good building guide

bre

Basement construction and waterproofing:

Site investigation and preparation

GBG 72

Part 1

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The requirement for building on sloping sites or increasing the area of buildings within limited height and footprint can often be met by incorporating a basement. The basement was popular in Victorian and Georgian times, particularly in housing, and recent industry initiatives have confirmed that there are still economic benefits to be had from including a basement.
One of the main challenges to be considered when designing below-ground accommodation is preventing water or water vapour ingress.
Part 1 of this Good Building Guide outlines the principles of constructing a waterproof basement and Part 2 describes the main methods of perimeter construction with advice on safety, insulation and installation of services.

Figure 1 Basement under construction on the BRE Innovation Park

Courtesy of Hanson

The economic case for incorporating a basement is obvious on city centre sites where deep basements for storage or car parking are common.

Basements were common in Georgian and Victorian times but rare in the 20th century when houses tended to be built on the ground on shallow foundations. Present day trench fill foundations are at least a metre deep and on clay or poor soils can be as much as 3.5 metres deep. In these circumstances, extending the foundations a little further and extending the excavation to create a basement becomes an economically viable proposition.

The Basement Information Centre (TBIC, previously the Basement Development Group or BDG) made cost estimates in 1991 (BDG), 1999 (BDG) and 2005 (TBIC) for various basement configurations. The 2005 cost estimate shows a typical three-bedroom detached house with a fully below-ground basement, divided into rooms and fully furnished to cost only 6.7% more than a house of similar size without a basement (11.5% in 1991 and 8.7% in 1999). A similar house with a partial basement was shown to cost only 1.9% more in 2005. Although the construction costs for a basement house are higher than an equivalent non-basement house, there is the potential to save 21% on land costs, which will be greater than the extra cost for incorporating a basement. These figures show the increasing viability for basement houses. Energy costs should also show savings of around 10% for a detached basement house.

Basement construction is used for a room or rooms in a building entirely or partly below ground level, including sloping sites where the rear and side walls are earth retaining.

Requirements for the structure are that it should:
- resist soil loading,
- support the building above, and
- remain dry, internally.

A variety of wall and floor constructions and waterproofing systems are available to the designer.

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Site investigation

The walls, the ground floor and the basement floor must resist structural loads, including possible flotation of the structure, and imposed loads from the surrounding soil. The waterproofing design and structural design both need to be considered together having initially taken account of the suitability of the site.

The site survey will need to include the following checks.

- **The level of the water table** which will vary with the time of the year, ie lower following a dry summer, and will be influenced by natural drainage and the presence of natural drainage
- **The ground conditions**
- **The presence of existing drains**
- **Possible ground contamination or radon:** effects of contaminants on materials used in basement construction must be considered (some membranes are vulnerable to degradation in the presence of certain contaminants). See BRE's *Construction of new buildings on gas contaminated land* (Hartless 1991) and *Designing quality buildings: a BRE guide*.
- **Existing foundations that it may be possible to reuse.** See *Reuse of foundations for urban sites* (Butcher et al 2006).

Box 1 Water table levels

High
The water table or perched water table* is above the underside of the basement floor slab

Low
The water table or perched water table* is permanently below the underside of the basement floor slab

Variable
The water table varies between high and low situations so the length of time during which a particular condition occurs will influence the design

* Perched water table is a reservoir of groundwater maintained temporarily or permanently above the standing water level in the ground below it. This is possibly caused by an impervious or low permeability stratum.

Drainage characteristics of the soil

Initial consideration will be the position of the water table which may be low, high or variable (Box 1).

Time of year is relevant as the water table can vary with the season. Flow of groundwater should be taken account of, either by positioning the building to avoid any damming effect, or by introducing a subsoil drain to alleviate hydrostatic pressure (see Figure 1).

Different soil types will have varying drainage characteristics, coarse soils, ie rocks, boulder and other gravels, sands and sandy soils, all have good to excellent drainage potential, whereas clayey silts and organic silts range from impervious to fair drainage properties. More detail is contained in Table 2A.1 of the *Approved Document: Basements for dwellings* (TBIC 2004).

Table 1 Choice of construction waterproofing. Reproduced from Approved Document: Basements for dwellings by permission of TBIC

Water table	Type A construction (Tanked protection)		Type B construction (Structurally integral protection: water-resistant concrete)				Type C construction (Drained cavity)	
	Water-proofing	Plus drainage	BS 8110	Plus water-proofing	BS 8007	Plus water-proofing	BS 8110 Plus moisture barrier	BS 8007
Low (soil permeability may affect risk)	✓	✓	✓	✓	✓ Acceptable	✓	✓	✓
Variable (subject to prevailing soil conditions)	← See Note 2 →			✓	✓ Construction	✓	✓	✓
High	← Not recommended →			✓ See Note 1	✓	✓ See Note 1	✓	✓

Decreasing risk of moisture penetration →

Notes:

1 In high water table conditions, the effectiveness of the additional waterproofing system will depend on its application and bond characteristics when permanently under water. (Seek manufacturer's advice.)

2 Constructions may produce acceptable solutions when variability is due to surface water or other infrequent occurrence and not due to an actual rise in water table. (Seek manufacturer's advice.)

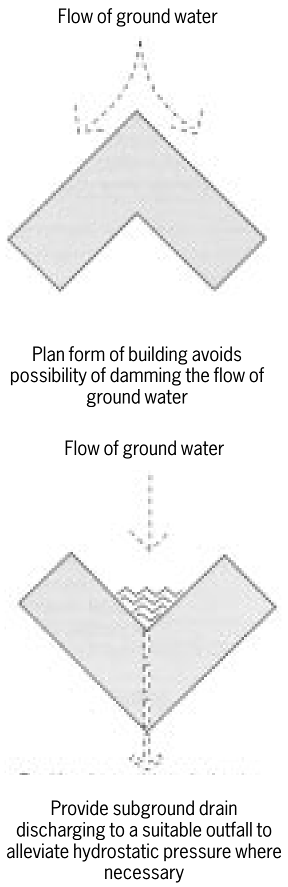

Figure 2 Effect of building orientation on flow of ground water. Reproduced from *Approved Document: Basements for dwellings* by permission of TBIC

The acceptability of construction types for a low, high or variable water table is summarised in Table 1.

Site preparation and the control of moisture

Control or complete exclusion of moisture is one of the main considerations when designing a basement. On some occasions, for example where the basement is unheated, control of water vapour may be necessary. Some dampness results from condensation and guidance on avoiding its worst effects are covered in BRE's *Understanding dampness*. The focus of this *Good Building Guide* is more on dampness due to penetration of groundwater, and/or rising damp.

Water may be under considerable pressure where the water table is high. In principle, effective tanking of a basement requires that the walls and floor (and importantly the junction of the wall and floor) should be resistant to the passage of water. However, on a relatively dry site, drained cavity construction can be used as an alternative to tanking provided measures are included to remove any water from a drainage channel.

The building should be orientated and designed at the layout stage to avoid the risk of increasing the hydrostatic pressure on the basement (Figure 2). Where this is not practicable and where there is likely to be a build-up of water pressure, the design should cover a full hydrostatic head or, as illustrated in Figure 2, provide a roddable subground drain to alleviate hydrostatic pressure.

The design brief will specify the proposed use for the basement, although any possible future change in use should be considered as it will be either very expensive or not possible to upgrade the performance of the construction at some later date. BS 8102 gives four grades of basement use, together with acceptable forms of construction (Table 2).

Types of construction

Three types of construction are specified in BS 8102 and are illustrated in Figure 3:

- Type A: tanked protection,
- Type B: structurally integral protection, eg water-resistant concrete,
- Type C: drained cavity.

Type A: Tanked protection

Construction comprises a concrete slab and walls of reinforced concrete or blockwork with external, sandwiched or internal waterproofing. The structural waterproofing must be able to resist water that may be under hydrostatic pressure. However, attention is drawn to Table 1 which indicates limitations to Type A construction when hydrostatic water pressure occurs. If blockwork is used for the walls, a cement rendering or flush pointing may be necessary to produce a satisfactory surface to receive the waterproofing.

Table 2 Level of protection to suit basement use. Data from BS 8102

Grade	Basement use	Performance level	Construction	Comment
1	Car parks, plant rooms, etc. (not electrical)	Some seepage and damp patches tolerable	Reinforced concrete to BS 8110	Groundwater check for chemicals
2	As for Grade 1 above but need for drier environment (eg retail storage)	No water penetration but vapour penetration tolerable	Tanked or as above or reinforced concrete to BS 8007	Careful supervision. Membranes well lapped
3	Housing, offices, restaurants, leisure centres, etc.	Dry environment required	Tanked or as above or drained cavity and dpms	As for Grade 2 above
4	Archives and controlled environment areas	Totally dry environment	Tanked or as above plus vapour control or ventilated wall control and floor cavity and dpm	As for Grade 2 above. Check for chemicals in groundwater

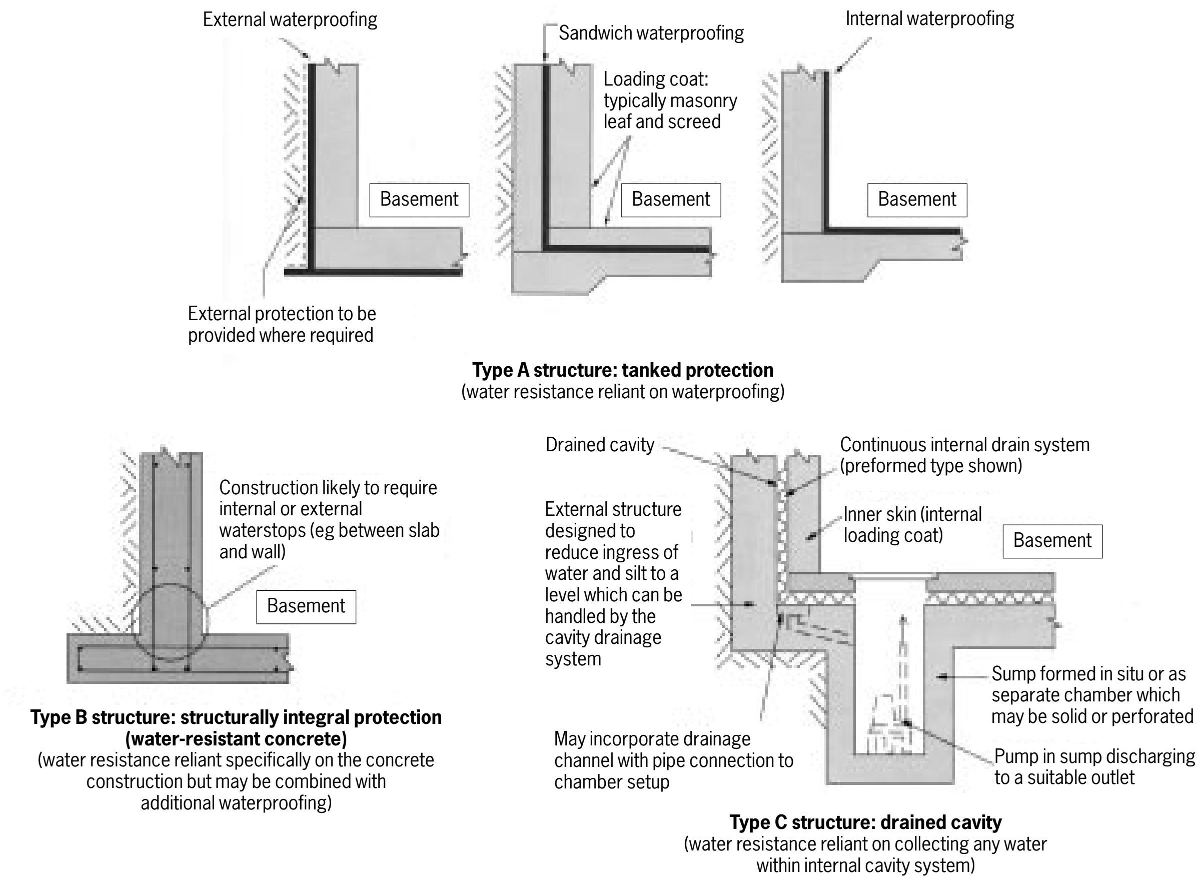

Figure 3 The three types of basement construction. Reproduced from *Approved Document: Basements for dwellings* by permission of TBIC

Type B: Structurally integral protection

Built of reinforced or prestressed concrete, the design should be carried out to the recommendations of BS 8007 or BS 8110. Waterstops will be required: external, internal, crystallisation, hydrophilic or injected will all be appropriate (see section on *Other waterproofing products*).

Type C: Drained cavity

As implied, a cavity provides a route for any water which seeps through the external wall to drain down to a sump or other measures. The external wall can be built from concrete or masonry and must provide adequate resistance to groundwater. Otherwise, the drainage system may be overwhelmed during storm conditions.

A proprietary cavity drainage system is typically used to create the floor and wall cavity, which is finished with a screed or render/blockwall. Alternatively, although less common these days, a system using an inner block wall with weep holes at the lowest course discharging into special floor tiles or no-fines concrete may be used.

A sump pump and its controls (possibly duplicated or alarmed where failure is unacceptable), and drainage system will be required to handle water seepage, although on sloping sites levels may allow the design of a gravity system. Where feasible, provision for rodding the drainage system to remove any silt should be introduced.

Waterproofing systems may also provide a high resistance to water vapour. Type B construction, without an added membrane, will not be as resistant to water vapour as Types A and C construction. However, water vapour is unlikely to be a problem with a heated basement. Consideration to resisting water vapour, therefore, tends to relate to unheated basements.

Box 2 Categories of waterproofing systems

- Bonded sheet membranes
- Cavity drain membranes
- Bentonite clay active membranes
- Liquid-applied membranes
- Mastic asphalt membranes
- Cementitious crystallisation active membranes
- Proprietary cementitious multi-coat renders, toppings and coatings

Box 3 Other waterproofing systems

- Waterstops
- Water-swellable waterstops
- Cementitious crystallization waterstops
- Post–injected waterstops

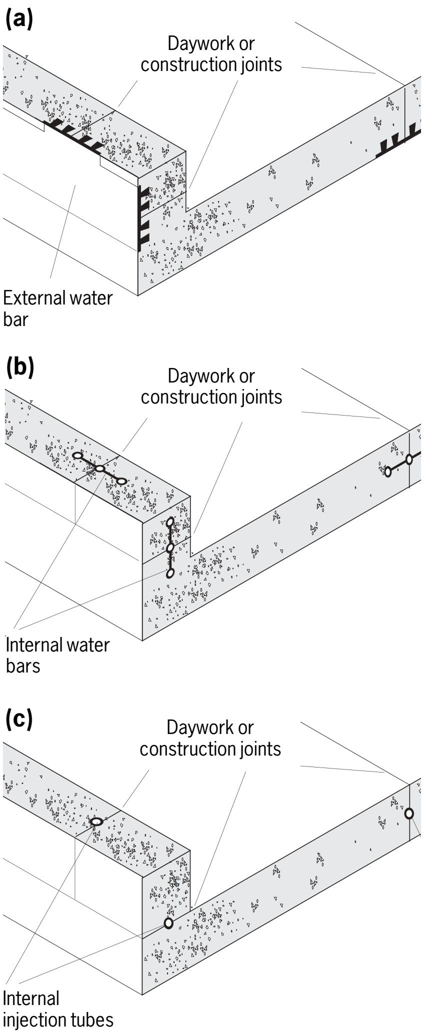

Figure 4 (a) Dovetail section rubber or plastics strip cast into the shuttered face of the pour. **(b)** Dumb-bell section rubber or plastics strip cast into the open face of the shuttering. **(c)** Perforated tube cast into the open face of the pour for later injection of resins into the joint

Waterproofing systems

Most of the proprietary waterproofing systems are covered by either British Standards or third-party certification (Box 2). Any vertical, horizontal or sloping waterproofing should be specified using one system. Hybrid designs of more than one system should not be attempted because of the danger of incompatibility and the difficulty of sealing junctions. Hot and cold systems must not be mixed.

Bonded sheet membranes

These comprise a modified bitumen on a carrier film and are cold-applied or heat-bonded to the structure. Applied externally, the water pressure will assist in holding the membrane in place whereas when applied internally, a loading coat, usually masonry, will be required to resist hydrostatic pressure. These products are flexible and can accommodate minor movement in the structure. They can provide protection against aggressive soils and groundwater if applied externally.

Cavity drain membranes

These are formed from high density polyethylene sheets dimpled to give a drainage path when placed internally against the wall or laid on the floor. A sump and pump will be required unless ground levels allow drainage to an external system or watercourse.

Bentonite clay active membranes

This product comprises sheets of sodium bentonite clay sandwiched between two geotextile sheets. Used externally, it will become wet and the impervious clay will swell sealing gaps and voids in the membrane. They are not suitable for use in acidic or excessively alkaline soils.

Liquid-applied membranes

These are one or two-part systems of bitumen, elastomeric urethane or modified epoxy, and are applied cold either externally or internally. A masonry loading coat is required internally to resist hydrostatic pressure. Externally, where there may be a danger of damage from digging, some protection will be needed.

Mastic asphalt membranes

This is a traditional method that is applied using three coats of a hot mastic liquid. On cooling, they produce a hard waterproof coating with a degree of flexibility. Used externally, protection is required in the form of a board or looselaid blocks. Internally, a masonry loading coat and floor screed is installed to resist hydrostatic water pressure.

Proprietary cementitious crystallization active systems

These are used on building materials containing free lime. The slurries, applied internally or externally, react with the free lime to block cracks and capillaries. They remain active and self-seal any future hairline cracks.

Proprietary cementitious multi-coat renders, toppings and coatings

Waterproof renders or toppings comprise a cementitious material that includes a waterproofer. Coatings are supplied as a pre-mix slurry and are applied as a thin layer. All can be applied internally as a single or multiple layer. They can be used externally on the walls.

Other waterproofing products (Box 3)

Rubber or flexible waterstops

The most common forms are extruded sections designed to provide a continuous barrier to water through joints in the concrete structure. Strips of rubber or plastics, dovetailed on one side, are fixed to the face of the shuttering and cast into the wet concrete. These are external to the structure (Figure 4a). If they are used horizontally they must be cleared of debris before placing the concrete. They resist the passage of water only from the face on which they are fixed. Waterstops designed to function in the middle of the wall are difficult to install as successful placing of concrete cannot be guaranteed. Strips of rubber or dumb-bell shaped plastics are cast into the open face of the pour. These are internal to the structure (Figure 4b).

Water-swellable waterstops

These function by the sealing pressure developed when the hydrophilic material absorbs water. In strip form, they are placed against the concrete joint before the next pour. They can be attached to rubber or PVC waterstops to provide a combined system.

Cementitious crystallization waterstops

These are cement, fillers and chemicals mixed on site as a slurry and applied to the face of the concrete before the next pour. Salt crystallisation within the pores and capillaries of the concrete provide the waterstopping.

Post-injected waterstops

A perforated or permeable tube is fixed to the first pour of concrete in the joint, leaving the open ends accessible. The second pour is made and, when the concrete is hardened, a polyurethene or proprietary fluid is injected to seal any cracks or fissures in the construction joint (Figure 4c).

Subsurface drainage

The water pressure external to the basement wall can be controlled by introducing subsoil drainage (eg a roddable land drain, a filtered fin drain or similar) at the lowest level of the slab, which is capable of discharging into the soil or down hill. Water can be led into this drain either by a vertical interceptor drainage layer protected by a geotextile fabric (Figure 5) or simply by backfilling with hardcore.

Figure 5 Example of a land drain. Courtesy of Safeguard Europe

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