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Construction Systems, Practices And Materials

HUAYU Waterproof

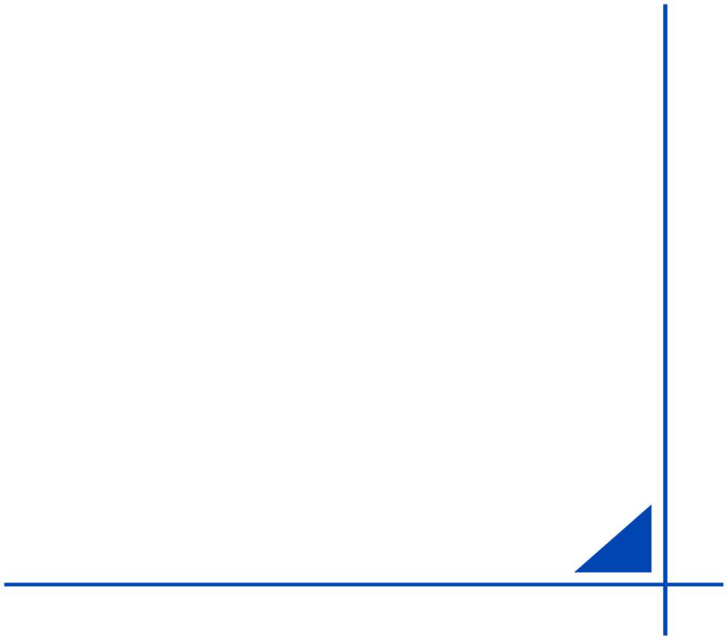


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1 Construction systems, practices and materials

1.1 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]

> 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

1.2 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

1.3 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.

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

1.4 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).

> 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

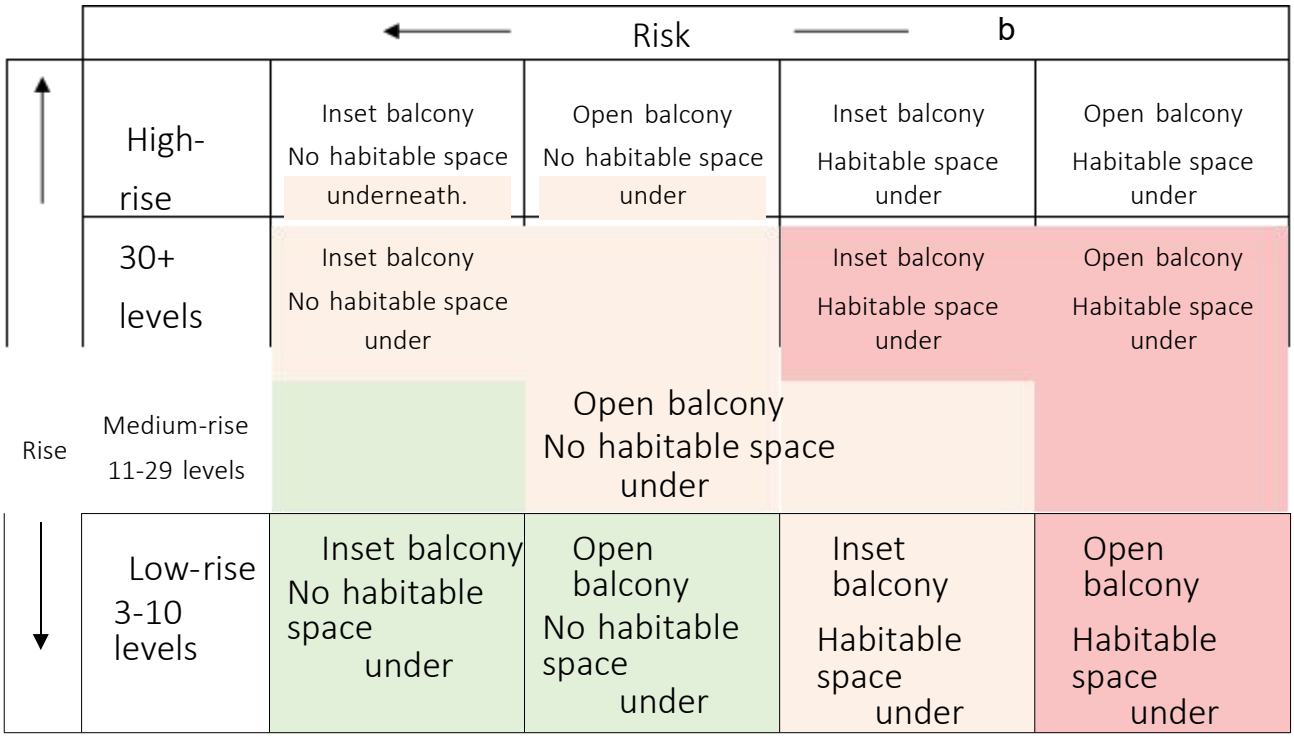
There is a lack of long-term reliability. Initial design, construction and maintenance are all lacking. This is why it a systemic issue. There is no annual maintenance. You can't expect every owner to know the seriousness – [they] may not know the seriousness of a crack...

- 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

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



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.

2. Post-construction repair and maintenance

2.1 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

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.