Climate change and innovation in house building

Designing out risk

NHBC Foundation

Housing research & development in partnership with BRE Trust

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August 2007

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NF 3
Published by IHS BRE Press on behalf of NHBC Foundation
August 2007
ISBN 978-1-86081-987-2

FOREWORD

This review focuses on a range of issues associated with the changing patterns, systems and methods of construction in new homes which have, over time, changed the risk profile for lenders who are used to traditional brick and block construction. The NHBC Foundation has already delivered research findings on the application and suitability of modern methods of construction (MMC) in the publication *A guide to modern methods of construction* (ref. NF1).

This review looks at the lending and insurance processes in relation to MMC to ensure clearer understanding of the types of risk presented by MMC and how these can be allowed for in forming new lending and risk profiles. It also provides guidance on specification and design so builders, developers, insurers and lenders can have increased confidence in the risk factors of new homes built with innovative technologies.

Climate change, which has also been addressed by NHBC Foundation research, presents its own challenges for managing risk profiles as evidenced by the countrywide damage caused by flooding and storms in recent years. Flooding and storm issues are not specifically covered in Building Regulations and this creates a lack of clarity and confidence in managing these risks. In the absence of these regulations it is possible to effectively mitigate these risks at the design stage.

It is important to remember that many of the perceived risk issues can be readily addressed at design stage and this review brings this into sharp relief, allowing greater confidence for lenders and insurers in understanding how risks can be minimised. The key issues covered in the review are: fire, water leakage, storm, flood, subsidence and security. As many of these can be presumed to also relate directly to the issue of climate change, it is important this review is seen as one key element in the broader debate on the climate change and sustainability agendas.

Innovations properly delivered via MMC can, in many cases, reduce the risk profile because construction of elements of the fabric of the home can take place in factory conditions which has a clear and beneficial impact on quality and maintenance of product specifications and standards. This review brings a greater understanding of such issues and addresses those which are of specific importance to either lenders or insurers such as durability, capability for repair and performance.

To help address these issues the review has formulated a series of design rules. These rules, if followed when specifying and designing homes, will assist in mitigating risk and addressing the concerns of lenders and insurers alike in their risk management processes. Understanding breeds confidence and the detail given in this review will assist insurers and lenders in making informed choices and asking the right questions to enable them to understand the potential risks in systems and how these can be addressed for their long-term risk profiling. In many cases the design rules involve designing out potential problems in the first instance. In addition the review provides design and specification tips specific to each potential risk area.

I am confident this review will be a valuable resource for the industry as a whole. It sets out design principles which will enable builders, developers, insurers and lenders to have greater confidence in innovations in technology as we move towards the 2016 zero carbon homes target and deliver the new homes laid out by the Prime Minister in his inaugural policy framework.

Imtiaz Farookhi

Chief Executive, NHBC

ACKNOWLEDGEMENTS

We would like to express our thanks to the following for supplying photographs for this review:

Paul Blackmore, BRE for Figures 8 and 9

The Northern Ireland Housing Executive for Figure 21

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1 Introduction

In the past 50 years, most dwellings in the UK have been built using brick and block or timber frame construction. These methods of building are well established and their design and construction are covered by a comprehensive range of codes of practice and standards. Lenders and insurers are familiar with them and can process applications for loans and insurance cover without undue concern. In recent years the process of design and construction of dwellings has become more complex and critical, particularly with respect to certain revisions to the Building Regulations such as parts E (Resistance to the passage of sound) and L (Conservation of fuel and power).

From the mid-1990s we have seen a resurgence of other forms of construction, of which lenders and insurers have little or no experience. These 'modern methods of construction' have many similarities with the older forms of non-traditional construction common between the end of the first world war and the mid 1970s. Lenders and insurers are therefore concerned that the problems associated with older forms of non-traditional construction could be repeated with the new forms of construction and are therefore uncertain about the level of risk that lending on or insuring such properties carries. There is a view that certain aspects of the performance of these forms of construction are not adequately covered by Building Regulations.

Another area of dwelling performance which lenders and insurers feel is inadequately covered, either by Building Regulations or design codes, is the consequences of climate change. This has focussed the minds of insurers because of the recent increase in the frequency and severity of flooding events. Flood resistance is not considered specifically within Building Regulations, and insurers are also concerned that the regulations are out of step with predicted increases in wind speeds and rainfall patterns that are likely to result from climate change.

Some of the issues related to innovation in construction and climate change that concern insurers and lenders could be addressed at the design stage by the architect or designer. However, a lack of communication between insurers, lenders and architects/designers often prevents this happening. This publication seeks to bridge this perceived gap between insurers/lenders and architects/designers by reference to the major perils that currently (or may in the future) cost insurers large sums of money. Issues that mortgage lenders feel could seriously devalue the property are also discussed. A condition of any mortgage will be that appropriate house insurance is in place – thus the interests of lenders are directly linked to those of the insurance industry.

Insurers cover the cost of repair or replacement of a building or component which may become necessary due to damage from the occupants or from the effects of a natural peril. Work carried out by BRE with loss adjusters as a part of the development of LPS 2020 (see section 1.1.2) identifies a number of perils and ranks them in terms of frequency and cost. Table 1 (which is produced in consultation with insurers and loss adjusters) lists the most significant perils (out of 10 that were considered) in order of priority.

TABLE 1

A summary of perils identified by loss adjusters

Peril	Frequency		Cost		Overall ranking
	Rating	Rank	Rating	Rank	
Fire	0.50	4	1.32	2	1
Water leak	1.86	1	0.14	6	2
Storm	1.45	2	0.18	5	2
Flood	0.18	6	1.64	1	2
Subsidence	0.36	5	0.55	4	5
Vandalism or theft	0.64	3	0.09	7	6

In addition to the perils listed in Table 1 there are a number of issues that may arise as new methods of construction are adopted and because of the impacts of climate change.

1.1 Innovations in construction: the lenders' and insurers' perspective

Innovations in construction occur for a variety of reasons such as:

- A desire to speed up the construction process.
- To reduce the amount of work undertaken on site.
- To mitigate a potentially disruptive situation such as delays due to a shortage of skilled labour.
- To improve quality control.

Innovation in construction can take two forms: either innovations in the construction process or in the end product.

1.1.1 Types of innovation

Process innovations alter the way a particular product (ie the dwelling) is produced, but do not change the end product. An example can be found with timber frame construction. For many years timber studs and sheathing materials have been assembled in factories to produce basic timber frame panels used to construct dwellings. All other materials (thermal insulation, linings, services, windows and doors) have been installed on site in the normal way. A recent innovation has been to extend the scope of the factory operation to include fitting some or all of the above components in the factory. The end product (the dwelling constructed on site) is indistinguishable from its more conventional counterpart. Such innovations, which introduce greater quality control into already established ways of building, should be welcomed rather than cause concern.

Innovative products on the other hand often incorporate new materials and construction techniques and can range from components to entire construction systems. Because of a lack of experience and an absence of a track record of performance the use of such systems raises legitimate questions with regard to their likely performance over time. More information on innovative construction methods and components can be found in *A guide to modern methods of construction* published by the NHBC Foundation.[1]

1.1.2 The end product

Both lenders and insurers have concerns about innovative forms of construction. The mortgage lender will want to know that the building is of a suitable build quality so that it has a good market value and is saleable. This quality of being saleable needs to be maintained throughout the period of the mortgage loan. Specific concerns of lenders (taken from the Council of Mortgage Lenders website www.cml.org.uk/cml/policy/issues/1330) are:

- **Durability:** achieve a life span of at least 60 years.
- **Whole life costs:** at a level comparable to traditional construction – particularly relevant for lenders to social housing providers.
- **Reparability:** no undue repair costs, and ability to use a range of local repair services.
- **Adaptability:** the property should, without difficulty, support the usual range of adaptations/extensions such as a porch and conservatory.
- **Insurability:** buildings insurance should be available on normal terms.

In addition to the above list market perception will also affect saleability. How a dwelling is perceived could in turn be influenced by its appearance (ie how does the building 'age' physically – does it appear to be maturing or deteriorating as the years go by?) and by any adverse reputation (eg has a systemic defect in a particular dwelling type become apparent – this would also be of concern to insurers).

The insurer will wish to know that the house is constructed to a suitable standard and that, in the event of damage, the construction is economically repairable. Specific issues for insurers relate to resilience and reparability.[2] The Association of British Insurers (ABI) has developed a number of 'Resilience scenarios' whereby the resilience of an untested MMC system should be compared to the performance of conventional buildings.[2] These are (in order of priority):

- Storm with wind speeds exceeding 80 km/h on average for eight hours, with occasional gusts of more than 120 km/h.
- Leak of 1000 L of water from an upstairs room due to a burst pipe.
- Single-room fire breaking out through the window, damaging the internal linings and external cladding above the window.
- 1 m deep dirty water flood lasting two days.
- Subsidence event resulting in a 50 mm drop on one corner of the building.
- Gas explosion in kitchen area.
- Vehicle impact on exterior corner, resulting in a 1 m deformation.
- Internal impact damage that exposes building insulation material (eg moving furniture or DIY).
- Attempted theft by forcing doorframe to gain access.

In addition the ABI has suggested a number or repair scenarios, also in comparison with conventional construction, that manufacturers might consider when developing their systems. They are (in order of priority):

- Costs and availability of replacement parts, including any bespoke components (including length of time to obtain and ease of installation).
- Costs and availability of labour – ease with which local trades could undertake repairs/alterations, or the need to employ manufacturer-approved contractors.
- Extent and speed to which building could be dried out after a flood.
- Degree of inter-connectedness between building components, eg bathroom or kitchen pods.

In order to address lenders' and insurers' concerns a certification system for innovative systems, elements and components for residential buildings (LPS 2020) was launched by

BRE Certification Ltd. in April 2006.[3] Assessment to LPS 2020 covers: quality control of factory-made components; installation on site; robustness; reparability and adaptability. In assessing robustness, reparability and adaptability the benchmark 'conventional' construction is taken as timber frame construction with brick cladding.

A part of the certification process also involves assessing the design factors and detailing that would reduce the risk of damage due to recognised perils. A number of related standards are being developed to cover enhanced performance and environmental protection. The new standards are likely to cover: fire performance, environmental profile, energy performance and flood resilience and security.

1.1.3 General design issues related to innovative construction forms

Lenders' and insurers' concerns revolve around:

- Durability of the fabric (ie a resistance to deterioration from natural processes such as weathering).
- Maintainability (including the costs of maintenance and repair).
- Resilience to damage from recognised perils.

It is true that many conventional constructions and materials deteriorate, require maintenance and suffer damage from insurable perils, but a number of factors mean that innovative constructions are treated differently by lenders and insurers:

- A lack of historic claims data for innovative constructions means that insurers have no way of accurately assessing risk and so cannot calculate premiums with certainty.
- The weathering characteristics of novel materials are not known so it will be difficult to predict how the building will 'age'.
- Non-standard components and materials can markedly increase repair and maintenance costs because they can be difficult and expensive to source, and specialised operatives may be needed to fit them.
- Maintenance schedules and techniques may differ from those of more conventional systems thus making it more likely that essential maintenance will not be undertaken, or will be carried out inadequately.
- Construction detailing may be novel and not 'intuitive', even for experienced operatives.
- The assembly of large prefabricated components may create voids within the structure that allow the rapid and undetected spread of fire or easy passage of water.

1.2 The impact of climate change on construction

There is now a growing consensus that the climate is changing faster than at any time in the past millennium, and that this will have major effects on many aspects of the built environment. In order to create a lasting structure designs may need to anticipate a diverse range of possible scenarios. The current predictions for climate change are described in the UKCIP02 scenarios prepared by the UK Climate Impacts Programme. These scenarios will soon be updated (further information from www.ukcip.org.uk/scenarios/ukcip08/). The UKCIP02 indicate the main consequences of climate change will be:

- More intense sunshine and associated ultraviolet levels.
- More extreme weather conditions in terms of wind and rain.
- Rising sea levels which are predicted to rise by between 260 and 860 mm above current levels by the 2080s.

The ways in which these changes will impact on buildings are not fully understood although a publication[4] by the Foundation for the Built Environment (now the BRE Trust) lists the following impacts of climatic factors (see Table 2) and impacts on the fabric of buildings (Table 3).

TABLE 2

Impacts of climatic factors*

Climatic factors	Impacts
Soil drying	Increase will affect water tables and could affect foundations in clay soils
Temperature	Maximum and minimum changes will affect heating, cooling and air conditioning costs. Frequency of cycling through freezing point will affect durability. Daily maximum and minimum will affect thermal air movement
Relative humidity	Increase will affect condensation and associated damage or mould growth
Precipitation	Increase and decrease will affect water tables (foundations and basements); cleaning costs will be increased in winter, with associated redecoration requirements; durability and risk of water ingress will be affected by combination of precipitation increase and gales
Gales	Increase will affect need for weather tightness, risk of water ingress, effectiveness of air conditioning, energy use, risk of roof failures
Radiation	Increase may affect need for solar glare control
Cloud	Increase in winter will increase the need for electric lighting; reduction in summer may reduce the need for electric lighting for certain buildings

* Information in Table 2 is based on material in FBE report FB2 (page 4): *Potential implications of climate change in the built environment*[4]

TABLE 3

Impacts of climate change on components, sub-structures and whole buildings*

Components, sub-structures and whole buildings	Impacts
Air conditioning/heating/ cooling systems	Savings in winter running costs, need to upgrade airtightness, increased cooling requirements and decreased heating requirements
Basements (sub-structure)	Increased risk of heave or subsidence, water ingress, consequential damage to finishes and stored items
Lighting systems	Increased cloud will reduce natural light, increased radiation may increase need for glare control
Mechanical and electrical services	Complex systems will have reduced life or reliability if increased temperature is not controlled; this may also have health and safety implications
Materials	Plastics will have reduced life due to increased radiation
Roofs	Increased fixing costs and risk of failures due to gales, wind and precipitation
Most materials	Increased salt spray zone in marine areas will reduce life duration
Whole building	Increased cleaning costs due to wind, gales, relative humidity, precipitation
Whole building	May alter construction costs and period owing to wet weather and associated loss of production. Costs may increase or decrease depending on season and region
Foundation and sub-structure concrete	Increased risk of damage by subsoil water
Structure/cladding/ renders/roofing membranes	Increased risk of cracking due to different thermal or moisture movements
Sealants	Increased risk of failure due to different thermal or moisture movements
Timber-framed construction	Increased risk of failure due to increase in relative humidity, depending on design

* Information in Table 3 is based on material in FBE report FB2 (page 4): *Potential implications of climate change in the built environment*[4]

Many of the impacts in Tables 2 and 3 would only affect the maintenance requirements, which are not normally covered by insurance policies. Others would have a direct impact on insurable perils. Maintenance is a factor in calculating whole life costs, which lenders are increasingly concerned about, and therefore all the impacts listed are relevant to some degree.

1.2.1 General design issues related to climate change

As well as changes in the way dwellings are constructed, climate change could potentially have a significant impact on many aspects of the performance of buildings, which in turn may increase risk and uncertainty for lenders and insurers. A prime example of increased uncertainty is illustrated by the recent increase in severe flood events which have prompted the Association of British Insurers (ABI) to include a large amount of information on the subject on their website (www.abi.org.uk/Bookshop/default.asp#Flooding_&_Climate_Change). The material on their website is aimed at a variety of audiences and covers issues from strategic planning for flood risk to information aimed at homeowners.

Increases to the level of solar radiation could lead to overheating which might increase the need for cooling, particularly at night. There may be security implications with night time cooling if air conditioning units are not used. Higher levels of solar radiation would also lead to dark materials directly exposed to the sun absorbing more heat and hence reaching higher temperatures. Thus differential thermal expansion may become more of a problem.

1.3 General design rules

From the specific issues listed in sections 1.1 and 1.2, a few general design rules can be developed.

DESIGN RULE 1

Where possible stick to conventional materials, which are widely available

Specialist materials are often specified for architectural effect or for enhanced performance, particularly for external cladding. Their choice at the design stage may seem perfectly reasonable because they can make the construction process more efficient or enhance the visual impact of the project. However, before choosing such materials or products consider:

- How easy it would be to source and fit replacements in the future?
- Will the same material, or a direct substitute, be available?
- Will it be available in the same colour, and if so is the colour likely to be 'fast' (ie not fade in sunlight)?
- Can it be fitted by competent DIY or typical builder?

Figure 1 Cladding panel with non-standard brick slips.

If the answer to any these questions is 'no' then the repair of the dwelling is likely to be expensive compared to more conventional constructions.

Figure 1 shows a cladding panel faced with brick slips. The brick slips are a non-standard size (50 mm x 250 mm) – if the panel were to be damaged and a replacement panel were not available then it would be difficult to repair or replicate.

DESIGN RULE 2

Minimise the number and complexity of bespoke/specialist components

Bespoke items such as prefabricated sub-frames, brackets and manifolds can increase the cost effectiveness of manufacturing innovative dwellings. Such items will be ordered by the manufacturer to their specific design requirements, and in sufficient quantities to complete the project. However, problems may arise during repair or refurbishment. Such components will probably be hidden from view and the builder may be completely unaware that they are there until the fabric is opened up. If the builder needs to get one made he will not have a detailed specification (which may include specific structural requirements) and may have to halt refurbishment work until the component can be manufactured, thus increasing the cost of repair. There is also a danger that the builder may resort to ad hoc solutions without full understanding of the implications.

Components such as the bracket shown in Figure 2 can improve the construction process but could lead to difficulty if replacements need to be sourced in refurbishment situations.

Figure 2 Bespoke/specialist components.

DESIGN RULE 3

Follow current good detailing practice, particularly for the prevention of water ingress

A fundamental concern for lenders and insurers relates to the ability of cladding materials to protect the structural element of innovative systems from exposure to water. NHBC requires a drained cavity between cladding systems and the structural elements of dwellings built with framed construction. The first line of defence against the weather is the cladding system itself – in order to function properly good detailing is important.

There will be an assumption on the part of lenders and insurers that homeowners will not necessarily carry out essential maintenance. The design should therefore be tolerant of that – cladding systems that rely on regular maintenance or on perishable materials (such as gaskets and sealants) to keep the underlying structure dry will not be looked upon favourably.

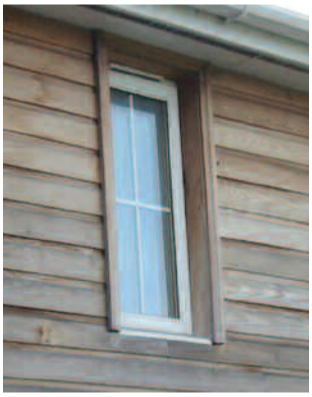

Figure 3 Poor detailing around a window.

Figure 3 shows an example of poor detailing. The front edge of the sill is flush with the face of the cladding – good practice would require the sill to project forward of the face of the cladding by 50 mm allowing the weather drip to shed water clear of the building. There are no sealants or flashings visible – it is highly likely that rainwater will get behind the cladding even in less windy conditions.

DESIGN RULE 4

Take account of solar overheating

The potential for overheating can be reduced by the introduction of solar shading (Figure 4) which prevents high intensity radiation from the mid-day sun entering the building but lets in low intensity radiation from the evening sun. To be most effective the shading should be placed on the outside of the glazing. If that is not practical, and the intensity of the solar radiation is not particularly high, then reflective blinds inside the glazing can have some beneficial effect. Reducing the area of glazing on south-facing facades will also reduce heat gain from solar radiation. More detailed guidance can be obtained from the Energy Saving Trust.[5]

Figure 4 Solar shading – keeps out the midday sun but lets in the evening sun.

Introducing thermal mass (ie materials such as concrete and masonry exposed to the interior space) or the use of lining boards containing phase change materials can also act to moderate internal temperature.

DESIGN RULE 5

Avoid dark-coloured materials in areas exposed to direct sunlight

Dark-coloured materials absorb more heat than lighter coloured ones, and consequently heat up to higher temperatures in direct sunlight. The extent of thermal expansion may be problematic particularly for polymeric materials which tend to have high coefficients of thermal expansion compared to other building materials. For example, for every 20°C change in temperature PVC-U will expand or contract by approximately 1.2 mm per metre length. Thus if a 5 m length of PVC-U gutter goes from a temperature of 0°C (say on a clear night) to 60°C in bright sunshine the overall change in length will be around 24 mm.

Problems may also arise with some cladding systems, such as external insulation systems with polymer render. The render skin is relatively thin and may buckle in direct sunlight as it heats up. Depending on how it is attached delamination from the insulation backing could also occur. The use of lighter coloured materials would reduce the extent of thermal movements and any problems resulting from them.

Having identified the issues raised by insurers and lenders and considered innovative construction and the effects of climate change, designers should address the implications in the building design. The following sections give examples where design could influence the performance of the dwelling in resisting the effects of perils so that repair and replacement costs are minimised. The suggestions are not intended to be an exhaustive list but a set of practical and realistic examples of what could be achieved.

2 Fire

2.1 Introduction

Fire damage represents the second most costly peril for insurance companies. In 2005 there were a total of 47 100 accidental fires in dwellings which resulted in 287 deaths and 9700 non-fatal injuries.[6] Fires result in a great deal of damage to the fabric of dwellings which can be costly to repair. However, these costs are increased by:

- Further damage from the water used to extinguish the fire.
- Smoke that can contaminate the fabric of the dwellings and the occupants' possessions.
- The costs of accommodating the occupants while the repair work is carried out.

In the UK all buildings have to comply with the fire regulations as set out in national standards (Approved Document B for England and Wales,[7] Section 2 of the Scottish Building Standards Agency domestic technical handbook[8] and Part E of the Building Regulations for Northern Ireland [can be downloaded from www.opsi.gov.uk]).

The risk of external fire spread is limited through regulatory controls on the materials used to form the external walls. The requirement is dependent on the height, use and position of the building relative to other properties. Performance is generally assessed against national test standards (principally BS 476 Parts 6 and 7)[9, 10] from which the appropriate classification is derived. However, harmonised European test standards such as BS EN 13823[11] are now being used as an alternative in conjunction with the relevant classification standard (BS EN 13501).[12] For external walls, an alternative to complying with the guidance based on the results of small scale tests is to carry out a large scale test such as that detailed in BS 8414.[13]

Some materials such as concrete, fired clay, ceramics, metals, plaster and masonry (without any organic additives) are classified as non-combustible because of their known performance. Other materials which may not be resistant to fire can be combined or treated to create systems that satisfy the fire regulations. Such systems usually require testing. One example would be timber products subject to a fire retardant treatment.

To limit internal fire spread and maintain compartmentation between occupancies it is necessary both to limit the heat release rate of the materials used to form the internal linings (in a similar manner to the discussion on external fire spread above) and to ensure overall stability for a period sufficient to ensure the safety of building occupants and the Fire Service. Stability and compartmentation are assessed against the relevant provisions of the national resistance to fire standards (BS 476 Parts 20, 21 and 22)[14] or the European equivalent harmonised standards (BS EN 1363,[15] 1364[16] and 1365).[17] This requires load bearing and separating elements (walls and floors) to be assessed against the criteria for load bearing capacity, integrity and insulation. The required period of fire resistance is specified in Approved Document B and is dependent on the height and use of the building.

2.2 Future changes

Changes to Part L of the Building Regulations mean that more insulation will be required in buildings. Improved thermal insulation may involve an increasing use of materials where the products of combustion have a high toxic yield. Additionally low density thermal insulation may disappear early in the development of a fire leading to the creation of voids within floors and walls which may allow rapid fire spread.

2.3 Potential issues concerning innovative construction

Some innovative construction systems (eg light gauge steel frame construction) rely upon the internal lining material to provide protection for the structural frame. A number of variables affect the performance of the lining material in this respect. They are:

- The performance in fire of the board.
- The number and type of fixings employed.
- The continuity of the board.

Alteration works, following occupation of the dwelling, may be undertaken by operatives (or the owners themselves) which may compromise the fire protection of the frame. The original design could anticipate future alterations (such as removal of an internal wall, or creation of an opening into a new extension) and make those alterations possible without the need to interfere with the fire protection of the structure.

A concern of insurers, as far as innovative structures is concerned, is the potential for creating voids within the construction that would allow easy and rapid spread of fire. There are two main elements of a structure within which this is possible: the floors and walls.

2.3.1 Floors

In floor constructions with solid timber joists the floor void is subdivided by the joists into a number of relatively small compartments which are only connected by notches and holes created for service runs, restricting (but not totally preventing) the spread of fire. Innovative joist systems such as metal web joists effectively create an open structure which would allow easy passage of fire within the floor void (Figure 5).

Figure 5 Metal web joists.

2.3.2 Walls

Volumetric construction comprises a number of three dimensional units which are stacked together on site. Each unit is manufactured with three or four walls, a ceiling and a floor, and when they are stacked on site there are inevitably voids created between adjacent units, both vertically and horizontally. The cavities created can be fire-stopped in the normal way but there is potential for spread of fire that is not present in more conventional construction, for example internal walls within a single dwelling may contain a cavity which could connect with a ceiling void.

Also, volumetric units are protected from the weather during transit. Such protection, which is usually a polymeric sheet material, often remains in situ once the units are assembled into the building. Such materials may increase the intensity of a fire within the cavity or lead to the generation of higher levels of toxic fumes in a fire situation.

2.4 Potential impact of climate change

Hotter, drier summers coupled with the possibility of more frequent lightning strikes, are likely to mean an increase in the risk of field and forest fires and it would be wise to have a suitable fire break between these and housing estates. The action required to minimise the risk of fire damage is to ensure there is a gap between the whole estate and the surrounding countryside. For example, communal space could be placed between dwellings and areas of dense vegetation.

2.5 Design and specification issues

There may be little that designers can do about the cause of fires in dwellings but they are able to specify materials and details which could resist spread of fire in the first place (especially in cavities and services) and allow a faster repair to be achieved after a fire, particularly where smoke has caused most damage. Easy-to-clean surfaces and coatings allow contamination to be removed. Impermeable coatings can restrict the passage of smoke and hence reduce residual odours.

The majority of fires in houses start in the kitchen or the bedroom. The requirement for early warning systems such as smoke detectors can save lives but it should also be an objective of the design to minimise damage to the fabric of the building in the event of fire. The properties of materials chosen to construct the dwelling should be considered carefully – however, it should also be borne in mind that a material good at minimising damage from one peril (such as fire) may not be the best one to minimise damage due to another peril. For example from the perspective of fire spread, insulation materials used in the fabric adjacent to the kitchen should be non-combustible. That may suggest mineral wool as an appropriate material. However, if the dwelling is built in an area that is prone to flooding, a closed-cell foam may perform better than mineral wool because the foam cannot absorb water and therefore may not need to be replaced after a flood event. In order to choose the optimum combination of materials a risk analysis may need to be undertaken.

DESIGN AND SPECIFICATION TIPS

Open plan room configurations and open staircases may be preferred by potential occupiers but such design features may be inherently more dangerous and lead to more damage to property because fire can spread more readily through open areas than between individual rooms.

There are other improvements that can be made. For example when PVC-U windows frames are specified then fire resisting stopping systems should be installed around the window frame to prevent hot gases entering the cavity. Gaps around services could be filled with an intumescent seal to reduce the possibility of fire entering a void.

Roof structures are becoming increasingly lightweight, eg by greater use of slender timber trusses or light gauge steel. In domestic situations these may not be well protected from fire. Fire spread to the roof externally from an upstairs window can enter the roof space via soffit vents. Placing these vents on the fascia or using tile vents further up the roof pitch, or better still using a vapour permeable underlay (VPU), could delay spread of fire and provide more time for the fire to be controlled resulting in less damage.

DESIGN AND SPECIFICATION TIPS continued

Anticipate future alterations to the building

In some forms of construction (eg timber frame or light gauge steel frame) the internal lining provides essential fire protection for the structure. Some alterations (such as changing the internal layout or building an extension) may expose the underlying structure. When the works are 'made good' the lining material and fixing regime may not offer the same level of fire protection. Where future alterations may compromise the fire protection of a structure try to take account of them in the original design. This may not be practical for some combinations of built form and construction method and the advice of a structural engineer should be sought at the design stage.

If the eventual occupier of the dwelling may install services (such as external lighting, waste pipes for domestic appliances or external water taps), that would involve penetrating the fire protection of the external wall, these services could be provided in the original design with proper intumescent fire sealing for any that penetrate the compartment walls.

Avoid creating voids in the structure

The creation of large voids within the structure should be avoided. If they cannot be avoided specify that the void is easily filled with a non-combustible material such as mineral wool or fibre glass insulation.

Consider the fire resistance of materials used in transportation and in the final structure

Consider the fire implications of materials (such as weather protection for transportation of volumetric units) that will be built into the final structure.

3 Water leaks

3.1 Introduction

Water leaks are commonly caused by a burst external water pipe or the failure of an internal fitting in an appliance such as a dishwasher. Overflowing or fractured water tanks can also be a source of water leaks.

The damage resulting from a failed fitting in a domestic appliance is usually relatively minor if the leak is identified quickly. Although such appliances are often isolated from the water main by small valves they are often not closed after each use. A burst water pipe can cause much more damage as it may not be readily apparent where the water is coming from and relatively large volumes can be involved.

Pipework is traditionally made from copper which can be joined by a range of methods, usually capillary soldered or 'compression' fittings, however push-fit and press-fit fittings are being increasingly used. Most new domestic plumbing is now plastic which is joined by either compression type or push-fit fittings for water supply pipes. Most push-fit fittings can be removed and re-fitted with purpose-designed tools, which makes servicing, alteration and repair straightforward.

Push-fit and press-fit fittings rely on the compression of a neoprene gasket to form a seal – a little care is needed in the preparation of the end of the pipe to avoid damaging the neoprene gasket on assembly but good quality fittings appear to be reliable. An insurance company and a number of builders have reported some issues with the joints failing in plastic plumbing systems.

3.2 Future changes

Water shortages may prompt changes to domestic plumbing. In particular more recycling of water is likely in areas of shortage such as the south east of England and in response to the increasing use of water meters, where the consumer pays for what they use rather than a 'flat rate'. Additional pipework and storage could be installed to collect and supply rainwater for uses that do not require potable water (dishwashers, clothes washing machines, flushing toilets) also, more dwellings are now installing solar hot water panels, but all this will increase the complexity and extent of domestic pipework, and hence the probability of leaks. If householders rely on the recycled water or rainwater for a particular application the facility will need to be provided to top the tanks up with mains water for situations when the storage tank does not have adequate supply – this may further increase the amount of pipework needed and hence the risk of leaks.

Such systems may be designed and installed by the occupier and may be less robust than commercially produced systems, so increasing the likelihood of leaks. The storage facilities are more likely to be outside the main dwelling envelope, increasing the likelihood of pipes bursting due to freezing. If such facilities were designed and installed at the time of construction then inappropriate or inadequate works by unskilled persons would be avoided, reducing the risk of leaks.

Increasing levels of energy efficiency mean that levels of loft insulation continue to rise. As a result, temperatures in loft spaces will drop, increasing the risk of frozen and burst pipes. Accordingly designs should avoid installing water-bearing pipes in such spaces or ensure they are fully protected from frost.

3.3 Potential issues concerning innovative construction

The main questions for insurers are:

1. Can water from leaks collect in concealed voids and spaces within the structure?
2. Would novel materials suffer irreversible damage if wetted?
3. Would the way the structure is put together increase the risk of water being directed to neighbours' properties?
4. Are repair costs likely to be substantially higher for innovative constructions (eg because of the need to buy specialist materials or components to effect proper repair, or because specialist trades are needed)?

Figure 6 Weather protection on volumetric units.

Volumetric units are fully protected from the weather for transportation purposes. The weather protection is not necessarily removed as the units are stacked together as Figure 6 illustrates and this may be convenient during the construction phase. Whether or not this is a good thing after completion will depend on the detailed design/construction. There is scope for substantial amounts of water to collect on the top of an individual unit – however, it will not necessarily find its way inside the unit since it may discharge over the side and run between units to ground level. Thus the leak may go unnoticed for a considerable length of time. However, having by-passed the unit immediately below, on medium or high rise constructions it may be directed inside a unit lower down via a cavity fire stop or other barrier, thus making it difficult to pinpoint the location of the leak and mitigate losses.

Access to services for ease of repair and maintenance can be another problem with both manufactured and conventionally built housing. If using pods (non-structural volumetric units such as shower or bathroom units built into the structure) then access for repair and maintenance should be carefully considered at the design stage.

3.4 Potential impact of climate change

There are no specific climate change related issues connected with leakage from water pipes. However, there may be an increased use of air conditioning equipment requiring proper discharge of the condensate and increases in humidity may lead to condensation on cold surfaces (eg metal water pipes) which may go unnoticed.

DESIGN AND SPECIFICATION TIPS

Design the plumbing for built-in appliances to allow easy shut off

When shut-off valves are provided beneath a work surface ensure that they are easily accessible (eg in an adjacent cupboard) and do not require the machine to be pulled forward in order to access the valves.

For factory-fitted plumbing specify a pressure test in the factory before dispatch

Once the factory made unit is built into a structure it may be difficult to access certain parts of the plumbing unless thought has been given to maintenance and repair at the design stage. Specifying a pressure test before dispatch to site will reduce the likelihood of a leak developing.

Create access points for maintenance of services

Where possible put services in an accessible space for maintenance (Figure 7). In flats service risers accessible from outside the units (eg in a communal corridor) are a good idea. If a leak occurs while the dwelling is unattended or unoccupied the water can be turned off without the need to gain access.

Minimise the impact of leaks

The designer can help to minimise the effect of water leaks by adopting the following points:

- The design of rooms that are expected to accommodate domestic appliances connected to the water main could include finishes such as tiled floor coverings to resist short-term damage from exposure to water avoiding the need for replacement.
- It should be possible to turn off the water supply to individual flats and houses from inside and outside the property.

Figure 7 Accessible service riser.

- Where possible do not locate water service pipes near to electrical fittings.
- At the design stage consider where leaks are most likely to occur and select appropriate materials that will be resistant to damage and provide adequate ease of access for quick repair.
- Consider the potential impact of leaks on adjacent dwellings.
- Consider the specification of equipment that monitors flow rates and can be programmed to switch off the supply when unusually long flow periods are detected.

4 Storm (wind and rain)

4.1 Introduction

Storm damage occurs mainly to roofs and is associated with a combination of high wind speeds and heavy rainfall. Occasionally heavy precipitation is in the form of hailstones.

Wind storms are a frequent feature of UK weather: most pass over unnoticed and do not give rise to claims against the insurance industry. However, occasionally an event occurs that results in loss of life and causes catastrophic damage. Between 1990 and 2000, weather-related insurance claims in the UK ranged between £360 m and £2.1 bn per year.

Typical storm damage is breakage or removal of roof tiles and slates or, in exceptional circumstances, the removal of an entire roof (Figure 8). Gable walls can also suffer damage due to suction forces (Figure 9). In general tiles located at the eaves, verge and hip are most at risk because the wind uplift forces are greatest at those locations. Because of that those areas of the roof require more fixings than other areas. Wind uplift on the whole roof is greater the lower the pitch (flat roofs being most at risk). As the pitch increases suction forces reduce, reaching zero at a pitch of around 30° – above that, wind exerts a downward force on the roof. However, even at higher pitches the edges of the roof are still at risk.

Figure 8 Wind damage to a roof.

Figure 9 Wind damage to a gable wall.

Older roof structures that require recovering may not have the load bearing capacity to support some tile systems and lighter weight products have been developed for such situations. Extreme weather in the form of prolonged periods of rainfall has led to some lighter weight tiles becoming unexpectedly heavier due to water absorption. In extreme cases this has caused the roof structure to collapse.

Storms can lead to rain penetration through external masonry walls. Walls without cavities are most at risk but cavities can allow water to track across to the inner leaf if the workmanship is poor (eg due to mortar adhering to wall ties or the presence of debris in the cavity).

4.2 Potential issues concerning innovative construction

Wind uplift of roofs in conventional construction is countered by a) the self-weight of the roof and/or b) tying the roof down to the upper 1 m of walls using straps. With innovative constructions both roof covering and walls can be lighter in weight. Lightweight coverings and cladding (eg tiles of thin profiled metal (Figure 10) and brick slip systems (Figure 11)) and lighter structural walls (such as light gauge galvanised steel) will make the total mass of the building much less than the equivalent built with clay tiles and masonry construction.

Figure 10 Modern lightweight roof covering made from profiled metal sheet.

Some innovative forms of construction also differ from conventional masonry in that they can resist tensile forces better. While this has certain advantages it means that loads can be transferred to lower parts of the building when high loads are being applied to the roof. After a severe storm event a masonry structure may show some cracking internally, immediately below the fixing point for the holding down straps, but damage to lightweight structures may not be visible to the loss adjuster because it could occur at junctions between units which may be hidden from view. Design codes allow for this type of loading but the importance of proper design and installation of the fixings should be emphasised.

Figure 11 Modern cladding systems can be much lighter than a 100 mm brick outer leaf.

High wind speeds also lead to high lateral forces on structures. Innovative constructions can be designed to withstand this loading situation with the inclusion of appropriate bracing but, as with wind uplift on the roof, any damage resulting from inadequate bracing may be difficult to see (Figure 12). Another factor to be considered at the design stage is how bracing may impact on the ability to make future alterations to the building. In the domestic sector, occupants of dwellings have an expectation that the dwelling can be altered or extended to cater for their changing needs.

Figure 12 Bracing in light gauge steel frame construction.

There is a danger that, during such future works, builders may remove or alter lateral bracing thus making the structure less able to accommodate lateral forces. The design should anticipate where future extensions/alterations may occur, and features such as lateral bracing could be designed accordingly.

Some innovative constructions are now being designed to be relocatable. Where this is the intention then the structure should be designed to withstand the highest wind loading at either the original site or the proposed future site. If the future site is not known then the most onerous conditions possible should be assumed.

4.3 Potential impact of climate change

Increases in winter rainfall and wind speeds are predicted and severe storms may occur more often which will clearly exacerbate the issues discussed in sections 4.1 and 4.2. Higher levels of rainfall could also lead to more frequent and more severe flooding events – see section 5 for more detail.

If wind speeds increase and high winds become more frequent current design codes may need revising to account for the larger suction forces that will result, eg by increasing the number and size of fixings for roof tiles. This may in turn have implications for the size of tiling battens and their fixings.

4.4 Design and specification issues

The following paragraphs discuss detailed design issues. An ABI report *The vulnerability of UK property to windstorm damage*[18] made the following conclusions relevant to new build housing:

- The British Standard wind loading codes of practice used in building design have more than doubled the design wind loads on some types of buildings since they were first introduced. In some parts of the UK, notably London, the south east and east of England, and Northern Ireland they have increased by a factor of more than three.
- The UKCIP 2002 report Climate change scenarios for the United Kingdom: The UKCIP02 briefing report[19] suggests that the largest increases in average wind speed in both winter and summer seasons will be along the south coast of England. The north of the UK is likely to experience storms within natural variability boundaries.
- As a consequence, design codes for buildings in the south east of England may need to be upgraded by at least 10%.
- Much of the wind damage that occurs to house roofs could be avoided by a better understanding of wind effects by the designer and appropriate attention to construction detail.
- Holding down straps are not required under Building Regulations Approved Document A (Structure)[20] for tiled and slated pitched roofs with a pitch of more than 15°. However, in the light of recent damage during high winds it may be prudent to specify holding down straps for pitched roofs where the pitch is less than 30°. Other changes may be needed for vertical claddings, the spacing of masonry wall ties and bracing of gable walls to roof structures.

The effectiveness of cavity walls in protecting buildings from water penetration due to heavy rainfall during storms should not be underestimated. Most new houses built by traditional methods include a cavity in the wall construction and either a rainscreen or cavity should be retained in future methods of construction. A number of single leaf masonry systems are being promoted as a way of increasing efficiency on site. Such systems will require good detailing and good workmanship on site if problems with rain penetration are to be avoided.

DESIGN AND SPECIFICATION TIPS

Check adequacy of structural fixings to tiles and claddings

BRE Digest 499[21] discusses the implications of climate change on the design of roofs, and BS 5534[22] provides details for how to calculate the mechanical fixing requirements for a roof. Digest 499 recommends that for pitched roofs the basic wind speed used in BS 5534 calculations should be increased by 10% to take account of the possible impacts of climate change.

The calculations detailed in BS 5534 are complex. As an aid to those without the resources to carry them out a simplified methodology has been produced (*Roof tile fixing specification: The zonal method user's guide*)[23] which allows the user to select a fixing specification based upon attributes such as type of tile, altitude of the site, location (to determine the wind speed zone), height of the building, pitch of the roof, the headlap requirement and whether or not counter battens are used. In order to account for climate change a higher wind speed zone could be used for all roofs (except those in north west Scotland) which would have the effect of over designing roofs in southern England.

Another way of allowing for more severe conditions would be to use larger diameter fixings, with a higher pull-out strength, than currently required under BS 5534 – this approach assumes that the tiles themselves can withstand the additional forces.

In flat roof construction the number and frequency of mechanical fixings should be increased.

Consider increasing minimum roof pitch for different types of covering

There is a relationship between the pitch of the roof and the overlap of different coverings: tile, slate, metal sheet, etc, and this must ensure wind driven rain does not penetrate the overlap. Designers specify roofs at pitches as low as 17.5° using interlocking slates for single storey low rise dwellings: these can perform successfully as long as the correct overlap is used but problems may arise when incorporating roof windows because some flashings may be at a lower pitch and even have a backfall. Roof designers should consider designing roofs to a pitch greater than the minimum as stated in BS 5534 for each type of slate or tile.

Improve design details for protecting walls from rain

Extending the roof overhang at the eaves can help to protect the supporting wall from the combined effects of wind and rain. This, though, may increase the forces on the roof in high winds, so it is important to ensure that adequate restraint (such as holding down straps) is specified.

The type of finish applied to mortar joints in masonry walling can influence the weather tightness. The best performance is achieved from ironed ('bucket handle') joints whereby the action of 'ironing' the joint with a convex tool compresses the surface of the mortar to leave a concave surface finish (Figure 13). Other finishes should be reserved for more sheltered locations.

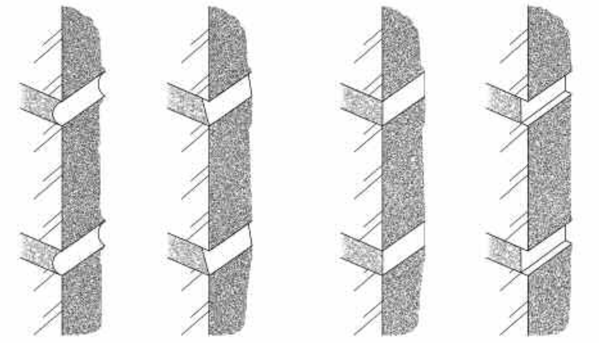

Figure 13 Types of mortar joint: 'bucket handle' joints are best for durability and weathertightness.

Walls in severe exposure areas can be protected by render or rain screen cladding systems. Avoid fully filling cavities with insulation in cavity masonry construction in very severely exposed areas.

Recessing windows in a check reveal can reduce the incidence of leakage on window-to-wall joints, and sub-sills with stooling (ie a raised portion to prevent water flowing into the building) can improve rain penetration problems at sill level. Sub-sills should also have a projecting weather drip – flush sills should be avoided (Figures 14 and 15). Cavity trays over openings should have stopped ends and adequate provision (eg weep holes) made to discharge rainwater to the outside.

Figure 14 Sub-sills should project forward of the masonry to shed water away from the structure – flush sills as shown above should be avoided.

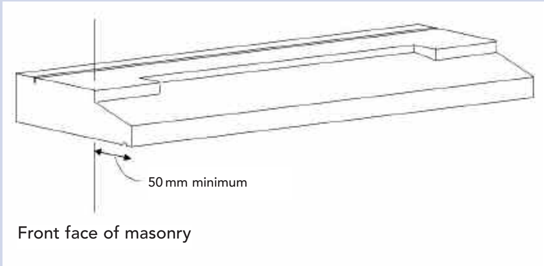

Figure 15 Stooled sub-sills encourage water to discharge from the front of the sill.

Consider using a higher driving rain index

The driving rain index map in BRE Report 466 *Understanding dampness*[24] shows a number of different zones (Figure 16). It would be possible to consider only the contour at 56.5 L/m^2 which results in the UK being split into the North West and the South East. This would reduce the UK to two zones which could be considered to be moderate (below 56.5 L/m^2) and severe (above 56.5 L/m^2). This approach has been adopted by one roof slate manufacturer.

This wind driven rain index applies to slates and capillary action. For tiles there is a CEN approach which is currently under development. It proposes various levels of test parameters based on wind and rain for a number of exposure zones. Proposed constructions are tested at the appropriate level of wind and rain for the given climatic zone.

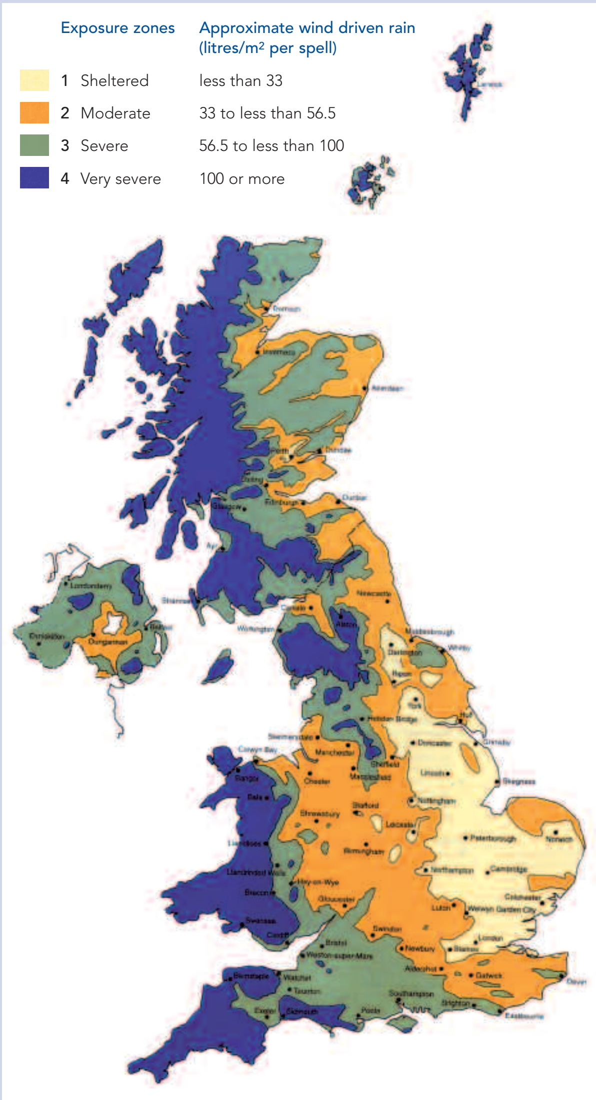

Figure 16 Distribution of wind driven rain across the UK.

Increase size of rainwater goods

The size of gutters is determined according to BS EN 12056-3: 2000[25] by calculating the amount of rainwater falling on a roof as a volume in a certain time. The gutter size to handle this volume of water is determined together with the number and size of down pipes required to empty the gutter. If rainfall increases as a result of climate change, either the amount of rainfall could be assumed to increase or the design capacity of rainwater goods could be increased by, say, 10% to take account of this, although a much greater increase in the size of rainwater goods may be needed if the intensity of individual rain events becomes very high.

DESIGN AND SPECIFICATION TIPS continued

Review detailing at eaves and ridge

The edges of roofs (such as eaves and ridges) are susceptible to high wind loads and therefore more likely to suffer damage. Traditional fixing methods such as bedding tiles and slates on mortar can deteriorate over time and if verge tiles overhang the barge board significantly it may not be possible to fix each tile with more than one nail. An alternative and more robust approach is to use purpose-designed 'dry-fix' mechanical methods of fixing at verges, hips and ridges (Figure 17).

Figure 17 'Dry' verge and ridge systems can reduce the risk of wind damage in those locations.

5 Flood

5.1 Introduction

Flooding has been a risk for houses in some parts of the UK for many years. Many coastal areas have sea defence systems – eg the Thames Barrier which has been protecting London for many years. The local effects of flooding can be devastating and when they occur can affect whole communities. The cost of repairing a flood damaged home is typically in the order of £30 000.

Floods are usually due to exceptional weather conditions and occur relatively infrequently. In recent years, however, flooding has increased in some areas partly due to unusual weather patterns such as sustained periods, or more intense bursts, of rainfall but other factors have also come into play. Water extraction patterns from rivers has changed – in some cases water extracted for industrial purposes has reduced because of a decline in some industries, although more water may now be extracted for drinking. As built-up areas grow in size, water runoff from buildings and impermeable paving means that the infrastructure to dispose of it can become overloaded making flash flooding more likely.

The damage caused by flooding normally affects buildings and their contents at basement and ground level. The amount of damage caused depends on the level that the water reaches within the property. It may be possible for homeowners to take steps to minimise damage to property, but only if there is sufficient warning to give homeowners time to respond.

Floodwater is not clean and often contains silt/sewage. Not only does the affected property need repairs to the fabric, but it will also need thorough cleaning afterwards. The drying out period can be very long, and contributes to one of the main costs of insurance claims which is temporary accommodation for the occupants.

5.2 Future changes

Land required for housing is at a premium, especially in already highly populated areas. The demand for land means that there is pressure to situate houses on land where there is a greater risk of flooding occurring. Government policy is promoting sustainable development in so-called 'growth areas' including the south east of England (London, Stansted, Cambridge and Peterborough), Milton Keynes and the south Midlands, and the Thames gateway. Many growth areas are in low-lying areas that may have an above average risk of flooding.

5.3 Potential issues concerning innovative construction

As for other perils the issues for innovative constructions are:

- Can water collect in voids and spaces within the structure that are hidden from view?
- Would novel materials suffer irreversible damage if wetted by water?
- Are repair costs likely to be substantially higher for innovative constructions (eg because of the need to buy specialist materials and/or components to effect proper repair, or because specialist trades are needed)?
- Can new materials be decontaminated?
- Could very airtight structures (particularly lightweight constructions) be buoyant in a flood, leading to damage at the points where they are fixed to foundations?

5.4 Potential impact of climate change

The UKCIP02 scenarios indicate that there will be hotter drier summers and milder but wetter winters. It is anticipated that the intensity of rainfall will increase ie a larger volume of water in a shorter period. This will mean a heavier loading of water into rivers increasing the risk of banks bursting.

Figure 18 Flooding in the UK – an increasing problem.

The height and range of tides may change, leading to flooding during particularly high tides. Coastal regions of low-lying land protected by sea walls and other defences will be at increased risk of flooding if sea levels rise. Decontamination of seawater is more difficult than river water because of the salt content.

5.5 Design and specification issues

A recent Department of Communities and Local Government (DCLG) report[26] of a project co-ordinated by Construction Industry Research and Information Association (CIRIA) lists four basic approaches that can be adopted when designing in situations where there is a risk of flooding. They are:

- **Flood avoidance:** Constructing a building and its immediate surroundings (eg approaches) in such a way to avoid it being flooded (eg by raising it above flood level, re-siting outside floodplain etc.).
- **Flood resistance:** Constructing a building in such a way to prevent floodwater entering the building and damaging its fabric.
- **Flood resilience:** Constructing a building in such a way that although floodwater may enter the building its impact is reduced (ie no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).

- **Flood repairable:** Constructing a building in such a way that although floodwater enters a building, elements that are damaged by floodwater can be easily repaired or replaced. This is also a form of flood resilience.

The most appropriate approach to take will depend on a number of factors (ie the likely depth, frequency and duration of flood) which would normally be known from a flood risk assessment. The DCLG report[26] has developed a number of design strategies based on various values for these parameters (in particular the depth of flood) with detailed recommendations on mitigation measures to be adopted for each approach.

From the perspective of this guide the assumption will be that water will enter the building. The focus is therefore on minimising any resulting damage, ie how to design for a flood resilient or a flood resistant construction. The cost of repairing a flood resilient dwelling can be significantly lower than that for a standard dwelling – under £10 000 per household. Also, as damage is on a lesser scale, families can return home more quickly and there is less disruption to family life.

DESIGN AND SPECIFICATION TIPS

Undertake a flood risk assessment

The first step in designing any development in a flood-prone area is to undertake a risk assessment. Local and regional planning bodies will have undertaken appropriate risk assessments at local and regional levels which should inform your own risk assessment. However, as PPS 25 points out: "Landowners have the primary responsibility for safeguarding their land and other property against natural hazards such as flooding."[27]

Do not build single storey buildings in flood prone areas

In the event of a rapid flood, the occupants' only safe refuge may be the first floor of their own home. Single storey dwellings would not provide a safe refuge in such circumstances. If the flood were to occur while the occupants were asleep they may become trapped before they realise what is happening.

Consider building on raised plots

Constructing the dwelling on a raised plot will give occupants a little time to put in place any damage limitation plan they may have, eg fitting flood barriers to doors or underfloor ventilation points. The height above the level of the surrounding area that the plot should be will depend on the height of the potential flood source (eg river or sea) and the area of land likely to be flooded. If the property is already above the 'normal' level of the flood source and the area likely to be flooded is large then raising the plot by a modest amount (eg 1 m) may prevent flood damage all together. If, however, the plot is at or below the normal level of the source, and the probable flooded area is small then flooding is likely to be rapid when it occurs and raising the plot by a small amount will be of no, or limited, value.

However, if the plot is raised remember to include provision for safe access to, and an escape route from, the property (there may be conflicts with Part M of the Building Regulations which need to be addressed). Also, do not raise plots if this would increase the risk of flooding in adjacent areas.

Do not attempt to exclude deep floodwater

As the difference in height between water outside and inside the building increases, the fabric experiences an increasing hydrostatic pressure. Ultimately this could lead to structural damage or collapse. If a water exclusion strategy is adopted consult a structural engineer to ensure that the structure can withstand the expected hydrostatic pressure.

Adopt flood resilient/resistant measures

Flood resilient/resistant measures could include:

- Kitchen and bathroom units made of plastic, stainless steel, solid timber or waterproof plywood, rather than chipboard or Medium Density Fibreboard (MDF) with laminate finishes.

DESIGN AND SPECIFICATION TIPS continued

- Skirtings and other trims should be of solid timber or plastic, rather than MDF.
- Modern stair strings often use MDF for risers and treads – specify solid timber or waterproof plywood.
- Use waterproof plywood for flooring rather than chipboard, or design a concrete floor with ceramic tiles (use exterior grade tile adhesive and a waterproof grout).
- Specify a waterproof render and lime plaster skim rather than gypsum plaster internally.
- If only a shallow flood is expected raise domestic appliances off the floor on plinths.
- Internal doors can be hung on rising butt hinges to allow easy removal before a flood and refitting after.
- Fit socket outlets and other electrical points above the expected level of flood. Electrical cables should drop down from ceiling level, preferably in plastic conduits to facilitate easy replacement if necessary.
- Flood guards, which can quickly and easily be erected around doors and may keep out flash floodwater for several hours.
- Toilet bung to be available for placement in the toilet by the occupier if flooding is expected.
- Pump-and-sump systems installed below floorboards to remove water faster than it can enter the house from below ground.
- Installation of one-way valves into drainage pipes to prevent sewage backing up.
- Fit airbricks with removable covers.

6 Ground movement

6.1 Introduction

Subsidence (unlike settlement) is the condition where ground movement occurs without additional load being applied. It can occur where ground support is compromised by activities such as mining or where voids in fill or made ground migrate to the surface or where certain soils dry out and shrink.

Changes in moisture levels can occur in a number of ways. Tree roots extract moisture from the ground and certain soils, such as clay, will shrink as their moisture content is reduced. The extent to which the ground is affected depends on the 'volume change potential' of the soil and the water demand of the tree. If a tree is felled the local clay soil will rehydrate causing it to swell (or 'heave') – it may be many years before the ground moisture content reaches equilibrium, so caution needs to be exercised if building on recently cleared ground. Sustained wet periods cause desiccated clay soils to expand while sustained dry periods can cause saturated clay soils to shrink. Most buildings are not affected by normal seasonal movements but if an extended period of low rainfall is experienced movement (and consequential damage) can occur.

Soft ground is characterised by low shear strength which results in a low bearing capacity. Soft ground is typically found in any area where there is a lot of water, such as estuaries, floodplains, near lakes, in the vicinities of springs and streams or even leaking drains and water supplies. It can be compressible (which can lead to excessive foundation settlement and tilting) and have low permeability which means that the raised water pressures in the soil resulting from foundation loads are likely to take a number of years to dissipate – ie the building may continue to settle for prolonged periods.

There are two basic types of fill:

1. **Engineered fill:** the fill material is selected and compacted in a controlled way to an appropriate specification to give the required engineering behaviour.
2. **Non-engineered fill**: filling has taken place in an uncontrolled way, eg to dispose of waste materials.

It is important to distinguish between these two types of fill because serious problems can arise when building on non-engineered fill. Two things need to be determined: can the fill support the building without excessive or differential settlement? And does the fill contain materials which are hazardous to health or harmful to the environment or buildings? Where settlement or other ground movement is anticipated, raft foundations can protect the structure from damage, but if the movement is not uniform over the plan of the structure then the whole structure (foundation and building) can tilt.

Guidance on foundations for a range of ground types is available in a number of BRE Digests and in Part 4 of the NHBC Standards (see Further reading). Foundation design for soft ground and fill is a specialist field and the services of experienced ground engineer should be obtained.

Subsidence and settlement can manifest themselves as cracking in buildings, but damage can also occur to buried services, particularly where they cross foundations. Problems can range from fracture of rigid pipes to the creation of a backfall as the building settles or as the ground through which the service passes rises due to heave.

In severe cases of ground movement underpinning of walls using a piled raft may be required. The property will need to be vacated and the insurance costs can typically be in excess of £100 000.

Building on unstable land can lead to severe cracking, distortion of concrete rafts and even partial collapse. Partial and total collapse are rare and are likely to be associated with the presence of old mine workings and forgotten tunnels. Natural cavities below ground may also go unnoticed (such as swallow holes and Dene holes in limestone). Coastal erosion can also cause the collapse of buildings built in close proximity to cliffs etc. It is important that the history of the land use is known at the design stage, and on site investigation planned to determine all the potentially adverse ground conditions.

Brick and block construction has been shown to crack due to relatively minor movements. These may be an early warning of more severe movements to come and hence appropriate investigations can be initiated at an early stage. This early detection can allow actions to be taken that could avert more costly repairs later.

6.2 Potential issues concerning innovative construction

Innovative structures can be much lighter than conventional structures so damage in those cases may be lower if foundations designed for masonry have been used. Many innovative constructions are able to withstand tensile forces, and so the manifestation of subsidence may differ from that observed in masonry. Damage may occur that is not visible externally until it is quite extensive.

Unlike masonry construction framed and panellised systems are normally tied down to the foundations – in cases of mild subsidence it is conceivable that in some situations the structure of the building could prevent the foundation dropping. However, many lightweight constructions are still clad with a conventional masonry outerleaf – in those situations there may be significant cracking to the outside of the structure, with relatively little damage showing internally.

There are a number of innovations in foundation design that may affect damage scenarios. Greater use of pile foundations with prefabricated grounds beams may result in lower levels of damage due to subsidence, whether innovative or conventional constructions are used.

6.3 Potential impact of climate change

The prospect of hotter and drier summers and winters with more intense rainfall suggests that ground movements are likely to increase particularly in clay soils.

DESIGN AND SPECIFICATION TIPS

Undertake a thorough land survey

As with all developments, a land survey should be carried out by geologists/geomorphologists with reference to old maps, place and street names. Documents that can be consulted are:

- British Geological Survey.
- Regional guides.
- Memoirs.
- Mining records such as Coal mining reports available on the web.

Increasing use of brownfield sites, where the previous uses of the site may not be well documented, means that greater emphasis should be placed on site investigation than for construction on greenfield sites where there is no previous disturbance or use of the ground. A number of companies specialise in the provision of site-specific information based on historic and current data and can be a very useful source of information. The results of a thorough survey will inform the decision on the most appropriate foundation design/system.

Consider deeper foundations or piles

The design of foundations is determined by the condition of the ground and the expected depth of soil that will be affected by seasonal changes in moisture content. The expected extremes in hotter and drier summers combined with wetter winters means that the depth of soil affected by seasonal changes in moisture is likely to increase. Increasing the depth of trench foundations or the use of piles would be ways of mitigating against future problems.

Design to cope with greater ground movement

The use of compressible materials and void formers should be employed to protect foundations from the effects of heave.

Using flexible pipes and joints can prevent damage to services from ground movement. If drain pipes pass through ground which is expected to exhibit heave then increasing the fall can guard against the development of a backfall which will prevent waste being carried away and increase the likelihood of a blockage developing.

Take advice on the management of trees to reduce desiccation of soils

Pruning, crown thinning and root restriction are all techniques that can have an impact on the amount of water extracted from the ground by growing trees. However, the long-term effectiveness of these strategies is variable, and professional advice should be sought on both the planting of new trees and the management of existing trees.

Use engineered foundations on difficult sites

There are numerous techniques for dealing with difficult site conditions, both in ground remediation and improvement techniques and in foundation design. Deciding the most appropriate strategy for a particular site is complex – getting it wrong can have very expensive consequences. Always take professional advice from a qualified engineer on all but the most straightforward sites.

7 Vandalism and theft

7.1 Introduction

Vandalism or theft occurs relatively frequently but ranks below other perils because of the relatively low insurance costs involved. Conventional constructions and components such as doors and windows are covered adequately by recognised standards (see for example www.securedbydesign.com) but the risks could be lowered further by selecting more robust materials and components in vulnerable areas.

7.2 Potential issues concerning innovative construction

Some innovative constructions and materials can lead to structures which are less robust than more traditional constructions from the perspective of their ability to withstand impact or attempts at forced entry. For example lightweight claddings at ground level may be more prone to damage from having a football repeatedly kicked against them. The cladding may be easy to remove allowing access to a framed construction which has not been designed to withstand forced entry through the structure – one instance has been reported of thieves gaining access through a party wall simply by removing the plasterboard linings.

Renewable technologies can present an attractive target to vandals and thought should be given to how that can be avoided.

7.3 Potential impact of climate change

Longer, hotter summers are likely to lead to an increase in overheating. Secure night-time ventilation that allows cooler air to be drawn through the dwelling is one way that such overheating may be mitigated.

DESIGN AND SPECIFICATION TIPS

Start lightweight claddings at first floor level

Use robust claddings at ground floor level to minimise accidental or deliberate damage (Figure 19). Lighter, less robust claddings should be started at first floor level or above.

Ensure that external walls are secure

When designing the external envelope a structural engineer may not consider security unless they are instructed to do so (Figure 20). Make sure that the design or specification covers security as well as compliance with Building Regulations.

Figure 19 Use robust claddings at ground level.

Figure 20 In addition to lateral bracing for structural stability this steel framed wall is also designed to keep out intruders.

Locate renewable technologies where they are less likely to be vandalised

Renewable technologies such as solar panels look fragile and may attract the attention of vandals. When designing site layouts try to avoid siting renewables in positions where they are visible from points where attempted vandalism may go unnoticed (Figure 21).

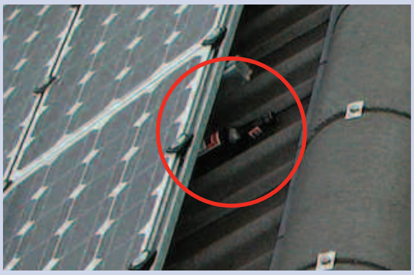

Figure 21 Do not give vandals an attractive target.

Design secure cross-ventilation

Specify windows that can be locked open for secure night time ventilation. Installing louvres above internal doors will facilitate cross ventilation while maintaining privacy for occupants (Figure 22 taken at the Integer House, BRE).

Figure 22 Internal louvres to allow cross ventilation of a dwelling.

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FURTHER READING

Digest 240	Low-rise buildings on shrinkable clay soils Part 1
Digest 241	Low-rise buildings on shrinkable clay soils Part 2
Digest 242	Low-rise buildings on shrinkable clay soils Part 3
Digest 298	Low-rise building foundations: the influence of trees in clay soils
Digest 412	Desiccation in clay soils
Digest 427	Low-rise buildings on fill Parts 1 – 3
Digest 471	Low-rise building foundations on soft ground
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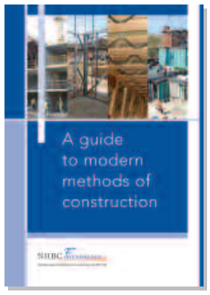
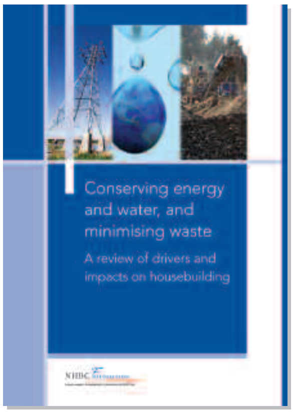
NHBC Foundation publications

A guide to modern methods of construction



This guide provides an accessible introduction to modern methods of construction. It will help developers, house builders, architects, planners and manufacturers to understand the variety of systems available and to appreciate how they can take advantage of the speed of construction and design opportunities they offer.

NF1, December 2006



Conserving energy and water, and minimising waste

A review of drivers and impacts on house building

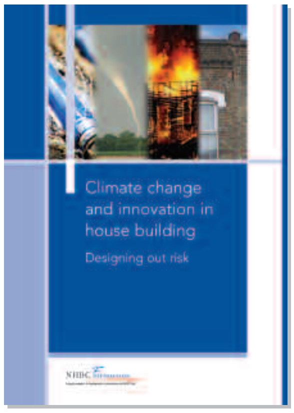
House builders are under pressure to deliver sustainably-designed new housing in a rapidly changing environment, as a result of ongoing legislative changes and other initiatives to combat climate change and conserve natural resources.

This review will help house builders, their advisors and suppliers, and others involved in the provision of new housing to understand the implications of these changes and to plan to take account of them.

NF2, March 2007

Climate change and innovation in house building

Designing out the risk



In the past 50 years, most dwellings in the UK have been built using brick and block or timber frame construction: lenders and insurers are familiar with them and can process applications for loans and insurance cover without undue concern. But recent years have seen the development of modern methods of construction, of which lenders and insurers have little or no experience, and they are uncertain about the level of risk that lending on or insuring such properties carries.

There is another area of dwelling performance – the consequences of climate change – that is not adequately covered by building regulations or design codes.

This review identifies the main areas of concern for lenders and insurers (fire, water leaks, storm, flood, ground movement, vandalism and theft), and focuses on how these concerns can be addressed at the design stage.

NF3, August 2007

NHBC Foundation publications in preparation

- Ground source heat energy: benefits and barriers in residential developments
- Hydraulic lime mortars
- Microgeneration and renewable energy technologies
- Risks in basement construction
- Site waste management plans

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NHBC Foundation
Housing research & development in partnership with BRE Trust

The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the country's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.

NF3
Published by IHS BRE Press on behalf of NHBC Foundation
August 2007
ISBN 978-1-86081-987-2