Risk Management to Reduce Substructure Leakage

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ABSTRACT

Basements and other substructures can leak both during and after construction, particularly when the structure is below water table level. Normally, ground water will try and seep through the cracks and joints, which may lead to leakage problems in substructure. As a construction profession, it is vital to understand the consequences & issues of leakage and providing a system to give water resistance in various forms, essentially waterproofing. This paper portrays various risks associated with waterproofing by providing information about the methods and processes involved; Also information’s are given to manage the risks in important issues that can lead to substructure leakage with highlighting the role of various players involved in construction.

1. INTRODUCTION

If the construction is below water table, the groundwater which is under pressure will flow through the path of least resistance zone such as cracks and causes leakage in substructure especially in basements. Potential consequences of leaking substructure are numerous but generally it results in cost associated remedial works and delays to the schedule of construction at construction stage and expenditure and disruption to the building function after construction stage. In most of the construction sites not much attention is given at design and construction stage about waterproofing. Conventional waterproofing methods are followed without studying ground condition and ground water regime and it leads to the leaking substructure. By proper investigation, design, construction and maintenance of waterproofing at various stages one can minimize the chances of leakage in substructure.

2. WATER PROOFING

The act of providing a system to give water-resistance is called waterproofing. Based on the performance level of the particular environment the grades of the water resistance are divided into four types (BS8102-1990).

**Table 1:** Grades of Water Resistance

<table>
<thead>
<tr>
<th>Grade</th>
<th>Performance Level</th>
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<tbody>
<tr>
<td>Grade 1</td>
<td>Some seepage and damp patches tolerable.</td>
</tr>
<tr>
<td>Grade 2</td>
<td>No water penetration but moisture vapour tolerable</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Dry environment</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Totally dry environment</td>
</tr>
</tbody>
</table>

**Grade 2**
A member that does not permit water penetration but water vapour is tolerable will come in this grade. The ‘beading’ which permitted in Grade 1 is not allowed in this grade. It has been suggested that the wall of a Grade 2 basement should be dry to the touch but discolouration of the wall due to moisture may be permitted; as may mineral residue left from water evaporation.

**Grade 3**
This grade requires a ‘dry’ environment. Any residue from the evaporation of water is not permitted and neither is discolouration of the walls though signs of such initial moisture ingress usually disappear in the first few weeks of construction. A Grade 3 internal environment is required if the basement is to be habitable.

**Grade 4**
A Grade 4 environment is described as ‘totally dry’.
compared to Grade 3’s ‘dry’. The requirements for archive and storage which would necessitate a Grade 4 basement call for a lower Relative Humidity and lower temperature ranges than the requirements for a Grade 3 habitable environment. A Grade 4 basement is therefore purely driven by the requirements for the internal environment and the need to provide ‘special’ conditions for archiving and storage.

**Methods of Achieving Water Resistance**

Waterproofing methods can be divided into three types based on the method employed (CIRIA (1995) Report 139). Description and some information on each of the methods are discussed here. In certain circumstances it may be necessary to employ a combination of these methods in order to achieve the required internal environment.

**Type A: Tanked Protection**

Tanked protection involves the application of an internal and/or external barrier system to obstruct water flow paths. The basement walls and slabs are not relied upon to prevent water ingress. This is normally achieved through the application of a membrane either in sheet form or liquid form. Some forms of sheet membrane may be stuck (bonded) to the substructure which prevents the spread of water beneath the membrane.

Tanked protection can provide resistance against both moisture and vapour penetration. The advantage of this form of protection is that it can be relatively cost efficient compared to the other two methods. In the correct circumstances tanking can be applied to make existing structures that are to be incorporated into the scheme waterproof.

Disadvantages include ensuring correct jointing, overlaps and good workmanship, especially in adverse weather conditions. For certain types of membrane, if any damage is done to the membrane, it can be difficult to find and fix the leak in the future. If internal membranes are insufficiently designed for water pressures they can burst or “blow”.

**Type B: Structurally Integral Protection**

This method of protection relies upon the structure alone (i.e. the substructure walls and slabs) for providing waterproofing protection. Leakage can occur through the structure or joints in the structure and therefore these elements must be designed to provide water-resistance. Many substructures are constructed from concrete; recently however, steel sheet piles and tubular piles have been used to form basement walls. Both concrete and steel basements can be provided structurally integral protection.

**Type C: Drained Protection**

This form of protection relies upon an internal ventilated cavity to channel water and drain it away. The substructure walls and slab may therefore allow some water ingress but it is discharged through the cavity. A cavity may be constructed in both the walls and the floor of the substructure.

**Fig. 1: Tanked Protection System of Water Proofing**

**Fig. 2: Structurally Integral Protection of Water Proofing**

**Fig. 3: Drained Protection of Water Proofing**

Drained protection can give a high level of resistance to water vapour and moisture ingress to the internal space; however, there can be cost and space implications associated with achieving this. The ventilation and drainage requirements of this form of protection should not be overlooked; as well as carrying an associated expense they require maintenance throughout the life of the structure.

**3. DEFINING THE INTERNAL ENVIRONMENT**

It is the duty of the Client in deciding what level of internal environment and hence what level of waterproofing is required. Also the same time the client has to ensure
whether these requirements are achieved or not. Requirement can be based on usage of structure, tenant requirement, space requirement, budget and investigations required.

**Identifying the Necessary**

The first step in defining the waterproofing requirements for the Client is to identify what is needed for them. The end usage for the substructure is the key factor when considering the internal environment required. It is also important to consider whether the usage may change over the building’s lifetime.

**Conveying Requirements**

The requirements can then be communicated to the Design Team. Based on this, the Design Team can then make proposals for which Grade is required and produce specifications. The Design Team should discuss all possible options and their implications with the Client.

A two-way dialogue between the Client and the Design Team about the requirements and how they are to be achieved makes sure that the Design Team produces the ‘right’ design and the Client knows what is achievable and the cost and risk implications.

4. **SPECIFYING WATER PROOFING REQUIREMENTS**

The specification is a key means of controlling the risk of leaking substructure as it sets out the design philosophy and measures for assessing whether construction has been completed correctly.

**Defining Responsibilities**

Ideally the Client should appoint a ‘single point of responsibility’ for substructure waterproofing; otherwise, there are possibilities that Client being left with a leaking substructure and no party will claim recompense for either repairs or damages. During the early stages of the project this single point of responsibility could be with the Consultant who should develop a design which meets the Client’s requirements. The Consultant may have to call upon the expertise of other members of the Design Team in order to produce a design which satisfies all architectural, engineering and construction requirements.

It is recommended that when the Main Contractor is identified they should be given the waterproofing design to review; make changes to it if necessary and then take on responsibility for waterproofing making. The Main Contractor may choose to spread risk onto Subcontractors but the Client still has one clear point of responsibility if the required internal environment is not met.

The interface between the responsibility for substructure and superstructure waterproofing design and construction should be agreed and clearly set out.

**Specification Documents**

A good specification will present a buildable design which allows waterproofing requirements to be met and sets out a suitable system for assessing whether the requirements have been met. All specifications should be produced by a competent party.

4. **MANAGING RISK**

Both the design and construction of a project may lead to substructure leakage. It is important to recognize that whilst it is possible to manage risk to an extent it is not possible to eliminate every eventuality.

**Design Issues**

Numerous case studies have been reviewed and the main issues associated with design leading to leaking substructure have been identified. These are discussed further below with recommendations on how to manage the risk of leaking substructure.

**Lack of Understanding of Ground Conditions**

The most important factors in the design of a waterproofing scheme are the ground conditions and groundwater regime at the site. To understand the ground conditions a ground investigation is crucial (Thomas Telford 1993). If an insufficient level of, or no, ground investigation is carried out the ground conditions and groundwater may not be characterized correctly. This may lead to the adoption of an unsuitable waterproofing system, either temporary or permanent.

Risk Management: An appropriate ground investigation must always be carried out early on in the project process. The investigation should aim to reduce the risk of unexpected ground conditions and allow the accurate characterization of the ground conditions and groundwater regime across the site. The Design Team should liaise with an Engineer with the Geotechnical experience required to assess the suitability of the basement form and waterproofing scheme given the ground conditions.

**Choice of an Inappropriate Scheme**

Sometimes waterproofing schemes adopted are incapable of providing the level of water-resistance required. This may result from inexperience on the part of the Designer or a lack of understanding of the capabilities of individual components of the scheme.

Risk Management: A significant way of managing the risk is to appoint a Designer who is competent and has experience relevant to the project. The early involvement of Contractors, Subcontractors and Specialist Manufacturers may allow risks to be picked up and designed out and responsibilities to be allocated prior to construction. Alternatively, construction planning expertise can be bought if required.
Poor Design at Interfaces
Areas where any form of interface occurs were often cited as problematic in design.

Risk Management: These areas should be identified early on as having the potential to leak. Responsibilities should be clearly defined for both the design and construction of these areas; particularly if it requires two parties working together.

Construction Issues
The construction of a substructure can influence whether the water-resistance is achieved or not. It is apparent that the level of workmanship and quality of construction is a large part of this; however, there are also other ways by which construction issues can cause or reduce leakage.

Workmanship
It was stated several times that ‘poor workmanship’ covers most of the causes, at construction stage, of substructure leakage. Whatever the basement construction and whatever type of waterproofing is being used the quality of construction has an influence on whether the substructure is water-resistant.

Risk Management: The first step to reducing the risk of leakage due to poor workmanship is to appoint a competent Contractor with the requisite experience of the works to be completed. This holds true whether appointing a Main Contractor to manage a Design and Build project or a Subcontractor to carry out a small package of works.

Construction Management
The management of site works can also impact on the water-resistance of substructures. A significant example of this is construction sequence and temporary works. Changes to these can have an enormous impact on the movement of retaining walls, particularly embedded retaining walls.

Risk Management: Early Contractor involvement can ensure that the construction plan does not conflict with assumptions made in the design of the substructure. Communication between the Design and Construction Teams is critical.

Remedial Works
Broadly speaking there are two forms of remedial works: those that are part of the construction process and may be allowed for from design stage and those that are required when something completely unexpected occurs.

Difficulties arise when it is not clear where the leak is coming from and as a result who is responsible. Leakage can also occur years after handover if groundwater takes a long time to recharge or groundwater levels suddenly rise.

Access to the leaking area, in order to perform the remedial works, needs to be considered. It should be considered at design stage with, for example, the Designer providing access points for grouting; it should also be considered at construction stage with the Main Contractor allowing the Subcontractor access to complete the works.

Communication
Physical interfaces can be a problem area for leakage; however, human interfaces are also vital. The successful choice, design and construction of a waterproofing system rely on communication within the Design Team, between the Design Team and Construction Team, and within the Construction Team. Information needs to be shared from the Client down through the Design and Construction Teams. As the information is shared, risks must be identified and communicated between the different parties involved in the project. The flow of information is critical from the very start of the project through to completion.

4. CONCLUSION
In construction activity the water proofing may be of small quantum of work and cost, but if it is not done properly it may lead to severe damage either physically or psychologically. This can be avoided by basic procedural work that includes investigation, requirement, design, construction and maintenance for waterproofing. Responsibilities must be allocated to the various agencies involved in the project and the same has to be performed, and monitored. This may considerably reduce the risk of leaking substructure.

REFERENCES