Best Practice Guidance

Type B Waterproofing Systems

PCA Property Care ASSOCIATION

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Supported by citb

Best Practice Guidance - Type B Waterproof Systems (BS8102: 2009)

1. INTRODUCTION

This document has been produced to provide guidance on the design, adoption and use of Type-B waterproofing in structures.

1.1 Type B Waterproofing as defined in BS8102: 2009

Type B (structurally integral) protection as defined by BS8102: 2009 (Code of practice for protection of below ground structures against water from the ground) 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.

When considering and or specifying a Type B integral system, this should only be carried out where there is knowledge and understanding of waterproofing in relation to BS8102: 2009 and in the case of concrete structures an understanding and competence in concrete construction.

The water tightness 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 detailing.
Defects can be minimised by correct specification and design and by careful construction.

The most common defects are:

- permeable concrete
- honeycombing through lack of compaction
- contamination of or cold joints
- cracks due to thermal contraction and shrinkage
- poor and inadequate placement of waterbars, hydrophilic strips and joints

1.2 Construction joints

These need particular attention as they are the vulnerable areas that are 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 compaction of the concrete. An alternative method of controlling water ingress at construction joints is to use a crystallisation or hydrophilic system which react in the presence of water to seal the joint. Other systems are also used (see section 6.2).

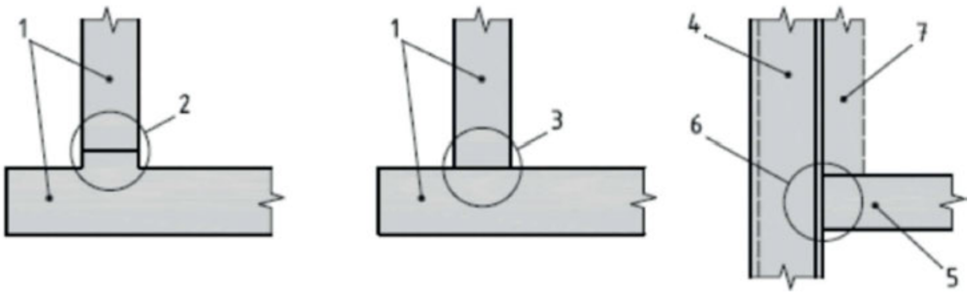
The construction of a ‘kicker’ after pouring the floor slab should not be encouraged as it is difficult to construct without defects. Therefore kickers should be cast with the slab using appropriate edge formwork but will require careful construction to obtain full compaction. Modern types of formwork and kicker less construction techniques mean that kickers no longer need be part of the construction process.

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.

Variable water tables present a reduced 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. Defects are not always identified during construction stage and only become evident after completion.

Type B - Structural integral protection - where the structure itself (waterproof reinforced concrete) is the protection.

Typical examples of structural waterproofing to Type B



KEY
1. Water-resistant reinforced concrete wall and slab
2. External or internal (within wall) water stop, as required
3. Water stop required at junction between wall and slab and at all construction joints
4. Concrete/steel piled wall
5. Water-resistant reinforced concrete floor slab or slab with added 'waterproofing' barrier
6. Water stop at junction to follow profile of wall
7. Piled wall might need to be faced to achieve desired water resistance

1.3 Existing Structures and Structures linked to new construction

Where designs involve existing structures, 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 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 design team 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 waterproofing specialists are consulted about a design at the earliest stage.

BS8102: 2009 defines:

> A waterproofing specialist should be included as part of the design team so that an integrated waterproofing solution is created. The waterproofing specialist should:
>
> a) be suitably experienced;
>
> b) be capable of devising solutions that accommodate the various project constraints and needs;
>
> c) provide the design team with information and guidance that assists with and influences the design, installation and future maintenance of the waterproofed structure.
>
> *NOTE The waterproofing specialist could be the manufacturer or material supplier, provided that the manufacturer/supplier has the relevant expertise.*

Waterproofing systems should be designed by a **Waterproofing Design Specialist** who can demonstrate that they have a suitable level of knowledge for designing waterproofing systems. See section 3.3 Designer.

1.4 Appropriate areas of use:
Appropriate areas where a Type B system could be adopted include:

- New build basements
- Any new Underground Structures
- Below ground structures
- Car parks
- Retaining walls
- Swimming pools
- Lift pits
- Tunnels
- A concrete structure that is designed to experience and resist the penetration of water under pressure

Podium Decks
Type B should not be relied on for Podium Decks without secondary protection.

1.5 Type B – Structural integral construction
Type B waterproofing should be installed in accordance with the design by suitably experienced and trained operatives who are fully aware of the requirements for placing concrete used in Type B systems.

The line, level and position of formwork and reinforcement should be checked prior to concrete placement to ensure that it is accordance with the design. Quality management systems and quality audits should be used to record and monitor the placement of concrete on site. Monitoring records may be requested.

2. DEFINITIONS
For the purpose of this document, the following definitions refer:

TYPE A (BARRIER PROTECTION)
Structure constructed from concrete or masonry, offering only limited protection against the ingress of water by the nature of its design. Protection is therefore primarily dependent on a barrier system applied to the structure, combined with serviceable land drainage where appropriate.

TYPE B (STRUCTURALY INTEGRAL PROTECTION)
Designed and constructed in reinforced or pre-stressed concrete to Eurocode 2; or to BS EN 8500 (to minimise water penetration); BS 8102 or to BS EN 1992 part 3 formerly BS 8007 (to prevent water penetration) dependent on the chosen grade of basement use.

TYPE C (DRAINED PROTECTION)
Constructed from structural concrete (including diaphragm walls) or masonry to minimise the ingress of water. Any water that does find its way into the basement is channelled, collected and discharged within the cavity created through the addition of an inner skin to both walls and floor.

ASUCplus
Association of Structural Underpinning Contractors.

ADMIXTUES
Water resisting admixtures are more commonly called 'waterproofing' admixtures and may also be called 'permeability reducing' admixtures. The main function is to reduce either the surface absorption into the concrete and/or the passage of water through the hardened concrete.

AUTOGENOUS HEALING
Natural process of re-hydration of cement grains within the hardened concrete due to water reacting with unhydrated cement to form fresh hydration products.

BCA
British Cement Association.

BRE
Building Research Establishment.

BSWA
British Structural Waterproofing Association.

CIRIA
Construction Industry Research and Information Centre.

CRYSTALLISATION
The reaction of water meeting “crystallising admixtures” that produces a swelling of the material which then blocks the capillaries.

CAPILLARY MOISTURE
Capillary moisture means moisture held in the capillaries of a material, and which exerts no hydrostatic pressure on the structure.

CONSTRUCTION JOINT
Joint formed in-situ in concrete when continuity is not possible.

EXPANSION JOINT
Joint that permits relative movement caused by expansion and contraction due to changes of temperature or moisture.

GGBS
Ground granulated blast furnace slag, by-product of steel manufacturing used as a cement replacement.

GEOCOMPOSITE DRAINAGE MEMBRANE
Geocomposite membrane materials consisting of a high flow rate drainage core coupled on one or both sides with filtering and/or impermeable elements to the other side.

“HONEYCOMBING”
Voids in the concrete as a result of poor compaction.

HYDRATION
Chemical reaction between cement and water.

HYDROSTATIC HEAD
Water pressure, expressed as an equivalent depth of water.

HYDROSTATIC PRESSURE
Water pressure exerted as a result of hydrostatic head, pressure created by water.

ICF
Insulating Concrete Form or insulated concrete form (ICF) is a system of formwork for reinforced concrete usually made with a rigid thermal insulation that stays in place as a permanent interior and exterior substrate for walls, floors, and roofs.

INTERSTITIAL CONDENSATION
Interstitial condensation is condensation occurring WITHIN the system, as opposed to the more common surface condensation.

KICKER
Small concrete up stand, cast above floor level to position wall or column formwork for the next lift.

KICKER LESS CONSTRUCTION
A mechanical means of retaining formwork in position, eliminating a kicker.
LABC - Local Authority Building Control.

MPA
Material Products Association.

MEMBRANE
A barrier that is impervious to water.

NHBC
National House Building Council.

OPC
Ordinary Portland Cement without any additions is now classified as Cem 1

PFA
Pulverised fuel ash, by product of coal burning power stations used as a cement replacement.

PLASTER
The term ‘plaster’ refers to any applied coat whose cementing action comes from either gypsum or cement/ lime.

PLASTIC CRACKING
Plastic shrinkage cracking is produced when fresh concrete in its plastic state is subjected to rapid moisture loss.

PLASTICISER / SUPERPLASTICISERS
Admixtures added to concrete to improve workability and / or reduce the water content. Also known as water reducing agents (WRA) or high range water reducing agents (HRWRA).

PRESSURE
Pressure is a load which is spread across an area, e.g. hydrostatic pressure.

RENDER
The term ’render’ refers to any applied coat which is made up of a sand: cement mix only, and can be used for coatings applied internally or externally. It may incorporate water-resisting admixtures, accelerators, plasticisers or other approved additives.

SEEPAGE
Slow transmission of water through discrete pathways of a structure.

SRC
Sulphate resisting cement.

PORE BLOCKER
An inert material that is deposited in the capillaries of concrete and so forms a physical barrier.

SHRINKAGE
When a mixture of cement and water hardens the resultant material occupies a lesser volume when in its plastic state. The contraction or decrease in volume of the concrete. The time sequence and shrinkage deformation level are influenced mainly by the start of drying, ambient conditions and the concrete composition.

STRESS
The pressure that builds up within the elements of a structure to resist applied loads and/or pressures.

TBIC
The Basement Information Centre.

TANKING
The term 'tanking' refers to a pressure resisting waterproofing system that is applied internally or externally to a structure, which will prevent any lateral penetration of liquid, either by capillary action or by hydrostatic pressure.

VAPOUR CHECK
Any layer which reduces the passage of water vapour, resulting in a build-up of humidity immediately behind it is known as a vapour check.

VAPOUR CONTROL LAYER
A vapour control layer is a strategically placed vapour check, used where control of water vapour is needed.

VAPOUR RESISTANCE
The ability to resist water vapour.

WATER-CEMENT RATIO
A measure of the durability defined by the ratio of "water to cement" within a concrete mix.

WATERPROOF
A material or layer that is impervious to the passage of water.

WATERPROOFING
The application of a material that is impervious to water.

WATER RESISTANT
A material or layer with a high resistance to the passage of water under pressure.

WATER STOP
Material designed to inhibit the transmission of water under pressure through joints in the structure.

WATER VAPOUR
Water in its gaseous phase.

3. PRINCIPLES OF DESIGN

3.1 BS8102: 2009

Code of Practice for the protection of below ground structures against water from the ground provides guidance on the methods which can be adopted to deal with and prevent the entry of water from the ground into a structure that is below ground level. It is widely referred to and used in basement waterproofing, making particular reference to:

- Adoption of a design team
- Water table classification
- Defects and remedial measures

It also refers to other waterproofing protection known as Type A (barrier protection) and Type C (drained protection) and how they can be combined with Type B systems where required.

Design should be in accordance with relevant building regulations and applicable statutory requirements.

All elements (including foundations, walls and floors) forming a below ground structure requiring waterproofing should be suitable for their intended purpose.

3.2 Design and Build Philosophy

As a general rule, design and construction should be kept as simple as possible. Consulting relevant waterproofing specialists as early as possible and working through details sequentially will help to avoid unbuildable details on site.

All floors, ceilings and walls below external ground level including the junctions between them, should be designed to resist the passage of water and moisture to the internal surface. The level of protection against water and moisture reaching the internal surfaces should be appropriate for the proposed use.

Habitable accommodation should be designed to “Grade 3” as described in BS8102: 2009 – that ‘no water penetration is acceptable and a dry environment will be provided if maintained by adequate ventilation’.

Non-habitable areas such as parking areas, storage or plant rooms where the internal finishes are not readily damaged by moisture should be designed to a minimum “Grade 2” as described in BS8102: 2009, as no water penetration is acceptable although damp is tolerated.

Retaining walls used to form elements such as light wells ideally should be designed to provide “Grade 1” protection.

Where there is any doubt about use, the level of protection required for habitable accommodation should be provided.

3.3 Designer

Waterproofing systems should be designed by a Waterproofing Design Specialist who can demonstrate that they have a suitable level of knowledge for designing waterproofing systems.

The Property Care Association (PCA) provides training for surveyors and designers of underground waterproofing systems. The Certificated Surveyor in Structural Waterproofing (CSSW) is a recognized industry qualification which requires an understanding of waterproof systems and the ability to comment on them. PCA has created a register of Waterproofing Design Specialists (WDS) who have shown further ability to provide design advice for structural waterproofing.

With the publication of the register of Waterproofing Design Specialists, developers, architects and builders can quickly locate individual practitioners who can assist in the design and planning of underground waterproofing. This ability will allow them to conform to the recommendation set out so clearly in BS8102: 2009.

The availability of the register will ensure that a properly vetted and approved Waterproofing Design Specialist is available and accessible to the leader of any design team.

The list of Waterproofing Design Specialists can be accessed - *www.property-care.org/ProGuidance.RWDS.asp*

3.4 Site Investigation
A site investigation is important as its results will have a bearing not only on the waterproofing options considered, but also how the structure is designed. Although the findings of a site investigation can be seen as conclusive, consideration should be given that it is often a 'snap shot in time' and conditions on or around the site may change in the future.

It should be assumed water will come to bear against the full height of the below ground structure at some time in its life. Initial designed use may find risk of future failure acceptable, but it may be changed to 'higher risk' use later. As such it may be that designing a system to offer full protection to full height, regardless of any water table classification, should be considered.

There are some overriding principles that need to be highlighted when selecting the form of construction and waterproofing system that a site investigation will assist with.

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.

As stated in BS5930: 2015, 'Investigation of the site is an essential preliminary to the construction of all civil engineering and building works'. BS EN 1997 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.

3.5 Risk Assessment
A risk assessment should be carried out which identifies any possible long-term water pressures, the effects of surface water percolation, use of external drainage and the effects of party wall impaction on neighbours.

It should take into consideration the possible effects of climate change, defective water goods, nearby trees, contaminants; and where external drainage is proposed, the effects dewatering may have on adjacent structures along with the potential for silting of drainage.

3.5.1 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.

High water tables present the greatest risk of failure to the waterproofing of a basement and it is therefore important to identify. 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 should also be given to the effect of possible planned developments adjacent or in close proximity to the site either under consideration or potentially possible in the future. Historic information on past flooding is valuable including any recording of rate of water ingress. If the water table is variable then it is advisable to design to the "highest level".

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.

More information on water tables and ground water can be found in the PCA document 'What is groundwater?'

3.5.2 Ground Conditions
The design of the basement should take into account all current and likely future ground conditions. The design of the waterproofing system should consider the likely effects of these ground conditions, including water, and assume exposure of the basement to full height of water within the design life of the building.

A summary of common investigations relating to ground conditions along with some useful guidance is given in the table below.

3.5.3 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 and performance 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.

3.5.4 Soil Type and Conditions
The type of soil can greatly influence the volume 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. 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.

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, sulphates, chlorides, VOCs and hydrocarbons.

BS8102: 2009 advises the designer to also take account of the presence of, or potential for, natural gases such as radon, methane and other gases such as CO_2 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. See section 3.7.2 for more information.

Investigations	Guidance and information
Desk study including reviewing • groundwater and flooding issues • flood potential of the site • available groundwater data • SuD's impact assessment • flood risk assessment • topography of the site • effects of adjacent surface finishes	*www.environment-agency.gov.uk/homeandleisure/floods* *www.bgs.ac.uk/research/groundwater/datainfo/levels/home.html* *www.metoffice.gov.uk/climate/uk/stationdata* TBIC - Guidance Documents (various) PCA - 'What is Groundwater?'
Contaminated and aggressive ground	Testing required if there is the potential for chemically aggressive ground and/or groundwater
Seasonal water level change including risks of flash flooding and water logging	The report should consider likely fluctuations and short term flooding events that typically occur during Autumn, Winter and Spring
Assessment of impact on the ground water flow where the construction is likely to have a "damming" effect	Interpretative report by a qualified engineer or hydrogeologists to include: • assessment of the direction of groundwater flow, • "Damming" effects on the groundwater regime, • "Damming" effect of adjacent structures.

3.5.5 Movement Risks

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.

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.

3.6 Sequence and Timing of Work

It is fundamental that the waterproofing elements of a structure are communicated with all relevant parties throughout the construction process. For this reason the waterproof design should take into consideration the construction stages and timing between them to ensure the end result and function of any installed material is as expected. All parties should be aware of the waterproofing materials that are introduced at each stage to avoid problematic post installations, miss-installations or potentially leaving them out altogether.

3.7 Considerations

3.7.1 Site De-watering

If de-watering of a site is deemed necessary it should be done to a degree suitable for the proposed system with due consideration to existing surrounding structures to ensure any potential movement to the surrounding land as a result of de-watering does not have a detrimental effect.

In any case specialist advice should be sought. Suggested further points of reading regarding dewatering are:

- CIRIA Document 515. Groundwater control – Design and Practice
- Construction Dewatering and Groundwater Control: New Methods and Applications, 3rd Edition (J. Patrick Powers, 2007)
- Groundwater Lowering in Construction: A Practical Guide (P.M. Cashman and Martin Preene, Ove Arup & Partners, UK, 2001)

3.7.2 Ground Gases

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. BS8102: 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, BR376, BR413 and the Health Protection Agency (HPA) documents:

- HPA-RPD-033, Indicative Atlas of Radon in England and Wales, 2007, ISBN 978-0-85951-608-2, available from HPA.
- HPA-RPD-051, Radon in Dwellings in Scotland: 2008 Review and Atlas, ISBN 978-0-85951-634-1, available from HPA.
- NRPB Documents, Vol 4, No.6, 1993, Radon affected areas: Scotland and Northern Ireland, ISBN 085951367X, available from HPA.

Attention is also drawn to the Building Regulations, and to further guidance on the characterisation and remediation of ground gases given in BS8485: 2015. Guidance on measures for large buildings is given in BRE guidance Radon protection for new large buildings. 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 give information on site preparation and resistance to moisture, and include guidance on ground contaminants.

Type B systems can NOT provide methane or radon resistance as a standalone system unless incorporating a membrane. BRE state that good quality concrete, properly placed, compacted and cured is an effective barrier against Radon provided it is not cracked. All concrete cracks! These may be micro-cracks which are not visible and do not let water in but they can allow Radon through. So, advice should be sought to ascertain whether additional measures are required. Membrane Manufacturers are an excellent source of advice.

3.8 Structural Stability

Parts of the building constructed below ground level that form usable spaces should be designed by an Engineer. The existing substrate should be assessed by the Structural Engineer for suitability for the proposed system.

The design should consider all imposed loads including:

- ground movement
- lateral forces from ground water and retained ground
- buoyancy
- loading from other parts of the building

For further guidance refer to The Basement Information Centre Design guide.

4. SHEET PILED WALL CONSTRUCTION

4.1 Sheet Piled Walls / Steel Retaining Walls

Steel piles can be used a permanent structural wall where the pile clutch interlocks may be adequately sealed. Steel structures should be designed and constructed in accordance with BS EN 1993-5

Manufacturers' guidance should be sought to achieve the necessary resistance to seepage. Sheet piled interlocks should be welded or sealed with a suitable hydrophilic material, and the welded clutches should extend beyond the base slab.

The connection between the sheet piles and base slab should be sealed using appropriate seals and water stops. Care is required with the practicality of fixing a hydrophilic strip to an uneven surface of a sheet piled wall without creating voids.

Welded sheet pile wall – floor detail with waterstop.

Typical "detailing" requires that all clutches should be welded prior to any secondary fixing where the sheet piling forms an integral part of the waterproofing system.

4.2 Standards

Guidance on welding is given in BS EN 1011 & BS EN ISO 15614-1. Further guidance can also be found in ICE'S specification for piling and embedded walls and BS EN 1993-5.

5. REINFORCED CONCRETE CONSTRUCTION

Concrete in which steel is embedded in such a manner that the two materials act together in resisting forces. The reinforcing steel—rods, bars, or mesh—absorbs the tensile, shear, and sometimes the compressive stresses in a concrete structure. In reinforced concrete, the tensile strength of steel and the compressive strength of concrete work together to allow the member to sustain these stresses over considerable spans.

5.1 Correctly specified Type B systems must include:

- In-situ concrete with minimum cementitious content of 350 kgs per cu.M
- A maximum Free Water/Cement Ratio of 0.45 with admixtures, limited crack widths and typically a S3 Consistence
- Cement type and content should comply with BS EN 8500: 2012 with respect to the "Exposure Class" for the specific conditions to be encountered
- Concrete must be supplied from a 3rd Party Accredited Supplier E.g. QSRMC or BSI approved supplier
- Pre-cast concrete systems assessed in accordance with NHBC Technical Requirement R3
- The Compressive Strength requirement should comply with the requirements of the Structural Engineer. It is NOT a specification for Waterproofing, which relies on Water/Cement ratio and admixtures

The design of in-situ Type B concrete systems should be in accordance with BS EN 1992-1-1 and BS EN 1992-3 or MPA publication ‘Concrete basements a Guidance on the design and construction of in-situ concrete basement structures’. Reference - Chapter 2.1 ‘Concrete and its reinforcement’s’.

Suitable quality management systems and quality audits from both the concrete supplier & contractor must be used to record and monitor the placement of concrete. Monitoring records should be supplied to the Client as requested.

Design details should recognise and record:

- the type of concrete
- type and position of reinforcement
- proportion of any admixture
- temporary support to the formwork
- the method of making good holes in the concrete formed from shutter bolts and tie bars
- positioning of structural elements
- Appropriate tolerances for the line and level of structural elements


A completely watertight concrete system to floor and walls

5.2 Concrete and Admixtures
Where the design of in-situ concrete waterproofing includes admixtures:

- its reinforcement should limit crack widths to 0.3mm for flexural cracks and 0.2mm for cracks that pass through section
- the dosage of the admixture(s) must be in accordance with the recommendations of the admixture supplier and the mix designs approved before commencement
- a quality management system and quality audits should be used to record and monitor the batching of admixture

Admixtures should be independently assessed specifically for the intended use and used strictly in accordance with manufacturer’s recommendations. (See section 11).

5.3 I.C.F. Construction for Basements
Insulated Concrete Formwork (I.C.F.) is used as a method for constructing basements in conjunction with the use of watertight concrete as the primary protection against water ingress.

Watertight Concrete is suitable for use in I.C.F. construction and has been used on many projects however there is concern with this type of construction and a history of failures. There are many I.C.F. systems, with some more robust than others with regard to below ground waterproofing and concrete practice in general.

Areas of concern are:

- Achieving a watertight below ground structure with any type of formwork relies on Good Concrete Practice as well as correct design to ensure concrete is fully compacted and “crack free”
- To aid compaction watertight concrete must be designed and supplied at an S3 Consistence class (or higher)
- Some I.C.F. systems are not robust enough to withstand the pressure exerted by the concrete at this level of workability when placed and subsequently vibrated, which can result in displacement of the formwork
- Watertight Concrete can be placed “stiffer” but this of course makes full compaction of the concrete more difficult to achieve

- With traditional construction methods, walls are designed with vertical joints to relieve the stress which occurs as the concrete dries out and inevitably shrinks.
- Plastic drying shrinkage and long term drying shrinkage can lead to cracks in the concrete which are a potential path for water ingress if they are the full depth of the concrete.
- Embedded steel is designed to further reduce the risk of cracking.
- With I.C.F. construction there are normally no vertical joints in walls and, although the formwork itself provides a good curing environment for the concrete, the risk of cracking is present.
- Construction joints between slabs and walls need to be carefully detailed and a suitable product used to ensure water ingress is avoided at this junction.
- Hydrophilic strips cast into the joint are commonly used. Care must be taken to ensure these strips stay dry prior to pouring the concrete. If this should prove difficult, perhaps because of prolonged wet weather, then alternative products such as metal waterbar should be considered.
- As well as "buildability" (which I.C.F. offers), a key factor in deciding on a suitable construction system is repairability (see BS8102: 2009 Code of Practice for Protection of below Ground Structures against Water from the Ground). In other words, if something goes wrong how easy is it to put right. The issue with I.C.F. is that because the formwork is permanent, the cause of any leaks that may occur for whatever reason are difficult to locate and repair.
- N.B. BS8102: 2009 also suggests that two lines of defence against water ingress should be considered; for example Type B waterproofing (watertight concrete) in conjunction with Type A (external tanking) or Type C (internal water management).

6. PRODUCTS

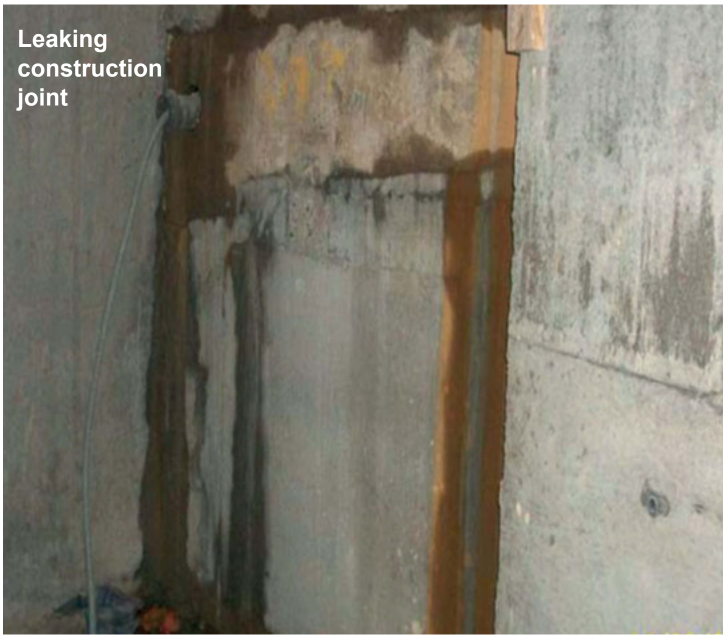
6.1 Definition:

Joints between components, movement joints and day work joints should be durable, watertight and include appropriate water stops or hydrophilic protection. Kickers, usually cast as part of the slab should also be "watertight concrete" and are used to form the joint with the walls.

Construction Joints need particular attention as these are the area's most commonly associated with leaks.

Construction joints are generally deemed to be a monolithic strong joint in reinforced watertight concrete, connecting work done on two different days. The first section has starter bars left protruding so that new reinforcement laps with the old.

Vertical concrete surfaces may have a trapezoidal profile or be cast against mesh to provide a mechanical key (as recommended in BS EN 1992. Formerly BS 8007 and BS 8110). Horizontal surfaces must be prepared to remove laitance or weak concrete as per Codes of Practice.
Water stops should be used to provide enhanced resistance to water transmission at joints in the concrete structure, e.g. at construction or day work joints, services or other penetrations.



Leaking construction joint

This could be formwork tie bolts or abutment to other structural elements of differing material nature. Designers need to ensure that the correct type of water stop has been chosen for the location, and great care must be paid to the jointing and positioning of water stops.

6.2 Types of Water Stops

The principal types of water stops can be classified as the following:

a) Passive sections:

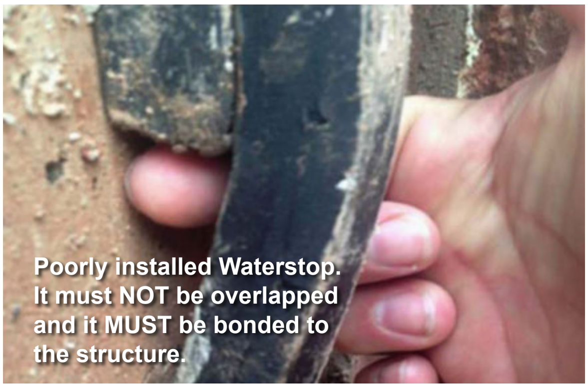
- rubber or flexible polyvinyl chloride (PVC) extruded profiles cast into the concrete on both sides of the joint, either at the concrete surface or mid-depth of the concrete section, to form a physical obstruction to water transmission.
- metal water bar strips placed mid-depth of the concrete section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

b) Active or hydrophilic strips or crystallization slurries:

- Preformed profiles or sealant composition of materials applied to the concrete joint at depth in the section.

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.

Waterstop seal penetration detail pre-applied to soil waste outlet prior to casting concrete slab.



Poorly installed Waterstop. It must NOT be overlapped and it MUST be bonded to the structure.

Alternatively, water stops may be cast totally within the site-placed concrete. These are known as internal or centrally placed water stops. Internal water stops 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.

Water-swellable Water Stops

Such water stops 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 water stop. The use of water-swellable strips is generally limited to construction joints.

Hydrophilic material may be applied to a conventional PVC water stop profile to provide a combined system that may also cater for expansion joints but care must be taken to ensure no overlapping of the hydrophilic occurs as this could create too much swelling should water penetrate.

Waterstop secured to tie bolts through reinforcement to retaining wall – minimum 50–75mm concrete cover. Consult with Manufacturer.

Steel Water Stops

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

Typical Water-swellable water stop to concrete joint

Cementitious Crystallisation Water Stops
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 water stopping 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 water stops
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. Once the required injection pressure has been reached then the central core can be flushed out to allow subsequent injection if necessary e.g. earthquake / ground movement.

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.

As all of the above systems vary, the manufacturer's advice on application method should always be followed.

Inadequate cover to a Waterstop

6.3 Typical Installation
Designers and Clients will need to understand the types of water stops available and their applications to ensure they cover the detailing required and MUST seek the advice of Material Suppliers during the design stage.

7. MOVEMENT JOINTS

Where possible movement joints should be avoided. Where they cannot be avoided they may need to be accessible for maintenance and Specialist Advice should always be sought. Using kickers to form joints between the slab and the wall will help to prevent contamination. The design must consider all temporary works. This should include the waterproofing details of shutter bolts and tie bars.

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.

- 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 water tightness, 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.

7.1 Products/Types

There are many types and materials used for waterproofing movement and expansion joints, these include mechanical steel & rubber, asphalt, pitchmastic, elastomeric polyurethanes, polyurethane epoxies and hypalon strips bonded with adhesives etc.

The selection and type of material/fabrication of the movement joint will depend on the anticipated/calculated movement and also the exposure of the joint. i.e. Will it be exposed to traffic, chemicals etc. The individual application MUST be addressed by the 'Design Team'. Appropriate selection of type of material is important and the Manufacturers advice should be sought when specifying.

8. CONCRETE DESIGN MIX

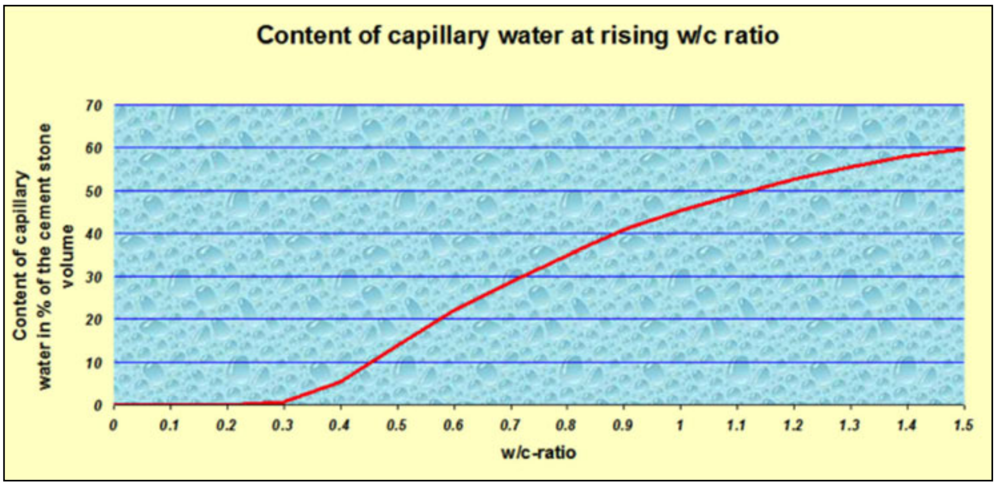
The principle of "Watertight Concrete" follows the logic behind BS EN 8500:2012 in that the "correct type" of cement is chosen for the conditions; the Water/Cement Ratio is 0.45 or below to ensure the minimum residual capillaries within the hardened concrete and the level of "Consistence" chosen fits with the method of placement the Contractor has decided to use.

Selection of a suitable concrete should always follow the correct selection process.

a. The "strength required" for a particular member together with the "Specific Exposure" to be encountered are the responsibility of the "Design Engineer"
b. The specific Mix specification will follow the above requirements but MUST be a minimum 350 kgs per cu.M of "Total Cement" and have a MAXIMUM Free Water/Cement Ratio of 0.45 should be identified
c. The "Contractor" specifies the Consistence (Slump) in line with his proposed method of placement. Ideally this should be a Minimum of S3
d. ALL the above information should be passed to the "Admixture Supplier" who will recommend the most suited "system" for the project
e. The "Concrete Supplier" should be provided with ALL the above information and MUST be 3rd Party Accredited E.g. BSI or QSRMC
f. ALL PARTIES should have attended formal training. This is normally provided by Manufacturers
g. The site operatives should be given "Toolbox Talks" to ensure the systems to be used are fully understood
h. A quality control plan should be put in place to ensure an accurate record of what has been used and placed e.g. Photographic records of preparation and formwork; copies of mix designs and delivery tickets. Records of weather conditions, slump and cube tests linked back to the individual pour

Durability

Durability is covered in concrete mix design – reference BS EN206 exposure classes and BRE Digest. In the UK this is covered in BS EN 8500: 2012 Part 1 and 2 and BRE Digest for "ground conditions".



Two fold increase in capillaries from 0.5 to 0.6 W/C Ratio

9. DEFECTS – CAUSES AND REMEDIATION

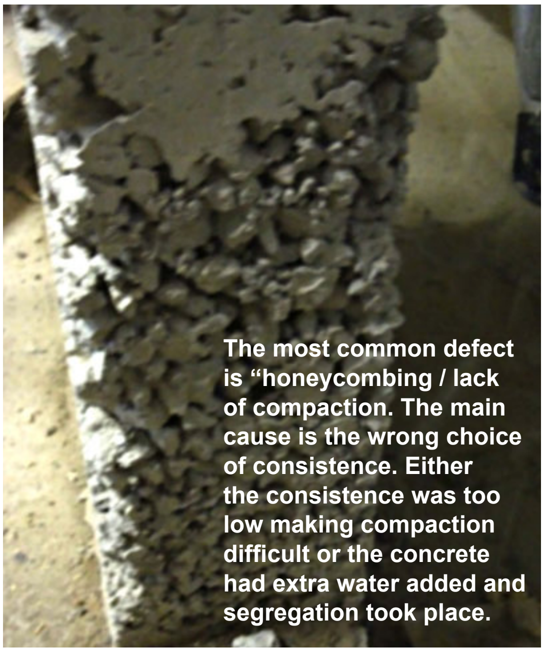
9.1 Types of defects - cracks, honeycombing & cracking

Plastic and long term drying shrinkage, thermal cracks, induced cracks, cracks caused by restraint are normally associated with Designer and / or Contractor issues and NOT the materials used.

Thermal Cracks: These are caused by temperature differentials, particularly in mass concrete due to the heat of hydration. As the interior concrete increases in temperature and expands, the surface may be cooler and contracting thus causing tensile stresses that may result in thermal cracks at the surface.

Drying Shrinkage Cracks – As most concrete mixes contain more water than actually required for the hydration process, the remaining water evaporates over time causing the concrete to shrink. Restraint to shrinkage causes tensile stresses to develop in the hardened concrete. Restraint to drying shrinkage cracking is a common cause of cracking in concrete.

Plastic Shrinkage Cracks – These are caused by the evaporation of water from the surface of freshly placed concrete faster than it is replaced by bleed water, thus causing the surface to shrink. Due to restraint from the underlying concrete, tensile stresses develop in the weak plastic surface concrete resulting in shallow cracks of varying widths and depths.



The most common defect is "honeycombing / lack of compaction. The main cause is the wrong choice of consistence. Either the consistence was too low making compaction difficult or the concrete had extra water added and segregation took place.

9.2 Causes of defects – Lack of Compaction

THE LEVEL OF CONSISTENCE I.E. SLUMP, IS THE CHOICE OF THE CONTRACTOR TO SUIT THE METHOD OF PLACING. IT IS ALSO THE RESPONSIBILITY OF THE CONTRACTOR TO COMMUNICATE WITH THE CONCRETE SUPPLIER TO ENSURE THE MIX DESIGN IS CORRECT. THIS WILL ENSURE NO EXTRA WATER IS REQUIRED AT SITE.

9.3 Remedial options / Responsibility

Material suppliers should be consulted in conjunction with the site documentation pack.

Repair Options include:

- Crack injection
- Repair mortars
- Epoxy coatings

Autogenous healing

Autogenous healing is a natural process of hydration that can occur in concrete in the presence of moisture and absence of tensile stress. It has practical applications for closing dormant cracks in a moist environment, such as may be found in mass structures and water retaining or watertight structures. It must NOT be relied upon to provide part or all of the waterproofing properties.

9.4 Optimum pour sizes.

Construct specification

- Walls: Aspect ratios should not exceed 3:1 unless it has been agreed with both the Structural Engineer and the Waterproofing System Manufacturer
- Floor Slabs: The pour sizes should follow the current guidelines in Construct - National Specification. Typically this is 400 sq. metres.

Minimum wall and slab thickness

- For Type B construction this is the responsibility of the Structural Engineer but 175mm is a typical minimum value that would allow for installation of suitable joint protection with the appropriate cover.

10. EXPECTED LEVEL OF MONITORING / INSPECTION

- Good communication is paramount between the ready mix suppliers, manufacturers and ground workers / contractors.
- The level and involvement of manufacturers will vary from one to another, however the manufacturers will ensure correct dosing of their admixtures and may involve them dosing the concrete at batching or overseeing the batching process of the ready mix supplier.
- The manufacturer will assess the mix design of the concrete prior to the start of the contract to ensure all mix criteria required for their particular system are met.
- The manufacturers or their designated supervisor would normally inspect all construction joint detailing, use of appropriate water stops etc. in relation to their system. Training and / or supervision should be given to the ground workers / contractors to ensure appropriate detailing to construction joints, service penetrations, tie bolts etc. is met.
- The ground worker / contractor is responsible for the placement, compaction and curing of the concrete and must ensure this is carried out to the appropriate standard.
- Manufacturer’s regular site inspection will also view and assess the placed concrete in relation to defects associated with poor or less than adequate compaction / curing regimes. Any defects would normally be highlighted and an agreed remediation would be required.
- Site visits may or may not be carried out by the admixture system manufacturer on all concrete pours this would be stipulated at the outset by the manufacturer. Such visits should record the site and pour location, pour size, date and weather conditions thus enabling complete traceability of all constituent materials within each section of the concrete structure from raw materials to final placement.

11. BIBLIOGRAPHY

11.1 Function

Water resisting admixtures are more commonly called ‘waterproofing’ admixtures and may also be called ‘permeability reducing’ admixtures. The main function is to reduce either the surface absorption into the concrete and/or the passage of water through the hardened concrete. To achieve this, most products function in one or more of the following ways:

- Reducing the size, number and continuity of the capillary pore structure
- Blocking the capillary pore structure
- Lining the capillaries with a hydrophobic material to prevent water being drawn in by absorption / capillary suction

These ‘waterproofing’ admixtures reduce absorption and water permeability by acting on the capillary structure of the cement paste. They will not significantly reduce water penetrating through cracks or through poorly compacted concrete which are two of the more common reasons for water leakage in concrete structures.

Water resisting admixtures have been shown to reduce the risk of corrosion of reinforcing steel in concrete subject to aggressive environments but this is subject to appropriate admixture types or combinations of types being used. Water resisting admixtures have other uses including the reduction of efflorescence, which can be a particular problem in some precast elements.

11.2 Standards

The class of admixture is covered by the requirements of BS EN 934-2: 2001 Concrete admixtures – Definitions, requirements, conformity, marking and labelling.(see Table below). BBA / CE Mark - “Admixture Systems” & water stops should conform to the relevant standards, carry CE mark where appropriate and have 3rd party certification or independent UKAS accredited test data.

11.3 Types

Their description should be included in documentation when they are used.

12. RELEVANT STANDARDS AND CODES

The following standards, codes and specifications are directly relevant to structural waterproofing:

TYPE	TABLE REFERENCE	REQUIREMENTS
Water reducing/plasticising admixtures	Table 2	Water reductions up to 12% against Control
High range water reducing/super plasticising admixtures	Tables 3.1 / 3.2	Water reductions >12% &/or slump Increase > 120mm against Control
Water retaining admixtures	Table 4	Reduction of bleeding over Control by ≤ 50%
Air entraining admixtures	Table 5	Total air content of 4 – 7%
Set accelerating admixtures	Table 6	Reduction of Initial Set @20°C ≥ 30 mins ; @5°C ≤60%
Hardening accelerating admixtures	Table 7	At 20°C & 24hrs ≥120% over Control. At 20°C & 28 days ≥ 90% of Control. At 5°C & 48 hrs. ≥ 130% of Control
Set retarding admixtures	Table 8	Initial Set ≥ Control + 90mins. Final Set ≤ Control + 360 mins.
Water resisting admixtures	Table 9	Capillary Absorption @ 7 days ≤ 50% of Control; @ 28 days ≤ 60% of Control.
Set retarding/water reducing/ plasticising admixtures	Table 10	Compressive Strength ≥ 100% of Control; Initial Set ≥ Control + 90 mins. Final Set ≤ Control + 360 mins.
Set retarding/high range water reducing/ super plasticising	Table 11.1 / 11.2	At 7 days test mix ≥100 % of control mix. At 28 days test mix ≥ 115 % of control mix. Initial Set: test mix ≥ control mix + 90 min. Final Set: test mix ≤ control mix + 360 min. Test mix ≥ 12 % water reduction compared with control mix.
Set accelerating/water reducing/ plasticising	Table 12	Strength @ 28 days, test mix ≥ 100 % of control mix. At 20 °C test mix ≥ 30 min. At 5 °C test mix ≤ 60 % of control mix. Water reduction ≥ 5 % compared with control mix.

- BS8102: 2009 Code of practice for protection of below ground structures against water from the ground
- BS EN 1990: Basis of structural design
- BS EN 1992-1-1, Eurocode 2: Design of concrete structures, part 1-1 general rules and rules for buildings
- BS EN 1992-3, Eurocode 2: design of concrete structures, liquid retaining and containing structures
- BS EN 1997-1 Eurocode 7: Geotechnical design, part-1 General rules
- BS EN 1997-2 Eurocode 7: Geotechnical design Part 2 ground investigation and testing, BSI 2007
- BS EN 206-1, Concrete, part 1: Specification, performance, production and conformity
- BS EN 12970 Mastic asphalt for waterproofing – Definitions, requirements and test methods
- Eurocode 2: Part 3: Liquid retaining and containing structures
- BS 8002: Code of practice for earth retaining structures
- BS 8500 Parts 1&2: Concrete - Complementary British Standard to BS EN 206-1

- BS 8500-1:2006+A1: 2012 Method of specifying and guidance for the Specifier
- BS 8500-2006+A1: 2012 Specification for constituent materials and concrete
- BS EN 934-2: 2001 Concrete admixtures – Definitions, requirements, conformity, marking and labelling.
- BS EN 197-1: 2000 Cement – Part 1: Composition, specification and conformity criteria for common cements.
- BS 5454 Recommendation for the storage and exhibition of archival documents BSI 2000
- Building Regulations

Other reference documents

- The Basement Information Centre (TBIC): Basements: Waterproofing – General Guidance to BS8102: 2009 (Design Guide)
- TBIC - The Building Regulations 2010 – Basements for Dwellings – Guidance Document 2014
- MPA: "Concrete Basements: Guidance on design and construction of in-situ concrete basement structures"
- CONSTRUCT. "National Structural Concrete Specification for building construction" 4th edition
- BRE Special Digest 1:2005- Concrete in aggressive ground
- CIRIA Report C660, Early-age thermal crack control in concrete
- CIRIA Report R140, Water resisting basements
- BCA: Basement Waterproofing Design Guide
- BCA: Basement Waterproofing Site Guide
- BSWA: Waterproofing Existing Basements
- NHBC: Waterproofing of below ground structures (New Standard)
- ASUCplus: Guidelines on safe and efficient basement construction directly below or near to existing structures 2013.

13. WARRANTIES / GUARANTEES / INSTALLER WARRANTIES

Typically these are where the contractor or installer guarantees the workmanship for a period of years (normally up to 10 years for Structural Waterproofing).

Insurance Backed Guarantees (IBG)

An Insurance Backed Guarantee (IBG) is a low cost, long term insurance policy (normally up to 10 years for Structural Waterproofing) which provides valuable protection for consumers when undertaking improvement projects. The principle of an Insurance Backed Guarantee is to honour the terms of the written guarantee, originally issued by the installing contractor, where that contractor has ceased to trade as defined within the policy document and is therefore unable to satisfy claims against that guarantee.

Latent Defect Insurance (For New Build Renovation and Repair work)

Property owners, construction professionals and other building stakeholders will know that defects can become evident long after practical completion of building works. The rectification of these defects can be a costly undertaking, and may result in expenditure which has not been budgeted, or otherwise provided for. For construction professionals, this naturally jeopardises the availability of funding, time and manpower for future projects.

Latent Defect Insurance products take approaches to protecting stakeholder's investments in construction projects. The propensity for defects to occur is minimized from the outset, as technical audits are carried out prior to and during the build. In addition to indemnifying insured parties in respect of latent defects themselves, the insurance may also confer additional benefits in the event of a valid claim, such as meeting the costs of alternative accommodation, and the fees of architects or other professionals.

Manufacturer Warranties
These are typically but not always accompanied by the contractors own guarantee. They offer protection in the event of a product being proven not to have performed as intended in which result the manufacturer is often limited to re-supply of the material only. It is extremely unlikely that any ISO9001 compliant company will supply defective materials, hence why these types of warranty / guarantee are issued alongside the installer's commitment.

Other schemes
There are other schemes and companies who offer insurance products covering waterproofing in new-build projects. The National House Building Council (NHBC) has the Buildmark scheme that provides 10 year warranty and insurance cover for newly-built and some new-build basement conversions in private homes. Premier Guarantee and LABC offer similar insurance products in the UK.

14. TRAINING / SUPERVISION

The Property Care Association (PCA) provides training for surveyors and designers of underground waterproofing systems. The Certificated Surveyor in Structural Waterproofing (CSSW) is a recognised industry qualification which requires an understanding of waterproof systems and the ability to comment on them.

Information about training courses and qualifications are available from the PCA website:
www.property-care.org

Schemes offered by bodies such as the NHBC and LABC have requirements for suitably qualified persons to be involved in the design and installation of structural waterproofing systems. If a project is involving such a scheme it should be confirmed if such qualifications are a requirement of any warranty application. In any case, manufacturer's guidance and recommendations should be followed, unless any bespoke details have been confirmed with them and other relevant parties.

Installer
One of the most regular causations of failed waterproofing systems is defects in the installation.

Conditions of certification for waterproofing systems will usually require that they are installed 'under license' of the supplier/manufacturer. In practice this does not always happen and it is not uncommon for waterproofing systems to be installed by operatives who have no relevant qualifications and/or no previous experience of installing waterproofing systems. This should not happen and in the main is the responsibility of the Main Contractor.

To improve this undesirable situation it is suggested that installations SHOULD be undertaken by suitably trained operatives. This could either be by operatives holding a relevant qualification in the application of structural waterproofing, such as a relevant vocational qualification. Alternatively operatives trained and licensed by the supplier/manufacturer or PCA training could also provide a suitable demonstration of skill and knowledge.

A "Site Documentation Pack" should be available on site recording all related works.

15. BIBLIOGRAPHY

Reading Lists

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http://www.property-care.org/ProGuidance.Waterproofing.asp

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