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Flood resistant and resilient construction – Guide to improving the flood performance of buildings

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Contents

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 November 2015. It was prepared by Technical Committee CB/501, *Flood risk and watercourses*. A list of organizations represented on this committee can be obtained on request to its secretary.

Relationship with other documents

This British Standard is based upon the guide *Improving the flood performance of new buildings - flood resilient construction* published by the Department for Communities and Local Government in May 2007. It takes account of additional research into the reaction of modern materials and construction methods to flooding and has been extended to apply to retrofitting of flood resistance/resilience to existing buildings, as well as to new buildings. It provides greater detail than the core document of the same title that can be freely downloaded from http://shop.bsigroup.com/BS85500

Information about this document

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Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Introduction

This British Standard is intended to help identify when flood resilient and resistant construction is appropriate and to give guidance on achieving these. This standard is applicable to new buildings, extensions and the retrofitting of existing properties.

National and local planning policies discourage inappropriate development in areas at risk of flooding. This standard does not promote development in flood risk areas, but provides guidance on reducing the potential consequences where buildings are located in an area at risk of flooding.

This standard is intended to help manage residual risk after other measures or approaches, such as avoiding risk, locating development in an area of low risk or raising floor levels (see **6.2**), have been implemented.

1 Scope

This British Standard gives recommendations and guidance on how to improve the resistance and resilience of buildings to reduce the impacts of flooding from all sources, by the use of suitable materials and construction details. Specifically, it provides:

a) recommendations for the adoption of flood resistant and resilient construction measures, including when to apply resistance and when to apply resilience; and

b) guidance on the design and specification of flood resistance and resilience for new buildings, extensions and retrofits.

The guidance covers masonry, light-weight steel-frame and timber-frame buildings.

It is not applicable to:

1) the structural design or layout of buildings;

2) the selection, fixing and deployment of flood protection products which are covered by other standards, such as PAS 1188 and *Delivering benefits through evidence: Temporary and Demountable Flood Protection Guide* [1];

3) the design of watertight concrete, which is specified in BS EN 1992-3;

4) the construction of amphibious or floating properties;

5) the construction of properties on stilts; or

6) detailed avoidance measures outside the perimeter (footprint) of the building, such as local land raising above the predicted flood level.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 8102, *Code of practice for protection of below ground structures against water from the ground*

BS 8533, *Assessing and managing flood risk in development – Code of practice*

BS EN 13914-1, *Design, preparation and application of external rendering and internal plastering – Part 1: External rendering*

PAS 1188-1, *Flood protection products – Specification – Part 1: Building aperture products*

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1 flood avoidance
construction of a building and its surrounds in such a way as to avoid (at site level) it being flooded

EXAMPLES

Raising ground or floor level above the predicted flood level, re-siting outside flood risk area, landscaping to direct/divert flood water away from building, the use of bunds.

3.2 flood resistance
construction of a building in such a way as to prevent or minimize flood water entering the building and damaging its fabric

NOTE Also known as "dry-proofing".

EXAMPLE

Use of low-permeability materials.

3.3 flood resilience
measures that can be incorporated into the building fabric and/or fixtures and fittings that can be installed to reduce the consequences of flood water entering the property

NOTE 1 This allows easier drying and cleaning following a flood and reduces the amount of time until the building can be reoccupied.

NOTE 2 Also known as "wet-proofing".

EXAMPLES

Use of sacrificial materials for internal or external finishes, e.g. gypsum plasterboard placed so that it can easily be removed below the flooded level and replaced, or materials that can resist the effects of flooding, e.g. tiled finishes.

3.4 water entry strategy
design strategy based on allowing water to enter a property rather than preventing its ingress

3.5 water exclusion strategy
design strategy based on the use of impermeable materials to minimize the ingress of water into a property

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4 Context

4.1 Resistance and resilience informed by flood risk assessment

National and local planning policies discourage inappropriate development in areas at risk of flooding. This British Standard does not promote development in flood risk areas, but provides guidance on reducing the potential consequences for buildings located in an area at risk of flooding.

The resistance and resilience measures recommended in this standard are based on a design strategy chosen in accordance with **6.1**, which in turn should be informed by a site-specific flood risk assessment for the building or development site. These measures should only be applied after other measures, such as avoiding risk by locating development in an area of low risk or raising floor levels, have been implemented (see **6.2**).

The flood risk assessment should be carried out in accordance with BS 8533. Key parameters of this assessment are the expected flood depth, duration and frequency, since these determine the likelihood of being able to keep water out of the building (resistance), and whether it is more cost-effective to plan for water ingress (resilience). In general terms, flooding associated with greater depths and longer durations requires the adoption of the water entry strategy, while shallow and short-duration flood water requires a water exclusion strategy and measures that do not need to be deployed by the householder. While the initial design strategy is based on the flooding characteristics, this might be changed subsequently to reflect the building construction type and performance requirements, the sensitivity of contents, the capability and circumstances of the householder, and the budget.

4.2 Types of flood and their characteristics

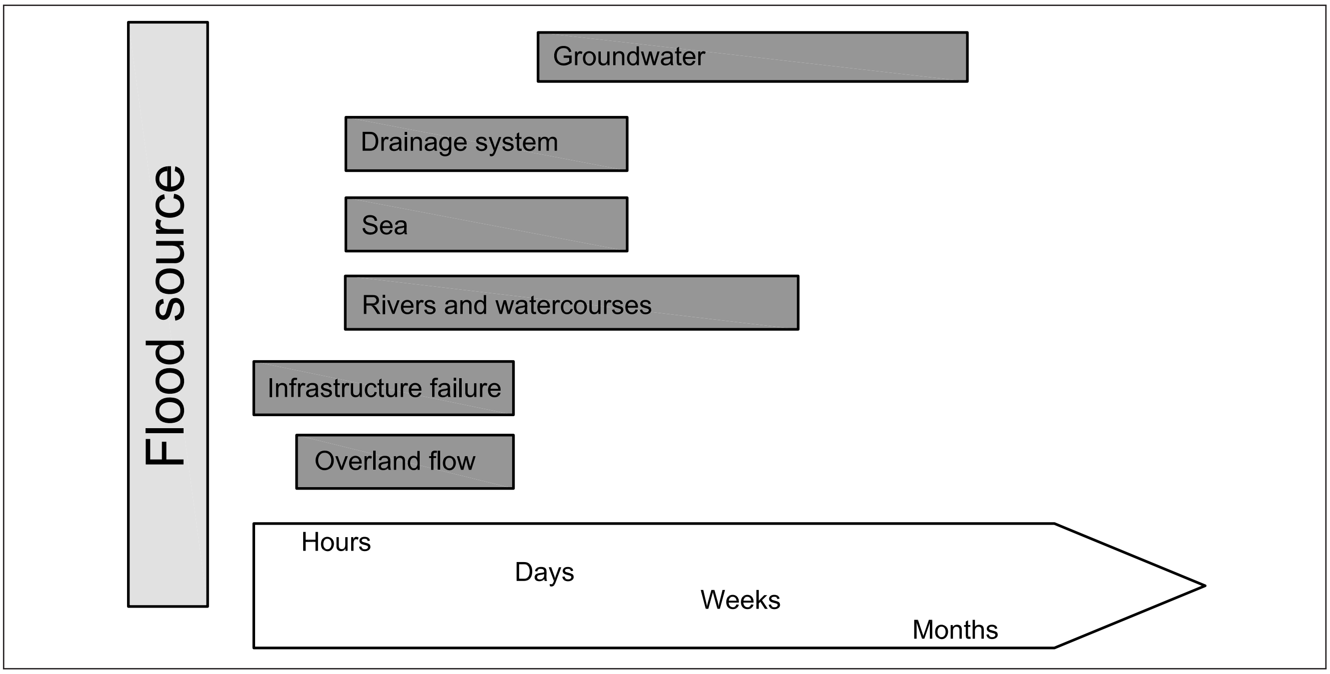
Figure 1 shows typical durations for different types of flooding.

Overland flow or exceedance of the sewerage infrastructure typically affects a property for up to a few days. However, in some areas the duration of flooding could be limited to only a few hours because the source of the flooding is an intense rainfall event. Such flooding would be expected to have a shallow depth. In contrast, groundwater is associated with extensive rainfall over a long period that has filled the available below-ground storage. Once established, this flooding can continue for many weeks or months. Although groundwater flooding affects fewer properties than other sources of flooding it often causes more damage. Failure of flood defences can result in significant flood depths and velocities in the zone immediately behind them, with impacts such as building damage or fatalities.

All of these flood characteristics (depth, duration and frequency of occurrence) are important in the choice of design strategy and the measures employed to deal with the flooding. However, although flooding can result from a single event or source, it more commonly occurs through a combination of events. Intense rainfall can lead to overland flow, but also cause watercourses to fill and overtop their banks. The flooding characteristics are determined as part of the site flood risk assessment (see **6.1**).

If the likely flood depths (generally of existing properties) are determined to be high (>600 mm), a structural engineer should be consulted to assess the structural integrity of the building and potential strengthening measures.

Figure 1 **Typical flood durations**



4.3 Construction opportunities

New buildings should be located, designed and constructed such as to prevent them from being flooded, taking account of the type, depth, duration and frequency of flooding.

When any work is being undertaken on an existing building (including flood reinstatement), the opportunity should be taken to improve the flood resistance and resilience characteristics of the building, even if it has not been flooded but has been identified as at risk in the flood risk assessment.

An extension should provide at least the same level of flood resistance and resilience as the rest of the building, taking account of the flood risk assessment. However, where the existing building does not have the necessary level of flood resistance, as established from the flood risk assessment, the extension should be appropriately flood resilient. Ideally, flood resistance and resilience should be provided as part of the construction work, to allow for the resilience of the whole building to be improved over time as opportunities arise.

4.4 Other considerations

The design of flood resistance and resilience of a building needs to take account of the requirements of local planning (including listed building status, conservation areas and other designations), Building Regulations [2], [3] and [4] and health and safety. Existing construction and occupation types need to be considered.

5 Response of buildings

5.1 General

The impact of flood water on a building depends on the nature of the flooding and the design and construction of the property. In order to be able to improve the flood performance of the building it is first necessary to understand the impact of flooding on the materials, components and elements of the building. A risk-based approach can then be adopted.

Resistance and resilience measures are aimed at minimizing water entry and avoiding excessive damage to the building, respectively, and both can reduce disruption to the occupiers.

The impacts of flooding on buildings include the following:

a) direct deterioration of materials, components and elements resulting in immediate change of their form and properties without returning to their previous condition after drying;

b) direct structural damage caused by the depth, duration and velocity of flood waters on the building structure, including debris impact;

c) inundation or saturation of materials that cannot be dried or recovered economically on site;

d) temporary contamination of the internal and external surfaces, as well as cavities in walls and floors; and

NOTE 1 Temporary contamination by flood water does not normally represent a health hazard once dry and thoroughly cleaned as necessary.

e) indirect secondary damage, such as mould growth and other problems arising from high atmospheric moisture.

NOTE 2 Secondary damage can be minimized by prompt action after an incident, especially drying measures.

Table 1 summarizes the potential flood impact on property, based upon depth and velocity, while Figure 2 demonstrates potential routes for entry of flood water into a dwelling.

Table 1 **Possible flood damage for a typical residential property** *(1 of 2)*

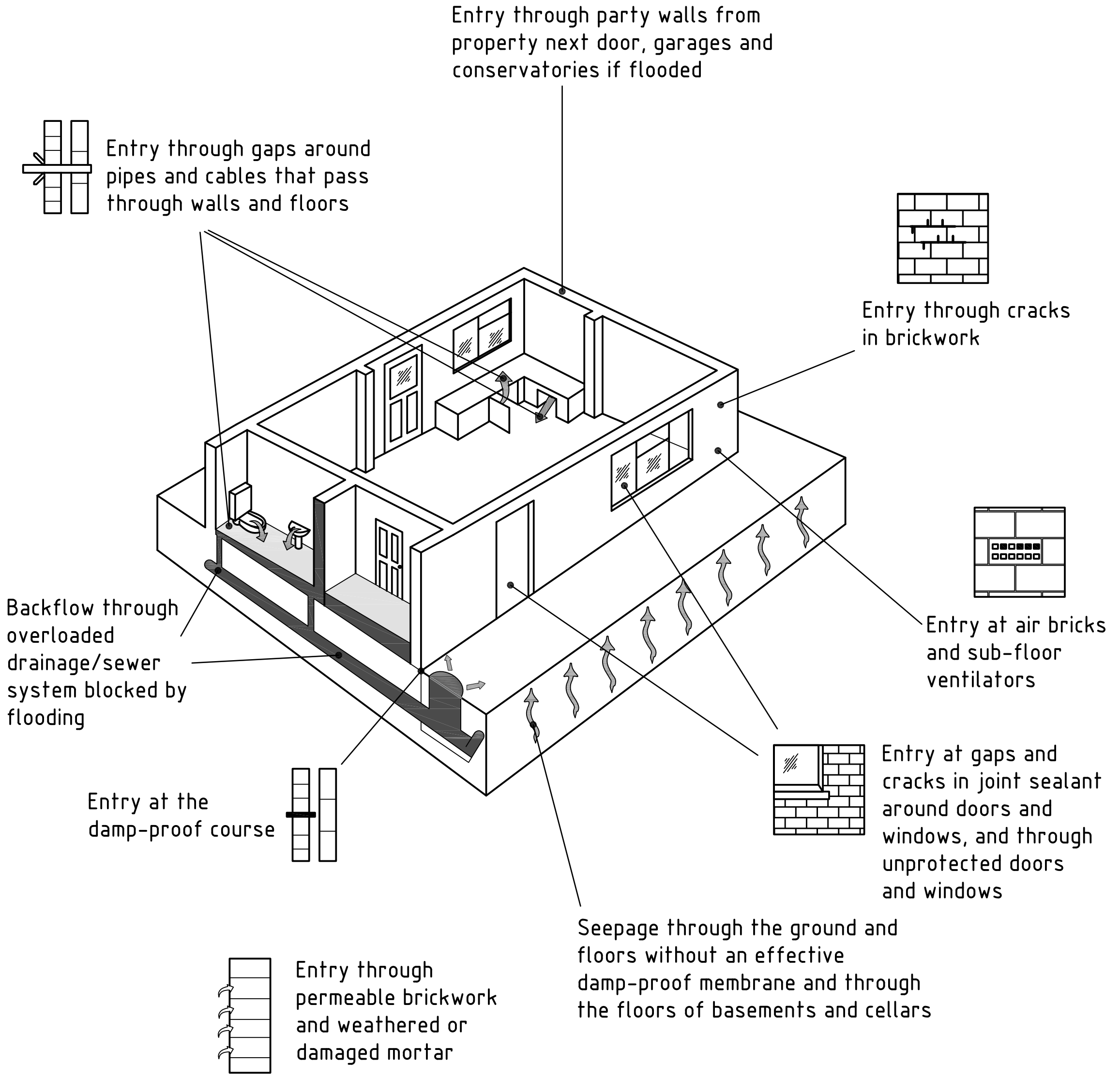
Flood water level	**Damage to the building**	**Damage to services and fittings**
Below door threshold level, e.g. basements	**Where the basement is constructed for occupation**: Deterioration of plaster, dry lining, composite and fibrous wall lining and flooring materials. Spoiling of decoration. Waterproofing measures designed to protect the basement from groundwater ingress can be affected. Open-cell and quilted insulation fitted to the internal walls can be damaged beyond economic repair. Pumping stations, sumps and channels associated with type C waterproofing are susceptible to blockage by silt and debris. **Where the basement is unsuitable for occupation**: Significant damage to the building's fabric is unlikely. However, timber and materials built onto or embedded within the walls are vulnerable to fungal decay if the surrounding masonry is not returned to a dry condition within a reasonable time.	Damage to electrical sockets, consumer units and utility meters. **Warning** Basements can be very rapidly inundated. Escape routes should be considered where there is a high risk of surface water flooding. Damage to fittings, wall and floor coverings.

Table 1 **Possible flood damage for a typical residential property** *(2 of 2)*

Flood water level	Damage to the building	Damage to services and fittings
Below door threshold level, e.g. basements	**Sub-floor voids and subterranean slabs:** Areas below the finished ground floor level might contain voids that can trap water. Failure to identify and remove this water could result in decay or deterioration in friable construction materials at or below the junction between the wall and floor. Mould and timber-decaying fungi can grow where damp conditions persist.	Floating, laminate or engineered floor finishes can swell or denature. MDF skirting boards, carpet gripper rods and other friable fittings can be denatured or affected by decay if exposed to damp conditions for protracted periods.
Shallow flooding	Build-up of water and silt in cavity walls, with potential reduction in the insulating properties of some materials. Damage to internal finishes, such as wall coverings, gypsum-based plaster and plasterboard dry linings. Timber-based materials exposed to water for protracted periods are likely to swell and crack, and warp if dried incorrectly. Damage to internal and external doors, skirting boards and other joinery timbers. Timber-decaying fungi and mould can develop unless water and humidity are correctly managed after flooding. Ground salts and other soluble contaminants present but immobile during dry periods can be put into solution during floods. Salts can be introduced by flood water after a single or repeated flooding event(s) (particularly seawater flooding). These can be transported through the fabric of solid walls to be deposited as hygroscopic contamination in wall finishes and plaster coats. Open-cell and quilted insulation within cavity walls can be damaged. In some circumstances it can retain water, impeding recovery. Corrosion of metal fixings and fittings.	Damage to electrical sockets, junction boxes, meters and gas meters. Damage to low-level gas boilers and some electrical underfloor heating systems. Damage to communication wiring and junction boxes. Carpets, laminate and composite floor coverings might need to be replaced. Kitchen units and bathroom cupboard carcases made of chipboard and wood composite materials are likely to denature and might require replacement. Insulation on pipework might need to be replaced if not closed-cell type.
Deeper flooding	Increased damage to walls (as above). Differences in water levels greater than 600 mm across walls can cause structural damage through hydrostatic pressure. The likelihood of damage depends on the load characteristics, form of construction, size of unrestrained panels and materials used in the building. Damage to windows can be caused by relatively small differential pressures. High-speed flow around the building perimeter can lead to erosion of the ground surface. There is a potential risk of damage to the structure from large items of floating debris, e.g. tree trunks. Scouring to friable wall surfaces and soft mortar joints can occur during very high flow events.	As above. Damage to units, electrical services and appliances that are sited higher on the walls of the building.

NOTE Guidance on cleaning and drying is given in Public Health England's Floods – how to clean up your homes safely *[5]. See also BS 12999.*

Figure 2 **Potential routes for entry of flood water into a dwelling**



NOTE Reproduced with modifications from Flood products – using flood protection products – a guide for homeowners *[6]. Copyright is claimed in Figure A.1. Details of the copyright owners can be found in the Foreword, Information about this document.*

5.2 Foundations

Foundations are typically formed from concrete, masonry and steel, and do not usually suffer material damage due to flooding. However, erosion of ground due to flood water velocity can result in instability or settlement of the foundations. Granular soils might be at greater risk from scour than cohesive clay soils.

Figure 3, illustrating a ground bearing slab, shows a potential flow path from the ground adjacent and under a dwelling, through porous substructure and into the wall cavity. The figure highlights the fact that measures taken above ground level might not fully prevent the ingress of water.

Figure 4 illustrates flow paths for a suspended floor.

Figure 3 **Water ingress into properties through the ground: Ground bearing floor**

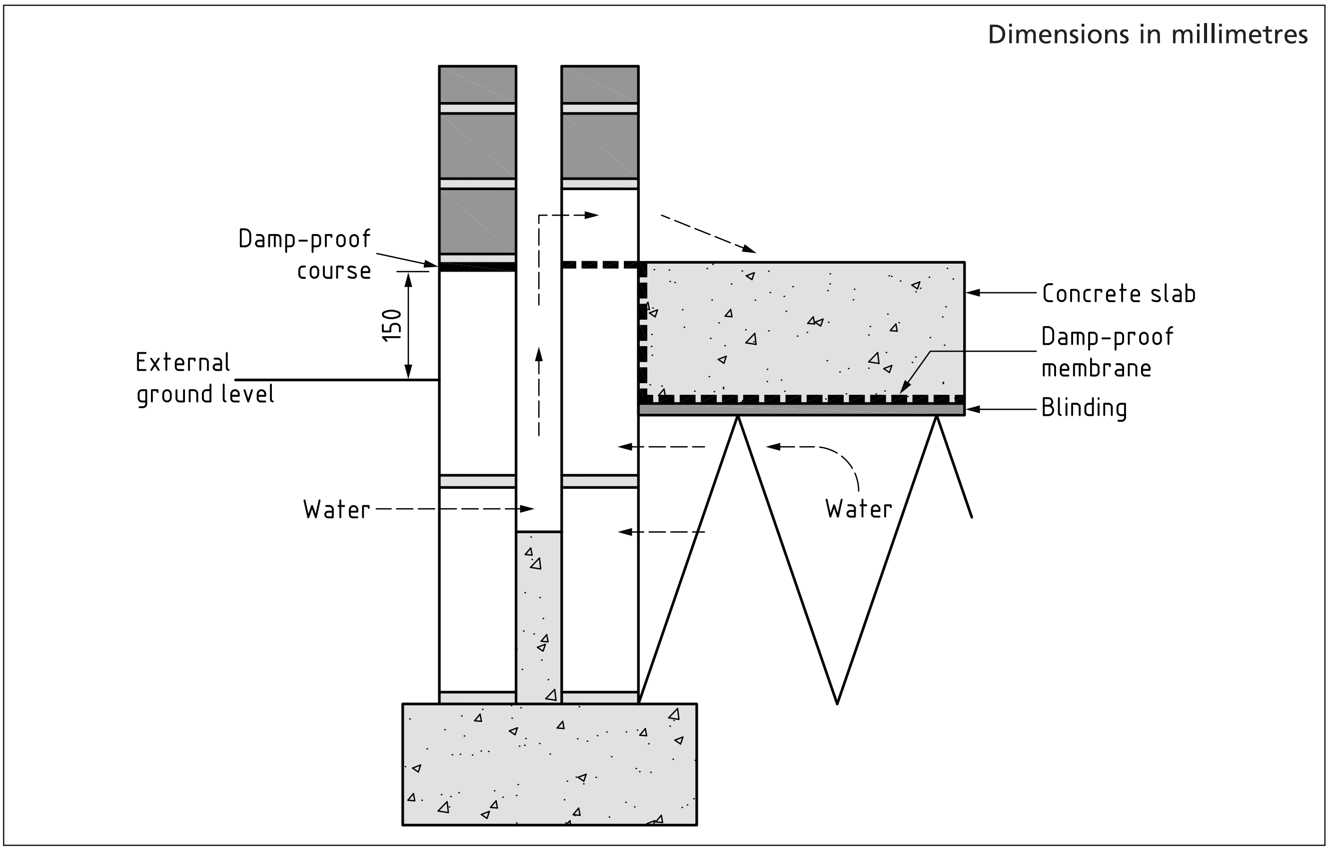
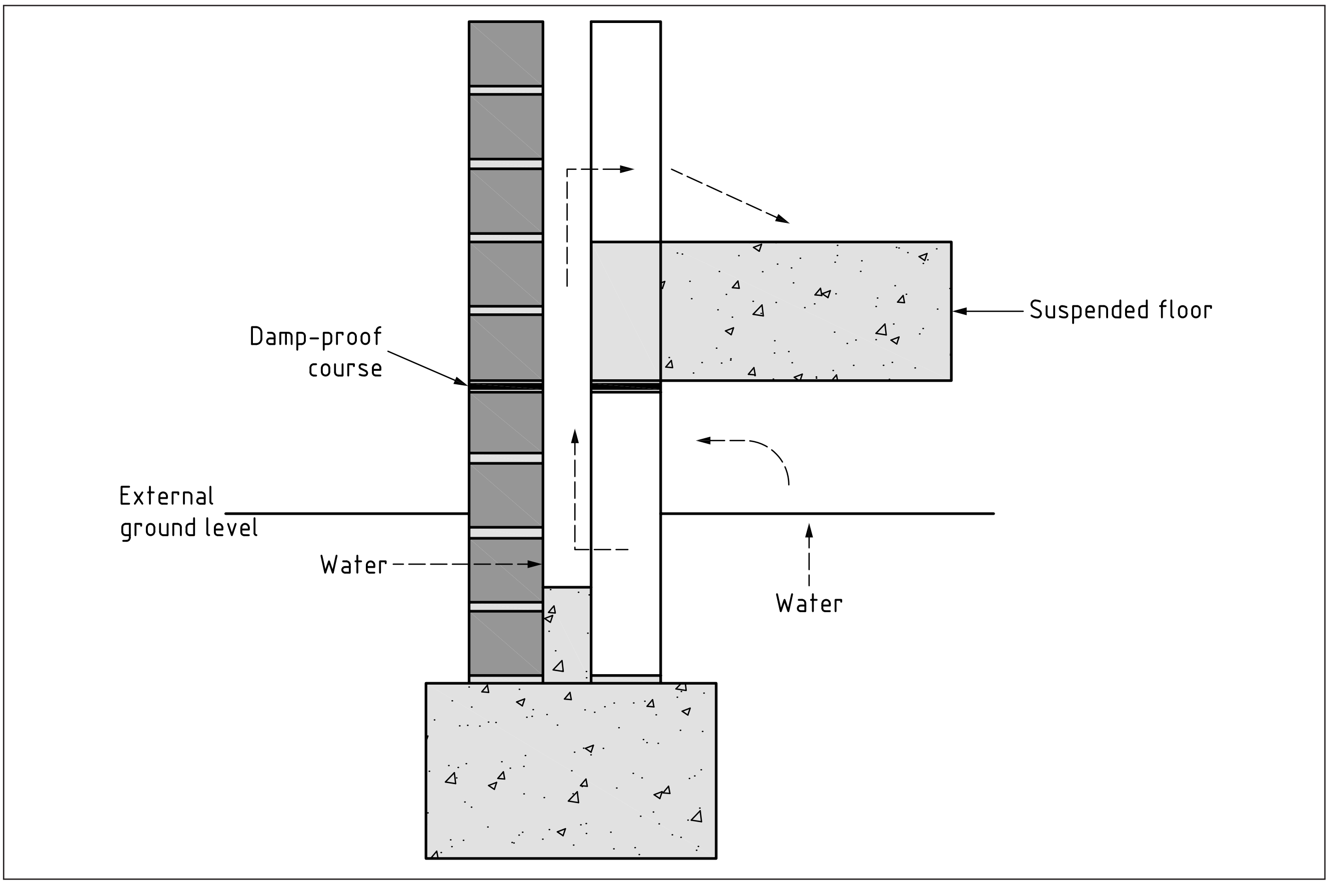


Figure 4 **Water ingress into properties through the ground: Suspended floor**



5.3 Basements

Basements protected in accordance with BS 8102 (see **7.2**) can suffer inundation from flood water entering the basement from above. Unprotected basements are, in addition, vulnerable to groundwater entering through the walls and floors and service entries.

5.4 Floors

Floors of all types can be affected by flood water, with resulting material or structural damage. Even shallow floods of short duration frequently result in contamination of the floor surface. The areas of risk are set out in Table 2.

Table 2 **Floors: Potential flood impacts** *(1 of 2)*

Item	Hazard	Impact
Floor structure	Uplift pressure	Cracking and heave of solid concrete floors Structural damage to suspended concrete slabs resulting in cracking Concrete can become wet and experience expansion and cracking; screeds are at particular risk of cracking and there might be a risk of cracking if subsequent drying is too quick and shrinkage is not accommodated Structural damage to suspended timber floor joists and boards resulting in displacement and instability
Floor slab: concrete	Contaminated flood water contact: longer duration presents higher risk	Localized salt attack on reinforcement in concrete slab in poor condition For precast floor slabs, contaminated water can enter cavities and be difficult to decontaminate and dry
Floor boards: timber	Flood water contact: longer duration presents higher risk	Water absorption by timber boards resulting in relatively lengthy drying requirements Floor boards can warp due to inappropriate drying Long-term deterioration can result if the moisture content is not reduced below 20%
Floor insulation	Flood water contact: in concrete floors water can seep between the finish/screed and the slab into the insulation In timber floors insulation is generally hung between joists or sandwiched between the floor boards and finish/screed	Absorption of water into insulation materials resulting in the need for replacement or specialist decontamination and drying techniques Water trapped between closed-cell insulation and the construction above and/or below needs to be removed by specialist drying techniques or the insulation removed and dried according to cost and practicality
Floor screed	Flood water contact: increased risk if the floor finish is permeable	Floor screeds based on gypsum or anhydrite are deteriorated directly by flood water Cement/Lime: sand mortars are not directly damaged, but might suffer from cracking if subsequent drying is too rapid

Table 2 **Floors: Potential flood impacts** *(2 of 2)*

Item	Hazard	Impact
Floor finishes	Flood water contact	Carpets and textile-based materials can be rendered unusable due to temporary contamination and deterioration (especially in longer duration floods) Timber finishes: hardwoods are resilient but likely to trap water beneath, and therefore require lifting to dry the sub-floor and avoid contamination; softwoods are more likely to be affected by water absorption and warping (due to swelling and/or subsequent drying) Tile finishes (ceramic, concrete, stone) are resilient to flood water and help to prevent water absorption in underlying screed and insulation
Underfloor heating	Flood water contact: seepage into ducts and service entries	With "wet systems" there is unlikely to be an impact on the underfloor pipes themselves as they are sealed System components need to be cleaned and serviced after a flood Electrical mat systems are likely to need replacement
Membranes	Differential pressure	Damage to membranes is unlikely as these are resilient materials, designed to be waterproof, and can be dried if necessary Radon, damp and ground gases could enter the building if a damp-proof membrane is damaged by differential movement or during remedial works

5.5 Walls

Walls of all types can be affected by flooding, with deterioration of materials and components occurring, as well as temporary contamination of internal surfaces. Table 3 sets out the risks to the different types of wall construction.

5.6 Doors and windows

When in prolonged contact with flood water, wooden external doors can swell, potentially making egress from the property more difficult. They can also warp or split when they are dried, preventing locks from engaging properly and lowering their thermal performance.

Flood water can enter hollow sections of doors and windows and their frames. Tidal and polluted flood water can lead to corrosion of internal metalwork. High depths of flooding put pressure on seals and potentially lead to premature failure.

Water can enter the inside of internal doors with hardboard or MDF (medium-density fibreboard) skins, which can result in collapse of the internal structure of a door or cause rotting from the inside. Pollutants in the flood water can be trapped inside the door.

Table 3 **Walls: Potential flood impacts**

Item	Hazard	Impact
External wall	High-velocity flood water	Removal of mortar jointing, particularly in older properties with lime mortar
	Debris-laden flood water	Physical damage
	Differential pressure	Structural damage
External cladding and insulation	Contact with flood water: High-velocity flood water Debris-laden flood water	Reduction in insulation effectiveness Silt ingress into cavity Potential corrosion of fixings Potential fungal growth and decay Physical damage
Cavity insulation	Contact with flood water	Matting and slumping of loose insulation Retention of water leading to fungal growth Reduction in insulation effectiveness
Internal wall finishes and insulation	Contact with flood water	Staining Degradation of gypsum-based plasters, including hygroscopic salts Lifting or peeling of decorative coverings and wall papers
	Prolonged contact with flood water	Possible corrosion or other failure Warping of woodwork such as skirting boards
	Prolonged contact with seawater	Absorption of salts
Timber frame	Contact with flood water	Potential fungal growth and decay Need for opening up for investigation and drying out For long duration flooding and/or inappropriate drying, potential for warping and distortion
Steel frame	Contact with flood water, especially sea water	Corrosion

5.7 Fixtures, fittings and services

Electrical services in flood water present a high risk of electrocution during the flooding and afterwards. Tidal flooding can cause corrosion of metal parts and pollution can cause bridging of components, both of which can cause electrical fires.

Silt in flood water can block parts of gas heaters and boilers, potentially leading to carbon monoxide being released. Flood water can short-circuit the electronic controls of gas fires and boilers, and their associated circulating pumps and solenoid valves.

Flooding causes movement of the building, either directly due to flood action or as a result of wetting and drying, which can lead to gaps in radon barriers. Radon fans can be switched off, either as a result of an outage of the electrical supply or damage to the fans and their wiring.

Prolonged contact with flood water can lead to swelling and irreversible damage of chipboard-based units. Pollution can be trapped behind and beneath units.

5.8 Resistance and resilience (materials and components)

Materials and components used for the building fabric and finishes need to be flood resilient and/or resistant for new buildings or retrofit situations. Foundations, floors, walls, fenestration and other elements should be assessed as to their relevant properties. At present, no recognized test methods or assessment methods cover these aspects, but assessments should consider properties such as water penetration, surface drying and retention of shape and form. Performance can vary by the type of flooding, and consideration should be given to the design strategy for the building (see Clause **6**).

Specifiers should be aware of the material performance issues and seek to fill gaps in knowledge using the advice of manufacturers or relevant independent organizations.

6 Design strategies

6.1 Influencing factors

Knowledge and understanding of the potential flood characteristics at a site are needed in order to formulate a design strategy that achieves appropriate mitigation for any potential flood risk.

The choice of strategy depends largely on the frequency and characteristics of the design flood event, the availability of space, cost and practicality. Some strategies are not applicable to existing buildings. New buildings should be constructed so that they are safe and resilient and do not require the use of operational measures, such as the use of temporary door guards, that are required to be deployed in a flood.

Recommendations for determining the types of flooding that could occur at a site and their characteristics are given in BS 8533, but lesser events can occur more frequently. The factors that influence the choice of design strategy are described as follows.

a) **Depth**

Predicted flood depth is the main parameter in the design strategy, since this dictates whether it is feasible to try to exclude and/or delay flood water from entering the property.

The design strategy should take account of both the most severe design flood and lesser, more frequent events. It is likely that for any one building different strategies will be combined to cater for different events.

b) **Source**

Flooding from seawater or overloaded sewer systems could result in contaminated water infiltrating the building fabric, causing cleaning and drying problems during repair. Therefore, a water exclusion strategy is more appropriate for these types of flooding. Groundwater flooding is normally best dealt with by a water-entry strategy, as experience indicates that a water exclusion strategy is unlikely to be successful.

c) **Duration**

Inundation of a building by flood water for long periods could damage the building fabric. For long duration flooding (e.g. a day or more), a strategy to keep water out of the building might not be a viable option. Mitigation measures might only delay the water entering a building long enough to enable evacuation or removal of contents.

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d) **Other considerations**

Where possible, it is preferable to evacuate a building before a flood event, as this avoids putting people in danger during a rescue or an emergency (e.g. medical emergency or fire). Where flooding is rapid and unexpected (e.g. flash flooding or a breach of defences) it might not be possible to evacuate, so a safer option might be for occupants to remain in the flooded building.

The ability to evacuate depends upon:

- ease of forecasting the flooding;
- speed of rise of flood water;
- availability of a warning;
- depth of flooding; and
- velocity of flooding.

Egress from a balcony, deck, door, window, etc., should be available to allow evacuation and access during a flood.

When a building is extended, there is a choice of making the extension resistant/resilient to the design event or providing the same level of resistance/resilience as the man building. The advantage of providing resistance/resilience to the design flood is that the extension can be used as a refuge during the flood and, after the flooding, can be returned to use before the main building. It also means that the whole building can be made resistant/resilient in stages, as opportunities present themselves to upgrade the existing building.

Where there is limited flood warning, the use of devices that require deployment as part of a water exclusion strategy are not appropriate.

6.2 Choice of strategy

In order of preference, the design strategy should be as follows.

a) **Avoidance**

Avoid building in a flood risk area or raise ground level/floor levels above flood level.

For design purposes, a freeboard should be used when setting the floor level of a property, to take into account uncertainties in data, estimates and irregularities in ground and water surfaces (e.g. waves resulting from wind or traffic). Floor levels should be raised above the design flood level, including an appropriate freeboard allowance to accommodate for uncertainty in the flood level estimate.

This strategy might not be possible for a variety of reasons, such as:

- existing property;
- increasing flood risk elsewhere;
- level access cannot be achieved; and
- planning restrictions.

Measures should not increase the flood risk elsewhere and ideally should reduce the overall flood risk. Compensatory flood storage areas might not be a feasible option.

b) **Site layout**

Local bunds, landscaping or construction of boundary walls to keep flood water away from buildings have the potential to minimize disruption to residents and clear-up costs. These measures are only likely to delay the flood water reaching a building, so it is prudent not to rely solely on them, particularly for long duration flooding. In general they are not appropriate for groundwater flooding.

Measures should not increase the flood risk elsewhere, and ideally should reduce the overall flood risk. Compensatory flood storage areas might not be a feasible option.

c) **Mitigation**

Flood mitigation assumes that flood water will reach the building. Mitigation measures can take the form of flood resistance (water exclusion) or flood resilience (water entry), but are often combined in order to cater for different events.

1) **Water exclusion (flood resistance)**

A water exclusion strategy to keep flood water out of buildings is most appropriate where flooding is low depth and short duration (either the design flood or for lesser, more frequent events). This strategy minimizes the impact of a flood on building occupants.

Individual properties or commercial buildings can be designed to be highly resistant to flood water entry by construction with water-resistant materials, such as appropriately-designed concrete.

Resistance measures are only likely to delay the flood water entering a building (particularly if they are designed to cater for events less than the design event), so the design should also incorporate resilience measures. The success of resistance measures relies upon good materials, workmanship and maintenance, and not breaching the measures (e.g. by ensuring any alterations such as new services are brought into the building above flood level or are properly sealed).

Keeping water out of the building results in hydraulic pressure on the structure from the flooding outside, so, unless the building is specifically designed to resist these pressures, once the depth of flooding exceeds around 600 mm, it is safer to allow water to enter the building.

2) **Water entry (flood resilience)**

This strategy assumes that water will enter the building (either as a result of a flood that exceeds the design event, the resistance measures failing or a deliberate effort to equalize hydraulic pressure on the structure). Once water has entered the building, resilience measures minimize damage and the time taken to reoccupy by choice of materials and construction features.

Flood resilience can also take the form of flood repairable materials, where flood damage is designed to be simply removed and replaced rather than dried out. The aim of this strategy is to facilitate minimal interior demolition, combined with appropriately monitored decontamination and drying procedures, with flood-affected materials being removed only when necessary. This strategy can be cost-effective and enables earlier reoccupation in most cases.

The water should be able to enter and drain from the house sufficiently quickly to maintain not more than a 300 mm difference between the inside and outside water levels.

This strategy is often used in combination with one of the other strategies. In particular, where the water is likely to be contaminated (e.g. seawater or sewage), as much resistance as possible should be provided with the resilience.

Table 4 summarizes the choice of strategy between flood resistance and resilience.

Table 4 **Selection of strategy**

Design flood water depth above ground floor level A)	**Strategy**
Less than 300 mm	Resistance B)
300 mm to 600 mm	Resistance + resilience
More than 600 mm	Resilience + resistance for lesser events

A) See **6.1**.

B) Groundwater and long duration flooding could additionally require resilience.

7 New buildings

7.1 Foundations

For suspended floors the foundation should be made as water-resistant as possible, to prevent water ingress into the void, e.g. using in-situ concrete rather than concrete blocks. For ground-supported floors, no special measures are necessary. Where high flood velocities are anticipated, the depth of foundations should be increased to mitigate damage from scour, particularly in fine-grained soils.

7.2 Basements

As indicated in **5.3**, basements can be affected by flooding from water entering from the ground floor level of the building or through the walls and floor of the basement, due to inadequate waterproofing measures.

New basements should be designed and constructed in accordance with BS 8102. This sets out three performance grades:

- Grade 1 – some seepage and dampness is permitted;
- Grade 2 – no water penetration, but dampness is permitted; and
- Grade 3 – no water penetration or dampness is permitted.

Three types of waterproofing protection are described:

- A – internal or external tanking;
- B – structurally integral protection; and
- C – internal drained cavity protection, with water removed by a sump and pump or by gravity.

Irrespective of the grade, a sump is needed in a basement at risk from water entry, to enable effective pumping out of flood water.

The walls and floor need to have a continuous water barrier, taken above the likely flood level outside the property.

With structural waterproofing the wall/floor junction requires particular attention for both the design and the installation of the waterproofing method chosen. In addition, all service entries and any movement joints should incorporate measures to prevent the passage of water to the interior.

Waterproofing systems that rely on drainage via mechanical means (e.g. a pump) require internal drainage beneath the floor levels and planned maintenance to ensure the pumps are kept in good working order and drainage channels are free from silt, debris and limescale, once the bulk of the flood water has been pumped out. New concrete might require a surface treatment to prevent a surplus of free-lime deposits from building up in the drainage channels.

Flooding can also be accompanied by power cuts, so the installation of an alarm system with control panel, battery back-up, or even a generator should be included in the installation.

7.3 Ground floors

7.3.1 General

The behaviour of ground floors in floods can be influenced by two different conditions:

a) water ingress from the ground (potentially resulting in uplift pressures); and

b) exposure to standing water.

Water ingress from the ground is potentially more severe as it is more likely to affect the structural integrity of the floor (see Figure 3 and Figure 4). Structural calculations might be necessary to ensure that the floor (including any lateral support provided at the perimeter) has the necessary strength to resist uplift forces without excessive deformation or cracking.

The floor construction can influence the length of drying time required following a flood. If the damp-proof membrane is between the slab and the screed, generally there is less damage than if it is located beneath the slab, because of relative drying times. However, the lack of weight on the membrane means that it is likely to move under hydrostatic pressure and potentially to tear.

Drying times for new concrete slabs and screeds are set out in BS 8203. Similar timescales should be anticipated for screeds and slabs that have been directly exposed to flood water.

Floor screeds should be resilient to exposure to standing water. Sand and cement screeds should be used in preference to calcium sulfate.

Mud, organic matter and oil from flood water delays drying of both the floor surface and the building fabric. Floor coverings (e.g. linoleum and vinyl sheeting) can become de-bonded by wetting or might have originally been loose-laid. Such materials hold water and delay drying.

Suspended ground floors are not generally recommended as water and mud can enter the underbuilding through ventilators and service entries. To enable detailed investigation and cleaning of the floor void, access for inspection should be provided. Where a suspended ground floor slab is used, it should be in-situ concrete (which requires formwork), with a damp-proof membrane bonded to the underside.

7.3.2 Water exclusion strategy

7.3.2.1 General

When applying a water exclusion strategy (i.e. minimizing water ingress through ground floor slabs) for predicted water depths above the floor of greater than 300 mm, it is important to carry out structural checks on uplift forces equivalent to the design flood level for the construction. Usual safety factors should be applied in all such calculations. Laboratory evidence on small slabs (0.5 m × 0.5 m) indicated that 150 mm thick concrete slabs on supporting soil can withstand such forces without allowing water ingress [7]. However, for larger slabs, uplift forces can cause deformation, induce cracking and lead to preferential paths for water ingress, so slabs should be designed to resist uplift forces.

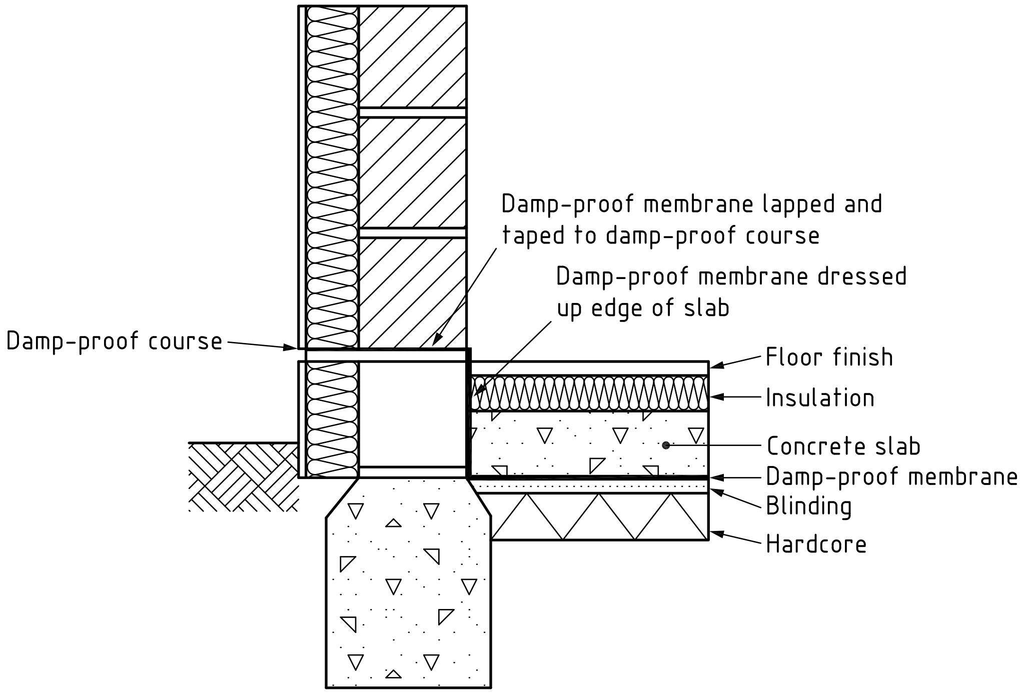
Recommended ground-supported and acceptable suspended floor arrangements are presented in Figure 5 and Figure 6.

7.3.2.2 Ground-supported floors

Ground-supported floors are the preferred option and concrete slabs of at least 150 mm thickness should be specified for non-reinforced construction. Hollow slabs are only suitable if the elements are effectively sealed.

Figure 5 shows floor insulation above slab and there is laboratory evidence to support this location, but there is currently no sound evidence that would prevent the use of below-slab insulation.

Figure 5 **Ground-supported floor – Preferred option**



NOTE More than 200 mm height of water above finished floor level can result in slab lifting and the potential for the damp-proof membrane to tear.

- Hardcore bed at least 100 mm thick of well-compacted inert material, blinded with fine inert material to provide a smooth base
- Robust damp-proof membrane, minimum 1200 gauge polythene but preferably more substantial
- Concrete slab at least 150 mm thick and able to resist uplift pressures
- Insulation as rigid closed-cell material
- Ceramic tiles or stone floor finishes and skirting boards

7.3.2.3 Suspended floors

Suspended floors (see Figure 6) might be necessary where ground-supported floors are not suitable, namely in shrinkable/expanding soils (e.g. clay) or where the depth of fill is greater than 600 mm. Uplift forces caused by flood water can affect the structural performance of a floor. Suspended floors are generally not recommended in flood-prone areas, for the following reasons:

a) where the sub-floor space might require cleaning following a flood, particularly a sewer flood where the accumulation of polluted sediment is expected, the sub-floor space should slope to an identified area and be provided with suitable access; and

b) if cleaning is required, floor finishes might need to be removed to provide access to the sub-floor space, so cheaper, sacrificial finishes would be the best option.

Suspended timber floors, particularly those including timber-engineered joists, are not generally recommended in flood-prone areas because some timber-based materials can deform significantly when in contact with water and might therefore require replacement. Rapid drying without humidity control and experience with flooding can also cause deformation and cracking.

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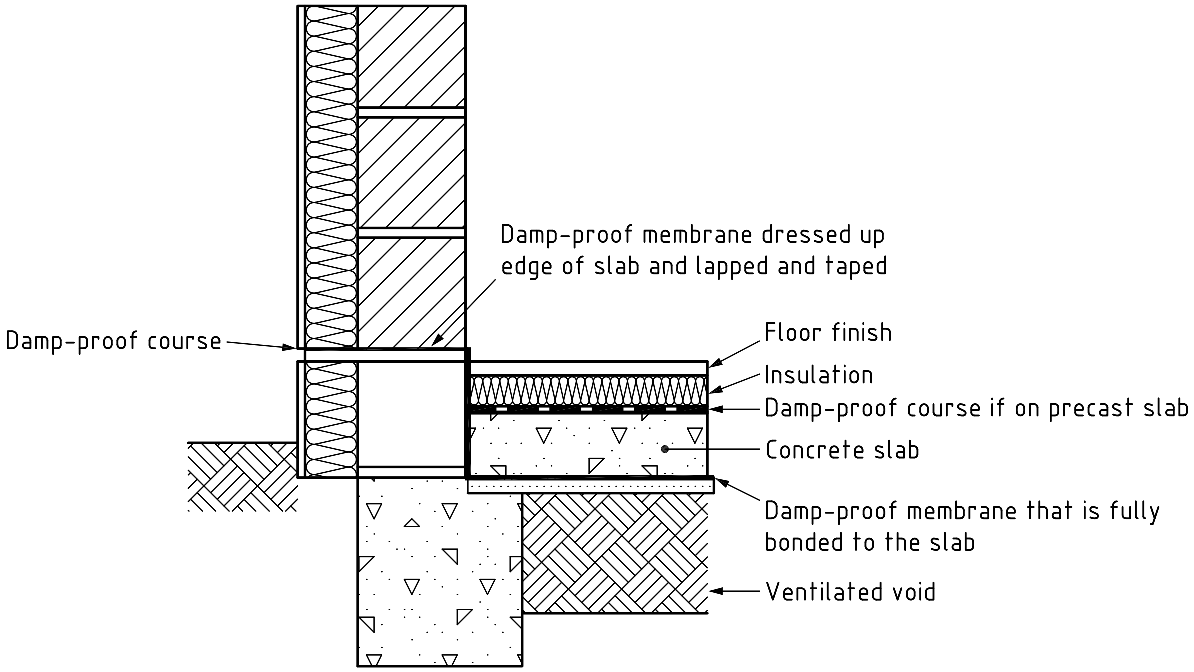
Figure 6 **Suspended floor – Restricted option**



- Reinforced concrete slab at least 150 mm thick and able to resist uplift pressures
- Damp-proof membrane of polythene at least 1200 gauge
- Insulation as rigid closed-cell material
- Ceramic tiles or stone floor finishes and including skirting boards

7.3.2.4 Materials and components

Exposed metalwork should be either corrosion-resistant or have a suitable coating, such as galvanizing or epoxy.

Hardcore and blinding: Good compaction is necessary to reduce the risk of settlement and consequential cracking.

Damp-proof membranes should be included in any design to minimize the passage of water through ground floors. Proprietary damp-proof membrane systems should be used that are bonded to the slab and installed in accordance with the manufacturer's requirements. Care should be taken not to stretch the membrane in order to retain a waterproof layer. Experience in Scotland indicates that welted joints in the damp-proof membrane can be an effective jointing solution [8] [1)].

A damp-proof membrane below the screed and insulation can be damaged by rising groundwater if not adequately bonded and loaded. If the area of damage is extensive, this will require considerable work to correct, especially where the damp-proof membrane is located under a screed and ground floor slab. There might be issues initially in identifying in the short-term penetrating water from below or absorbed flood water that is still drying out. It is therefore recommended that damp-proof membranes are placed below the slab, rather than below the insulation.

1) see also http://www.gov.scot/Resource/0046/00460618.pdf [viewed: 4 November 2015].

Insulation materials: Water lowers the insulation properties of some insulation materials. Floor insulation should be of the closed-cell type to minimize the impact of flood water. The location of insulation materials, whether above or below the floor slab, is usually based on either achieving rapid heating of the building or aiming for more even temperature distribution with reduced risk of condensation. Insulation placed above the floor slab (and underneath the floor finish) rather than below minimizes the effect of flood water on the insulation properties and is easier to replace, if necessary. However, water entry can cause insulation to float (if associated with low mass cover) and lead to de-bonding of screeds.

No firm guidance can be provided on the best location for insulation where the primary source of flooding is from groundwater. For other types of flooding, placing insulation below the floor slab might be adequate but the characteristics of the insulation could be affected by the uplift forces generated by the flood water.

Floor finishes, floor sumps and services: For the water exclusion strategy, there is no specific guidance on floor finishes, floor sumps and services. However, to provide some resilience in the event of residual flooding, see **7.3.3**.

7.3.3 Water entry strategy

Materials that retain their integrity and properties when subjected to flood water (such as concrete), or those that can easily be replaced (sacrificial materials), should be specified. Construction should allow easy access for cleaning (e.g. below suspended floors) and drainage.

Concrete ground-supported floors (see Figure 5) are the preferred option and concrete slabs of at least 150 mm thickness should be specified.

Suspended floors might be necessary where ground-supported floors are not suitable [see **7.3.2.3** a) and b)]. Alternatively, external access to the sub-floor space can be considered as a design option.

Suspended steel floors might be adequate provided they incorporate resilient features, such as anticorrosion properties, and conform to required structural capability.

Suspended timber floors, particularly those incorporating timber-engineered joists, are not generally recommended in flood-prone areas because most wooden materials tend to deform significantly when in contact with water and might require replacement. Rapid drying can also cause deformation and cracking.

Hardcore and blinding: Good compaction should be achieved to reduce the risk of settlement and consequential cracking.

Damp-proof membranes should be included in any design to minimize the passage of water through ground floors. Proprietary damp-proof membranes bonded to the floor slab should be installed where possible. Joints between membrane sheet sections should be undertaken strictly in accordance with the manufacturer’s instructions and may include the use of jointing and double-sided tapes and adequate overlapping of the materials. Care should be taken not to stretch the membrane in order to retain a waterproof layer. Experience in Scotland [8] has indicated that welted joints in the damp-proof membrane can be an effective jointing solution, but the quality of the welts is very dependent on workmanship.

Insulation materials: Water lowers the insulation properties of some insulation materials. Floor insulation should be of the closed-cell type to minimize the impact of flood water. The location of insulation materials, whether above or below the floor slab, is usually based on either achieving rapid heating of the building or aiming for more even temperature distribution with reduced risk of condensation. Insulation should be placed above the floor slab (and underneath the floor finish) rather than below, to minimize the effect of flood water on the insulation properties and be more easily replaced if needed.

Floor finishes: There are two possible approaches that depend on an assessment of the likely frequency of flooding and cost of material and installation:

a) use of sacrificial materials or reliance on high-quality durable materials, such as timber flooring and soft furnishings, e.g. carpets; and

b) use of materials that are likely to withstand exposure to flood water without significant deterioration, such as ceramic or concrete-based floor tiles, marble, stone or sand/cement screeds.

All tiles should be bedded on a cement-based adhesive/bedding compound and water-resistant grout should be used.

Concrete screeds above polystyrene or polyurethane insulation should be avoided as they hinder drying of the insulation material due to the relative impermeability.

Suitable materials for skirting boards include ceramic tiles and PVC. Ceramic tiles are likely to be more economically viable and environmentally acceptable. Replacement timber might be a suitable option where the use of sacrificial materials is adopted.

Floor sump: Provision of a sump and small capacity pump in the floor at a low point of the ground floor, possibly with perimeter drainage to help drain flood water, is recommended where the expected frequency of flooding is high. This system helps the draining process and speeds up drying. A sump of dimensions (450 × 450) mm (or 450 mm diameter) by 300 mm deep is generally adequate for pumping out after a flood. Sumps for pumps dealing with seepage (e.g. in a basement) should be calculated on the likely seepage rate or, where this is not known, be around (1 000 × 1 000 × 1 000) mm to enable a pump to be installed completely within the sump and allow for an alarm and some storage capacity in the event of a pump or power failure (see BS EN 12056-4 for further details).

Consideration should be given to using manual or automatic underfloor sump pumps where appropriate. Mains electricity powered pumps might not be appropriate as electricity supplies could be cut off during flooding. The provision of dewatering puddle pumps and sump pumps requires clear guidance and instruction on the correct use and maintenance of the pumps. Adequate ventilation of any pump or generator exhaust fumes is of critical health and safety importance.

Use of underfloor heating should be considered carefully in buildings in areas subject to flooding, due to potential problems with flood water becoming trapped under insulation layers.

Services: Underfloor services containing electrical elements or ferrous materials should be avoided, and ideally any underfloor heating pipes should be contained within a floor screed to avoid water retention between floor construction layers after flooding and assist with drying.

7.4 Walls

7.4.1 Water exclusion strategy

7.4.1.1 General

The water exclusion strategy for walls is applicable to design flood depths of up to 300 mm or up to 600 mm, if allowed by the structural assessment of the design.

7.4.1.2 Masonry walls

Solid walls with external insulation are preferred to cavity construction as this avoids problems of contamination entering the cavity. Where a cavity is used, closed-cell insulation should be used.

Mortar joints should be thoroughly filled to reduce the risk of water penetration. There is evidence that thin layer mortar construction (or "thin joint" as it is also commonly known) is a good flood resilience option [7].

If frogged bricks are used, they should be laid frog up so that filling becomes easier and coverage more certain. Bricks manufactured with perforations should not be used for flood resilient design.

Where possible, low-water-absorbing bricks and mortar mixes should be used up to the predicted flood level, plus one course of bricks to provide freeboard (up to a maximum depth of 600 mm above floor level). This increases resistance to water penetration. Blocks (and dense facing bricks) have much improved performance when covered with render.

Aircrete blocks allow less leakage than typical concrete blocks, but concrete blocks dry more quickly. For a water exclusion strategy the expected amount of leakage is minimal, so Aircrete blocks are recommended, although they can retain moisture for longer than concrete blocks. Natural hydraulic lime plaster depends on contact with the air to set and harden. When new, it crumbles very easily under high water pressure. Anecdotal evidence from traditional buildings suggest good performance under flood conditions.

Highly porous bricks, such as some hand-made bricks, should not be used.

Solid masonry walls are a good option but need to be fitted with internal or external wall insulation in order to conform to the Building Regulations [2], [3] and [4].

7.4.1.3 Framed walls

Timber-framed walls containing construction materials that have poor performance in floods, for example oriented strand board and mineral wool insulation, should not be used. Timber-framed walls are not recommended in a water exclusion strategy. Steel-framed walls might offer a suitable alternative option, but specialist advice should be sought on how to incorporate resilient materials/construction methods in the design, in particular with regard to the insulation.

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Reinforced concrete wall/floor construction should be considered for flood-prone areas, i.e. where the frequency of flooding is predicted to be high. This form of construction is effective at resisting forces generated by flood water and provides an adequate barrier to water ingress (provided service ducts and other openings into the building are adequately sealed). Design details for this type of construction are beyond the scope of this document.

External renders are effective barriers to water penetration and should be used with blocks (or bricks) at least up to the predicted flood level, plus the equivalent of a course of bricks as freeboard. Structural checks might be necessary to ensure stability, because of the external water pressures that could occur for design flood depths above 300 mm. External cement renders with lime content (in addition to cement) can induce faster surface drying.

7.4.1.4 Insulation

External insulation is better than cavity insulation because it is more easily replaced if necessary.

Cavity insulation should preferably incorporate rigid closed-cell materials as these retain integrity and resist moisture take-up. Other common types, such as mineral wool batts, are not generally recommended as they can remain wet for several months after exposure to flood water, which slows down the wall drying process and compromises the insulation properties of the wall. Blown-in insulation can slump due to excessive moisture uptake, and some types can retain high levels of moisture for long periods of time (under natural drying conditions).

7.4.1.5 Internal linings

Properly bonded internal cement renders are effective at reducing flood water leakage into a building and assist rapid drying of the internal surface of the wall. When used with solid walls and external renders they can offer effective protection against water ingress. The extent to which render prevents drying of other parts of the wall is not currently clear. This could be important, particularly for solid wall construction. This applies also to external renders.

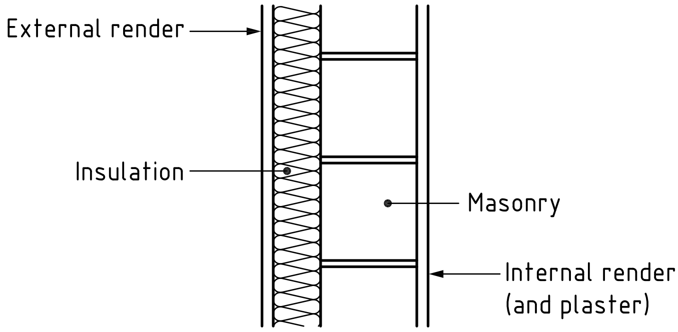
Unless it is intended to be replaced after a flood, standard gypsum plasterboard should not be used below the design flood level, as it tends to disintegrate when subjected to flood water. Where it is intended to be sacrificial, cutting the sheets 50 mm above the design flood level and masking with a dado rail can be helpful when making repairs. Splash-proof boards do not necessarily offer protection against flood waters, which can remain for some time and exert pressure on the boards.

Thoroughly hardened internal lime plaster/render might effective but currently there is a lack of evidence.

NOTE Because of its high pH, lime inhibits mould growth.

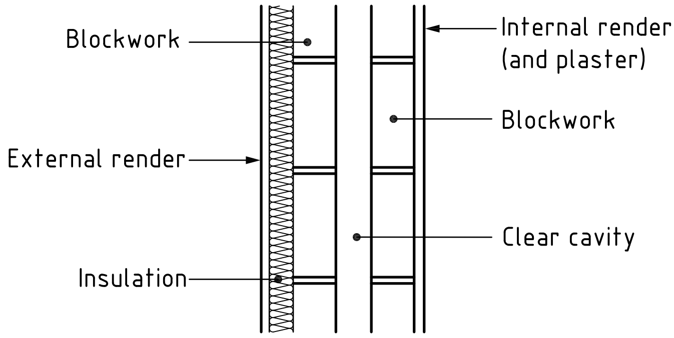
Examples of recommended wall arrangements are presented in Figure 7 to Figure 9.

Figure 7 **Solid external walls**



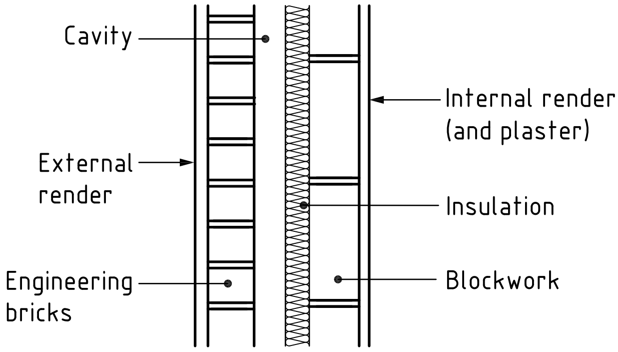
- External cement-based render, preferably with lime content, should be used. Composition depends on the masonry background. Good quality external renders should be used in accordance with BS EN 13914-1. Preference should be given to the use of proprietary render mixes (see BRE Information Paper 16/03 [9]) rather than site-mixed, unless quality of the site process is controlled. As well as supplying flood resistance properties the material itself should be resilient to flood water and suitable for the exposure of the site to wind-driven rain (see BRE GG 18, *Choosing external rendering* [10]).
- External closed-cell insulation should be used in preference to internal insulation. Use proprietary external thermal insulations insulation systems.
- Masonry with minimum thickness of 300 mm or, alternatively, reinforced concrete wall.
- Internal cement-based render, preferably with lime content, should be used. Composition depends on the masonry background. Good quality internal renders should be used in accordance with BS EN 13914-1.
- A number of impervious coatings (some employing nano technologies) are available that, when applied at the point of manufacture or during the construction phase on site, can provide long-term (25-year) waterproofing for building materials.

Figure 8 **Cavity external walls – Clear cavity**



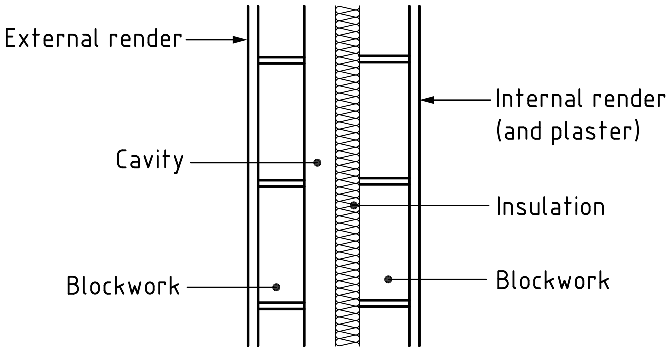
- External cement-based render, preferably with lime content, should be used. Composition depends on the masonry background. Good quality external renders should be used in accordance with BS EN 13914-1. Preference should be given to the use of proprietary render mixes (see BRE Information Paper 16/03 [9]) rather than site-mixed, unless quality of the site process is controlled. As well as supplying flood resistance properties the material itself should be resilient to flood water and suitable for the exposure of the site to wind-driven rain (see BRE GG 18, *Choosing external rendering* [10]).
- Internal cement-based render, preferably with lime content, should be used. Composition depends on the masonry background. Good quality internal renders should be used in accordance with BS EN 13914-1.
- Stainless-steel wall ties minimize corrosion and consequent staining.

Figure 9 **Cavity external walls – Part-filled cavity: Option A**



- External face consisting of low-water-absorption bricks (4.5%) up to required level for flood protection (up to 600 mm maximum above floor level plus one course). Other external facing materials can be used above this level, but ensure interface is watertight.
- Rigid closed-cell insulation.
- Internal face consisting of blocks.
- Internal cement-based render, preferably with lime content, should be used. Composition depends on the masonry background. Good quality internal renders should be used in accordance with BS EN 13914-1.
- Stainless-steel wall ties minimize corrosion and consequent staining.
- Internal boards can be of manganese oxide or other water-resistant construction that are not sacrificial, but permanent long-term solutions requiring less drying time.
- Sacrificial plasterboard can be used, but needs to be removable between ground floor and flood level and should be fitted horizontally to make removal easier. In some cases a dado rail can be used to cover the joints.

Figure 9 **Cavity external walls – Part-filled cavity: Option B**



- External cement-based render, preferably with lime content, should be used. Composition depends on the masonry background. Good quality external renders should be used in accordance with BS EN 13914-1. Preference should be given to the use of proprietary render mixes (see BRE Information Paper 16/03 [9]) rather than site-mixed, unless quality of the site process is controlled. As well as supplying flood resistance properties the material itself should be resilient to flood water and suitable for the exposure of the site to wind-driven rain (see BRE GG 18, *Choosing external rendering* [10]).
- External face consisting of blocks.
- Rigid closed-cell insulation.
- Internal face consisting of blocks.
- Internal cement-based render, preferably with lime content should be used. Composition depends on the masonry background. Good quality internal renders should be used in accordance with BS EN 13914-1.
- Use external insulation in preference to internal insulation.
- Stainless-steel wall ties minimize corrosion and consequent staining.

7.4.2 Water entry strategy

7.4.2.1 Masonry walls

Good quality facing bricks should be used for the external face of a cavity wall.

Soft bricks, which can easily crumble when subjected to water, should not be used. Fired clay is unlikely to crumble with water contact alone; unfired clay might do so.

Concrete blocks dry more quickly than Aircrete blocks. However, Aircrete blocks allow less leakage. For a “water entry strategy” which is aimed at allowing water passage through the property, concrete blocks are recommended.

Clear cavity walls, i.e. with no insulation, have better resilience characteristics than filled or part-filled cavity walls as they dry more quickly (see Figure 8).

7.4.2.2 Framed walls

Timber-framed walls containing construction materials that have poor performance in floods, namely oriented strand board and mineral wool insulation, should be avoided. Timber-framed walls are generally not recommended, unless a sacrificial approach is adopted whereby some materials will be stripped to allow drying.

Steel-framed walls might offer a suitable alternative option, but specialist advice needs to be sought on how to incorporate resilient materials/construction methods in the design. Steel frames should be galvanized or have some other form of corrosion protection. Further protection can be provided by using a bituminous paint.

External renders should not be used as they provide a barrier to water penetration and could induce excessive differences in depth between outside and inside of the property, resulting in possible structural problems.

7.4.2.3 Insulation

External insulation is better than cavity insulation because it is easily replaced if necessary and is generally protected by rigid lining which can create a barrier to water.

Cavity insulation should incorporate rigid closed-cell materials as these retain integrity and have low moisture take-up. Other common types, such as mineral wool batts, are not generally recommended as they can remain wet several months after exposure to flood water which slows down the wall drying process. Blown-in insulation can slump due to excessive moisture uptake, and some types can retain high levels of moisture for long periods of time (under natural drying conditions).

7.4.2.4 Internal linings

Internal cement renders should be avoided as these can prevent effective drying.

Standard gypsum plasterboard should be used up to the predicted flood level (plus freeboard of 50 mm) as a sacrificial material. For this purpose, the use of a dado rail to separate the above and below flooded area could be useful. Splash-proof boards do not necessarily offer better protection against flood waters, which might remain for some time and exert pressure on the board.

Above predicted flood level (plus freeboard) the use of plasterboard or internal cement renders is appropriate.

Anecdotal evidence suggests that lime plaster can be a good solution. Lime plaster depends on contact with the air to set and harden, typically 6 months or more. When new, lime plaster crumbles very easily under high water pressure.

8 Retrofit

8.1 Foundations

When retrofitting it is normally unnecessary to alter or disturb the foundations, unless damage has occurred or scour of foundations is likely.

8.2 Basements

The basement is often the first part of a building to be affected by flood water, due to:

a) water entering air bricks or a threshold at ground floor level and tracking down to the lowest level; or

b) groundwater entering at basement floor level due to an increase in the water table level or hydrostatic pressure forcing water through joints in the floor, walls or service entries.

Basements should be designed in accordance with BS 8102.

If a basement cannot be made water-resistant, measures are required to enable water to be directed and removed via drainage and gullies leading to one or more sumps with pumps installed (see **7.2**).

As with resilient finishes for ground floor levels, basement floors and walls should ideally be lined with materials that can get wet and be dried without any deterioration.

Floors and walls can be lined with waterproof materials that are able to withstand being submerged under flood waters. These include sand and cement renders, expanded polystyrene foam boards that do not absorb water, and ceramic tiles fitted with waterproof adhesives and grout.

Timber products, plasterboard and other absorbent materials are not suitable. Whilst any decorations are likely to be damaged by flooding it is advisable to use porous (non-vinyl) paints that allow moisture to evaporate through the affected surfaces rather than finishes that trap moisture behind when drying after the flood water has been removed.

It is important that water entering a basement is removed as soon as possible as there are not the risks to the structure as with walls above ground and deep water flooding. Basement walls should be designed to withstand the forces of hydrostatic pressure at all times.

8.3 Floors

Solid floors provide the best resistance to, and resilience against, flooding. However, it is important that any damp-proof membranes are continuous and any joints fully taped and sealed. The membranes should be taken up vertically at the floor edges to link effectively with damp-proof courses and all detailing undertaken with care in accordance with the manufacturer's requirements to prevent water/moisture ingress.

Insulation and any underfloor heating should be installed above the damp-proof membranes, on the "dry side", to prevent water ingress to these elements and hindering of the drying process after flooding.

Further options for resistant and resilient floor design are given in **7.3**.

8.4 Walls

Retrofitting of internal walls is generally concerned with choosing appropriate resilient measures, as part of a water entry strategy, and **7.4** gives options that are suitable in an existing property. External walls could be treated to provide a water exclusion strategy for the bottom 300 mm to 600 mm, and the appropriate parts of **7.4.1** should be consulted.

Attention should be given to any party walls between neighbouring properties as water can also enter by this route.

Water entry through walls occurs mainly through the mortar joints rather than soaking through the bricks or stones. Therefore, the mortar joints of the walls should be maintained in good condition with a mortar mix as originally used in the construction.

If walls are very porous external water repellents may be considered. However, advice should be obtained from an independent professional surveyor or engineer to ensure there is no risk of trapping dampness or possibility of frost damage with applying these materials.

Cavity wall insulation can be affected by flood water, especially the loose fibre or cellulose varieties. Ideally, water should be prevented from reaching the cavity (see **7.4.1**). However, access should be provided to enable loose materials or absorbent insulation to be either dried or removed if necessary.

Polyurethane foams are available that can be injected into existing cavity walls and provide a stabilizing bond to the wall construction. Independent professional advice should be obtained before considering the installation of any cavity insulation to avoid potential problems with increased risk of frost to the outer leaf and condensation problems within the wall or the interior of the property. Guidance for the assessment of the suitability of external cavity walls of traditional construction for filling with thermal insulants is given in BS 8208-1.

Walls and some solid floors can also be protected from water ingress by cement-based renders, impervious slurries, resins, bonded-sheet membranes, brush or spray-applied silicones, liquid-applied bituminous coatings and other proprietary products. The manufacturer should be consulted about the suitability for the specific application. With masonry it is important that any cracks in rendering are made good before application. The system used should be applied and designed to provide continuous barrier protection that links to aperture protection.

NOTE A number of impervious coatings employing nano technologies are available for waterproofing masonry walls.

Consideration can be given to installing cavity drain membranes and linings, with concealed perimeter drains, sumps and pumps, where the internal plaster is damaged or improved protection is required against future flood water ingress. These works should be undertaken strictly in accordance with the requirements and approval of the system supplier.

9 Doors, windows and air vents

9.1 General

Doors, windows and air vents are potential flow paths into properties. Design considerations for resistance and resilience apply equally to new buildings and retrofit situations, so this clause considers only the difference between water exclusion and entry strategies.

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9.2 Water exclusion strategy

9.2.1 Doors

Raising the threshold to be above the design flood level, while satisfying level access requirements, should be the primary measure to protect external and internal doors. To assist in the exclusion of flood water, doors conforming to PAS 1188-1 should be used. If shallow flooding can be excluded, then internal doors could be of any type, although the ability to remove these quickly, for example by using butt hinges, should be considered to avoid any damage.

9.2.2 Windows/patio doors

Standard window designs can be used when the flood depth is less than 600 mm as they are unlikely to be affected. Patio doors are vulnerable to flood water and similar measures to those used for doors should be taken. Unless they conform to PAS 1188-1, sliding and bi/tri-fold patio doors should be avoided. Low-level glazing should be avoided. Special care should be taken to ensure adequate sealing of any PVC door frames to the fabric of the house. All doors (either part or fully glazed) should be fitted with toughened glass.

9.2.3 Air vents

Special designs of air vent are available in the market to prevent water ingress in circumstances where the predicted flood depth is low (i.e. <300 mm), e.g. automatic air vent. Careful consideration should be given to effectively sealing any associated joints.

9.3 Water entry strategy

9.3.1 Doors

Even in a water entry strategy, external doors should be of a strong, sealed type to resist water pressures, with good fit to the frame to limit the water ingress rate. Doors conforming to PAS 1188-1 should be specified. Unless part of a flood-repairable strategy, hollow core timber doors should not be used where the predicted frequency of flooding is high. Where an adequate flood warning system is in place, consideration should be given to the use of internal doors that can be removed easily and stored. Where no warning system is in place or flooding is difficult to predict, it might be necessary to replace internal doors if these are likely to be immersed in water for significant periods or where temporary contamination is likely.

9.3.2 Windows/patio doors

For flooding with higher depths (>600 mm) the water pressure against patios and windows should be considered, as this could cause sudden failure and rapid water ingress. The use of glazing in the bottom 600 mm of doors, especially double doors, should be avoided. Debris in flowing water can also present an additional hazard, so the assessment of flood risk, prior to installation of resistant/resilient measures, should consider whether the property lies in a main flow route. These hazards should be considered carefully when patio doors are being retrofitted or replaced.

10 Fixtures, fittings and services

10.1 General

There is no major difference between new building and retrofitting when specifying designs for fixtures, fittings and services; the main consideration is the design strategy and any residual risk to be avoided.

Except during a flood, it is essential that ventilation is not blocked as this leads to poor indoor air quality, mould and corrosion.

NOTE Where a vent is temporarily blocked during a flood, it is essential that fuel burning appliances are not used due to the risk of carbon monoxide poisoning. Similarly, internal combustion engines and portable barbecues ought not to be used inside buildings.

All service entries should be sealed [e.g. with proprietary plugs or waterproofing materials designed for this purpose, expanding closed-cell (plastic) foam or similar closed-cell material].

Pipework: Proprietary sealants and/or hydrophilic materials should be used externally around pipes which are below the predicted flood level.

Drainage services: Non-return valves are recommended in the drainage system to prevent back-flow of diluted sewage in situations where there is an identified risk of the foul sewer surcharging (see BS EN 13564-1).

Maintenance of these valves is important to ensure their continued effectiveness.

Water, electricity and gas meters should be located above predicted flood level.

Electrical services: Electrical sockets and meters should be installed above flood level to minimize damage to electrical services and allow speedy reoccupation. Electric ring mains should be installed at first floor level with drops to ground floor sockets and switches. Service ducts should be sealed externally.

Heating systems: Boiler units and ancillary devices should be installed above predicted flood level and preferably on the first floor of two-storey properties. Controls such as thermostats should be placed above flood level. Conventional heating systems, e.g. hot water pipes, are unlikely to be significantly affected by flood water unless it contains a large amount of salts. The less common, hot-air duct-heating remains effective provided it is installed above the design flood level.

Communications wiring: Wiring for telephone, TV, Internet and other services should be protected by suitable insulation in the distribution ducts to prevent damage. Any proposed design solution for flood insulation on all potentially vulnerable wiring should be discussed with the relevant service providers.

10.2 Water exclusion strategy

There is no specific guidance for the water exclusion strategy additional to that set out in **10.1**.

10.3 Water entry strategy

The main principle is to use durable fittings which are not significantly affected by water that could enter the building (e.g. plastic materials).

Fittings (e.g. electrical appliances, gas oven) should be placed on plinths as high as practicable above the floor level so that they are above the design flood level.

Durable kitchen units can be manufactured using suitable materials, such as powder-coated steel for the frameworks, removable marine ply cabinets and stone worktops. Durable kitchen units are available from some manufacturers that can be cleaned following a flood. These might be more expensive than standard units. Alternatively, a sacrificial approach might be more appropriate. The approach used should be discussed and agreed with the property owner.

Joints between kitchen units and surfaces should be adequately sealed to prevent any penetration of water behind fittings.

NOTE The average life of a kitchen unit is approximately 7 years.

When allowing water in, it is important to provide means for effective drainage and cleaning. Providing gaps behind kitchen units facilitates drainage and allows access for forced drying, if proved to be necessary.

11 Other issues

11.1 Workmanship

High-quality workmanship should be ensured at all stages of construction. This is particularly relevant for a water-exclusion strategy.

11.2 Sustainability

With the introduction of energy performance certificates (EPCs) and display energy certificates (DECs), refurbishment offers an opportunity to improve the energy performance of the existing building stock. Setting out a refurbishment or refit should involve specifying improved energy performance as there are significant benefits to be realized, both in cost reductions and reduction in carbon dioxide emissions.

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Further reading

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