggested inspection checklist

7.3.3 Structural engineers to lead the design

A key finding from the literature review was that most of the available research has been conducted by lawyers, architects, builders, strata managers, waterproofing companies/ contractors/ specialists etc., but not by structural engineers who are responsible for designing the concrete stratum which is always built first and provides the primary barrier of water resistance.

> There's a growing recognition that structural engineers take precedence as the principal waterproofing influencers within the construction process. Waterproofing consultants hold the secondary role.
>
> - Structural Engineer 1

Twenty-one stakeholder interviewees (fifteen structural engineers, two architects, one waterproofing specialist, one construction manager, one builder and one building surveyor), and almost half of the online survey respondents (44%)[32] indicated that structural engineers must play a key role in the designing of concrete balconies in apartment buildings by providing the expected deflection for concrete balcony slabs. While there is an expectation from industry that structural engineers are to provide the deflection (in order to specify appropriate fall) and movements (in order to select the appropriate membrane), this is not always the case at present. These expectations are possible to meet if the design role of the concrete balcony is led by a structural engineer.

> When it comes to the waterproofing of an element, the structural engineer is the most important person.
>
> - Waterproofing Specialist 3

The structural engineer should be responsible for designing and detailing the concrete balcony, not just to ensure its strength, but also for serviceability, durability (corrosion) and waterproofing.

> Engineers do not think about waterproofing. They provide reinforcement and other details. To some extent the information on slab deflection is there but they may be hidden under 3000 pages of computation. Structural engineers must give the deflection with high and low points so that the architect can provide the fall and locate the drainage location.
>
> - Construction Director 1

> It starts with the design. It starts with documentation; structural engineers play a quintessential role in limiting water ingress.
>
> - Structural Engineer 2

[32] See Figure 25 (The role of the structural engineer in the communication of deflection performance) in Appendix A: Online survey.

Recommendation 5: A structural engineer should take a lead role in the design and detailing of concrete as the primary water shedding element.

Expertise provided by a structural engineer should guide the design and detailing of the concrete balcony.

This leading role should include:

- working with architects to provide design and details of the balcony concrete with integrated hobs and falls to NCC requirements (per AS 4654.2)
- providing the expected deflection at the tip of the cantilever and for spanning elements at the mid span of the slab
- providing the movements at all joints (slab/wall junction, expansion/control joints, and construction joints).

Ideally, this would be supported by others working with the structural engineer:

- Project engineers should submit all the above information to RBS as part of the building permit approval.
- Project architects should submit plans and section drawings (showing appropriate levels of slab and outlet locations) with levels and architectural specifications to the RBS as part of the building permit.

This package should include a drainage lay-out as supplied by a registered hydraulic engineer or licensed plumber.

7.3.4 The role of the Relevant Building Surveyor during construction

The role of the RBS throughout the entire construction process is that of an independent third-party person who ensures that the building work complies with the relevant statutory requirements and building standards. The RBS can be either a municipal building surveyor (MBS) if appointed by application to a local council, or a private building surveyor (PBS) if directly appointed by the building owner or their authorised agent.

An RBS is responsible for assessing building permit applications, which certify that a proposed building's documentation (such as detailing, drawings, and structural information), will comply with the relevant building laws, including the planning permit (if applicable). The RBS will specify on the building permit the mandatory inspections that will be required throughout the course of the building work. This will include the legislatively required inspections and may also include a variance to carry out additional inspections (e.g. an RBS could determine that a concrete balcony structure could require an inspection once complete). In this manner, a building permit supports the building work to be undertaken according to approved plans, and specifications.

The RBS's role is complex, and it can vary from project to project. The RBS is primarily responsible for the oversight of compliance in construction practice during certain mandatory inspection stages ensuring the construction undertaken conforms with the certified design (*Building Regulations 2018*). The RBS is also primarily tasked with the responsibility of assessing design documentation prior to the building permit approval stage and ensuring the planning permit is in line with the building permit. This involves assessing whether the design documentation complies with various building regulations, the *Building Act 1993* and the NCC. It is to be noted that this becomes difficult in the event a complex performance-based solution is incorporated into the design wherein the RBS is entitled to rely on the competency of the design engineer and other relevant personnel (City of Melbourne, 2021).

> Conditions on site restrain trades from following the exact plans. It is the domain of the builder. They control the site. It is all up to them. They are the registered individuals and in control of all site works. There are checkpoints where a building surveyor must be called to site. The builders are the ones who are self-certifying the work. Then they are calling out a surveyor. It is the builders' responsibility to check the waterproofing guy's work. It's not a specific inspection point but if everyone does their job correctly then it shouldn't be an issue.
>
> \- Building Surveyor 2

Certain aspects of the RBS role include affirming building works performed are in accordance with relevant standards and meet performance requirements of NCC, checking for compliant structural documentation provided by architects/engineers, compliant building work during construction and issuing directions for rework where necessary, including reporting non-compliance to the VBA.

The additional areas inspected by the RBS are based on risk and in general based on the relevance to the project. Balconies with habitable space below can be considered as a high-risk area and the building surveyor can include this as an area for mandatory inspection in the building permit. This creates certain issues regarding potential oversight on the quality and adequateness of the work done in terms of waterproofing balconies. This is further exemplified in the case of multi-story residential apartment buildings where its impractical to inspect every aspect of buildings and their balconies.

> [The] RBS should be involved in every stage of the way, a non-compliant design should be picked up at the point of permit and inspections, but in every state other than NSW it is very unclear who is primarily responsible.
>
> \- Academic 1/Architect 1

It is the role and responsibility of the RBS to conduct inspections during certain mandatory inspection stages to ensure the construction conforms to the design. This includes mandatory inspections as specified in regulation 167 of the *Building Regulations 2018*. While inspection stages are mandatory during specific intervals along the construction phase, it must be noted that waterproofing is not currently a mandatory inspection requirement in Victoria under the *Building Regulations 2018*.

A majority of the stakeholders who participated in the online survey (61%) for this research believe that more concrete balcony inspections, that include the input of a structural engineer, are required during construction.[33]

[33] See Figure 28: Requirement for more inspections) in Appendix A: Online survey.

Recommendation 6: Concrete balcony construction should require a mandatory inspection.

Concrete balcony construction should be prescribed by legislation (or an appropriate instrument) to include a two-stage mandatory inspection by a suitably qualified and competent building practitioner (which may include a structural engineer and/or architect) and/or the RBS.

This inspection could include:

1. A pre-membrane mandatory inspection of concrete balconies to include, at a minimum, the inspection and certification of the suitability of concrete for installation of membranes (including of concrete substrate, fall, drainage points, movement joints).
2. A post-membrane mandatory inspection to include, at a minimum:
    - a review by the RBS of information about the applied membrane, its status as an approved product, and its suitability for application to the balcony (information as supplied by the waterproofing consultant/installer)
    - the preparation and submission of a certified inspection report by the builder to the RBS.

These activities would be prescribed by the RBS in building permit approval documentation.

These activities would apply to a suitable number of balconies on a per-building basis, for each level of balcony risk. For these balconies, a construction plan (including dates for concrete placement, waterproofing testing/installation and pods/pavers or screed and tiling) must be prepared and supplied to the project team beforehand.

Recommendation 7: Inspection of concrete balconies may be conducted via representative model.

The builder shall construct a representative model of a balcony floor at a location as agreed to by the consultant team. This model may be used to represent all balconies built to the same specifications for the building.

Where a balcony construction (including waterproofing) is required to be completed, then all relevant inspection certificates, with attached inspection notes, shall be submitted to the RBS as an approved construction.

Balconies with a dimensional variation of up to 10 per cent need not be repeated, with the exception of balconies with habitable space underneath, which must be inspected.

7.4 Construction systems, practices and materials

7.4.1 Failure attributed to construction processes

All elements that protect a balcony area from being subject to water leakage are produced through labour during the construction process. Therefore, it is extremely important that these waterproofing systems are applied as per the manufacturers' construction details and with a level of care. Although inspections may be carried out throughout the waterproofing process, this does not eliminate all prospect of future issues (Zaidi & Davies, 2010).

A waterproofing specialist interviewed for this research emphasises that it is not just failure of the membrane that causes water leaks in concrete balconies. There are other issues that also require consideration:

> Proper termination of membranes is crucial, especially regarding their integration with services, drainage points, and outlets. Neglecting these details can lead to water infiltration underneath the membrane. Membranes might fail due to improper installation, using the wrong type, or incorrect joint placement in the constructed structure.
>
> - Waterproofing specialist 1

One aspect of the exterior of balcony areas which is prominent in waterproofing issues is exterior walls. An examination of building envelope defects (Donnan, 2010) identified common causes to be a lack of knowledge about certain key materials, no comprehension of specified details, lack of skills, poor quality of finish, and no consideration for consequences of specified methods. This finding is supported by Kubal (2008) in his *Construction Waterproofing Handbook*, in which he describes the issue of inadequate construction of building envelopes by general and sub-contractors. The author attributes a lack of attention to detail, poor communication between contractors and untrained or inexperienced personnel to water ingress issues.

Incorrect installation of membrane systems is a frequent problem as identified by Kubal, 2008. A waterproofing specialist interviewed for this project agreed that a well-trained (certified) applicator is crucial for a successful defect free application:

> Water defects caused by incorrect waterproofing is a massive issue because it's not just about the membrane being installed or processes that were in place. But then there's these structural issues that can occur and they may not be present for years. A leak in the membrane often due to a product being damaged after being installed. It can also be due to incorrect falls, wrong substrates.
>
> - Waterproofing Specialist 1

Surface preparation for waterproofing materials is another factor that is crucial to be undertaken correctly during the construction process (Sriravindrarajah & Tran, 2018). When dealing with some liquid applied waterproofing membranes that are used for concrete surfaces, it is especially important for the surface to be adequately prepared. This involves ensuring surface is dry and any voids or imperfections are amended before application (Borle & Ghadge, 2016). A study about how certain application factors can affect the effectiveness of waterproofing membrane identified incorrect mixing of membrane solutions as an issue (Mailvaganam & Collins, 2004).

The importance of construction systems, practices and materials as a key contributor to water leakage in concrete balconies is supported by the online survey conducted for this research; over a third of all survey participants (37%) identified that poor construction was the most important contributor to water leakage in concrete balconies.[34]

[34] See Figure 24 (Most important activities to minimise water leakage in concrete balconies) in Appendix A: Online survey.

> A theoretical point of view compared to the practical application can differ. You learn a lot more on the practical things and seeing what the issues are. There are constant challenges that people on site have to deal with, especially time constraints and time pressure. Often mistakes are made because people are rushing to get things done and not following procedures correctly.
>
> - Waterproofing Specialist 1

Identification of defects after the construction process

After the construction process has been completed it is important to recognise possible indications that there is an issue with the waterproofing system of the balcony. Some of these factors may be noted through inspections or may not be visible until much later, where it is important for the owner or occupant to then recognise. Some of these signs may include wet walls, wet floors, bubbling of the membrane, water ponding and mould growth (Sriravindrarajah et al., 2018). These issues may occur due to several reasons such as poor workmanship, incorrect design, and misconducted inspections.

All these factors that arise during the construction process can be linked to leakage in apartment concrete balcony systems, but may not be detected immediately. Therefore, it is important that once these processes and tasks have been completed, there is a detailed checking process that can eliminate and detect any non-compliance and defects in completed work.

> [The] membrane applicator doesn’t perform necessary checks before or after applying the membrane. For example, the applicator didn't check the moisture content of the substrate before applying the product, or didn’t check whether the thickness of the membrane is consistent, or didn't consider environmental factors of the day.
>
> - Waterproofing Specialist 1

7.4.2 Value management activity

Some 30 per cent of stakeholder interviewees (mainly architects and engineers) raised concern about the way they felt they were required to change architect-crafted details to builder-preferred details for balcony construction under value management and cost cutting exercises. Some interviewees expressed concern that if they refused, the builder would get another consultant who would complete the revised works as directed. These comments were made from multiple disciplines, including from architects, engineers and building surveyors.

> With the housing construction boom, builders have adopted speedy construction and the preferred method is a two-way post-tensioned flat slab. Having a set down for a balcony or even a bathroom is a nightmare for builders, and this is why we have opted to have the required falls in the screed rather than the recommended approach [per AS 4654.2] of integrated slope in the slab. Builders claim that the step-down in the slab not only costs extra dollars and time delays but also affects the building height.
>
> - Builder 1/Construction Director 1

> A lot of times, we face restrictions from developers because they are trying to put in as many floors as they can within x amount of building height restrictions. But the reality is that the physical properties of an element are constant. You know your 100 mm diameter pipe is still 100 mm, you can't make it any smaller.
>
> \- Architect 2

> Developers/Builders are the boss. If you don't do what they want, you won't get the next job. So, you go along with them without set down in the slab even though you know that it's going to cause future issues.
>
> \- Structural Engineer 15

> Getting a structural engineer to come in and look at the structural integrity of all the different aspects of the build form is extremely expensive. So of course a developer will shirk their responsibility wherever they can and try and get the bare minimum of people to come and inspect so it could be anyone in the building inspection game inspecting it and it may not be a structural engineer. The scope of inspection will be limited, they will go through the building and they're just looking at what they can observe if something is missing here, fire collar missing there, etc - doing visual inspection, and they are not looking at the design because owners corporations won't pay for that.
>
> \- Academic 2/ Owners Corporation 1

7.4.3 Selection and installation of waterproofing membranes

Temperature, thermal expansion and ultraviolet light

Exposure to ultraviolet light is one factor that impacts waterproofing; this is particularly so in balconies due to their exposure to the elements. The varying temperatures between summer and winter can cause thermal expansion effects to deteriorate the membrane.

Consideration of thermal expansion needs to be taken when designing waterproofing materials of balconies, in particular the selection of membrane. During design evaluation of the thermal expansion coefficient of the membrane will be a crucial factor in the success of the waterproofing system (Francke & Runkiewicz, 2022).

Other factors that must be factored into design against thermal expansion may include geographical location, weather patterns, possible impact of radiation from the sun and colour of the material/surface. It is important that these are all considered for all balconies, otherwise a discrepancy in quality and resistance to leakage will be noticeable.

There are a multitude of applications of membranes within various locations of the building envelope. For membrane that is exposed to sunlight, consideration should be given to type of membrane that can withstand UV rays, such as a Polyurethane Liquid Membrane. Use of unsuitable materials could result in fraying, deterioration of bonding agents used, or shorten the working life of products.

> To ensure effective waterproofing, the proper membrane must be applied in the correct location and manner, considering joint and substrate conditions. This approach allows prediction and control of movements, minimizing crack openings and structural membrane is compatible with anticipated movements, as legal cases have revealed discrepancies between claimed and actual membrane capabilities. Often, improper membrane usage and placement lead to failures. Adequate allowance for structural movement is vital to prevent tearing or detachment. While membranes contribute, proper substrate drainage, sizing, and collection methods are equally essential. Membranes should be seen as a backup, not the sole waterproofing solution.
>
> - Structural Engineer 1

With each method of laying a waterproofing membrane, there arises new potential for error in the overall watertightness of the structure. Waterproofing membrane ineffectiveness relating to water leakage within the balcony system involves significant challenges and considerations that cannot go unacknowledged during construction and design. These problems may be caused from a variety of factors such as incorrect design, poor installation, failure of material and key aspects of details missed or not correctly executed.

Lap joint detailing is one method that can be successfully used for sheet membranes on the subsurface floor of balcony areas. However, one possible issue with the use of lap joints is shearing failure due to movement within the structure. Movement of the balcony substrate may occur over time, as the foundations of the building or other structural elements connecting to the balcony move. This movement over time is not preventable in most residential buildings, however, during the design stage of the balcony, movement of the structure should be considered. As deformation occurs, the two membranes may separate due to loss of adherence and a fracture may occur (Gonçalves, Lopes, De Brito, & Lopes, 2008).

Deterioration in the bonding agent within the lap joint may result in a shear failure, causing the waterproofing material to be compromised. Research conducted has revealed that elevated temperature can cause extreme deterioration in overlap joint types due to adhesive and tensile strength being impacted negatively (Chung, et al., 2020).

Unsuccessful installation can also be attributed to water leakage. One instance where this may occur could be in the direction of the lap joints being placed. The fall of the balcony surface should run parallel to the overlapping sheet of membrane. If the installer were to not do so, and the fall and overlapping sheet instead run in opposite directions, water leakage may occur. Surface deflection is one cause whereby if the substrate below the membrane is not smooth, or distributes the sheet or joint in any way, tear or bridging failure may occur.

Construction methods: balcony finished floors

Concrete balcony areas in apartment buildings can be constructed with varying finishing surfaces, including the use of screed and tiles, or pods and pavers (see Chapter 5). However, there are significant issues that can arise with waterproofing when these strategies are adopted. The type of materials used will determine the lifespan of the waterproofing system, and if incorrect materials are selected based on the conditions, problems can arise quickly.

As noted above, temperature plays a significant role in the use of tiles in balcony or terrace areas. For example, it has been established that the use of purely cementitious adhesive can cause damage to ceramic tiles due to high stress in the mortar and movement at the base of the tiling (Felixberger, 2006). This evidence suggests that the thermal effects from the sun can raise the temperature of ceramic tiles measuring five meters in length by 40 degrees Celsius, causing the tiles to expand by 1.2 mm. This demonstrates how the use of tiles can be affected by UV exposure and thermal effects and highlights the importance of UV considerations to be taken when waterproofing residential balconies and potential problems that can occur.

This is significant as failure in the adhesive of tiles or pavers can create separation; these gaps allow for water to pool in these areas, and eventually it seeps into the subsurface of the balcony.

Vertical terminations

Vertical upward sections of membrane in balcony areas also propose opportunities for waterproofing defects. One factor of error is the incorrect, or lack of, use of sealant. Use of a sealant is shown to provide better bonding of membrane to avoid peeling or lifting of edges (Almonbhi, 2018). Slippage at the edges could also happen without a sealant being used in these situations. Presence of sharp edges on the corner of the concrete surface also poses risk of tearing of the membrane. Loose stone, or other objectives between the two surfaces can also be problematic according to Almonbhi (2018). The bottom fillet of this section is also an important aspect, with a fillet being required to avoid a right-angle situation where the membrane would be subjected to a sharp turn. Loading of tiles or other heavy finishing surface can also be problematic due to membrane not being very resistant to loading from sharp edges.

Vertical downwards termination is another method commonly used in balcony areas. This type of application carries some similar risk to previously mentioned details such as, correct application of adhesive at edges, surface preparation and deterioration due to sharp edges (Gonçalves, Lopes, De Brito, & Lopes, 2008). One crucial factor of this instance is the need for the membrane to continue around the entire the edge of the balcony surface, completing a U-turn path. If the membrane does not follow this path and instead is terminated at the end of the top surface of substrate, then the risk of water leakage arises. Water may be able to continuously flow around and possibly protrude the building exterior (Riggie, 2020). It is also important to include the fillet in the concrete substrate of the underneath surface when constructing this design. The fillet allows for water to stop travelling around the bottom of the balcony and is made to drip at this point. If this is not included, it again risks water travelling past the terminated membrane and towards structural components of the building. Although it must be noted that this method is not applicable above habitable areas.

> If the structure itself is not designed in a way that allows for correct falls, the drains are not recessed, or the substrate quality is poor. These then will have an effect on the membrane. And it's a responsibility of all parties involved to be aware of the waterproofing membrane.
>
> - Waterproofing Specialist 1

Ensuring that waterproofing products are fit for purpose

The New South Wales (NSW) Government introduced law reforms in 2020 to deal with such problems by including waterproofing as a *building element* for building design work (New South Wales Government (Fair Trading), 2020).

The implication of including waterproofing as a "building element" for building design work is that waterproofing design now falls under regulated design, which therefore requires it to be undertaken by a design practitioner who is registered under the Design and Building Practitioner scheme, and lodged on the NSW Planning Portal before any relevant building work has begun. If Victoria can implement a similar requirement, the likelihood of implementing compliant designs would be increased.

Ratcliff (2018) suggests a register of membranes (tested to relevant standards), standardised product data sheets that allow consistent comparison to be made at product selection, and a register of membranes from which unsuitable products could be struck off:

> Australia seems to be the dumping ground for waterproofing membranes that are not fit for purpose. Under section 18B(1)(b) of the HBA,[35] it is an implied warranty that 'all materials supplied… will be good and suitable for the purpose for which they are used'. Many materials, including membranes, have not been tested by CSIRO[36] or Branz[37]. They say a product complies but, when push comes to shove, they don't comply. A certifier asks for confirmation that materials have been tested and they haven't been evaluated, the developer is then left in the lurch…
>
> Further, there needs to be the creation of standardised data sheets, so architects and designers can go to a manufacturer with information that is laid out in the same format. Some manufacturers spin data or don't give you the necessary information, if there were standardised data sheets for different membranes, everyone would be working to the same information and this would provide clear information for designers of systems, to make sure that the materials are used appropriately. Putting it simply, if you use the right product for the right project, this won't cost anymore and will save rectification costs. If there was a systems approach which works, this would solve all these issues.

These suggestions would be particularly useful for practitioners, given that in general, waterproofing membranes do not have WaterMark certification and only sometimes have CodeMark certification.

Recommendation 8: Appropriate products should be installed by an appropriately qualified installer per the manufacturer's instructions.

This provides increased assurance that installation is compliant and fit for purpose.

1. Waterproofing membrane suppliers shall ensure that the membrane supplied complies with AS 4654.1.
2. Waterproofing membranes shall be installed as per manufacturer specification, and the termination height shall comply with AS 4654.2.
3. Membrane installers should be appropriately qualified for the types of waterproofing work undertaken.
4. Membrane installers shall ensure that the membrane had been installed as per manufacturer's specification, and accordingly issue a warranty certificate and maintenance manual.
5. An approved membrane register, and a list of certified installers, should be made available to consumers and practitioners.

[35] *Home Building Act 1989* (NSW), section 18B.
[36] Commonwealth Scientific and Industrial Research Organisation (CSIRO).
[37] Building Research Association of New Zealand (BRANZ).

7.4.4 Risk-based approach to design and construction of concrete balcony types

The 2020 Senate Economics Reference Committee's Inquiry into Non-Conforming Products (Parliament of Australia, 2018) examined the impact of non-conforming building products and possible improvements to regulatory frameworks. While it did not consider balcony construction specifically, it did provide a recommendation for the consideration of a mandatory third-party certification scheme for high-risk building products, and a national register for those products.

This was followed by Recommendation 21 within the BCR (Shergold & Weir, 2018) for an agreed position from Building Ministers about the potential establishment of a compulsory product certification system for high-risk products. In response, the ABCB released the National Building Products Assurance Framework (BPAF) in 2021, which represented a nationally agreed response to BCR recommendation 21 (Australian Building Codes Board, 2021). The BPAF was seen as the first step in addressing the problems associated with building product safety. Following further consideration, in 2024 the Building Ministers agreed to further implement the BCR recommendations by considering a national scheme that supports the safety and reliability of building products (Department of Industry, Science and Resources, 2024). There is opportunity for the consideration of the classification of some building and construction issues of concern on a risk-based basis, with stronger regulatory provisions proportionate to the identified risk.

The risks associated with some types of concrete balconies, particularly those with habitable spaces below, have been discussed throughout this paper. Consequences of these risks are to human health, safety and amenity, and include the potential for issues with structural integrity as well as the development of mould. Identifying specific balcony types as high risk would allow regulatory focus on the areas where it is most required. When asked about a risk rating approach, such as the one proposed by this research, 79 per cent of survey respondents endorsed the need for a classification or risk rating system.[38] A number of stakeholder interviewees (two building surveyors, three policy advisors, six engineers and two architects) also supported a risk rating approach with respect to stringent design plus mandatory inspections. Seventy-six per cent of online survey respondents indicated that they would like to see a higher risk rating applied to cantilevered balconies.[39]

A proposed assessment of concrete balconies and their associated risk ratings are provided in Table 5. Open concrete balconies with habitable space below pose the highest risk in terms of safety and financial consequences.

Construction of concrete balconies associated with a high risk rating must be attendant with strong regulatory provisions. The proposed risk ratings will assist practitioners and RBS to determine the amount of certification and parallel activity required (such as inspections) that should be allocated per balcony construction type (see section 5.2 for definitions of balcony construction types).

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[38] See Figure 29: Greater design requirements based on classification/risk rating systemThe role of the structural engineer in the communication of deflection performance) in

Appendix B: Stakeholder interviewsOnline survey.

[39] See Figure 33: Requirement for higher risk rating for cantilevered concrete balconies) Appendix A: Online survey

Table 5: Building rise, balcony types and associated risk (Class 2 apartment buildings)

Rise		← Risk →			
↑	High-rise 30+ levels	Inset balcony No habitable space underneath.	Open balcony No habitable space under	Inset balcony Habitable space under	Open balcony Habitable space under
Rise	Medium-rise 11-29 levels	Inset balcony No habitable space under	Open balcony No habitable space under	Inset balcony Habitable space under	Open balcony Habitable space under
↓	Low-rise 3-10 levels	Inset balcony No habitable space under	Open balcony No habitable space under	Inset balcony Habitable space under	Open balcony Habitable space under

> We have been relying heavily on waterproofing membranes to do the work, but membranes only have a limited life, from about 5-15 years… the building/slab needs to last much longer, about 50-60 years… so let's assume the membrane is going to fail - and it will fail. I think you are looking at it correctly and a risk rating system will be beneficial.
>
> \- Academic 1/Architect 1

> We love to inspect each, and every balcony in apartment buildings but we don't, and we do inspect a percentage of balcony to cutdown the cost. I would welcome any move towards adopting a risk rating system coupled with balcony mandatory inspection. Great Idea!
>
> \- Construction Director 1

More than half of the of online survey respondents (57%)[40] and stakeholder interviews (55%) indicated that more stringent requirements, with prescriptive structural design and material specification, are required.

[40] See Figure 34: Stringent requirements for concrete balconies) Appendix A: online survey

Recommendation 9: Concrete substrates should be designed as water retaining elements depending on the risk score of the balcony.

Concrete balconies should be classified according to the risk to on safety, rectification cost, and any other relevant negative impact to community.

A suggested approach is detailed in Table 5 above. Key implementation recommendations are:

- Balconies with habitable space underneath are to be classified as high risk
- Concrete substrates should be designed as water retaining elements depending on the risk score of the balcony
- A two-way post-tensioned flat slab with no set down for the balcony must not be permitted for balconies with habitable space underneath. This is due to the frequency of defects associated with this design (see section 5.3.7)
- For durability design of the concrete the concrete exposed surface shall be treated as external ignoring the presence of water proofing membrane
- The risk score shall be increased for balconies near (<1km) coastal areas. This increase is due to the increased likelihood of corrosion of metal components (including concrete reinforcement elements as well as elements of balustrades (Wittocx, et al., 2022) in locations where elevated salt content is present in the air
- Movement joints/ construction joints and post-tensioned anchor pockets shall be avoided on concrete balcony slabs for balconies that have habitable space underneath.

7.5 Post-construction repair and maintenance

7.5.1 Maintenance and repair works

A large number of the defect reports concerning concrete balconies considered within the present research identified that the failure of waterproofing membranes and little or no maintenance contribute to water leakage in concrete balconies (see section 7.1). This water leakage generally occurs through concrete cracks/joints/slab wall junctions, and can result in not only making the habitable space underneath the balcony unusable, but may also corrode the reinforcement in the slab and slab/wall junction.

> …we are [located on] a peninsula, the sea is the attraction and so everybody wants to have balconies and terraces and be able to look outside. But then with this comes a dramatic problem. That is the problem of water… but also of corrosion in terms of the reinforced concrete balconies. One of the issues is chloride penetration; the other one is carbonation of the concrete.
>
> - Academic 5/Structural Engineer 15

> I don’t think anyone maintains anything with balconies. With pods and pavers systems, there is a chance of removing pods, and cleaning the drain, and inspecting the membrane… but with [a] screed and tile system, a membrane cannot be inspected as it is covered by screed and tiles. [Over the] last 10-15 years builders, prefer [sic] to have pods and pavers as [a] balcony finish in apartment buildings.
>
> - Construction Director 1

Typically, balconies are constructed such that the floor slopes gently towards a stormwater outlet/drain, and the balcony will have 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. For example, it may fail immediately, after one year, or even twenty years. The failure of a waterproof membrane may in some cases constitute a building defect, but in others, it may be caused by poor maintenance, or a lack of maintenance.

The ’design life’ of a concrete balcony is 50 years, and the warranty period on a typical waterproofing membrane is generally 10-15 years. This means the balcony needs to be maintained and the waterproofing membrane may need replacement at least twice during a balcony’s design life.

The interviews conducted during the present research supported that maintenance is a concerning issue. Almost all (90%) of the interviewees raised concerns about the lack of awareness or inattention of apartment owners.

> Homeowners don't realise they have to maintain the balcony waterproofing membrane.
>
> - Waterproofing Specialist 1

> There is a lack of long-term reliability. Initial design, construction and maintenance are all lacking. This is why it a systemic issue. There is no annual maintenance. You can’t expect every owner to know the seriousness – [they] may not know the seriousness of a crack...
>
> - Building Surveyor 2

> Looking at the maintenance and the long term, it is something that always concerns me. That part is never properly coordinated.
>
> - Structural Engineer 3

Recommendation 10: The maintenance manual supplied to owners/occupiers is to include key maintenance requirements of concrete balconies.

Upon completion of a building, a building practitioner should be required to provide a maintenance manual for owners/occupiers detailing the maintenance requirements of the concrete balcony.

The building manual, provided by the RBS to the building owner as described within the *Building Act 1993* (see s41A, s41B, and s44A) should include the elements listed below. These elements should be prescribed for inclusion in Victorian Building Regulations or other appropriate documents:

- as-built structural and architectural drawings of the balcony, at a minimum showing cross-sections of the components of balconies requiring regular maintenance
- keeping the drainage outlet and overflow pipes clear of and blocks or damages
- an indication of the loading capacity of the balcony structure, with simple illustrations of examples of planters, furniture and equipment suitable to the balcony, and
- an explanation of the consequences of infrequent or absent maintenance.

7.5.2 Overloading of balconies

If the concrete balcony's slab is not designed to accommodate heavy loading, then the slab may deflect more than is allowable by design. This can result in water stagnation issues, and cracking in the concrete, which in turn can lead to water penetration through the slab, and the negative consequences that result.

Figure 22 highlights the potential for loading issues imposed by heavy pots and plants.

Figure 22: Balconies with plants, presenting the potential for heavy loading issues

A vast majority of the stakeholders interviewed for this research (80%) talked about the misuse of balconies, mentioning overloading with excessive screed, an excessive number of guests during functions, and heavy planter boxes being placed on balconies post-construction. British Standard 8579:2020 (British Standards Institution, 2020) recommends displaying the safe working load in the balcony area to minimise the risk of unexpected over-loading. This requirement is not present in Australian regulations but may provide owners and occupants important information when furnishing balconies.

> …AS 1170 provision is inadequate. The consumer is unaware of the load restrictions on balconies. Big parties… can attract 100 or more people, where an 8 x 3 balcony can only have maximum of 25 people. Also, consumers are unaware of the maximum planter box loading. I have seen people having planter boxes with 800-900 mm high soil which is probably not considered by the structural engineer.
>
> - Academic 3/Structural Engineer 8

Recommendation 11: Greater consideration of load limits in AS 1170.

AS 1170 should provide revised guidance about load limits.

Suggested amendments to AS 1170.1:2011 are as follows:

- For all concrete balconies, slabs shall be designed to:
  1. a Live Load of min 4.0 kPa or equal or more than the leading floor Live load, or
  2. 4 kN point loads at 1.0 m centres,

  whichever produces the maximum design actions.
- Pods and pavers may not be a solution for high loads unless the design allows for high point loads as noted above.
- Wind uplift on pods and pavers are to be checked.

Recommendation 12: Victorian planning provisions to consider load limits.

The rise in the use of green balconies means that loading should be considered as early as possible in the life cycle of a building, including the planning process.

There is an increasing trend for the use of balconies as green spaces, which are associated with heavy plant loading.

Content of the Victorian Planning Provisions would benefit from addressing the loading requirements of plants and garden on balconies. Ideally, this would be informed by a review of loading allowances on balconies.

> I think just the importance of preventing water ingress in general, mould growth and all that stuff is starting make consumers a bit more aware. We've certainly seen lots of things in the media. You know about some of the impacts of that. So understanding, you know, going beyond just identifying when there might be an issue, but actually actively preventing that in your property I think is something that we could do a lot more to educate consumers on and from and then it sort of goes all the way back to the start of that process again in documenting that appropriately, making sure that all the practitioners that are involved.
>
> - Policy Advisor 4

7.6 Guidance, education and training

7.6.1 Availability of a dedicated concrete balcony construction guideline

According to interviews conducted by Johnston and Reid (2019) with relevant stakeholders, it was found that interviewees expressed frustration with the costs associated with buying AS. Although AS are referenced in the NCC as documents required to achieve compliance, there is currently a lack of open access to these referenced documents.

The VBA had previously produced a guideline regarding the design and building of waterproofed balconies, though it has now been archived (Victorian Building Authority, 2015). Given the age of the document, and its narrow availability on the wider internet since its removal from the VBA's website, it is likely that awareness of this document among practitioners is low. Indeed, the online survey conducted for the present research found that over half of the building practitioners surveyed (including architects, engineers, builders and waterproofers) agreed that better and clearer guidelines on the application of current requirements are needed.[41]

The VBA's archived 2015 guideline provided plain-language information for practitioners that included:

- critical details to be included in designs (including the use of a membrane that complies with AS 4654.1:2012), to be submitted to the RBS
- guidance for building surveyors regarding the evidence to meet regulations for waterproofed balconies
- recommendations about product types (e.g. warning against the use of chipboard substrates and bathroom-grade membranes)
- guidance about water flow direction and drainage.

Given that many of these issues have been found to be problematic within the present research, the argument for a Victorian guideline that supports the compliant design and building of waterproofed balconies is compelling, particularly given the benefits to Victorian consumers associated with safer homes and reduced costs in rectifying defects.

This research found that there is an urgent need of a technical reference document or guideline; this was a unanimous suggestion by interviewees.

Further, an overwhelming majority of the online survey respondents supported the idea of having a dedicated standard for concrete balconies (85%.)[42]

> There are some good guidelines and diagrams have been incorporated in the recently released British Standard BS 8579 which can be easily accommodated in a technical guide/practice note.
>
> - Structural Engineer 2

If dedicated guidance is provided about concrete balcony design and construction, then such guidance would benefit from a checklist template (as per section 7.3.2).

[41] See Figure 38: (Sufficiency of regulation and the need for better and clearer guidance documents) in Appendix A: Online survey.

[42] See (Support for a dedicated concrete balcony construction standard or Section of the NCC) in Appendix A: Online survey.

> There's really been a lack of guidance around the best way to deal with waterproofing issues and water ingress. There has been advice for building surveyors, architects and engineers. But there is no consolidated pack of guidance material for everyone. And it has been long overdue.
>
> \- Structural Engineer 11

Recommendation 13: A technical reference document/guideline for concrete balconies should be developed.

A technical reference document and/or guideline about the design, building and waterproofing of concrete balconies should be made freely available to practitioners.

1. At a minimum, this technical reference document/guideline should include:
    a. an updated version of VBA's now-archived guideline regarding the design and building of waterproofed balconies (Victorian Building Authority, 2015)
    b. a design flow chart (see Figure 4 in section 3.3 for an illustrative example) and a accompanying sample design process, including structural calculations.
    c. a practical tool to evidence accountability for, and acceptance of, concrete balcony detailing. This could be in the form of a checklist (see Figure 21 in section 7.3.2 for an illustrative example).

       When checked off and signed, this checklist could be submitted to the RBS as supporting documentation.
2. To remove barriers to industry uptake, the technical reference document/guideline should be made available to practitioners free of charge.

7.6.2 Substrate design and crack control provisions within Australian Standards

Clause 2.9 of AS 4654.2 specifies that the concrete substrate design is to be carried out using AS 3600.

Concrete balconies can hold water if drainage is blocked, which can then lead to the blockage of the overflow pipe. In this scenario, arguably, as the balcony is holding water, the slab needs to be treated as a water retaining structure. Accordingly, then the concrete substrate design should be made according to AS 3735.[43]

The key difference between these codes is with regards to the limitation of cracking. Crack control is very important for concrete balconies for two main reasons:

1. Preventing water leakage.
2. Preventing corrosion of reinforcement.

[43] Standards Australia. (2001). Concrete structures for retaining liquids. (AS Standard No.AS3735).

The main types of cracks which contribute to the above are:

1. Shrinkage cracks, which extends to the full depth of the slab
2. Flexural cracks which extend the flexural tension portion of the slab depth:
    a. For a cantilevered slab – relates to the top reinforcement
    b. For a simply supported slab – relates to the bottom reinforcement.

Comparison of crack control provisions between AS 3600 (applied to concrete structures) and AS 3753 (applied to concrete structures for retaining liquids) demonstrate that any concrete balcony built to AS 3600 would have greater tolerance for cracking, thus rendering those concrete balconies more prone to weakness and defects. Table 6 provides a comparison between the two AS. A 12 mm diameter bar is chosen as a comparison point as it is one of the bar diameters specified across both of these AS.

Table 6: Comparison of AS crack control provisions

Note: Comparison figures are provided for a 12 mm diameter bar only.

		Flexural crack control			Shrinkage crack control	
AS	**Construction type**	**Reference**	**Maximum crack width**	**DtS limit of steel stress**	**AS Reference**	**Reinforcement ratio to control crack width**
AS 3600: 2018	Concrete structures	Table 9.5.2.1 (A)	0.2 mm*	210 MPa	Cl 9.5.3.4	0.006
AS 3735: 1991	Concrete structures for retaining liquids	Table 3.2	0.15 mm	150 MPa	Cl 3.2.2	0.0048±

* based on the exposure condition.

± AS 3600 does not clearly specify that there is a necessity to limit cracks to 0.2 mm width; this is inferred by the authors. It is recommended that AS 3600 provide clearer guidance on this matter in Table 9.5.2.1 (A) of the AS.

A well-designed concrete balcony with an appropriately installed integral step, fall and hob is expected to shed water through a well-designed drainage system. If the drainage is blocked, the balcony should shed the water via an overflow pipe. If water does pond in the balcony basin, even for a short period, then the waterproofing membrane is expected to safeguard the concrete. However, if the waterproofing membrane has failed, the concrete alone must be sufficient to protect any habitable space below from water penetration. For this reason, it is advisable to design the concrete slab with a greater degree of crack control. A number of stakeholders interviewed for this project across a diverse range of roles (six structural engineers, two architects, one building surveyor and one builder) supported this perspective.

Recommendation 14: Greater consideration of crack control in AS 3600.

AS 3600 should provide clearer guidance in Table 9.5.2.1 (A) about crack width limits.

All concrete substrates shall be designed to have crack width limited to 0.2 mm, except balconies which have habitable space under shall be designed to have a crack width limit of 0.15 mm. Furthermore, shrinkage crack control reinforcement shall be provided in all direction to provide a strong degree of crack control.

Suggested amendments to AS 3600:2018 are as follows:

- For concrete slabs exposed to weather such as balcony, terraces and rooftops shall be designed as follows:
    i. Top cover shall be increased by 10 mm (Minimum f'_c=40 MPa).
    ii. Slab shall be designed for crack control (Cl 9.5.2) with a crack width less than or equal to 0.2 mm.
    iii. Add to - 9.5.3.4 (d): for all concrete balcony slabs, a strong degree of crack control reinforcement shall be provided in both directions.
    iv. Mix design shall be prescribed to achieve watertightness and low shrinkage (56-day min 450 microstrain).

> For smaller restricted areas (such as balconies), there should be an increase in the design load because the smaller the area, the bigger the concentration factor, but he questions whether this is actually implemented in practice. Interviewee speculated that the thickness of the balcony simply follows the thickness of the floor behind the balcony.
>
> - Academic 3/Structural Engineer 8

Table 2 in section 6.2.1 illustrates the structural behaviour of a cantilevered concrete balcony. From this, it can be stated that:

- Increasing the cover from 20 mm to 30 mm can increase the deflection by approximately 27%. Crack control requirements can increase the reinforcement by 50%.
- Ignoring loads from barriers can increase the deflection by 35%, and slightly increase the reinforcement.
- Incorrect assumptions about screed and tiles can increase the deflection by 54% and the reinforcement by 75%. Adding a planter at the edge of the cantilever can increase the overall deflection by 345% and the reinforcement by 205%.
- There can be a 400% accumulated increase in deflection and 215% increase in reinforcement.

This simple analysis clearly demonstrates the importance of appropriate cover, and the benefits of selecting the cover for exterior exposure, (regardless of protection afforded by the membrane) and the appropriate loadings on the balcony.

7.6.3 Opportunities for education and training

There is a general lack of current studies, literature and information on the issue of practitioner awareness of AS content relevant to the design and construction of concrete balconies. However, several defect reports, forensic analyses by experts in the field and stakeholder interviewees suggest that a concrete slab with adequate set down, fall, drainage and overflow pipe would solve a majority of the water leakage issues currently existing in concrete balconies. This suggests that mandatory provisions within the NCC and AS are not always followed by practitioners. There could be many reasons for this, including a lack of knowledge from practitioners working with concrete balcony structures.

In October 2018, the Master Builders Association Waterproofing Advisory Panel shared insights and challenges surrounding the strict following of AS (Heaton, 2019). Seven areas of concern regarding current opportunites for education and training were identified:

- a lack of waterproofing expertise from designers, builders, and certifiers
- a lack of training in waterproofing within building courses
- an absence of requirements for builders to undertake waterproofing training
- architects and engineers not being trained in waterproofing and flashing design, installation, and assessment
- an absence of subjects that are specific to waterproofing in current building courses
- a lack of a mandatory requirements for builders to undertake continuing professional development training in core areas of waterproofing and flashing
- a lack of uptake in apprentice level training in waterproofing.

These findings are supported by the online survey conducted as part of the present research, where all participants agreed that training and education is important to curtail water leakage. Sixty-two per cent of the survey respondents indicated that current training and education in concrete balcony waterproofing design are inadequate, while 26 per cent were unsure.[44]

> There's nothing in the AS 3600 that indicates what you should do… from [a] prescriptive point of view for balcony and step down. It just says: 'if you are going to construct something, this is the way you're got to do it.' It doesn't say 'in these circumstances you should have a step down.' And the only reference that there is for the poor old designer and builder is that there is this funny little standard or reference in the waterproofing standard (AS 4654,1 and 2) [of] which 99.9% would never know existed.
>
> \- Waterproofing Specialist 2

Only 20 per cent of the stakeholders who participated in the online survey conducted for this research believed that building practitioners are competent with regard to regulatory provisions for concrete balcony design, construction and certification.[45]

Sixty-six per cent of stakeholders who participated in the online survey for this research indicated that a statewide seminar engaging stakeholders and other interested parties about concrete balcony design would be beneficial.[46]

[44] See Figure 36 (Sufficiency of current education and training in concrete balcony waterproofing design) in Appendix A: Online survey.
[45] See Figure 30: Competency of building practitioners for concrete balcony design, construction and certification) in Appendix A: Online survey.
[46] See Figure 41: Awareness: Statewide seminar on concrete balcony design) in Appendix A: Online survey.

Recommendation 15: Increased opportunities for education and training.

Avenues to increase the opportunity for practitioners to participate in ongoing education and training throughout their careers should be explored.

Avenues might include:

1. educational opportunities to upskill practitioners to a wider knowledge about how to minimise water leakage issues, such as technical evenings, workshops, seminars, and short courses, and
2. teaching balcony design detailing and waterproofing at an undergraduate level or within TAFEs, that will enhance the capability of practitioners at the start of their careers to prevent and resolve water leakage issues.

Recommendation 16: Enforcement of ongoing education and training.

Activity to ensure the uptake of ongoing education and training should be enforced within the regulatory system.

This might include:

1. the introduction of mandatory continuing professional development (CPD) requirements that include balcony design and waterproofing. This will ensure the consistency of skills of the practitioner cohort, and
2. the issuance of licencing and registration could require the successful completion of authorised assessed modules.

7.6.4 Lack of available information about membranes

An issue raised by Heaton (2019) is that even where relevant AS are followed, there is a lack of information available for practitioners and consumers alike surrounding what types of membranes should be used in which areas of construction.

Product specification is an extremely important aspect of design, and the lack of information in (or availability of) guiding documentation such as AS may lead to poor decisions with respect to membrane choice. These issues are likely to particularly challenge an inexperienced engineer or builder who has not designed or built a balcony area previously. The consequences of these poor decisions may negatively impact the health and safety of occupants and fail to protect the economic value of the structure held by the owner.

8 Conclusion

This research provides a broad examination of water leakage in concrete balconies through an academic and grey literature review, an evaluation of key AS and other guidelines, and a synthesis of diverse industry and stakeholder feedback. Evidence provided within this research confirms that water leakage in concrete balconies is not only a serious building defect, but a significant economic burden to community and industry.

In examination of the causes for the water leakage in concrete balconies, this research team has adopted a holistic, whole of life perspective that considers all key components of the concrete balcony structure over time. Key recommendations include reforms to the design and construction of water shedding elements, planning, adequacy of detail in design, coordination and responsibility of parties, inspections, certification, maintenance, and education and training.

The research team is confident that this research sheds light on the underlying issues that cause water leakage in concrete balconies. Adoption of the recommendations made by this research for regulatory change, development of technical requirements and guidance, and education and training for practitioners will increase positive outcomes for both community and industry.

9 List of recommendations

Recommendations for reform

Recommendation 1: Concrete balcony design drawings must contain suitable levels of detail.

Building permits must include a certified design that provides detail about concrete balcony construction. This should include information about deflections and movements, and any other necessary information to facilitate the construction of the waterproofing design (e.g. product requirements).

This could be achieved by:

1. The production of a concrete balcony construction detail (showing compliance to NCC and relevant AS), along with the waterproofing specifications, in collaboration by the structural engineer, the project architect, the hydraulics engineer and or licensed plumber.
2. The inclusion of the concrete balcony construction detail (per point 1 above) within the building permit application package is supplied for the building surveyor's approval as part of the issuance of a building permit.

Recommendation 2: Design to be coordinated between relevant parties at the outset of the design process.

An initial coordination workshop should be held by key players to develop and document an agreed concept sketch for concrete balcony detail.

Planning, clear communication and coordination among all players must be established from the beginning of the project. This particularly applies to structural engineers, architects, hydraulic engineers, the RBS, the quantity surveyor and waterproofing consultants.

An initial coordination workshop should be held by key players to develop and document an agreed concept sketch for concrete balcony detail. This will facilitate producing a certified balcony construction detail (which, as outlined in recommendation 1, could be required for permit application).

For their own benefit, the developer/builder should initiate this coordination workshop. In the request for tender (RFT), requirement of this workshop should be included.

Recommendation 3: The builder should submit a signed Inspection and Testing Plan to the RBS prior to the issuance of an occupancy permit.

This will identify the chain of responsibility and clarify accountabilities. Accordingly, parties will be able to readily identify which practitioner is required to act to ensure compliance.

An Inspection and Testing Plan (ITP) for the design and construction of the concrete balcony must be prepared by the project team (consisting of project structural engineer, hydraulics engineer, project architect, builder's project manager, and waterproofing contractor).

The ITP must address all necessary requirements for the design, construction and waterproofing of the concrete balcony, and identify the hold points and accountable persons.

A final copy of the ITP (signed by all project team members) must be submitted by the builder to the RBS prior to issue of an occupancy certificate.

Recommendation 4: A detailed checklist should be available to practitioners to record acceptance of concrete balcony detailing.

This will identify the chain of responsibility and clarify accountabilities, as parties will be able to readily identify which practitioner is required to act to ensure compliance.

A detailed checklist that identifies the chain of responsibility and associated accountabilities during design and construction should be freely available to practitioners.

This would ideally be provided in tandem with dedicated guidance about the design and construction of concrete balconies (see also 7.6.1).

Recommendation 5: A structural engineer should take a lead role in the design and detailing of concrete as the primary water shedding element.

Expertise provided by a structural engineer should guide the design and detailing of the concrete balcony.

This leading role should include:

- working with architects to provide design and details of the balcony concrete with integrated hobs and falls to NCC requirements (per AS 4654.2)
- providing the expected deflection at the tip of the cantilever and for spanning elements at the mid span of the slab
- providing the movements at all joints (slab/wall junction, expansion/control joints, and construction joints).

Ideally, this would be supported by others working with the structural engineer:

- Project engineers should submit all the above information to RBS as part of the building permit approval.
- Project architects should submit plans and section drawings (showing appropriate levels of slab and outlet locations) with levels and architectural specifications to the RBS as part of the building permit.

This package should include a drainage lay-out as supplied by a registered hydraulic engineer or licensed plumber.

Recommendation 6: Concrete balcony construction should require a mandatory inspection.

Concrete balcony construction should be prescribed by legislation (or an appropriate instrument) to include a two-stage mandatory inspection by a suitably qualified and competent building practitioner (which may include a structural engineer and/or architect) and/or the RBS.

This inspection could include:

1. A pre-membrane mandatory inspection of concrete balconies to include, at a minimum, the inspection and certification of the suitability of concrete for installation of membranes (including of concrete substrate, fall, drainage points, movement joints).
2. A post-membrane mandatory inspection to include, at a minimum:
    - a review by the RBS of information about the applied membrane, its status as an approved product, and its suitability for application to the balcony (information as supplied by the waterproofing consultant/installer)
    - the preparation and submission of a certified inspection report by the builder to the RBS.

These activities would be prescribed by the RBS in building permit approval documentation.

These activities would apply to a suitable number of balconies on a per-building basis, for each level of balcony risk. For these balconies, a construction plan (including dates for concrete placement, waterproofing testing/installation and pods/pavers or screed and tiling) must be prepared and supplied to the project team beforehand.

Recommendation 7: Inspection of concrete balconies may be conducted via representative model.

The builder shall construct a representative model of a balcony floor at a location as agreed to by the consultant team. This model may be used to represent all balconies built to the same specifications for the building.

Where a balcony construction (including waterproofing) is required to be completed, then all relevant inspection certificates, with attached inspection notes, shall be submitted to the RBS as an approved construction.

Balconies with a dimensional variation of up to 10 per cent need not be repeated, with the exception of balconies with habitable space underneath, which must be inspected.

Recommendation 8: Appropriate products should be installed by an appropriately qualified installer per the manufacturer’s instructions.

This provides increased assurance that installation is compliant and fit for purpose.

1. Waterproofing membrane suppliers shall ensure that the membrane supplied complies with AS 4654.1.
2. Waterproofing membranes shall be installed as per manufacturer specification, and the termination height shall comply with AS 4654.2.
3. Membrane installers should be appropriately qualified for the types of waterproofing work undertaken.
4. Membrane installers shall ensure that the membrane had been installed as per manufacturer’s specification, and accordingly issue a warranty certificate and maintenance manual.
5. An approved membrane register, and a list of certified installers, should be made available to consumers and practitioners.

Recommendation 9: Concrete substrates should be designed as water retaining elements depending on the risk score of the balcony.

Concrete balconies should be classified according to the risk to on safety, rectification cost, and any other relevant negative impact to community.

A suggested approach is detailed in Table 5 above. Key implementation recommendations are:

- Balconies with habitable space underneath are to be classified as high risk
- Concrete substrates should be designed as water retaining elements depending on the risk score of the balcony
- A two-way post-tensioned flat slab with no set down for the balcony must not be permitted for balconies with habitable space underneath. This is due to the frequency of defects associated with this design (see section 5.3.7)
- For durability design of the concrete the concrete exposed surface shall be treated as external ignoring the presence of water proofing membrane
- The risk score shall be increased for balconies near (<1km) coastal areas. This increase is due to the increased likelihood of corrosion of metal components (including concrete reinforcement elements as well as elements of balustrades (Wittocx, et al., 2022) in locations where elevated salt content is present in the air
- Movement joints/ construction joints and post-tensioned anchor pockets shall be avoided on concrete balcony slabs for balconies that have habitable space underneath.

Recommendation 10: The maintenance manual supplied to owners/occupiers is to include key maintenance requirements of concrete balconies.

Upon completion of a building, a building practitioner should be required to provide a maintenance manual for owners/occupiers detailing the maintenance requirements of the concrete balcony.

The building manual, provided by the RBS to the building owner as described within the *Building Act 1993* (see s41A, s41B, and s44A) should include the elements listed below. These elements should be prescribed for inclusion in Victorian Building Regulations or other appropriate documents.

- as-built structural and architectural drawings of the balcony, at a minimum showing cross-sections of the components of balconies requiring regular maintenance
- keeping the drainage outlet and overflow pipes clear of and blocks or damages
- an indication of the loading capacity of the balcony structure, with simple illustrations of examples of planters, furniture and equipment suitable to the balcony, and
- an explanation of the consequences of infrequent or absent maintenance.

Recommendation 11: Greater consideration of load limits in AS 1170.

AS 1170 should provide revised guidance about load limits.

Suggested amendments to AS 1170.1:2011 are as follows:

- For all concrete balconies, slabs shall be designed to:
  - i. a Live Load of min 4.0 kPa or equal or more than the leading floor Live load, or
  - ii. 4 kN point loads at 1.0 m centres,

  whichever produces the maximum design actions.
- Pods and pavers may not be a solution for high loads unless the design allows for high point loads as noted above.
- Wind uplift on pods and pavers are to be checked.

Recommendation 12: Victorian planning provisions to consider load limits.

The rise in the use of green balconies means that loading should be considered as early as possible in the life cycle of a building, including the planning process.

There is an increasing trend for the use of balconies as green spaces, which are associated with heavy plant loading.

Content of the Victorian Planning Provisions would benefit from addressing the loading requirements of plants and garden on balconies. Ideally, this would be informed by a review of loading allowances on balconies.

Recommendation 13: A technical reference document/guideline for concrete balconies should be developed.

A technical reference document and/or guideline about the design, building and waterproofing of concrete balconies should be made freely available to practitioners.

1. At a minimum, this technical reference document/guideline should include:
   a. an updated version of the VBA's now-archived guideline regarding the design and building of waterproofed balconies (Victorian Building Authority, 2015)
   b. a design flow chart (see Figure 4 in section 3.3 for an illustrative example) and an accompanying sample design process, including structural calculations.
   c. a practical tool to evidence accountability for, and acceptance of, concrete balcony detailing. This could be in the form of a checklist (see Figure 21 in section 7.3.2 for an illustrative example).

      When checked off and signed, this checklist could be submitted to the RBS as supporting documentation.
2. To remove barriers to industry uptake, the technical reference document/guideline should be made available to practitioners free of charge.

Recommendation 14: Greater consideration of crack control in AS 3600.

AS 3600 should provide clearer guidance in Table 9.5.2.1 (A) about crack width limits.

All concrete substrates shall be designed to have crack width limited to 0.2 mm, except balconies which have habitable space under shall be designed to have a crack width limit of 0.15 mm. Furthermore, shrinkage crack control reinforcement shall be provided in all direction to provide a strong degree of crack control.

Suggested amendments to AS 3600:2018 are as follows:

- For concrete slabs exposed to weather such as balcony, terraces and rooftops shall be designed as follows:
  i. Top Cover shall be increased by 10 mm (Minimum f'_c=40 MPa).
  ii. Slab shall be designed for crack control (Cl 9.5.2) with a crack width less than or equal to 0.2 mm.
  iii. Add to - 9.5.3.4 (d): for all concrete balcony slabs, a strong degree of crack control reinforcement shall be provided in both directions.
  iv. Mix design shall be prescribed to achieve watertightness and low shrinkage (56-day min 450 microstrain).

Recommendation 15: Increased opportunities for education and training.

Avenues to increase the opportunity for practitioners to participate in ongoing education and training throughout their careers should be explored.

Avenues might include:

1. educational opportunities to upskill practitioners to a wider knowledge about how to minimise water leakage issues, such as technical evenings, workshops, seminars, and short courses, and
2. teaching balcony design detailing and waterproofing at an undergraduate level or within TAFEs, that will enhance the capability of practitioners at the start of their careers to prevent and resolve water leakage issues.

Recommendation 16: Enforcement of ongoing education and training.

Activity to ensure the uptake of ongoing education and training should be enforced within the regulatory system.

This might include:

1. the introduction of mandatory continuing professional development (CPD) requirements that include balcony design and waterproofing. This will ensure the consistency of skills of the practitioner cohort, and
2. the issuance of licencing and registration could require the successful completion of authorised assessed modules.

Recommendations for future research

In the course of conducting this research, a number of opportunities for future research were identified by the researchers. Support for further research about concrete balconies failures due to water leakage was provided by online survey responses, as 68 per cent of survey participants agreed that there is insufficient research in this area (see Appendix A: Online survey).

Research recommendation 1: Researchers should be provided with greater access to case details about building structure defects and disputes.

Concrete balconies that are subject to legal dispute, and the cause of the dispute, should be made available to researchers.

To improve balcony construction, the information on current defects and root causes must be studied to avoid the same defects happening again.

During the research, the authors faced several challenges in securing case studies.

Several engineers, architects, builders, waterproofers/installers/suppliers, strata managers/owner's corporation members and building surveyors were prepared to talk to the authors confidentially, but were reluctant to reveal details for publication, even after anonymity was offered. It may have been the case that there may be repercussions and or they would not like to take the responsibility of the occurrence.

To overcome this, VCAT/VMIA claims were examined as a potential additional source of data. However, available documents generally did not include details about concrete balcony construction or other key building structure information.

1. VCAT/VMIA case details including all drawings and specification should be made available to researchers and other training bodies.
2. Where city councils and private building surveyors can assist researchers in providing valuable data for case studies, they should do so.
3. Where law institutes, insurers and government authorities can assist researchers in providing valuable data for case studies, they should do so.

Research recommendation 2: Research should be conducted about the impact of requirements for increased insulation on concrete balconies.

The impact of requirements for increased insulation on concrete balconies may change due to the evolution of energy efficiency requirements.

The implications of greater insulation requirements (due to increased energy efficiency requirements) upon balcony design and construction details may require a drastic change in current practices, and thus research into the potential implications is required.

Research recommendation 3: Design life of buildings should drive the focus of future research.

Future research, and regulatory building audits, should focus on buildings that have reached their design life.

Auditing the building with a team of practitioners (architects, engineers, builders and waterproofers), and documenting the status of the building with its history would be useful for identifying and recommending better practice guidelines.

Balconies could be classified into the following groups:

1. Building aged less than or equal to 50 years:
    a. Buildings aged 0-10 years (equal to the warranty period of the membrane)
    b. Buildings aged 11-20 years
    c. Buildings aged 21-30 years
    d. Buildings aged 31-40 years
    e. Buildings aged 41-50 years, and

2. Buildings aged over 50 years.

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Appendix A: Online survey

To understand practitioner knowledge and views about water leakage in concrete balconies in apartment buildings, an online survey was conducted via the Housing Industry Association website. The survey was open from July to August 2023, and 131 people responded to the survey. A summary of the responses is presented below.

Participants

The largest respondent group was design engineers (76 participants; 58%) (Figure 23). The significant participation of design engineers is taken to indicate the importance of concrete balcony design to these professionals, particularly with respect to minimising water leakage. However, the potential for this cohort to skew survey results must be noted, as members of other building professions may hold different views on design matters.

The second largest share of respondents was 'Other' (15 participants; 11%). 'Other' respondents classified themselves as being of the following affiliations:

- Education/Academic/Student/Researcher (x6)
- Forensic Investigator
- Forensic Structural Engineer
- Building Developer/Client/Homeowner
- Consulting engineering - specialist in concrete materials and construction quality.
- Site inspection engineer
- Inspector (x4)

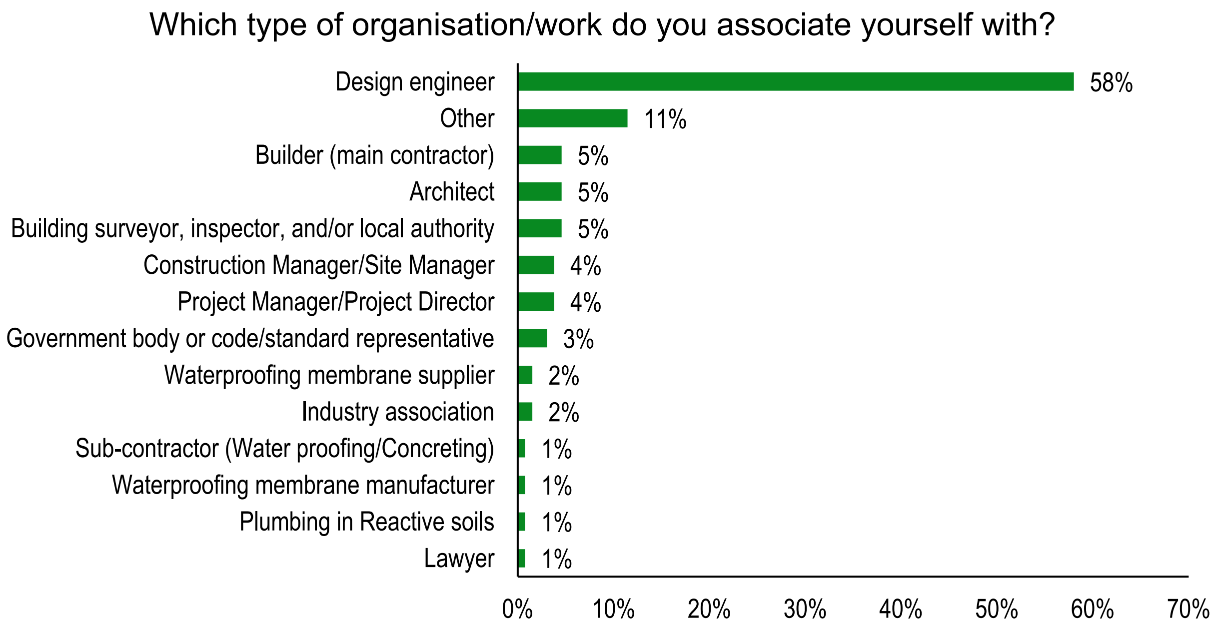


Figure 23: Participants' professional affiliations

Summary of key online survey findings

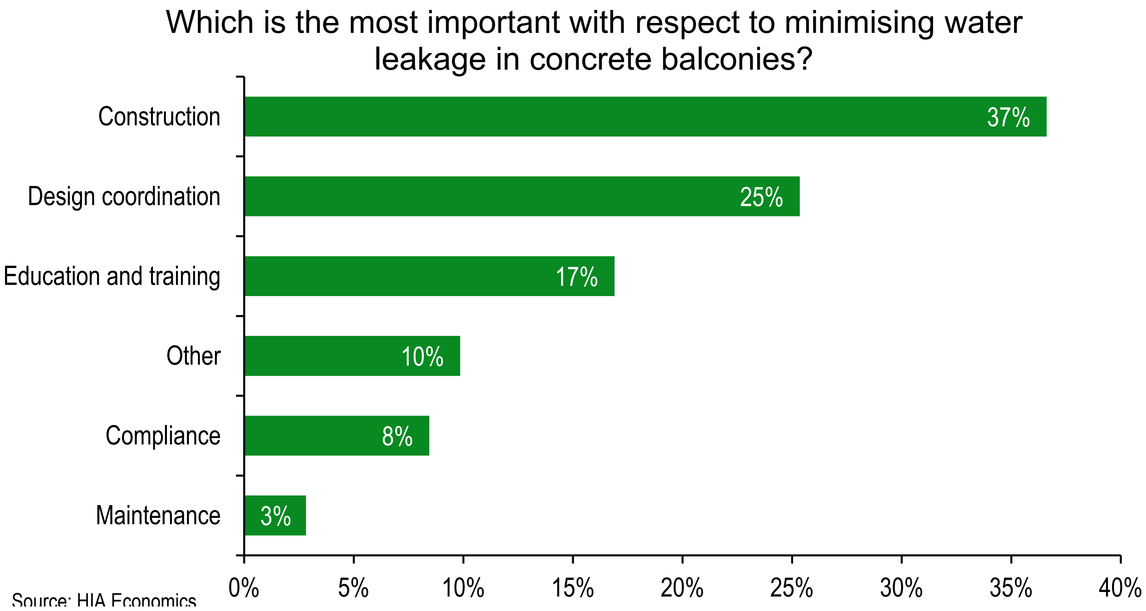


Figure 24: Most important activities to minimise water leakage in concrete balconies

Design, detailing, coordination and planning of concrete balconies

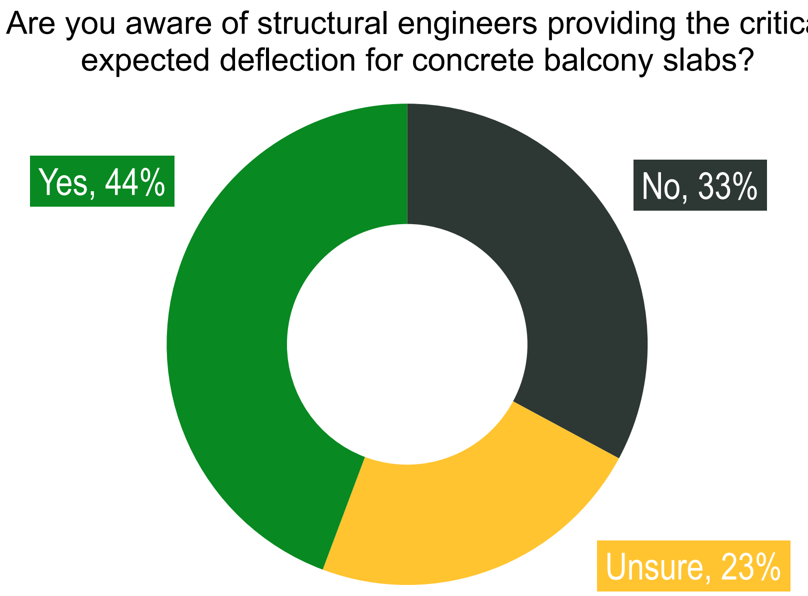


Figure 25: The role of the structural engineer in the communication of deflection performance

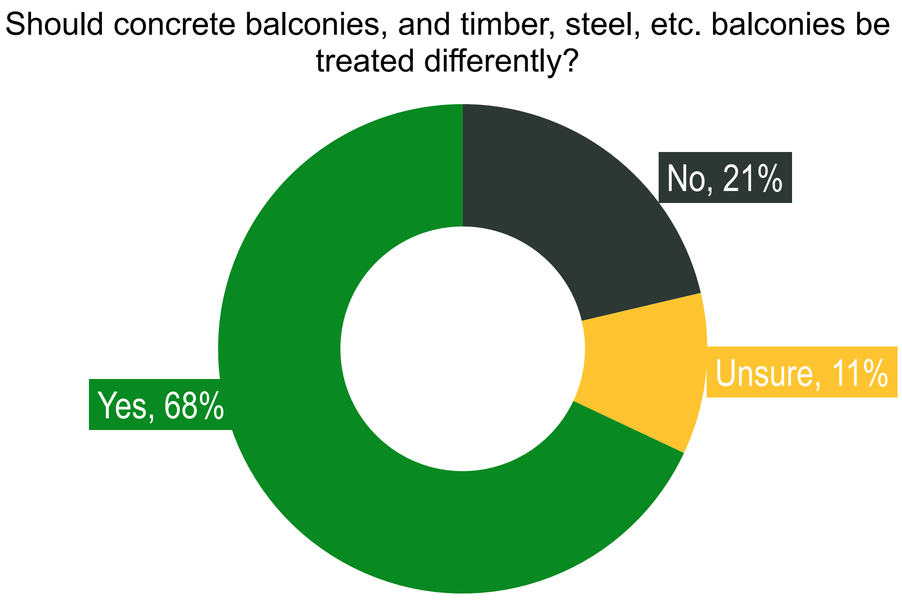


Figure 26: Concrete balconies to be treated differently from timber, steel and other balconies

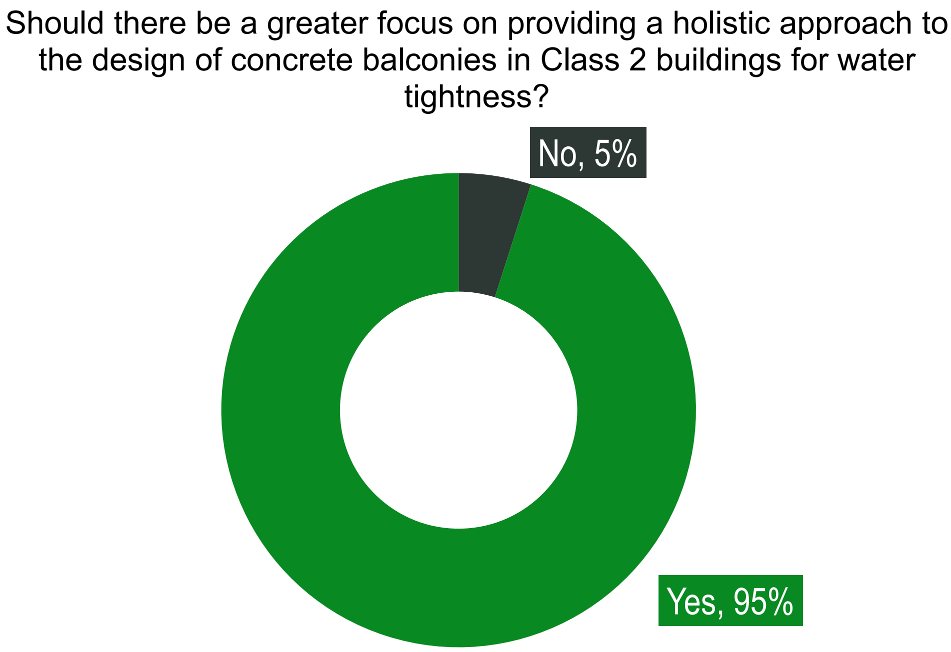


Figure 27: Holistic approach to design

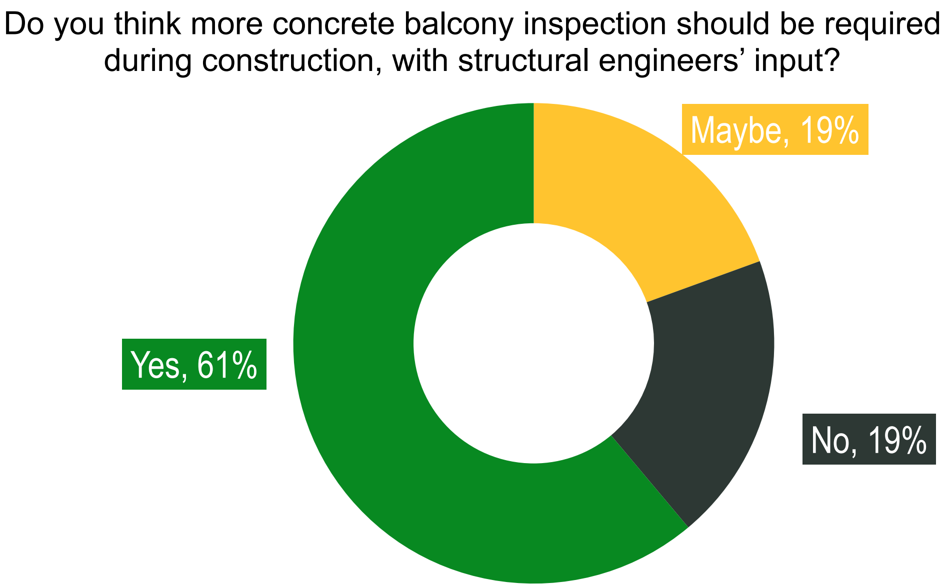


Figure 28: Requirement for more inspections

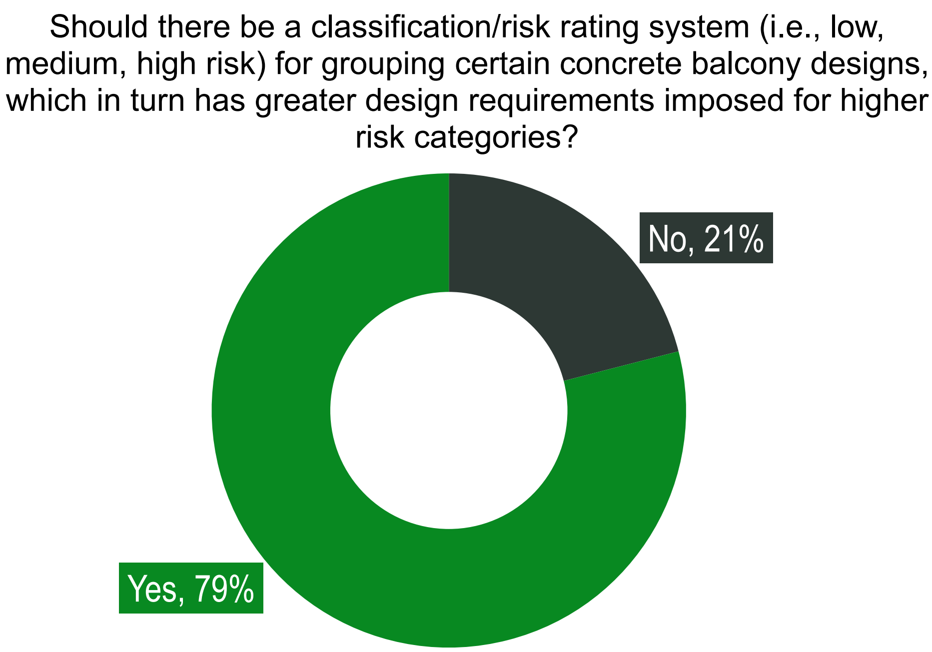


Figure 29: Greater design requirements based on classification/risk rating system

Roles and accountabilities of parties

When asked about the party who signs off on balcony design and on-site balcony works, respondents provided mixed responses. The most common response (approximately 30% of responses) was the Building Surveyor. This was followed by Engineers (28%), Builders (9%) and architects (7%).

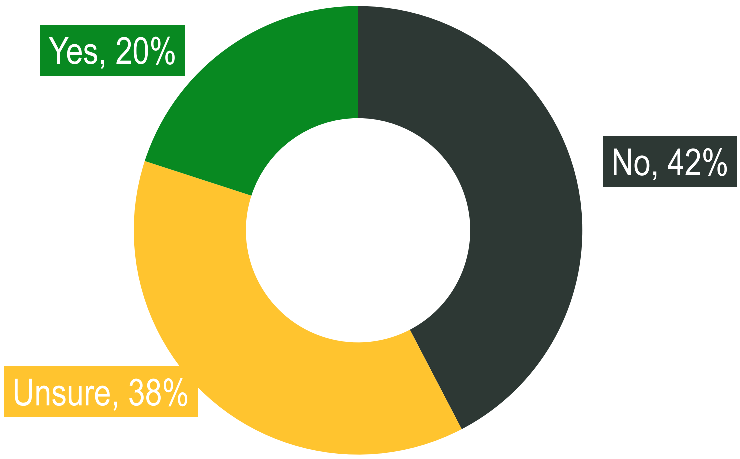


Figure 30: Competency of building practitioners for concrete balcony design, construction and certification

Balcony work sign off responsibility

Survey participants were asked who signs off on balcony works. Responses are outlined in Table 8:

Table 7: Interviewee perception of responsibility for sign off on balcony works

Location of respondent	**Responses**
Indonesia	• Architect, engineer, contractor
Victoria, Australia	• Architect, structural engineer, building surveyor • B/S • BS, Engineer, and builder • Builder • Builder • Building Inspectors and Building Surveyors • building surveyor rely on subcontractors certificates • Building surveyor • Building surveyor • Building surveyor • Building surveyor • Building surveyor and accredited waterproofing contractor • Building Surveyor on design, finished job is not officially signed off • Building surveyors/most of the case PT professional engineering • Certifying Engineer (Civil)

Location of respondent	Responses
	• Don’t know, RBS presumably. • Engineer • Engineer and architect • Engineers should sign off on their work and a regulatory oversight is needed to check/verify their work • Inspecting Engineer/Building Surveyor • Multitude, but essentially, architect, structural engineer, waterproofing installer, registered building surveyor • my director • no one • Nobody • Not enough emphasis on balcony inspections and design • plumber and the engineer • Project engineer • PT eng and RBS • RBS • Rbs • Should be 3 part signoff, Structural, supervisor and building surveyor/inspector • Structural Engineer • Structural Engineer • STRUCTURAL ENGINEER CERTIFIER • Structural engineer for pre-pour, architect for design and Building surveyor for final • structural engineers • Supervisor • The structural engineer for the design, the constructor for the installation • two issues here not to be conflated; Design and Construction. Design is prepared by designer of documents (~Arch). RBS endorses design as part of BP. The construction phase is for the registered builder, they are the first and primary approver as they carry out the work (or their trades do under their supervision). RBS/Inspector approval finished product as part of Mandatory inspection stages.
New South Wales, Australia	• All practitioners • Architect is responsible to coordinate top of concrete surfaces, steps rebates, slopes to drainage, structural engineer provides wind pressure and minimum thickness and considering any cast in pipe work – provide coordinated connections & slab movements. Build should have to simply follow • Builder. • Project Engineer and Building Inspector? • Should be water proofing consultant, who is not a registered class of practitioner in NSW! • Structural engineers • The Architect, design engineer, hydraulic engineer
Queensland, Australia	• Engineer + Contractor
Not Stated	• All stakeholders • Builder and waterproofing specialists • Building Surveyor

Location of respondent	Responses
	• builder • Not sure but it must be a Building Inspector appointed by the building surveyor • Q A inspection • structural engineer • To my knowledge no one at present

Construction systems, processes and materials

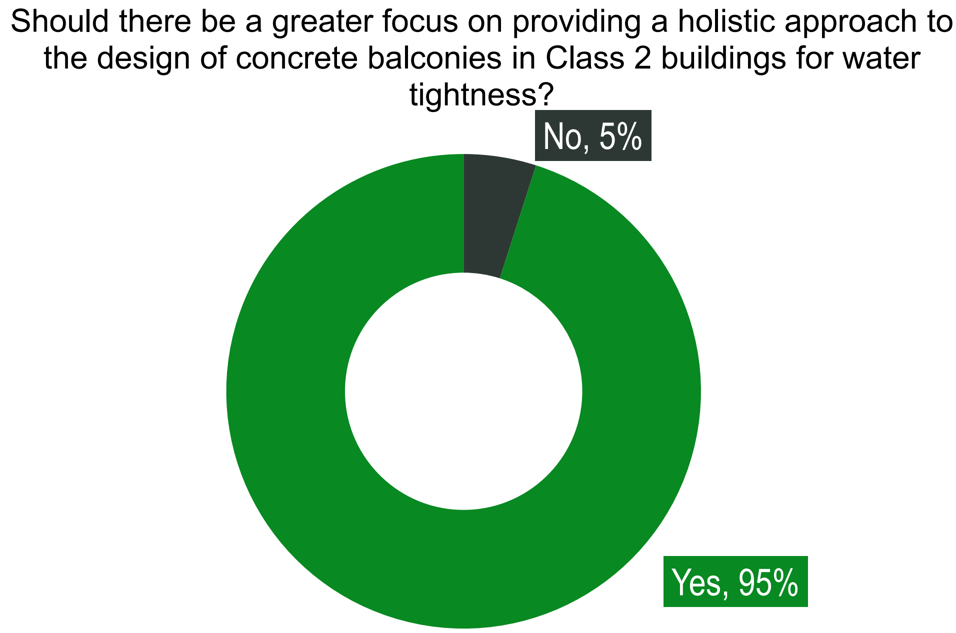


Figure 31: Significance of design

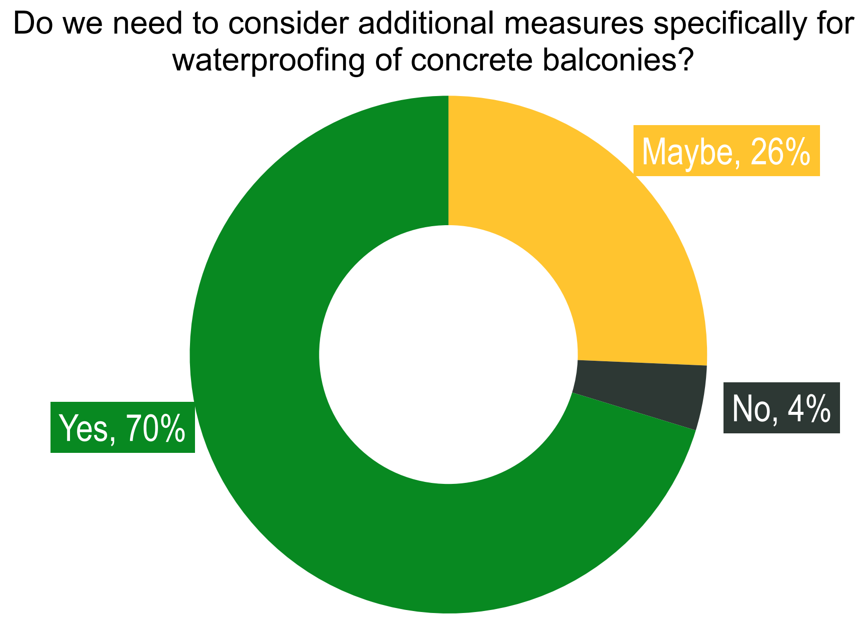


Figure 32: Additional measures required for concrete balconies

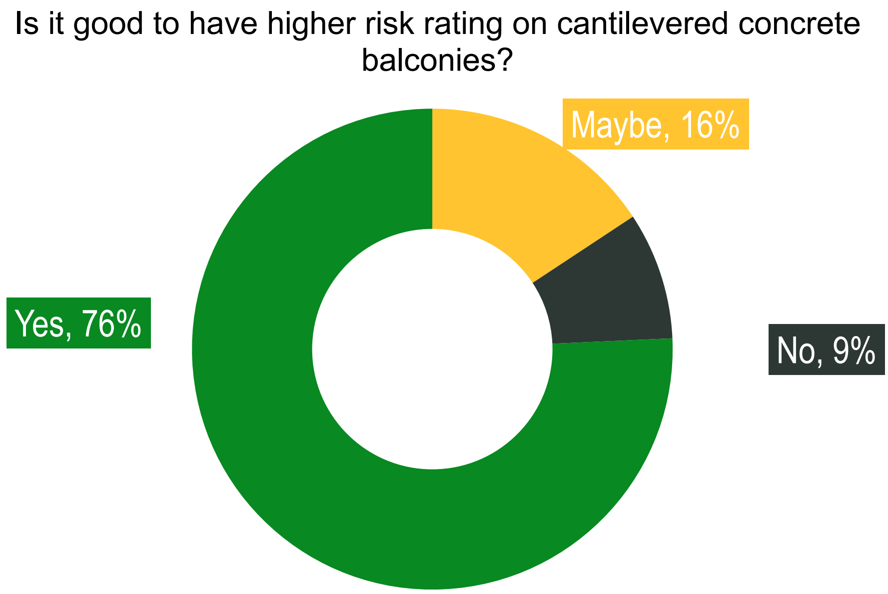


Figure 33: Requirement for higher risk rating for cantilevered concrete balconies

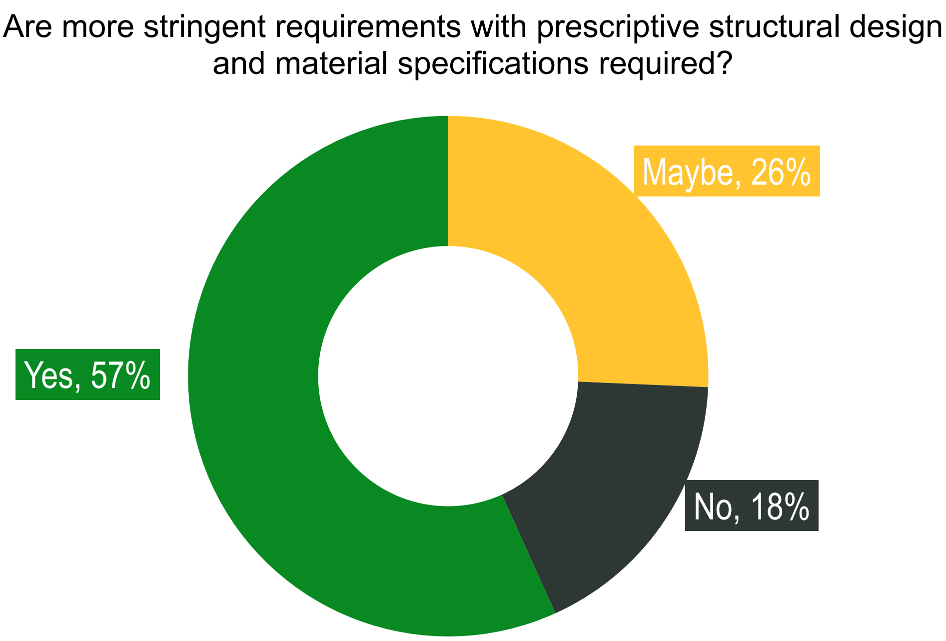


Figure 34: Stringent requirements for concrete balconies

Guidance, education and training of practitioners and consumers.

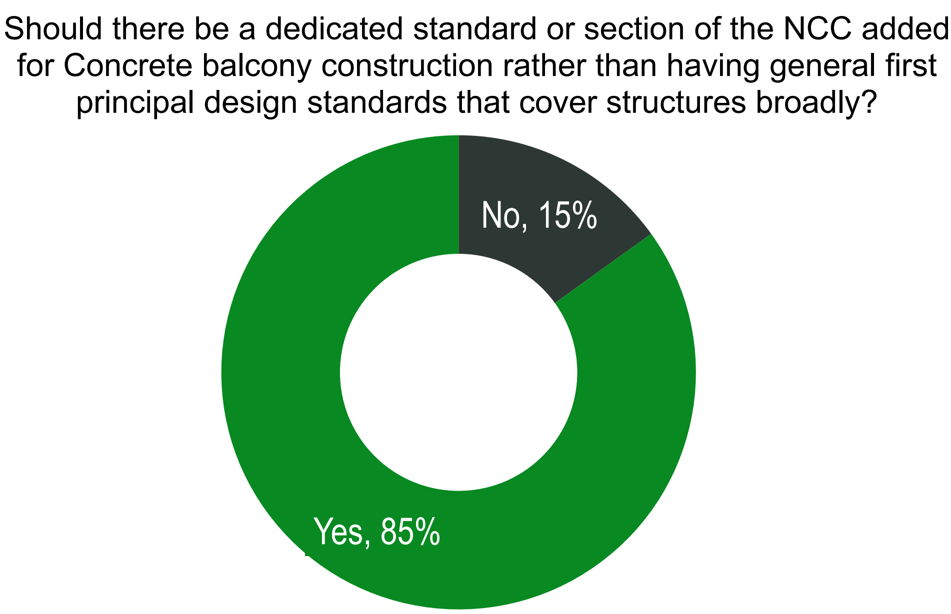


Figure 35: Support for a dedicated concrete balcony construction standard or Section of the NCC

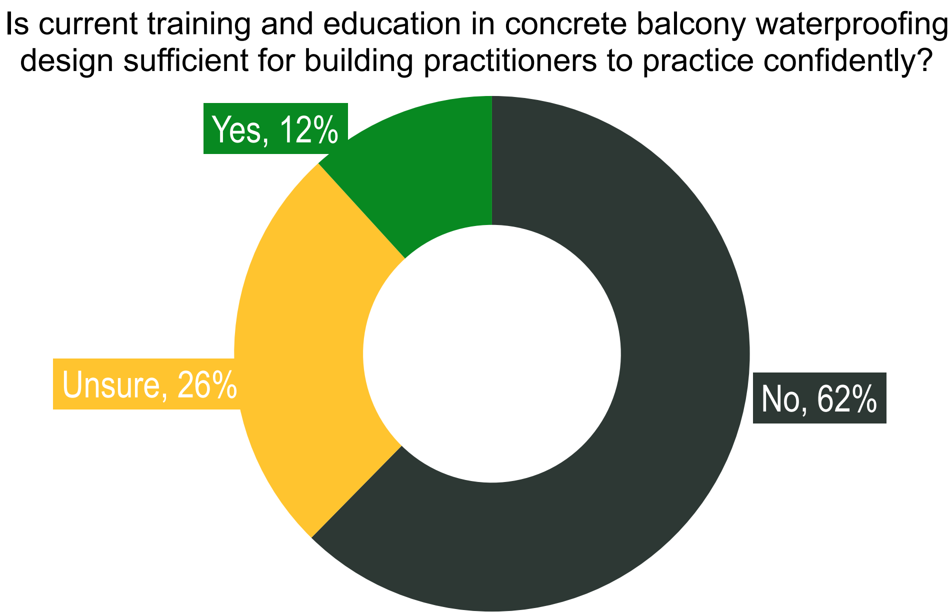


Figure 36: Sufficiency of current education and training in concrete balcony waterproofing design

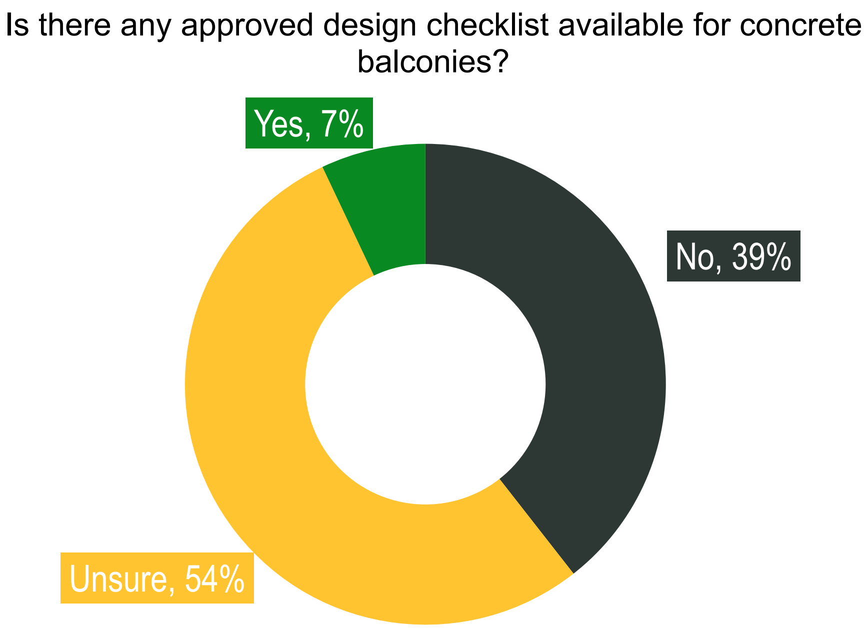


Figure 37: Availability of approved design checklist

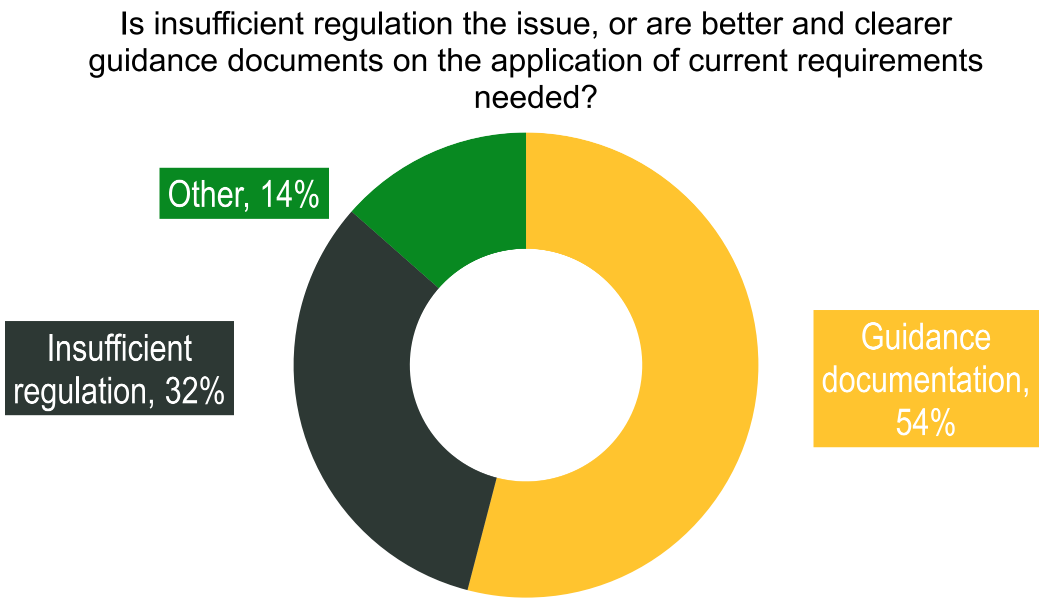


Figure 38: Sufficiency of regulation and the need for better and clearer guidance documents

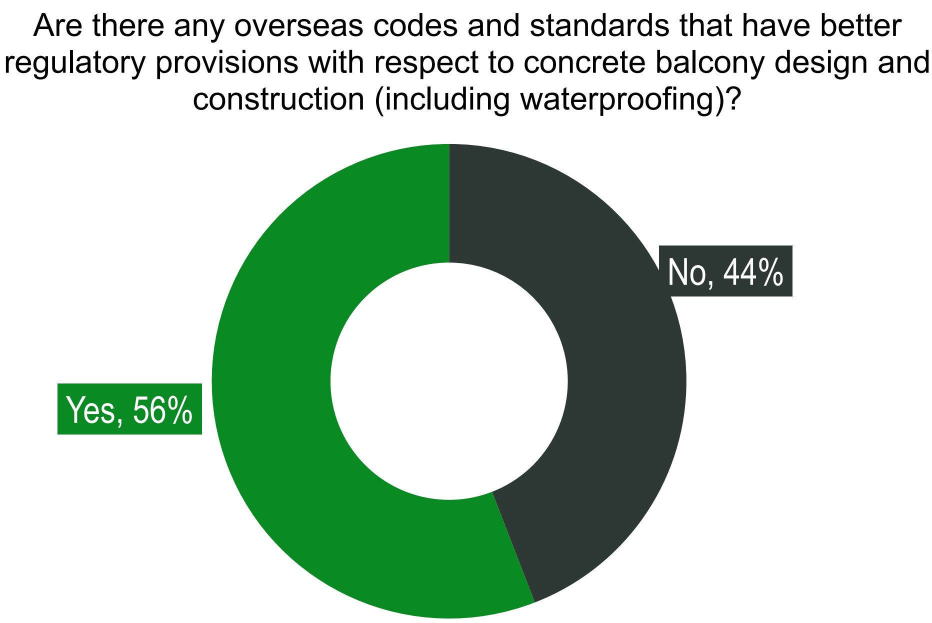


Figure 39: Overseas codes and guidance documents

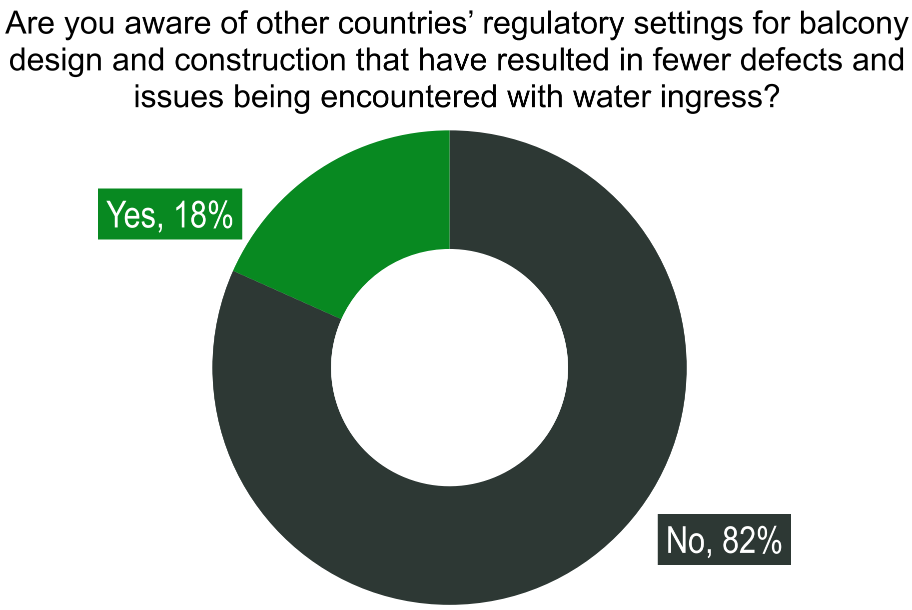


Figure 40: Overseas regulations for better and clear guidance

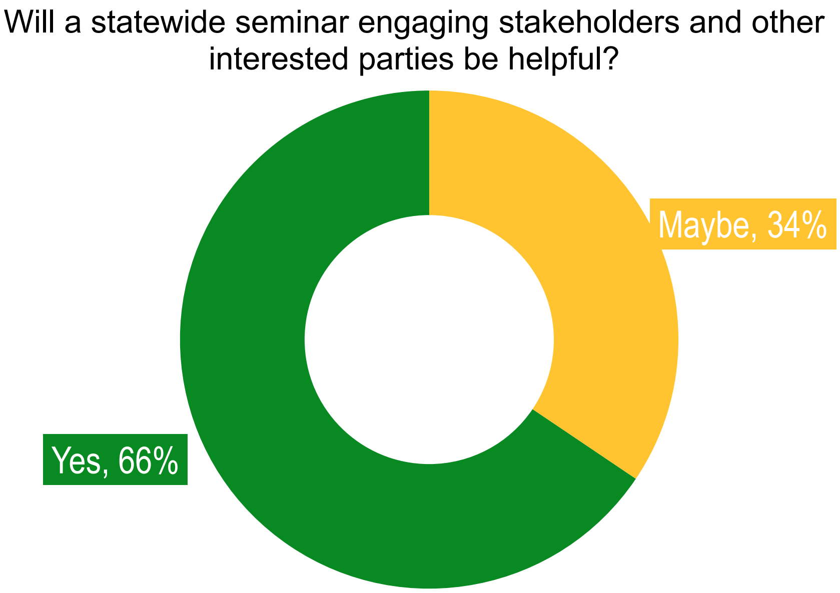


Figure 41: Awareness: Statewide seminar on concrete balcony design

Future research

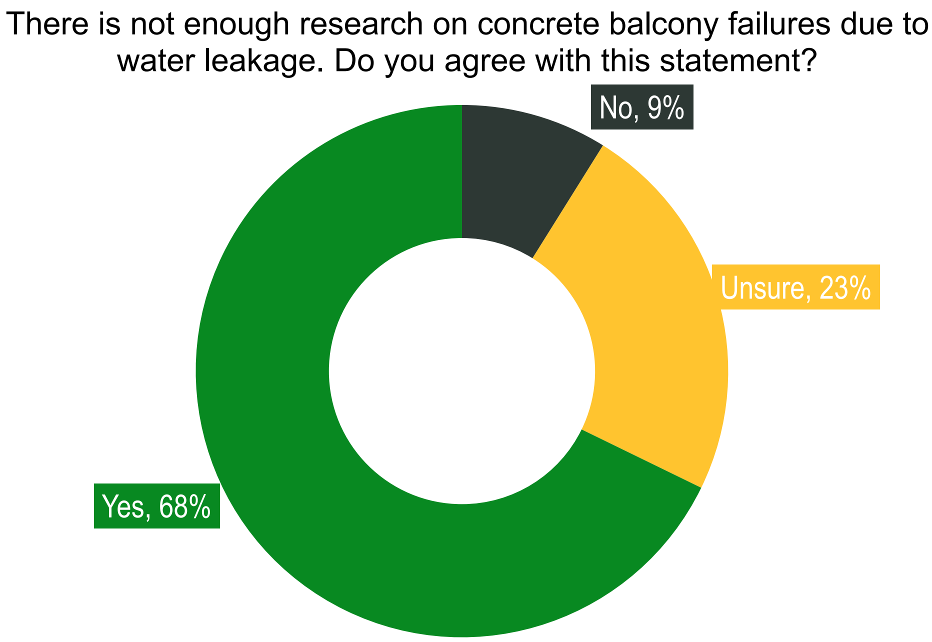


Figure 42: Sufficiency of research

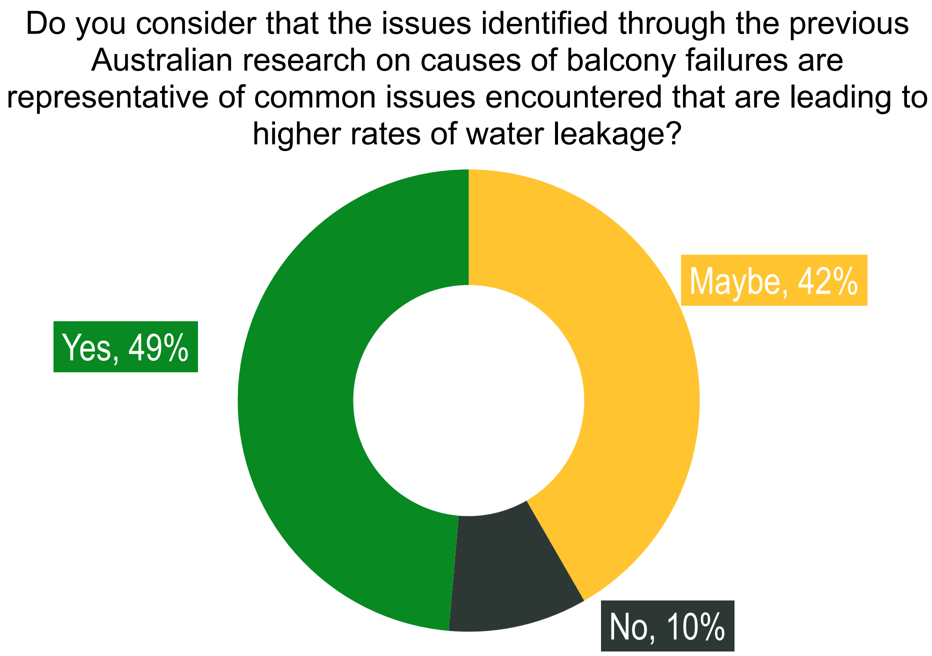


Figure 43: Representative nature of existing research

Appendix B: Stakeholder interviews

Participants

Thirty-three stakeholders and industry representatives were interviewed for this research. To maintain confidentiality, interviewees were anonymised per Table 8.

Table 8: Stakeholder interview participants and their assigned identification

Identification Code	Professional Affiliation(s)
Academic 1/Architect 1	Academic/Lead Arch. Scientist
Academic 2/ Owners Corporation 1	Academic/Strata
Academic 3/Structural Engineer 8	Academic/Structural Engineer
Academic 4/Structural Engineer 13	Academic/Structural Engineer
Academic 5/ Structural Engineer 15	Concrete Institute Member/Academic/Engineer
Architect 2	Lead Architect
Architect 4	Lead Architect
Builder 1/Construction Director 1	Construction Director/Builder
Builder 2/Architect 3	Developer/Builder/Architect
Building surveyor 1	Building Surveyor
Building Surveyor 2	Building Surveyor/Structural Engineer
Construction Director 1	Construction Director
Construction Manager 1	Construction Manager
Owners Corporation 2	Owners Corporation Member
Policy Advisor 1	Policy Advisor
Policy Advisor 2	Policy Advisor
Policy Advisor 3	Policy Advisor

Identification Code	Professional Affiliation(s)
Policy Advisor 4	Policy Manager
Structural Engineer 1	Forensic Engineer/Structural Engineer
Structural Engineer 2	Lead Structural Engineer
Structural Engineer 3	Lead Structural Engineer
Structural Engineer 4	Lead Structural/Façade Engineer
Structural Engineer 6	Lead Structural Engineer
Structural Engineer 7	Lead Structural Engineer
Structural Engineer 9	Lead Structural Engineer
Structural Engineer 10	Lead Structural Engineer
Structural Engineer 11	Lead structural Engineer
Structural Engineer 12	Lead structural Engineer
Structural Engineer 14	Lead Structural Engineer
Technical Manager 1/Structural Engineer 5	Technical Service Manager/Engineer
Waterproofing Specialist 1	Waterproofing Specialist
Waterproofing Specialist 2	Waterproofing Specialist/Expert advisor
Waterproofing Specialist 3	Waterproofing Specialist/Educator

The research team collated a stakeholder list (builders/architects/engineers/government agencies/building industry associations/universities/strata managers) and identified the appropriate persons for stakeholder interviews. The research team then contacted these stakeholders via phone/email for the interviewees' agreement for participation.

Online interviews of stakeholders were conducted by our research team. Interviewees were supplied with a consent from, consent statement, sample interview questions and an agenda. Thirty-four interviews were conducted with 33 participants between August and November 2023. These 33 participants self-identified as belonging to 45 categories of building practitioner (Figure 44). Design Engineers were largest group (33%) followed by industry associations (11%).

Each interview was held for one hour online via Microsoft Teams, during which a recording was taken for reference. Thirty-four hours of interview footage was obtained from the interviews. The interviews began with a brief introduction from the interviewee with respect to their background, current work, and role in concrete balcony systems.

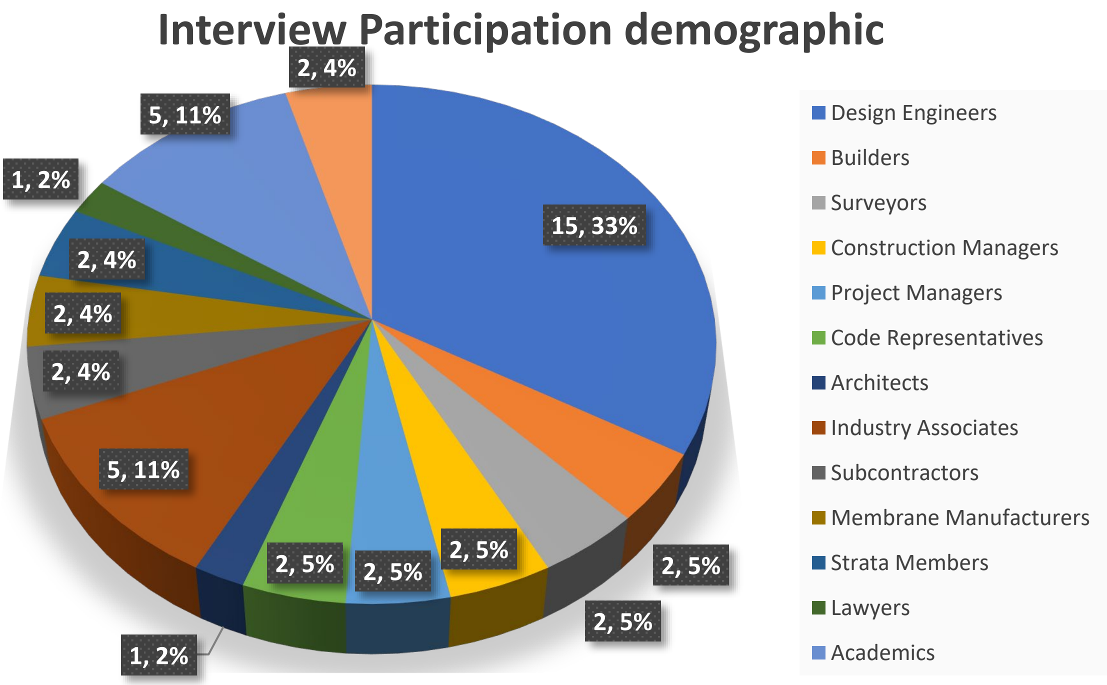


Figure 44: Composition of Interviewees

Summary of key interview findings

Activity to prevent water ingress

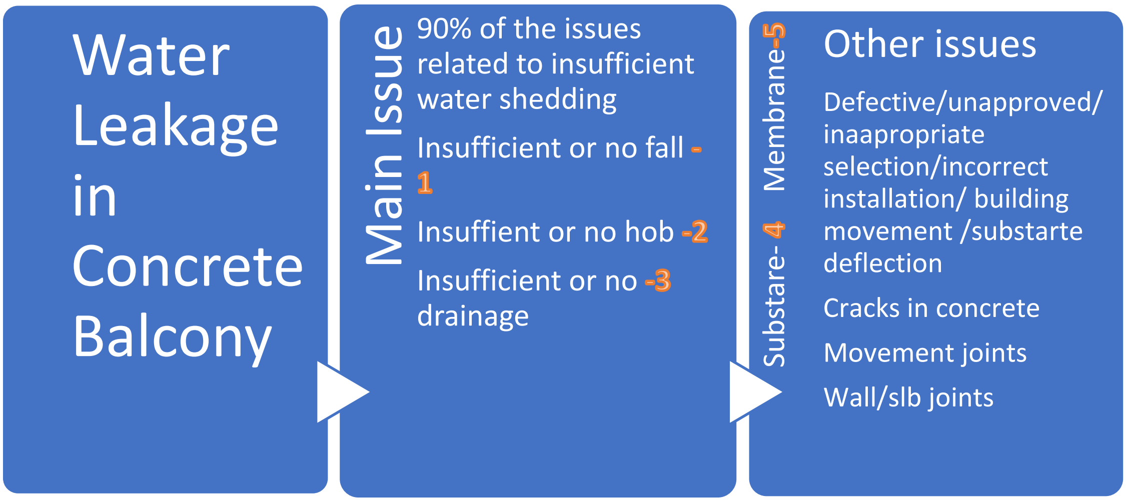
Overall, interviewees identified a series of key actions that could address the problem of water ingress to concrete balconies:

- education for industry, including on awareness and severity of the issue, and the content of regulatory requirements (e.g. NCC, and AS 4654.1 and 2)
- practitioners treating the concrete slab as 'the first line of defence for waterproofing,' and Structural Engineers providing certified design and details for the slab

- regulatory reform to mandate:
  - the installation of approved waterproofing membrane materials by licenced practitioners
  - mandatory regulatory inspection of concrete balconies and
  - a chain of responsibility established at the initiation of the project by the RBS (including the concrete balcony design and detailing in the building permit certification by structural engineers)
- government initiatives to recognise the professional performance of engineers, architects, builders, and associated trades (e.g. through a bonus point scheme)
- a simple guideline for practitioners
- a maintenance manual for homeowners.

Interview questions about water leakage in concrete balconies

The key issues causing water leakage in concrete balconies were summarised below for interviewees:



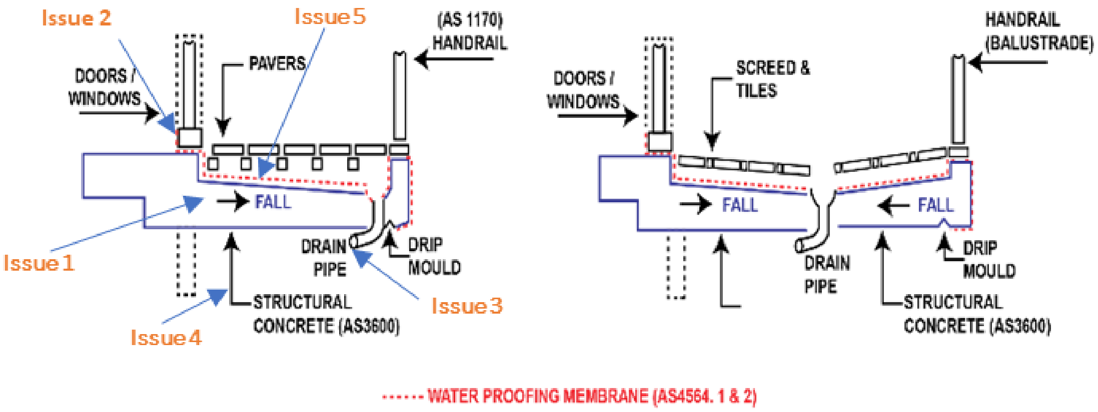


Figure 45: Main Causes for water leakage in concrete balconies

Causes of water ingress

When asked about the key cause of water ingress to concrete balconies, interviewees indicated that designs and drawings were important:

For me it really is a design thing, you can't get your engineer and architects to agree on the same thing. [The] architect has a concept they want to achieve, and [the] engineer has constraints. That where the real issue starts.

[The] waterproofing membrane is the final line of defence, if you are relying on a final finish as your primary defence, you are already losing the battle.

- Builder 1/Construction Director 1

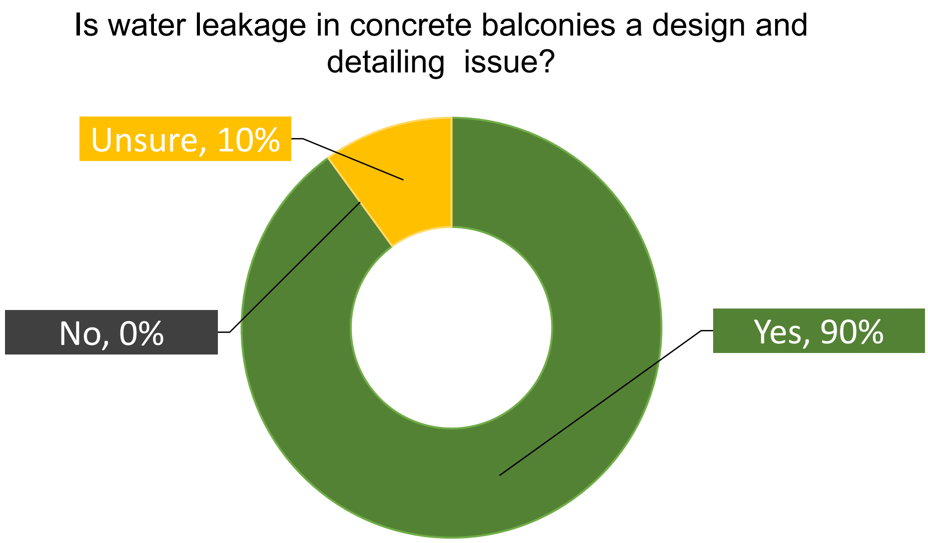


Figure 46: Water leakage as a design and detailing issue

We find that the leaks are almost always on the drawings. Only in five or ten per cent of the case, the drawing is fine and the installation wrong.

Poor design creates a problem for the builder/installer/applicator for them to have to redesign it to try and make it work on the run. And then they get blamed for changing the design and for the leakage, when the thing never had a chance to be buildable in the first place.

- Waterproofing Specialist 3

Responsibility for water ingress

When asked who is responsible for water ingress to concrete balconies, interviewees indicated that the responsibility is not always clear. The roles of the structural engineer and the RBS were also highlighted.

RBS should be involved in every stage of the way, a non-compliant design should be picked up at the point of permit and inspections, but in every state other than NSW it is very unclear who is primarily responsible.

- Academic 1/Architect 1

There's a growing recognition that structural engineers take precedence as the principal waterproofing influencers within the construction process. Waterproofing consultants hold the secondary role."

- Structural Engineer 1

When things go wrong and you try to get a forensic assessment of what went wrong, all too clearly the line of responsibility is not there, and whether that's due to poor record keeping or due to legal advice is unsure.

- Building Surveyor 2

Most structural engineers have no idea about waterproofing… There is a general lack of understanding of who is responsible for waterproofing and where that responsibility lies. Is it the architect, the structural engineer, the hydraulics engineer or the builder/contractor and who is responsible? I suggest they are all responsible.

- Structural engineer 9

Prevention of water ingress

When asked what was needed to prevent water ingress to concrete balconies, interviewees emphasised the importance of design over waterproofing products.

If you actually design the balcony correctly, provide enough falls etc, you can virtually say that you actually don't even need the waterproofing products. Because if it's designed right, the water will get away so quickly, you don't need to worry about ponded water or anything else like that.

- Waterproofing Specialist 3

We are over-reliant on the waterproofing membrane when we mention waterproofing, and waterproofing membrane are expected to solve all of the problem and it doesn't work since it is specifically fragile. So it will depend on the structural integrity of the balcony to perform to expectation.

- Academic 3/Structural Engineer 8

Observations by occupation

Key observations gathered from participants, where relevant, were grouped by occupation. These observations are listed in Table 9.

Table 9: Interview observations by occupation

Occupation	Observation
Design Engineers	Structural engineers should lead concrete balcony design and detailing, and concrete should be treated as the primary waterproofing element.
Water proofers/ Installers / Tilers	Leaks in membranes are often due to products being damaged after being installed. It can also be due to incorrect falls or substrates.
Waterproofing Consultants	Concrete should be treated as the primary waterproofing element.
Architects	Balcony waterproofing details should be treated as a high-risk element like fire and cladding. Sign-off by building practitioners and building surveyors must be made a mandatory requirement.
Building Surveyors	Ultimately, the building surveyor signs off and takes responsibility of any non-compliances.

Design, detailing, coordination and planning of concrete balconies

> You just enforce a mandatory requirement of step and fall in concrete balcony slabs and no flat slabs are allowed. Ninety per cent of the water leakage will go away. In all my buildings we have a coordination meeting with the architect, engineers and water proofers and have come up with a feasible solution and we never had leakage issues.
>
> - Builder 2/Architect 3

> Deflections on cantilevered balconies, where over time through creep the balconies are deflecting more than what they were intended to. So falls that were cast or put into balconies no longer work, and so you get ponding of water because the drainage outlets are too high or in the wrong location because of deflection.
>
> -Structural Engineer 1

> There is absolutely no justification for cutting corners or reducing anything on something like a balcony because there is no fail safe, no redistribution or sending of loads anywhere else in the structure to help you out it it's absolutely game over.
>
> If you don't have any police, then laws don't exist, They just books on the shelf. So what's the point of that?
>
> -Structural Engineer 10

> No one person can design the [entire] building anymore. Collaboration between all involved is the way forward for a defect free building.
>
> -Policy Advisor 2

Roles and accountabilities of parties

Fourteen stakeholders interviewed agreed that project structural engineers must play a lead role coordinating the design and detailing of concrete balconies (eight structural engineers, three waterproofing specialists, two architects, one construction manager, one construction director and one builder).

> Project Structural Engineer takes a lead role working with architects to provide design and details of the balcony concrete with integrated hobs and falls to NCC requirements (AS 4654.2).
>
> - Structural Engineer 1

> Project Structural Engineer must provide the expected deflection at the tip of the cantilever and for spanning elements at the mid span of the slab.
>
> - Structural Engineer 1/Waterproofing Specialist 3

> Project Structural Engineer must provide for movements at all joints (slab/wall junction, expansion/control joints, construction joints)… Project Engineers must submit all the above information to [the] RBS as part of the building permit approval.
>
> - Structural Engineer 1/Waterproofing Specialist 3

During interviews with key stakeholders, the relationships between the roles and responsibilities of parties during concrete balcony construction were explored. The perspectives shared by Interviewees are summarised in Table 10.

Table 10: Roles and responsibility for concrete balcony construction per stakeholder interviewees

Occupation (Role)	Responsibility
Developer	Request for information on balcony details.
Builder	Provide concept sketches.
Building surveyor	Request for information on balcony details.
Planner	Ensure building heights are adequate have the required step and fall in the balcony.
Architect	Provide plan and sections details in consultation with structural engineers and hydraulics engineer/licensed plumber.
Structural engineer	Design and detail balcony as per architect’s details and ensure a step and fall is included.
Hydraulic Engineer/Licensed Plumber	Provide falls and drainage details and connecting to storm waterpipe.
Concrete subcontractor	Construct slab as per structural and architectural drawings.
Waterproofer/Tiler	Check suitability of concrete slab for approved membrane installation.
Strata manger/consumer	Ensure as-built drawings for balcony construction are supplied.

Construction systems, processes and materials

Fifteen stakeholders interviewed suggested that for durability design of the concrete, the concrete exposed surface must be treated as external (i.e. ignoring the presence of waterproofing membrane). These stakeholders also favoured a mandatory inspection for concrete balcony construction. Some variation of these suggestions were mentioned by eight structural engineers, three waterproofing specialists, two architects, and two builders.

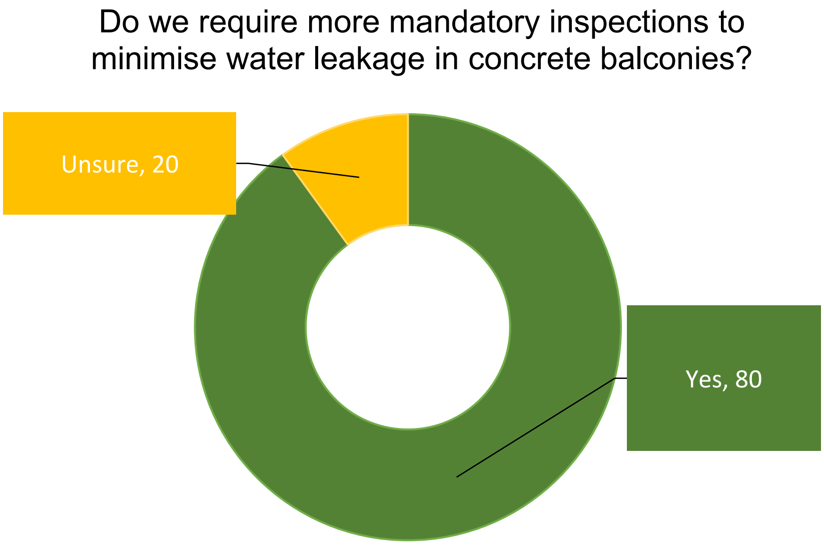


Figure 47: Requirement for more mandatory inspections

> Concrete balconies must be classified according to the risk caused on safety, inconvenience, and rectification cost. The balconies with habitable space under to be classified as high risk.
>
> - Academic 1/Architect 1

> Failure of watertightness in one apartment leads to failure in every apartment building. If the membranes have failed in the internal and also the external where there is a balcony, then it has probably failed in every single unit, or every single lot. The cost of rectification, the time to rectify and the processes that need to be engaged with is a very complex issue.
>
> - Academic 2/Owner's Corporation 1

> One issue we found was that the detailing on that project was quite poor, we had a project where a down pipe had been cast in the hob. We spent 3 months investigating this case.
>
> - Builder 1/Construction Director 1

One particular issue is that the problem presents on one side and then the leak happens on the other side of the building. And to try and trace that back to the root cause is very expensive and very time consuming. And sometimes you may not actually find where that root cause is.

- Owner's Corporation 2

It wasn't the membrane, but the physical properties of the substrate. So they… look at the wrong issues.

- Structural Engineer 14

My speculation is that now that design[s] have reliance on the waterproofing membrane to do all the work.

- Academic 3/Structural Engineer 8

Serious nature of the issue

When asked about the problem of water ingress to concrete balconies, eighty per cent of participants indicated that they believed the problem to be severe.

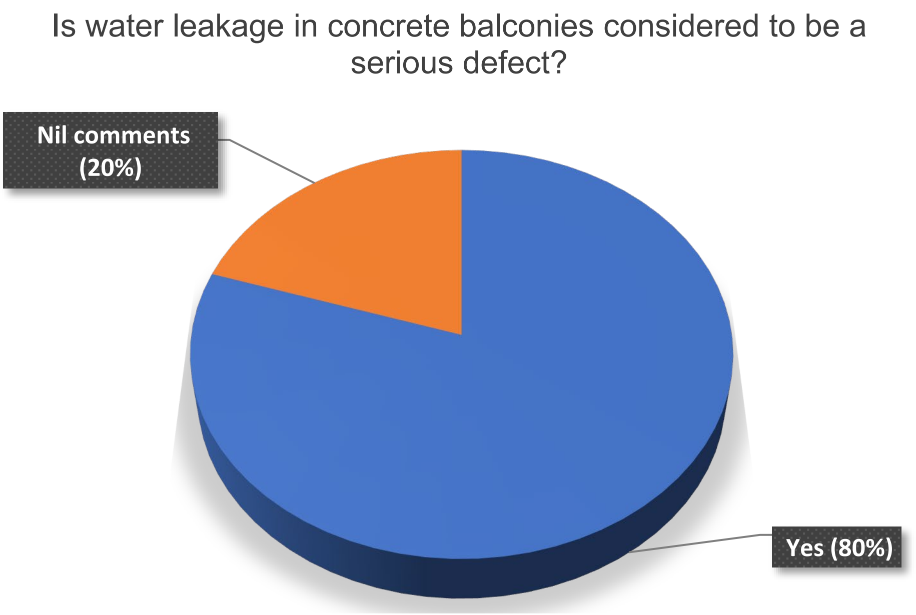


Figure 48: Severity of the problem of water ingress and concrete balconies

Water ingress has been reported left, right and centre. The encounter with water ingress and many aspects have been increasing by the day and progressively. It is a multitude multifactorial problem that we need to identify and close as quickly as possible.

- Structural Engineer 2

Water leakage in concrete balcony is a very serious problem.

- Structural Engineer 11

It certainly is serious from the perspective that water damage can cause. Obviously been identified through your research report as being significant interest to Victoria. There's a significant number of balconies which contribute to this problem and is a significant issue and one that governments are interested in increasing or improving their standards around.

- Policy Advisor 1

Obviously, there's various studies and through various jurisdictions that have suggested that issues around waterproofing generally whether it's internal, external is a problem. It's socially commonplace or common cause of defects in buildings waterproofing… I think it is an issue that it seems to be a common defect in in a lot of buildings. There is a great raising attention of government. And then so I think it is potentially a significant problem.

- Policy Advisor 2

I do think it's quite serious. I think water ingress in general in buildings is a sort of an ongoing issue and one that industry and regulators have been familiar with for a reasonable time, and I think, yeah, this is where, this one particularly is probably starting to become more prevalent as consumers get more aware of the rights and responsibilities and that sort of thing. Realistically you know this one definitely sort of starting to emerge as one of those sorts of key issues.

- Policy Advisor 4

Guidance

There is not enough literature on the waterproofing of concrete balconies, and issues with the leakage. And I think to actually look and try to find good guidance material that publicly available is quite hard. I certainly have some of my own internal library files where you've gathered bits and pieces and hand sketches, and all sort of different things that you can adopt, but to actually find good quality guidance material is hard.

- Structural Engineer 11

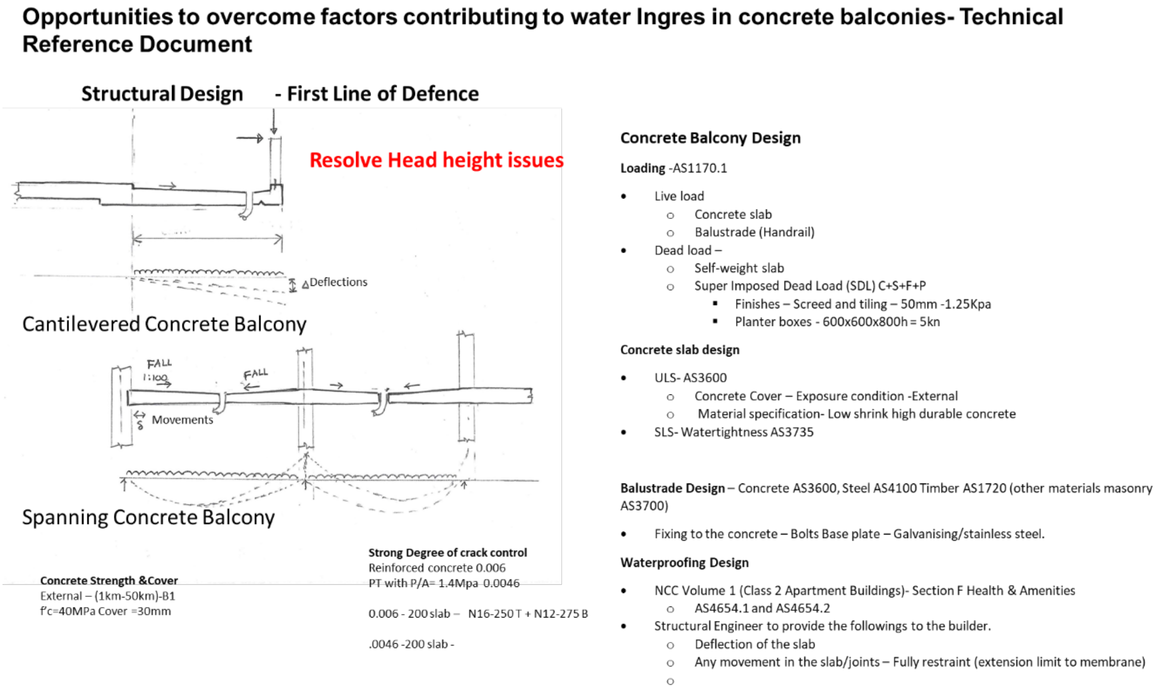


Figure 49: Sample technical reference document - guidance for concrete balcony design

Post-construction maintenance and repair

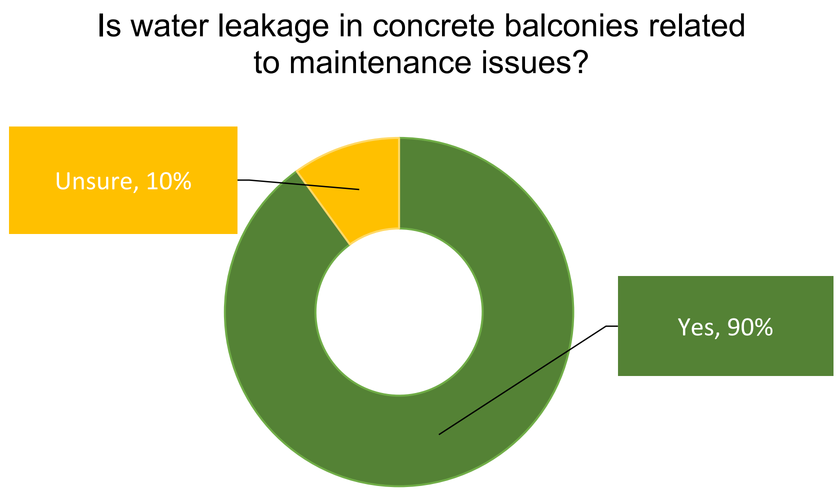


Figure 50: Severity of the problem of water ingress to concrete balconies

Appendix C: Case studies

A number of stakeholders who were approached for participation in this research, with a view to providing a potential case study, indicated that while that they would not discuss the balcony defects in buildings with which they themselves were involved, they would agree to discuss works done by others. A number of stakeholders were similarly prepared to confidentially discuss defect issues associated with their work, but were not prepared to release those details as a published case study.

Given this limited availability, six case studies were identified and considered from the perspective of root cause defect analysis. These six case studies are outlined below as Case Study A through Case Study F.

A parallel insight is that stakeholders interviewed for this research agreed that root cause analysis of defects in concrete balconies is rarely done, and that there is a similar lack of focus on post-defect documentation and review as a continuous improvement exercise. It is possible that a general reluctance within industry to publicly share important lessons about building defects lessens the opportunity for industry and others to learn from them.

> Statistics on defects and case studies are difficult to establish. You go around and ask strata managers and strata [owners' corporation] managers [about] serious defects… in your buildings you [sic] are reluctant to report it and we will keep it confidential, and they say: "Every time it rains our balcony leaks." There is no root cause analysis conducted on these defects. The only people who might have this information are the remedial waterproofing contractors. But not sure [sic] whether they will reveal such information.
>
> - Policy Advisor 3

Summary of conclusions drawn from case studies

Observations about well-performing balconies

Construction described within the case studies obtained for the present research demonstrated that well-performing concrete balconies[47] included:

- balconies with a set down and an integrated fall to the concrete substrate (see Figure 51 through Figure 54)
- a membrane on the substrate with fall and set down as per AS 4564.2 (see Figure 51 through Figure 54)
- an approved and appropriate membrane selected for joint movements supplied by the design engineer and installed by a certified installer
- movement joints/expansion joints correctly detailed as per AS 4654.1 and 2.

[47] See Case Study C as an example.

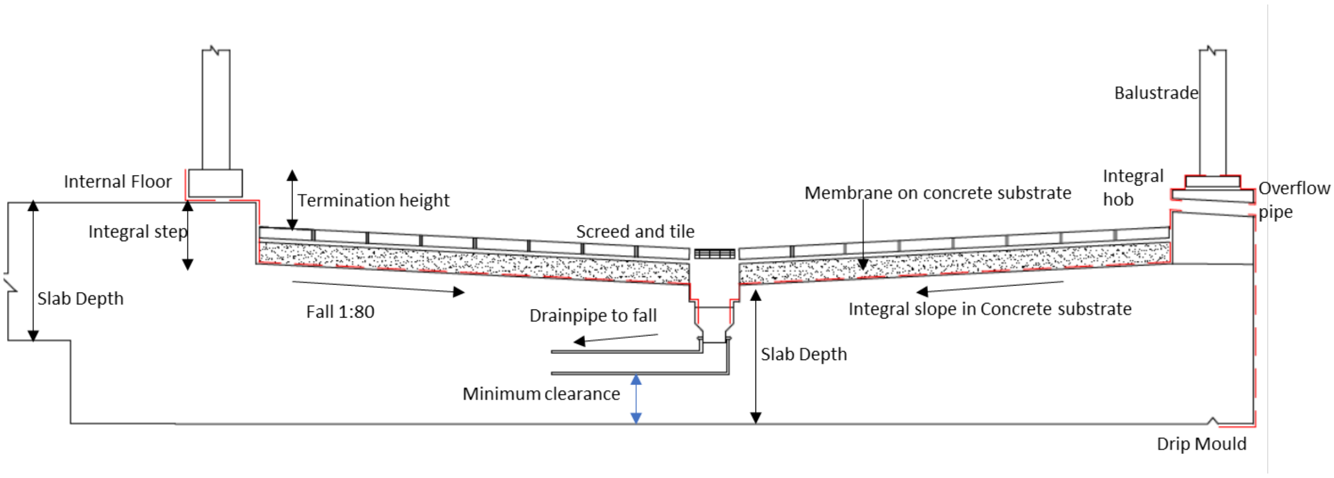


Figure 51: Sketch, as described by architect to comply with NCC requirements (spanning balcony with screed and tiling) The method of construction for the tile and screed complies with AS 3958:2023 (clause 3.2.4).

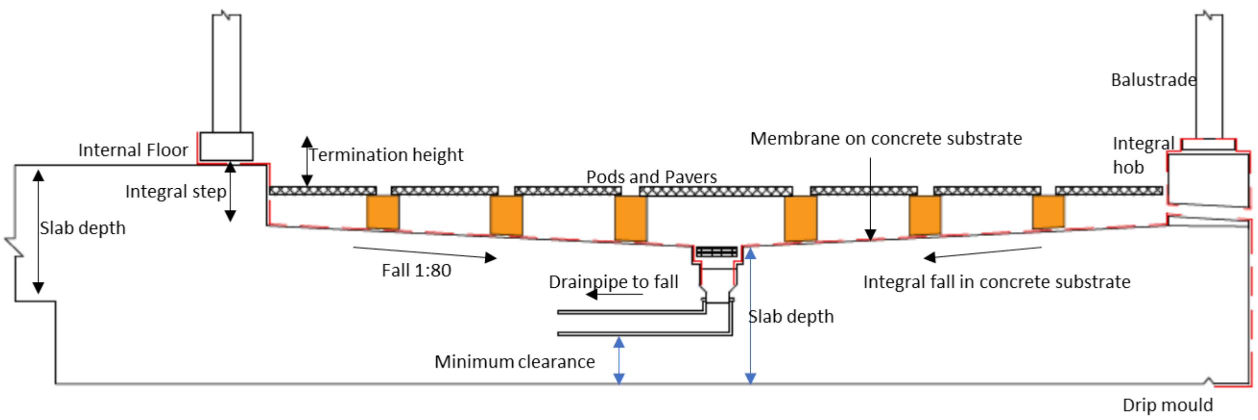


Figure 52: Sketch, as described by architect to comply with NCC requirements (spanning balcony with pods and pavers)

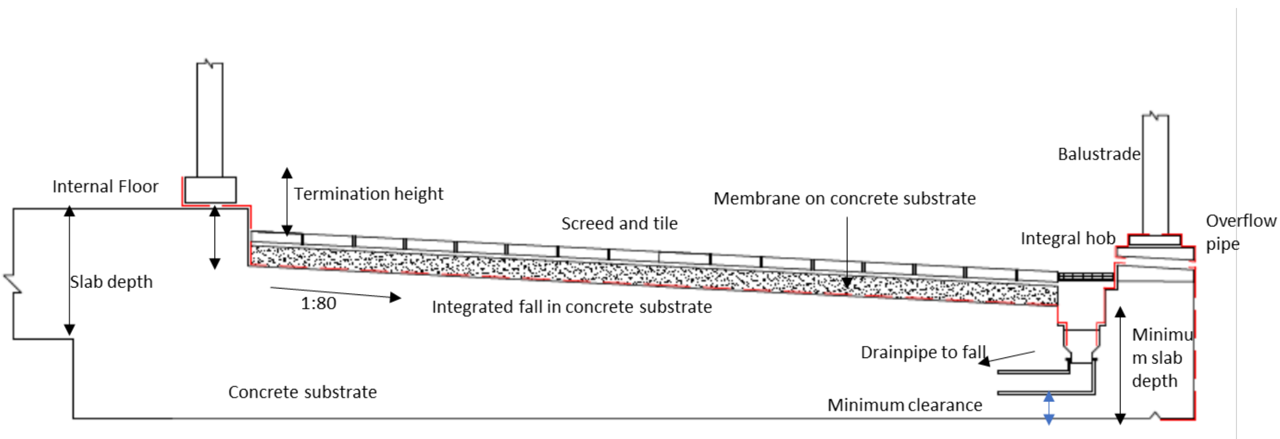


Figure 53: Sketch, as described by architect to comply with NCC requirements (cantilevered balcony with screed and tiling) The method of construction for the tile and screed complies with AS 3958:2023 (clause 3.2.4).

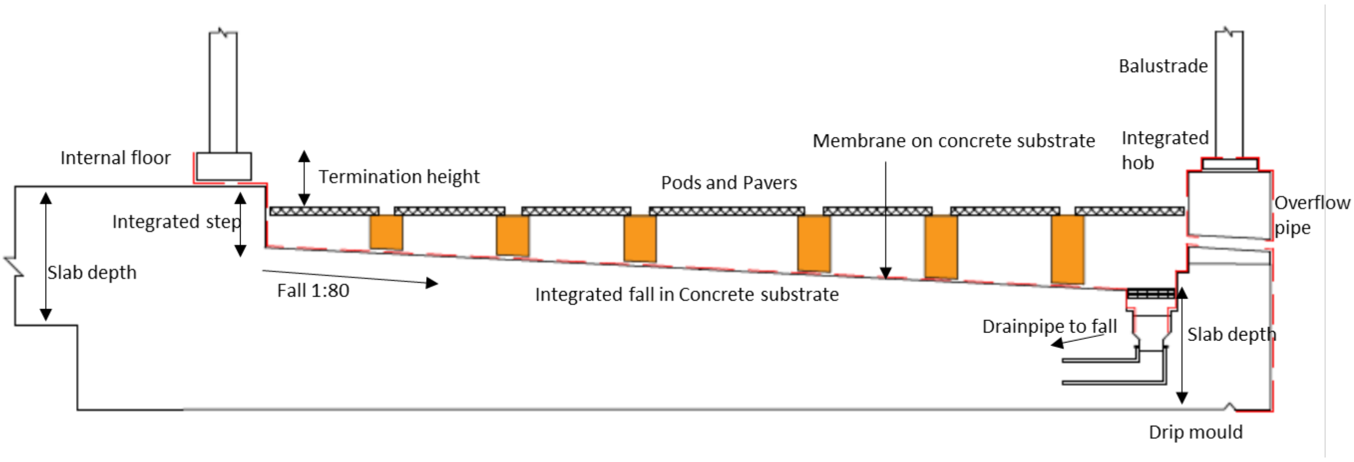


Figure 54: Sketch, as described by architect to comply with NCC requirements (cantilevered balcony with pods and pavers)

Observations about poorly-performing balconies

Construction described within the case studies obtained for the present research demonstrated that poorly-performing concrete balconies[48] featured:

- screed to fall and membrane laid on flat concrete surface (see Figure 55 and Figure 56, reproductions of Figure 11 and Figure 12)
- no set down, and or insufficient integrated fall (see Figure 57 and Figure 58, reproductions of Figure 15 and Figure 16)
- incorrectly treated movement joints/expansion joints
- the use of a membrane that is not an approved product
- installation by a waterproofing contractor or 'tiler' who does not hold appropriate VBA registration
- membranes installed directly onto screed (see Figure 57 through Figure 60)
- slab thickness that does not meet minimum thickness requirements (per the structural engineer) (see Figure 61), noting that if this is resolved by increasing thickness and adding a step, then further issues may arise regarding head height
- inappropriate termination height due to the absence of a step (see Figure 61), noting that if this is resolved by varying the hob height, then further issues may arise regarding the internal floor level.

[48] See Case Studies D and F as examples.

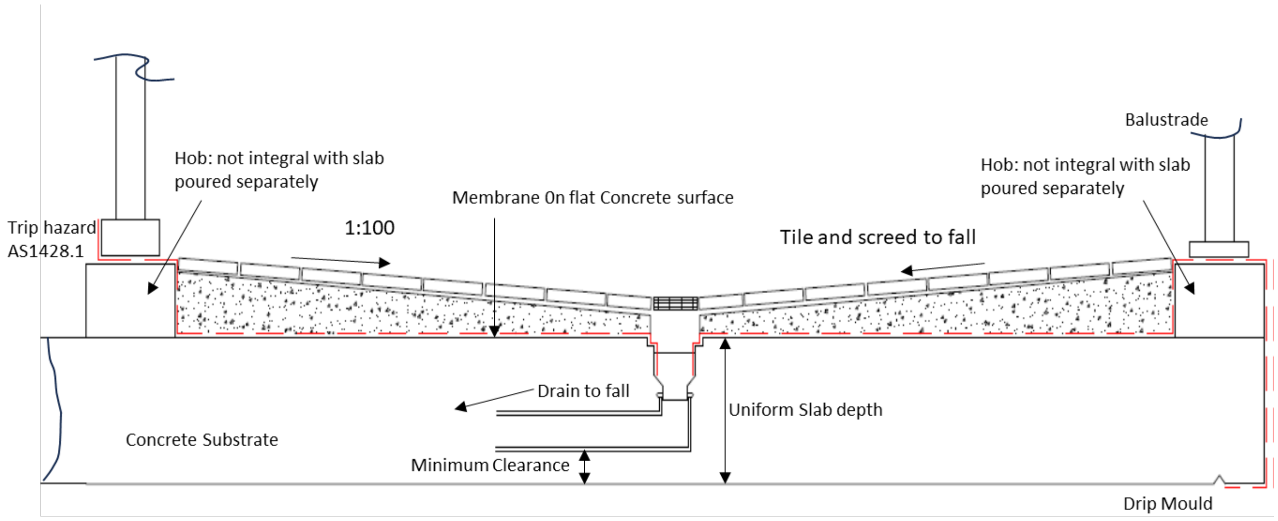


Figure 55: Preferred construction by builders (screed to falls and no set down)
The method of construction for the tile and screed complies with AS 3958:2023 (clause 3.2.4).

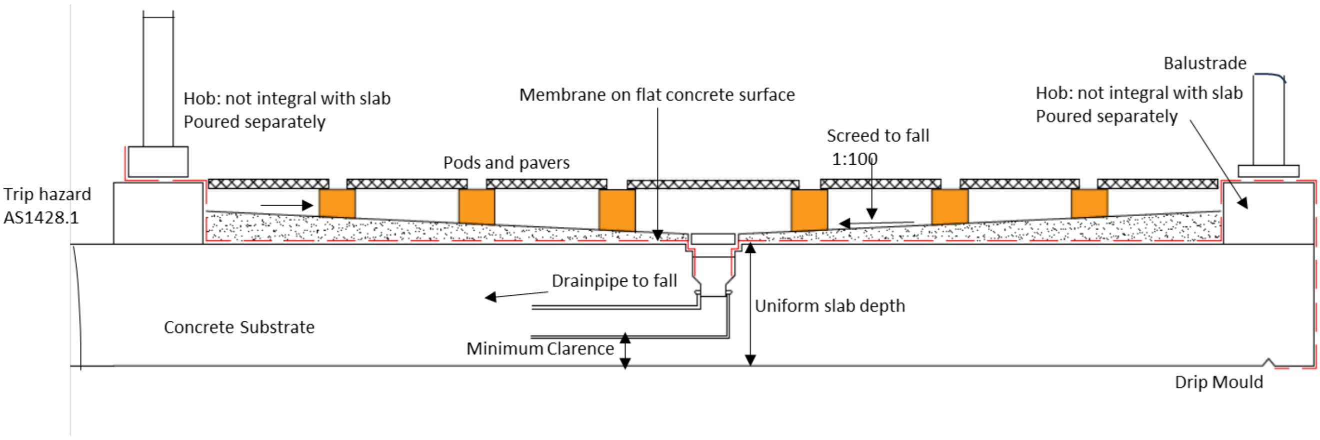


Figure 56: Preferred construction by builders (screed to falls with tiles/pavers and no set down)

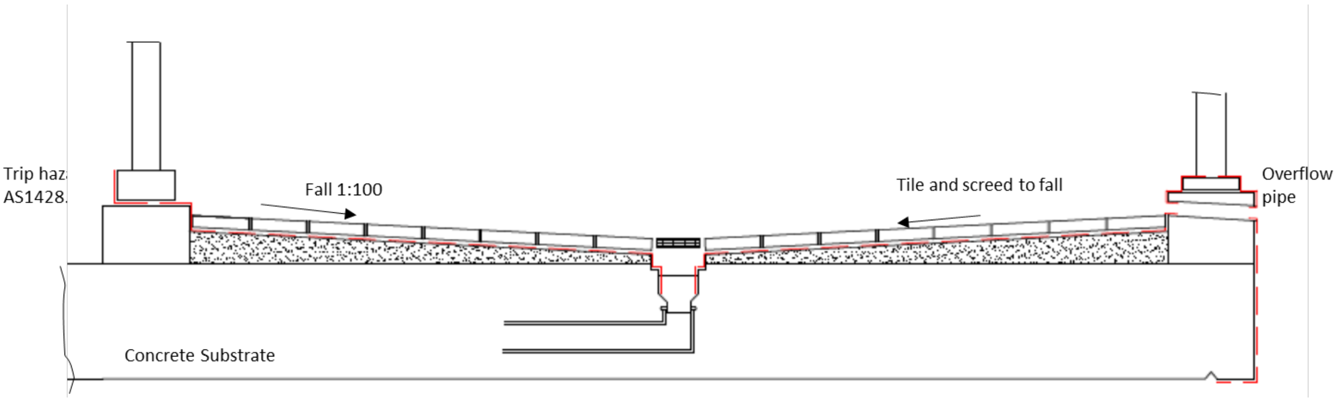


Figure 57: Sketch, compliance via performance solution, described as a common preference of builders
The method of construction for the tile and screed complies with AS 3958:2023 (clause 3.2.4).

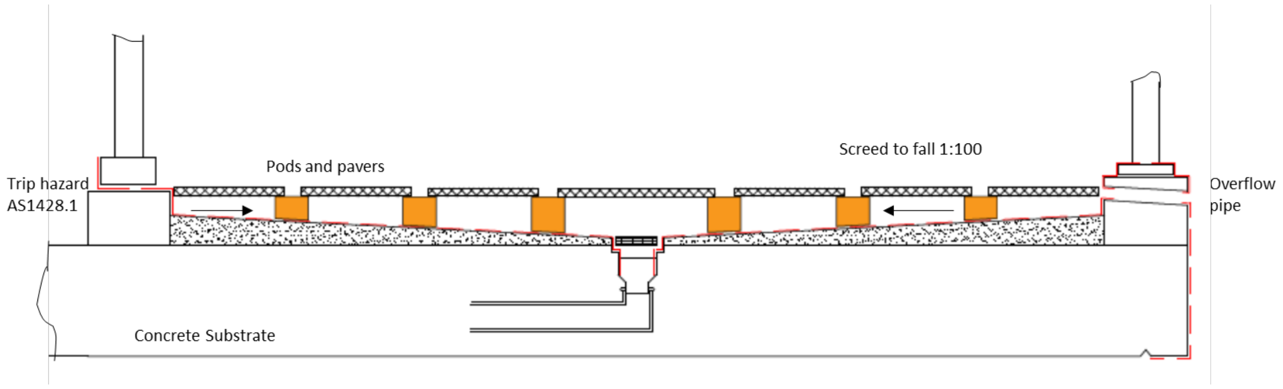


Figure 58: Sketch, as described by architect to comply with NCC requirements

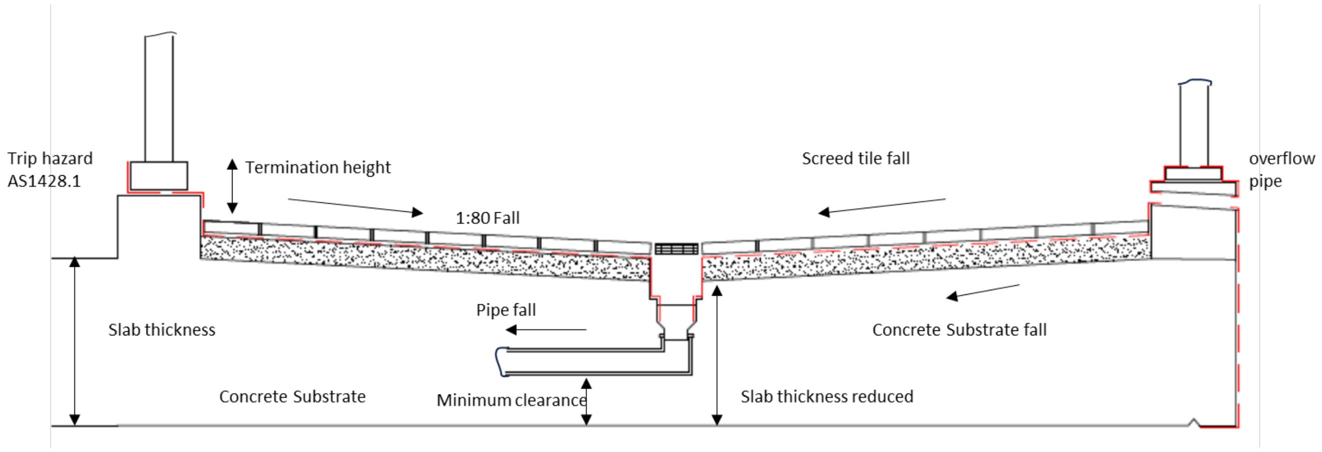


Figure 59: Sketch, as described by architect to comply with NCC requirements

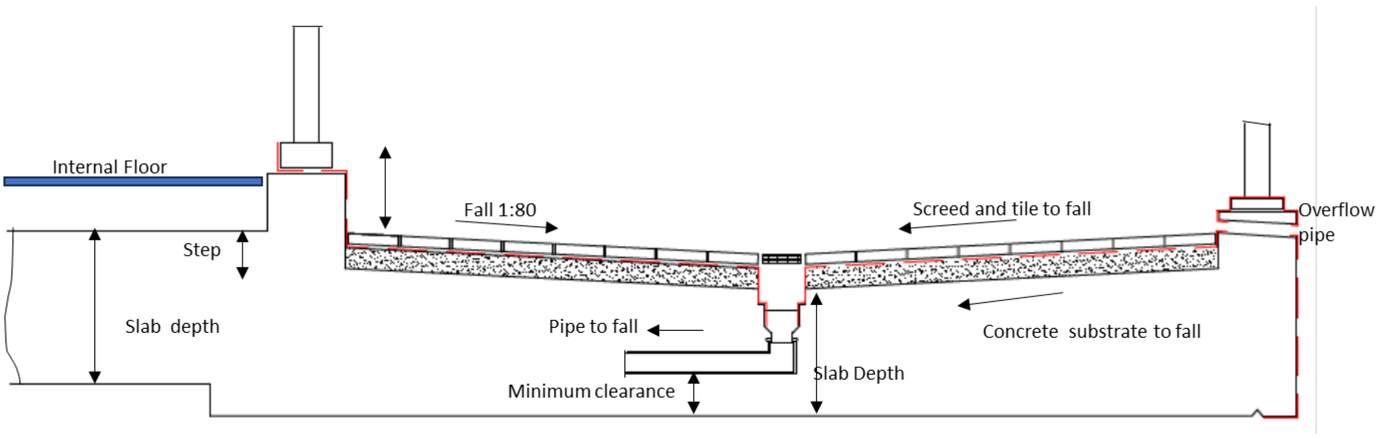


Figure 60: Sketch, as described by architect to comply with NCC requirements
The method of construction for the tile and screed complies with AS 3958:2023 (clause 3.2.4).

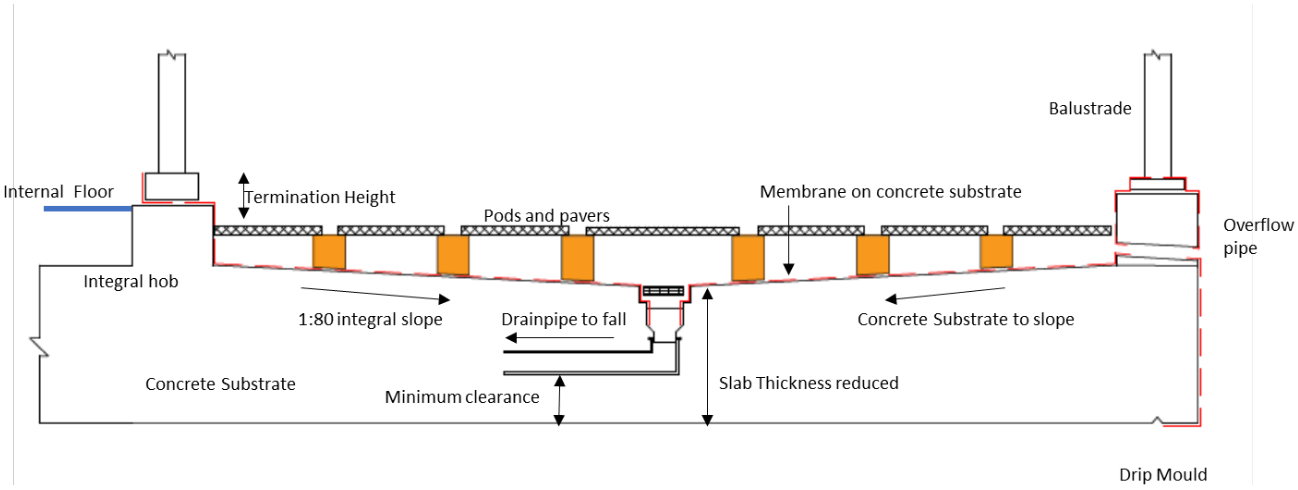


Figure 61: Sketch, as described by architect to comply with NCC requirements (membrane on concrete)

Elements of concrete balconies from case studies and their impact on performance

The elements identified above as being common to well- and poorly-performing concrete balconies are summarised in Table 11 below, with additional consideration of the compliance pathways adopted for the buildings of the case studies.

This table is indicative that a concrete balcony design in compliance with the NCC's DtS pathway provides good confidence that a balcony, if well-constructed, is likely to perform well. In comparison, concrete balcony designs that feature Performance Solutions are at a higher risk of defects. However, as a small number of case studies were performed, these results should be interpreted with caution.

Table 11: Elements of concrete balconies from case studies, and impact on performance

Code & AS requirements	Well performing concrete balcony, compliant to NCC 2022	Poorly performing concrete balcony, compliant to NCC 2022	Poorly performing concrete balcony, not compliant to NCC 2022
Compliance pathway present	DtS	DtS and Performance Solution(s) per A2G2	Performance Solution(s) per A2G2
Integrated Step	✓ Figures: 51, 52, 53 and 54	✓ Figures: 59 and 60	Not present Figures: 55 and 56
Fall integrated to concrete substrate	✓ Figures: 51, 52, 53 and 54	✓ Figures: 59, 60 and 61	Not present Figures: 55 and 56
Integrated Hob	✓ Figures: 51, 52, 53 and 54	✓ Figures: 59, 60 and 61	Not present Figures: 55 and 56
Membrane on concrete substrate to fall	✓ Figures: 51, 52, 53 and 54	Not present Figures: 59 and 60	Not present Figures: 55, 56, 57 and 58
Membrane on fall (per AS 4654.2)	✓ Figures: 51, 52, 53 and 54	Not present Figure: 56	Not present Figures: 55 and 56
Termination height (per AS 4654.1)	✓ Figures: 51, 52, 53 and 54	✓ Figures: 59, 60 and 61	Not present Figures: 55, 56, 57 and 58
Overflow pipe	✓ Figures: 51, 52, 53 and 54	✓ Figures: 57, 58, 59, 60 and 61	Not present Figures: 55 and 56
Membrane installed (per AS 4654.1)	✓ Figures: 51, 52, 53 and 54	✓ Figures: 57, 58, 59, 60 and 61	✓ Figures: 55 and 56
Disability provision	✓ Figures: 51, 52, 53 and 54	Not present Figure: 59	Not present Figures: 55, 56 and 57

Case Study - Project A

This project was chosen to illustrate the design development process prior to permit submission.

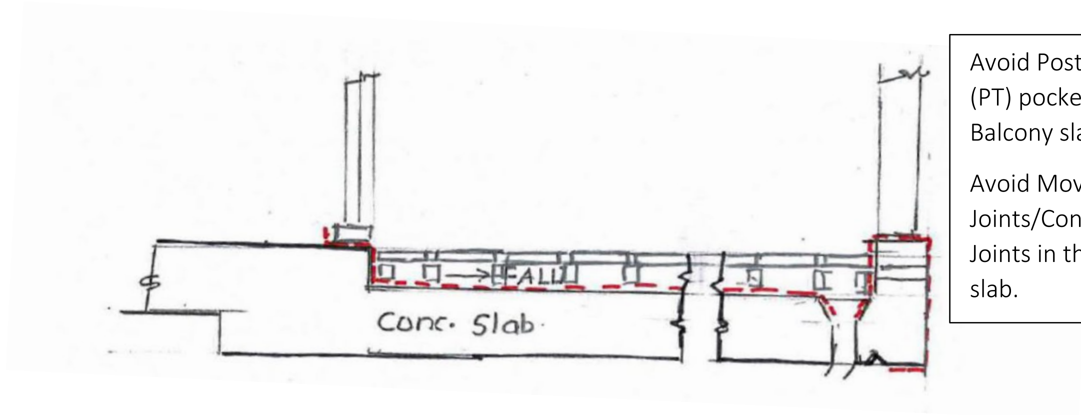
Context

Project A is part of a 5-storey building with 27 apartments on each level with concrete balconies for each apartment. The project was at its design development stage.

An agreement was sought from the Project architect and the structural engineer to case study this as a test project to investigate the balcony construction compliance requirements. On 21 November 2023 the Chief Investigator (CI) participated in the design team meeting.

Design issues raised

The issue of having steps in a post-tensioned flat slab was raised as a concern by the senior structural engineer (Figure 62).[49]

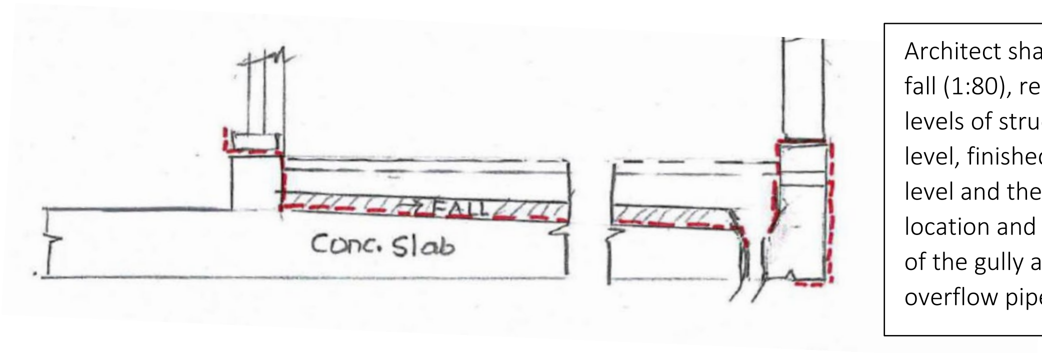


Avoid Post-Tension (PT) pockets in the Balcony slab.

Avoid Movement Joints/Construction Joints in the balcony slab.

Figure 62: Concept sketch as described by the structural engineer

The senior architect raised concerns about losing head height, and a possible rejection by the builder due to the difficulty in forming folds in the slab (as any cost variation may have to be borne by the builder). A flat slab, hob and screed to falls is the method preferred by the builder, and the senior architect observed that the builder may look for an alternative consultant team who could do away with steps (Figure 63).



Architect shall show fall (1:80), reduced levels of structural level, finished floor level and the location and levels of the gully and overflow pipe.

Figure 63: Concept sketch as described by the architect

[49] Note: Sketches shown in Figure 62 to Figure 64 were hand drawn by the CI during the workshop.

Builder’s preferred construction

Builders generally favour speedy construction methods, and one of the preferred methods is a two-way post-tensioned (PT) flat slab. Having a set down for balconies (or bathrooms) introduces complexities for builders, and therefore some practitioners may opt to have the required falls in the screed rather than the recommended approach of an integrated slope in the slab.

A stepdown in the slab not only incurs extra costs and time in the build phase, but also affects the building height. For this reason, many apartment buildings are constructed with hobs and screeds to falls (Figure 64), a method which is associated with water leakage on concrete balconies (see also section 7.4 of this report).

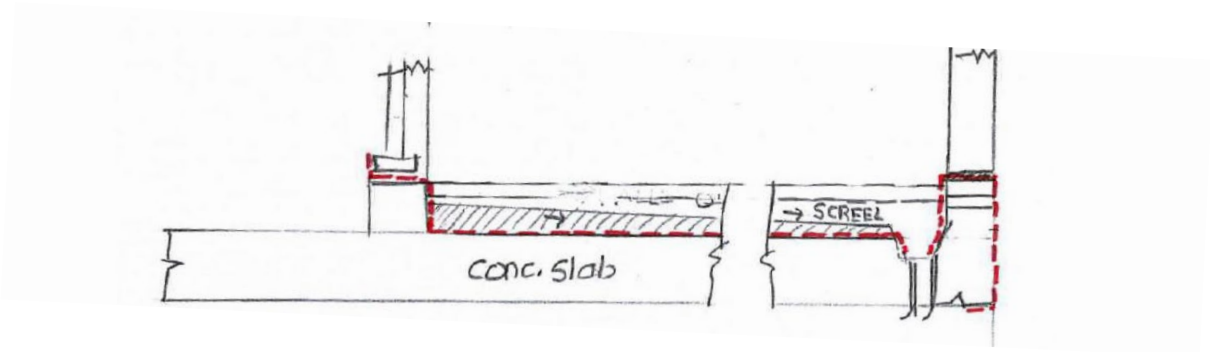


Figure 64: Original details – Concept sketch as described by the builder (seeking a performance solution)

Case Study - Project B

This project was chosen to illustrate a construction of a balcony approved with no fall provided in the balcony floor.

Context

Project B is part of a two storey Victorian duplex townhouse completed in 2020, with an inset balcony partially over the garage. Though this building is a Class 1 structure, the issue highlighted here is applicable to Class 2 buildings.

Balcony construction details

The balcony features a set down and fall to a strip drain and tile finish. The balcony is partially above a garage. A comprehensive detailing by the architect shows the set down and falls, and notes the appropriate NCC and AS references (Figure 65).

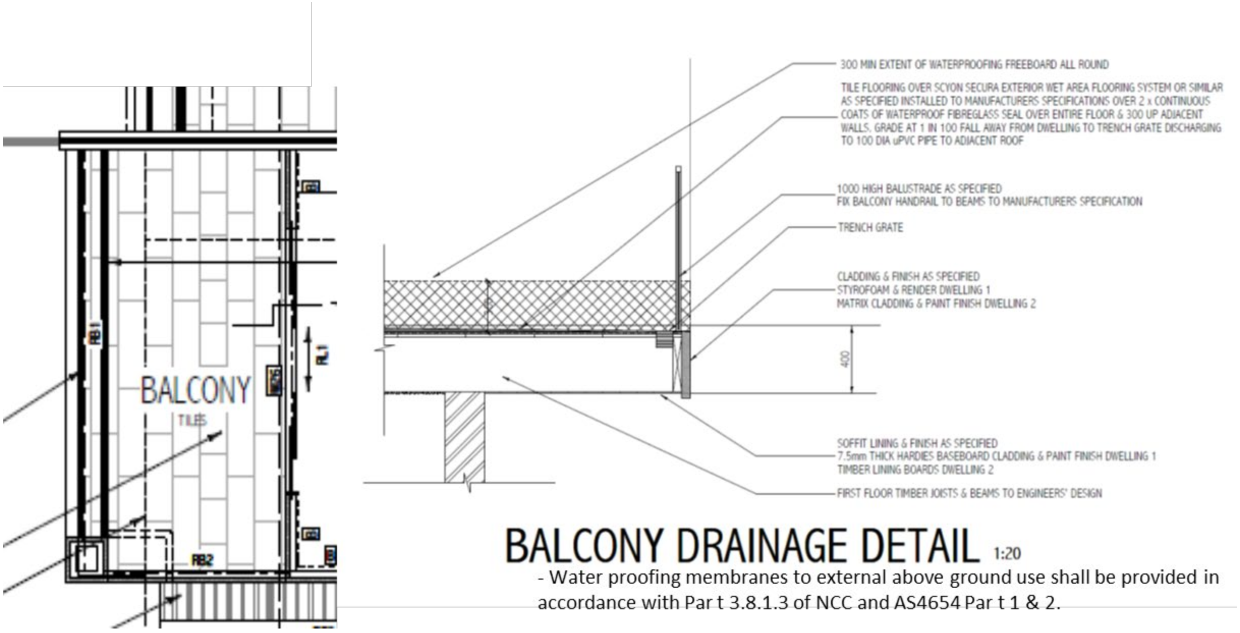


Figure 65: Extract of the architect's detail

Description of the defect

A water patch occurred on the ceiling of the garage (Figure 66).

Figure 66: Case Study B - defects observed
From left to right: water leakage (wet patch on ceiling), water pooling (stagnation), and set down membrane termination.

Inspection of the defective balcony

The garage ceiling was removed, and the balcony floor soffit was inspected to locate the leak. The following observations were made:

- The balcony was filled with water (a counterintuitive finding, as an inset balcony should hold less water from to rain and wind), and water leakage was detected along the strip drain.
- Water pooling was observed on the balcony and the level was checked and found that there was no slope provided on the floor.
- Grout leaching through tile was observed near the strip drain.
- A pot plant on the balcony was observed with mud stain on the pot, probably due to watering of the plant and subsequent overflow (maintenance issue).
- A similar balcony construction where no leakage was observed and inspected for comparison. It was noted the balcony floor was constructed with a 1:100 slope. This balcony was clear of any pot plants.

Suggested corrective actions (Proposed by the CI)

1. The balcony floor slope must be corrected to the minimum required fall of 1:100. An approved membrane must be installed by an installer with suitable education and experience (for example, as evidenced by a certification).
2. A maintenance guide must be provided to the owner about having weighted items such as pot plants on the balcony. Pot plants are particularly identified as an item of potential concern as they present two issues when placed on a balcony: 1) weight that may potentially exceed the capacity of the balcony, and 2) excessive watering, causing the potential for overflow onto the balcony floor.
3. An exploration of why the building works were passed by the building surveyor.

Lessons learnt

1. Inspection of the floor prior to and after waterproofing must be made as a mandatory requirement.
2. Ensure the installer is qualified to perform the waterproofing or ensure that the registered practitioner who employed the installer is present during the installation of waterproofing membrane.
3. Maintenance of the balcony including pacing pot plants and watering of these plants must be included in a maintenance manual.

Builder's remediation

The existing tiling and screed were removed, and a new membrane was applied on a 1:100 fall screed. Any certification of the installer could not be verified; the installer appeared to be working under the supervision of a builder who may have a DB-U registration.

Approximate costs of the remediation

The remediation costs were the labour of an installer and labourer for three days, plus materials.

Case Study - Project C

This project was chosen to illustrate a construction of a concrete balcony with appropriate integral fall and set down in concrete substrate. This is a good example of a comprehensive concrete balcony detail.

Context

Project C is part of a four-storey building with ten apartments on each level. Each apartment has a concrete open balcony.

Balcony construction details

The balconies have an integrated set down and fall, with a pods and paver finish.

The detail (Figure 67) was supplied by the project architect. The project architect also indicated that a coordination meeting with the developer, chosen builder, and Structural/Civil/Hydraulic engineers is the key to a successful outcome.

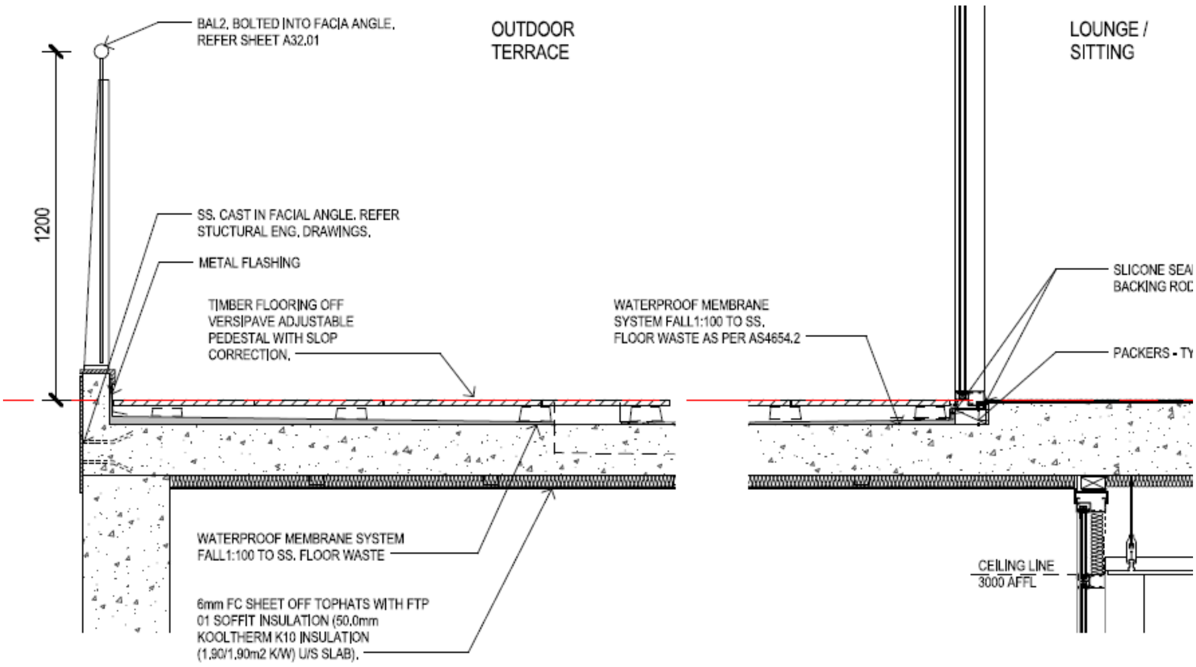


Figure 67: Original details - construction screed and tiles (architect's detail)

Concrete balcony defects

No defect reported to date.

Conclusion

This type of balcony detail (integrated fall, set down with pods and paver finish) is working well. This example shows that a well-planned, fully coordinated design that is compliant to the NCC and relevant AS results in a defect-free concrete balcony.

Case Study - Project D

This project was chosen to demonstrate the complexities around responsibility, conflicting assumptions and lack of communication about the loading capacity of the structure, difficulties in obtaining documents required, and insufficient documents provided to the structural engineer for review.

Context

Project D is part of a five-storey mixed used Victorian apartment building completed in 2003. The Level 4 apartment concrete spanning balcony studied has a habitable space underneath it.

Concrete balcony defects

Concrete balcony leakage to the Level 3 habitable space underneath it (Figure 68) and the sagging of a handrail (Figure 69) were reported in 2019.

A water leakage inspection was conducted by experts in leak detection by inspectors appointed by the Owners' Corporation. The homeowner appointed structural engineers to investigate any structural issues. In the absence of structural drawings, concrete scanning was requested by structural engineers.

Figure 68: Defect – water leakage (wet patch on ceiling)

Figure 69: Defect - sagging of handrail (heavy loading)

Cause of the water leakage

The waterproofing membrane either failed, or was not installed properly. There are three possible causes of this, although it was not possible to determine which caused the issue:

1) leakage through concrete cracks (not reported in inspections)
2) water ingress through the joint between the slab and the supporting wall (Figure 71), and/or
3) overflowing gutter (Figure 70) / inefficient flashing / waterproofing details.

Balcony Construction

Initially no balcony construction details were available for review for this research. The repair contractor indicated that the balcony is a concrete spanning balcony with hob and screed to fall. Water collection occurred via a common roof gutter at the edge of the balcony (Figure 70).

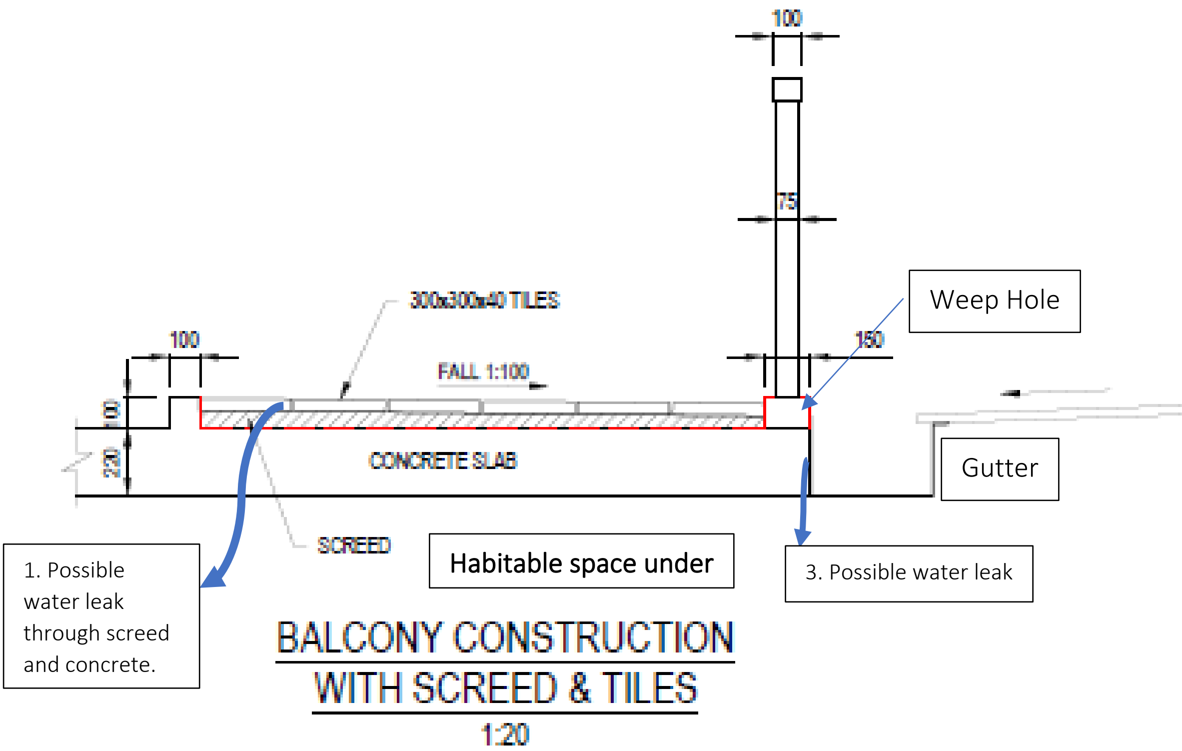


Figure 70: Original details - construction screed and tiles (CI's interpretation)

Loading

From the structural engineer's computation: LL = 3.0 kPa, SDL = 40 mm tiles + no screed allowance (Figure 70 provides the CI's interpretation of the original balcony details).

The authors have calculated that screed could impose an additional load of 1 kPa (refer to Table 2 for the additional deflection due to increase in SDL).

This additional load was taken into account during repair, where the selection of tiles and screed was made such that there is no load increase to the original load allowance.

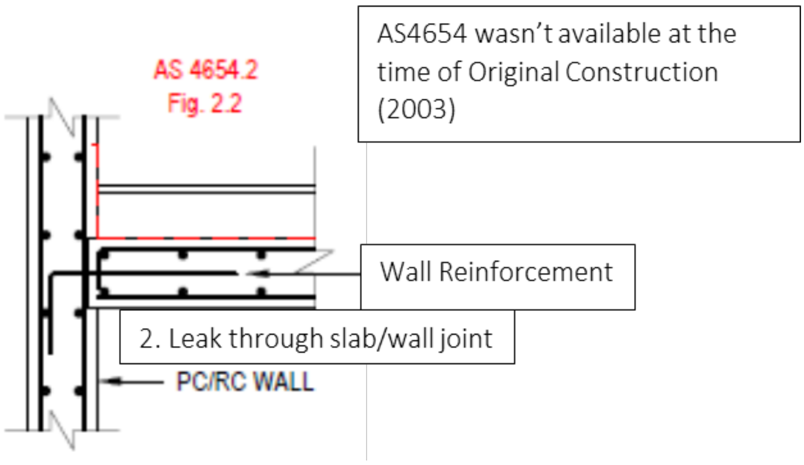


Figure 71: Original details - PC wall/RC slab connection (CI's interpretation)

Performance Solution adopted

The owners informed the authors that the balcony was tested by the water proofing contractor as a Performance Solution method to comply with the NCC. The testing details were not revealed by the owners.

Repair of the balcony

Repair was initiated by the Level 4 apartment owner. A new waterproofing membrane was installed, and the balcony repair work was completed with a pods and pavers solution to reduce the heavy loading caused by a sloping screed (see Figure 72 provides the CI's interpretation of the details of repair).

While the building's construction occurred before AS 4654 was first published in 2009, the repair works must comply with current standards (AS 4654.1 and 2). The authors could not confirm the compliance to regulations, as the details of the performance solution were not revealed.

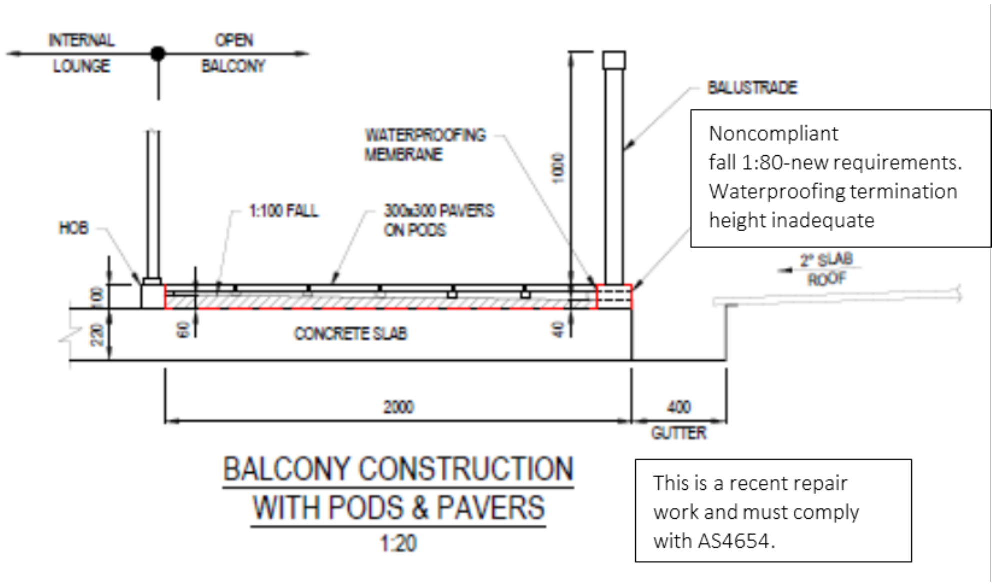


Figure 72: Details adopted for repair works - pods and pavers (CI's interpretation)

Repair costs

The repair cost for removing the existing screed tiling and waterproofing membrane and replacing them with an approved membrane (with a 10-year warranty) with sloping protective screed and lightweight pavers is around $40-50k. According to the owner the relocation cost for the apartment owners below is estimated around $300-400k.

Analysis of the balcony

The authors made an examination of all available information about the balcony. The findings were:

- Architectural drawings of the original specification are comprehensive, and instructions detailed by the architect are sufficiently detailed (see Figure 73).
- No allowance was made for screed loading by the structural engineer. They may not be aware of the extra screed laid by the builder, nor it's' weight. The engineer should have requested the balcony waterproofing details prior to finalising their computations.
- The supplied permit package showed that no request was made by the RBS for balcony construction details.

- Construction drawings were not made available to the author. However, it was observed that no slope was provided in the concrete slab by the builder (or their nominated practitioner). Screed was made to slope to the roof gutter. The water proofing membrane was laid flat, and upright termination was inadequate. Waterproofing did not comply with AS 4654.1 and 2 (although these Standards were first published in 2009, after this building was constructed).
- It was observed that there were planter boxes and other equipment which may have not considered in the structural design. No maintenance guide was available for homeowners about loadings.

J2. WATERPROOF MEMBRANES TO WET AREAS UNDER FLOORINGS, TILING, PLANTERS, INCLUDING TERRACES AND BALCONIES AND OTHER SURFACES WHERE SHOWN ON DRAWINGS.

J2.1 MEMBRANE - GENERALLY

Waterproof Membrane shall be Emer-Clad of Parbury Technologies, tintable, with polyester fabric applied over first coat in accordance with manufacturer's instructions. Apply 5 coats each 150 micron. Joints in concrete/fibre cement sheet shall be polyurethane and not silicon.

The membrane shall applied by experienced Applicators, who receive training and accreditation from the Membrane Manufacturer.

All surfaces to which the membrane is to be fixed shall be dry, clean, smooth and free of looseness and voids. Other trades preparing these surfaces shall cooperate with the membrane roofer to ensure that the finish is acceptable for laying the membrane. Commencement of laying membrane shall be taken as acceptance of the substrate surface be the Applicator.

Apply Parbury's Emer acrylic sealer to full extent of floor and walls. All movement joints and cracks to be sealed prior to membrane installation.

Flashing tape shall be malleable tape and to be used for moulding in gussets, pipe flashings and where shown on drawings.

The Parbury's Emer proof WB membrane shall be applied strictly in accordance with the manufacturer's directions. Polyester fabric shall be embedded into wet Emer-Proof WB.Apply second coat of Emer-Proof WB. Apply a fillet of Parbury Hilastic 66 at all right angle junctions.

Figure 73: Extract of architectural specification

Suggested corrective action as proposed by the CI

There are several low to medium rise apartment buildings which have similar design and construction and are at risk of water ingress. For these buildings we recommend a concrete balcony audit by a team of professionals including a structural engineer, an architect, and a waterproofing consultant to be conducted to ensure the balconies and any habitable spaces underneath are safe.

Owner experience

The owners are still anxious about their balcony, as the apartment owners below still claim that water leakage is occurring.

Case Study - Project E

This project was chosen to study the performance of the adopted construction method in terms of regulatory compliance and water leakage issues.

Context

Project E is part of a 33 level Victorian apartment building. Construction was completed in 2019. Several concrete balconies have habitable spaces underneath them.

Defects

No balcony leakage defect has been reported to date.

Balcony construction detail

The research team's discussion with structural engineers, architects and builders revealed aspects of the balcony's construction detail (see Figure 74 for the CI's interpretation of the balcony construction details).

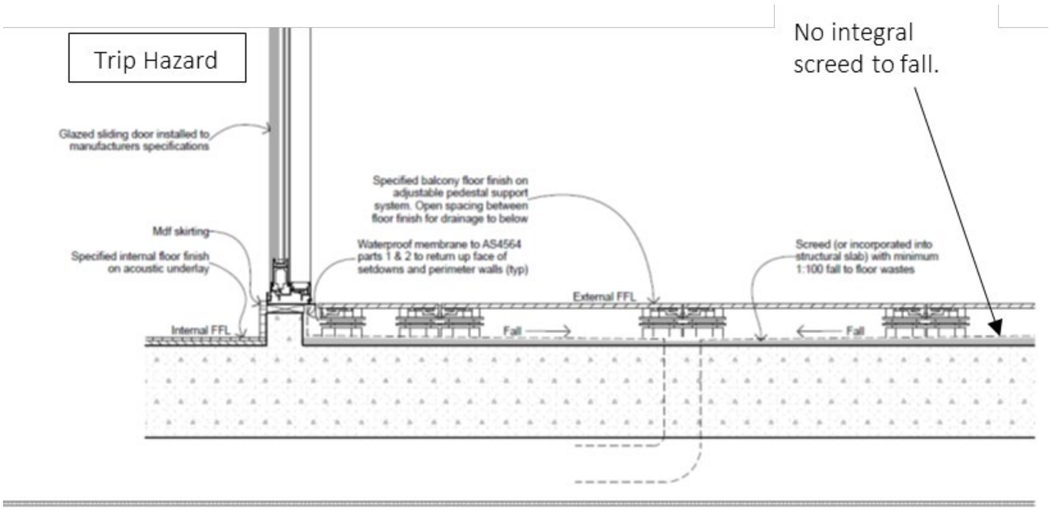


Figure 74: Balcony construction (CI's interpretation of the balcony construction details)

The balconies are open cantilever and inset spanning concrete balconies. Most of the slab constructions are two-way PT flat slab construction. They feature hobs and screed to fall with membrane applied on the screed, and the balconies are finished with pods and pavers (Figure 75).

A number of balconies have PT pockets. These pockets can cause water leakage if not filled properly; as a result the PT strands could be susceptible to hydrogen embrittlement, resulting in the slab's structural integrity being compromised.

Figure 75: Case Study E - balcony construction

Architectural specification

Balcony waterproofing details were not made available to the authors. However, the architectural specification was made available by the project structural engineers. The specification was very comprehensive and covered all codes and regulation requirements. A summary of the specification as supplied by the project engineer is provided below (note that while the summary was provided to the authors, the documents referred to in the summary were not):

Summary of Architectural Specification

- Waterproofing: external and tanking
    - an 8 page document was prepared.
- Standards applied: Membrane materials
    - AS 4654.1 and AS 4654.2.
- Inspection
    - Inspection was conducted by the Architect.
- Submissions
    - products documentation
    - samples
    - prototypes
    - shop drawings
    - membrane.
- Balcony preparation
    - falls in substrates are greater than 1.5% (1:60)
    - joints and fillets Internal corners:
        - 45-degree fillets
        - external corners: round or arris edges
        - control joints: prepared all substrate joints to suit the membrane system.

Case Study - Project F

This project was chosen to illustrate the perspective of senior practitioners about common methods of construction adopted by builders.

Context

Project F includes a selection of a number of high, medium, and low-rise Victorian apartment buildings with open and inset concrete balconies. Construction on these buildings was completed between 2012 and 2019. This case study included a workshop to explore methods of construction.

Construction

A two-way PT flat slab with no set down for balcony construction was adopted. The balconies feature 100 mm hobs with falls in the screed, sloped to an edge strip drain next to doorway (see Figure 76).

A number of concrete balconies demonstrated water leakage associated with this commonly adopted construction type as reported by the Senior Structural Engineer.

NCC Compliance

Compliance with the NCC was examined via performance solution-based testing.

Workshop findings

A workshop was conducted in August 2023. Practitioners involved in the project focused on the concrete balcony detail, construction and the performance of concrete balconies constructed per the details presented in Figure 76. This experienced team provided the following conclusions:

Team member	Observation
Structural Engineers	Structural engineers must provide deflections and movements at joints.
Architects/Engineers	Architects and Engineers may provide integrated set downs and falls in concrete substrates, but builders may change this to hob and screed to fall construction to cut costs. On some occasions, Architects and Engineers may have agreed with the decision of the builder for fear of not being allowed to continue on the job.
Builders/Developers	It is difficult to achieve a set down on a slab. For inset or recessed balconies, where water collection is very much less than on open balconies, hob and screed is a preferred solution. For all open balconies, set down and integrated fall are preferred. Hydraulic engineers should design for water collection for open balconies. Some builders insist on a certified waterproofing installer and obtain a warranty for the waterproofing membrane.

Suggested corrective action as proposed by the CI

This method of construction is of such a high risk (see section 7.4.4) that it must not be allowed for balconies where habitable space exists underneath the balcony.

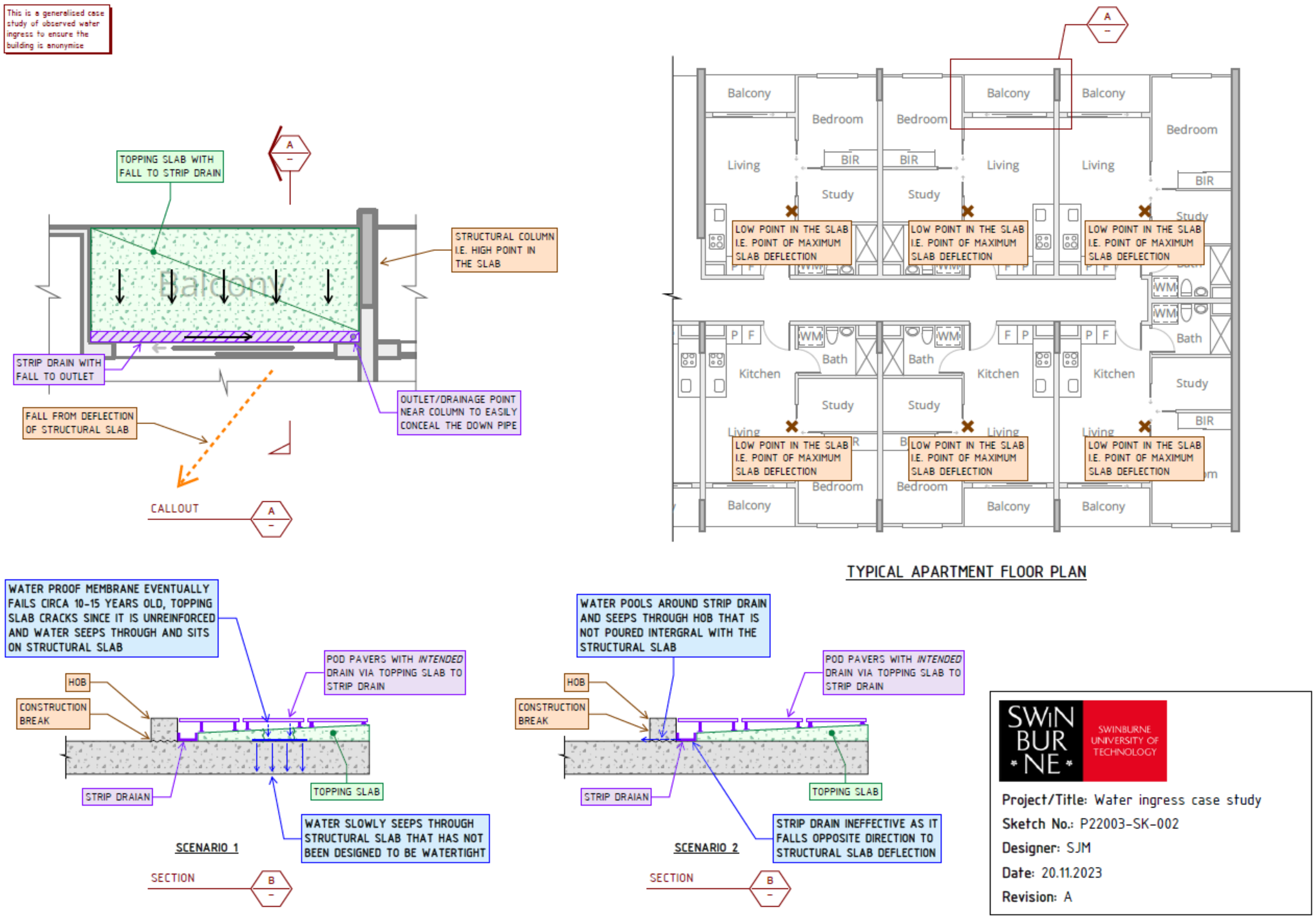


Figure 76: Case study F - Design detail construction drawings