Basements: Waterproofing

General guidance to BS 8102:2009

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The Concrete Centre

Foreword

This publication examines the factors to consider when deciding on the form of basement construction, and types of waterproofing for single-storey domestic basements. It provides guidance on the form and characteristics of the main categories of waterproofing systems: bonded sheet membranes, bentonite clay active membranes, liquid-applied membranes, mastic asphalt, cementitious proprietary multi-coat renders, toppings, coatings, and cementitious crystallisation active systems and cavity drain systems. It also contains information on soil characteristics and detailed illustrations relating to drainage, waterproofing and means of assessing risk. The guidance in this publication follows the principles given in BS 8102:2009, which should be referred to for more recommendations and guidance on methods of dealing with and preventing the entry of water from surrounding ground into a structure below ground level for both shallow and deep basements.

Acknowledgements

The Basement Information Centre is grateful for the assistance and comments provided for this publication by its Technical and Marketing Committee and its members.

TBIC also acknowledges the support given by the various organisations and individuals who contributed to the original 1994 edition of this publication.

A list of members providing products and services for new-build, refurbishment and retro-fit basements may be found on The Basement Information Centre's website www.basements.org.uk or www.tbic.org.uk, which also lists other publications and provides more information on the design and construction of basements for dwellings.

Many construction activities are potentially dangerous, so care is needed at all times. Current legislation requires all persons to consider the effects of their actions or lack of action on the health and safety of themselves and others. Advice on safety legislation may be obtained from any area offices of the Health and Safety Executive.

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INTRODUCTION

Basements provide an opportunity for builders to achieve a good return on their outlay, and for their customers to benefit by being offered houses with greater potential[1]. Reference 1 also provides further guidance on how basements can be a viable part of the solution for sustainable housing in the UK, through consideration of Planning Policy, the Code for Sustainable Homes and their development benefits, and the key issues to be considered at each stage of the design and construction process for single-storey basements for domestic housing.

Including a basement maximises available land space, provides more stable construction, is thermally efficient and offers ideal quiet areas and further space for storage or accommodation. Basements can be economically introduced onto most sites[2] and, in particular, have clear advantages on sites with poor ground that may otherwise be regarded as difficult and possibly uneconomic to build on. This publication follows the guidance given in BS 8102:2009[3] and is intended to help the builder or designer arrive at the most appropriate form of construction and waterproofing solution. Further guidance on design matters for basements may be found in Reference 4.

A best practice guide to the design and construction of concrete basements[5] aims to assist generalist structural engineers, who have some grounding in soil mechanics, with the design of basements with modest depth (say, not exceeding 10 m). It covers the salient features for the design and construction of such basements in accordance with the Eurocodes.

Scope

The details and comments given in this publication are generally limited to Grade 2 and 3 internal environments, as defined in BS 8102, where no water penetration acceptable, which are appropriate for residential basements.

The Grade 2 environment is for use as workshops and plant rooms, and other areas where the performance level permits no water penetration, but higher levels of water vapour would be tolerable and surface condensation may occur.

The Grade 3 environment is for ventilated residential and working areas which require a drier environment.

BASEMENT USAGE

Table 1 relates environmental performance levels to basement usage, and defines them from Grades 1 to 3. Most basements will be for domestic accommodation, which is Grade 3. Grade 1 environment can from BS 8102 be suitable for car parking but this allows some leakage, which will likely not be desirable or acceptable for domestic garages. Some domestic basements may be for permanent workshops or garages, and a Grade 2 environment may be acceptable. However, since usage may change, it is better to construct a basement to a Grade 3 environment than to upgrade it later.

Guidance with respect to ventilation may be found in References 6 and 8.

Table 1 BS 8102 Grades of waterproofing protection

Grade	Example of use of structure	Performance level
1	Car parking; plant rooms (excluding electrical equipment); workshops	Some leakage and damp areas tolerable, dependent on the intended use [A)] Local drainage might be necessary to deal with leakage
2	Plant rooms and workshops requiring a drier environment (than Grade 1); storage areas	No water penetration acceptable Damp areas tolerable; ventilation might be required
3	Ventilated residential and commercial areas, including offices, restaurants etc.; leisure centres [B)]	No water penetration acceptable Ventilation, dehumidification or air conditioning necessary, appropriate to the intended use

[A)] Leakage and damp areas for some forms of construction can be quantified by reference to industry standards, such as the ICE's *Specification for piling and embedded retaining walls* [(7)].

[B)] Archives, landmark buildings and stores requiring a controlled environment need special consideration, e.g. see BS 5454 for archives[(8)].

BS 8102:1990 referred to Grade 4 environments. However, this grade has not been retained as its only difference from Grade 3 is the performance level related to ventilation, dehumidification or air conditioning (see BS 5454 for recommendations for the storage and exhibition of archival documents). The structural form for Grade 4 could be the same or similar to Grade 3.

The attainment of environmental performance is achieved by attention to waterproofing design principles, a selection procedure – which requires consideration of structural form, and selection of appropriate waterproofing materials – and other design considerations. These are dealt with in the following sections.

DESIGN PRINCIPLES

Specialist input

The specification of waterproofing systems is a specialised task. It is recommended that, once the design team has given the system some thought, an appropriate specialist should be contacted immediately for early advice and help on the waterproofing design. This is a fundamental change introduced into BS 8102.

General

BS 8102 indicates that in order to develop a robust design for protecting a structure against groundwater, the following factors should be assessed:

a) the likely highest level of the water table, the drainage characteristics of the soil and other site-specific properties;

b) the appropriate waterproofing measures, i.e. Type A, B or C protection (see *Types of waterproofing protection*) and, where necessary, external drainage based on:

   1) the results of the site evaluation, including the classification of the water table; and

   2) the intended use of the structure**,** with consideration given to any requirement for future flexibility. This should be undertaken in consultation with the client;

c) the appropriate type of primary waterproofing system.

There are other factors that need to be taken into account as given in both BS 8102 and within this publication but choosing a suitable basement construction may in simplistic terms be divided into four main steps:

- Decide on basement usage.
- Gather site information.
- Decide on form of construction and type of waterproofing.
- Assess buildability and reparability.

The general principle is to assess the risk of water reaching the structure and the nature of the structural options with respect to water resistance and then to select a waterproofing system appropriate to achieving the required basement internal environment.

Figure 1 outlines by way of a flowchart the principal factors and stages that need to be addressed in order to produce a robust waterproofing solution for a below-ground structure. This figure and the principles outlined in this section follow the philosophy given in BS 8102.

The directional arrows in Figure 1 indicate that some matters are interrelated, and that a degree of iteration might result from a need to also address suitability, buildability and reparability. The principal issues (Figure 1) do not necessarily need to be addressed in the order shown but all will need to be understood and evaluated.

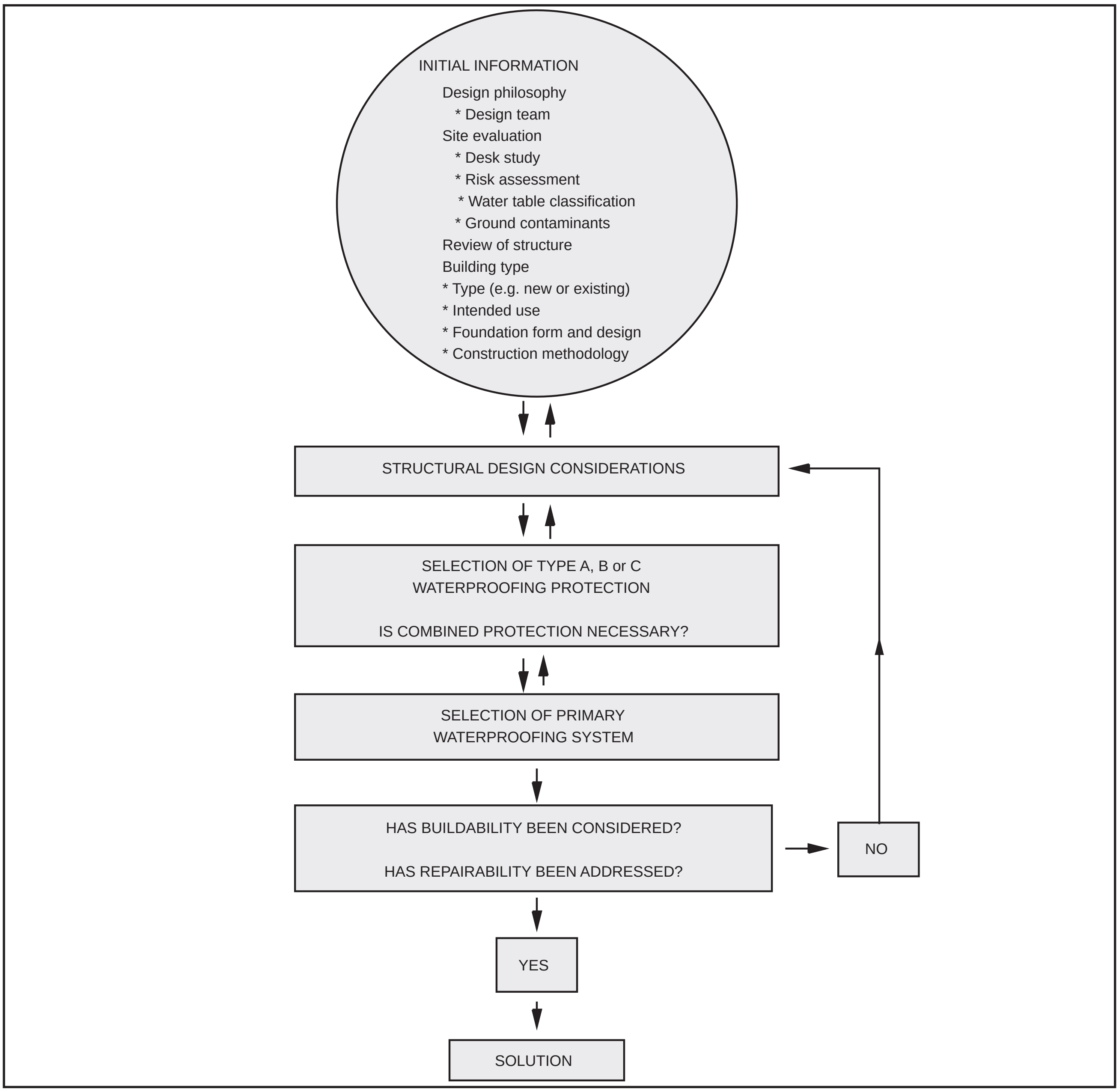


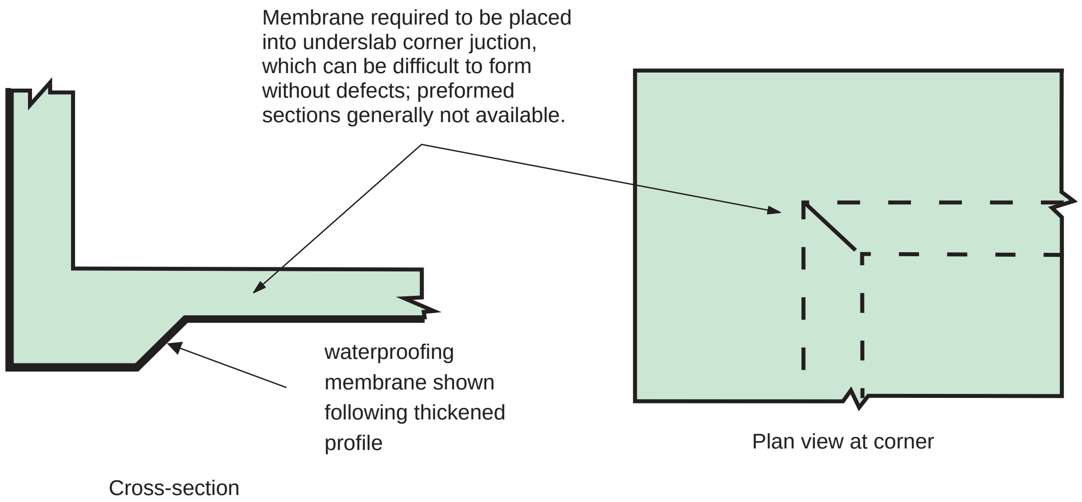
Figure 1 Design flowchart

Other factors that need to be determined and/or addressed in order to develop a robust design for protecting a structure against groundwater are:

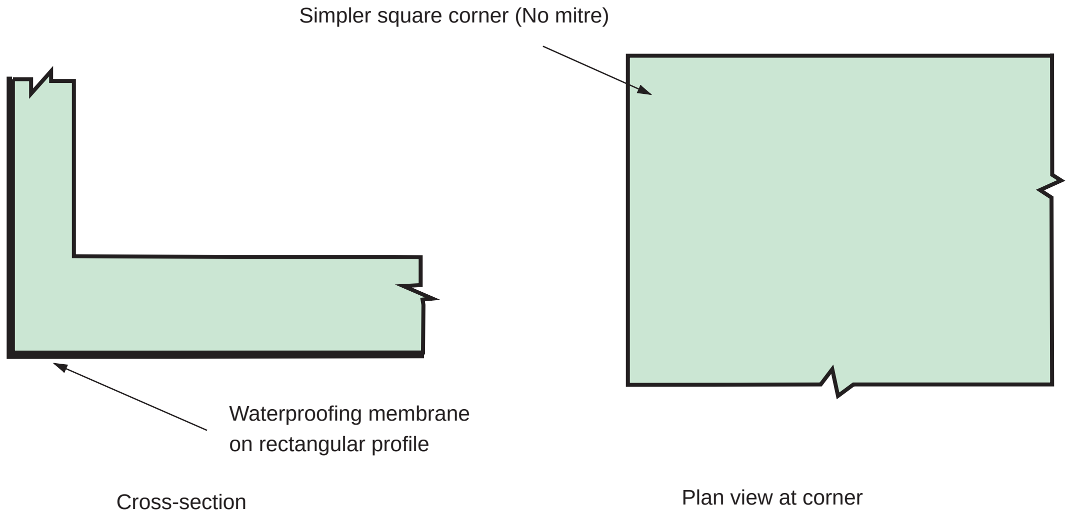
- the level of protection needed based on the intended use of the structure, with consideration given to any requirement for future flexibility. This should be undertaken in consultation with the client (see *Basement usage*);
- the position of the water table, the drainage characteristics of the soil and other site-specific properties (see Selection procedure) and the implications of constructing a new basement with regard to the likely groundwater characteristics;
- the need for continuity in waterproofing protection, taking into account the proposed type of foundations (see *Design factors affecting construction*);
- the appropriate type of waterproofing protection, i.e. Type A, B or C (see *Type of waterproofing protection*); and
- the appropriate type of primary waterproofing system (see *Form and characteristics of waterproofing materials*).

It is important, particularly for new-build basements, that the structural, building services, overall building weatherproofing design and basement waterproofing designs are considered together, as they will normally interact.

A two-dimensional drawing shows a simple profile but a three-dimensional review of the structure and waterproofing should be undertaken so as to identify any complex geometries which will not be readily identified from normal two-dimensional details. An example is given in Figure 2, which shows the effect of applying a waterproofing barrier to a thickened-edge slab (Figure 2(a)) compared to a slab of constant thickness (Figure 2(b)). In Figure 2(a) the mitred corner to the underside of the slab can cause problems in correctly applying some waterproofing barriers, which can lead to defects and the need for repair. The section with constant thickness indicated in Figure 2(b) allows for easier and more reliable waterproofing to be applied to the underside of the slab. This example shows how simplifying the structural shape can ease the application of the waterproofing and render it more reliable.



a) Slab with thickened edge complicates the application of a waterproofing barrier



b) Slab of constant thickness can simplify the application of waterproofing barrier

Figure 2 A & B Effect on waterproofing when assessed on a three-dimensional basis

The design should also cater for, or enable, post-construction treatments to enhance performance or to overcome possible deficiencies in the waterproofing construction.

Figure 3 is used to illustrate the benefit in considering the need for possible repair as this can lead to a more robust design.

Figure 3(a) shows an original design that utilised a Type B construction, with an oversailing cavity wall having the inner leaf carried down past the principal retaining wall. This, when examined, highlights the fact that should a defect (crack) develop in the external basement wall the incoming water could track around the cavity (and enter a considerable distance away). In addition the internal leaf of the cavity wall also prevents access to repair the basement wall. By considering a structure in this way can lead to a reassessment of design – for example in Figure 3(b), whereby a drainable channel or Type C membrane system could be incorporated within the cavity. External subsoil drainage could also be used to lessen risk. Figure 3(c) shows the external retaining wall thickened to support the oversailing masonry wall, which then allows direct access to the wall in the event of a defect, for example to enable crack injection. Again external drainage would, in appropriate condition, lessen risk.

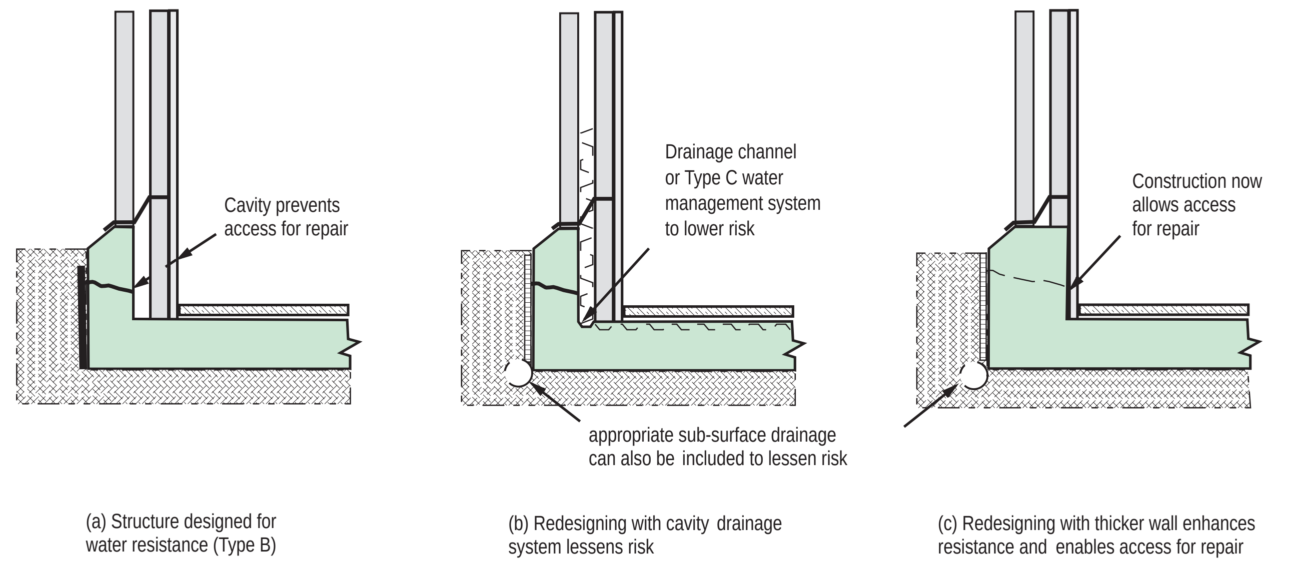


Figure 3: Consideration of need for repair leading to an alternative design

Figure 3 is used in this publication prior to examining the principal forms of waterproofing protection and characteristics of waterproofing materials as it highlights an important design issue often overlooked in the past. This reflects and highlights the need to address buildability and reparability as introduced into BS 8102: 2009.

Another important design principle is to ensure that adequate details are provided for the system in general (e.g. wall base details, laps in membranes), or changes in level of the slab, or at the head of the wall where it adjoins the superstructure and/or at windows that extend below ground level (see *Waterproofing details*).

The structure should also be analysed as a three-dimensional box, particularly for Type B (structurally integral) construction. And where serviceability cracking could have a detrimental effect on an applied waterproofing.

Figure 4 shows typical bending moment distributions on both vertical cross-sections and horizontally. It would also be beneficial to assess these bending moments taking some account of soil–structure interaction as this will more accurately determine ultimate and serviceability stresses, and thereby result in more design control of water resistance.

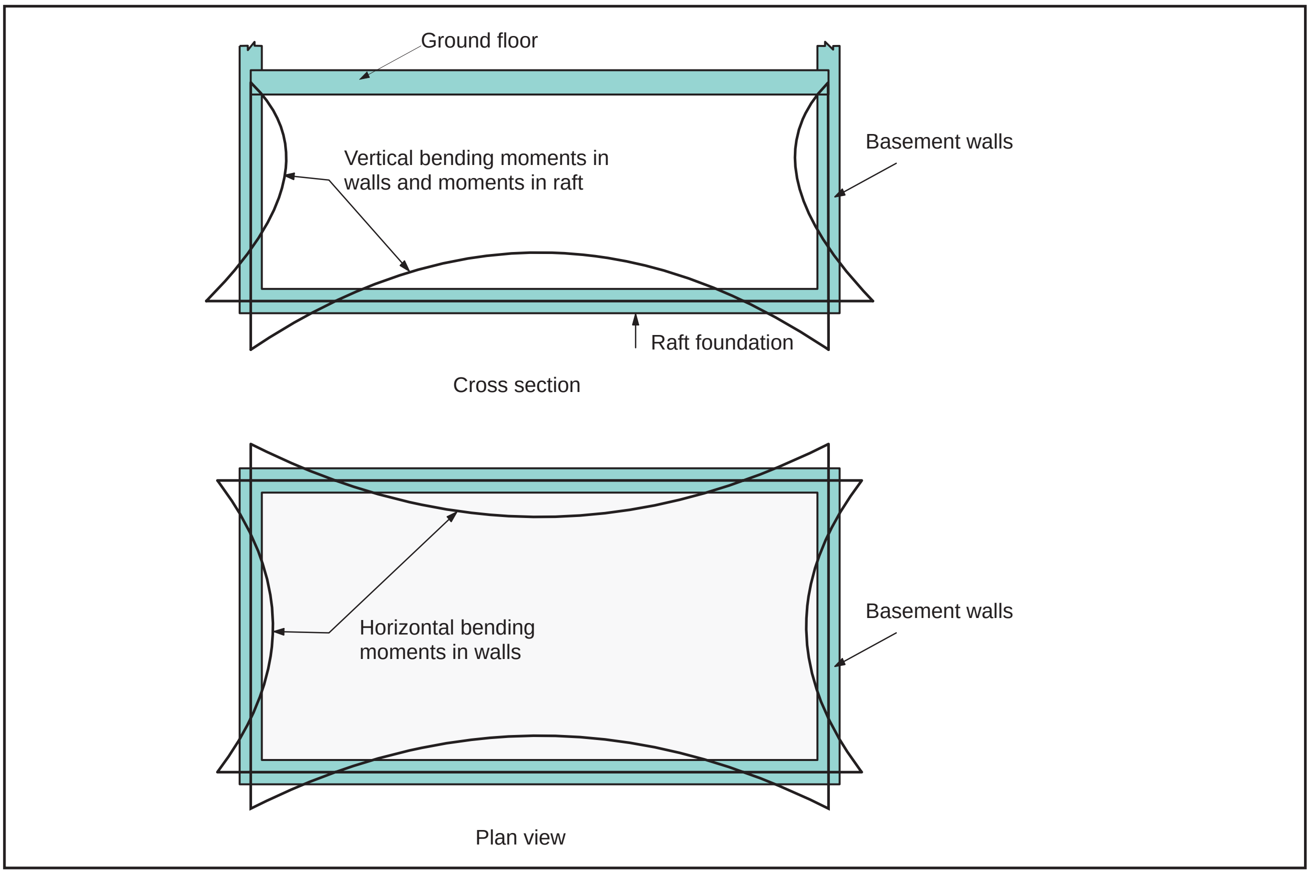


Figure 4 Bending moments in walls and raft foundation

Similarly, the effect of plain and reinforced concrete structures should also be taken into account when selecting the applied waterproofing membranes. BS 8102 indicates that barrier-specific properties should be evaluated, to ensure that they can cater for any predicted cracking from the structure (see Figure 5). Barrier materials will typically accept local strains and cracking in a reinforced concrete structure, but some may not so readily cater for the wider cracks in a plain (unreinforced) structure designed as cracked sections. This is also represented in Figure 1 by the directional arrows between selection of waterproofing materials and types of waterproofing protection.

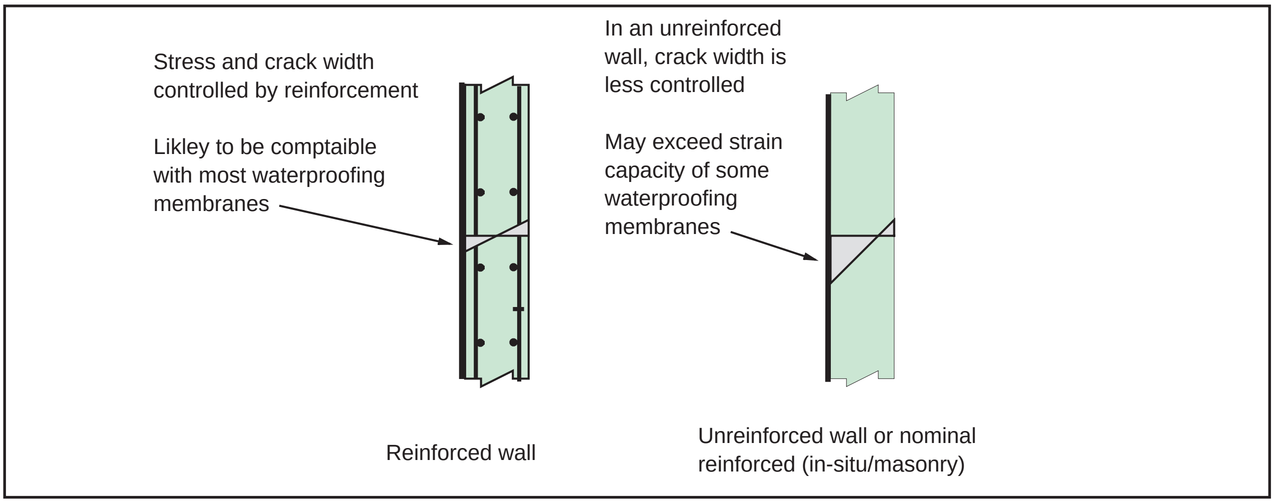


Figure 5 Effect of structure on applied waterproofing barrier

STRUCTURAL WATERPROOFING IN EXISTING STRUCTURES

Many of the considerations applicable to structural waterproofing design in new construction apply equally to the design of systems for existing structures, and this document serves equally well as a guide to review these necessary considerations for this purpose.

However, contrary to new-build scenarios, there are limitations inherent when working within the confines of an existing structure, in that there is typically a limited opportunity or scope to make structural alterations for the purpose of installing a given system.

Additionally, while in the case of new construction waterproofing, the designer is providing the initial or first-stage measures of protection against groundwater, in existing structures it is often the case that designs are provided for the purpose of remedying failures in those initial measures, to address problems with systems of considerable age in older or historic property, or to facilitate change of use.

If options are limited by the confines of the structure, it is important to understand what that structure is, and equally, the nature of any installed waterproofing measures within it, which may further influence design.

Therefore, an analysis, through visual inspection, inspection of drawings (where available), and potentially intrusive investigation, i.e. trial hole formation, should be undertaken so that a thorough understanding of the structure and how it is constructed, is developed. The effects of any structural discontinuity (see Figure 11(a)) as may typically occur in an existing structure must also be assessed.

Once the structure is understood, and objectives and instructions are defined, it is the role of the waterproofing designer to configure products and systems within that structure, all while considering the appropriate factors detailed within this guide, so that the objectives are successfully met and structures are protected in the long term.

Much of the failure associated with structural waterproofing is attributable to insufficient consideration of the relevant factors, leading to poor design, It is therefore advisable that where specifying waterproofing, these factors are examined rigorously, and that ideally specialists be consulted about a design at the earliest stage.

SITE INVESTIGATIONS

Aspects of gathering site information are dealt with in the subsections that follow but there are some overriding principles that need to be highlighted when selecting the form of construction and waterproofing system.

- High water tables present the greatest risk of failure to the waterproofing of a basement and it is therefore important to identify it. A watercourse or water table that rises and falls and the potential for a perched water table must also be identified. How often and for how long the water table stays high are also important factors. If the water table rises briefly – say, after heavy rain – and then immediately falls again, the risk of water penetration through external waterproofing and then through the structure is less than if the water table stays high for a much longer period. Consideration may also need to be given to the effect of planned developments adjacent or in close proximity to the site under consideration.

- The likely presence of water and the position of the water table must also be established for construction purposes. The main contractor may need to lower the water table temporarily to enable the construction and waterproofing to go ahead. In addition, any lowering of the water table will need to be maintained until the loads acting on the basement, from either itself or in combination with the superstructure, are greater than the forces that would be generated by the water pressures as the water table returns to its original level.

- The existence of any aggressive elements in the ground and/or the groundwater must be established to ensure that the most suitable combination of structure category and waterproofing system is selected.

- As stated in BS 5930[9], 'Investigation of the site is an essential preliminary to the construction of all civil engineering and building works'. BS EN 1997[10] provides guidance on geotechnical design. Assessment of ground conditions is particularly important for basements, since the materials used and the performance of the finished structure will be greatly influenced by the ground conditions. Several factors need to be assessed and reference should be made to the above Standards.

Brief details of some aspects of site investigations are given below.

Water table

The existence of a watercourse or water table and its seasonal position below ground will need to be established. The site history and name clues such as 'Pond Lane' can help. Evidence of a flooding site could suggest an impermeable soil or a high or perched water table.

Ground drainage

The topography of the land and the direction and movement of any groundwater should be determined as they will have a bearing on any proposals to provide drainage to reduce local groundwater pressures.

If there are any drains or land drains, their positions should be established. Any new construction proposals should not interrupt drains that still function unless measures are taken to redirect them or to intercept the water by a new drainage system.

Soil type and conditions

The type of soil can greatly influence the quantity of water reaching the basement wall. Free-draining soils not subject to variability in water tables generally present fewer problems than clays, which tend to be impermeable. It is important, therefore, to determine the soil type and, in particular, its drainage characteristics. Table 2, adapted from Reference 11, which is based on the extended Casagrande classification system, gives the generalised drainage characteristics, and shrinkage or swelling properties of the main soil types. This may be used to assist in determining the effect that the site's soil may have on retaining water, developing water pressure and risk (see Table 3 and *Assessing risk*). It should be noted that the soil around a basement may not be uniform and therefore care needs to be taken when assessing its overall characteristics. Such assessment is best left to specialists.

Table 2: Characteristics of soils which affect basement construction

Material	Major divisions	Sub-groups	Drainage characteristics	Shrinkage or swelling properties
Coarse soils and other materials	Boulder and cobbles	Boulder gravels	Good	Almost none
	Other materials	Hard: hard broken rock, hardcore, etc.	Excellent	Almost none
		Soft: chalk, soft rocks, rubble	Fair to practically impervious	Almost none to slight
	Gravels and gravelly soils	Well-graded gravel and gravel–sand mixture, little or no fines	Excellent	Almost none
		Well-graded gravel–sand mixture with excellent clay binder	Practically impervious	Very slight
		Uniform gravel with little or no fines	Excellent	Almost none
		Poorly graded gravel and gravel–sand mixture, little or no fines	Excellent	Almost none
		Gravel with fines, silty gravel, clayey gravel, poorly graded gravel–sand–clay mixtures	Fair to practically impervious	Almost none to slight
	Sands and sandy soils	Well-graded sands and gravelly sands, little or no fines	Excellent	Almost none
		Well-graded sand with excellent clay binder	Practically impervious	Very slight
		Uniform sands with little or no fines	Excellent	Almost none
		Poorly graded sands, little or no fines	Excellent	Almost none
		Sands with fines, silty sands, clayey sands, poorly graded sand–clay mixtures	Fair to practically impervious	Almost none to medium

Table 2: Characteristics of soils which affect basement construction, continued.

Fine soils	Soils having low compressibility	Silts (inorganic) and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Fair to poor	Slight to medium
		Clayey silts (inorganic)	Practically impervious	Medium
		Organic silts of low plasticity	Poor	Medium to high
		Heavily over-consolidated clays independent of plasticity	Practically impervious	Medium to high
	Soils having medium compressibility	Silt and sandy clays (inorganic) of medium plasticity	Fair to poor	Medium to high
		Clays (inorganic) of medium plasticity	Fair to practically impervious	High
		Organic clays of medium plasticity	Fair to practically impervious	High
		Intermediate over-consolidated clays independent of plasticity	Practically impervious	Medium to high
	Soils having high compressibility	Micaceous or diatomaceous fine sandy and silty soils, elastic silts	Poor	High
		Normally consolidated clays (inorganic) of high plasticity, fat clays	Practically impervious	High
		Normally consolidated organic clays of high plasticity	Practically impervious	High
		Normally consolidated and lightly over-consolidated clays independent of plasticity	Practically impervious	High
		Peat and other highly organic swamp soils	Fair to poor	Very high

Some soils contain chemicals that may harm both the structure and the waterproofing system. Check the ground for materials that are detrimental, such as peat, sulfates and chlorides.

BS 8102:2009 advises the designer to also take account of the presence of, or potential for, natural gases such as radon and methane when considering waterproofing. This is mentioned so that designers can take note of the perceived risks from radon and advise their clients accordingly. It should also be noted that high levels of radon can accumulate even where basements are protected by a waterproofing membrane (that is also effective as a radon barrier), and this may lead to the installation of a radon management system where the risk assessment, particularly in existing structures, indicates that legislation might otherwise apply.

The likelihood of gases can be established from the underlying geological structure, and guidance for its control may be found in a number of documents and via official sources on the internet. BS 8102:2009 makes reference to maps of areas where basic or full protection against radon needs to be provided that are contained in the Building Research Establishment (BRE) reports BR211[12], BR376[13], BR413[14] and the Health Protection Agency (HPA) document *Radon in Dwellings in Scotland: 2008 Review and Atlas*[15]. Attention is also drawn to the Building Regulations[16], and to further guidance on the characterisation and remediation of ground gases given in BS 8485[17]. Guidance on measures for large buildings is given in BRE guidance *Radon protection for new large buildings*[18]. In view of health issues concerning radon, due vigilance should be observed regarding any revisions to these documents and other official sources.

Methane and other gases are likely to be linked to infill and made-up ground, particularly where large amounts of organic matter have been buried. Such sites can also present risks from acid wastes, mineral oil shales, and other fill materials.

Some slags and other residues often contain toxic materials and some furnace ashes may be reactive. The Building Regulations[16] give information on site preparation and resistance to moisture, and include guidance on ground contaminants.

Movement risks that may affect basements

A change in ground moisture content – caused, for example, by the removal of trees – can result in ground movement and affect the load-bearing capacity of soil and applied waterproofing. Clay and peaty soils are particularly prone to volumetric changes leading to varying foundation pressures and movement.

The remains of former buildings or structures on the site need to be assessed. They are best removed to avoid differential movement due to bearing over firmer points. Steeply sloping sites may have high land-slip risks, which should be assessed before proceeding further.

Particular care is needed where there are changes in the soil strata that may cause differential foundation movement. Although such matters can be catered for structurally, they do present problems. For example, although expansion joints are a common solution, they may not be appropriate because of the difficulties of maintaining watertightness, particularly in a waterlogged site.

If the risk of movement is high, movement joints should be considered. Where possible, designers should not attempt to create waterproofed expansion joints but instead should design discrete boxes that can be separately waterproofed.

TYPES OF WATERPROOFING PROTECTION

BS 8102 describes three types of waterproofing protection: Type A, B and C. These are shown diagrammatically in Figure 6, and discussed below, together with the factors affecting their choice.

Type A (barrier) protection: where the structure has limited integral protection against water penetration and therefore relies permanently on a waterproofing membrane to keep water out. The chosen structural waterproofing system must be able to deal with groundwater pressure together with any superimposed or service loading.

Type B (structurally integral) protection: where the structure itself is constructed as an integral water-resistant shell.

Invariably built of reinforced concrete, the basement structure must be designed within certain strict parameters to ensure it is water resistant.

Type C (drained) protection: where the structure provides primary resistance against penetration and incorporates a drained cavity within the basement structure. There is permanent reliance on this cavity to collect groundwater seepage through the structure and direct it to drains or a sump for removal by drainage or pumping.

Structural walls may be reinforced or plain concrete or masonry. The external basement wall must provide enough resistance to water ingress to ensure the cavity accepts only a controlled amount of water or dampness.
This system does not provide a hydrostatic barrier but provides protection by means of water management.

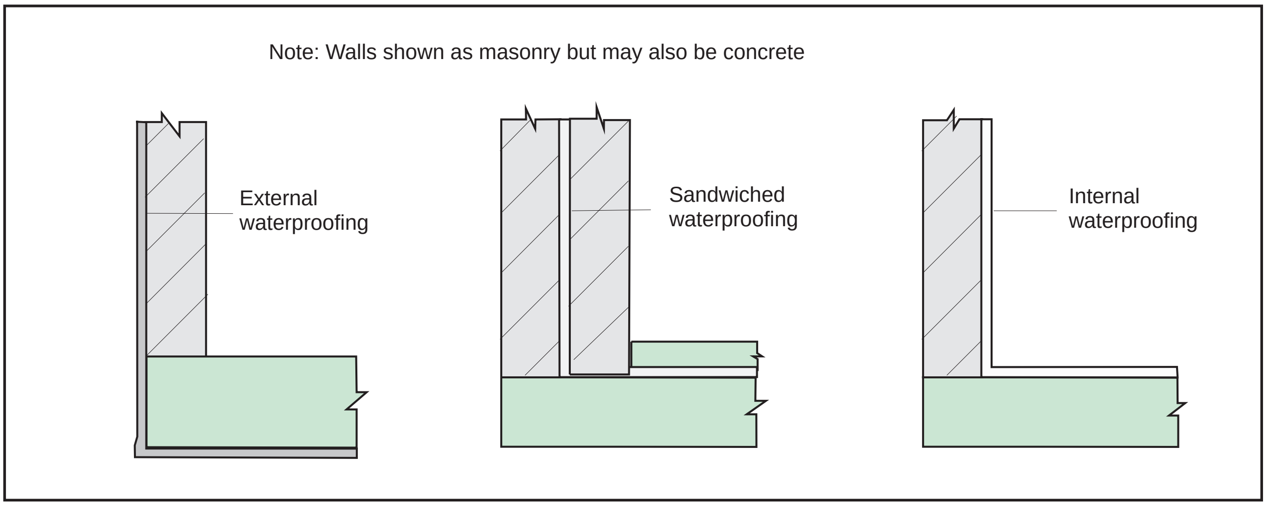


Figure 6a. Schematic illustration of Type A (barrier) protection

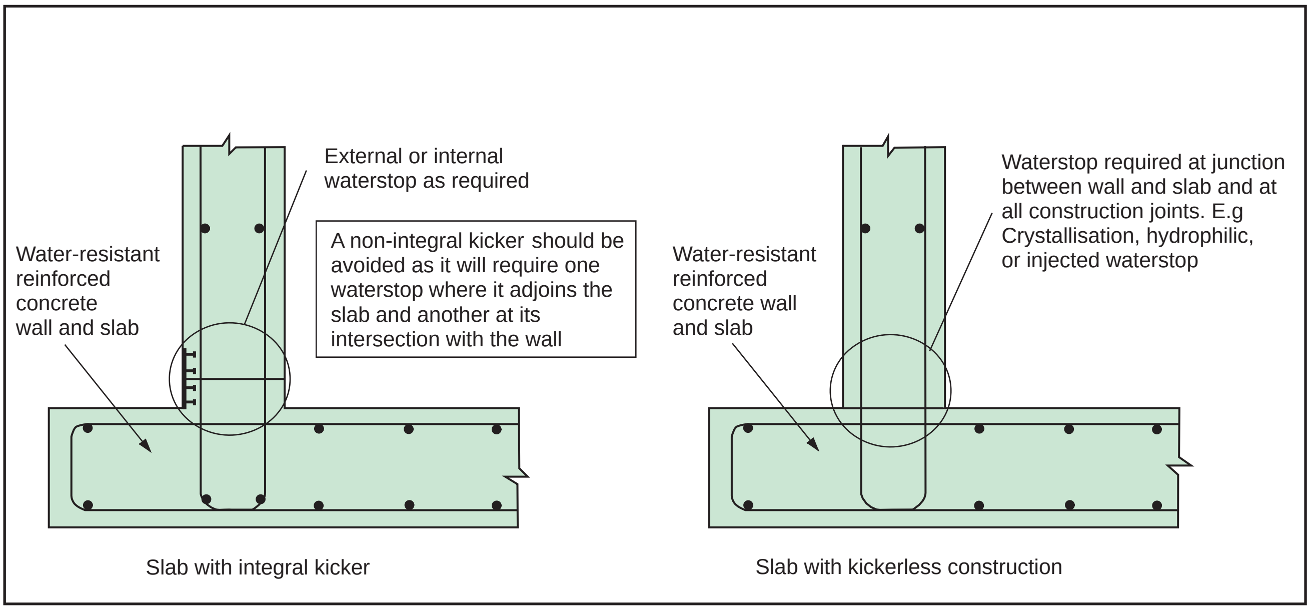


Figure 6b. Schematic illustration of Type B (structurally integral) protection

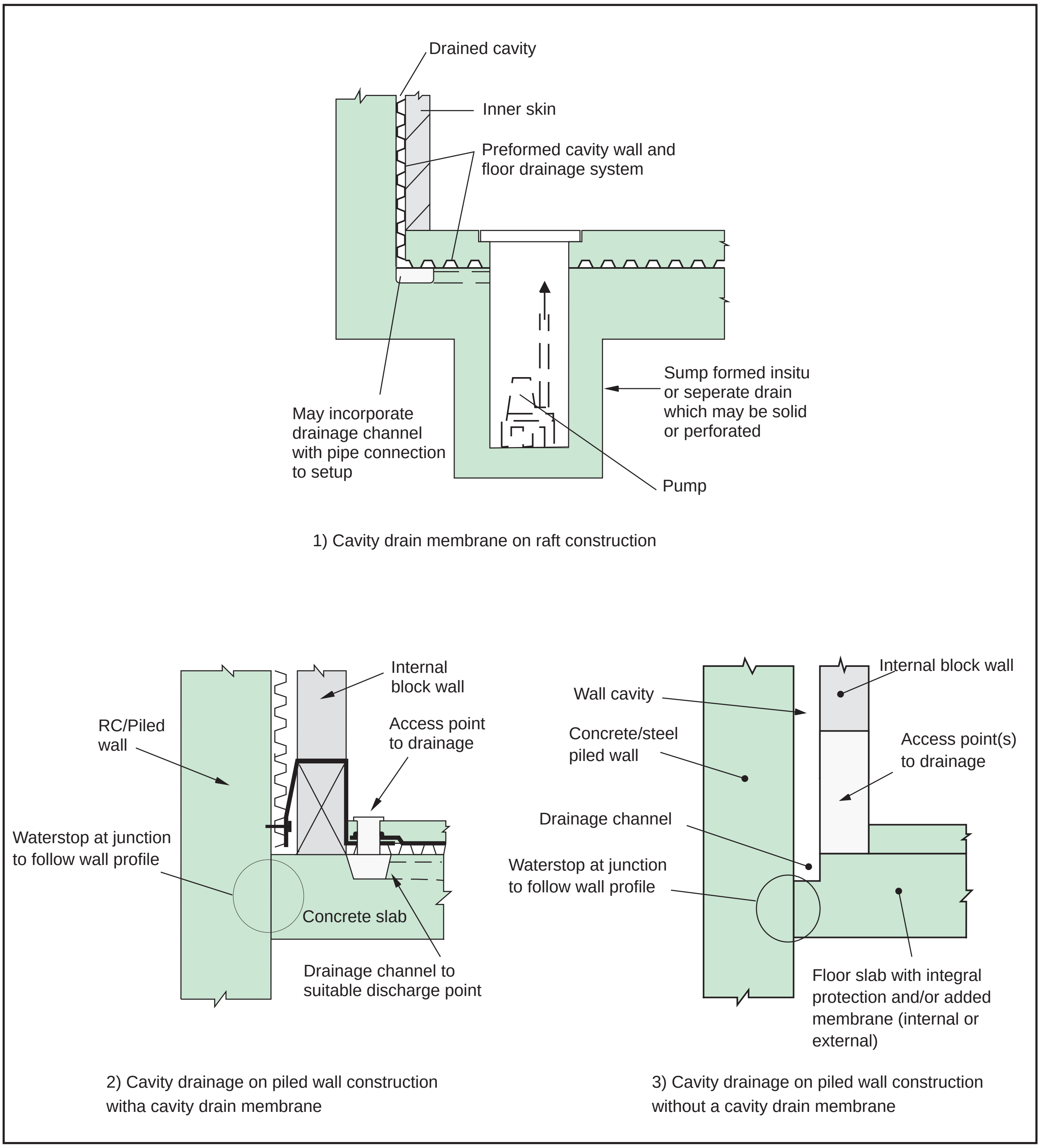


Figure 6c Schematic illustration of Type C (drained) protection

Characteristics of the types of waterproofing protection

Theoretically any structural waterproofing membrane designed to resist a hydrostatic head should not let any free water pass through it. However, in practice, consideration must always be given to what would happen as a result of any defect. The effects of water table conditions on the three basement types are discussed below. Where the site drains well enough to prevent the build-up of hydrostatic water pressure, all three forms of construction carry little risk of damp penetration.

Type A

The watertightness of the Type A basement relies fundamentally on the effectiveness of the waterproofing system. With a high water table, any defects in the waterproofing barrier will allow water to penetrate and if the structural elements are permeable (e.g. masonry) will allow free water to enter the basement. If this water is not removed, the basement will fill to the level of the water table. Structural elements that are less permeable (e.g. concrete walls) which resist or lessen the occurrence of free water can extend the usage of Type A construction.

Since fundamental reliance is placed on the waterproofing system in Type A structures, account must be taken of the need to gain access if a defect occurs.

Externally applied systems may require subsequent excavation. However, locating the source of a defect in a system not continuously bonded to the substrate wall can be difficult.

An internal system makes accessing and remediating the defect more straightforward but consideration needs to be given to internal fittings.

Where the site is permanently free-drained, any defects in the system will allow moisture to move under capillary action (which is influenced by the amount of water resistance offered by the structural wall elements). Where the defect is small, this may result in some dampness in the structure, but will not necessarily show itself on the internal surface. However, any decoration or surface coating that acts as a vapour check will increase the risk of interstitial condensation[19] and hence possible damage.

With a varying water table, significant water ingress through defects will occur only during storm or water-logged conditions and again will depend on the resistance of the structural elements. If the water table is high only briefly, the ingress might not be enough to show itself. The longer it stays high, the greater the risk of significant dampness or even partial flooding.

The incorporation of maintainable land drains can be used under appropriate ground conditions to achieve a situation where all moisture is under capillary action. Scheduled maintenance of land drains is required.

Type B

The watertightness of the Type B construction is reliant upon the design and construction of the basement as an integral shell, using a concrete of low permeability, and appropriate joint details.

Defects can be minimised by correct specification and design and by careful construction. The most common defects are: permeable concrete and honeycombing through lack of compaction; contamination of, or cold, construction joints; cracking due to thermal contraction and shrinkage.

Construction joints need particular attention as these are the areas most commonly associated with leaks. While attention needs to be paid to jointing and positioning of water stops, great care is required in the placing and compacting the concrete. An alternative method of controlling water ingress at construction joints is to use a crystallisation or hydrophilic system that reacts in the presence of water to seal the joint. Other systems are also used (see *Ancillary materials*).

The construction of a ‘kicker’ after pouring the floor slab should not be encouraged as it is difficult to construct without defects. Therefore kickers should be cast with the slab using appropriate edge formwork but will require careful construction to obtain full compaction.. Moderm types of formwork and kickerless construction techniques mean that kickers no longer need be part of the construction process – see Figure 6 (Type B (*structurally integral) protection*).

With a high water table, minor defects in the concrete usually result in only small amounts of water penetrating, and stopping these is usually fairly straightforward. Remedial action may, depending on the form of construction, be carried out from the inside, so avoiding the need for external excavation (see Table 3).

Variable water tables present less of a problem, unless the water table stays high for a long time. In a free-draining site, it is rare for a defect to be so serious that the water comes through by capillary action. The water and water vapour resistance of Type B protection relies on the materials incorporated into the external shell of the structure itself and will be a function of the section thickness

Type C

Type C construction relies on water being resisted by the structural elements and any water that penetrates the external shell of the structure being collected in a cavity formed between the external wall and an internal lining/wall. There is permanent reliance on this cavity to collect groundwater seepage and direct it to a suitable discharge point, e.g. drains or a sump for removal by gravity drainage or mechanical pumping. The amount of free water entering the cavity will depend on the volume of external water and its hydrostatic pressure, and on the resistance of the structure itself to water ingress. Designers need to consider any risk associated with a constant supply of possible contaminated water to the structure.

Such systems typically remove water via a mechanical sump pump system, or occasionally by gravity to low ground or drains externally where properties are formed into sloping sites. However, the need to control ground gases, e.g. radon, may not allow the use of gravity drainage. In all cases, consideration should be given to the point at which water discharges, understanding that the effectiveness of the system is reliant on removal of water, so an appraisal of this factor is required.

Type C pumped systems should be engineered to cope with worst-case water ingress. If drainage capacity is exceeded, this may result in dampness or flooding. Type C systems are designed to control and manage leakage and seepage into a structure where water ingress unacceptably high, the water resistance of the structure should be improved by remedial measures prior to the installation of the type C system.

Backup pumps and alarms should in most situations be included, particularly where the consequences of failure are great. It should also be noted that:

- Type C systems require a maintenance schedule, as failure of mechanical pumps could result in flooding;
- blockage of the cavity by silt or lime or other contaminants could result in flooding. (The design of the system should allow for clearing of silt should blockages occur in the system including discharging drains.)

Maintenance should be undertaken by a specialist, making assessment of the requirement to upgrade and replace pumps as necessary.

When combining systems in order to minimise the risks or negate the need for remedial measures, consideration should be given to the compatibility of the combining systems.

Combined/combination systems

Consideration can also be given to the use of combined systems (e.g. type A and type B, Type A and Type c or Type B and Type C) where the assessed risks are deemed to be high (see *Selection procedure*), where consequences of defects or inadequate workmanship are high, or where additional vapour checks are required to a system where water vapour penetration can occur.

Type B structures are designed to be water resistant; additional waterproofing systems may be applied internally or externally to control water vapour movement, where appropriate, or to provide further protection against water ingress.

Thus combining a type B system with a type A or type C would be deemed to have the least risk associated with them in areas of high risk (see BS 8102:2009 clauses 5.1.2and 5.1.3).

For further information on the suitability of construction forms related to the level of risk see *Selection procedure* below.

SELECTION PROCEDURE

Having completed the investigation as explained later in this publication, the design team should be able to decide the waterproofing strategy. Table 3 is provided to help in the selection process. However, as indicated under *Design principles* above, choosing and specifying a waterproofing system is a specialised task. It is therefore most desirable that the manufacturers of the likely systems are contacted early. Their expertise will help ensure a lowest-risk system. is achieved.

Guide to assessing basement designs

Table 3 gives general guidance on the suitability of various forms of construction which will depend on soil type, topography and the position of or potential position of the water table. Table 3 indicates where a type of construction related to a given level of risk can provide acceptable construction. It relates to the three basic types of waterproofing protection as detailed in later sections, but is presented at this stage as it reflects the earlier design principles and provides an understanding of the suitability of constructions under differing levels of risk. It also shows where differing types of construction can further decrease risk (for example, by the use of combined systems).

The sections that follow, give more guidance on the types of waterproofing protection referred to, the assessment of site conditions, materials, other design considerations and constructions options that will be needed to finalise the basement waterproofing design.

Table 3 takes into account the element or elements which provide the principal control of water resistance. For example, a Type A construction in which reliance is essentially dependent on a waterproofing membrane can provide an acceptable solution in well-drained soils but may be unsuitable or require additional drainage or waterproofing in soils with particularly low permeability. At the extreme, the low permeability might cause a temporary perched water table, so creating in effect a variable water table or hydrostatic pressure on the wall.

Similarly, if a variable water table stays high for some time, thus behaving as a permanently high water table, a Type A construction may not be acceptable without further upgrading. Such upgrading could involve internal cementitious waterproofing or the creation of a drained cavity.

Table 3 indicates acceptability of Type A, Type B and Type C under differing levels of risk, and shows where the construction has decreasing risk. However, to be effective, Type B will require proper attention to construction joints and Type C will require a maintenance schedule (pump servicing etc.).

The above shows the significant effect that the water table has on the selection process, and how, in consultation with the waterproofing manufacturers, it may be possible to modify a basic construction to make it suitable for a more severe situation.

A Grade 3 environment can be achieved by using a similar construction to that required for Grade 2, but with additional ventilation or dehumidification, the cost of which may be influenced by the initial type of construction and the external soil conditions.

When combining systems in order to minimise the risks or negate the need for remedial measures, consideration should be given to the compatibility of the combining systems.

Table 3 Use of different protection types based on water table classification

<table>
<tr><th rowspan="3">Risk associated with water table</th><th rowspan="3">Water table classification (see Notes)</th><th colspan="4">Types of water-resisting construction</th></tr>
<tr><th rowspan="2">Type A</th><th colspan="2">Type B</th><th rowspan="2">Type C</th></tr>
<tr><th>Piled wall</th><th>RC wall to BS EN 1992[20]</th></tr>
<tr><td>Low</td><td>Low</td><td>Acceptable</td><td>Acceptable</td><td>Acceptable</td><td>Acceptable</td></tr>
<tr><td></td><td>Variable</td><td>Acceptable if ‘variable’ classification is due to surface water: seek manufacturer’s advice.</td><td rowspan="2">Acceptable where:
a) the piled wall is directly accessible for repair and maintenance from inside the structure
or
b) the piled wall is combined with a fully bonded waterproofing membrane
or
c) the piled wall is faced internally with a concrete wall to BS EN 1992[20].</td><td>Acceptable</td><td>Acceptable</td></tr>
<tr><td>High</td><td>High</td><td>Acceptable where:
a) an appropriate cementitious multi-coat render or cementitious coating is used
or
b) the wall is of concrete to BS EN 1992[20].</td><td>Acceptable</td><td>Acceptable</td></tr>
<tr><td colspan="2">Measures to reduce risk</td><td colspan="4">• Appropriately designed and maintained subsoil drainage (see BS 8102:2009 clause 6.1)
• A fully bonded waterproofing membrane (see Figure 6).
• Lower permeability of the main structural wall.
• Waterproofing admixture (to BS EN 934(21)) with appropriate supervision (see BS 8102:2009 clause 10.2.1.5).
• Discharge systems (e.g. pumps) must be maintained for the system to remain effective (see BS 8102:2009 clause 11.4.1).
• Combined systems (see BS 8102 clause 12).</td></tr>
<tr><td colspan="6">Notes: Low : where the water table is assessed to be permanently below the underside of the base slab.
High : where the water table is assessed to be permanently above the underside of the base slab.
Variable : where the water table fluctuates.
Soil permeability may affect risk under a low and variable water table (see Assessing risk).</td></tr>
</table>

Assessing risk

Ground conditions dictate the options available. The least severe conditions give the most options, while the most severe leave the design team with very few. The severity falls into three basic categories according to the position of the water table, although variations can occur within them. If natural gases are present, specialist advice should be sought.

Where groundwater or ground contains aggressive chemicals such as sulfates, chlorides, methane and other gasses their precise nature and concentration must be determined and the structure must be designed to be able to directly withstand the aggressive chemicals, or a suitable external protective membrane should be used.

Risk assessment should also consider:

a) the effects of climate change, burst water mains and sewers, adjacent trees, sulfates, chlorides, radon and other gases; and

b) where external drainage is proposed, the effects of drawdown on adjacent structures, the potential clogging of drainage and biofouling issues.

Even when the site investigation indicates dry conditions, the risk of some waterlogging in the future should be assumed. It should be noted that even in permeable subsoil, groundwater requires time to drain away and this can result in limited pressure coming to bear against the structure from time to time.

Permanently low water table

If the water table is permanently low, and there is no significant risk of percolating water building up a hydrostatic head, then conditions are the least severe. In this situation, the design team has an almost free hand to choose the most appropriate form of construction and waterproofing system.

With low-permeability soils such as some clays, there is a risk of a perched or variable water table – and therefore of water pressure against the structure – unless adequate maintainable drainage can be provided. Such drainage could, for example, consist of land drains discharging to the downside on a sloping site.

An alternative would be a maintainable, water-activated, submersible sump pump taken below the lowest slab level. This may also be considered on a normally free-draining site to cater for unexpected adverse conditions.

Variable water table

If the site cannot be drained and the water table rises occasionally, the degree of risk is increased. Just how severe a risk depends on how high and for how long the water table rises. Assessment of the level of the water table should not rely on single tests due to the effects of seasonal variation and soil properties. Generally, in these circumstances, the design options are more limited.

If the water table remains high for long periods, then a second, backup waterproofing system could be considered. However, the water-resistant structure must remain the first line of defence against water penetration.

Permanently high water table

If the water table is permanently above floor level, the level of risk is increased and the design options are further limited.

In this, the most severe category, the nature of the risk is the same as for a variable water table except that the risk is higher. This is because the water exerts a permanent pressure on the structure.

All other factors discussed under *Variable water table* apply.

Control of groundwater to reduce risk

The effect of groundwater may be controlled by an appropriately designed sub-ground drainage system.

This may vary from a simple external geocomposite drainage sheet or other vertical drainage layer in a low-risk situation through to high-risk conditions where a complete under-slab control system is employed.

An under-slab drainage might be installed to lower the water table permanently, so that the degree of risk is proportionally reduced, leaving the design team with the same options as given above for *Permanently low water table*. However, this latter approach will seldom be used on small developments as it requires extensive evaluation by a specialist as water movement can have an effect on surrounding properties. It will also require a full maintenance procedure (see BS 8102).

Cut-off walls may also be used to control groundwater (see BS 8102).

However, if there is any doubt about the long-term effectiveness of the drainage system, or control of groundwater, the risk is increased and the structure must be considered to be in a category of either variable or permanently high water table.

FORM AND CHARACTERISTICS OF WATERPROOFING MATERIALS

Since reliance has often to be placed on the waterproofing system, the designer must ensure that the materials are properly selected and adequate for the proposed location and conditions. It is imperative that all continuous horizontal, sloping or vertical waterproofing be specified, and executed, in one proprietary waterproofing system.

Most proprietary systems and materials are covered by British Standards, Agrément certificates or manufacturers' and installers' warranties.

There is a wide range of products used for structural waterproofing. The typical range of barrier materials and cavity drain membranes is given in BS 8102. For ease of understanding, this publication separates them into seven distinct categories according to product type, form and application as follows:

Category 1: Bonded sheet membranes
Category 2: Cavity drain membranes
Category 3: Bentonite clay active membranes
Category 4: Liquid-applied membranes
Category 5: Mastic asphalt membranes
Category 6: Cementitious crystallisation active systems
Category 7: Proprietary cementitious multi-coat renders, toppings and coatings

Categories 1 and 3–7 are regarded as barrier materials for use as Type A protection (and may be combined with a Type B protection) whereas Category 2 is a membrane that creates a drainable cavity and is part of a Type C protection system.

Category 1: Bonded sheet membranes

Bonded sheet membranes are generally cold-applied or heat-bonded to the finished structural walls. Both are modified bitumen on a range of carrier films. They are applied externally. Composite polymeric sheet membranes are also available. They are attached to the enabling works (reverse tanking) but subsequently fully bonded, by means of a specifically formulated pressure-sensitive adhesive, to the poured concrete.

Design considerations

- Flexible and able to adapt to minor movement and shrinkage within the substrate.
- They are of consistent thickness and quality.
- May provide protection against aggressive soils and groundwater when applied externally.
- Require good surface preparation.
- Substrate must be free from surface water for bonding to occur.
- Generally, suitable only for uncomplicated foundation systems such as plain rafts.

Category 2: Cavity drain membranes

Cavity drain membranes are high-density dimpled polymer sheets, placed against the structure. The dimples form permanent cavities between the structure and the internal shell. They are used internally to drain and control water ingress, and are not designed to sustain water pressure as specific barrier membranes (Category 1 and 3–7).

Design considerations

- Installed following construction of the basement.
- Defects may be rectified before completion.
- Minimum preparation of substrate needed.

- There is no hydrostatic pressure on the system: water entering the cavity is collected and drained/pumped away.
- They are of consistent thickness and quality.
- Flexible and able to adapt to minor settlement and shrinkage within the substrate.
- Simple internal applications can overcome complicated designs, e.g. piles and ground beams.
- With high or variable water tables, blockages or failure of drains/pumps may lead to flooding.
- Where recycled materials are to be used, their durability should be checked with the manufacturer.
- Planned maintenance is a requirement.
- Assessment of the permeability of the wall is required in order to determine requirements for water collection and discharge.

Category 3: Bentonite clay active membranes

Bentonite clay active membranes are sheets of sodium bentonite clay sandwiched between two layers of geotextile or bentonite fixed to a foil membrane. The bentonite within these sheets comes in two forms: dry bentonite which requires hydration of the bentonite for it to swell, bond together and form an impermeable barrier to the passage of liquid; and factory prehydrated bentonite where the bentonite has been activated to provide an immediate impermeable barrier in its as-delivered state. Both systems have the capacity to swell to many times their original thickness, sealing any cracks in structures and self-sealing any movement in the sheets. These membranes are used either externally or sandwiched between secant or sheet piles and the structural concrete of the building they waterproof.

Design considerations

- Bentonite membranes can be applied with minimum surface preparation.
- They can be applied to green concrete and where the surface to which they are applied is damp.
- Bentonite remains 'live' and as such can self-seal minor punctures and defects when installed.
- Manufacturers should be consulted when using in saline, acidic or alkaline environments as some bentonite systems have limitations of usage in these conditions.

Category 4: Liquid-applied membranes

Liquid-applied membranes are one- or two-part systems. They are applied cold, generally in two coats as a bitumen solution, elastomeric urethane or modified epoxy. They can be applied both externally and internally. In the latter case, the loading coat must be strong enough to resist hydrostatic pressure, unless used as a vapour barrier in Type B construction.

Design considerations

- Being jointless, they maintain continuity of membrane.
- May be applied to difficult substrate profiles.
- Elastic and flexible, thus accommodating minor movement and shrinkage within the structure.
- Can protect the structure against aggressive soils and groundwater when applied externally.
- Have high substrate adhesion and chemical resistance.
- When applied internally, must be restrained by a loading coat.
- Substrate must be free from surface water for bonding to occur.
- Requires good surface preparation.
- Careful application needed to achieve correct thickness of dried film.

Category 5: Mastic asphalt membranes

Mastic asphalt membranes are applied in three coats as hot, mastic liquid. They cool to a hard, waterproof coating, but retain a degree of flexibility. Application can be external or internal. If internal, the loading coat must be strong enough to resist hydrostatic pressure.

Design considerations
- Because of the multiple coats, there is little risk of defects in one coat being carried right through the total membrane.
- May provide protection against aggressive soils and groundwater when applied externally.
- Substrate must be dry before application.
- Requires protective screed on horizontal membrane before loading coat is installed.
- Externally applied membranes are generally unsuitable for complicated foundations such as piles.

Category 6: Cementitious crystallisation active systems

Cementitious crystallisation active systems are coatings applied as internal or external slurries. By reacting with free lime in concrete, they block cracks and capillaries.

Design considerations
- Provide in-depth waterproofing of concrete and construction joints.
- The chemicals remain active and will self–seal leaks.
- In construction joints, they assist repair of local defects.
- Applied externally, may protect against aggressive soils and groundwater.
- Require good surface preparation.
- Will not self-seal cracks greater than hairline (0.3 mm).
- Cannot be used on building materials containing no free lime.
- Will not waterproof defective concrete, such as honeycombing.

Category 7: Proprietary cementitious multi-coat renders, toppings and coatings

Proprietary cementitious multi-coat renders, toppings and coatings are applied as a layer(s) to form a dense, waterproof membrane. Waterproof renders or toppings consist of a layer or layers of dense cementitious material incorporating a waterproofing component. Cementitious coatings are premixed slurries applied as a thin layer. All are designed to be used inside the structure but can be external.

Design considerations
- Can be applied internally with no loading coat requirement.
- Effective against severe groundwater infiltration.
- Easily applied to difficult substrate profiles.
- When applied internally, defects are easy to find and repair.
- Require good surface preparation.
- Provide a durable surface suitable for direct finish.
- When applied externally, may protect against aggressive soils and groundwater.
- They may be rigid and may reflect any cracking of the substrate, although flesible versions are available.
- Mechanical fixings should be appropriately detailed.
- Bonding of waterproof membranes to concrete or masonry substrates should be continuous, permanent and durable.

ANCILLARY MATERIALS

Waterstops

Waterstops for basement construction may be of one or a combination of the following types, according to the location and function:

The principal types of waterstops can be classified as the following:

a) Passive sections:
   - rubber or flexible polyvinyl chloride (PVC) extruded profiles cast into the concrete on both sides of the joint, either at the concrete surface or mid-depth of the concrete section, to form a physical obstruction to water transmission;
   - steel water bar strips placed mid-depth of the concrete section to form a physical obstruction to water transmission.

b) Active or hydrophilic strips or crystallization slurries:
   - preformed profiles of materials or sealant composition applied to the concrete joint at depth in the section. The materials swell or give rise to crystal growth on contact with water providing an enhanced obstruction. They can used as a sole material or in a composite product with passive waterstop sections;
   - post-injected systems.

c) Permeable hose or other sections that are fixed to the construction joint surface before casting the second pour, to facilitate the injection of a specialist sealing resin into the joint, when required.

Rubber or flexible PVC waterstops.

These are extruded profiles fabricated with junction pieces to provide a linked continuous system through all the joints or discontinuities within a concrete structure.

Plain web profiles are available for non-moving or low-movement construction and contraction joints. Profiles incorporating a centre bulk or box are used where there is movement, as in expansion joints.

Alternatively, waterstops may be cast totally within the site-placed concrete. These are known as internal or centrally placed waterstops. Internal waterstops will resist the passage of water through a joint from either face. However, they can be more difficult to install and fix, can be dislodged during casting of section and are probably best avoided in domestic basements unless great care is taken and the work properly supervised and inspected.

External waterstop profiles are also available and are positioned on one face of the concrete. These rear-fixed or surface waterstops simplify the shuttering and installation but will resist the passage of water only from the face in which they are installed.

Steel waterstops

These are flat metal strips embedded in concrete across joints to form a continuous fluid-tight diaphragm.

Water-swellable waterstops

Such waterstops depend upon a sealing pressure being developed by the water absorption of a hydrophilic material or filler. They are available as strips for bonding or nailing to the first-placed concrete immediately before the second pour. The strips may be wholly of hydrophilic material, or compounded with a rubber, or part of a composite profile. They can be applied against existing concrete since they avoid the problems of breaking out to install a conventional rubber or PVC waterstop. The use of water-swellable strips is generally limited to construction joints.

Hydrophilic material may be applied to a conventional PVC waterstop profile to provide a combined system that may also cater for expansion joints.

Cementitious crystallisation waterstops

These differ from the previous two categories in that the product consists of cements, fillers and chemicals to be mixed on site as slurry. The slurry is applied to the face of the first-poured concrete before the second pour. The waterstopping action results from salt crystallisation, in the presence of water, within the pores and capillaries of the concrete. These products are not suitable for use in expansion joints

Post-injected waterstops

These consist of a perforated or permeable tube fixed to the first pour of concrete in the construction joint with either end attached to fittings connected to the formwork, or protruding from underneath it. The tube is then cast into the construction joint.

After the concrete has hardened, a polyurethane resin or other propriety fluid is injected under low pressure to flow through the tube and, when the exit of the tube is sealed, it flows freely out of the perforations into any cracks, fissures or holes in the construction joint. The injected material then sets to seal all water paths through the joint.

Pump systems

Basement waterproofing sump pump systems are typically provided as a packaged unit comprising a purpose-designed preformed sump liner or chamber with an integrated access cover over, which houses single or multiple automatic float-switch operated pumps. The pumps activate and remove water when it reaches a set height within the liner.

Pumps are always included at the lowest point within a structure, allowing collection of penetrating water by gravity, and then lifting this up to a suitable external discharge point which must be identified and appraised.

Battery backup protection pumps are typically included to protect in the event of a power cut, with additional mechanical pumps being added to provide further redundancy or additional capacity as necessary. Such systems should include high-level alarms to forewarn in the event of a problem, which may alert via local audible alarm or, where required, remote telemetric phone call.

Sump systems may also be employed to accept some water from additional sources such as gullies in light-wells and stairwells, but the system designer should be consulted if any additional sources of water are to be connected into the pump system.

Bandage joint systems

Where movement is expected in joints or cracks – in both new and remedial work – bandage joint systems may be used. These consist of strips of synthetic polymer membrane, bonded across the joint with a suitable adhesive. As systems vary, the manufacturer’s advice on application method and adhesive should always be followed.

Membrane protection products

If construction operations may damage applied membranes, adequate protection must be provided. This can consist of vertical blockwork and a 50 mm screed to horizontal surfaces. Alternatively, protection boards supplied by most membrane manufacturers may be used. They are more convenient since they provide immediate protection. They also eliminate a ‘wet trade’ operation and allow the following works to continue immediately after laying.

Protection boards should be rot-proof and robust enough to withstand site operations. They should therefore be chosen in consultation with the supplier of the waterproofing system. A protection board may be used in vertical applications.

Alternatively, if vertical protection and drainage are required, a geocomposite drainage sheet could be used; its greater cost may be offset by the reduction or elimination of hydrostatic pressure on the membrane as a result of the better drainage.

Where protection products are used to protect the waterproofing membrane, backfilling should be carried out in layers with care, compacting each layer to avoid subsequent settlement of backfill material. This should minimise the likelihood of the waterproofing membrane and protection boards being dragged down the structure as uncompacted backfill settles.

OTHER DESIGN CONSIDERATIONS

As well as the general characteristics of the categories of waterproofing already given, certain aspects are common to several systems. The final selection made will depend on the form of structure and on other design and construction aspects such as the need to control water vapour.

Vapour control

As well as controlling water ingress, Categories 1 to 5 can also act as an effective vapour check. Although this is often seen as an advantage, some structures need to allow for water vapour movement, in which case a Category 6 or 7 system will be needed. The vapour resistance of Category 7 systems can vary significantly with the product. It is important, therefore, to decide whether water vapour needs to be controlled or not – see *Condensation* below.

Chemical and gas barrier

An external membrane can protect the main structure from water and possibly water vapour. However, if the ground or groundwater is contaminated with aggressive chemicals, radon, methane and other gases, their precise nature and concentration must be determined and the membrane manufacturer must be consulted to ensure that it provides an effective ground barrier appropriate to the site conditions. See also Approved Document C of the Building Regulations(16) for requirements with respect to site preparation and resistance to contaminants (e.g. radon and other ground gases) and moisture (see also *Soil type and conditions* above).

System restraint

Categories 1, 3, 4 and 5 needs to be restrained so that they can resist the forces involved. When applied externally, the structure provides the restraint. When Categories 1, 4 and 5 are employed internally, they need to be restrained by a loading coat. This will take up space within the structure. Categories 2, 6 and 7 can be used internally without a loading coat.

Substrate movement

Categories 1 to 5 have reasonable strain capacity and will usually accommodate some flexing or design cracking of the structure. Categories 6 and 7 may be more brittle with low strain capacity and so less tolerant of structural flexing. They may crack if the substrate cracks but may still control moisture ingress if the cracks are fine.

Expansion joints

Care is needed when considering systems used with expansion joints: always consult the manufacturer. However, although joints can be detailed to cater for movement, it is far better to design the structure in a way that avoids expansion joints.

Defects and repair

Categories 1, 3, 4, 5 and 7 rely on their impermeability to control water ingress. Defects in the materials or in their jointing may require remedial treatment. With externally applied systems, this may mean excavation. It is often difficult, therefore, to reach defects in externally applied systems, and there can be problems in locating defects in systems that are not continuously bonded. Particular difficulties will arise where the water table is high permanently or for long periods, since ground dewatering would be required. Access following construction may not be desirable or possible, in which case an internal system (Type A or Type C system) or the use of Type B system may be preferable. The performance of internal waterproofing systems can be affected by any puncturing of the system by fixings and fittings. The performance of Category 2 can also be affected by failure or blockages of any pumps or discharge systems. Categories 3 and 6 are active systems and can 'self-heal', even years later.

Condensation

Because window areas of basements are often reduced or recessed they can restrict natural ventilation in other areas of a house. They therefore need to be carefully designed to ensure condensation is controlled and ventilation maintained.

Approved Document F[6] gives guidance on ventilation, how to estimate its risk and effects, and design solutions for both above- and below-ground structures (basements).

Water vapour tends to move from areas of high vapour pressure to low vapour pressure. The vapour pressure in a specific area relates directly to the humidity of the air at that point, which in turn depends on the temperature and the amount of free water available to be released into the air.

Although it is commonly thought that water vapour will always pass from the ground into a basement, this is not so. In most domestic situations, water vapour will move, if the water table is low, from within the structure towards the ground. If the water table is high, water vapour will penetrate the basement but usually at such a low rate as to be of little consequence.

A vapour-permeable waterproofing system can thus be advantageous if the vapour tends to move from the inside to the ground, but will allow relative humidity within the basement to rise if the reverse conditions apply.

A system that acts as a vapour check can be advantageous if the vapour tends to move from the ground into the basement but similarly will allow the relative humidity to rise if the reverse is true. However, a vapour check applied externally can cause interstitial condensation[5]. This should not be a problem as long as it is allowed for in the design.

In general, careful consideration must be given to the effect that the waterproofing system has on the resistance to water vapour. In practice, where internal conditions in a basement are controlled by properly designed heating and permanent ventilation, the condensation risk can be reduced to be no worse than in the rest of the dwelling. The advantages/ disadvantages of vapour-permeable/impermeable systems are then usually negligible.

If the environment is controlled solely by natural air movement, the condensation risk increases and more care is needed in the choice of waterproofing and insulation systems.

Thermal insulation

Including a basement can improve the thermal insulation of the structure since the lower basement slab is more efficient than a slab at ground level. The surrounding earth will also improve the thermal transmittance of the basement walls. For guidance on the level of insulation to achieve a specified U-value of between 0.25 to 0.6 W/m^{2}K was given in *Approved Document – Basements for dwellings*[4]. The pending replacement of this publication will provide guidance for values between 0.15 to 0.30 W/m^{2}K. Where insulation is required, it may – depending on whether it is placed inside or outside the basement walls – dictate the form of construction and waterproofing system. Any external insulation must have low water absorption and be frost resistant to prevent loss of its thermal insulation properties.

EFFECT OF CONSTRUCTION OPTIONS

Basement site locations and forms

There are many potential basement locations. Design forms and waterproofing methods will therefore depend on, for example, the prevailing terrain, soil conditions, water tables, proximity of adjacent buildings and the requirement of the end user. Typical locations and forms of basement construction are illustrated and summarised for three types of site: sloping, flat and infill.

Sloping sites

Sloping or elevated sites allow both full and semi-basements or split-level dwellings to be built, with cut-and-fill options (Figure 7). Since these sites can normally be effectively drained, properties would be at little risk from percolating groundwater. Economical Type A tanked basements can therefore be built, simply designed in concrete or masonry, with appropriate drainage provisions. More robust Type B or Type C may also be used.

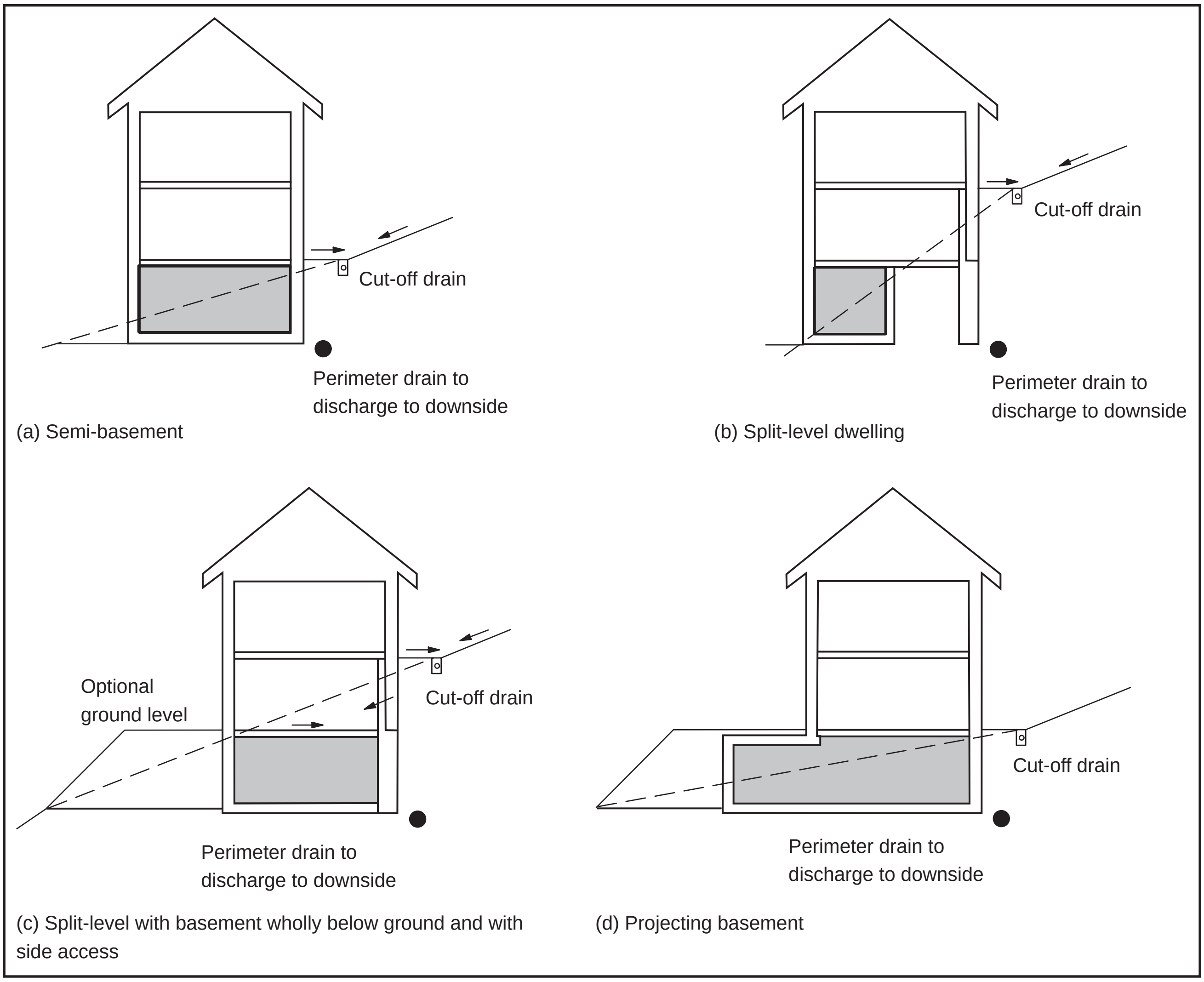


Figure 7: Basements on sloping or elevated sites

Flat sites

Flat sites provide the opportunity for basements wholly or partially below ground (see Figure 8). Excavated material may be reused to landscape around basements partially below ground, giving the dwelling an elevated aspect.

Type A or C construction may be used if the site is free-draining or is in an elevated position with drainage provisions.

Basements constructed on a flat site in low-lying areas with impermeable soils can be difficult to drain. Where there are problems with perched, fluctuating or permanently high water tables, substructures designed in water-resistant Type B construction or Type C combination systems would therefore be advisable. Any window fire exit must be above the highest anticipated water level.

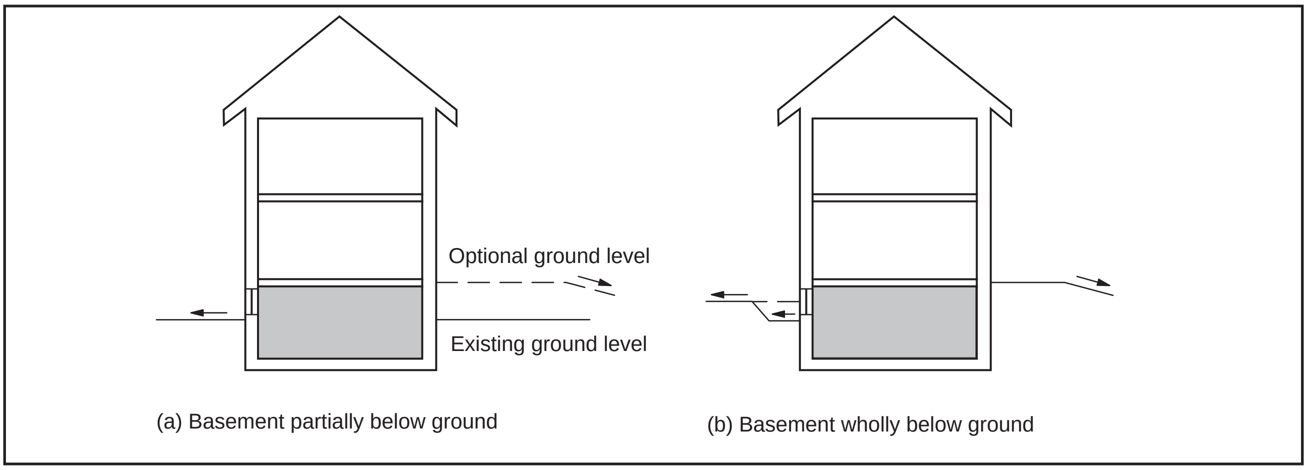


Figure 8: Basements on flat sites

Infill sites

Inner-city areas provide more opportunities for house basement construction because high land values increase property costs. Infill sites between adjacent dwellings can be developed (Figure 9). However, these may be more susceptible to periodic flooding from existing defective water mains. Design preference is for Type B construction (perhaps with internal waterproofing) or Type C drained cavity provisions.

Where adjacent properties have to be underpinned, it can be difficult to achieve continuity in external or pre-applied waterproofing systems. Alternative systems should therefore be considered.

Semi-basements on infill sites can probably use a bunded catchment area. If so, the bund walls should be designed as Type A tanked construction or Type B water-resistant concrete, with a drainage sump for rainwater (similar to the sump shown for Type C constructions – see Figure 6). Clearly, this form of construction can be adopted for both flat and sloping sites.

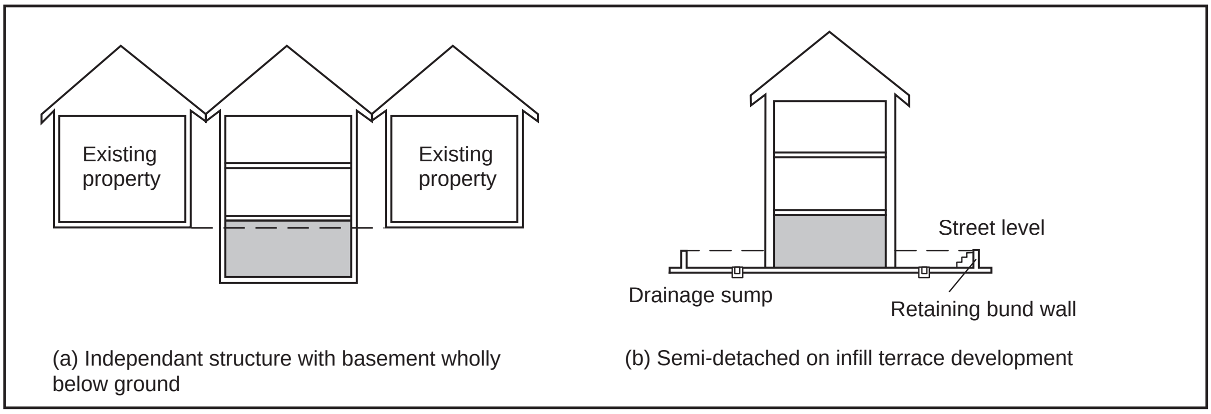


Figure 9: Basements on infill sites

Design factors affecting construction

Basement drainage

Attention should be given to the need for land drainage requirements for Type A tanked structures and reinforced concrete Type B structures. Lack of proper maintainable drainage to basement surrounds may result in hydrostatic pressure and subsequent leakage if there are any defects in the waterproofing or concrete.

Installing an appropriate geocomposite drainage sheet and fin or land drains will help deflect and drain water away from the perimeter of buildings, so improving the total waterproofing (see *Waterproofing details* below).

An additional water-activated pump may be used to deal with runoff water. This can be particularly useful where the water table becomes perched because the soil is too impermeable to handle the percolating surface water, as with a clay soil. Such pumps, which are normally installed outside the structure, can be used to ensure that the severity of water conditions does not exceed that taken for design. They can be used either to extend the application of Type A, B and C construction or to provide an additional escape for water, but may not be appropriate in all situations. The outlet from such pumps must discharge to areas where the water cannot feed back to the pump inlet.

The orientation of the basement area to the general flow of groundwater should also be considered – see Figure 10. Any L- or V-shapes with a re-entrant angle against the natural drainage flow can act as dams and increase the risk of hydrostatic pressure. Where basements are constructed against the flow of water, sub-drainage should be provided and graded to storm drains or open outlets on the downside of the building.

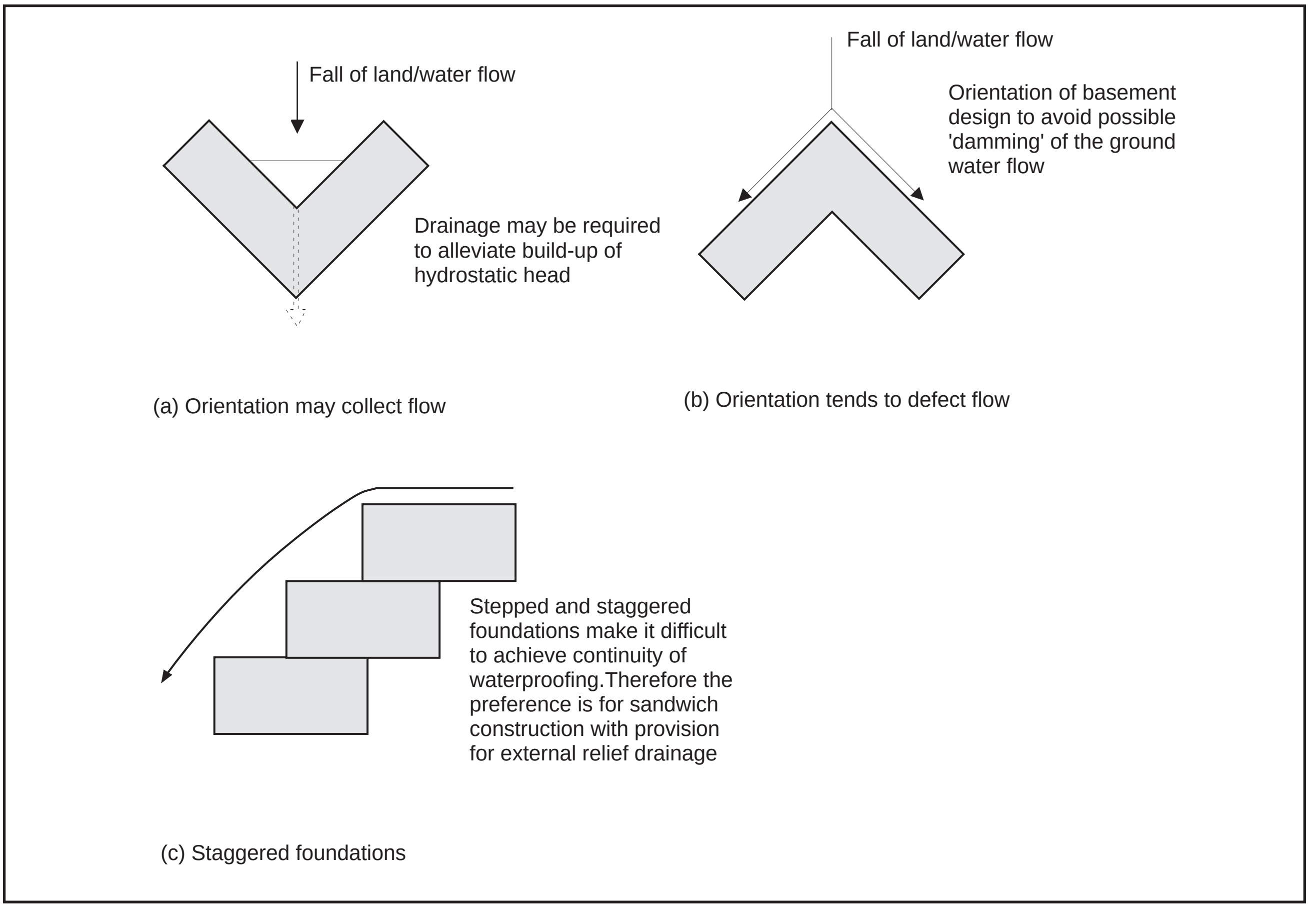


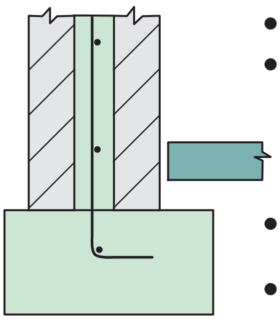
Figure 10: Drainage, orientation and foundations

Foundation design

Structures should be designed to keep foundations as simple as possible. Expansion joints and complicated shapes are best avoided, since they are points of weakness and require a lot of attention to detail.

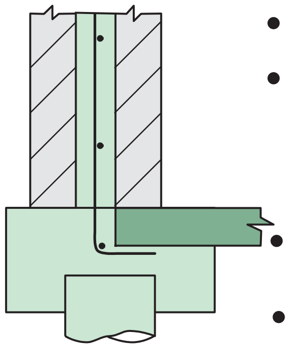
Complicated foundation designs do not lend themselves to external waterproofing. When deciding on the form of construction and waterproofing, the designer should consider ‘buildability’ and the acceptable level of risk, relative to the cost of achieving the desired performance. Consideration must also be given to how remedial work may be carried out if this performance is not attained.

Common foundation designs are shown in Figure 11 with suggested waterproofing options.



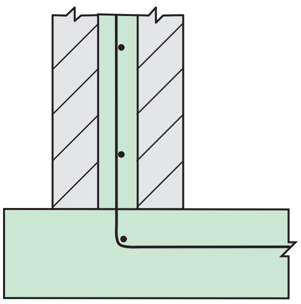
- Type A (barrier) protection
- External or internal waterproofing. But external waterproofing may be required to modify the exposure situation of a masonry retaining wall
- Retaining wall may also be of in-situ concrete
- High-risk design due to lack of continuity between wall and floor. Reinforcement may be required to control cracking

(a) Strip foundation



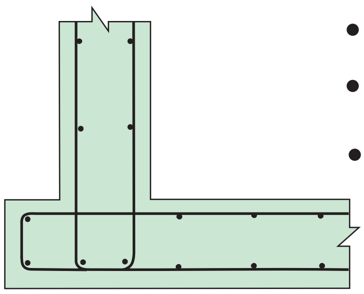
- Type A (barrier) protection
- External or internal waterproofing. But external waterproofing may be required to modify the exposure situation of the retaining wall
- Retaining wall may also be of in-situ concrete
- Care needed to achieve continuity of waterproofing membrane when applied externally

(b) Piled ring beam and reinforced masonry wall



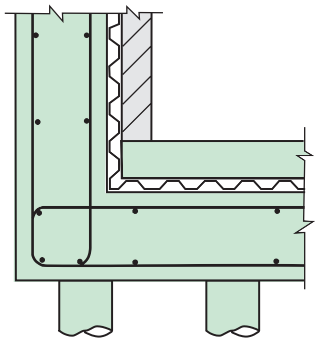
- Type A (barrier) protection
- Simple design
- Retaining wall may also be of in-situ concrete
- External waterproofing may be rquired to modify the exposure situation of the retaining wall

(c) Reinforced masonry wall with reinforced concrete raft



- Type B (structurally integral) protection
- Reinforced concrete design to BS EN 1992
- May be combined with external/internal waterproofing or drained cavity construction to enhance performance

(d) Reinforced water-resistant concrete box



- Type C (drained) protection
- Internal drained cavity construction
- Concrete design to BS EN 1992
- Without a drained cavity this could represent a Type B structure on a piled foundation

Figure 11 Common foundation/waterproofing constructions

WATERPROOFING DETAILS

Details of waterproofing options and forms of construction

The principal form of construction outlined in Design Principles and Types of waterproofing Construction may involve a variety of waterproofing options. The principal details and elements of the main waterproofing systems are shown in Figure 12.

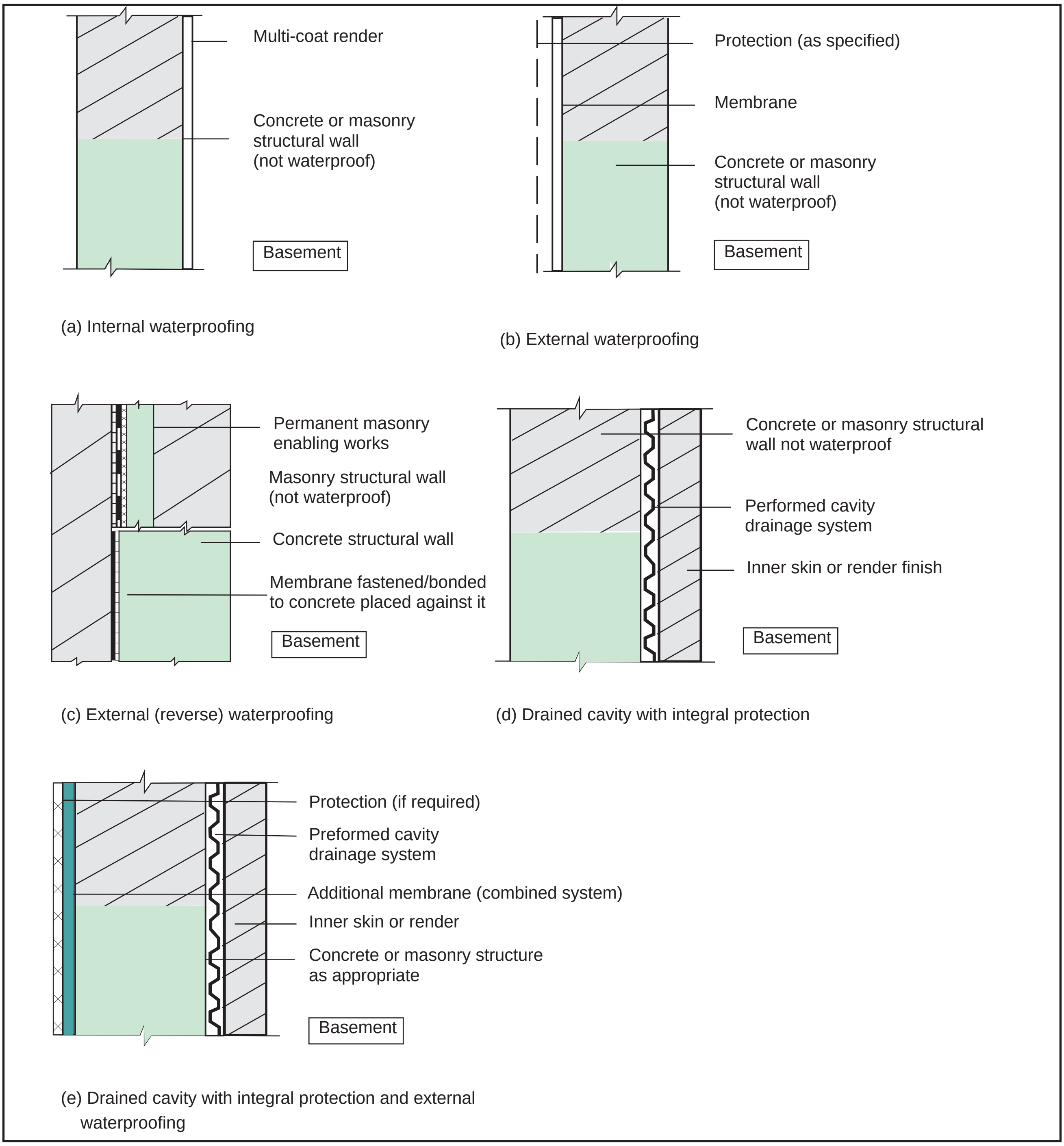


Figure 12: Alternative waterproofing systems

As already indicated, each waterproofing system may be used as the sole protection or combined to give additional protection. The final choice depends on the site conditions and the level of waterproofing necessary. Some systems may also make use of externally applied subsurface drainage (e.g.geocomposite drainage sheets) (see below and Figure 13) to prevent or lessen hydrostatic pressure reaching the external structure or waterproofing system.

Subsurface drainage

Subsurface drainage may also be appropriate for preventing or lessening the risk of hydrostatic pressure reaching the external structure of the waterproofing system. It can be provided by one of the following methods:

a) permeable granular fill;
b) no-fines or hollow blockwork;
c) geosynthetic drainage composite;
d) underslab drainage.

This form of drainage can be effective in controlling percolating water where the outlet from the subsurface drainage can drain freely away. The ability to drain will depend on the permeability of the ground (see Table 2 which gives an indication of the effect that the site's soil may have on retaining water). The use of subsoil drainage on low-permeability soils (e.g. clay) will not be effective unless this drainage system incorporates a sump and pump. Even then the water may simply return into the system and the pump may effectively just be recirculating the caught water. Such pumps will need to be sufficiently sized and designed to operate over a longer duration. For these reasons the designer may be best advised to select a more robust waterproofing construction that is capable of providing water resistance without the need for subsurface drainage. Clearly subsurface drainage may still be employed. See Figure 13 for examples of the positioning of land drains.

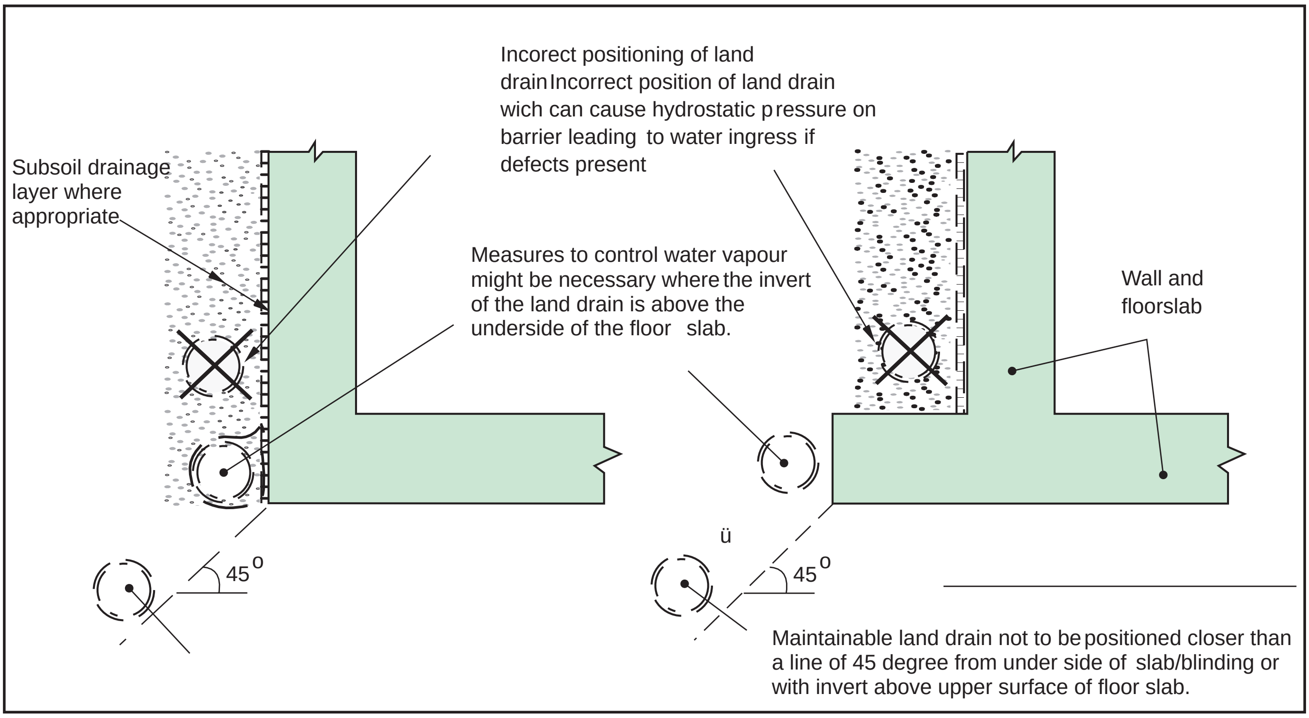


Figure 13: Subsurface drainage positioning

To be effective, all laps in the waterproofing system must be fully weathered and sealed. The system will generally need to be continuous around the basement walls and floors and extend at least 150 mm above ground level. Continuity of waterproofing between the junction of the superstructure and the basement walls must also be assured (Figure 14).

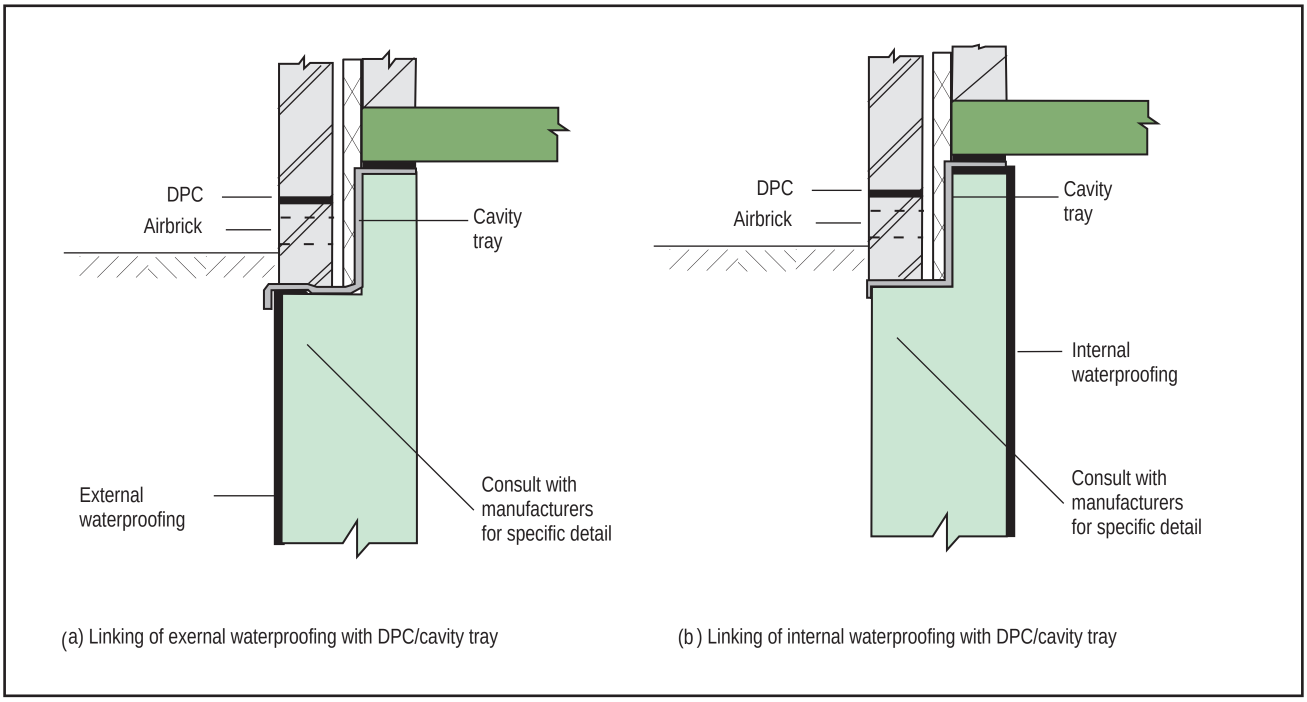


Figure 14: Continuity of waterproofing – linking with superstructure

The effect foundations have on achieving continuity in the waterproofing system must be assessed (see *Foundation design* above). Details to cater for steps in the foundation can be produced as in Figure 15.

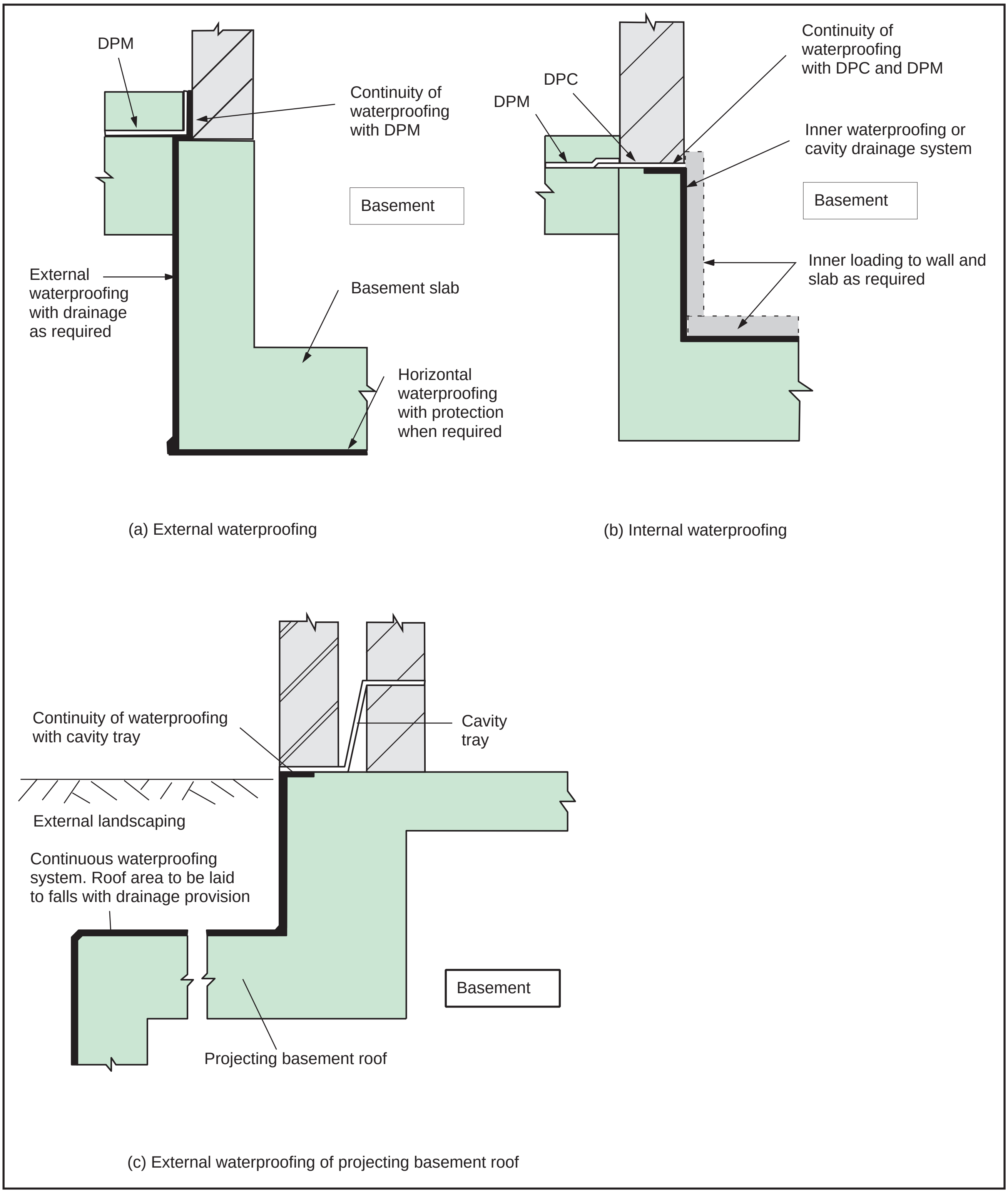


Figure 15: Continuity of waterproofing – step changes in construction

Another area that requires consideration in foundations is the junction between a pile and the basement floor (Figure 16). The presence of the reinforcement can inhibit the continuity of a membrane. Consideration can be given here to the use of water-resistant concrete and/or appropriate membrane details (seek manufacturer's advice for this and similar details).

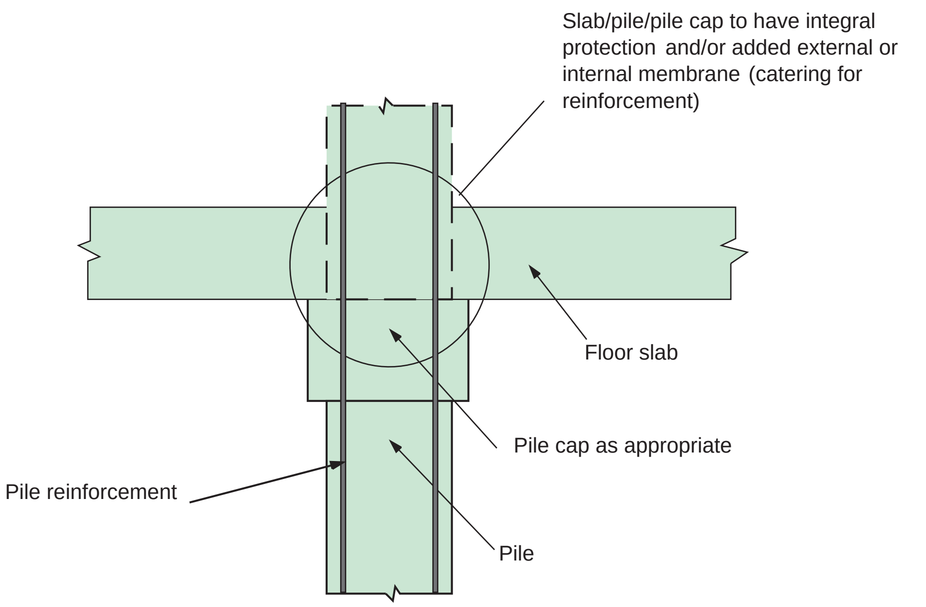


Figure 16 Junction between pile/pile cap and basement floor

Discontinuity of waterproofing should be avoided as it has a higher risk. However, certain situations may allow discontinuity but this should be discussed with an appropriate specialist because of its effect on water and gas resistance of the structure. However, the requirements to control radon and other ground gases may eliminate discontinuity of the waterproofing.

Preference should always be given to taking services up and over the walls to avoid penetrating the basement walls below ground and problems of backflow. This should be considered even where the invert of the main sewer is below the level of the basement floor, otherwise backup of the sewer may load to the top of the inspection chamber resulting in hydrostatic head and backflow to the facilities in the basement. Drainage of light-wells may be similarly affected if gravity fed to mains drainage. There will be several ways for this to be facilitated and one example is given in Figure 17, which makes use of a general service pit that can enable all service entries to be installed off the critical path. Measures to control ingress of radon and other ground gases may also be required.

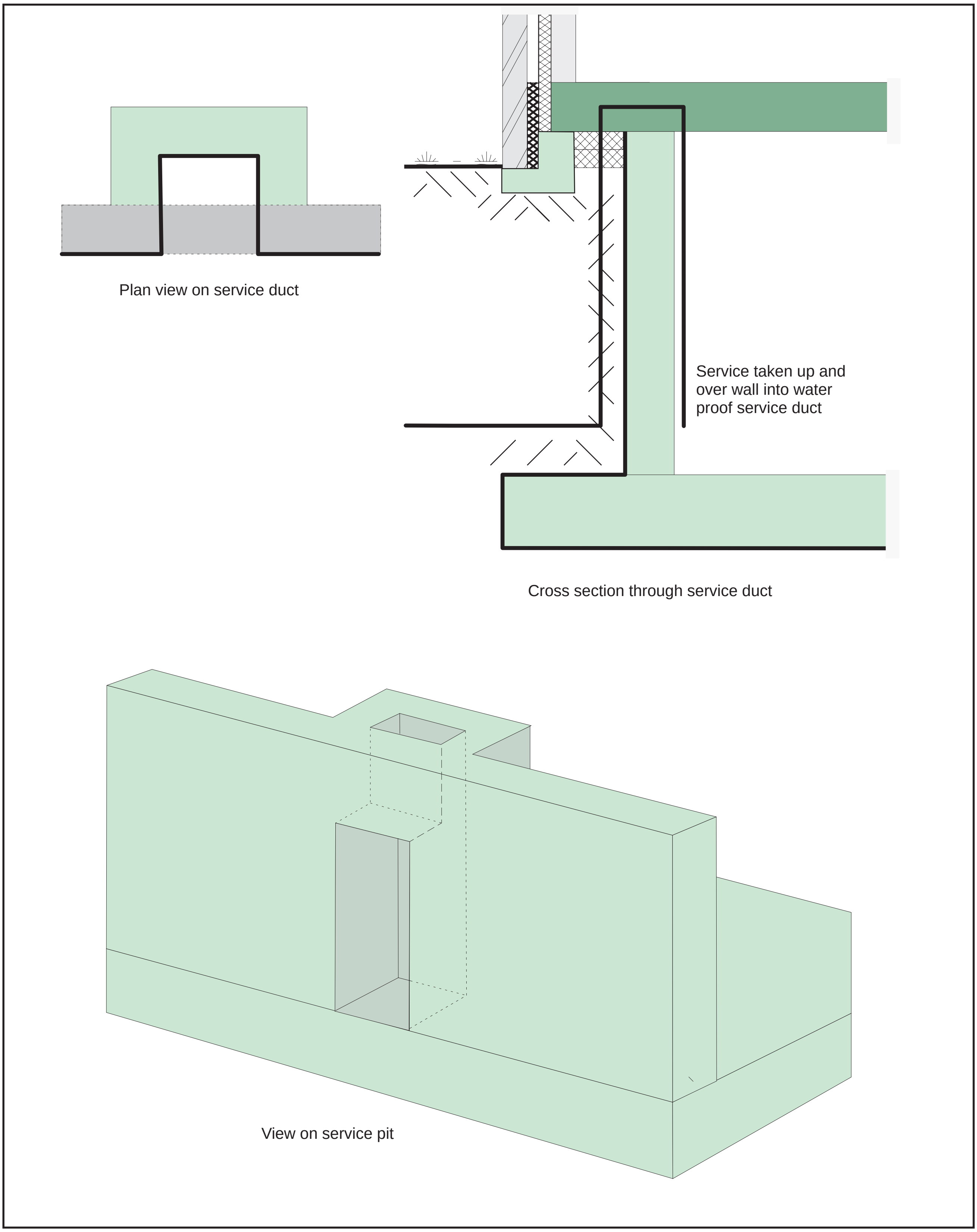


Figure 17 Service entry by way of a service pit (avoids service penetrating wall)

If holes for services are unavoidable, they must be properly detailed. Details will vary according to the category and size of the penetration and the waterproofing system being used. The service itself must also be waterproofed into the service penetration.

Because of the variations between different waterproofing systems and type and form of service, they must be discussed with the manufacturer and specific details decided for the project in hand. Avoid using general manufacturer's details as they are most unlikely to suit every case.

GLOSSARY

Biofouling	The undesirable accumulation of micro-organisms, plants, algae, and/or animals on wetted elements
Cavity drain membrane	Dimpled, flexible, high-density polymer sheet, which can be placed against the internal face of a structure after construction and is designed to intercept water penetrating the structure and direct it to a drainage system
Combined system	Two or more waterproofing systems used together
Construction joint	Joint formed in-situ, for example in concrete, when continuity is not possible
Cut-off wall	Embedded retaining wall designed to surround and seal off an area, to inhibit water inflow from the surrounding area
Damp	The condition of a material when wetter than air dry
Damp area/ Dampness	Area which, when touched, might leave a light film of moisture on the hand but no droplets of water (i.e. beading)
Drained cavity	A continuous cavity which intercepts and drains away incoming water
Embedded retaining wall	Wall used to support the sides of an excavation, installed in advance and penetrating below the lowest level of the below-ground construction
Expansion joint	Joint that permits relative movement caused by expansion and contraction due to changes of temperature or moisture
External waterproofing	Where the waterproofing system is positioned and placed against the outside face of the main structure
Free-draining	Ground through which free water rapidly drains away
Ground barrier	Impermeable barrier between the structure and the ground intended to prevent or impede the ingress of water, dampness, radon, methane and other ground gases and contaminants
High water table	Where the water table is above the underside of the lowest floor level
Hydrostatic head	Water pressure, expressed as an equivalent depth of water
Hydrostatic pressure	The water pressure exerted as a result of a hydrostatic head
Integral protection	Where the structure itself provides the necessary protection to the passage of water
Kicker	Small concrete upstand, cast above floor level to position wall or column formwork for the next lift
Kickerless construction	A mechanical means of retaining formwork in position, eliminating a kicker
Loading coat	A material applied to the waterproofing membrane to enable it to resist hydrostatic pressure
Low permeability	Resistant to water penetration
Low water table	Where the water table is permanently below the underside of the lowest floor level
Membrane	A material which forms a continuous effective barrier to the passage of water
Moisture	Water in the form of vapour as well as liquid

Perched water table	Reservoir of water in the ground maintained permanently or temporarily above the standing water level in the ground below it, and is caused by the presence of an impervious soil or a stratum of low permeability
Protection layer	An element used to provide protection to a waterproofing system
Sandwiched waterproofing	Where the waterproofing system is between the two non-tied leaves of the main structure
Seepage	Slow passage of moisture through discrete pathways of a structure
Tanking	Application of an appropriate waterproof membrane to the walls, the base slab and, where relevant, the roof of a below-ground structure, such that the entire envelope of the structure below ground is protected against water ingress
Type A (barrier) protection	Protection against water ingress which is dependent on a separate barrier system applied to the structure
Type B (structurally integral) protection	Protection against water ingress which is provided by the structure
Type C (drained) protection	Protection against water ingress into usable spaces which is provided by the incorporation of an appropriate internal water management system
Vapour check	Membrane or other element that restricts the transmission of water vapour
Vapour resistance	The ability of a material to resist vapour penetration
Water	Water in its liquid form
Waterproof	Impervious to water (also known as 'watertight')
Waterproofing	Application of waterproof/water-resisting materials
Waterproofing system	Materials and methods used to protect a structure from water ingress and might also provide resistance to the diffusion of water vapour
Water resistance	Ability of a material to prevent water penetration
Water-resistant	Having a high resistance to water penetration
Waterstop	Material designed to inhibit the passage of water through discontinuities in the structure
Water vapour	Water in its gaseous state
Water vapour resistance	Ability of a material to resist water vapour penetration

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Chapter 5.1 'Substructure and ground-bearing floors' includes guidance on basements.
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