Waterproofing for buried decks

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Abstract. Buried decks are an increasingly common feature in the modern built environment. This increase may be partly attributed to growing awareness of the need for sustainability. Green roofs, sustainable urban drainage, water attenuation and even parks and farms are being located on top of ground floor roof structures and cut and cover tunnels. Waterproofing of these decks is vital in order to use the space created beneath and, also, to prolong the life expectancy of the structure.

This research explores some of the available best practice guidance and then compares the key waterproofing design features with opinions from industry. Opinions are gathered through seventy-eight questionnaire respondents made up of UK based professionals dealing with waterproofing of buried decks.

This research suggests that buried deck waterproofing design can reduce risk by employing the following features: (a) reinforced concrete structural deck, (b) fully-bonded waterproofing membrane, (c) waterproofing laid to a gradient to falls, and (d) provision of a drainage void over the waterproofing layer.

As a result of these findings this paper calls for more authoritative best practice guidance on buried deck waterproofing design in a bid to reduce pressures in procurement that lead to weaker waterproofing design choices.

This research may be of interest to those involved in the design and construction of underground structures including cut and cover tunnels, station boxes, malls, basements and more. The research identifies some fundamental features of podium deck waterproofing design and clarifies which design choices are perceived to deliver more robust waterproofing than others.

1. Introduction

Buried decks are an increasingly common feature in the built environment. With growing urbanization across the world leading to greater pressure on land use the below ground opportunity is greater. At the same time urban planners are recognizing the necessity for societal sustainability which calls for high quality public realm at ground floor level. The result of these forces is that buried decks are becoming an increasingly common feature in cities.
In addition to the calls for greater value added from city centre plots and the demand for high quality public realm greater awareness amongst built environment professionals for the critical importance of environmental sustainability leads to greater demands on what is hidden between the public realm and the below ground occupied space. Obvious examples include blue roof systems for their Sustainable urban Drainage Systems (SuDS) qualities and planted vegetation for their aesthetic and biodiversity benefits.

It is frequently taken for granted that the space below buried decks will remain dry regardless of what the design use is above. However, these building elements are high risk. Waterproofing failure is not uncommon, and the cost of failure is frequently very high due to the extensive build-up above the waterproofing. Rectification of waterproofing defects from below buried decks, including cut and cover tunnels, frequently considers the use of resin injection; however, this approach is often not entirely successful.

When the designed use above is a public realm incorporating water attenuation and irrigated vegetation systems the demand on waterproofing is apparent. This paper discusses the waterproofing design principles relating to cut and cover tunnel lids and basement roofs which are exposed to the external environment. Such building elements may be described as a plaza, a terrace, a podium deck, buried decks and more.

2. Literature
In 2011, Henshell & Griffin wrote a “Manual of below-grade waterproofing”. Buried decks, or plazas, are said to be at greater risk of water ingress than roofs on account of their proximity to ground level and the risks of vehicular traffic. To mitigate these risks Henshell and Griffin recommend the following features:

- Cast insitu reinforced concrete decks are better than alternatives. The need to accommodate long term creep is highlighted.
- Liquid membranes on account of their “localization of leaks” (p.155)
- Drainage design with a one or two percent positive drainage recommended.

Rutila, Klein, & Normandeau (2011), Alazar & Hoffman (2016), Dodge & Lewis (2013) all cite similar features in order to mitigate risks of waterproofing failure in buried decks. [3–5]

Hockey, in 2016, wrote an article entitled “Why podium deck waterproofing systems fail”. Again, design features including falls, drainage layers and bonded waterproofing are cited keys in preventing waterproofing failure.[6]

2.1. Guidance for waterproofing of buried decks
In the UK best practice guidance is a key component in a built environment professional’s arsenal. If we have complied with best practice the risk of professional negligence is low. However, the best practice guidance relating to buried decks is sparse as these elements of buildings are still fairly niche and unusual.

Some of the key best practice guidance documents designers may look to include:

- BS 8102:2009 Code of Practice for Protection of below Ground Structures against Water from the Ground[7]
- BS 6229:2018 Flat Roofs with Continuously Supported Flexible Waterproof Coverings-Code of Practice[8]

However, neither of these documents really address buried decks, or not in sufficient detail at least. BS 6229:2018 considers roofs, and whilst this content is relevant roofs are not generally located at ground level and are expected always to shed water. BS 8102:2009 does address ground level roof structures over basements but dedicates only a paragraph to buried decks which reads as follows (BS 8102:2009, p11):
In cases where the below ground structure is fully buried or the substructure extends beyond the superstructure, protection should be provided against water ingress through the roof slab, for example by:

i) encouraging water to drain away from the structure;

ii) providing drainage above the roof slab;

iii) using an external barrier.

Whilst this content is certainly helpful the level of detail is not sufficient to be of use to designers of waterproofing systems.

In the UK, other important sources of guidance would come from latent defect insurance providers (the most well known being NHBC). These insurance providers have a strong history of learning from claims and using technical guidance as a means to ensure developments are lower risk. The NHBC suffered twenty one million pounds of basement related claims between 2005 and 2011. [9] Buried decks made up seventeen percent of this expense. [9] Despite this, again, it is unclear which is the relevant part of the NHBC guidance. One might look to their technical manual Chapter 5.4 “Waterproofing of basements and other below ground structures or Chapter 7.1 “Flat roofs and balconies”[10]. Again, these documents are either directed at basements or roofs, but not both together.

This lack of guidance relating specifically to buried decks leaves designers, developers and insurers at greater risk of failure. This risk of failure is increased as we pursue greater sustainability issues by temporarily storing water on buried decks for blue roofs.

3. Method

This paper extracts some research findings from a research Masters thesis (Interdisciplinary Design for the Built Environment run by the University of Cambridge).

The primary research question for this research is “what are the important design considerations for buried decks?”

This paper discusses a questionnaire which was put to the UK construction industry which gathered seventy-eight responses.

The questionnaire was disseminated by a convenience sampling method and used social media platforms (primarily LinkedIn). As such there is there is the opportunity for bias to be represented as responses are more likely from personal contacts and there is a risk that such contacts hold similar views.

4. Findings

Seventy-eight complete responses were gathered from the waterproofing industry in the UK. The initial questions asked respondents about their level of experience and background. Roughly half of respondents represented companies that supply waterproofing materials. Most respondents had over ten years of experience and most respondents confirmed that they would feel comfortable designing waterproofing systems for podium decks.

The questionnaire presented respondents with a likert scale to express their level of agreement with statements relating to substrates, falls, bonded waterproofing and drainage. The following figure shows generally strong agreement with the statements offered.
The above chart suggests general consensus amongst respondents that reinforced concrete substrates are better than ribbed deck or block and beam. Subsequent questions sought to discover the reasons for this preference. Respondents were presented with a likert scale offering agreement levels with the statement “If a podium deck is leaking and localised waterproofing repair is required, reinforced concrete decks are more easily repaired than block and beam decks”. The following chart suggests wide agreement with this statement.
A further question, again with a likert scale offering agreement levels, was posed: “If a podium deck is leaking and localised repair is required fully bonded systems are more easily repaired than loose laid systems”. The following chart suggests wide agreement with this statement.

![Fully Bonded Systems More Easily Repaired Than Loose Laid](image1)

**Figure 3 - Ease of repair with fully bonded waterproofing systems**

A further question, again with a likert scale offering agreement levels, was posed: “If a podium deck is of reinforced concrete with a fully bonded waterproofing system, resin injection can be a successful repair strategy”. The following chart suggests a lower level of agreement.

![Resin Injection Can Be Successful With RC Decks](image2)

**Figure 4 - Efficacy of resin injection repairs with reinforced concrete decks and fully bonded waterproofing systems**
5. Discussion

This questionnaire received seventy-eight responses from professionals who have some involvement in waterproofing of buried decks within the UK built environment. Indeed, many of the respondents claimed to be at ease designing waterproofing for buried decks and some claimed to be comfortable acting as an expert witness within this field. Nevertheless, the findings are by no means generalisable and can only be considered broadly indicative.

Respondents appear to show support for the use of reinforced concrete as a structural substrate over alternatives presented in the questionnaire (block and beam or ribbed deck). From the results of subsequent questions, it may be fair to suggest a significant cause for this preference toward reinforced concrete is relating to the ability to repair.

The consideration of repairability appeared more distinct when combined with the use of a fully bonded waterproofing system (as opposed to a loose laid system). The advantage of a fully bonded system is related to the prevention of lateral movement of ingressing water. If water is allowed to move laterally under the waterproofing membrane, as with a loose laid system, the location of the defect can be very difficult to determine and this can make localised repair extremely difficult. As a result, if water cannot track laterally, as with a fully bonded system, and the deck substrate is of reinforced concrete the use of resin injection into the concrete is a common repair strategy. However, this approach only showed some consensus support within the questionnaire sampled.

Figure 1 shows that amongst the features of waterproofing design offered there was strongest consensus on the use of a fully bonded waterproofing system. It seems likely that this is related to the prevention of lateral migration rather than the ability to employ resin injection as a repair strategy. Within the UK basement waterproofing industry, the importance of repairability is laboured in the most authoritative best practice guidance (BS 8102:2009) and this might explain the favour for fully bonded systems as it is not possible to repair a system within which one cannot locate the defect. Whilst fully bonded systems may aid in defect location, these systems do have some considerable weaknesses, not least the lesser ability to accommodate movement to substrates. In Europe there appears to be a stronger uptake in the use of sensor technology for permanent leak detection as there is some guidance on such systems [11].

Figure 1 also suggests strong consensus on the importance of falls as opposed to “zero falls”. Zero falls is a term defined as a deck with a gradient between 0 and 1:80 but, importantly, with no backfalls or ponding. This question was perhaps not sufficiently clear as there was much room for respondents to be unaware of the strict definition of zero falls and also many buried decks achieve neither “zero falls” or falls but instead have backfalls or ponding. Nevertheless, the inference from this result suggests that most UK designers of buried deck waterproofing systems would much prefer the provision of a gradient to falls.

Related to this element is the provision of a drainage layer. In buried deck systems even where falls are provided if water has no means by which to travel down the gradient, for example where relatively impermeable materials make up the overburden, then the benefits of a gradient to falls diminish. Figure 1 shows some consensus support for the provision of a drainage layer with the gradient to falls; however, this had the lowest level of support amongst these four features.

6. Conclusions

Literature suggests some features important in mitigating risks of waterproofing failure in buried decks including reinforced concrete decks, provision of a gradient to falls and a fully bonded waterproofing system.

The responses from this questionnaire appear to support these design features. The questionnaire responses suggest repairability is an important consideration in the preference toward reinforced concrete decks. These considerations may well be of use in the design of the upper surface of cut and cover tunnels.

A useful area of further research would relate to the reasons for the preference toward fully bonded waterproofing systems and to what extent these relate to the ability to locate defects. Such research
would be beneficial in the consideration of the use of sensors and leak detection technology in buried roof systems.

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