# Reducing the Risk of Leaking Substructure
# A Clients' Guide

September 2009

## Foreword

Early in 2008, a workshop hosted by Stent Foundations Ltd with several of the UK's leading Consulting engineering companies identified the need for high level, risk based guidance on waterproofing requirements for projects with basements. The need was clear. Project teams would benefit greatly if Clients, Insurers and others involved with construction projects in a non-technical sense could fully appreciate the nature of the risks associated with water ingress below ground whether during construction, operation or on transfer of ownership.

The members of the Institution of Civil Engineers contribute individually to the ICE’s Research and Development Enabling Fund, which forms part of a portfolio of charitable activity undertaken by the Institution. The Fund aims to promote the technical development of civil engineering and tackle problems in design or construction identified by practitioners. There was an obvious match with this project. By the summer of 2008, with commitments of financial and in kind support from its partners on the project, Arup, Buro Happold, Mott Macdonald, Ramboll and Tony Gee and Partners, Stent had secured the approval of the R&D Fund Trustees and the project was launched.

This project has been an exemplar of the use of the ICE’s R&D Fund to enable new work to be carried out that would not otherwise have been achieved, in a spirit of cooperation and for the wider benefit of the industry and its clients. The result is a testament to the talent and commitment of our profession. I am delighted to have the opportunity to introduce this important report and commend it to you.

**Dr Scott Steedman FREng FICE CEng**
**Chairman, ICE R&D Fund**

## Acknowledgements

### Research Contractor

This Guide was produced through the ICE Research and Development Enabling Fund with Ramboll UK as the Research Contractor.

| | | |
|---|---|---|
| **Authors** | **Michelle Maloney** MEng ACGI | Ramboll UK |
| | **Hilary Skinner** MA (Cantab) | Ramboll UK |
| | **Mohsen Vaziri** BSc MSc PhD CEng MICE | Ramboll UK |
| | **Jan Windle** BEng MSc DIC CEng MICE | Ramboll UK |

### Steering Group

The production of this document was guided by a steering group of professionals from across the construction industry. The authors would like to offer their thanks to the steering group for all of their help throughout the project.

| | | |
|---|---|---|
| **Project Leader** | Viv Troughton | Stent Foundations Ltd |
| **Members** | Jim Cook | Buro Happold Ltd |
| | John Crack | Canary Wharf Contractors Ltd |
| | Russell Doughty | Buro Four Project Services Ltd |
| | Rab Fernie | Cementation Skanska Ltd |
| | Kelvin Higgins | Geotechnical Consulting Group Ltd |
| | John Huddart | Bovis Lend Lease |
| | Deborah Lazarus | Ove Arup & Partners Ltd |
| | Rachel Monteith | Sir Robert McAlpine |
| | Richard Newman | Tony Gee & Partners LLP |
| | Duncan Nicholson | Ove Arup & Partners Ltd |
| | David Puller | Bachy Soletanche Limited |
| | Matthew Sharratt | WSP Group plc |
| | Hugh St John | Geotechnical Consulting Group Ltd |
| | Tony Suckling | Ove Arup & Partners Ltd |
| | Brett Wharton | Stanhope plc |
| | Derek Winsor | Mott MacDonald Group Limited |

### Other Contributors

The authors are also very grateful to the following individuals who contributed to the production of this Guide by agreeing to be interviewed and supplying interesting Case Studies.

| | |
|---|---|
| David Ball | The Concrete Society |
| Brendan Brophy | Atkins |
| Barry Dobbins | Waterman Group plc |
| Helen Logan | Allies and Morrison |

Illustrations by Paul Weston Associates.

## Executive Summary

### *Purpose of this Guide*

This Guide has been produced for Clients; however, it is hoped that it may also help architects and engineers' understanding of substructure waterproofing issues. It explains the risks associated with waterproofing by providing information about the methods and processes involved; it also gives information on how to manage the risks.

### *Why This Guide is Necessary*

It is well documented that basements and other substructures can leak both during and after construction. Once construction is below the water table groundwater will try and seep through cracks and joints into open spaces. Potential consequences of leaking substructure are numerous but generally result in costs associated with remedial works and delays to programme in construction and expenditure and disruption to the building operation after construction.

### *Defining Waterproofing Requirements*

Although the 'waterproofing' of substructure is often discussed, this is slightly misleading as it implies the substructure will be completely impervious to groundwater. Defining the level of substructure water-resistance goes beyond whether the structure is dry or damp.

The Client should ideally have a clear idea of what the substructure is to be used for and what internal environment is acceptable as early as possible on a project. It is also important to consider whether the substructure usage may change over its lifetime. The cost implications of achieving the internal environment should be considered. A two-way dialogue between the Client and the Design Team about the requirements and how they are to be achieved enables the Design Team to produce the 'right' design and explain what is achievable to the Client.

### *Specifying Waterproofing Requirements*

It is often acknowledged that the various members of the Project Team are reluctant to take on responsibility for waterproofing. Ideally the Client should appoint a single point of responsibility for substructure waterproofing. Early on in the project this may be the Lead Consultant. The Lead Consultant may have to call upon the expertise of other members of the Design Team. Construction planning expertise can be bought in if required.

Once the Main Contractor is identified they should be given the waterproofing design to review, and depending on the form of contract, make changes to it if necessary and then take on responsibility for substructure waterproofing making allowance for risk in their contract sum if necessary. If there is a series of packages of work, one Contractor should be made responsible. The contractual issues and allocation of responsibility should be considered at the start of the project.

Depending upon the level of complexity of a waterproofing scheme several documents may be required to specify various components. In order to make sure that all of these documents are consistent with one another there is often the need for an overall Waterproofing Philosophy document.

### *What Can Go Wrong and How to Manage Risk*

Numerous case studies have been reviewed and the main issues associated with design and construction that can lead to leaking substructure have been identified and are discussed in the Guide. Recommendations for managing the risks are given.

An allowance should be made in both the programme and budget for remedial works associated with waterproofing.

The successful choice, design and construction of a waterproofing scheme rely on communication throughout the Project Team with information being shared from the Client down.

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# 1 Purpose of this Guide

## 1.1 Introduction

This Guide has been produced for Clients; however, it is hoped that it may also help architects' and engineers' understanding of substructure waterproofing issues. It will explain the risks associated with waterproofing by providing information about the methods and processes involved. In turn it is hoped that a greater understanding of the risks involved will allow earlier identification, leading to risk reduction. The Guide also gives information on how to manage the risks.

Whilst providing Clients with information about the risks involved it is hoped that the Guide will also help Clients to understand what is practicably achievable in terms of waterproofing.

This Guide is not intended to be a technical document nor offer technical guidance. Where technical issues have been discussed it is with the aim of giving greater general clarity to the subject. Discussions of technical issues are intended for those who will evaluate the significance and limitations of such discussions and take responsibility for their use and application.

Throughout the Guide, Case Studies have been used to illustrate certain points. The Case Studies are based on the experience of industry professionals; all references to name and location have been removed to maintain anonymity.

## 1.2 Production of the Guide

This Guide has been written by a Project Team guided by a Steering Group. To gather information for this guide, a series of interviews were carried out with professionals from across the construction industry. The interviews gathered the experiences and opinions of people involved with the various different aspects of a construction project. Table 1 summarises the parties interviewed.

**Table 1: Interviews completed during production of the Guide**

| | Clients[1] | Consultants[2] | Contractors[3] |
|---|---|---|---|
| **Interviews Completed** | 4 | 10 | 6 |

1. Where 'Clients' are Clients and Project Managers;
2. Where 'Consultants' are Structural Engineers, Geotechnical Engineers and Architects;
3. Where 'Contractors' are Main Contractors and Subcontractors.

The results of the interviews are summarised in Sections 3 to 6, which form the bulk of this guide, with key points summarised at the end of each chapter.

## 1.3 Constraints and Limitations

Although this guidance has been produced based on UK experience, it is not intended to be limited to use in the UK. The guidance is intended to provide accurate information in regard to the subject matter covered at the time of publication. It is distributed with the understanding that the authors are not engaged in rendering a specific legal or any other professional service. While every effort has been made to ensure, to the best of the authors' knowledge, the accuracy and completeness of the guidance at the time of publication, no warranty or fitness is provided or implied, and the authors shall have no liability (including that for negligence) nor responsibility to any person or entity with respect to any loss or damage arising from or related to its use or reliance upon it.

## 2 Why This Guide is Necessary

### 2.1 Why Waterproofing is Necessary

Water can seep through cracks and joints and most materials including concrete, stone and brick. It is well documented that basements and other substructures can leak. Anecdotal evidence collected during the production of this guide suggests that half of all basements leak at some point during their construction and that a lesser, but still significant, proportion leak post-construction. These are not meant to be shocking statistics, rather serve to highlight that leakage is a common problem and waterproofing should not be overlooked.

But why is substructure leakage so common? The simple answer is that if the construction is below the water table, the groundwater is under pressure and will flow through the path of least resistance e.g. cracks in the substructure and ultimately into the basement itself. A further complication is that substructure cannot be constructed in one piece and therefore contain construction joints which can act as water paths.

Figure 1 presents a schematic of the ways in which water can flow through an embedded retaining wall; similar water paths would be expected for a concrete box type basement (excluding number 4). Water may flow as either a liquid or as water vapour.

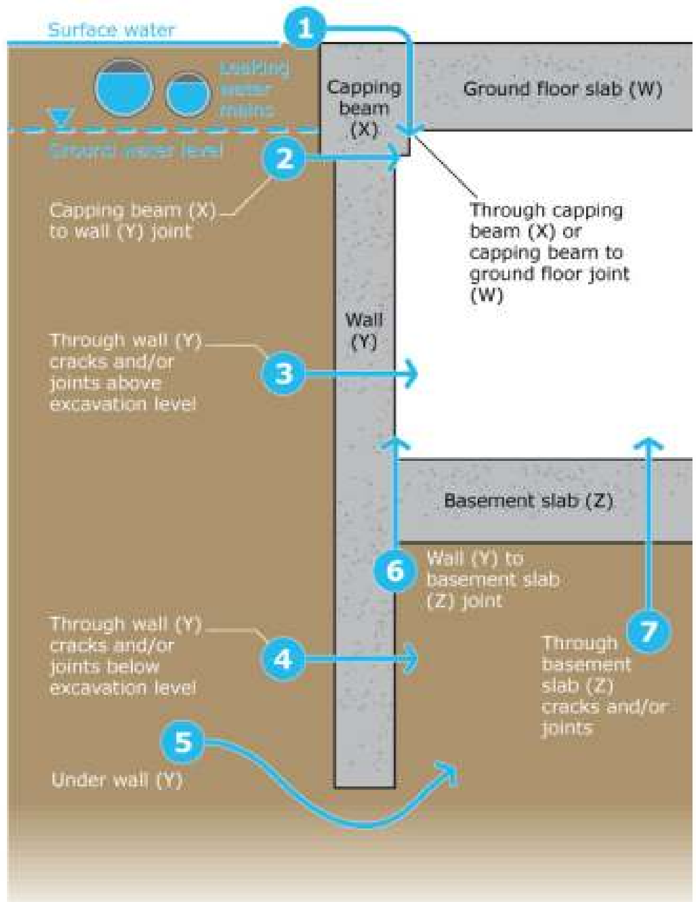


**Figure 1: Some potential water sources and paths through an Embedded Retaining Wall**

### 2.2 Consequences of leaking substructure

It is important to understand the risks of substructure leaking due to the serious consequences that may arise as a result. Equally important is the understanding that leaks may occur either during or after construction. The following is a summary of potential consequences of leaking substructure.

*During Construction:*

- Costs associated with remedial works and programme delay;
- Costs associated with repair of equipment and finishes already installed;
- Disruption to construction and delays to subcontractor mobilisation whilst remedial works are carried out or the flow of water is stemmed;
- Liability due to damage of private or public property;
- Costs associated with disputes.

*Post-Construction:*

- Costs associated with remedial works;
- Costs associated with disruption to building operations including:
    - Loss of rent;
    - Reduction in value of the property;
    - Damage to reputation of landlord/developer;
    - Consequences of facility being unavailable (e.g. business disruption).
- Prevention of access to basement areas;
- Damage to archived documents, stored goods or plant;
- Endangerment of building operatives or the general public through damage to electrical plant.
- Liability due to damage of private or public property;
- Costs associated with disputes.

**Case Study 1**
A small commercial development had its existing basement extended and deepened. An external tanking system was used to provide water-resistance to the reinforced concrete basement structure. Following completion of the concrete structure, the pumps used to control groundwater during excavation were switched off and the basement leaked. Follow on trades, such as plasterers and electricians were unable to start on site until it was dry; however, they were due to start on other jobs before the remedial works could be completed. New Subcontractors had to be found with costs for delay and disruption being incurred.

**Case Study 2**
As part of a commercial development a basement was constructed for car parking and retail storage. Following heavy rainfall, leakage in the basement was such that large quantities of stock were damaged. A significant package of remedial works was required and the building's tenants were unable to use the basement for storage or car parking. The tenants refused to pay rent and the building owner lost revenue.

### 2.3 Importance of choosing the right waterproofing scheme

Apart from managing the risks, it is important to understand the waterproofing options available; each method will have cost and space implications for the basement scheme. Section 3 discusses various waterproofing methods.

### 2.4 Why Clients need to understand the risk

A Client makes decisions which will, directly or indirectly, influence the risk of substructure leaking. An understanding of the risk enables informed decisions to be made and therefore better management of the risks. It will allow a Client to make decisions on waterproofing requirements and the management of the Design and Construction teams. It will also help the Client to understand the advice given by these professionals.

# 3 Methods of Substructure Waterproofing

## 3.1 Introduction

As a Client it may not be necessary to consider the technical ins and outs of the various methods of waterproofing; however, it can be useful to understand the jargon that is used in the discussion of waterproofing methods. This chapter aims to explain firstly what is meant by 'waterproof' and then how 'waterproof' is achieved.

## 3.2 What is waterproof?

Although the 'waterproofing' of substructure is often discussed, this is slightly misleading, as it implies the structure will be made completely impervious to water. CIRIA Report 139, on Water-Resisting Basement Construction (CIRIA, 1995), gives a thorough set of definitions for terms such as 'waterproof' and 'water-resistance'. The definitions as given in CIRIA have been adopted for use within this report and are included within the Glossary.

On a sliding scale of water-resistance, vapour-proof would be at one extreme end (see Figure 2). Vapour-proof implies the complete absence of water in either liquid or gaseous form. Waterproof would be some way along the scale towards vapour-proof. It is important to consider that not all structures will be able to reach 'waterproof' on the scale.

## 3.3 Defining levels of water-resistance

Defining the level of water-resistance goes beyond whether the substructure is dry or damp. Again, the idea of dampness could be seen as being on a sliding scale with 'dry' being at one extreme end as shown on Figure 2.

The level of water-resistance a basement needs is generally defined for design using the grading system within BS8102 (BSI, 1990). This British Standard gives four 'Grades' of internal environment, which are based on basement usage. Associated with each Grade is a Performance Level to which the waterproofing system must comply in order to achieve the Grade. BS8102 is being updated and it is possible that changes will be made to the grading system. All descriptions within this Guide relate to the 1990 edition of BS8102.

Figure 2 shows how the Grades fit in with the idea of a sliding-scale of water-resistance. The Figure is indicative only and serves to aid understanding rather than provide a definition of the Grades.

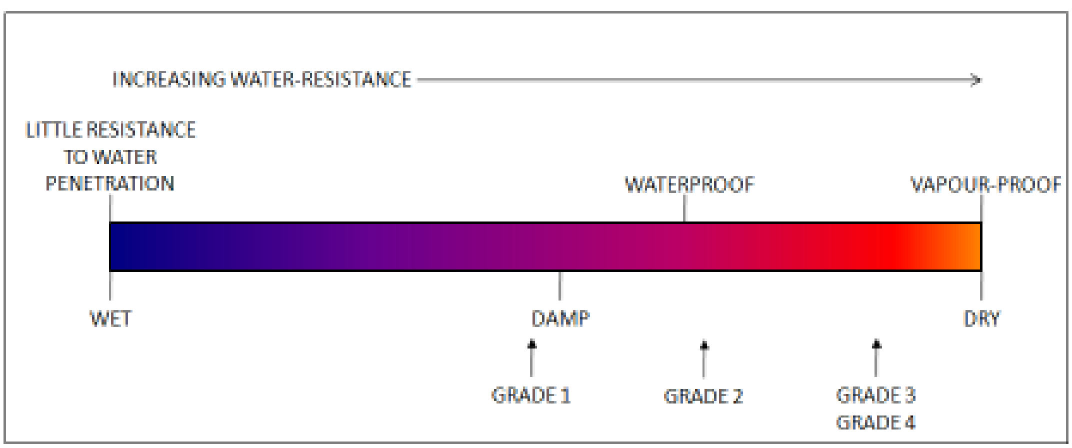


**Figure 2: Schematic showing substructure conditions and Grades of internal environment on a sliding scale of water-resistance**

CIRIA Report 139 gives additional description and commentary on the BS8102 (1990) grading system (CIRIA, 1995); this is presented within Table 2. CIRIA also gives guidance on temperature ranges and Relative Humidity acceptable for each Grade.

The BS8102 Grades work well as a means of defining water-resistance; however, care should be taken to avoid ambiguity in their interpretation. Some of the current descriptions are subjective and it is therefore recommended that a dialogue is had between the Client and the Design Team to make certain that the Grade chosen meets the Client's requirements. Defining waterproofing requirements is discussed further within Section 4.

The following sections give additional description of the Grades.

**Table 2: Level of protection to suit basement use**

| BS8102 (1990) Grades | | | CIRIA (1995) Commentary |
|---|---|---|---|
| **Grade** | **Basement Usage** | **Performance Level** | |
| Grade 1 (basic utility) | Car parking; plant rooms (excluding electrical equipment); workshops. | Some seepage and damp patches tolerable. | Unless there is good ventilation, or local drainage, visible water may not be acceptable even for the suggested uses.<br><br>The performance level defined in BS8102 for workshops is unlikely to meet the requirement of the Building Regulations, Approved Document C, for workshops, which are more likely to require a Grade 3 (habitable) environment. |
| Grade 2 (better utility) | Workshops and plant rooms requiring drier environment; retail storage areas. | No water penetration but moisture vapour tolerable. | The performance level assumes no serious defects in workmanship, although these may be masked in dry conditions or impermeable ground. |
| Grade 3 (habitable) | Ventilated residential and working areas including offices, restaurants, leisure centres, etc. | Dry environment. | As Grade 2.<br><br>In highly permeable ground multi-element systems (possibly including active precautions) will probably be necessary. |
| Grade 4 (special) | Archives and stores requiring controlled environment. | Totally dry environment. | As Grade 3. |

### *3.3.1 Grade 1*

The key words in the British Standard description of a Grade 1 basement are 'some seepage' and 'damp patches tolerable'. There can be a certain degree of interpretation attached to both these phrases. It is recommended that a discussion is had with the Design Team over what is understood by both phrases. Grade 1 can require ventilation to prevent ponding of seepage.

The ICE's Specification for Piling and Embedded Retaining Walls (SPERW), whilst not specifically referring to Grade 1 conditions, speaks of a criterion for piled walls where there is 'no weeping of water' but 'beading of water is permitted' (ICE, 2007). The ICE's SPERW also suggests that damp patches will be permitted providing 'the total area of dampness does not exceed 10% of the visible area of the front face' and 'no individual patch of dampness has an area in excess of $4m^2$'. This gives an idea of the conditions that may be considered acceptable within a Grade 1 environment.

CIRIA Report 139 suggests that minor seepage through walls, traces of water at cracks and construction joints, and traces of water on the floor limited to a few millimetres in depth in a channel along the wall should be anticipated (CIRIA, 1995).

Figure 3 presents photographs showing typical conditions within a Grade 1 basement. The photographs in Figure 4 show an internal environment which would not comply with Grade 1.

Grade 1 internal environment. Damp patches on slab. Traces of water in channel on floor.

Grade 1 internal environment. Some seepage and beading through cracks but water not flowing.

**Figure 3: Typical internal environments within a Grade 1 basement.**

Leak through joints in concrete wall. Water is 'running' therefore exceeds 'some seepage' criterion.

Leak through joints in secant pile wall. Water is 'running' and damp patches exceed 10% of wall face.

**Figure 4: Internal environments which would not comply with Grade 1.**

### *3.3.2 Grade 2*

According to the British Standard, a Grade 2 basement does not permit water penetration but water vapour is tolerable. The 'beading' permitted for a Grade 1 basement is therefore no longer allowed. 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. Again, these conditions should be discussed and agreed with the Design Team to avoid misunderstanding.

Figure 5 presents photographs showing typical conditions within a Grade 2 basement.

No damp patches but discolouration to concrete on underside of slab due to evaporation of moisture.

No damp patches but discolouration to slab due to evaporation of moisture.

**Figure 5: Typical conditions within a Grade 2 Basement.**

### *3.3.3 Grade 3*

A Grade 3 basement requires a 'dry' environment. The step up from a Grade 2 to a Grade 3 basement implies that moisture vapour is controlled. 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. The key word in the British Standard description of basement usage for a Grade 3 environment is 'ventilated'. Therefore, some Mechanical and Electrical plant (i.e. an active precaution) is likely to be needed.

A Grade 3 internal environment is required if the basement is to be habitable.

Figure 6 presents a sketch showing typical conditions within a Grade 3/4 basement and typical substructure and plant requirements to achieve these internal environments.

### *3.3.4 Grade 4*

There is often confusion between the requirements for a Grade 3 and a Grade 4 basement. 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. The need for Mechanical and Electrical systems to regulate the environment should be assumed for Grade 4 basements.

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. A 'dry' basement will also be achieved by a Grade 3 environment. The same basic building fabric may be used for both Grades 3 and 4 with the difference coming from the plant requirements.

Figure 6 presents a sketch showing typical conditions within a Grade 3/4 basement and typical substructure and plant requirements to achieve these internal environments.

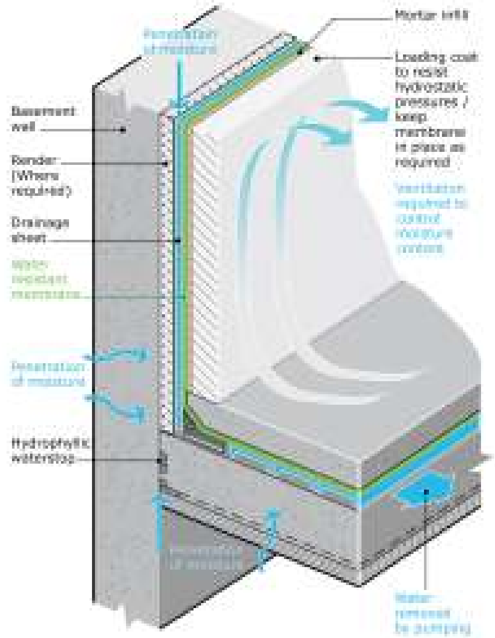


**Figure 6: Typical waterproofing requirements for a Grade 3/4 basement**

## 3.4 Methods of achieving water-resistance

For ease of classification BS8102 (1990) splits waterproofing methods into three different “types”: Type A, Type B and Type C. The following sections provide a description and some information on each of the methods. In certain circumstances it may be necessary to employ a combination of these methods in order to achieve the required internal environment. Although a Client could expect their designer to make a firm recommendation on the type of waterproofing adopted, it can be useful to understand the language which is used to discuss waterproofing to ensure that requirements have been communicated correctly.

For all of these methods, it is important to recognise that their appropriate implementation is driven by several key factors:

- Internal environment to be achieved;
- Ground conditions: highly permeable ground, variable ground or ground containing boulders can all be problematic for waterproofing;
- Groundwater conditions including water pressure and chemical content: high groundwater pressure will require a more robust waterproofing scheme and aggressive ground may affect the suitability of waterproofing methods;
- Depth and method of construction of basement;
- Whether the substructure is to be constructed adjacent to or within an existing building;
- Architectural finish required, some methods of waterproofing affect ability to fix to the internal face of the wall;
- Imperfections associated with the waterproofing method.

Any one of these factors could render a waterproofing method inappropriate for use on a project. It should not be assumed that because a method has worked in one situation it can automatically be applied to another.

### 3.4.1 *Type A: Tanked Protection*

Tanked protection involves the application of an internal and/or external barrier system to obstruct water flow paths (see Figure 1). 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” when pressure builds up behind them unless a sufficient loading coat is placed.

Figure 7 shows a sketch of a typical tanking detail and a photograph showing an example of tanked protection.

Membrane being applied to substructure walls and beneath slab. It will bond to the concrete cast against it.

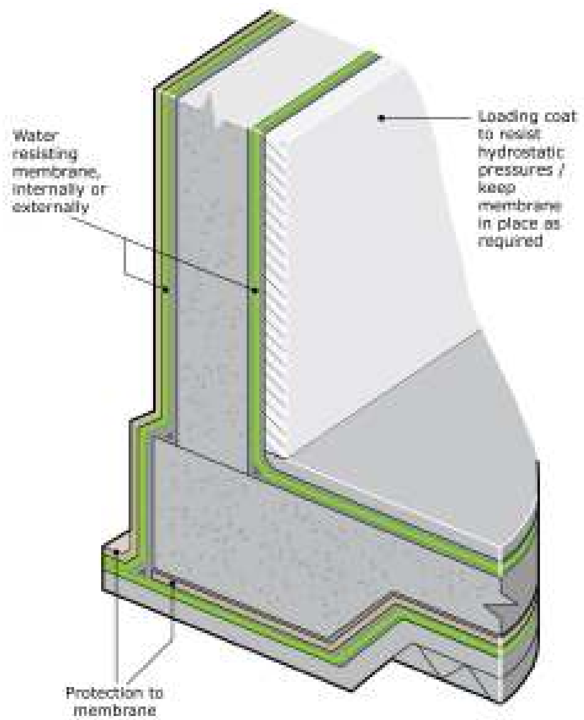


**Figure 7: Example of tanked protection (Type A) and sketch showing typical detail.**

### 3.4.2 *Type B: Structurally Integral Protection*

This method of protection relies upon the structure alone (i.e. the substructure walls and slabs) providing waterproofing protection. Leakage can occur through the structure or joints in the structure (see Figure 1) 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. The following paragraphs discuss how both concrete and steel basements can provide structurally integral protection.

***Concrete Substructure***

When talking about concrete substructure providing protection against leakage, it is important to recognise that concrete can crack. However, there are various ways of either preventing or controlling concrete cracking including:

- Controlling the environment in which concrete gains its strength and hardens (i.e. the curing process);
- Reducing the permeability of the concrete by either controlling the water/cement ratio; replacing the cement within the concrete with substances such as Pulverised Fuel Ash (PFA) or Ground Granulated Blastfurnance Slag (GGBS) or by using a water-resistant concrete mix;
- Inclusion of additional reinforcement.

Concrete to concrete joints can be vulnerable to leakage and therefore to achieve structurally integral protection, joints need to be sealed. The use of ‘hydrophilic strips’ which swell upon contact with water can be used to seal joints if practicable to install.

***Steel Substructure***

The joints between steel sheet piles and tubular piles need to be considered for structurally integral protection to be provided. Joints may be sealed through the use of:

- Welding seams (where accessible i.e. above excavation level);
- Non-swelling sealants;
- Hydrophilic sealants.

Figure 8 presents a sketch showing a typical detail for structurally integral protection and a photograph showing an example of structurally integral protection.

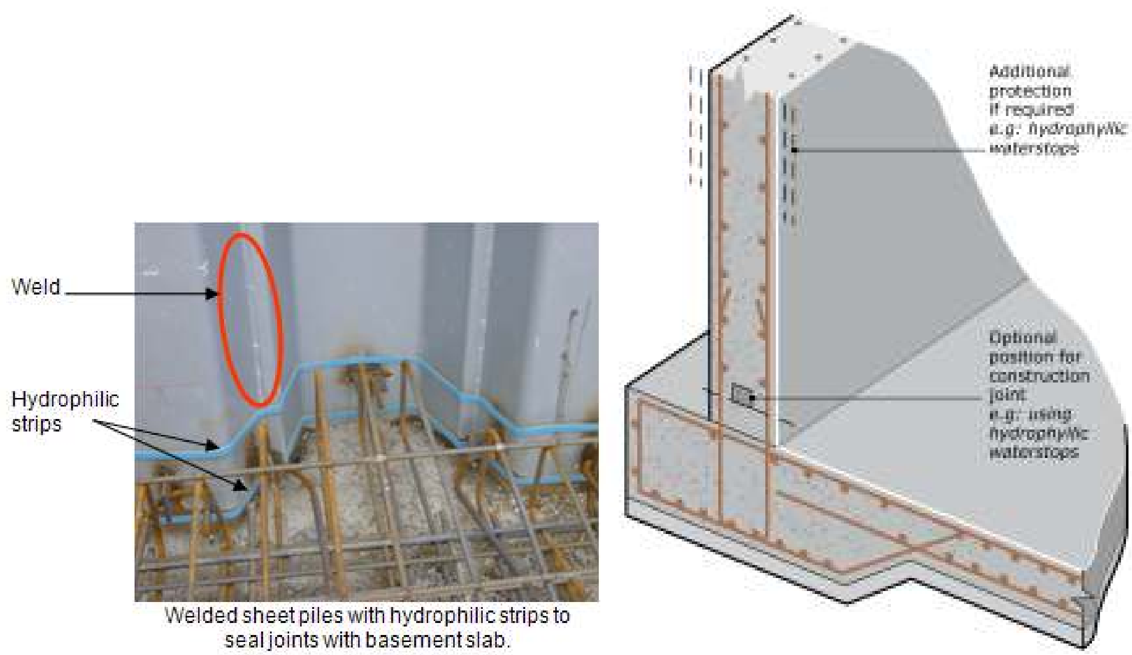


**Figure 8: Example of structurally integral protection (Type B) and sketch showing typical detail**

An advantage of structurally integral protection is that the basement structure can be made to give a certain level of protection without additional means.

A disadvantage of this form of protection is that the resistance to vapour is likely to be less than for tanked or drained protection. The use of additional reinforcement, admixtures or cement replacement substances may increase the cost of the concrete.

### *3.4.3 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 (see Figure 1) but it is discharged through the cavity. A cavity may be constructed in both the walls and the floor of the substructure.

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.

Figure 9 presents a sketch showing typical details for drained protection.

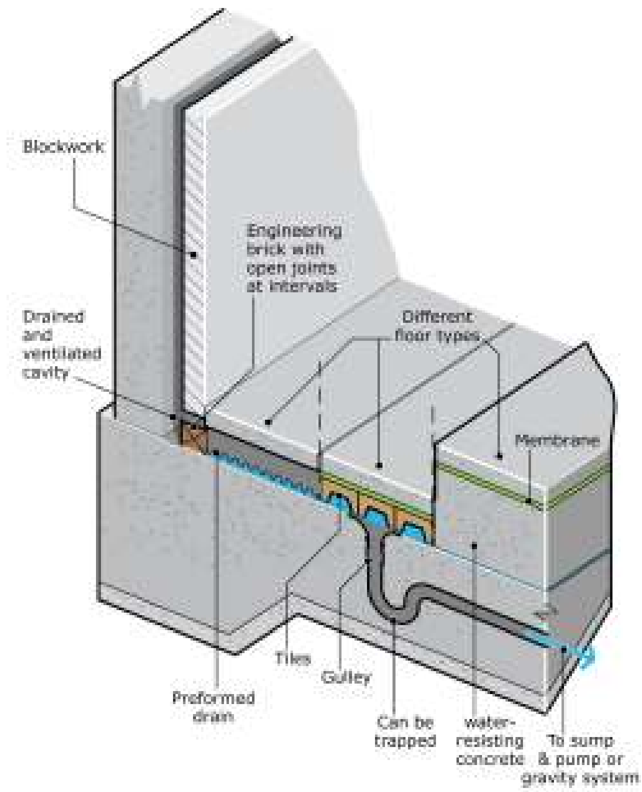


**Figure 9: Sketch showing typical detail for drained protection (Type C)**

## 3.5 Implications of achieving waterproofing Grades

Having discussed the requirements of the British Standard Grades and the pros and cons of various waterproofing methods, it becomes apparent that there can be significant cost implications associated with achieving a water-resistant basement; particularly for the higher Grades. As you move up through Grade 1 to Grade 4 there is typically an increasing cost. A higher Grade basement may also take longer to construct if it involves several methods of waterproofing.

Beyond the cost implications associated with achieving various Grades there can also be implications for the available substructure space. If a Type C system is required to achieve a required internal environment, the space required for the cavity and the interior wall needs to be taken into account early on in the scheme design. If mechanical and electrical plant is required this also needs to be taken into account and discussed with the Services Engineer at an early stage.

The need for a 'dry' basement should be considered very carefully given the structural, mechanical and electrical systems required to achieve this. It may be that only certain areas of a basement, for example those containing electrical plant, need to be of a high Grade whilst the rest of the basement could be a lower Grade. Higher Grades might have lifelong maintenance requirements, for example: maintenance of the ventilation and heating systems and keeping drainage channels clear.

Defining water-resistance requirements is discussed more in Section 4.

### 3.6 Key points for Clients

- On a sliding scale of water-resistance, 'vapour-proof' would be at one extreme end. Some structures may not be able to achieve 'waterproof' conditions.
- Care should be taken to avoid ambiguity in the interpretation of BS8102's grading system. A dialogue should take place between the Client and the Design Team to make certain that the Grade chosen meets the Client's requirements.
- Any number of factors could render a waterproofing method inappropriate for use on a project. It should not be assumed that because a method has worked in one situation it can automatically be applied to another.
- There can be serious cost, space and time implications associated with achieving a water-resistant basement; particularly for the higher Grades.
- Higher Grade basements might have lifelong maintenance requirements.

# 4 Defining Internal Environment

## 4.1 Introduction

The purpose of this Section is to aid Clients in the definition of their required internal environment for substructure. A clear definition of requirements doesn't so much reduce the risk of leakage as to help the Client to obtain the internal environment they need and want. It also prevents the Client having expectations which cannot be met by the chosen scheme.

The first part of this section aims to guide the Client in deciding what level of internal environment and hence what level of waterproofing is required. The second part discusses how the Client can ensure these requirements are achieved.

## 4.2 Identifying what is necessary

The first step in defining the waterproofing requirements for a scheme is for the Client to identify what is needed from them. This is not a simple case of stating the need for a 'dry' basement; as discussed previously 'dry' conditions would be at the extreme end of a scale of dampness. A decision needs to be taken on how far along that scale it is necessary to be.

The end usage for the substructure is the key factor when considering the internal environment required. A basement to be used for retail storage could perhaps be further away from 'dry' on the scale than a basement to be used for archiving. It is also important to consider whether the basement usage may change over the building's lifetime. The basement structure can be constructed so as to allow future flexibility in usage; for example by installing sump drainage to a Grade 1 basement to allow for future upgrade to office space.

**Case Study**

A new development is to have a single-storey basement that is to be used for car parking. A reinforced concrete (not water-resistant) structure is under construction. During construction the Client decides he wants to move his archiving space from an external location to within the basement of the new building. The current form of construction does not allow the internal environment required for archiving to be achieved. A drained cavity wall and additional drainage has to be incorporated into the scheme, further reducing the net floor area of the basement and the remaining space available for car parking spaces. Some other building facilities have to be moved above ground to compensate, losing space above ground. Plant for ventilation and temperature control is required.

Whilst in some instances the internal environment required will be non-negotiable (e.g. for archiving), in other cases it may be down to a Client's preferences. In this case serious consideration should be given to whether, for example, water vapour is tolerable. If it were decided that some moisture in the air was acceptable it could push a basement down from Grade 3 to Grade 2. This would be significant in terms of reducing the Mechanical and Electrical requirements and associated maintenance. Conversely, the internal environment given by a Grade may not always be suitable for the suggested use; for example, Grade 1 may not always be suitable for car parking in a high specification development.

## 4.3 Conveying requirements

The Client should have a clear idea of what the basement is to be used for and what internal environment is acceptable. These requirements can then be communicated to the Design Team either through the Client's Brief or Employer's Requirements documents or face-to-face via meetings. It may well be that the Design Team have to help the Client fully develop the brief before this if possible. Based on this, the Design Team can then make proposals for which Grade is required and produce specifications (discussed further within Chapter 5). 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.

The earlier in the project that the waterproofing requirements are defined and discussed, the easier it is to account for them in the scheme and the more likely it is that cost savings can be achieved through value engineering. The later that the consideration of waterproofing requirements is left, the more expensive it can be to incorporate them into a scheme.

The following are questions that can be used to start the discussion between Client and Designer:

- What will the basement be used for?
- Will the building be sold or let in the short term/long term or will you occupy it yourself?
- What are likely future tenant requirements?
- Is there a minimum space requirement?
- What is the budget for underground construction?
- What investigations will be required?

## 4.4 Key points for Clients

- The Client should have a clear idea of what the basement is to be used for, immediately and in the future, and what internal environment is acceptable.
- A two-way dialogue between the Client and the Design Team is needed to make sure that the 'right' design is chosen and the Client's expectations can be met.
- The Design Team should discuss all possible waterproofing options and their implications with the Client.

# 5 Specifying Waterproofing Requirements

## 5.1 Introduction

This Chapter sets out how waterproofing requirements should be specified and who takes responsibility for the design and construction of a waterproofing system. 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.

## 5.2 Defining responsibilities

It is often acknowledged that the various members of the Project Team are reluctant to take on responsibility for below ground waterproofing. It is considered that this is due to the perception of the risk involved and the likelihood of claims arising. The risks associated with ground based hazards are generally difficult to quantify and it is sometimes difficult to assess how much risk is being taken on. In addition, it is rare for one party to have the complete expertise required to manage the risk as the skills of say an architect are quite different from those of a structural engineer; a geotechnical engineer or a subcontractor.

Ideally the Client should appoint a 'single point of responsibility' for substructure waterproofing; otherwise, there are countless examples of a Client being left with a leaking basement and no one party to claim recompense from for either repairs or damages. During the early stages of the project this single point of responsibility could be with the Lead Consultant who should develop a design which meets the Client's requirements as discussed in Section 4. The Lead 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. Construction planning expertise can be bought in if required.

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 (depending on the form of contract) and then take on responsibility for waterproofing making an allowance for risk in their contract sum if necessary. 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.

If there is no Main Contractor but a series of packages of work (i.e. it is a Management Contract) one Subcontractor should be chosen as the single point of responsibility. The interfaces between this Subcontractor and the other Subcontractors need to be managed carefully; work may be completed on site which affects waterproofing before the Subcontractor responsible for waterproofing comes on board. Managing the risk across this interface can be particularly challenging.

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

It is recommended that Clients look at the contractual framework for the waterproofing package at the start of a project and decide how they want to allocate responsibility and hence which procurement route is best for controlling risk. To meet the Client's needs a 'fully integrated supply chain' of expertise from across the construction industry is required.

**Case Study**

A deep basement is constructed in London. The basement leaks through cracks in the concrete walls when dewatering is switched off and the required internal environment is not achieved. The Designer claims that the concrete in the walls was sufficiently designed to control cracking and hence prevent water ingress. The Concrete Contractor claims that the walls were constructed as specified and workmanship is not to blame for the cracks. Neither party has ultimate responsibility and the dispute is not resolved. The Client has to pay for remedial works.

The same Client is working on another deep basement in London with the same Project Team. This time the Client makes the Concrete Contractor ultimately responsible for substructure waterproofing. The Concrete Contractor increases their contract sum to reflect the additional risk being taken on. The desired internal environment is achieved. The additional sum that the Client paid the Concrete Contractor is significantly less than the cost of the remedial works on the previous job.

### 5.3 Specification documents

The specification documents are an important part of controlling the risk of leaking substructure. 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. A bad specification is therefore one that either presents a design that cannot be built; or a design that will not allow the waterproofing requirements to be met; or which cannot be assessed as successful or not. All specifications should be produced by a competent party.

Performance based specifications can be used to define the end result required rather than the process of achieving the end result.

### 5.4 Waterproofing Philosophy

Depending upon the level of complexity of the scheme, several documents may be required to specify various components of the waterproofing (e.g. retaining wall; concrete liner wall; membrane etc.). In order to ensure that all of these documents are consistent with one another there is often the need for an overall Waterproofing Philosophy document. This document sits below the Employer's Requirements or Client's Brief but above specifications with the aim of linking everything together and providing a clear summary of the intentions for substructure waterproofing. The Waterproofing Philosophy could extend to the whole building; at the least it should clearly address the juncture between substructure and superstructure waterproofing.

### 5.5 Compliance with specification

Specifications often contain some form of criteria by which the water-resistance of the substructure component can be assessed. These parameters may be either quantitative or qualitative.

Opinions vary on whether a quantitative or qualitative system is better. Some feel that a quantitative system provides a more scientific form of measurement and is more valuable in the case of a dispute occurring; whilst others feel that the measurable parameters are often arbitrary and have no real meaning.

Whichever system is adopted, it should be appropriate to the Grade required and the achievable level of waterproofing. For example, a qualitative system may not be appropriate for assessing whether a Grade 3 or 4 environment has been achieved.

**Examples of Quantitative Parameters**
The ICE's SPERW document gives quantitative parameters for assessing the water-resistance of the exposed face of the embedded retaining wall between the top of the wall and formation level (ICE, 2007). For example: 'the total area of dampness does not exceed 10% of the visible area of the front face' and 'no individual patch of dampness has an area in excess of 4m$^2$'.

CIRIA Report 139 gives guidance on Relative Humidity and Temperature parameters to be used in the assessment of the internal environment achieved (CIRA, 1995). For example:
*Grade 1*
Relative Humility: >65% normal UK external range
Temperature: Car parks: atmospheric
Workshops: 15~29°C
Mechanics plantrooms: 32°C max at ceiling level

**Example of Qualitative Parameters**
Some companies use terms such as 'glistening' or 'beading of water' to assess the water-resistance of a structure.

## 5.6 Key points for Clients

- Ideally the Client should appoint a 'single point of responsibility' for substructure waterproofing;
- Early on in the project the Lead Consultant could be the single point of responsibility. When a Main Contractor is appointed they should be given ultimate responsibility for the substructure waterproofing. If a Management Contract is to be used one of the Subcontractors should be given ultimate responsibility;
- Contractual issues should be considered at the start of a project and a decision made on how responsibility is to be allocated and hence which procurement route is best for controlling risk. The contractual framework for both consultants and contractors needs to reflect this;
- Several specifications may need to work together to cover the design of the waterproofing system. An overarching Waterproofing Philosophy document is useful for the coordination of the design and specification.
- 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;
- Whether a quantitative or qualitative system for the assessment of waterproofing is adopted, it should be appropriate to the Grade required and the level of waterproofing achievable, and be stated in the contract documentation.

# 6 What Can Go Wrong and How to Manage Risk

## 6.1 Introduction

This Chapter considers how both the design and construction of a project may lead to substructure leakage; examples are given for both. It is important to recognise that whilst it is possible to manage risk to an extent it is not possible to eliminate every eventuality. On the other hand, nothing would ever get built if one were too risk averse.

Following the discussion of design and construction issues, this Chapter goes on to discuss other means of managing risk in terms of remedial works and the importance of communication. The case studies within this Chapter are based on the interviews carried out in the production of the Guide.

## 6.2 Design issues

### *6.2.1 Introduction*

The design adopted for a waterproofing system is obviously critical in achieving the level of water-resistance required. 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.

### *6.2.2 Lack of understanding of ground conditions*

Possibly the most important factors in the design of a waterproofing scheme are the ground conditions and groundwater regime at the site. Only when these are properly understood can a suitable and efficient waterproofing solution be chosen.

In order to understand the ground conditions a ground investigation is crucial. If an insufficient level of, or no, ground investigation is carried out the ground conditions and groundwater may not be characterised correctly. This may lead to the adoption of an unsuitable waterproofing system, either temporary or permanent.

> **Case Study**
> A secant pile retaining wall was constructed to form a new basement. The ground investigation had identified the ground conditions as impermeable clay with silt bands; however it was not picked up that the silt was significantly more permeable than the clay or that there were boulders within the clay. It was intended that the retaining wall would provide sufficient temporary waterproofing during excavation. However, the boulders knocked the piles off tolerance during their excavation and water was able to flow through the silt lenses through gaps in the wall into the excavation. Additionally silt was washed into the basement causing the potential for subsidence behind the retaining wall. Significant work was needed to remedy the problems.

The Client should ensure that the Designer carries out a hydrology study to assess the impact of the new basement on the groundwater regime. Constructing new substructure can alter water flow in the ground and cause groundwater levels to rise locally.

The waterproofing system adopted is strongly influenced by the form of basement construction (i.e. a continuous concrete box; secant pile wall etc.). In turn, the form of construction is very much determined by the ground conditions; therefore, if the wrong form of construction is chosen for the ground conditions, the waterproofing system may also be inappropriate.

An understanding of the ground conditions is required to predict the movement of the structure as a whole after installation of the waterproofing.

It is also crucial to understand the water pressures acting on substructure walls and slabs and therefore potential water paths either through joints in the wall, joints in the slab or joints between the slab and the wall (see Figure 1 in Section 2.1).

*Managing the Risk*

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 characterisation of the ground conditions and groundwater regime across the site. The ICE publication “Without site investigation ground is a hazard” highlights the consequences of inadequate ground investigation in terms of escalating costs and late completions (SISG, 1993).

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.

### 6.2.3 Choice of an inappropriate scheme

The interview process revealed that sometimes waterproofing schemes had been adopted which were 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.

Conversely, examples were also given of the use of excessive waterproofing schemes, where in an attempt to avoid leakage the Designer has adopted a scheme that gives an unnecessary level of protection. This has undesirable cost implications for the Client.

*Managing the Risk*

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.

The Designer should evaluate all possible options and systems relevant to the project.

### 6.2.4 Poor design at interfaces

Areas where any form of interface occurs were often cited as problematic in design. Examples that were given of difficult interfaces are:

- Substructure to superstructure interface where the waterproofing details may not meet or may be incompatible.
- When old and new basements meet; for example, when a new basement is constructed in the footprint of an old basement.
- Connection between slabs and walls.
- Penetrations through substructure e.g. for pipe work.

These design details can cause problems because often the best solution for one component does not work for the other and it can be challenging to find a solution that works for both.

*Managing Risk*

These areas should be identified early on as having the potential to leak. Time and money should be set aside for remedial works. Responsibilities should be clearly defined for both the design and construction of these areas; particularly if it requires two parties working together. Proper attention should be given to achieving a design solution that is appropriate for the interface a whole.

The ICE's SPERW document (ICE, 2007) specifies that the Contractor provides a Wall Manual with the tender; it is stated that as a minimum the wall manual shall comprise a design summary and a construction sequence drawing. The intention of this is to improve clarity, particularly at the interfaces between the various parties involved.

#### 6.2.5 Buildability and other influences from construction

Several examples were given of a design being specified which was not possible to build as specified therefore leading to leakage. This is generally where the Designer does not understand the practicalities either of the construction site or the installation of the particular waterproofing detail. Two general examples given were incompatible arrangements of waterproofing details and the design of systems intolerant of poor workmanship.

**Case Study**
A Designer specified the use of a rubber membrane over a secant piled retaining wall to provide tanked protection. The geometry of the basement required several complicated details involving overlapping of the membrane. Weather conditions on site made handling of the membrane difficult and several of the details were not completed as specified. Once the dewatering system was switched off leakage started.

The temporary works stages and therefore the construction sequence have an influence on wall movement and consequently are important when considering waterproofing for an embedded retaining wall. If the construction stages are not considered in retaining wall design the wall may move more than anticipated and crack thereby creating water paths into the basement.

*Managing the Risk*

The early involvement of Contractors or a Specialist Manufacturer can go a long way to reducing buildability problems. When a Contractor is brought onto a project at a late stage the design scheme has often progressed to point where they can have no meaningful input. Having a Contractor involved at an early stage enables the construction phases of the substructure to be considered in its design.

### 6.3 Construction issues

#### 6.3.1 Introduction

The construction of a substructure can influence whether the water-resistance is achieved. It is apparent that the level of workmanship and therefore the quality of construction is a large part of this; however, there are also other ways by which construction issues can cause or reduce leakage. This is discussed further in the following sections with recommendations for how to manage the risk of leaking substructure.

#### 6.3.2 Workmanship

During the interview process, numerous instances of poor workmanship leading to leakage were given. 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.

**Case Study**
The five most cited instances of poor workmanship leading to leakage are given below:

1. Incorrect placing of hydrophilic strips or water bars;
2. Membranes not overlapped properly or damaged prior to installation;
3. Poor quality placing of concrete;
4. Drains installed incorrectly or in the wrong place;
5. Not dewatering to specified level.

*Managing the Risk*

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.

A further significant means of limiting poor workmanship is to give the Main Contractor, the Specialist Subcontractors (if relevant) and the Designer supervisory roles. Full-time roles may provide the best results but have cost implications. A Client should weigh up the cost of supervision against the cost of remedial works required to repair leaking substructure. The party in the supervisory role should be competent with the relevant experience.

### *6.3.3 Poor construction at interfaces*

As discussed within Section 6.2.4, areas where any form of interface occurs were often cited as problematic with the same examples given for construction as for design.

**Case Study**
A deep basement was constructed using piled retaining walls. A capping beam running around the perimeter of the basement was constructed to tie the piles together and spread load onto the piles. Groundwater was higher than the base of the capping beam. The substructure work went to site whilst the rest of the scheme was still at design stage; the layout of services had not been decided on and therefore voids for the services had not been left in the capping beam when the concrete was poured. Holes had to be drilled into the beam causing the concrete to crack and water to leak into the basement.

*Managing Risk*

These areas should be identified early on as having the potential to leak. Responsibilities should be clearly defined for the construction of these areas; particularly if it requires two parties working together. Time and money should be allowed for in the construction programme for the repair of leaks, if they should occur.

### *6.3.4 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.

**Case Study**
A piled retaining wall was constructed to support the sides of a motorway underpass. In the temporary case the wall was unsupported and slowly deflecting thereby causing leaks. The Main Contractor insisted that the Piling Contractor stopped all leaks before the wall was signed off and the road constructed. However, as soon as soon as the road was constructed the wall would have been propped and movement would have stopped making leaks easier to fix. A lot of time was spent remedying the leaks before the road was constructed whereas a different construction sequence would have allowed leaks to be fixed and the project to be completed earlier.

*Managing Risk*

As discussed within the Design Issues section, 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.

## 6.4 Remedial works

Remedial works are an important consideration when discussing leaking substructure. 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.

An experienced Contractor will allow for routine remedial works in his tender if he identifies difficult ground conditions or a complex build. In the case of embedded retaining walls, the ICE's SPERW document recommends that where leaks occur 'between the top of the wall and formation level' it is the Piling Contractor's responsibility to repair the wall; where leaks occur from 'water flowing over the top of the wall, through the wall beneath formation level, through the ground beneath formation level, through any joints between slabs and the wall or through any slabs' responsibility lies elsewhere and should be defined within the Project Specification (ICE, 2007).

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. This is further reason for the Client having a single point of responsibility to turn to if leakage does occur.

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.

It is recommended that Clients recognise that remedial works may be needed and ensure that the party responsible for substructure waterproofing allows for time and money to complete remedial works.

## 6.5 Communication

As discussed in Section 6.2.4, 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.

In order to allow effective communication, regular multi-disciplinary meetings should be held, with all appropriate parties in attendance. Often a project risk register is a useful tool for communication between parties. However, this may not provide sufficient information on how waterproofing risks are being managed and additional information may need to be included. The Waterproofing Philosophy Document discussed within Chapter 5 could also be a useful means of sharing information specifically relevant to waterproofing; all relevant parties should input to it and have access to it.

## 6.6 Key Points for Clients

- The early characterisation of the ground conditions and groundwater regime through investigation is recommended.
- Competent Designers and Contractors with relevant experience should be appointed.
- Involve Contractors, Subcontractors and Specialist Manufacturers in the design process to better allow risks to be identified and responsibilities to be allocated. Alternatively construction planning expertise can be bought if required. Construction expertise can also allow issues with buildability and construction phasing to be identified and resolved.

- Identify interface areas as having the potential to leak early on. Clearly define responsibility for both the design and construction of these areas, particularly if it requires collaboration between two parties. Allow budget and programme for remedial works in these areas.
- Implement a system of site supervision involving the Contractor, Specialist Subcontractor (if involved) and the Designer.
- If possible make one party responsible for all substructure construction relating to waterproofing thereby making them responsible for all remedial works.
- Recognise that remedial works may be required and ensure they are allowed for in substructure programme and budget.
- Access to the leaking area, in order to perform the remedial works, needs to be considered at both design and construction stages.
- Communication throughout the design and construction process is key.
- Hold regular multi-disciplinary meetings with all appropriate members of the Design and Construction Teams in attendance.
- Compile a sufficiently detailed project risk register at the start of the project and update with information from all appropriate members of the Design and Construction Team.
- A Waterproofing Philosophy document may allow effective sharing of information between different members of the Design and Construction Teams.

# 7 Summary

Key points have been made at the end of each Section within this Guide. The recommendations associated with these points are summarised in Table 3. Key points which were made for information have not been included.

**Table 3: Summary of Recommendations**

| Section | Key Points | Action | Responsible Parties |
|---|---|---|---|
| 3.3 | Avoid ambiguity in interpretation of waterproofing Grades. | Client and Design Team to have dialogue to make sure that the chosen Grade meets the Client's requirements. | Client<br>Design Team |
| 4.2 | The Client should have a clear idea of his waterproofing requirements. | Identify what the basement is to be used for and what internal environment is acceptable. | Client |
| 4.3 | Manage Client expectations and make certain the correct Grade is chosen. | Client and Design Team to have a two-way dialogue about the Client's requirements and how they are to be achieved. | Client<br>Design Team |
| 5.2 | A single point of responsibility should be allocated for substructure waterproofing. | Clearly define responsibility at appointment stage.<br><br>Take design responsibility. | Client<br><br>Lead Consultant<br>Main Contractor |
| 5.3<br>6.5 | An overarching Waterproofing Philosophy document is useful for the coordination of the design and specification. | Coordinate production of Waterproofing Philosophy. | Lead Consultant |
| 6.2.2 | Carry out early characterisation of ground conditions and groundwater regime. | Commission ground investigation early in project. | Client<br>Lead Consultant |
| 6.2.3<br>6.3.2 | The appointment of competent Designers and Contractors with relevant experience can prevent both the adoption of an inappropriate scheme and poor workmanship. | Appoint competent Design and Construction Teams. | Client<br>Lead Consultant<br>Main Contractor |
| 6.2.3<br>6.2.5<br>6.3.3 | Early involvement of Contractors, Subcontractors and Specialist Manufacturers allows risks to be identified, responsibilities to be allocated and issues with construction phasing and buildability to be identified and resolved. | Bring Construction Team onboard early on in project or take other specialist advice. Buy in construction planning expertise if required. | Client<br>Lead Consultant |

| Section | Key Points | Action | Responsible Parties |
|---|---|---|---|
| 6.2.4 | Interface areas have a high potential to leak. | Clearly define design and construction responsibility.<br><br>Allow programme and budget for remedial works to these areas. | Client<br>Lead Consultant<br>Main Contractor<br><br>Client<br>Main Contractor |
| 6.3.2 | Site supervision can help limit poor workmanship. | Implement a system of site supervision involving both the Designer and Contractor. | Client<br>Lead Consultant |
| 6.4 | Difficulties arise with allocating responsibility for leaks when it is not clear where the leak is coming from. | Make one party responsible for all substructure construction relating to waterproofing (also responsible for all remedial works). | Client |
| 6.4 | Access to the leaking area, to perform remedial works, should be provided. | Access for remedial works should be considered at design stage with e.g. Designer providing access points for grouting.<br><br>Access for remedial works should be considered at construction stage with e.g. Main Contractor giving access to Subcontractor. | Lead Consultant<br><br>Main Contractor |
| 6.5 | Communication throughout design and construction is key. | Regular relevant multi-disciplinary meetings.<br><br>Sufficiently detailed and updated project risk register. | Lead Consultant<br><br>Lead Consultant |

## Glossary of Terms

The definitions within this Glossary are taken from both BS8102 (BSI, 1990) and CIRIA Report 139 (CIRIA, 1995) and supplemented with additional information.

**Active Precautions** — Methods, or processes, used to control the internal environment, capable of a limited range of response to variations of external conditions. Methods include pumped drainage, heating and ventilation. They require inspection, maintenance and possible replacement during the life of the structure.

**Beading** — State in which individual droplets of water (held by surface tension effects) form on the surface of the wall and adhere to the wall. The water beads do not coalesce with each other. The beads remain stationary on the surface do not flow (ICE, 2007).

**Client** — The developer, owner, occupier or other person for whom the basement is being designed and built, improved or repaired. If the Client is not also to be the sole occupier of the basement, he will have contracts with the occupiers and should provide the Design Team with all necessary information on the intended occupancies.

**Construction Team** — The organisations employed by the Client to construct the substructure.

**Design Team** — The organisations employed by the Client to produce the design and specification of the substructure. This may include the architect; the Structural Engineer; the Services Engineer; the Main Contractor or Subcontractors.

**Designer** — A member of the Design Team.

**Damp** — The condition of a material with higher water content than the surrounding air, but not wet.

When touched, a damp patch may leave a slight film of moisture on the hand, but no droplets of water or greater degrees of wetness are left on the hand. On a concrete surface a damp patch is discernible from a darkening of the colour of the concrete (ICE, 2007).

**Grades** — BS8102 grades of internal environment (BSI, 1990).

**Lead Consultant** — The party who leads the Design Team and coordinates all aspects of design. Generally has a direct link to the Client and is appointed to this role.

**Moisture** — Water in the form of vapour as well as liquid.

**Relative Humidity** — The Relative Humidity (RH) describes the amount of water vapour in a gaseous mixture of air and water. In an air-water mixture the RH is the ratio of the partial pressure of the water vapour in the mixture to the saturated vapour pressure of water at a prescribed temperature.

**Vapour** — Water in its gaseous form.

**Vapour-proof** — Impervious to water and vapour; not permitting water or vapour to penetrate.

**Waterproof** — Impervious to water, not permitting water to penetrate.

**Waterproofing** — The act of providing a system to give water-resistance.

**Watertight** — Waterproof.

**Water-resistant** — Has a high resistance to water penetration.

**Water-resistance** — The extent to which a material prevents water penetration.

**Weeping** — State in which droplets of water form on the surface of the wall and coalesce with other droplets. The coalesced water does not remain stationary on the wall surface, but instead flows down the wall (ICE, 2007).

**Wet** — The presence of water as a liquid, as saturated dampness, as a surface layer, a flow or a pool. This will usually be visible as a dark staining or a glistening when illuminated.

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