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Flood resilient construction – Improving the flood performance of buildings – Guide

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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 31 March 2025. 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 the committee manager.

Supersession

This British Standard supersedes [BS 85500:2015](#), which is withdrawn.

Information about this document

This is a full revision of the document, and introduces the following principal changes:

- makes reference to, and is consistent with, the CIRIA *Code of practice for property flood resilience* [1];
- includes a comprehensive list of the impacts of flood water on all materials and building elements;
- includes more detailed guidance, supported by engineering drawings for new and retrofit resilient designs; and
- benefits from the increased attention to property resilience promoted by the Property Resilience Roundtable.

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Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Use of this document

As a guide, this British Standard takes the form of guidance and advisory recommendations. It is not to be quoted as if it were a specification or a code of practice.

Presentational conventions

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

Additional commentary, explanation and general informative material is presented in smaller italic type.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. “organization” rather than “organisation”).

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Introduction

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 where buildings are located in an area at risk of flooding.

This British 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, have been implemented.

1 Scope

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

- a) assessing options for flood resilient measures, following a comprehensive flood hazard assessment and building survey; and
- b) the design and specification of flood resilience for new buildings, extensions, conversions and retrofits.

The guidance covers the main types of building construction in the UK, for which experiential and other evidence is available. This British Standard is intended to be consistent with and complementary to the *CIRIA Code of practice for property flood resilience* [1] (see 4.2). It necessarily cannot cover all construction types and materials, and so additional guidance would need to be sought for any examples not covered in this British Standard.

It is not applicable to:

- 1) the detailed structural engineering;
 - 2) the site layout of buildings;
 - 3) the specification, fixing and deployment of flood resistance products, which are covered by other standards and documents, such as the [BS 851188](#) series and *Delivering benefits through evidence: Temporary and demountable flood protection guide* [2];
 - 4) the design of watertight concrete, which is specified in [BS EN 1992-1-1](#);
 - 5) amphibious or floating properties;
 - 6) properties on stilts; or
 - 7) 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 are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document¹⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[BS 8102](#), *Protection of below ground structures against water ingress – Code of practice*

[BS 8533](#), *Assessing and managing flood risk in development – Code of practice*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

[BS 851188](#) (all parts), *Flood resistance products*

[BS EN 12086](#), *Thermal insulating products for building applications – Determination of water vapour transmission properties*

3 Terms and definitions

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

3.1 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 competent individual

person with an appropriate qualification and relevant, approved experience to undertake the required task or activity as part of the flood resilience delivery process

3.3 design flood

estimated magnitude of flood event usually expressed as a maximum flood level, used as a performance objective in the design of a flood risk management scheme, such as the design of flood resilience measures for a building

NOTE 1 The design flood is associated with a probability of occurrence, expressed often as an annual exceedance probability, or return period.

NOTE 2 The design flood is expected to include an allowance for climate change appropriate to the assumed lifetime of the building under consideration.

3.4 flood hazard assessment

survey undertaken by a competent individual to determine the flood hazard to the building under consideration, covering all likely sources of flooding and the associated parameters of water depth, velocity, direction, duration and frequency of occurrence

3.5 flood recoverability

design and use of materials, products and building methods that prevent the fabric of the building from being unduly damaged by flood water and allow it to recover in a timely and economic manner after the flood

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” or “water entry strategy”.

EXAMPLES Use of materials that can resist the effects of flooding, e.g. tiled finishes or lime plaster.

3.6 flood resilience

combination of both resistance and recoverable measures that can be incorporated into the building fabric and/or fixtures and fittings so as to reduce the consequences of flood water affecting the property

3.7 flood resistance

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

NOTE Also known as “dry-proofing” or “water exclusion strategy”.

EXAMPLE Use of low-permeability materials or flood barriers/doors.

3.8 freeboard

factor of safety in flood protection design (usually expressed as height above flood level), which is used to compensate for factors related to the uncertainties in the available data and design process

3.9 water entry strategy

design strategy based on allowing water to enter a building rather than preventing its ingress

3.10 water exclusion strategy

design strategy based on the use of impermeable or low-water penetration materials to minimize the ingress of water into a building

4 Resilient design process

4.1 Definition of resilience

Resilience is a key concept within flood risk management, implying an approach that comprises some resistance to flooding, an ability to recover in a timely manner and effectively after a flood, and a “build back better” or adaptive design process that incorporates learning from each flood event. Property flood resilience (PFR) is consistent with the wider resilience definition, in that it comprises resistance and recoverability measures and approaches, which are informed by the previous flooding history at the building backed up by a comprehensive flood hazard assessment and building survey.

Property flood resistance comprises materials and approaches to manage water entry into the building. The aim is to minimize water entry through the use of appropriate materials and products and good construction detailing for the external walls. External flood barriers and doors are common methods to prevent water entry through building apertures.

Property flood recoverability comprises the use of materials, products and construction methods that prevent the internal fabric of the building from being unduly damaged by flood water and allow it to recover quickly after the flood. Such approaches are allied to lower water retention, quicker draining or drying times, low deformation and degradation of materials when wet, and ease of cleaning, repair or replacement.

4.2 CIRIA Code of Practice scheme delivery process

This British Standard seeks to provide technical information, factors to assess and options for property level flood resilience. It is to be used to complement the framework provided by the CIRIA *Code of practice for property flood resilience* [1], which comprises six stages that define and inform a comprehensive end-to-end PFR scheme delivery process.

- a) PFR Stage 1: Hazard assessment – Deliver a property level flood hazard and flood risk assessment that clearly summarizes the available hazard information to determine the likelihood and consequences of flooding from different sources. This information is used to inform the selection of suitable PFR measures.

- b) PFR Stage 2: Property survey – Carry out an appropriate flood risk survey of the property and end-user requirements. The purpose of the survey is to assess the current level of flood resilience and to provide information for the detailed design and implementation of PFR.
- c) PFR Stage 3: Options appraisal – Based on the outputs from the hazard assessment and property survey, produce a detailed PFR options appraisal and design that is agreed by all parties, and informs the installation of appropriate PFR measures.
- d) PFR Stage 4: Construction – Select PFR products and install them such as to provide the greatest opportunity for PFR to deliver the levels of resistance and recoverability required. As well as following regulatory guidance, construction activity should follow manufacturer's guidance and demonstrate good practice.
- e) PFR Stage 5: Commissioning and handover – Check that the completed PFR construction work operates effectively as designed, that the users have all relevant information and are informed about any operation and maintenance needs.
- f) PFR Stage 6: Operation and maintenance – Check that the completed PFR construction works are properly operated and maintained. The responsibilities and duties for operation and maintenance should be clearly defined and scheduled. An independent post-installation audit (PiA) should be conducted following completion.

The guidance in this British Standard can help to select PFR design solutions which are robust and based on a comprehensive assessment of the relevant issues.

Each CIRIA CoP stage contains a set of requirements, which defines what is to be achieved to enable delivery of a successful PFR scheme. In addition, there are three overriding principles that underpin the CIRIA *Code of practice for property flood resilience* [1]:

- 1) competence of individuals – each aspect of the PFR process is undertaken by an appropriate individual acting in accordance with a set of professional standards or requirements;
- 2) proportionality – the specification and deployment of PFR measures is proportionate to the flood risk of the property and the resources available; and
- 3) provision of PFR information to the end user – this is particularly important regarding the deployment and maintenance aspects which are passed to the end user.

This British Standard is primarily concerned with PFR Stage 3: Options appraisal, which involves the design and specification of appropriate PFR measures for the property under consideration. As this options appraisal is informed by a flood hazard assessment and property survey, these requirements are summarized in the following subclauses.

4.3 Flood characteristics and hazard assessments

The resistance and recoverability measures recommended in this British Standard are based on a design strategy described in Clause 6, which in turn should be informed by a site-specific flood hazard assessment for the building or development site and its immediate environs. Key outputs of the assessment are the expected flood depth, duration and frequency.

The flood hazard assessment should be carried out in accordance with BS 8533.

- a) A comprehensive assessment should be undertaken of all flood hazards to the building under consideration. The scale and extent of the assessment should be proportionate to the perceived flood hazard, although this might not be well-understood initially.
- b) The flood hazard should be assessed for all sources of flooding (fluvial, coastal, surface water, groundwater and the interaction with surface and foul drainage from the property) and should follow the source–pathway–receptor approach for all probabilities of flooding.

- c) Appropriate hazard identification and data sources should be used to determine flooding characteristics at the site, including flood depth and velocity, duration, speed of onset and frequency of inundation.
- d) Public data sources, such as flood risk maps published by the Environment Agency (EA), Natural Resources Wales (NRW), Scottish Environment Protection Agency (SEPA) and Rivers Authority – Northern Ireland (RA-NI) should be supplemented by historical flooding records, including the experiences of the property owner or occupier and the information captured in flood reports or in flood risk assessments prepared by developers. Other relevant information might be held by the local authority, utility companies and other environmental bodies.

NOTE Attention is drawn to the requirement for Section 19 flood reports in England and Wales in accordance with the Flood and Water Management Act 2010 [3], in Scotland with the Flood Risk Management (Scotland) Act 2009 [4] and in Northern Ireland with the Water Environment (Floods Directive) Regulations (Northern Ireland) 2009 [5].

- e) Flooding pathways to the building should be identified along with any existing or already planned measures to reduce or divert the flood water before it reaches the building.
- f) In addition to allowing for the current and historical flood hazard at the building, the future hazard should be calculated across the full asset life of the building and be aligned with relevant climate change scenarios over that time frame. This should include analysis of both medium and high greenhouse gas emissions scenarios.
- g) An understanding of whether contaminated water is present, e.g. oil, mud, sand, backing up or flowing in of sewer water, or other likely contaminants based on the building occupancy or nearby building use.
- h) Prior to completing the building survey, the presence of local public flood defence measures and other flood mitigation measures, e.g. local sustainable drainage measures, should be understood by consulting relevant records for the standard of protection provided.

4.4 Building surveys and design reviews for new builds

Surveys of existing buildings and design reviews for new builds should assess their current level of flood resilience in the context of the flood hazard assessment in accordance with the CIRIA *Code of practice for property flood resilience* [1]. These should be completed by suitably competent individuals. Consultation with specialists might be required, depending upon the nature of the issues identified and the depth and sources of flooding present.

Building surveys should be highly structured in their approach and should take into account multiple factors in order to develop a successful property level flood resilience strategy that is both economic and effective for the building user. This should document the materials and construction elements that make up the building that could potentially be impacted by flood water. A comprehensive list of these construction elements and impacts is given in Clause 5.

The building survey is the most appropriate means for determining end-user needs and available resources to support a proposed PFR solution. New build reviews should take into account approaches which are appropriate for the anticipated end users of the building.

NOTE In Scotland, an approved building warrant is required before any new build work can commence. In the case of PFR, the building warrant applicant is expected to satisfy the building standards verifier that mandatory standard 3.3 Flooding and groundwater from the Building Standards technical handbook: domestic [6] had been achieved in the design.

The most important aspects for property level flood resilience surveys are to confirm:

- a) whether any installed property flood resistance measures (i.e. those measures designed to keep the flood water out) have been correctly designed and installed and are being appropriately maintained;
- b) that the installed flood resistance measures would be available for a flood event if they require someone to be present to actively fit them. Such flood resistance measures should take into account the availability and capacity/resources of those required to install them, and if there would be sufficient notification of the flood event. Where adequate warning cannot be provided then reliance should only be placed upon passive flood protection measures; and
- c) the presence of flood recoverability within the existing property and whether it has been correctly designed and installed and appropriately maintained.

5 Impacts of flooding on buildings

5.1 General

The impact of flood water on buildings depends on the nature of the flooding and the design and construction of the property. In order to improve the flood resilience of a building it is first necessary to understand the impact of flooding on the building and its elements, materials and components, as determined from the flood hazard assessment and building survey/design review. This includes impacts of flood water on the materials used in the building, and routes of water entry and egress, potential “moisture reservoirs” in the structure, areas susceptible to damp or decay, and secondary impacts such as structural damage due to material damage. A risk-based approach can then be adopted to improve the resilience of the property through use of resistance and recoverability strategies.

Impacts of flooding on buildings include the following:

- a) deterioration of materials, components and elements through wetting resulting in change to form or properties without returning to their previous condition after drying;
- b) damage to services, including heating, cooling, domestic hot and cold water and electrical installations through wetting resulting in irreparable damage to machinery and installations, or change in form and properties without returning to the previous condition after drying;
- c) direct structural damage caused by the depth, duration and velocity of flood waters on the building structure or elements, including debris impact, erosion and undermining of the structure and buoyancy/displacement;
- d) inundation or saturation of materials that cannot be dried, cleaned or recovered economically on site;
- e) contamination of the internal and external surfaces, as well as cavities in walls and floors that cannot be cleaned economically or without further damage; and
- f) indirect secondary damage, such as mould growth or corrosion, arising from high atmospheric moisture; increased damage to wet materials perhaps due to weather exposure (e.g. frost); wicking or transfer of moisture during clean-up and repair; structural collapse through deterioration of structural elements following flood damage; explosions or fires due to deterioration of services; requirement to strip out undamaged materials to clean and dry.

The extent of direct damage depends on flood characteristics (such as depth, duration, velocity and source of flood water) as well as property characteristics (such as structural form, materials used and pre-existing building condition).

Indirect secondary damage can be minimized by prompt action after an incident (ideally within 24 h to 48 h of the flood), especially measures to make building services safe, controlled pumping, cleaning and drying measures and measures to reduce moisture levels in the atmosphere. However, it is useful to determine the potential for secondary damage because, for example, interruption of the mains electricity supply to the property might impact on the ability to operate equipment such as pumps managing water entry and post flood drying equipment, extending recovery time for the property. Standalone equipment is often in short supply after a flood event due to high demand.

NOTE Guidance on cleaning and drying is given in Public Health England's guide [7] and BS 12999.

5.2 Flood characteristics

The depth of flooding affects the elements and services exposed to contact with the flood water depending on their vertical location. Floods can be below ground floor level, typically affecting basements, sub-floor structures and services; shallow floods (less than 300 mm) additionally affect floors, low lying services, walls and doors; and deeper flooding can reach higher level services, windows and ceilings.

The depth and velocity of flooding affect the hydrostatic and hydrodynamic pressures on the elements and structures. Hydrostatic pressure is increased when there is a difference between water levels (pressure) on either side of an element and can be horizontal (e.g. across walls, causing more rapid ingress or collapse) or vertical (e.g. causing floor displacement or distortion). Water that is travelling at higher velocity exerts greater pressure.

The source of flood water affects the contaminants and debris likely to be present in the water; this could have implications for material and structural damage. Sea water contamination can introduce corrosive chlorides; groundwater might bring transported ground salts; overwhelmed drainage might introduce pathogens; pluvial and fluvial flows might bring large debris items. These do not usually cause a health hazard once cleaned thoroughly but it is important to test for contamination after restoration procedures are completed to evidence treatment has been successful.

The duration of flooding has implications on the extent of ingress into materials. Duration also affects the ability of materials to return to their previous performance and form after drying. In short duration floods, apertures and cracks are the main ingress route whereas in longer duration flooding water might be further absorbed into and pass through materials. Integrity of these materials is then potentially compromised. In addition, duration affects the promptness with which mitigating actions can be taken to prevent secondary damage.

Table 1 summarizes the potential flood impact on different building elements while Figure 1 illustrates potential routes of entry and elements exposed for different depths of flooding for a common masonry building. Similar routes of water entry would exist for other building constructions and associated materials.

Damage varies depending on whether water is largely excluded from the building envelope or not. Potential entry routes are complex and need to be understood.

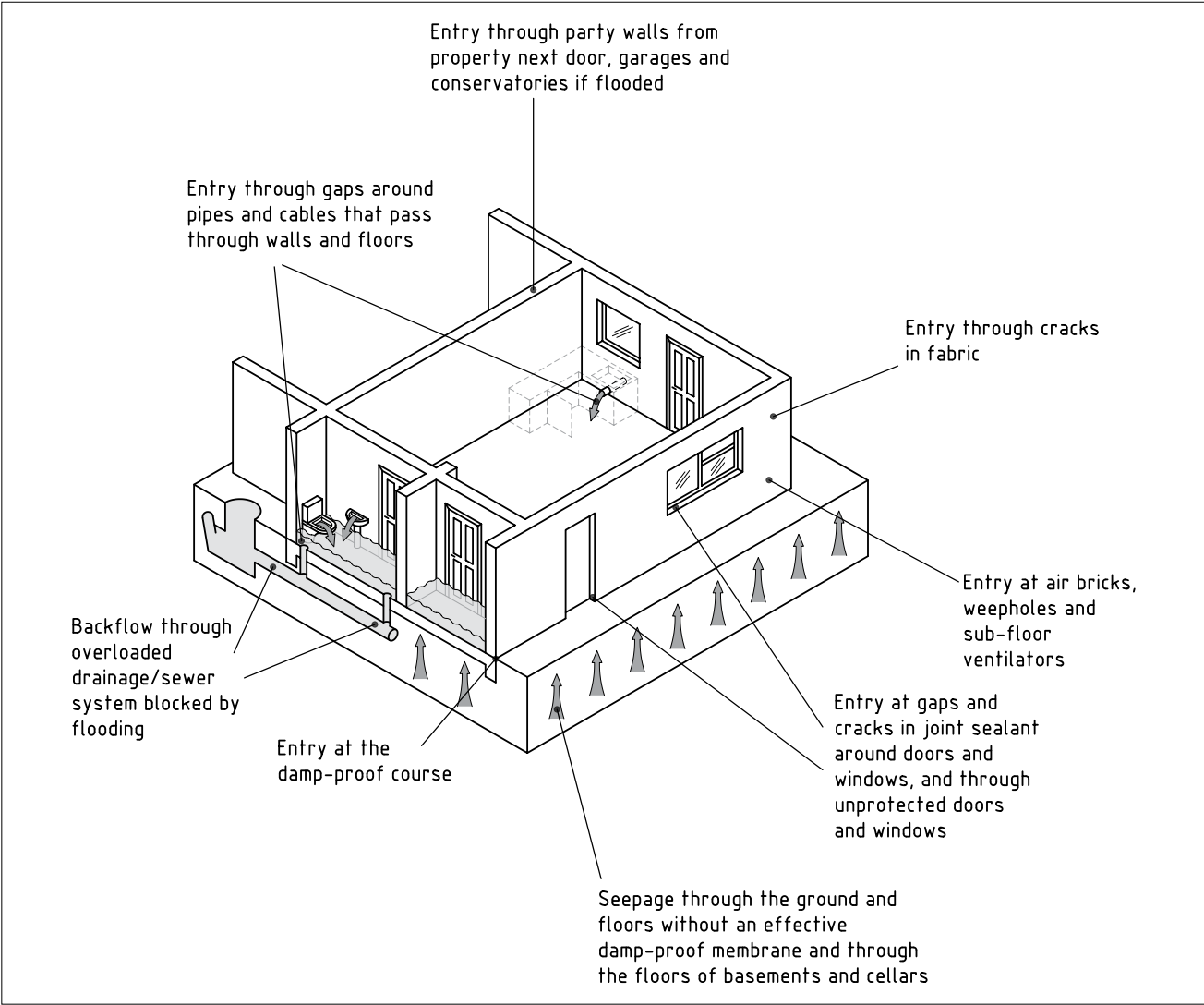
Table 1 — *Potential damage to typical building elements*

Element	Hazard/ingress impact
Building superstructure	High-speed flow around the building perimeter can lead to erosion of the ground surface, undermining the structure. Damage to the structure from large items of floating debris, e.g. tree trunks, fuel and water tanks, vehicles. Hydrodynamic pressure of fast flowing water can cause structural failure. Differential hydrostatic pressure might cause structural damage. Buoyancy and fast flowing water can displace whole structures. Structural damage or structural failure can lead to total loss of buildings.
Sub-floor void and subterranean slabs	Areas below the finished ground floor level might contain voids that can trap water. Depending on the presence or absence of damp proof course (DPC), damp proof membrane (DPM) or waterproof barrier, water or dampness could travel upwards into normally dry walls and floors. 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.
Foundations	Foundations are typically formed from concrete, masonry or 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. Hydrostatic pressure resulting from rising ground water and flooding can cause instability of foundations, which normally shows as cracking of floors and walls.
Basement or cellar below ground level (Basements can be situated entirely or partly below ground level, typically deeper than 1.2 m, but guidance here relates to all spaces below ground level requiring waterproofing measures)	Basements, even those protected in accordance with BS 8102 (see 7.2.2), can suffer inundation from flood water entering the basement from above. Effectively designed waterproofing systems (excluding type C as defined in BS 8102) would normally not be damaged by hydrostatic pressure or flood water that enters the basement. Unprotected basements (i.e. unwaterproofed cellars, or basements with ineffective waterproofing measures) are, in addition, vulnerable to groundwater entering through the walls, floors and service entries. Where there is an effective waterproofing system, water usually needs to be evacuated mechanically. Basements might trap water causing ongoing and secondary damage. Where basements have their own separate entrance or windows water can enter through doors and windows and water can be removed more easily. CAUTION: Basements can be very rapidly inundated. Escape routes should be determined where there is a high risk of surface water flooding.
Basement unsuitable for occupation (e.g. a cellar)	Significant damage to the building's structural fabric is unlikely. Timber, wood-based products 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. Even if not occupied, meters for utilities and other services or plant might be in basements and suffer damage. Waterproofing measures designed to protect the basement from groundwater ingress can be affected but not normally if they are designed and installed in accordance with BS 8102.

Table 1 — *Potential damage to typical building elements (continued)*

Element	Hazard/ingress impact
Basement constructed for habitation (i.e. with internal fixtures and fittings)	Elements of habitable basement suffer similar direct internal damage as ground floor elements, but secondary damage can be more severe as recovery by drying presents greater difficulty because there is less opportunity for the structure to dry outwards and membranes might complicate any required strip out. Impacts include deterioration of plaster, dry lining, composite and fibrous wall lining and flooring materials and thermal insulation materials; spoiling of decoration; and short term or permanent reduction in insulating properties for some materials. Pumping stations, sumps and channels associated with type C waterproofing (i.e. a drained protection waterproofing system) might be damaged under flood conditions.

Figure 1 — *Examples of potential routes for entry of flood water into a building*



5.3 Building characteristics (form and elements)

5.3.1 General

The combined effect of building characteristics (structural form, materials used and pre-existing building condition) and flood characteristics (see 5.2) influence the amount and type of building damage. Structural characteristics are described in this subclause and materials in 5.4.

Building condition aspects (including quality of construction, level of maintenance and defects) are highly relevant to the assessment of potential damage suffered by existing buildings and therefore should be taken into account for retrofitting measures as well as in the design of new builds to give sufficient attention to quality and ease of maintenance.

5.3.2 Floors

Floors of all types can be affected by flood water, with resulting material or structural damage, but the extent and type of damage depends on the type of floor construction, materials used and type and duration of flood. Temporary contamination of the floor surface inevitably results even from shallow floods of short duration. A summary of common areas of risk are set out in Table 2.

Table 2 — *Floors: potential flood impacts*

Item	Commonly experienced flood action and impact	Secondary damage and occasionally experienced flood impacts
Floor structure – timber from sawn wood	Most timber (see 5.4.5) swells after inundation with water and then shrinks as it dries. This can result in warping or cracking. If care is taken, it is usually possible and desirable to dry and retain both joists and floorboards of traditionally constructed suspended timber floors. Timber composites might absorb water during inundation and then delaminate and denature during drying.	Flood water contact can cause contamination. Shrinkage and warping can result in distortion to solid wooden elements. Timber-decaying fungi and mould can develop unless water and humidity are correctly managed after flooding.
Floorboards – solid planed and sawn timber	Absorption of water into boards can cause swelling. Wet timber can be susceptible to distortion and warping during both the wetting and drying process.	Flood water contact can cause contamination. Mould or fungal growth can occur if the timber is not returned to a dry condition within a few weeks of inundation. Where boards have become lifted away from joists after flooding due to water absorption or hydrostatic pressure, the likelihood of irreversible distortion of unrestrained joists and floorboards increases.
Floorboards – composites, chipboards, laminates and plywood	Absorption of water into boards can cause swelling. Unless these materials have been made to be stable in water, e.g. marine ply, it is likely that the process of water absorption will cause the adhesives that bond the material components, to break down as it swells. Such denaturing causes irreversible dimensional changes and significant structural degradation.	Flood water contact can cause contamination. Discoloration, swelling, lamination loss, loss of structural integrity in boarding susceptible to water damage. Waterproof or water resisting timber composite decking varies in its ability to survive flooding so secondary effects can vary from being insignificant to complete failure.

Table 2 — Floors: potential flood impacts (continued)

Item	Commonly experienced flood action and impact	Secondary damage and occasionally experienced flood impacts
Structural ground bearing floor	Some concrete screeds can become wet and experience expansion and cracking. Movement, as a result of changes in the ground conditions during or after a flood event, can result in cracking.	Flood water contact can cause contamination. Salt attack on reinforcement in poorly constructed slabs. Floor structures can be subject to uplift pressure from water pressure below and from material expansion; however, this is extremely rare. Absorption of water into concrete in longer duration floods can be slow to dry. Risk of secondary cracking if subsequent drying is too quick and shrinkage is not accommodated.
Structural ground bearing floor (lime based)	Limecrete floors fail under extreme force from below, resulting in cracking or heave. Flood water contact can cause contamination, but lime is highly alkaline.	Salt might form on the surface of the limecrete but can be effectively removed.
Suspended concrete slab or beam and block floor	If a water barrier is not effectively installed, water can penetrate a discontinuous floor assembly from the sub-floor void with impact on materials in wall cavities and above the structural floor; e.g. at wall/floor junctions.	Flood water contact can cause contamination. Flood water rising in the void below the suspended floor can pass through voids and joints in the structural floor wetting the blocks. However, this is not an issue if they are below the DPM or waterproof barrier.
Floor insulation	Flood water contact through water seeping between the finish/edge of the slab or joists into the insulation. Some insulation materials can absorb water with potential short term or permanent reduction in insulating properties (see 5.4.1 for information on different forms or insulation material).	Water can be trapped in or between insulation and other floor structures and requires drying if above the DPM or waterproof barrier. Absorption of water into some types of insulation materials can cause compression, displacement slumping and/or contamination, but should not be assumed to have taken place. Thermal performance can be diminished through compression, slumping or displacement.
Floor screed	Flood water contact seeping through permeable or around non-permeable finishes or membranes. Floor screeds that are based on gypsum or anhydrite are deteriorated directly by flood water.	Cement/Lime: sand mortars (see 5.4.4) are not directly damaged but might suffer from cracking if subsequent drying is too rapid or adjacent materials cause movement.

Table 2 — *Floors: potential flood impacts (continued)*

Item	Commonly experienced flood action and impact	Secondary damage and occasionally experienced flood impacts
Floor finishes	Floor finishes can be contaminated and saturated; this might be temporary and recoverable. Carpets and textile-based materials might be rendered unusable due to wetting, contamination and deterioration depending on their quality and type of fixing. Acrylic-based materials can experience debonding and staining. Timber or timber-based finishes can absorb water and exhibit swelling which might be temporary or cause permanent damage. They can also suffer from staining and delamination. Displacement of floor finishes due to water pressure, impact or swelling of adjacent materials is possible. Permeable finishes allow water to reach potentially sensitive materials below, but this is a rare occurrence especially when tiles are adhered to concrete floors. Impermeable finishes can prevent water absorption in lower layers but also can trap moisture between finishes and structures depending on the floor build up.	Debonding of tile finishes can occur and mortars deteriorate particularly if water pressure is coming from below. Tile finishes: tiles/grout vary greatly in the porosity, so some water might be absorbed into some tiles/grout. They can be dried but might occasionally experience staining, which might not be permanent.
Floor membranes and barriers	Water damage to floor membranes and barriers is unlikely as these are resilient materials, designed to be in contact with moisture, and can be dried if necessary.	Differential pressure could cause movement, potentially stressing and damaging membranes and barriers, depending on their type and joint. Membranes might need to be removed to facilitate drying or might be damaged during other remedial works.

5.3.3 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.

Table 3 — *Walls: potential flood impacts*

Item	Commonly experienced flood action and impact	Secondary damage and occasionally experienced flood impacts
External walls and cavities	Dirt debris and contaminants on wall surface. Build-up of water and silt in cavity walls. Insulation materials within cavity walls might be displaced or slump such that the thermal performance is permanently diminished. Open cell and fibrous materials can absorb water with potential short-term or permanent reduction in insulating properties.	High-velocity or deep flooding can cause structural damage due to differential pressure. Impact from floating debris can cause damage. Contaminants and dirt not removed can cause damage to wall surface. Short-term or permanent reduction in insulating properties for some materials. If not removed, silt can create conditions for damp. Corrosion of fixings and wall ties if inadequately dried or repeated floods.
Internal surfaces (external walls)	Damage to internal decorative finishes, such as wall coverings, e.g. lifting and peeling of wallpaper, staining or abrasion. Damage to plasterboard dry linings (see 5.4.6). Ground salts and other soluble contaminants present but immobile during dry periods can be brought to the surface by the process of drying. These are often visible as hygroscopic salts on plaster/wall finishes.	Debonding of tiles might occur to non-solid substrate (e.g. plasterboard). Swelling and warping of wooden fittings. Displacement of insulation. Prolonged contact with salt water damages plaster. Presence of wet or damp insulation if not removed or dried can cause secondary damage
Partition/ internal walls	Damage to surface linings and finishes, saturation of insulation.	Damage from floating household items. Damage to lighter construction/timber frames might require replacement.
Masonry, external and party wall structure	Damaged/soluble mortars displaced.	Scouring to friable wall surfaces and soft mortar joints can occur during very high flow events. Frost creates fritting/spalling after floods in wintery conditions.
Timber frame: external and party wall structure	Where solid timber is used as a rain screen on the outer wall, this can easily allow flood water to penetrate into the cavity wall system and then through the inner wall leaf. Trapped water and damp material in timber frame structures and voids leads to the need to open up structure for drying. Prolonged contact with water can cause deterioration of panels and possible loss of structural integrity. Modern lightweight timber frames can distort on wetting and drying. Ingress of flood water between unsealed wall panels of the inner wall leaf and between unsealed joints between the sheet material and the wood stud framing.	Trapped moisture could lead to fungal growth and decay. Secondary damage to frame and panels from the need to open up structure, often requiring replacement.

Table 3 — *Walls: potential flood impacts (continued)*

Item	Commonly experienced flood action and impact	Secondary damage and occasionally experienced flood impacts
External and party wall structure: steel frame	Horizontal metallic members can hold pooled water, potentially extending drying times associated with ancillary items within its system. C, H or U profiled channels might need to be physically drained. Contact with flood water, especially sea water can cause corrosion.	Accelerated corrosion of steel frame where non-galvanized/coated
External wall – External wall insulation (EWI) systems or lightweight framed cladding and insulation	Damage to/contamination of cladding from contact with flood water.	Detachment of cladding due to high-velocity flood water or debris impact
Wall membranes and barriers	Water damage to wall membranes (e.g. breather membranes) and barriers (e.g. vapour control layers) is unlikely as these are resilient materials, designed to be in contact with moisture, and can be dried if necessary.	Differential pressure, flowing water and debris could cause mechanical damage to membranes and barriers, depending on their type. Membranes might need to be removed to facilitate drying or might be damaged during other remedial works.

5.3.4 Doors and windows

External doors and windows can be vulnerable points in the building envelope if they are part of a resistant approach. It is therefore important to take into account potential damage to the door and window units, including their frames, hinges, etc.

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. This can also cause secondary damage to sealed glazing units. For doors and low-level windows, high depths of water or high-velocity flooding causing pressure differential can cause failure of the door or window structure. This is particularly the case for single glazed or thin panelled doors and windows, wide stretches of doors and windows, and some conservatories. Pressure can also affect hinges or seals, causing long-term damage or displacement during the flood. Debris impact can damage doors and glazing panels.

Flood water can enter hollow sections of aluminium, steel, UPVC (unplasticized polyvinyl chloride), UPVC composite doors and windows and their frames, causing drying difficulties but most can be retained. Tidal and polluted flood water can lead to corrosion of internal metalwork or contamination that is difficult to treat. For automatic doors and windows, power assisted units, up and over doors and other electrical and mechanical features, water and silt can cause malfunction that can make egress more difficult and also require replacement.

Water can enter the inside of internal hollow core doors, 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. Softwood doors can warp.

5.3.5 Fixtures and fittings

Once water enters the building envelope, fixtures and fittings below the flood water become vulnerable to damage from flood water contact.

Decorative features such as skirting boards and architraves can detach from the wall, causing damage to the wall surface. Timber-based unprotected elements [for example, chipboard and medium density fibreboard (MDF)] can suffer swelling, warping and contamination.

Fitted units such as kitchens, bathroom cabinets and bookcases can suffer damage from immersion, depending on the material, that could include warping, delamination, corrosion of fixings, hinges, etc. Contamination that is difficult to treat can lead to irreversible damage to chipboard units. If fixed units suffer collapse, they might cause further damage to walls and other fixtures as they do so. Water can become trapped in voids. Floating items can cause damage to surfaces of units.

Sanitary fittings are generally robust to contact with clean water. They can suffer damage from debris. Seals might be damaged under pressure, particularly backflow, causing displacement with potential for impact damage. Composite or light plastic units can warp under pressure. Water, silt and pollution can be trapped in voids.

5.3.6 Building services

Building services, whether internal or external to the building, are generally not designed to be flood resilient and might be damaged during the flood event, necessitating repair or replacement. These include:

- a) lighting;
- b) data;
- c) radiators;
- d) ventilation systems;
- e) ground source heat pumps;
- f) air conditioning;
- g) septic tanks/fuel tanks;
- h) underfloor heating;
- i) lifts, escalators;
- j) oil heaters, hydrogen heaters, hybrid;
- k) electrical transformers;
- l) fire, gas, smoke and carbon monoxide detection systems;
- m) surveillance systems; and
- n) meters.

Flooding can cause damage to these services. Expert advice should be sought to establish whether and to what extent damage has occurred and which appropriate rehabilitation approach to adopt.

Electrical services in flood water present a high risk of electrocution during the flood event 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 is likely to damage fixed electrical items and sockets, for example, by short-circuiting 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.

5.4 Impact of flooding on building materials

5.4.1 Insulation materials

5.4.1.1 General

A wide range of insulation materials can be incorporated into the fabric of a building in locations where they could come into contact with flood water. Insulation materials are generally lightweight but can respond in different ways when exposed to flood water and subsequently have different residual characteristics and influences on the adjoining building fabric once the flood event has passed.

The resilience of the insulation material is secondary to the resilience of the structure containing the insulation material. The insulation material can confer a benefit, a disbenefit or be neutral in this respect. It is possible to anticipate the resilience of the structure/insulation combination by assessing the basic characteristics of the insulation, but it would normally be necessary to confirm this with rigorous scientific investigations that could include physical testing as well as modeling simulations.

Insulation materials can have, beyond thermal insulation, secondary characteristics that are essential to their fitness for purpose that might be affected by exposure to flooding, most commonly strength and reaction to fire characteristics.

Manufacturers' information such as data sheets and Declarations of Performance (DOPs) should be consulted to obtain information regarding the basic material characteristics. Similarly, the manufacturers' guidance should be followed to determine if the material can be regarded as flood resilient in specific applications.

5.4.1.2 Insulation type

With respect to the impacts of flooding, it is possible to divide insulation materials into two distinct types: reflective insulation and bulk insulation.

Reflective insulation achieves its thermal performance by providing a low emissivity (shiny) surface adjacent to an unventilated airspace.

Bulk insulation materials achieve their thermal performance by trapping gas in a matrix of cells or fibers. Reflective layers are often attached to the outside of bulk insulation to create a hybrid product.

When determining resilience to flooding, bulk insulation can be further subdivided into closed cell foam, open cell, mineral wool and other fibrous and non-plastic-foam insulations.

Materials that are described as closed cell foams include some materials which, when exposed to prolonged immersion, absorb water.

5.4.1.3 Relevant impacts of flooding on the characteristics of insulation materials

Flooding could have one of the following impacts on any thermal insulation product's contribution to the thermal performance of the structure.

- a) Short-term degradation of thermal insulation value – recoverable – primarily due to water absorption. Most likely to occur in open cell foam, mineral wool and other fibrous and non-plastic-foam insulations, recovery of thermal insulation value is achieved by a combination of drainage and drying.

- b) Long-term degradation of thermal insulation value – non-recoverable (in an acceptable period of time, which is likely to be within the general recovery period of the building) – due to water absorption. Depending on the duration of the flood, this could occur in both open cell foam, mineral wool and other fibrous and non-plastic-foam insulations as well as products described as closed cell but which absorb water when immersed for prolonged periods.
- c) Change in dimensions. Thickness reduction, shrinkage, deformation – primarily due to hydrostatic forces or hydrodynamic or debris impact – resulting in the insulation no longer providing the thermal insulation performance expected.
- d) Displacement of insulation product from original position – primarily due to flotation or hydrostatic forces. Flotation is most commonly associated with both open cell foam and closed cell foam. Displacement could occur with all types of insulation depending on the forces applied and the way the insulation is incorporated into the structure – when insulation is displaced it no longer provides the thermal insulation performance expected.
- e) Surface degradation – tarnishing and loss of low emissivity surfaces and consequent loss of thermal performance due to contamination chemical attack, debonding and abrasion, most commonly associated with reflective insulation and hybrid reflective/bulk insulation.
- f) Loss of strength – prolonged exposure to moisture could impact strength characteristics of insulation that results in loss of function in the building, for example, floor insulation or external wall insulation.

5.4.1.4 Impacts of insulation materials that have been exposed to flooding on the building

Following flooding, insulation products can have a significant impact on the building elements that contain them. This depends on the type of structure, the nature of the flood and the type of insulation. The potential impacts on the building structure include:

- a) loss of thermal insulation value of the building elements;
- b) retention of water in the spaces occupied by the insulation;
- c) retarding of the drying of the building fabric;
- d) promoting mould growth;
- e) retention of contaminants within the insulation;
- f) loss of function or durability in a floor; and
- g) loss of function and or durability in an external wall insulation system.

The presence of insulation can therefore lead to secondary damage and the actions following a flooding event that are required to mitigate or correct these impacts should be determined on a case-by-case basis.

5.4.1.5 Identifying insulation products with appropriate characteristics to support flood resilient construction

5.4.1.5.1 General

Most insulation products are placed on the market with a DOP, referring to the relevant designated product standard. These standards specify how the characteristics in the declarations are determined and expressed and as such provide reliable information.

NOTE Attention is drawn to the Construction Products Regulations 2019 [8].

Several of the characteristics that can be declared from these standards are useful in determining if the product has basic characteristics that support flood resilient construction whilst others can contribute to classification of an insulation product that is determined to support flood resilient construction via system testing or the analysis of experience of what does and does not work in real flood events.