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2 authors:

Andrew Tagg
HR Wallingford

Manuela Escarameia
HR Wallingford

HR Wallingford
Working with water

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A. Tagg & M. Escarameia

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THE ROLE OF BUILDING FLOOD RESILIENCE IN THE FLOOD RISK MANAGEMENT HIERARCHY

A F Tagg[1] and M Escarameia[2]

[1] *HR Wallingford Ltd., Oxfordshire, UK*
[2] *Grontmij, Reading, Berkshire, UK (formally at HR Wallingford Ltd., Oxfordshire, UK)*

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Abstract
New planning policy in England and Wales should direct future development away from areas of high flood risk, but it is inevitable that some development will be necessary in places that flood, albeit with a low or residual risk. As part of the hierarchy of flood mitigation measures, a growing consideration promoted by Government, planners and insurers is to design and construct these new dwellings so they are more resistant or resilient to flood damage. Flood resilient repairs have also been promoted for many years for existing properties that suffer from flooding. These approaches are particularly important since climate change is likely to bring with it an increased flood risk. HR Wallingford took a key role within a research consortium that produced fresh guidance on 'Improving the flood performance of new buildings'. The report, published in May 2007, was jointly funded by Communities and Local Government and Defra/Environment Agency. Part of the research involved the laboratory testing of materials and construction assemblies at HR Wallingford under appropriate flood conditions. Results on water penetration and drying ability have provided new information to corroborate previous opinion, both 'anecdotal' and expert. This paper outlines the various stages in the production of this new guidance document, which in addition to the laboratory testing also undertook a comprehensive literature review, including information from North America, the Netherlands and Australia. The guidance manual provides information on flood *avoidance* and *resistance* measures but it is mainly concerned with *flood resilient design and construction*. Flood resilient construction has clear benefits. It can limit damage to the fabric of a building and minimise the time during which families are without their home. As a result it can help to reduce the stress and anxiety that flooding can cause.

1 Overview of Planning and Flood Risk Management in the UK

As a result of the wettest May-July period in England and Wales since records began in 1766, severe flooding occurred in the summer of 2007. In the counties of Yorkshire and Humberside alone over 5000 residential properties were flooded and in Gloucestershire over 350,000 people were without mains water due to flooding of the local water treatment works (The Pitt Review, 2007).

As highlighted by the recent flooding events, approximately 10% of UK properties are at high risk of river and coastal flooding but the situation is worse if overland flooding is taken into account. On average there are over 7000 cases of sewer flooding every year (Association of British Insurers, web site) and in large urban areas it is estimated that about half of all the flooding problems is due to sewer overloading. This situation is likely to get worse with more frequent high-intensity rainfall events and higher winter rainfall, which are predicted to occur as a result of climate change.

Across Europe there has been a shift in approach over the past decade, from one of flood defence and flood management, to flood risk management. This takes a more holistic view of all flood risks and costs, matching potential actions against the benefits that may be delivered to society. New UK policy has acknowledged that flood risk management should consist of a portfolio of approaches which include using the planning system as the primary means of avoiding and reducing flood risk to and from new development. Adequate planning procedures offer opportunities to reduce flooding through changes to the urban fabric and are an important element for managing flood risk in the long term (Stern, 2007).

In England, a major policy initiative has been the publication of Planning Policy Statement 25, or PPS25 for short, which deals with flood risk (DCLG, 2006). Compared with previous policy documents, flooding is now taken into account at all stages of the planning process with the ultimate aim of ensuring safe development for sustainable communities. The assessment of flood risk follows a three-tiered approach which includes: Regional Flood Risk Appraisal, Strategic Flood Risk Assessment and site-specific Flood Risk Assessment. This risk-based sequential approach requires an extended role for the Environment Agency (EA) as a statutory consultee. Where new development is, exceptionally, considered necessary in certain areas still at flood risk, policy aims to make it safe, without increasing flood risk elsewhere, and, where possible, reducing flood risk overall.

2 Flood resilience at building level

Under the theme “Making Space for Water: increasing resilience to flooding” (Defra, 2007), a growing consideration is to design and construct new dwellings so that they are more resistant and resilient to flood damage. This new approach has been promoted not only by Government (Defra, DCLG) but also by insurers. Flood resilient repairs have also been promoted for many years for existing properties that are subjected to flooding. These approaches are becoming increasingly important since climate change is likely to bring with it an increased flood risk in the UK. Improvements at building level are one of the key adaptation strategies to climate change envisaged in the Stern Review.

In the context of this paper, it is important to define the terms resistance and resilience, as there can be confusion. Resistance is defined here as measures taken at building level to prevent floodwater entering the building. Resilience is defined as sustainable measures that can be incorporated into the building fabric, fixtures and fittings to reduce the impact of floodwater. These facilitate drying and cleaning and reduce the time to re-occupy the property.

It is important to note that flooding has not only the potential for considerable disruption to normal life and eventual danger but can also cause severe stress to those forced out of their homes, sometimes for several months or even years. The National Flood Forum, a charity organization that champions the interests of those who have been flooded or are at risk of flooding, is aimed at providing support and promoting measures that contribute to flood alleviation. Amongst these measures are temporary flood protection products, which can be placed over building apertures to prevent water ingress. A certification process has been in place to ensure the products are reliable and fit for purpose. Although useful for existing properties, recent guidance does not recommend them for new buildings as measures should be primarily introduced at building fabric or development site level rather than relying on user intervention.

3 Improving flood resilience of new build

3.1 Scope and objectives of project

A project commissioned jointly by the UK Department for Communities and Local Government (DCLG) and the Environment Agency entitled "Improving the flood resilience of buildings through improved materials, methods and details" investigated flood resistant and resilient construction. This project used quantitative and qualitative analysis to widen the existing evidence base (which was largely based on anecdotal and non quantified information) for the development of new recommendations and design guidance. For the first time in the UK, laboratory testing was used to investigate specifically the performance of building materials and constructions under simulated flood conditions, both during the wetting and post-flood drying stage.

The project focused on domestic properties but issues that are relevant to other types of building were also identified with regard to the adaptation and repair of existing constructions. The objectives included:

- incorporation of existing information from previous and current work on flood resilience, resistance, repair and protection
- gathering of baseline laboratory data to determine the performance of materials and composites to water penetration, damage and drying ability
- development of design guidance for minimizing the impact of floods on buildings as part of the hierarchy of approaches within flood risk management.

3.2 Outputs

The main outputs from the project were:

- Guidance for developers and designers "Improving the flood performance of new buildings: flood resilient construction"
- Proposals for incorporating flood resilience in the English (and Welsh) Building Regulations (namely in Approved Document C - Site preparation and resistance to contaminants).

This project aimed to close the loop between the Planning System (with key responsibility to determine whether flood effect mitigation is required) and Building Control (responsible for its application). In practice, proof of compliance to the amended Building Regulations would be sent to the Local Planning Authority prior to commencement of building work, thereby integrating planning and building control together to manage flood risk. Building inspectors would have an added responsibility in ensuring that flood minimization measures are actually incorporated.

4 Collation of evidence

4.1 Literature review

The interaction between building fabric and floods was reviewed through: the collation and analysis of existing practice and guidance in the UK and overseas; and the assessment of available data on the effect of floodwater on building materials and structures (Wingfield at al, 2005). An important part of the body of evidence related to the experiences and investigations undertaken in North America.

It was apparent from the review of existing design guidance that the factors and techniques required to minimize the impact of floodwater in buildings were generally understood but recommendations were based largely on experience and common sense. Scientific experimental data that would underpin such guidance was found to be rather sparse. One major conclusion from the literature review was that experimental work was needed to counteract the paucity of existing data on performance of building constructions subjected to floods.

Figure 1 Testing arrangement for facing bricks

Figure 2 Testing arrangement for cavity wall (facing brick external face and Aircrete blocks on internal face) with rigid closed cell insulation

4.2 Experiential evidence

Observational data on flooded dwellings/buildings (including drying data from the 2005 flood in Carlisle, Cumbria) were identified and collected in order to further understand how the flooding process occurs and how it affects a building and its materials during the drying and restoration phase. Current building practices in flood prone areas and their usefulness for flood resilience were also identified through a series of interviews with companies/groups involved in flood repair/management. The main findings (Tagg et al, 2006) were:

- A lack of agreement on definitions of resilience/resistance was apparent and this caused some confusion;
- The majority of effort and interest was concerned with the retrofit of resilient measures for existing properties;
- There has been limited research on deriving resilient standards for new build;
- There have been several publications that provide guidance on resilient measures but the material is of a very similar nature, and represents expert opinion and common sense, little being based on hard technical evidence; much of the advice relates to the fixtures and fittings, and post-flood repairs (e.g. raising electrics, check valves on service ducts, raising appliances and units above flood level, using plastic/ceramic/steel fittings).

The need for a protocol for data collection by flood restorers was identified; this would take full advantage of unique opportunities that are presented to the flooding community for systematic gathering of valuable data during and following flood events.

4.3 Laboratory tests

An extensive laboratory study was carried out to provide baseline information on the behaviour of materials and composite constructions during floods. Given the wide range of available materials/composites and the time required for construction, curing, testing and demolishing of test specimens, it was necessary to limit the testing to types that are most commonly used in the UK for domestic new build. In total the testing involved 13 different materials (e.g. bricks, blocks, mortar, timber materials, plasterboard), 12 different types of wall construction, 8 floors and 4 "promising" methods that included splash-resistant plasterboard and thin joint construction – see Table 1 and Figures 1 and 2.

Table 1 Materials and composites tested

Materials	**Masonry cavity walls**
<u>Bricks:</u> Engineering bricks (Classes A and B) Pressed Facing Bricks (sand and spike textured) Hand-made facing bricks	<u>Empty cavity:</u> Engineering bricks and concrete blocks Engineering bricks and Aircrete blocks Facing bricks and concrete blocks Facing bricks and Aircrete blocks Facing bricks and concrete blocks and external cement render
<u>Blocks:</u> Concrete blocks (3.5N and 7N) Aircrete (Autoclave concrete)	<u>Full fill:</u> Facing bricks and Aircrete blocks and mineral fibre insulation Facing bricks and Aircrete blocks and blown-in insulation Facing bricks and concrete blocks with mineral fibre insulation and internal lime based plaster
<u>Timber board</u> OSB2 11mm and OSB3 18mm thick	<u>Part fill:</u> Facing bricks and concrete blocks with rigid foam insulation
<u>Mortars</u> Below DPC 1:3 (cement:sand) Above DPC 1:6 (cement:sand)	**Timber framed walls**
Floors	External facing bricks, empty cavity
Concrete slabs (0.5m by 0.5m): 100mm thick, strength 32.5 150mm thick, strength 32.5 150mm thick, strength 42.5 150mm thick, strength 42.5, polythene sheet below slab - 300m overlap - Taped lap - Blockwork foundation, side wall - Blockwork foundation, side wall, concreted trench - Blockwork foundation, corner wall, concreted trench	External concrete blocks with cement render, empty cavity
	External concrete blocks with lime render, empty cavity
	"Promising methods"
	Thin layer mortar joint on solid block wall
	Solid masonry wall with external insulation
	Masonry cavity wall with external and internal renders
	Timber framed cavity wall using splash-proof plaster board

The following resilience characteristics were investigated; others such as propensity for mould growth, resistance to cycles of freeze/thaw and cleanability could not be covered in this study:

- Water penetration – the seepage through the material/composite (volume/time)
- Drying ability – the capability to regain original moisture condition
- Retention of pre-flood dimensions/integrity – the lack of deformation or change in form or appearance.

The test procedure attempted to mimic as far as possible real flood conditions and comprised the following phases:

- Wetting phase: three days exposed to 1m head of still water on external face, followed by one day of external and internal wetting to simulate conditions where water has entered the property and cannot escape; in the case of floors, these were exposed to an uplift force exerting on the underside of the floor

- Drying phase: at least six days during which the test units were allowed to dry naturally under laboratory ambient conditions.

Based on the analysis of the laboratory results and assessment of other evidence, tables were produced classifying the flood resilience characteristics of materials and wall types into good, medium and poor. Detailed test results can be found in Escarameia et al (2006).

5 Guidance and recommendations

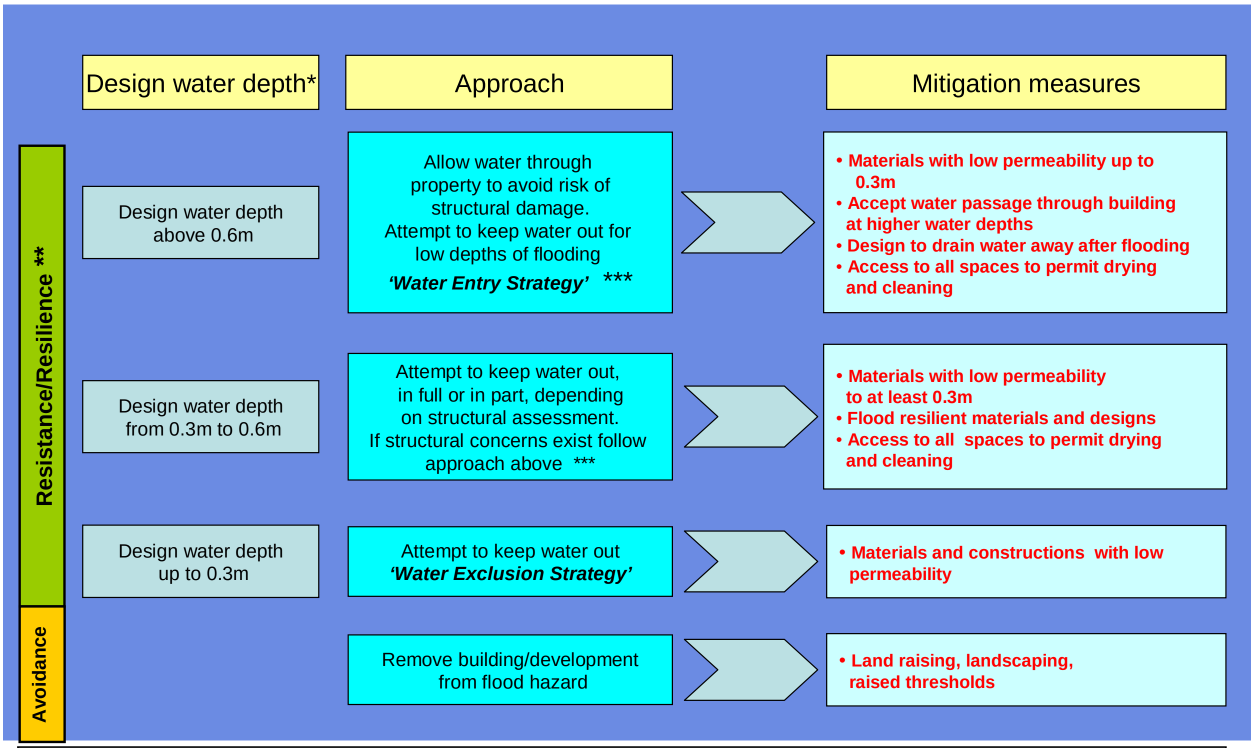
A guidance document aimed primarily at developers and designers, but also useful to local authority officials, regulators and insurers, was published giving recommended design strategies for incorporation of resilience into new buildings as well as detailed construction advice (DCLG, 2007). Being closely allied with recent UK planning documents, the guidance is based on using the design flood depth associated with all possible sources of flooding, derived from a site-specific flood risk assessment. The recommended procedure will lead to site-level flood avoidance (by raising the land, landscaping, raising thresholds) or, if this is not possible, to either a *water exclusion* or a *water entry* strategy (Figure 3):

- In a *water exclusion strategy*, favoured when low flood depths are involved, up to 0.6m, emphasis is placed on minimizing entry of floodwater whilst maintaining structural integrity and facilitating drying and cleaning; this can be achieved with low permeability materials such as engineering bricks and cement renders on walls and concrete floors;
- In a *water entry strategy*, favoured when higher flood depths are involved, emphasis is placed on allowing water into the building, facilitating draining and consequent drying. For typical masonry constructions laboratory tests have indicated that a water level difference of about 0.6m or above between the outside and the inside of the building can cause structural damage.

There are several factors that underpin this design philosophy. All the existing information indicates that water can enter a building by many routes, including through service openings, through the building fabric itself and by flow through the ground. The design guidance acknowledges this ease of water entry by promoting resilient materials that are easily cleaned and dried for flood depths above 0.3m. The critical design flood depth of 0.6m is conservative compared to other values that have been used previously, such as for performance testing of flood protection products, which have assumed 0.9 or 1.0m. The literature review indicated that when velocities are taken into account, a typical UK masonry wall may experience some form of structural failure at lower flood depth differentials of 0.5 to 0.7m. Water depths above 0.6m are likely to be associated with higher velocities and the transport of large debris, and therefore the project steering group took the view that a conservative value was appropriate for the construction of the building fabric. The guidance stresses that where a water-exclusion strategy is being proposed, the risks posed by flood water, in terms of structural stability, are considered by a qualified engineer during the building design phase.

6 Conclusions

Flood resilient construction has clear benefits. It can limit damage to the fabric of the building and minimise the time during which families are without their home. As a result it can help reduce the stress and anxiety that flooding can cause. Houses fitted with resilience measures can be re-occupied after a few days whereas several months (or even years) are sometimes needed for “standard” properties after a major flood event. Shortage of competent flood repair organisations and delays in re-occupying homes have been key features of the recovery from major flooding in the UK since 2005.



Notes:
* Design water depth should be based on assessment of all flood types that can impact on the building
** Resistance/resilience measures can be used in conjunction with Avoidance measures to minimise overall flood risk
*** In all cases the 'water exclusion strategy' can be followed for flood water depths up to 0.3m

Figure 3 Rationale for building resilience design strategies

The guidance described in this paper, which has been publicly available since May 2007, applies principally to new build, although to what extent it is being used at the present time is not clear. Widespread adoption of resilient construction will only take place in England and Wales when these requirements are incorporated into the Building Regulations, which may take several years to achieve. However, the biggest impact on reducing flood risk and flood damages will occur if the recommendations are taken up for existing properties, which dominate the housing stock in the UK. Promotion of flood resilience by insurers and government has been on-going for some years, and with the predicted increase in flood risk, it is hoped that the take-up will increase in the future.

7 Acknowledgements

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HR Wallingford
Working with water

HR Wallingford Ltd
Howbery Park
Wallingford
Oxfordshire OX10 8BA
UK

tel +44 (0)1491 835381
fax +44 (0)1491 832233
email info@hrwallingford.co.uk

www.hrwallingford.co.uk