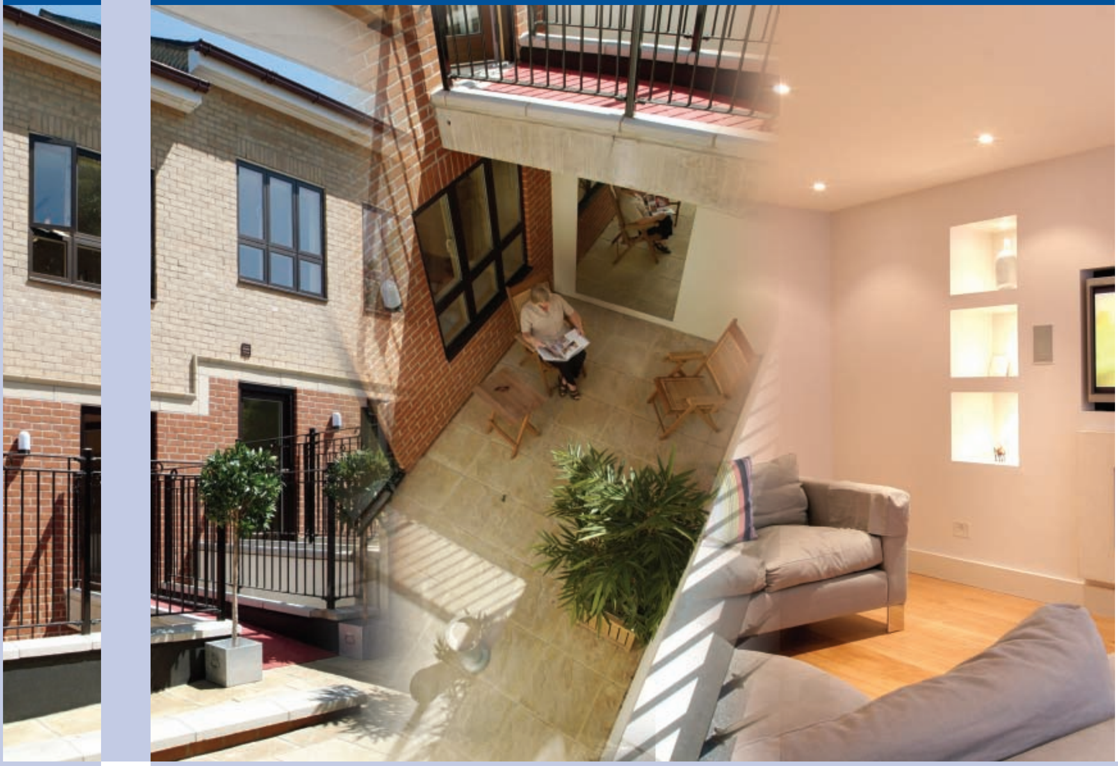

Risks in domestic basement construction

NHBC FOUNDATION

Housing research & development in partnership with BRE Trust

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October 2007

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NF 4
Published by IHS BRE Press on behalf of NHBC Foundation
October 2007
ISBN 978-1-84806-009-8

FOREWORD

As pressure on land and the demand for more family homes continues, particularly since the government outlined new growth targets in the Housing Green Paper in July, house builders are increasingly considering the use of basements to maximise the available living space in new dwellings.

However, the construction of basements does have inherent risks, among them water ingress and load-bearing capacity, and this guide is intended to address issues of risk management in the construction of basements for residential buildings. Primarily the construction of basements requires greater thought and detailing at the site survey and design stages to ensure risks are addressed and designed or managed out. Soil and site conditions are key contributory factors for potential failure and therefore the importance of geotechncial data cannot be underestimated.

One primary advantage of basements is that they offer the potential for meeting density requirements whilst continuing to deliver the living space which consumers are increasingly demanding in family homes. This has the potential to offer increased revenues from higher prices, but this must be weighed up against the increased construction costs and risk factors. In addition to being detailed in this guide, risk factors and design principles are laid out in the accompanying BRE Good Building Guide 72 *Basement construction and waterproofing*, published in two parts.

This guide also looks at the evolution in basement construction methods which has come about as part of the broader adoption in the industry of modern methods of construction, which have been detailed in previous NHBC Foundation research publications.

Masonry and concrete construction are familiar to the industry but basements are increasingly being constructed with sheet or contiguous piles and modular units, technologies which require a different set of skills. This skills issue, alongside training, must not be overlooked. As the use of basements in homes becomes more prevalent, the industry must be certain that site staff have the requisite training and skills to ensure consumers are not left with a product which does not meet their expectations. The detailing in this guide, if followed, should minimise negative impacts on the consumer.

Whilst Building Regulations do not explicitly cover basement construction a new accredited contractor system is being introduced by the Basement Information Centre. Currently the Approved Document *Basements for dwellings*, written by the Centre brings together the requirements from other Approved Documents pertinent to basement construction. It is hoped this new accredited contractor system will bring further clarity to the regulatory framework for basement construction.

Overall the use of basements can provide many benefits beyond increased living space, including improved thermal and sound insulation, technically efficient foundations and the capability to incorporate zero carbon technologies such as ground source heat pumps. In addition there are benefits on the planning front with basements meeting drivers on density and offering greater living space where planning restricts the height of dwellings.

Coming at a time when government, the planning regime and the market are driving an increase in the use of basements I believe this guide is particularly relevant, providing a valuable resource for the industry and opening the debate on how to move forward in this area.

Imtiaz Farookhi

Chief Executive, NHBC

ACKNOWLEDGEMENTS

We would like to express our thanks to the following companies and organisations for supplying photographs for this guide:

Location/page number	Company/organisation
Front cover	The London Basement Company Ltd
3	The Big Basement Company Limited
5	Quad-Lock (England) Limited
Front cover, 6,11,13,19	The Basement Information Centre

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SUMMARY

Including basements in houses increases the floor area and living space, and the value to the owner. Basements can allow higher housing densities, which offers increased value to the developer. However, these increases in value may be accompanied by a need for greater site investigation and more detailed design to minimise the risks in construction and use.

This guide summarises current trends in basement provision, and the regulatory, performance and planning issues that affect basements. Novel techniques for constructing basements, such as sheet piles and modular units, which can speed up construction and provide all the benefits of a basement as increased living space, are outlined together with traditional basement construction techniques. However, the risk associated with basement construction requires increased design assessment, which also needs to take account of construction site skills.

This guide identifies the principal risks involved in the design and construction of basements. It emphasises the need to obtain appropriate geotechnical data and to interpret it rigorously before using it to design and construct suitable waterproofing measures.

1 Introduction

Basements in houses can provide extra living and storage space within the original building footprint or can provide the same overall floor space on a smaller plot. In many circumstances basements are an attractive way of increasing housing density while still providing desirable living space. However, including basements in new developments and refurbishments can increase the construction costs, and this needs to be balanced against the extra value they provide. Basements also pose additional risks because the ground and groundwater conditions need more investigation than foundations for houses without basements. These additional risks need to be identified so they can be mitigated.

This guide identifies the primary risks in basement construction and outlines measures to minimise the risks at all stages of design and construction. To accompany this guide, a two-part BRE Good Building Guide, *Basement construction and waterproofing* (GBG 72), has been published by IHS BRE Press, which provides a concise and accessible guide to the key practical issues relating to design and construction of basements. Part 1 *Basement construction and waterproofing: Site investigation and preparation*[1] is a summary of the principles of constructing a waterproof basement to resist moisture ingress and of the main methods for perimeter construction and safety, insulation and services. Part 2 *Basement construction and waterproofing: Construction, safety, insulation and services*[2] describes the main methods for perimeter construction with advice on safety, insulation and services. Good Building Guide 72 parts 1 and 2 should be read in conjunction with this guide (available from www.ihsbrepress.com).

1.1 Scope

Basements offer an opportunity to increase building value. However, these increases in value come with a need for greater site investigation and more detailed design to minimise the risks in construction and use.

There are industry efforts to put into place a certification/assessment scheme to indicate that basement contractors are competent. Housebuilders may face additional risks in design and construction related to flood resistance, water resistance, ventilation and other factors. This guide identifies these risks and attempts to quantify the measures that may be needed to ensure that the opportunities of maximising floor space by using basements are taken appropriately.

1.2 Benefits of basements

Domestic basement construction can maximise the floor space available in a house or can provide the same overall floor space on a smaller plot. This benefits housebuilders and buyers for whom the increase in space can be a significant advantage, particularly as housing densities continue to increase.

Planners, warranty providers and regulatory bodies generally recognise the benefits of increased unit density with maximised useable space. Additionally, if a basement is to be constructed, a thorough ground investigation is needed, so the ground conditions on the site will be better understood. The development may also benefit from enhanced foundations, thermal insulation and sound insulation.

The greater engineering input into the design and construction of basements means that the engineering risks must be properly assessed and managed. A new accredited contractor system is being introduced by the Basement Information Centre and run by the Specialist Concrete Contractors Ltd (SpecCC) which will help to ensure that appropriate levels of skill and supervision are employed. Shortage of skills can be a problem on sites, so this scheme may also be expected to help address this.

2 Trends in basement construction

Basement construction is undergoing a revival, as rising land costs and housing density drive developers to seek the maximum floor area for the minimum building footprint. Small developments that include basements will generally use traditional construction methods whereas larger developments may adopt novel techniques where the economies of scale can make them economically and environmentally cost effective.

Section 2 outlines the construction techniques currently used, highlights their advantages and disadvantages, and notes possible risks in the construction and use of basements.

2.1 Traditional basement construction

Masonry construction

Masonry construction is the simplest method of basement construction: a concrete floor slab is formed in the base of an excavation, the sides of which are either supported by temporary works or battered back for safe working. The basement floor slab will need to be formed with water barriers linked into the masonry basement walls. Access to the outside of the basement walls during construction also allows an external water barrier to be applied. This method is the most straightforward and permits good access for installing these barriers. Any drainage outside the basement wall can be installed before the excavation is backfilled and before the temporary earth support is removed.

Although water barriers are typically placed external to the structure, which is the NHBC preferred option, internal systems directly applied to the masonry can be acceptable where they are shown to be appropriate by design and site conditions. Internal drained cavity (Type C construction) water-resisting systems can offer the lowest risk.

Masonry construction can be of hollow blocks or of filled cavity (Figure 1). The voids in hollow blocks may offset vertically and require special attention to mix specifications and compaction with a full height pour. Placing and compaction in low lifts eases this aspect but increases the number of laps required with the reinforcement.

Plain masonry offers an alternative construction method but wall thickness will be increased and significantly so where vertical loads on the wall are low. Also particular attention will need to be given to the selection of the water barrier. (The Basement Information Centre is due to release an addendum in late 2007 to the Approved Document – *Basements for dwellings*. Addendum 1: *Plain masonry and plain in-situ concrete retaining walls*.)

Figure 1 Blockwork walls *(courtesy of The Basement Information Centre)*.

Reinforced concrete

Basement walls can be constructed in cast-in-situ reinforced concrete, with water barriers included in the cast-in joints (Figure 2). The outside of the finished wall is accessible for inspection and for the application of a secondary external water barrier and drainage systems.

This form of construction will generally be reinforced but plain wall design may also be possible. However, in the latter case some reinforcement may be required particularly horizontally to control cracking.

Figure 2 Cast-in-situ reinforced concrete.

Concrete construction usually includes the water resistance in the structure (referred to as Type B construction) where the concrete contributes to the overall water resistance. Subject to the risk severity of the site, the concrete wall may need an additional water resisting membrane. Admixtures may also be added to the concrete to enhance its water resistance.

This form of construction is traditionally used with removable formwork but can also be constructed with permanent formwork systems such as insulating concrete formwork. This is an innovative modern method of construction, which typically consists of permanent polystyrene to replace the temporary formwork or moulds used traditionally. The central core is filled with in-situ concrete, which carries the vertical or lateral loads (soil loads in the case of basements) acting on the wall.

This form of construction can use tanking (Type A construction) or Type B construction with respect to achieving water resistance. Type B construction will require particular care in the selection of the mix and compaction, and attention to day-work joints and joints between floor and wall in order to provide adequate the appropriate level of water resistance from the inner concrete wall. Where such controlled measures cannot be relied upon then tanking water resistance (Type A) construction should be assumed. Any water barriers or membranes used with insulating concrete formwork should be water based, as bitumen membranes can attack polystyrene or other materials used in insulation.

Cast-in-situ reinforced concrete

Basement walls and foundations can be formed directly into the ground before the basement is excavated (Figure 3). A deep trench fill or contiguous piled wall foundation is constructed below the intended level of the basement floor. Reinforcement is placed in the foundation, which acts as the foundation both to the building and to the basement wall supporting the ground around the building. The soil in the basement can then be excavated without the need to support the surrounding ground. The main difficulty with this method is installing a water barrier in the foundation and connecting it to the basement floor slab so that it is completely waterproof. This difficulty can be overcome by building a secondary wall against the inside wall of the basement, which will include a water barrier, drainage and extra insulation.

Figure 3 Contiguous piles with ground anchors *(courtesy Roger Bullivant Ltd)*.

2.2 Novel construction techniques

Precast reinforced concrete modular units

Reinforced precast concrete modular units can be made in a factory and connected together onsite to form the basement structure (Figure 4). Precast sections can be supplied ready to be placed on a precast floor slab and jointed together to form an integral box on which the rest of the dwelling can be constructed. The advantages of this type of system are that construction onsite is rapid and that integral water barriers can be incorporated into the joints and the concrete modular section. A variation on this is a complete precast basement floor, wall and ceiling unit that is placed directly onto a prepared base in the excavation. Precast units need to have a high quality prepared base so that the water resistant systems properly link and there is no differential movement between the unit during construction and use that will damage the water barrier.

Figure 4 Precast insulated concrete panels.

Figure 5 Steel panels *(courtesy of the Steel Construction Institute)*.

Steel sheet piling

Steel sheet pile walls are often installed as temporary works to support an excavation in which a basement structure is to be built (Figure 5). However, the sheet pile wall can also be used as a permanent basement wall and foundation with water barriers built into the clutches (sliding joints between each sheet pile) or with welded clutches. The integrity of the basement floor slab and sheet pile water barrier will need careful design and an inner wall including insulation. A ring beam can be cast at the top of the sheet pile wall to provide a base for the superstructure. With modern push-in sheet pile installation methods the noise and vibration traditionally associated with sheet pile installation are significantly reduced.

This form of construction is not likely to be economic for small developments, but may be suitable for developments where the basements form a large area, such as flats.

Contiguous piling

Contiguous bored piles are those drilled, reinforced and cast very close together which forms a perimeter wall to the basement. These piles are installed and followed by the excavation to form the basement. The piles both support the ground laterally and can be used as a foundation to support the building. The resulting internal wall will be rough and so an internal panel wall will be required and a drained cavity (Type C) construction. This method of construction is usually used for deep basements and large structures but could be applicable for other situations.

Contiguous bored pile walls are commonly confined to ground conditions where naturally dry soil exists. The piles are installed as close together as possible to form the perimeter wall before any excavation takes place. The accuracy of the pile placement depends on the type of pile and the method of placing. Figure 6 shows cast-in-situ piles used in this way. The advantages are similar to diaphragm walling, with the exception of water tightness. More efforts are required to provide an acceptable face finish to the walls. In cost terms, they are likely to be similar to diaphragm walls. Figure 7 illustrates contiguous piles after excavation.

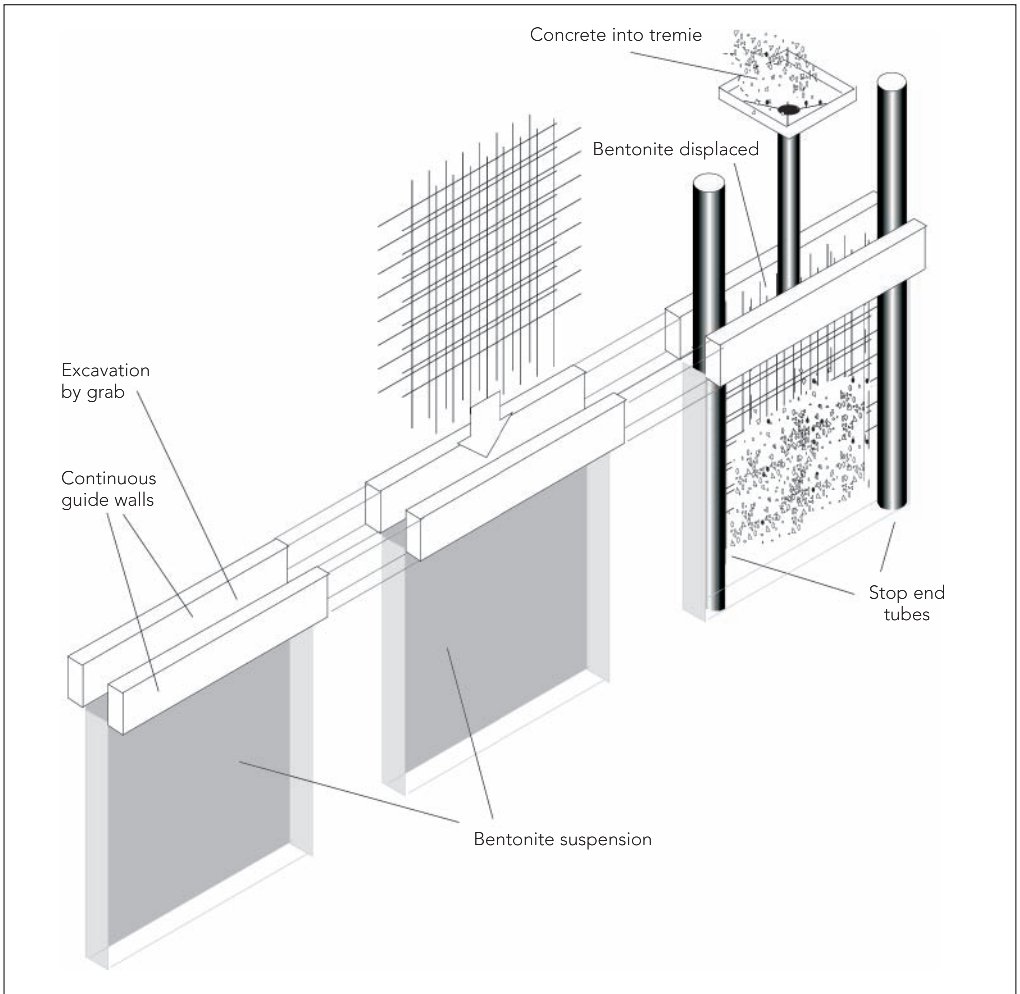

Figure 6 Stages in the construction of a diaphragm basement wall using a bentonite slurry to maintain the walls of the excavation until the reinforcement and concrete are placed.

Figure 7 Contiguous piles after excavation.

Diaphragm walls

Diaphragm walls are constructed by excavating slots between guide walls before the main basement excavation. The slot is filled with a bentonite slurry to keep the slot open while the excavation is completed, the reinforcement, panel water resisting joints placed and the concrete poured to displace the bentonite. The diaphragm wall is cast in panels with water resisting joints so producing an essentially water resistant basement wall. The basement can then be excavated and the basement floor cast with water resisting joints. As for contiguous piles this method of construction is mainly used for deep basements (two or more floors) but could be effective in difficult ground or where party wall issues prevent traditional construction.

Diaphragm walls are commonly used on clay and gravel sites. The resulting wall is substantially watertight. The method and sequence of construction are shown in Figure 8.

The advantages of this method are that:

- installation is free from vibration and excessive noise.
- walls are constructed with minimum disruption to adjacent areas.
- walls avoid the need for temporary sheeting to the excavation and become the final structural wall.
- walls are substantially watertight.

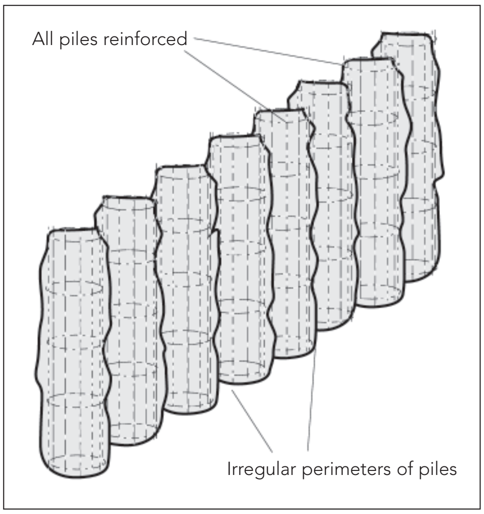

Figure 8 Cast-in-situ piles conform to the final shape of the excavation, leaving a rough surface when exposed.

However, they will still require support, either from the permanent structure within the basement or by ground anchors acting outside the walls.

3 Regulatory and performance issues in basement construction

3.1 The Building Regulations

The Building Regulations (2000) Approved Documents do not explicitly cover basement applications. However, the Approved Document *Basements for dwellings*,[3] published in 2004 by the Basement Information Centre, draws together the various requirements from other Approved Documents that are applicable to basement construction; it also includes design items that are not covered in the Approved Documents. For the size and depth of the basement and groundwater conditions on the site, *Basements for dwellings* provides construction guidance in relation to The Building Regulations. Reference should be made to the latest editions of all the relevant Approved Documents for changes since 2004, such as the most recent editions of Part B (Fire safety) – Volume 1: *Dwellinghouses*,[4] Part F *Ventilation*[5] and Part L1A *Conservation of fuel and power* (New dwellings).[6]

Where groundwater conditions are not favourable, or where deeper basements are proposed, a developer must seek additional guidance or specialist advice. On such sites, the additional investigation and design needed for deeper foundations will provide more knowledge about the ground conditions, and enable construction planning to be better focussed, and risks to be assessed with more confidence.

Ventilation

Section 1 of Approved Document F *Ventilation*[5] deals with ventilation for basements. A basement that is connected to the floors above via an open space, ie a stairwell, can be considered as part of the dwelling. If the connection is not through an open space then the basement has to be treated as a separate dwelling. This will require extra ventilation systems, either passive or mechanical, particularly where the basement is fully below ground level. (Approved Document *Basements for dwellings*[3] has not yet been updated to deal with the changes to Part F but the requirements are relatively straightforward).

Fire spread

In Approved Document B (Fire safety) – Volume 1: *Dwellinghouses*[4] measures to protect basements against spread of fire can be more onerous than for superstructures but structural requirements of traditional construction can easily be met. Extra provision is required for venting heat and smoke and in some circumstances compartmentalisation of the stairwell access will be required. Provision of the means of escape in case of fire is also necessary.

Disabled access

Approved Document M *Access to and use of buildings*[7] sets out requirements for provision of access to basement areas and for access from car parking areas (if they are in the basement).

Contamination/site moisture

Approved Document C *Site preparation and resistance to contaminates and moisture*[8] incorporates requirements for preventing gas migration. There is an additional cost for disposal of contaminated spoil. Measures required for site drainage purposes would need to be carried out anyway for basements but may need to be deeper than for buildings without basements. This deeper drainage may incur a small additional cost.

Conservation of fuel and power

Approved Document Part L1A: *Conservation of fuel and power* (New dwellings)[6] was reissued in 2006 with significant changes. The principal change made was that there is now only one method of showing compliance to The Building Regulations which is based on the latest version of SAP 2005.

3.2 Flood plain development

Planning Policy Statement 25: *Development and flood risk*[9] makes susceptibility of land to flooding a material planning consideration. Local planning authorities have the power to impose a condition on planning permissions by specifying a minimum ground floor level. The use of basements is discouraged where flood risk is high. However, special floating basements have been developed and used for particularly high risk situations.

3.3 Health and safety

The management of health and safety onsite will require additional input from the scheme designer since basement construction may involve the following, which the contractor will need to take into consideration:

- Extra excavation
- Working in excavation
- Working from height
- Temporary stability
- Craning of large basement parts or movement of smaller units.

4 Drivers and barriers to basement construction

Section 4 reviews the drivers to including basements in buildings, the barriers and technical issues relating to their use, and how the risks of basement construction can be minimised.

4.1 Drivers

The primary driver for the supply of housing with basements is the opportunity to increase floor area without using extra land. The simplest way of increasing the floor space is often to use the roof space. However, if planning constraints restrict the height of the building a basement can provide additional floor area. This is particularly in areas of high land value where the inclusion of a basement may be an economic way to increase floor area. Further, on sloping sites partial basements can increase floor area without increasing the height of a building.

A basement can provide a more flexible space than the roof space and may be expected to add value to the house. A home with a basement provides:

- improved thermal insulation, because the ground around the basement is easy to insulate.
- improved sound insulation between adjacent dwellings and between the dwelling and the external environment.
- space and opportunity for alternative heating methods eg ground source heat pumps.
- a technically efficient foundation.
- a reduction in the risk of damaging ground movements.

Planning issues

Basements can help with planning issues in the following ways:

- Provision of a basement can increase density without reducing habitable space, increasing the numbers of each type of housing to be included in a development.
- Where planning requirements restrict the footprint or height of a development, the inclusion of a basement can provide living/car parking space. Infill development, traditionally undertaken by smaller building companies, can add value by including basements.

In some places the inclusion of a basement would not be recommended:

- In the flood plain of a river, water course or body of water such as a lake.
- In a low lying area liable to flooding caused by severe rainfall and where a minimum ground floor level is specified.

Additionally the imposition of the Planning Gain Supplement, where the value of a development will be used as a basis for a 'taxation' (ie to capture a 'modest' portion of the increase in land value that occurs when full planning permission is granted) will need careful investigation as to its impact on a development and could convince developers to avoid the increase in value by the inclusion of a basement.

Housing density requirements vary from area to area. The calculation of dwellings per hectare can use:

- floor plan
- number of habitable rooms
- number of bedrooms
- number of housing units.

In general, a minimum density may be required and basement areas may or may not contribute to the calculation. Similarly, both the threshold over which affordable housing (generally at a rate of 25%) and the number of dwellings to be provided may be made on any of these criteria, or onsite size. In some areas the provision of housing with basements may help or hinder the calculation from the point of view of the developer.

In some contexts, particularly where a local authority is most concerned with fitting developments into the local setting, the density required may be determined by the surrounding building forms. Similarly, requirements for parking provision or 'overlooking' can also affect densities achievable. Undercroft or basement parking is often encouraged.

Cost and programme

The space gained by designing a house with a basement has cost implications, and so initially the largest growth in their provision may be in areas where land prices are higher such as the South East of England. However, if the use of basements is identified at an early stage in a development, extra costs can be minimised. For a large development the provision of basements would allow a decrease in building footprints without reducing the floor area of the dwellings. This in turn will increase the density and cut the land cost per dwelling.

The use of basements must be identified early in the development timescale, as a number of technical issues must be addressed if an extended construction programme is to be avoided. Most importantly, early consideration of deeper foundations, water-resisting requirements and access can help to reduce the risks that may arise from unforeseen ground conditions.

Liability and warranties

Liabilities and warranties for basements will fall under the standard NHBC arrangements with builders and developers. In addition the ASUC+ basement defects insurance guarantee is a one-off latent defects insurance that is applicable to retrofit basements, new build basements and extension of existing basements. The guarantee is only applicable provided the ASUC+ member company completes the work and has agreement with the ASUC+ underwriters.

4.2 Barriers

Basements are not the most cost effective way of increasing floor area in a dwelling unless planning constraints restrict height and land costs are high.

The spoil from constructing conventional foundations can usually be used elsewhere on the same site. However, it may not be possible to use the large volumes of spoil generated from excavating a basement on the same site: if this is the case, extra costs will be incurred for transport and disposal. Spoil disposal is becoming more expensive, both in transport and landfill tax, and both are likely to increase further in the future. Additional control and supervision may be required during basement construction.

To avoid the risk of water and dampness entering living spaces in basements, the design, specification and installation of water resistance must be thoroughly and competently carried out. Basement construction in areas with a high water table needs specialist design and proven construction techniques. The water-resisting system must be proven to be durable so that it continues to work without any failure occurring for many years. Water-resisting systems and construction techniques are not generally well known by builders, and specialist technical help in both design and construction is required for a successful outcome.

In some cases, such as development in flood risk areas, the minimum floor level is imposed as a planning condition. The provision of houses with basements is not encouraged by current legislation and practice, despite their obvious benefits.

The provision of fire escapes from basements is more demanding on the design, and space for access (possibly at both front and rear of the property) will use up valuable space and increase the effective footprint of the dwelling.

4.3 Technical issues

Technical issues in the design and construction of basements are fully covered in the Approved Document *Basements for dwellings*, revised in 2004,[3] published by The Basement Information Centre. The basic principles of basement design are clearly explained for traditional construction methods of masonry and reinforced concrete but new techniques, such as precast concrete units and sheet steel construction, are not included. The Approved Document covers all other design and construction aspects of basements that need to be considered, such as ventilation, fire, and thermal insulation, which are found in other Approved Documents. The document also includes a flow chart to help in the design of basements, which if followed, will ensure all aspects of the basement design are considered.

Basements constructed using steel elements are covered in *Steel intensive basements*,[10] published by the Steel Construction Institute. This publication covers all aspects of basement construction using steel sheet piles but is mainly aimed at construction of commercial buildings such as office blocks and car parks. However, the principles of basement construction are covered with particular attention being given to achieving water resistance and sheet steel pile driving.

Ground conditions

In general more information will be required about the ground conditions when designing a basement than for a conventional foundation system. As part of the site investigation for the proposed development a quantitative assessment of the ground conditions should be made. (See Approved Document C: *Site preparation and resistance to contaminates and moisture*[8] and the BRE Digest series on *Site investigation for low-rise building*.[11]) The properties of the soil will be required at a greater depth than for a building without a basement, and the groundwater regime will need to be established and likely changes in groundwater levels in the future assessed. However, the foundation design for vertical loading should become simpler as the foundation load of a traditional house will be close to the load removed by the excavation of the soil to form the basement. Hence the net increase in loading of the ground at basement floor level will be small. The basement walls will need to resist lateral earth pressures (see BS 8002)[12] from the surrounding ground and these will need to be assessed from the soil property data: extra soil tests may also be needed.

Future changes in groundwater level are difficult to predict although seasonal changes can be assessed from water company or Environment Agency records. Information on the following characteristics provides a good basis to help determine likely groundwater changes:

- geology
- topography
- history of industrial use
- current industry.

Expert interpretation of the geology will show whether the ground is impervious or has perched water tables, and the location of underground drainage paths. Information about the topography and the geology will help determine the local drainage regime, surface drainage and any abandoned natural drainage channels that could be regenerated should the groundwater level rise. If a large area of land is to be built on, it is important that the existing groundwater regime is disturbed as little as possible by using soakaways to feed the surface runoff into the ground where it would have gone had the buildings not been present.

Some industries (such as open-cast mining) artificially lower the groundwater, while others (such as papermaking) extract water for use in their activities. When these industries stop, the artificially changed groundwater level will take many years to recover to its natural level, particularly if the surface runoff from roofs and roads from housing developments on the same sites is fed away in drains. Water abstraction by modern industry is more tightly controlled so should not prove a problem. All this information should be considered together to assess the cumulative or balancing effect.

Forms of construction

A wide range of construction techniques can be used to form the basement walls of a house, as discussed in section 2. The main construction types are:

- masonry
- reinforced concrete
- cast-in-situ reinforced concrete
- precast reinforced concrete modular units
- steel sheet piling
- contiguous piling
- diaphragm walls.

All these forms of construction must resist lateral earth pressures and support the superstructure of the building. In some cases the vertical loading will be taken by piles integrated into the design. Masonry walls using panels of blockwork or columns of engineering bricks are usually constructed on a floor or foundation slab. Cast-in-situ concrete and the associated formwork require careful design, so that it can be constructed effectively. The reinforcement must be designed and detailed for the anticipated loads, so that waterproofing can be readily incorporated.

Precast reinforced concrete modules will need bedding on a prepared base. Special attention must be given to the foundations to avoid differential settlement between the modules which would compromise the integrity of the build and the waterproofing.

Steel sheet piling requires the clutches (joints between the sheet piles) to be sealed against water ingress. It will usually be used in conjunction with a concrete floor slab, so will need careful detailing and ground support design to avoid differential settlement. An advantage of steel sheet piles is that they can act as ground support during construction, simplifying the construction process. In other systems, steel sheet piles are installed as temporary works to allow the construction of the basement and removed later. An alternative is to batter the sides of the excavation but on most sites insufficient land is available for this.

Waterproofing

The Building Regulations 2000 require under Approved Document C: *Site preparation and resistance to contaminates and moisture*[8] that the walls, floors and roof of the building shall adequately resist the passage of moisture to the inside of the building. Part C provides guidance with respect to walls (including windows) and floors. Guidance for basements is given in Approved Document *Basements for dwellings*.[3]

The main problems in obtaining adequate water resistance are:

- incompatibility between different systems.
- defects in material application, in particular:
- sealing between any vertical elements
- sealing between wall and floor elements.
- under compaction and lack of attention to construction joints in Type B construction.

However, good design can greatly assist in lessening the effect of such problems. For example, vertical movement joints in basements are best avoided. Also design where possible for continuity of structure and ensuring compatibility between wall and floor systems and ensure compatibility between structure and any water-resisting system.

These can be avoided if the basement elements are properly designed and constructed but are very difficult to remedy if a basement subsequently starts to let in water. Incompatibility of different systems, defects in workmanship and on occasions movement or differential movement of the structure are the main problems in actually obtaining adequate water resistance. Other common problems are porous concrete and errors during construction that compromise the integrity of the waterproofing.

Proper basement design will incorporate land drainage behind the basement walls and provision for maintenance of that drainage.

Thermal insulation

The interior lining to a basement requires insulation since the ground temperature will be below that required in the dwelling. The requirements for thermal insulation that are set out in Approved Document L1A: *Conservation of fuel and power* (New dwellings) (2006 edition)[6] should be applied to basements in the same way as for the rest of the dwelling. Composite or sandwich materials should be used with the insulation to guard against condensation.

Approved Document Part L1A[6] sets out the required energy performance of dwellings, and Approved Document *Basements for dwellings*[3] provides guidance on the amount of insulation required to meet the requirements.

The amount of insulation required may be applied externally or internally but in both cases due attention needs to be given to possible thermal bridges created by the ground level and structural elements.

Any insulation placed externally must be appropriate for the loads to which it will be subjected.

The air temperature of the soil may be higher than internal air temperature for unheated basements (eg car parking/garages and may require measures to deal with water vapour (increased ventilation or vapour barriers).

Sound insulation

The ground is a particularly good attenuator of noise which will insulate adjacent properties from acoustic noise so further measures are not normally needed.

Ventilation

Living spaces must have adequate ventilation (Approved Document F – *Ventilation*)[5] and this requirement is met by window design for rooms above ground level. Either forced or natural ventilation, or a combination of both, must also be designed into the basement that is treated as an extra storey. If the basement is to be treated as an extra storey, the storeys must be linked by an open space such as a stairwell. However, the advice given in Approved Document B (Fire safety) – Volume 1: *Dwellinghouses*[4] could, dependent on basement use, lead to the stairwell being changed from an open space to a compartment to stop fire spreading. This would require the ventilation provision to be modified accordingly. Ventilation of semi-basements is easier as some natural ventilation can be provided by the windows. However, if the basement is single sided then the provision of mechanical ventilation may be required.

4.4 Minimising risk

Before construction

Before construction begins risk can be minimised by good, well planned site investigation to clearly assess the existing groundwater regime and possible future changes and establish the relevant soil properties for the foundation and retaining wall design. Such soil properties should typically include load-bearing capacity, soil movement characteristics, permeability and topography (surface configurations).

During design and construction

The design and construction of a basement will be integral with the building foundations and due consideration should be taken of Approved Document A: *Structure*.[13]

The design of the water resistance of the basement must, most importantly, be integrated with the structural elements so it is durable for the life of the building and will remain effective if the groundwater regime changes or minor differential movements occur. The buildability of the design should be assessed to determine whether it can be successfully constructed by traditional skills-based builders or whether specialist contractors will be required.

It is important that construction of basements and associated systems are supervised and checked to ensure that they are constructed in accordance with the designer's intentions. Information from the ground investigation should also be checked against the ground excavated for the basement to determine if the ground being excavated is as expected. Any soft spots or soil types not identified in the ground investigation should be assessed by a competent person before proceeding to the construction phase.

In use

Considerations of a basement and its associated systems in use will include maintenance and operation of drainage and ventilation systems, access for fire escape and change of use.

If forced ventilation is not maintained then the ventilation will fall below that recommended in Approved Document F: *Ventilation*.[5] Change of use, eg from garage to living space, will need careful consideration of ventilation and fire regulations to comply with The Building Regulations 2000.

5 Conclusions and recommendations

Design of basements for housing is heavily dependent on geotechnical information obtained from ground investigation. This is required to ensure correct structural design and correct selection and installation of the water-resisting system.

To minimise these risks designers and contractors should ensure that the:

- geotechnical investigation clearly shows the groundwater regime and its likely future state.
- geotechnical investigation gives quantitative data for the design of the basement, retaining walls and foundations.
- waterproofing of the integrated foundation and basement are designed properly in accordance with best practice recommendations.
- correct skills are available for the basement construction.
- construction of the basement, retaining walls and foundations and drainage is properly supervised.

The above factors are the key to achieving more robust and reliable basement construction, which are given in more detail in Appendix 2 of Approved Document *Basements for dwellings*.[3] This provides a simple multistage design procedure that is recommended to be followed, and is a prerequisite for assessed companies to be included in the Basement Information Centre accredited contractors' list (in preparation). The guidance in Appendix 2 referred to is specific to new build but it will, in parts, also be applicable to refurbishment and retrofit basements, and the Centre intends to develop more specific guidance for these.

Further guidance on obtaining water-resistance for basements and the principles of design and installation and applications of water-resisting materials and systems is given in References and Further Reading.

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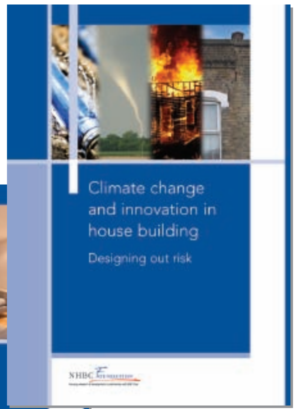

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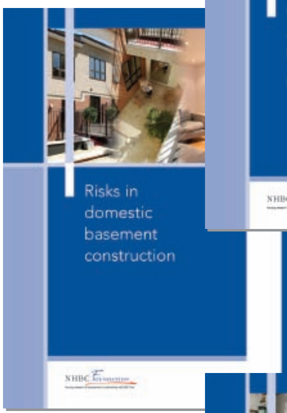

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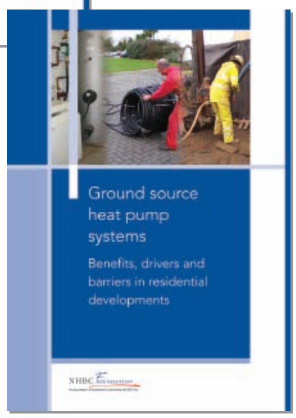

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Risks in domestic basement construction

Including basements in houses increases the floor area and living space, and the value to the owner. Basements can allow higher housing densities, which offer increased value to the developer. However, these increases in value may be accompanied by a need for greater site investigation and more detailed design to minimise the risks in construction and use. Construction site skills must also be taken into account.

This guide summarises current trends in basement provision, and the regulatory, performance and planning issues that affect basements. It also identifies the primary risks in basement construction and outlines measures to minimise the risks at all stages of design and construction.

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NF4
Published by IHS BRE Press on behalf of NHBC Foundation
October 2007
ISBN 978-1-84806-009-8