6. WATER RESISTANT BASEMENTS

6.1 RULES OF THUMB

Minimum thickness

Preferred minimum thickness of walls and slabs: 300mm
Where thicker consider surface zones of 200mm each face for reinforcement to control shrinkage/thermal cracking.

Reinforcement

Typically for water resistant walls: T16 @ 200 c/c in both faces and in both directions
or T12 @ 150 c/c in both faces and in both directions

Standard cover

Assumed concrete grade 35 (This should be a minimum)
Put the horizontal reinforcement furthest from earth face.

Face	Cover (mm)
Earth face of walls where shuttered	50
Earth face of walls (cast against earth)	75
External exposed faces of walls	40
Bottom and sides to base	75
Internal faces	Greater of 25 or bar diameter

Waterstops / waterbars

- Required by BS 8102 for grade 1 basements with concrete design to BS 8110
- Give extra "comfort" at construction joints, otherwise total reliance on workmanship
- Not essential but often desirable
- Use external waterstop for basements (preferred)
- Can use centrestop in vertical construction if necessary (e.g. swimming pool), must be carefully supported/kept in place.

6.2 ESTABLISH CLIENT'S REQUIREMENTS / EXPECTATIONS

These can vary even for the same type of space. Tables 6.1 and 6.2 (from CIRIA Report 139) will help.

Establish (for example): a). Does small amount of leaking (liquid) matter (for people and contents)?
b). Do stains matter? (aesthetics)
c). What level of (vapour) ingress is acceptable/tolerable (for people and contents)?

Note. Some of the requirements for a particular performance will not be within our control (heating, ventilation etc).

6.3 CONSTRUCTION OPTIONS

Structural concrete can prevent ingress of liquid water, except at joints and cracks. It will **not**, generally, prevent the passage of moisture vapour.

Steel sheet piling can prevent ingress of liquid water, except at joints. It will also reduce the passage of moisture vapour. Consider welded sheet piling – low carbon type.

Construction option	Advantages	Disadvantages
Cut & cover	• Allows easy inclusion of membrane external to the structure • Enhanced quality of concrete elements • Continuous construction • Good finish • Straightness of line of walls	• Deep basements not easy • Not always sufficient room (e.g. inner city sites)
Sheet piling Post and panel	• Provides restraint to the ground • Provides restraint to water flow (both short and long term) • Can be used as a shutter for the concrete	• Provides restraint to concrete - increased risk of cracking • Difficult to install a membrane on external face of structure
Diaphragm wall & Secant piles	• Provides restraint to the ground • Provides some restraint to water flow • Can build deep basements	• Difficult to install a membrane on external face of structure • Allows water through the joints (use drained cavity?) • Difficult to get an effective connection with the slab • Poor appearance • Expensive
Contiguous piles	• Provides restraint to the ground • Cost	• Little restraint to water flow • Difficult to get an effective connection with the slab • Difficult to install a membrane • Poor appearance • Expensive

Table 6.2 (from CIRIA report 139) gives examples of types of basement.

6.4 WATERPROOFING OPTIONS (Combined with options of structure)

Tanking (Type A)

- Preformed membranes or liquid applied
- Can prevent liquid and vapour passage
- Best installed by open cut construction
- Best installed external to construction (outside face of structural wall)

Structurally Integral Protection (Type B)

- Reinforced concrete with calculated crack widths to BS8110 Part 2 possible for Type 1
- Concrete design to BS8007 required for type 2 and 3
- If used, particularly for type 2 and 3 basements, there must be careful consideration of mix design and the workmanship required as well as a strategy for dealing with leaks.

Drained cavity (Type C)

- Provide channels to allow drainage of water
- Ventilate cavity externally to reduce vapour and build up of other gases
- Ventilate basement to reduce vapour
- Automatic pump may be required in sump
- Design inner leaf as free-standing or restrained at top by slab
- Beware vermin

6.5 CRITICAL POINTS

- Re-entrant corners – keep plan form simple
- Penetrations e.g. pipe services (group together), earthing pits
- Wall/slab junctions - particularly in non-open excavation
- Changes in section/depth e.g. lift pits
- Pile/slab junctions
- "One column per pile" junctions, e.g. steel columns into top of pile.

6.6 CONSTRUCTION JOINTS

- Need to control the effects of temperature and shrinkage
- The fewer, the better
- Arrange the sequence of castings to reduce restraint from adjacent pours
- Recommended spacing of joints (principally to control workmanship, not cracking):

Construction	Max. area (m?)	Max. dimension (m)
Watertight walls	25	5
Watertight slabs	100	10

May be reviewed for particular cases

6.7 MOVEMENT JOINTS

- Rarely necessary below ground level
- Potential weak points. Only consider providing them if essential to control movements e.g. between tower and podium blocks above.

6.8 REFERENCES

CIRIA Report 139 Water – resisting basements 1995
CIRIA, Guide 5, Guide to the design of waterproof basements
BS 8007: 1987: Design of concrete structures for retaining aqueous liquids
BS8102: 1990: Protection of structures against water from the ground
BS8110: Part 1: 1997: Structural use of concrete: Code of Practice for design and construction
BS8110: Part 2: 1985: Structural use of concrete: Code of Practice for special circumstances
OVE ARUP PARTNERSHIP: Structural Typical details for use in buildings
OVE ARUP & PARTNERS, Reinforcement detailing manual
Notes on Materials 86, 138, 145
Notes on Structures 4, 24, 29

Table 6.1 Guide to level of protection to suit basement use from table 2.1 of CIRIA 139
(The first four columns are from table 1 of BS8102)

Grade of basement	Basement usage	Performance level	Form of protection*	Commentary on Table 1 of BS8102: 1990
Grade 1 (basic utility)	Car parking; plant rooms (excluding electrical equipment); workshops	Some seepage and damp patches tolerable	Type B. Reinforced concrete design in accordance with BS8110	Unless there is good ventilation, or local drainage, visible water may not be acceptable even for the suggested uses. Calculated crack widths less than 0.3 mm to BS8110 Part 2 BS8110: Part 1 contains only limited guidance on crack control and lacks consideration of early thermal movement. Using Part 1 may result in the formation of cracks with widths unacceptable in permeable ground. There is no guidance on control of thermal cracking in BS8110. Groundwater should be checked for chemicals, which may have a deleterious effect on the structure or internal finishes. The performance level defined in BS8102 for workshops is unlikely to meet the requirements of the Building Regulations, approved Document C for workshops, which are more likely to require a Grade 3 (habitable) environment.
Grade 2 (better utility)	Workshops and Plantrooms requiring drier environment ; retail storage areas	No water penetration but moisture vapour tolerable	Type A Type B. Reinforced concrete design in accordance with BS8007	Membranes may be applied in multiple layers with well-lapped joints. The performance level assumes no serious defects in workmanship, although these may be masked in dry conditions or impermeable ground. Groundwater should be checked as for Grade 1. A high level of supervision of all stages of construction is necessary.
Grade 3 (habitable)	Ventilated residential and working areas including offices, restaurants etc., leisure centres	Dry environment	Type A. Type B. With reinforced concrete design to BS8007. Type C. with wall and floor cavity and DPM	As Grade 2 In highly permeable ground multi-element systems (possibly including active precautions) will probably be necessary.
Grade 4 (special)	Archives and stores requiring controlled environment	Totally dry environment	Type A. Type B. With reinforced concrete design to BS8007 plus a vapour-proof membrane. Type C. With ventilated wall cavity and vapour barrier to inner skin and floor cavity with DPM	As Grade 3

Table 6.2 Guidance on the functional environments requirements for basement usage (Table 2.2 of CIRIA 139)

Grade of basement	Relative humidity	Temperature	Performance level	
			Dampness	**Wetness**
Grade 1 (basic utility)	>65% normal UK external range	Car parks: atmospheric Workshops: 15~ 29°C. Mechanical plantrooms: 32°C max, at ceiling level	Visible damp patches may be acceptable	Minor seepage may be acceptable
Grade 2 (better utility)	35~50%	Retail storage: 15°C max Electrical plantrooms 42°C max	No visible damp patches, construction materials to contain less than the air-dry moisture content	None acceptable
Grade 3 (habitable)	40~60% 55~60% for a restaurant in summer	Offices: 21~25°C Residential: 18~22°C Leisure centres: 18°C for spectators 10°C for squash courts 22°C for changing rooms 24~29°C for swimming pools Restaurants: 18~25°C Kitchens 29°C max	None acceptable Active measures to control internal humidity may be necessary	
Grade 4 (special)	50% for art storage >40% for microfilms and tapes 35% for books	Art storage: 18~22°C Book archives: 13~18°C	Active measures to control internal humidity probably essential	
(N.B. The limits for a particular basement application should be agreed with the client and defined at the design approval stage).				

Table 6.3 Construction methods and examples of passive precautions available to achieve the required Grade of internal environment in deep or shall basements. (Table 3.1 of CIRIA 139)

Basement depth and construction materials	Target internal environment / examples of construction methods and passive precautions			
	Grade 1 (basic utility)	Grade 2 (better utility)	Grade 3* (habitable)	Grade 4* (special)
	Limited environment control *possibly* adequate (Low cost, low reliability)			***Complete environment control*** normally required (High cost, high reliability)
	Some water penetration Acceptable	Water penetration Unacceptable	Increasing requirements for vapour control	
Shallow (assumed no hydrostatic pressure, i.e. groundwater level below basement floor or drainage provided) likely to be residential Masonry, reinforced masonry, plain or reinforced (pre-cast or in-situ) concrete or steel sheet piling	Grade not usually acceptable for residential basements	Masonry or plain concrete plus tanking (Type A) or drained cavity (Type C) protection ——— Reinforced concrete box (Type B) protection	Masonry or plain concrete plus tanking (Type A) protection and/or Type C protection ——— Reinforced concrete box (type B) plus tanking vapour barrier (Type A) or drained (type C) protection	If grade required the methods and precautions for shallow basements with permanent hydrostatic pressure should be followed
Shallow (with permanent hydrostatic pressure) Masonry, reinforced masonry, plain or reinforced (pre-cast or in-situ) concrete or steel sheet piling	Masonry, plain or reinforced concrete box construction plus tanking (Type A) or drained (Type C) protection ——— Reinforced concrete box (Type B) protection ——— Steel sheet piling in conjunction plus drained (Type C) protection	Masonry, plain or reinforced concrete box construction plus tanking (Type A) or drained (type C) protection ——— Reinforced concrete box (Type B) protection	Masonry or plain concrete plus tanking (vapour barrier, Type A) *and* drained (Type C) protection ——— Reinforced concrete box (Type B) plus tanking (vapour barrier, Type A) or drained (Type C) protection	Reinforced concrete box (type B) with tanking (vapour barrier, Type A), plus drained (Type C) protection Passive precautions alone are not likely to be sufficient
Deep (with permanent hydrostatic pressure) Reinforced concrete including piled or in-site perimeter wall.	Reinforced concrete box (Type B) protection ——— Concrete piled wall possibly requiring drained cavity (type C) protection	Reinforced concrete box (Type B) protection ——— Concrete piled wall or reinforced concrete box (Type B) plus drained (Type C) protection	Concrete piling or reinforced concrete box (Type B) plus an internal vapour barrier (Type A) or drained (Type C) protection Passive precautions alone are not likely to be sufficient	Concrete piling or reinforced concrete box (Type B) plus tanking (vapour barrier, Type A) and drained (Type C) protection Achieved only at high cost Passive precautions alone are not likely to be sufficient

Notes: When tanking is required, external or sandwich tanking systems are recommended for both new and existing basements where it is possible to use them. Such systems become feasible either by virtue of an existing permanent external surface (including faced sheet piling) or where working space is created through open excavation. The choice of tanking system also requires an assessment of the external hydrostatic pressure and its effect on the basement wall design and construction. For deeper basements, or where excavation is impracticable, internal protection by cavity construction with internal or reverse tanking may be used. This implies a reduction in usable volume or increased excavation volume. Integral protection must not be damaged by wall fixings. The costs of available options and associated risks will need to be evaluated. Where significant quantities of water are likely to accrue in sumps on a regular basis the drainage authority should be approached at an early stage to request acceptance of the discharge.

* The design for Grade 3 or Grade 4 should take account of the contribution of active precautions (heating and ventilation, etc.) in achieving the required internal environment.