DEREK WORTHING, NIGEL DANN AND ROGER HEATH

Marshall and Worthing's The Construction of Houses

SIXTH EDITION

eRESOURCES

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MARSHALL AND WORTHING'S THE CONSTRUCTION *of* HOUSES

The sixth edition of *The Construction of Houses* builds on the success of the previous five editions. The book provides a comprehensive introduction to the principles and processes of the construction of houses and their services. As such it is aimed at providing a broad understanding of domestic building construction for students as part of their academic studies and as a useful information source for practitioners.

The existing chapters have all been updated and most of them expanded to take account of changes to dwelling house construction since the last edition and there are new chapters on 'Modern Methods of Construction' and 'Regulatory controls and building standards'. Additionally, many new and/or updated photographs and diagrams have been added.

As with the previous editions, the authors have concentrated on presenting current mainstream approaches to the construction of houses. The detailed, yet accessible, text that is supported by hundreds of coloured photographs and diagrams provides clear explanations of the many complex processes that go into the building of a house. A deeper insight into modern construction is also given by the book's consideration of historical building techniques from the 18th century onwards in order to illustrate how and why we build houses in the way we do now.

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SIXTH EDITION

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

Sixth edition published 2021
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

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First edition published by Estates Gazette 1990
Fifth edition published by Routledge 2013

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Worthing, Derek, author. | Dann, Nigel, author. | Heath, Roger, author.
Title: Marshall and worthing's the construction of houses / Derek Worthing, Nigel Dann, Roger Heath.
Description: Sixth edition. | Abingdon, Oxon; New York, NY: Routledge, 2021. | Revised edition of:
The construction of houses / Duncan Marshall ... [et al.]. 5th ed. London; New York: Routledge, 2013. |
Includes bibliographical references and index.
Identifiers: LCCN 2020029654 (print) | LCCN 2020029655 (ebook) | ISBN 9780367027568 (hbk) |
ISBN 9780367027582 (pbk) | ISBN 9780429397820 (ebk) | ISBN 9780429674266 (epub)
Subjects: LCSH: House construction. | Dwellings--Design and construction. |
BISAC: TECHNOLOGY & ENGINEERING / Construction / General.
Classification: LCC TH4811.C655 2021 (print) | LCC TH4811 (ebook) | DDC 690/.8--dc23
LC record available at https://lccn.loc.gov/2020029654
LC ebook record available at https://lccn.loc.gov/2020029655

ISBN: 978-0-367-02756-8 (hbk)
ISBN: 978-0-367-02758-2 (pbk)
ISBN: 978-0-429-39782-0 (ebk)

Typeset in Myriad
by Newgen Publishing UK

Visit the eResources: www.routledge.com/9780367027582

Duncan Marshall

Duncan Marshall and Derek Worthing wrote the first edition of *The Construction of Houses* in 1990. They remained the sole authors of the next three editions, until sadly Duncan died in 2009.

We all wanted to acknowledge the seminal role Duncan played in developing the character and content of the first four editions of the book. For this reason, and because all of the new material was written without him, we have titled this Sixth Edition '*Marshall and Worthing's The Construction of Houses*' and Duncan no longer appears in the list of authors.

Duncan's memory lives on in this new Sixth Edition, which we would again like to dedicate to him.

Derek Worthing, Nigel Dann and Roger Heath

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Contents

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Preface

The Construction of Houses was first published in 1990 and this, the sixth edition, was completed 30 years later in the summer of 2020. The book has continually evolved through each edition. Some of the developments are obvious at first sight with the change from black and white images to colour, and the increase in the number of pages being perhaps the most immediately striking examples. The other major development has been the greater emphasis on issues of sustainability, and particularly energy use, that reflect those changes in how we build houses that have been driven by the climate crisis. As well as updating all the chapters, strengthening the coverage of energy issues and adding many more images, this edition contains brand new chapters on 'Modern Methods of Construction' and 'Regulatory controls and building standards'.

Despite these changes, the aim of the book remains the same as it did for the first edition: to produce an interesting, up-to-date and informative introduction to domestic building construction and services which will be of value to all students studying a subject associated with the Built Environment, as well as a useful information source for practitioners. The book is not a catalogue of modern construction details, but rather is intended to provide a balance of knowledge and understanding in order to give readers a good grounding for further study.

Although, as stated earlier, the content has been updated and new material added, this latest edition retains the characteristics of the first edition where the authors felt it important to explain *why* things were done rather than just *what* was done, as well as to describe and explain construction and services with a clear and concise use of language. Likewise, the main objectives of the book remain the same:

- *To provide a broad understanding of the principles of house construction*
- *To introduce the reader to current building practice*
- *To explain earlier forms of house construction.*

With regard to the latter point each chapter, where appropriate, traces the evolution of modern construction from the 18th century onwards. This is done in order to illustrate how building practice has largely developed through an understanding of yesterday's successes and failures as well as more recent technical and regulatory requirements for how a house fulfils its function. This historical development aspect of the book therefore provides a deeper insight into modern construction and how and why we build houses in the way that we do now.

The book provides a comprehensive introduction to the principles and processes of the construction of houses and their services. As with the previous editions, the authors have concentrated on presenting current mainstream approaches to the construction of houses. The detailed text, supported by hundreds of coloured photographs and diagrams, provides clear explanations of the many complex processes that go into the building of a house. It should be noted that, as the title implies, this is a book about house construction and so, although there are one or two references to the difference in treatment between flats and houses, these are in the nature of asides rather than a detailed discussion of the construction of those domestic dwellings which are not houses.

The first five chapters of the book are mainly contextual and as such are important in providing the opportunity for an even better understanding of those that follow. The book is then divided into chapters looking at the key elements of a house and how they are built. The chapters covering building services concentrate on providing a broad introduction to the various systems and installations available, rather than a detailed examination of their individual components.

It is important to understand that the construction methods and materials that are described in this book, whilst current and up to date, intentionally reflect 'the norm' in new build house construction as it stands at the beginning of the third decade of the 21st century. It therefore reflects that which is currently being built by the 'average' developer for the majority of occupiers. So, for example, whilst there is a strong emphasis in the book on construction materials and services which have been developed and utilised as a reaction to the climate crisis and the notion of sustainability (such as solar panels, photovoltaic cells, etc.), it does not include discussion of elements or features which are currently not mainstream (such as straw bales, green roofs, etc.) – or at least not mainstream for the developers of mass housing. Also the book does not consider the 'one-off' type of design and construction that might be used by, say, individual architects for single clients and which might utilise, for example, 'steel and glass' designs or the use of glulam beams, etc. This is not to dismiss such approaches, but to include them would inevitably mean that the intended focus of the book, i.e. presenting current mainstream approaches to the construction of houses, would be compromised or perhaps confuse a reader new to the subject. Nor does the book include a discussion of services provided by, for example, wind power, community heat and power, or indeed carbon capture, because the focus is on the individual house – albeit that such installations might possibly be built as part of a larger development.

Finally, it is worth saying that the writing of this new edition coincided with an unprecedented number of dilemmas, tragedies and upheavals that will, almost certainly, have an effect on how we build houses. These include the climate crisis and the Government response to it. This will inevitably continue to drive change throughout the foreseeable future – and hopefully do so in a more sustained manner than in the past. Another example is the more specific tragedy of the fire at Grenfell Tower, which will not only result in more stringent legislation regarding fire precautions (and not only in high-rise dwellings), but hopefully also in the provision of more resources for building control plus a greater emphasis on robust inspection and testing during and after construction. To these examples, we can add the impact of the decision to leave the European Union which may affect the progress made on the environmental legislation which affects housing and may also possibly exacerbate the problem of a sufficiently skilled workforce to deliver the volume and quality of houses planned and required. However, this may be offset by the Government's increasing promotion of modern methods of construction. There are also of course the possible effects of Covid-19 which are unknown at the time of writing, but which may result in a delay in developing and applying environmental and other technologies due to the potential severity of any economic recession, as well as possibly lead to more and better controls on air pollution inside and outside the home.

Acknowledgements

We would like to thank and acknowledge the assistance of the following organisations and individuals:

Advance Appliances Ltd
Alan Lamb
Bovis Homes
BRE (formerly the Building Research Establishment)
Brick Development Association
British Gypsum
Christopher Alda
Clay Pipe Development Association
Creagh Concrete
David & Marilyn Allan
David Hardwick
Floorspan UK Ltd
Gledhill
H+H UK Ltd (Celcon)
Hepworth Building Products
Hepworth Clay, Wavin Ltd
Ian & Julia Crawford
Ian Childs
Jon Reeves
Knightstone Housing Association
Lead Development Association
Marley Eternit
Mighton Products
Naylor Bros (Clayware) Ltd
Pasquill
Passivhaus Trust
Paul Revell
Polypipe Terrain
Prestoplan
Redrow
RMC Flooring
Roger Bullivant Limited
Solar Trade Association
Steetley Brick & Tile Ltd
Steve Brown
Streif Sustainable Building Systems
Styro Stone GB Limited
Surebuild (steel framing)

Surestop Limited
Truss Form (Midlands) Ltd
The Trussed Rafter Association
University of the West of England, Bristol
Viridian Solar
Wolf and Scotts of Thrapston
Yorkshire Fittings

1 Introduction

Section One: Introduction

This chapter sets out some guidance for those new to the subject on how to set about the study of building construction. It includes general principles on a number of over-arching principles and procedures that apply to the construction process, particularly to houses. These are also highlighted, but not necessarily discussed in detail, in the chapters that follow. Brief reference is also made in this chapter to sources where further information on building construction and design may be found.

House construction in England is the main focus of this book. It also covers domestic construction in Wales, although this will gradually diverge from English construction as a result of the recent (2014) separation of the Building Regulations in these two countries. Specific building practices that differ from those in Scotland and Northern Ireland also exist, but the general principles of construction are similar throughout the United Kingdom.

The book focuses on low-rise domestic construction, i.e. houses of two or three storeys and bungalows. Where appropriate, reference is made to flats/apartments, although these are more often to be found in high-rise buildings which are, generally, outside of the scope of this book.

Section Two: How to 'read' construction

Generally

Some students of building construction have no difficulty in assimilating and understanding what it is all about. The written descriptions and the details set out in the construction diagrams all make logical sense from the moment they open their first textbook. Other students simply struggle; however often they read the text and review the diagrams and photographs, all they see is a mist of facts and details, none of which makes clear sense. Even if one part does become clear, making connections with the other areas of construction remains difficult.

How is it possible to overcome this challenge?

Many students do overcome this initial barrier, including at least one of the authors who spent the first year of his studies wondering if the construction of a building would ever make sense. There is probably no 'Eureka!' moment for most of us; it is simply a matter of working out a strategy that enables us to comprehend the construction process and its details.

One method of study that creates difficulties for many students of construction is attempting to learn the subject from just reading one or more textbooks. Construction is very much a hands-on subject and attempting to learn about it by simply cramming information from a book is not highly productive for most of us. The learning process needs a much more pro-active engagement with the subject. This book provides basic knowledge, but the student also needs the stimulus of going out and looking at buildings in the light of that knowledge. This will aid assimilation. If possible, also look at active building operations. It is also very helpful to sketch or draw construction details, whether from real life or from a textbook.

The importance of sketching as a learning aid

It is an important skill for any student of construction (and for the experienced practitioner as well) to be able to sketch or draw construction details, whether from real life or by copying from a textbook. Even in this digital age, where computer-aided drawings (CAD) are the standard, many employers require the ability to sketch as a key skill.

Sketching, in this sense, means ***freehand drawing***, although drawing, in the strict sense, is based on straight lines produced with the use of straight edges and set-squares to aid greater accuracy (and confidence). You may have heard of technical drawing, which normally involves drawing to scale, but that level of accuracy is not needed at this stage, unless you plan to make design part of your future profession. As a beginner, you may also find it helpful to purchase a good book on architectural draughtsmanship.

In this book, as in other books on construction, there are many diagrams showing plans, sections and elevations of houses. These, in combination with the accompanying text, help to explain design and construction principles and application. An example of each is illustrated in Figure 1.1.

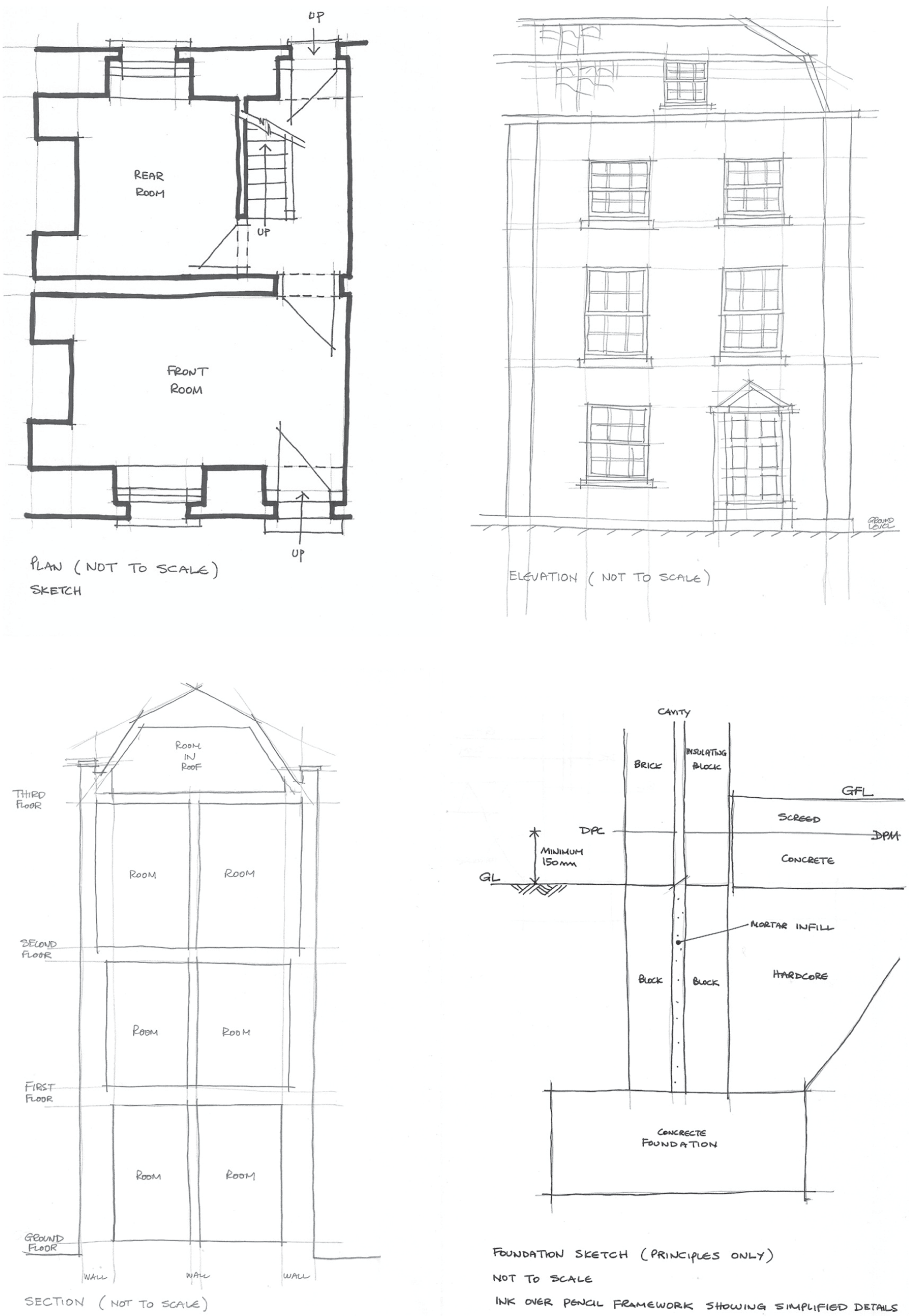

Figure 1.1 Examples of sketched details

The first three sketches are of a Georgian house – plan, elevation and section. The fourth sketch (bottom right) is of a modern foundation and cavity wall. In all of them, you can see the initial pencil framework on which the hard detail is finally sketched.

The first point to understand is that you need to learn to sketch (or draw) what you actually see. Choose a simple diagram from the book and then redraw it as a sketch. Always sketch or draw using a fairly soft pencil, such as HB, or a mechanical/propelling pencil. It can be helpful to sketch on graph paper, especially if you lack confidence in your draughtsmanship.

Lines may be wobbly at the first attempt, but that is unimportant. What matters is that the sketch gives you a better appreciation of the construction detail. The lines will become straighter and more clearly defined with practice. Use light pencil lines to start with to shape an outline or framework of what you see (at this stage a ruler may be helpful) and then firm the lines up (freehand) to give a copy of what you see – you can try inking them in as shown in the sketch of the floor plan in Figure 1.1.

Such an exercise will transform the selected detail, be it of a foundation or a roof, from some vague representation in your textbook to hard fact that means something to you. If it does not work first time, repeat the exercise as many times as necessary for the construction detail to become meaningful. The use of different coloured pencils or pens to highlight particular details can also aid your knowledge assimilation.

Repetition of the exercise for the same piece of detail or sketching of the different parts of a building should enable you to develop a skill that you initially feared. It is surprising how students who believe that they have no artistic or technical ability can, with application, develop sufficient drawing skill to really aid their understanding of construction details and processes. Even a really crude sketch, clearly executed, can be informative. Sketching also means clearer communication of construction principles and ideas in terms of examinations or in a future career.

As practice makes you more proficient, you could practise sketching what is known as an orthographic projection. This is a method where you draw or sketch a three-dimensional object, such as a brick or a house, in two dimensions, i.e. on a sheet of paper. Detailed guidance on how to go about this can be obtained from books on draughtsmanship, where you will find that there are a number of different types of orthographic projection, including isometric projection. You could start by sketching something simple, such as a brick, and graduate to more adventurous subjects. An example of a brick drawn in isometric projection is shown in Figure 1.2.

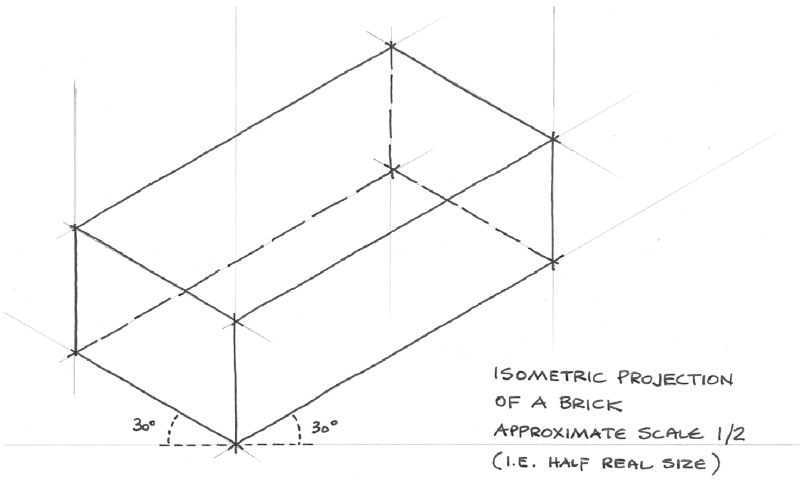

Figure 1.2 An example of an isometric projection

This diagram is an example of an isometric projection of a brick. Note how more informative it is than merely looking at diagrams of each of the side and end elevations.

When undertaking detailed design of a building, it is usual practice to produce scale drawings showing the design information. Sketching, in contrast, is not usually to scale as it is difficult to draw in freehand to an exact scale. The technical drawings, e.g. plans, elevations and sections, are normally drawn to one or more scales that reflect the level of detail required by the development team, so that land, buildings or objects shown are represented at a size that is in proportion to actual size – normally a smaller scale for land and a larger scale for construction details. For example, 1/50 (which means that the drawing is one-fiftieth of the full-size object) would be used for a floor plan or elevation, whilst 1/200 would be used for a site plan showing a proposed building in outline plus the land on which it sits. Today, technical drawings for building projects are normally produced by computer-aided design (CAD) programs.

Section Three: Computer-aided Design (CAD) and Building Information Modelling (BIM)

Computer-aided Design (CAD)

Historically, the design element for all new buildings and for alterations to and redevelopment of existing buildings was provided by hand-drafted drawings on paper. This was the case until the final quarter of the 20th century when CAD started to become used in the construction industry.

CAD was originally developed in the 1950s, but it did not become much used for building design until the 1980s. Early CAD programs produced 2-D drawings that were little different from hand-drafted drawings and were still produced on paper.

Over the last 30 years or so, CAD has developed significantly to the point where it is now capable of producing highly sophisticated 3-D digital models which, when combined with virtual reality (VR), enable a walk-through experience to be achieved. A recent further development of VR is augmented reality which allows the designer to see its creation in a real-world environment.

The use of CAD has led to the introduction of Building Information Modelling (BIM) systems in which the level of digital information can encompass all aspects of design including management processes, costing and links to contractors and manufacturers as well as the use of a building over the entire life cycle of a building. The UK Government positively encourages the use of BIM wherever possible in the construction industry and, in particular, for its own higher-cost procurement.

CAD has fundamentally changed the way that buildings are designed. All stages of a building's design can be undertaken at the touch of a computer mouse as well as changes to any design element. CAD tends to be used more commonly for the design of new buildings, although it can be applied to existing buildings and often is, especially if they are large and/or historic.

There are a number of CAD programs available. Amongst the more commonly used are:

- ***AutoCAD*** – *one of the most popular building design programs, it produces 2-D and 3-D drawings*
- ***SketchUp*** – *a free 3-D CAD modeller from Google*
- ***Autodesk Revit*** – *can undertake design from concept stage to 3-D modelling and BIM.*

Building Information Modelling (BIM)

There is no precise definition of BIM. Generally, it is recognised as a process of creating and managing digital construction project information across its complete life cycle, i.e. from concept and through all stages of design and construction and, potentially, through a building's life. Digital information is created, shared, reviewed and adapted by the design, construction and user team on the basis of a fully collaborative approach.

This is achieved by means of a common data environment (CDE), which is a single source of project information that all parties can access and manage. The data collected is both **graphical**, i.e. 2-D (e.g. plans, elevations) and 3-D (e.g. projections and models), and **non-graphical** (e.g. bills of quantity, schedules). CDE enables collection, management and dissemination of all the documentation necessary for the project. This results in a number of significant benefits for a project including time, material and cost savings, raised health and safety standards and procedures and better quality of design and construction.

BIM is ultimately based on the Employer's Information Requirements (EIR); these are obtained from the employer's internal team, the construction team and the operator/s of the built asset. In simple terms, the EIR are the employer's brief for the project.

BIM currently has four activity levels as defined by the UK BIM Task Group, with each level indicating a higher and more sophisticated level of digital information exchange. These are briefly described in Table 1.1.

Table 1.1 The four current levels of BIM

BIM LEVEL	DESCRIPTION
Level 0	This is BIM in its simplest form, i.e. entry level BIM. Production is of 2-D CAD information with low-level digital input and leads to drawings being printed on paper. Level 0 is used for basic product information and does not lead to digital collaboration.
Level 1	This involves a higher-level managed mixture of 2-D and 3-D CAD supported by a common data environment (CDE). The former produces application documentation suitable for statutory approval and for product information; the latter produces documents for concept and detailed design work.
Level 2	Information is created in separate discipline models and then linked, distributed and managed in a 3-D collaborative CAD environment via a common data environment (CDE). This allows BIM modelling and virtual reality to take place. The UK Government now requires all public bodies to meet BIM Level 2 requirements.
Level 3	Although not yet fully defined, Level 3 is about whole lifecycle management of a building or development, i.e. from concept stage to ultimate demolition after use. The aim for Level 3 is to produce a fully collaborative digital project where all parties can access and modify all data including building information, construction sequencing, lifecycle management information and costing.

The UK Government, through its *Government Construction Strategy 2016–20*, has been an international leader in the use of BIM in construction and from 2016 set a requirement for all centrally procured construction contracts to make use of Level 2 BIM with the ultimate aim of moving up to Level 3. Also, in 2017, the Government set up the Centre for Digital Built Britain in partnership with the University of Cambridge with the aim of digital technology enabling better design, construction, operation and integration of the built environment.

There is also significant use of BIM in the private sector for new-build projects and increasing use for projects involving work to existing buildings, especially historic buildings. Recently, the Government has proposed that BIM be mandatory on all high-rise projects over 18 metres in height in order to meet some of the safety requirements raised by the Grenfell Tower disaster.

Section Four: Some key design and construction terms

You also need to become familiar with some of the key terms that are used by construction designers and contractors. They include elements of construction, materials and components.

Element of construction (or element) – This is the term used to describe the basic units with which a building is formed, such as the walls, the floors and the roof. A simple building such as a garage will have six elements – four external walls, the ground floor and the roof. A building of complex design will have many more elements, e.g. external and internal walls, several floors, a number of different roofs. The elements are carefully fitted together so that, in principle, walls provide support to each other as well as to the upper floors and the roofs above.

Material – Each element is formed from one or more materials. An example of an element is a wall and this may be solid or have two skins with a cavity between. The wall may be formed from one or more materials, e.g. each skin of a cavity wall can be formed from different materials with the outer skin of brick and the inner skin of concrete blocks.

Components – The wall may have one or more components built into it, e.g. a window or a door. Internal fittings, such as kitchen units, baths or wash-hand basins and the like, are also components.

Substructure – Buildings have above and below ground construction. That part of the construction below ground is known as the substructure.

Superstructure – All of the construction above ground level is called the superstructure.

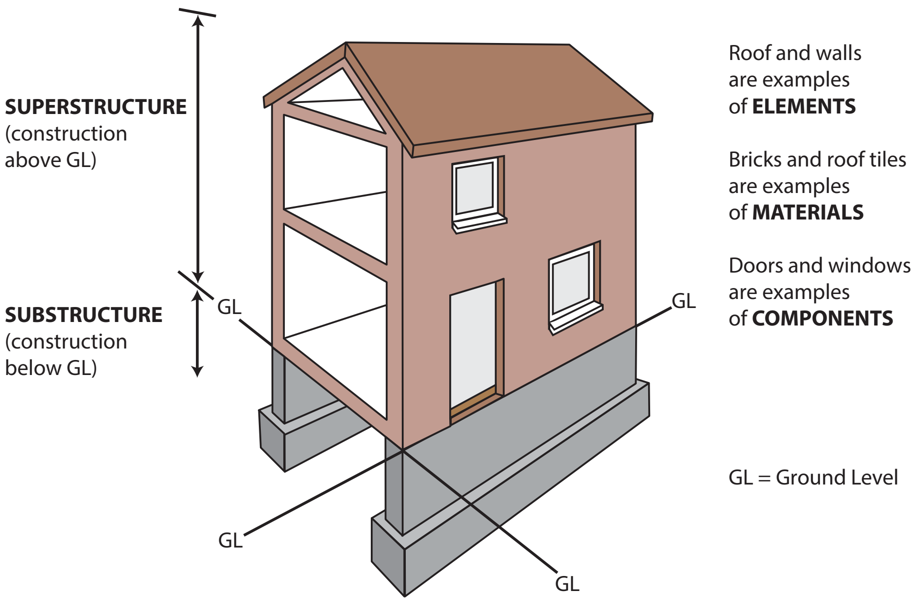

Figure 1.3 Identifying parts of a building's structure

Section Five: Metric and imperial dimensions

One further important point needs to be made. Until comparatively recently, UK building design and construction was based on the imperial system of measurement rather than the metric system. All construction design and manufacture is now based on the latter system and you will find only metric dimensions used in this book.

However, when inspecting and dealing with construction in older buildings, it should be noted that component and material sizes do not readily translate between the two measurement systems and, therefore, it is helpful, but not essential, to be knowledgeable in both. Some metric sizes make sense (e.g. a 200mm x 100mm piece of timber) whilst others are odd conversions from the old imperial sizes. An example of this is that of a standard brick. Under the imperial system, its nominal measurements were 9" (228.6mm) long x 4½" (114.3mm) wide x 3" (76.2mm) high. A metric brick is nominally sized at 215mm x 112.5mm x 65mm with a 10mm joint all around. Although slightly smaller, this is a close conversion from the older imperial size.

Metrification also means there needs to be care taken when working on older buildings to take account of sizing differences. However, some manufacturers of materials and components do still provide imperial products for the conservation and refurbishment markets.

Section Six: Construction procurement – a brief overview

There are two distinct elements to the construction process – design and construction – and the whole process from initial idea to delivery of a finished building is known as procurement. Building procurement is a very complex subject, with a number of possible methods, and the following description is a simplified introduction to it.

A person or organisation (known as the client or employer) will wish to have building works carried out, e.g. a project for the construction of a new house. Frequently, the client will raise the finance for the project and look for a professional designer (e.g. architect, architectural technician, building surveyor) and a building contractor; this is known as **traditional procurement**, where design and construction are undertaken by separate organisations. However, in an increasing number of projects, the client will look to have the whole construction process undertaken by a single organisation that undertakes both the design and the construction; this is known as **design and build procurement**.

The two procurement methods referred to above are those commonly used for house construction. Selection of a contractor is normally by means of a **tender** – this is a procedure in which competing contractors submit a price plus other required information that enables the client to make a choice of a specific contractor and the price for the project.

Whichever procurement method is used, once appointed (normally by means of a formal contract), the chosen contractor will carry out the building works. Sometimes the contractor will undertake all of the necessary works itself but, more often, it will be carried out by specialist **subcontractors** who work under the direction of the contractor (which is then often referred to as the main contractor). Subcontractors include bricklayers, electricians, plasterers, plumbers and roofers. Specialist **suppliers** provide materials (such as sand, cement, bricks, plaster) and components (such as bathroom and kitchen fittings, doors and windows).

An alternative and increasingly popular means of new house construction is that of **self-build**. This involves an individual, or group of individuals, who wish to have a new house or houses built for their own occupation, finding suitable land, organising plans from a professional designer and then actually getting involved in the construction process itself, often by physically building the house or houses themselves. Alternatively, they appoint specialist contractors to undertake all or some of the construction work under their own general direction or that of a professional project manager. Self-build currently provides approximately 20 per cent of all new homes in the UK.

Finally, it should be noted that the construction industry has always been one of the most dangerous industries to work in. It is safer now than it has been because there is wide-ranging and continually increasing legislation that applies in terms of the health and safety of the workforce and those it comes into contact with (see Chapter 3).

Section Seven: Conclusion

It needs to be realised that the construction process is a continuum. The development and application of new design and building techniques, materials and components never ceases. The environment in which it takes place does not remain constant. The performance requirements of buildings are continually changing, usually to meet increased standards. The way in which space is used as well as the appearance (internally and externally) of buildings are all subject to frequent change as they react to shifts in the housing and other sectors of the property market that are driven by consumer demand, government legislation and the influence of building designers.

Further knowledge can be gained from the many other sources of information on both the design and the construction of buildings that are available to the student or the practitioner. These include textbooks and websites as well as a great number of journals, magazines and guidance notes including those published by professional bodies and trade organisations.

This chapter and those that follow aim to give a clear insight into the principles of domestic construction. Those principles, once properly understood, can also be used in learning the construction principles of other types of buildings, e.g. commercial and industrial buildings.

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2

Modern Methods of Construction (MMC)

Section One: Introduction

The UK construction industry employs approximately 10 per cent of the UK workforce and is approximately 10 per cent of the economy. The UK Government has a target of building 300,000 new homes by the mid-2020s, but the industry is still over-reliant on traditional building methods and construction projects are essentially labour-intensive.

Traditional construction was based on brick or stone walled buildings; for centuries, buildings had solid walls with, more recently, cavity walls from the second quarter of the 20th century. Essentially, domestic low-rise construction changed very little in terms of the speed and quality of the production processes involved.

System buildings (see Chapters 16 and 17), based in part on prefabrication, were introduced after the First World War and, again, after the Second World War to provide a quicker construction process during periods of high housing demand linked to a lack of an experienced construction workforce and problems of the available supply of materials. Approximately one million prefabricated homes were built, many of a temporary nature, in the period between 1945 and 1970. Unfortunately, they were not always of a high standard due to a mixture of poor design, construction problems and poor workmanship.

Some prefabrication of houses continued throughout the last quarter of the 20th century, e.g. timber frame housing. Higher standards of prefabricated buildings were being achieved by the end of the century, but it had also become apparent that a greater level of high-quality prefabrication was needed in order to answer a number of key demands on the construction industry, e.g. to enable faster construction, to overcome shortages of skilled labour and to reduce construction costs.

A number of external factors were (and are) also driving change in the construction industry. These include:

- *Demand for increased new housing provision*
- *Need to offset the effects of climate change*
- *Drive towards sustainable development*
- *Desire to build energy-efficient houses.*

Overall, the aim was, and is, to produce higher quality new housing stock through greater quality control and enhancement, whilst also reducing key construction factors such as:

- ***Construction time*** *– e.g. it takes approximately 30% less time to build a timber-frame house than a standard cavity-walled house*
- ***Use of skilled workers*** *– there is an increasing shortage of relevant skills in the construction industry*
- ***Cost of construction*** *– however, this is only achieved once larger scales of production are attained*

- ***Amount of waste*** *– with some off-site prefabrication, up to an 80% saving of waste can be made*
- ***Number of injuries and deaths in the construction industry*** *– the industry is inherently dangerous and off-site manufacture reduces the possibility of health and safety incidents.*

Modern Methods of Construction (MMC) was derived as a term to highlight the creation and use of better prefabricated building products and processes throughout the UK construction industry that would result in greater efficiency and higher quality. These products and processes would also meet rising standards of sustainability and environmental performance. Overall, the aim of MMC is to provide economic and energy-efficient buildings, at the same time delivering cost savings (potentially up to 20 per cent) and time savings (potentially up to 50 per cent) in the construction process. One major manufacturer/developer states that a 2-bed housing unit can be produced in two weeks, a 1-bed unit in 7 days. It also states that (apart from the substructure) the only site-based operations required are to bolt the timber-framed modules it produces together and apply external cladding.

The term MMC is wide-ranging and relates to both off-site and on-site construction processes. Some of these 'modern' methods have been used for some time, but they are all increasingly seen as providing the means of providing sustainable and affordable housing.

- ***Off-site construction processes*** *– This term refers to a range of relatively new industrialised construction processes and technologies that involve factory prefabrication, modular construction, off-site construction, manufacture and/or assembly and other forms of system building. In 2012, the Steel Construction Institute (SCI) estimated that there could be a reduction of as much as 75% of site labour through the use of off-site construction.*
- ***On-site construction processes*** *– These include the use of innovative building systems that commonly make use of on-site assembly of pre-manufactured components and material as well as the recycling of materials and the reduction or avoidance of waste.*

Figure 2.1 This photograph shows both off-site construction (the timber frame) and on-site construction (the beam and block floor)

It should be noted that MMC is based on standard prefabrication and construction processes. This may mean that they are not always suitable for specific one-off projects and more complex architectural requirements. Furthermore, any MMC system must have been assessed and approved in terms of relevant British Standards and Codes of Practice as well as Building Regulations and any planning and other regulatory requirements.

Finally, the quality of the installed system or component will depend on the competence of the site-based workforce and management as well as the accuracy of the final site-based assembly. For example, a site-formed foundation must be precisely laid out and levelled in order to receive prefabricated panels, which must then be correctly connected together. Detailed advance planning will also be essential in terms of the arrangements for suitable site access, off-loading and storage (although site storage of prefabricated components should always be kept to a minimum period in order to avoid the possibility of damage).

Section Two: Design for Manufacture and Assembly (DfMA)

The use of Design for Manufacture and Assembly (DfMA) has been well established in the automotive and consumer product sectors for some time and is now starting to influence MMC. The focus of DfMA is to undertake a design approach that enables ease of manufacture and increased efficiency of assembly by simplifying the manufacturing and assembly processes. These key factors are achieved through identifying, quantifying and eliminating inefficiency and waste.

DfMA aims at speedier construction processes involving quicker assembly times, lower assembly costs and higher quality, all leading to increased reliability. At the simplest level, these aims can be achieved by minimising the number of components used in the construction process and by creating simplified factory-based automation as well as eliminating the necessity for on-site adjustments.

DfMA is based on two separate methodologies, both of which are aimed at maximising the efficiency of the production process. The principles of each are set out in Table 2.1.

Table 2.1 The two Design for Manufacture and Assembly (DfMA) methodologies

METHOD	DESCRIPTION
Design for Manufacture (DfM)	This focuses on the selection of the most cost-effective materials and processes and minimising manufacture's operational complexity, e.g. avoiding unnecessary features.
Design for Assembly (DfA)	This focuses design on maximising a product's ease of assembly with the aims of minimising the number of assembly operations and the reduction of assembly costs, e.g. the use of snap-fit connectors rather than threaded fasteners.

Recognition of the efficiencies that can be created by the use of DfMA has led a number of construction contractors to adopt it for various off-site prefabrication processes, e.g. pre-cast concrete floor slabs or planks.

Section Three: MMC processes

Introduction

Although there is no precise definition of MMC processes, in 2007, the Housing Corporation (a non-departmental UK Government body abolished in 2008) divided MMC into five categories and these are still recognised under the general headings as shown in Table 2.2.

Table 2.2 The five categories of Modern Methods of Construction as defined by the Housing Corporation

GENERAL TYPE OF MMC	CATEGORY OR TITLE
Off-site manufacture (OSM)	1. OSM – Volumetric (also called modular construction) 2. OSM – Panellised construction systems 3. OSM – Hybrid construction 4. OSM – Sub-assemblies and components
Non off-site manufactured MMC	5. Non off-site manufactured MMC

A brief description of each of these processes based on Table 2.2 is set out below, with some further, more detailed discussion set out in later chapters.

1. Off-site manufacture (OSM) – Volumetric (also called modular construction)

Fully fitted-out three-dimensional units (known as pods or cells) are factory-produced before being installed on site to form a cellular system. These systems tend to be used for repetitive designs, so are eminently suitable for housing. The pods can be fitted like pieces of a jigsaw puzzle to create a complete building, although they are frequently installed individually to create an individual self-contained pod or cell within a new or existing traditionally constructed building.

The individual pods or cells, which are often room-sized, are transported to site and stacked above each other on prepared foundations to form entire buildings or individual rooms. The pods are secured to each other by a variety of connectors including bolts or dowels. Each building or room (pod) can be completely factory-finished to include all services and decorations and be ready for immediate occupation. The pods have the added bonus of providing better insulated and more airtight buildings.

OSM Volumetric is mostly used for multi-storied buildings such as flats, although individual pods, i.e. smaller bathroom and kitchen cells, are increasingly used for housing.

Figure 2.2 Individual shower pods ready for site delivery

Fully fitted-out shower pods with the fittings and local pipework, etc. ready for connection to the hot and cold water and electrical service supplies once installed on site.

2. Off-site manufacture (OSM) – Panellised construction systems

Factory-formed flat panels (wall, floor and roof panels – the latter two also known as cassettes) are assembled on site to create an entire three-dimensional structure. Alternatively, they can be designed to fit into an existing structure. The prefabricated off-site manufacture allows for rapid erection on site and the panels can have services pre-installed.

There are many different types of panellised construction, but the two main types of manufacturing process are:

- **Open panel system** – also known as open cell system. Only the frame of timber or steel is prefabricated, the panel can be structural or non-structural. Any insulation, internal lining boards, vapour control and external cladding is added on site as are windows, doors, services and decorations.
- **Closed panel system** – also known as closed cell system. Fully lined and insulated structural panels are created on a production line. The panels may be formed with timber frames, steel frames or concrete panels. Windows, doors, services and decorations can be installed in the factory or on site. A variant is the filled cell system which is similar to the closed panel or cell system except that the plasterboard is not fitted (this allows for easier installation of any site-fitted services and avoids damage to any panel).

Figure 2.3 The different open and closed panel systems

Open panel light steel frames (LSF) have been used to construct a pair of houses. Here we are looking through a party wall and can see the frames forming the adjoining house. A top storey frame is leaning against the party wall. (LSF are discussed in more detail in Chapter 17.)

Timber frame buildings can be of open panel construction and historically were, but modern timber frame buildings are commonly of closed panel construction. This timber-framed building has partially closed panels. (Timber-framed buildings are discussed in detail in Chapter 16.)

Other types of panellised construction systems include:

- **Structural Insulated Panels (SIPs)** – a form of sandwich construction in which two sheets of material are bonded to a foam insulation core. This creates a structurally strong unit which is used primarily for wall and roof panels (or cassettes). (See Chapter 16 for a detailed description of SIPs.)

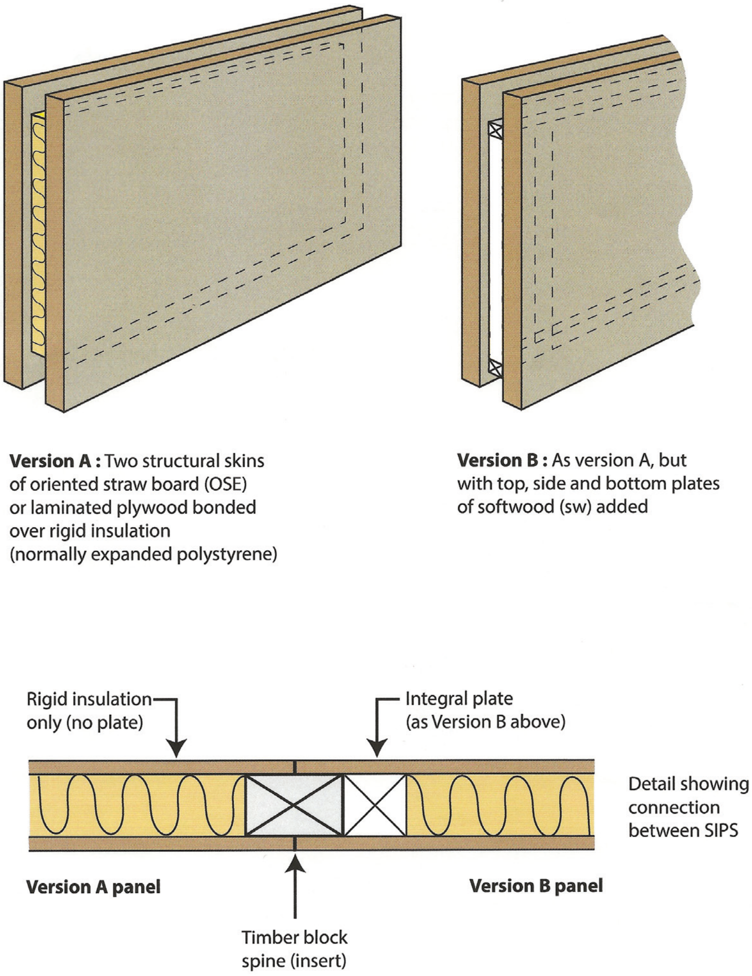

Figure 2.4 Diagrammatic sketch of a SIP panel

- **Prefabricated cassettes** – floor and roof cassettes are commonly used in residential construction. Roof cassettes are often used where the roof space is designed to be used for accommodation purposes and consist of timber or steel SIPs that span between the eaves and ridge of a house. Floor cassettes are pre-formed sections of floor complete with flooring (board or chipboard) and joists (timber, metal or web). Ceilings normally have to be installed on site.

Figure 2.5 An example of a floor cassette

This floor cassette is formed around a light steel framework and is ready to be installed as part of the upper floor of the steel-framed building behind. Note the pre-formed holes in the floor for the service installations.

3. Off-site manufacture (OSM) – Hybrid construction

Hybrid construction is also referred to as semi-volumetric construction as it combines both volumetric units and panellised systems. It involves the installation of highly serviced volumetric pods (or cells) such as bathrooms or kitchens into dwellings that have been constructed with panels.

4. Off-site manufacture (OSM) – Sub-assemblies and components

These are prefabricated sub-assemblies or components that can be incorporated into MMC dwellings or into conventionally built dwellings. They include both large and small sub-assemblies, e.g. prefabricated (i.e. pre-assembled) plumbing systems; prefabricated chimneys, dormers, door canopies and porches; prefabricated foundations; trussed rafters; door sets.

Figure 2.6 Typical examples of OSM sub-assemblies

In the top photograph, a prefabricated false brick chimney is waiting to be lifted into place. In the middle photograph, factory-created timber I-beams have been used to form the structural element of this upper floor and the bottom photograph shows a floor formed with mass manufactured metal web joists.

5. Non off-site manufactured MMC

These are on-site systems that make use of modern materials and construction techniques in innovative ways. They include structural systems that do not properly fit within off-site prefabricated systems. On-site construction and/or assembly of components is used in a highly efficient manner in order to achieve increased speed, quality and cost-saving. Often, this will involve the use of conventional components, but in an innovative way. Examples include:

- **Thin joint masonry** – autoclaved aerated concrete blocks manufactured to carefully controlled sizes and finish are laid with 2–3mm thick horizontal and vertical mortar joints (rather than the normal 10mm joints). The high-quality masonry combined with the thin joints provide a wall that is more easily erected, has greater thermal efficiency and offers a base for a sprayed plaster finish.
- **External Wall Insulation System (EWIS), also known as an External Thermal Insulation Cladding System (ETICS)** – these are pre-designed and manufactured insulation systems for external application to buildings. They are non-loadbearing and generally consist of separately installed layers of insulation, an external water-resistant protective layer and a decorative finish. (They are discussed in Chapter 5.)
- **Permanently Insulated Formwork (PIF)** – the principle of PIF, also known as Insulating Concrete Formwork (ICF), is that modular hollow blocks are formed from insulation material (usually expanded polystyrene, sometimes wood cement) to create a formwork of up to 3 metres high into which concrete is poured. The insulating formwork is left in situ to provide a permanent shuttering for the structural walls of the house. The interlocked elements of the formwork can be reinforced with steel rebar or plastic connectors. Once the concrete has cured, it creates a highly insulated and high strength concrete frame that will meet current Building Regulation thermal requirements and can be as low as 0.10W/m^2K (suitable for Passivhaus design). Finishes of plaster, render or other cladding material can be applied.

  The system has been used for some 50 years, especially by the self-build market, as it requires only semi-skilled labour and is quick to construct. In recent years it has gained more general popularity within the construction industry. The basic modular blocks can be fabricated on or off-site and fitted together as construction proceeds. Furthermore, ICF is one of the few walling systems approved for the construction of domestic basements. (One typical ICF or PIF system is that of 'Styro Stone' (a registered trademark) and this is discussed in more detail in Chapter 17.)

Section Four: Conclusion

Overview

It will be realised from reading this chapter that MMC is a dynamic process that involves many different individual design, manufacturing and construction processes. It also involves many different parties engaging in the MMC processes either as decision-makers in both the public and private sectors or as designer and as constructors. This chapter has identified and discussed the bare principles and set out some examples of MMC. However, it needs to be realised that MMC embraces many different types of both on-site and off-site processes, certainly far more than can be described in this textbook.

There are many recent examples of increasing investment by UK developers and investors in MMC in the UK housing market and it is starting to attract international investment. Recently, a number of international house developers and manufacturers have started to enter the UK housing market by engaging in alliances with UK developers. Some of these partnerships are underpinned by finance from the Government's Home Building Fund administered through Homes England, which was established in 2018 to accelerate housing development. Furthermore, the Government is funding its Construction Innovation Hub to find ways in which to transform the methods used to design, construct and manufacture buildings.

There is little doubt that, in the last few years, there has been increasing awareness by the UK Government, the construction industry and its clients that MMC is an essential element now and in the future of an efficient and cost-effective industry. In 2015, off-site manufacture was used for approximately 15,000 new homes, but has been increasing since that date, particularly since 2018. This is, in part, driven by recent UK Government proposals to use off-site manufacturing to modernise construction processes, but also because developers have identified that MMC results in improved overall efficiency and increased productivity by the workforce as well as better quality, accelerated delivery of the completed housing and increased profitability.

3-D printing and the future

Exactly how far MMC can be taken remains to be seen, but increasing use of established MMC processes and the introduction of new and increasingly sophisticated processes, such as 3-D printing, mean that its common use in the future appears likely for both whole buildings and also the various elements and components that need to be provided in their construction.

3-D printing is the process of manufacturing a physical object from a 3-D digital model. This is achieved by laying down many thin layers of printed material to produce the object required. The first products, created in the 1980s, were small objects and quite crudely formed. The first commercially viable printers were developed in 2006 and their capability then developed rapidly over the next ten years or so. This led, in 2018 in France, to the creation, with a 3-D printer, of a complete full-scale family house. This took 54 hours to build and achieved a saving against traditional construction of 20 per cent. The 2019–2020 coronavirus outbreak in China resulted in isolation pods being 3-D printed in their dozens to meet emergency needs.

Currently, the greatest use of 3-D printing in the construction industry is for the creation of detailed models during the design process to assist in decision-making prior to construction. In the future, it is likely that parts for buildings, if not whole buildings, will be commonly manufactured by this process.

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3 Regulatory controls and building standards

Section One: Introduction

Overview

This chapter sets out a brief overview of key statutes, regulations and over-arching advice as well as UK and EU standards that apply to the design and construction of houses. These matters are also highlighted, but not necessarily discussed in detail, in the chapters that follow. Brief description is also included on a number of organisations that provide key guidance on good building standards.

Historic background

The materials and techniques used in the construction of low-rise houses have changed considerably during the last few hundred years and this evolution is due to a number of factors besides the obvious one of advances in technology. Economic, political and social pressures have all played their part in affecting the quality of our built environment. Perhaps the most influential factors were the social pressures brought about in the 19th century by the realisation of the connection between poor housing and health.

This led to a number of Acts of Parliament from the middle of the 19th century onwards, which eventually established basic requirements for good construction and sound housing conditions. These requirements included adequate sanitation, adequate water supply, freedom from damp, adequate natural light and adequate ventilation. These key criteria still influence how houses are built today, e.g. building design standards are set out in the Building Regulations (which are discussed later in this chapter).

Other legislation affecting the construction of houses includes statutes such as the Public Health Acts, Housing Acts, Planning Acts and various regulations such as the Water Regulations. Brief details of some of the key statutes and regulations are set out below and further references can be found in the chapters that follow.

Section Two: Statutory control of design and construction

Planning Controls

The Town and Country Planning Act 1947

There was no national legislation governing planning until the Town and Country Planning Act 1947 from which date all 'new development' within the United Kingdom requires planning permission. Subsequent legislation has amended the 1947 statute, but the principle is still that all new development is subject to planning control. This includes new buildings, new extensions if above a certain size or to the front of a building, demolition of a building, rebuilding and the change of use of a building. There are further planning controls over **listed buildings** (i.e. buildings placed on the **Statutory List of Buildings of Special Architectural or Historic Interest**) and over buildings situated in a Conservation Area (as designated by the **Town and Country Planning Act 1990**).

Planning applications

A planning application is submitted to the planning department of the appropriate local authority setting out details of the proposed development. In terms of a wholly new building, the application may be for outline permission or detailed permission. There is a fixed time period in which a local authority must make a decision on the application or reject it.

- ***Outline planning permission*** *– a planning application with fewer details of the proposal that is submitted to a local authority to find out whether the proposal is likely to be accepted. Often, permission will be granted subject to 'reserved matters' – matters, such as appearance, means of access, landscaping, layout and scale, which will be subject to the submission of a detailed planning application later.*
- ***Detailed planning application*** *– an application showing full details of the proposed works for a new building or one that involves making a material change in the use of a building.*

The planning application may be passed (often, with conditions) or rejected by the local authority. If a planning application is rejected, there is a system of appeal, which is made to the **Planning Inspectorate**, currently part of the Ministry of Housing, Communities and Local Government.

The statutory controls allow certain classes of development to houses, but not to flats, maisonettes and other buildings, to be permitted development, i.e. certain changes can be made to a house without the need to obtain planning permission. These '**permitted development rights**' are set out in the **General Permitted Development Order 2015** (as amended) and include, subject to certain restrictions, such building works as the erection of small extensions and porches and some types of loft conversions. Local authorities can introduce their own restrictions with regard to permitted development rights, often with regard to conservation areas.

Some building works such as internal building works or general maintenance works to an existing building are not classed as 'development' and may not need permission unless the works will change the building's external appearance or are being undertaken in a protected building, e.g. a listed building.

Trees and hedgerows

Any tree of significance that is 6 metres or more in height can have a **Tree Preservation Order (TPO)** placed on it by a local authority. The TPO may be in place to protect a single tree, trees in a group or even a woodland. Once in place, local authority approval is needed to top or lop a tree or to chop it down. A court can overrule a TPO if it considers the tree to be a nuisance to an adjoining neighbour. Breach of a TPO is an offence under the **Town and Country Planning Act 1990.**

Under the same statute, all trees (with some exceptions) in a Conservation Area that have a trunk diameter exceeding 75mm (measured 1.5 metres above ground level) are protected and a **Section 211 Notice** must be issued to the local authority six weeks before any activity to lop, top, cut down or uproot them. This gives time for a TPO to be considered. Breaching this requirement can lead to a fine of up to £20,000.

New development often involves the removal of hedges. This must be carefully considered as, under the **Hedgerow Regulations 1997**, it is an offence to remove more than 20 metres of a hedge in a rural area without planning permission. It is also a legal requirement to inform the relevant local authority before the removal of any important hedge or part thereof, i.e. a hedge of historical importance.

The Building Regulations in England

Introduction

This subsection reviews the over-arching principles of the Building Regulations as they currently apply in England. Further reference is made to these principles in the chapters that follow, with the exception of Part B: Fire: Volume 1: Dwellings which is discussed in more detail at the end of this subsection.

Historic background

Limited regulation of building construction in England and Wales began in the 12th century, although more detailed control occurred as a result of the Fire of London, which led to the London Building Act of 1667. More local legislation followed over the next two centuries for London and there were local statutes for Bristol and Liverpool. More generally, the Public Health Acts of 1848 and 1858 allowed local authorities generally to create their own byelaws, initially covering public health and followed by further byelaws for the structure and stability of buildings.

The **Public Health Act 1875** led to the introduction by the Local Government Board of **Model Byelaws** in 1877. These provided guidance to local authorities in England and Wales for the control of construction standards, although it was several years before this practice became widespread, particularly outside the main urban areas. The Model Byelaws did not apply to London, which had its own London Building Acts for the control of construction within the capital.

The Model Byelaws were updated at intervals until 1965, when the first national mandatory Building Regulations for England and Wales were introduced. Again, these did not apply to London. The Building Regulations have been regularly updated since their introduction and, from 1987, they have applied to London as well.

On 31 December 2011, building regulation powers for England and Wales were separated, with those for the latter devolved to the Welsh Government. There are also separate Building Regulations for Scotland and for Northern Ireland. This textbook is based on the current Building Regulations for England only, although the differences at the time of writing this edition with those for Wales are relatively small.

The Building Regulations for England

All new building work and most alterations to existing buildings must meet the requirements of the current edition of the Building Regulations. These set mandatory standards of design and construction and are currently made by the Government under the statutory powers of the Building Act 1984. Their primary purpose is to establish minimum standards to ensure the health and safety of a building's occupants. They do not set out the quality or levels of workmanship to be achieved by the designer or the constructor.

The Building Regulations are divided into some 16 Parts (see Table 3.1) and are reviewed and updated at regular intervals. The latest full review at the time of writing was the **Building Regulations 2010** and the latest Part to be updated was Part B in 2019. A further standard review was due to take place at the time of writing, but this has been overtaken by the tragic events of the fire and deaths at the Grenfell Tower in London. The Building Regulations will be thoroughly overhauled as a result of this tragedy and also to deal with the effects of climate change.

A key point to note is that the Building Regulations are not applied retrospectively and, once controlled work has been completed, a building does not have to conform to later and higher building standards unless it has work undertaken on it that requires further statutory permission. This means that many buildings, including houses, do not comply with current building standards.

Approved Documents

Schedule 1 of the Building Regulations 2010 sets out its substantive requirements, originally divided into Parts A–P with Parts Q and R being added since 2010. Guidance on how to comply with the regulations is set out in a series of '**Approved Documents**' with each linked to a specific Part. The Approved Documents set out 'broad functional requirements' for the performance of a building. They offer a designer the opportunity of strictly following the technical guidance that they contain or, alternatively, undertaking more liberal interpretation as long as the design meets the minimum performance standards set out.

Table 3.1 The Building Regulations 2010 – Parts A–R

PART (NOTE: THIS IS ALSO THE APPROVED DOCUMENT TITLE)	TITLE
A	Structure
B	Fire Safety – *divided into:* Volume 1: Dwellings Volume 2: Buildings other than dwellings
C	Site preparation and resistance to contaminants and moisture
D	Toxic substances
E	Resistance to the passage of sound
F	Ventilation
G	Sanitation, hot water safety and water efficiency
H	Drainage and waste disposal
J	Combustion appliances and fuel storage systems
K	Protection from falling, collision and impact
L	Conservation of fuel and power – *divided into:* L1A – Conservation of fuel and power – new dwellings L1B – Conservation of fuel and power – existing dwellings L2A – Conservation of fuel and power – new buildings other than dwellings L2B – Conservation of fuel and power – existing buildings other than dwellings
M	Access to and use of buildings – *divided into*: Volume 1: Dwellings Volume 2: Buildings other than dwellings
N	Glazing – withdrawn and incorporated in Approved Document K
P	Electrical Safety – dwellings
Q	Security (*a new Part added in 2015*)
R	Physical infrastructure for high speed electronic communication network (*a new Part added in 2016*)
Regulation 7	Materials and workmanship

Note: Where individual Building Regulations' Parts or Approved Documents are referred to in the following chapters, the initial reference will be (for example) either to the Building Regulations: Part A – Structure or to the Approved Document: Part A – Structure. Subsequent references in that chapter to that same Part or Approved Document will adopt the industrywide abbreviation of naming just the Part, i.e. Part A.

The 'Approved Documents' are individually updated on a fairly frequent basis (most recently in 2013, 2015, 2016, 2018 and 2019). The latest Approved Documents have removed much of the prescriptive technical advice that was previously offered and designers and constructors are now directed to British Standards, British Board of Agrément Certificates and Eurocodes (see later in this chapter). A sense of the range of the performance requirements of the Building Regulations 2010 (as amended) can be gained from Table 3.1.

As well as the Approved Documents, there are sections within the Building Regulations dealing with definitions, procedures to be followed and the types of building that are exempt from control. Each edition of the Building Regulations has raised and extended the performance standards required of buildings, much of the recent focus being on electrical safety and sustainability requirements including the conservation of energy.

Application, approval and inspection

When the Building Regulations were introduced in 1965, local authorities were given the responsibility of ensuring that their provisions were met. Each local authority established a Building Control Service/Department to undertake the role. The procedure has involved the vetting and approving of submitted detailed applications based on proposed building plans and, once approved, the carrying out a number of inspections at critical stages of the work as it progresses.

The Building Act 1984 also introduced **Approved Inspectors** who are companies or individuals registered with the Construction Industry Council Approved Inspectors Register (CICAIR), which is a wholly owned subsidiary of the Construction Industry Council (CIC). Currently, an application can be submitted to either a local authority Building Control office or a registered Approved Inspector.

Once the proposed plans have been approved, it is a legal requirement of the Building Regulations that Building Control or an Approved Inspector is given notice before construction commences as well as when the work reaches specific stages, e.g. excavation for foundations, damp proof course level, drains laid, structural timbers installed.

There is also an alternative procedure in which no formal submission of plans is made before building takes place and notice of construction is given to the chosen building inspector body at least 48 hours before building commences. This simplified fast-track approach greatly reduces the amount of time involved as getting formal approval can take a minimum of 8 weeks and can often take longer, but it is risky as the design and the work may be rejected without notice. It should only be undertaken for small-scale works of simple design and construction where there is little chance of formal refusal or amendment.

The Building Regulations: Approved Document: Part B: Fire – Volume 1: Dwellings

The relevant requirements of the Building Regulations are more generally discussed in each of the chapters that follow. However, Approved Document Part B: Fire – Volume 1: Dwellings is discussed here, as its over-arching requirements do not easily fit into those chapters. Volume 1 includes dwellings under single occupancy as well as flats and houses in multiple occupation (HMOs).

In Approved Document Part B, it states that the provisions set out in the document have a number of general aims (see Table 3.2).

Table 3.2 The general aims of the Building Regulations: Approved Document: Part B – Volume 1: Dwellings

REQUIREMENT	AIM
B1	To ensure, when there is a fire, both: (A) a satisfactory means of sounding an alarm AND (B) a satisfactory means of escape for people
B2	To inhibit the spread of fire over internal linings of buildings
B3	The building must be built such that all of the following are achieved in the event of a fire: (A) the premature collapse of the building is avoided (B) sufficient fire separation is provided within buildings and between adjoining buildings (C) automatic fire suppression is provided where necessary (D) the unseen spread of fire and smoke in cavities is restricted
B4	To restrict both: (A) the potential for fire to spread over external walls and roofs [including compliance with Regulations 6(4) and 7(2)] AND (B) the spread of fire from one building to another
B5	To ensure both: (A) satisfactory access for the fire service and its appliance AND (B) facilities in buildings to help firefighters save the lives of people in and around buildings.

To meet these over-arching aims, Approved Document Part B sets out the principles of fire design that need to be met including the need for:

- *All buildings to have a fire detection and alarm system to British Standard (BS) 5839-6 which should incorporate smoke detectors and heat detectors as appropriate*
- *All habitable rooms (excluding kitchens) to have either an opening directly onto a hall leading to a final exit (i.e. a door leading to a safe external space) OR an emergency escape window or door (leading to a safe internal or external space)*
- *Buildings containing flats to have a common protected means of escape with limited travel distances from a habitable room to a final exit*
- *The provision of fire doors with minimum fire resistance periods, e.g. 30 or 60 minutes*
- *The control of internal fire spread including the fire behaviour of insulating core panels used internally*
- *The compartmentation of walls and floors to form a complete barrier to fire between compartments (i.e. separate units of accommodation) and these to have appropriate fire resistance*
- *Further requirements to apply when any dwelling has an upper storey more than 4.5 metres above ground level including the provision of a sprinkler system as an alternative provision (but mandatory requirement for flats with a floor more than 30 metres above ground level). These requirements also apply where a loft conversion is undertaken.*

The above list should not be considered comprehensive and there are many further requirements that need to be considered when undertaking the design of a new dwelling, undertaking works of redevelopment of an existing dwelling including extending it or a change of use of an existing building into a dwelling.

There are further mandatory requirements for houses in multiple occupancy (HMOs), i.e. a property with at least three occupants who are not in a single household, but share facilities, e.g. kitchen and/or bathroom. Such an occupant is six times higher at risk of death from a fire than in a comparable single occupancy house. These extra requirements are imposed by various statutes and regulations that are quite separate from the Building Regulations.

Other important statutes and regulations (in date order)

Defective Premises Act 1972

This statute applies to dwelling houses in terms of new construction, enlargement of an existing dwelling or conversion to a new dwelling. It does not apply to repairs and maintenance works. It states that the work is to be done in a workmanlike or professional manner with proper materials and the dwelling is to be 'fit for habitation' when complete. It imposes a legal liability on a contractor and a designer to a domestic client plus any subsequent purchaser or tenant within a six-year period from completion of the building works.

Health and Safety at Work etc. Act 1974

Background

The construction industry has been, and still is, one of the most dangerous industries in the UK. In 2018–2019, there were 30 deaths in the construction industry, only slightly less than agriculture (32 deaths), but more than manufacturing (26 deaths), out of a total of 147 deaths for all industries. There are also high levels of work-related injury and illness linked to construction. Death and injury are caused by site 'accidents', e.g. falls from height, falling material and collapses of built elements. Illnesses are the result of exposure to dangerous materials or inappropriate practice, e.g. dermatitis due to handling cement, cancer due to asbestos, musculoskeletal injury due to lifting heavy loads.

Workplace injury and ill-health in the construction industry cost an estimated £1.2b in 2018/19 (approximately 8 per cent of total industry costs). In recent years, fines applied by the courts have increased considerably and a breach leading to injury rather than death can now attract a fine exceeding £1m and a criminal conviction.

The Act

Historically, various statutes were introduced on a piecemeal basis to deal with health and safety (H&S) in the UK, but without great effect until the enactment of the **Health and Safety at Work Act etc. 1974** (HSWA). This statute (and its procedures) was the first piece of health and safety legislation that applied to *all* places of work in the UK and it provided a framework that enabled the introduction of further working H&S regulations by the Government. The law now recognises that it is impossible to remove all risks from work-related operations, but that an employer (and an employee) must act in accordance with recognised H&S and good working practices and procedures. Each employer must issue a safety policy, safety statement and other appropriate documentation.

The Act also established the **Health and Safety Executive (HSE)**, which is responsible for the administration, management, development and enforcement of occupational health and safety law. The HSE promotes compliance of health and safety statutes and regulations by means of advice, inspection, enforcement (in collaboration with local authorities) and prosecution. If it finds a contravention during an inspection of a building site, an HSE inspector can serve an **Improvement Notice** (for a serious offence), requiring action with a period of time, or a **Prohibition Notice** (where there is the risk of serious personal injury or death) which takes effect immediately.

The HSE publishes **Approved Codes of Practice (ACoP)** that offer advice on how to meet the regulations. Each ACoP has 'special legal status'. If a party is prosecuted for a breach of H&S law, it will need to show that it has complied with the law with regard to the matter. It can do this by showing that it has followed the advice included in an

ACoP. It is also possible to show that it used an alternative method in order to achieve compliance.

Any breach of the HSWA and other H&S legislation is a criminal offence. It needs to be noted that it is the only area of British law in which a party suspected of an offence is presumed to be guilty rather than innocent. Apart from any criminal liability on the part of the offender, there may also be a civil liability for a breach of contractual duty, breach of negligence in tort or breach of statutory duty. However, in most cases where there has been a breach, the HSE does not prosecute the offender unless there has been a death or serious injury involved. Lesser offences are heard in a Magistrate's Court and more serious ones in a Crown Court. If found guilty, the offender may be fined, imprisoned or both.

Health and safety regulations

There are a considerable number of H&S regulations and anyone working in the construction industry and allied professions must be fully conversant with those that impact upon any relevant activity. A small sample is set out below:

- **Personal Protective Equipment at Work Regulations 1992 (PPE 1992)**

  PPE 1992 imposes duties on an employer concerning the provision and use of personal protective equipment by all of its employees. PPE is equipment, such as safety helmets, high-visibility and other clothing, safety footwear, safety goggles, ear protectors, safety harnesses, that protects the user against health and safety risks in the workplace.
- **Control of Substances Hazardous to Health Regulations 2002 (COSHH)**

  Many dangerous substances that are used in the construction industry are now subject to these regulations. These substances can take many forms including:
  - *Mists, fumes and vapours*
  - *Dusts*
  - *Chemicals and products containing chemicals*
  - *Asphyxiating gases and gases generally*
  - *Biological agents, e.g. germs.*

  If packaging has any of the hazard symbols, then the product or substance is classed as a hazardous substance.

  COSHH requires employers to prevent or reduce workers' exposure to risk from hazardous substances. It sets out over-arching requirements for the discovery of health hazards, assessment of risk followed by the use of control measures to reduce harm.

  Apart from COSHH, asbestos, lead and radioactive substances have their own regulations.
- **Control of Asbestos Regulations 2012**

  Asbestos is a natural fibrous rock-based material that was used in the construction industry until 1999, so any building constructed, converted, refurbished or repaired before that date may contain the material. It was extensively used, especially in the 1950s and 1960s, in all types of building including low-rise domestic construction. Its uses included sprayed and boarded insulation material for heating systems, different types of roof coverings including slates and corrugated sheets, external and internal lining boards (where it was often used because of its fire-resisting capabilities), sprayed and applied finishes, such as textured coatings, e.g. Artex, commonly used to finish ceilings.

  Three of the six types of asbestos were commonly used – white (known as chrysotile), brown (amosite) and blue (crocidolite). Unfortunately, all asbestos is a health hazard, being highly toxic if inhaled, when it can cause a range of respiratory diseases including asbestosis, pleural thickening, lung cancer and mesothelioma, another form of cancer. About 4,500 people, most of who worked in construction, die from asbestos-related diseases each year; any illness often not appearing for several decades after exposure.

Asbestos products are safe as long as they are whole. However, when worn, damaged or cut, asbestos fibres are released into the atmosphere where they can be ingested. Although asbestos can no longer be used as a construction material, its existing presence in a building in an *undamaged* state is acceptable.

In terms of the redevelopment of existing houses, if a building is known to contain asbestos, or suspected of containing it, and its deteriorated state or proposed construction work requires its removal, any such activity needs to meet the requirements of the Control of Asbestos Regulations 2012. These are the most recent regulations on asbestos and place a legal duty on those in control of buildings to manage the risks from any asbestos that may be present. This includes carrying out a risk assessment by a specialist surveyor to determine whether a building contains asbestos and, if so, identifying where and how much. It also requires the building owner/occupier to have up-to-date records of its location and condition and a material risk management plan. If asbestos is identified, any removal should only be carried out by a licensed contractor. A breach of the regulations can lead to a fine and/or imprisonment.

- **Construction (Design and Management) Regulations 2015 (CDM 2015)**

  The law now requires all building projects to be properly managed and controlled with regard to health and safety. CDM 2015 applies to *all* construction work in terms of both its design and its construction. The regulations require the employer, designer and constructor of any building works to take full account of all health, safety and welfare implications during the design, construction, use and, ultimately, the demolition of a building. This includes all projects for new buildings and the conversion, redevelopment, refurbishment, repair, maintenance and demolition of existing buildings.

  Before any design or construction takes place, CDM 2015 requires a series of **dutyholders** to be appointed by the client. Ultimate responsibility for the project and the health and safety of all those involved rests with the client, so his or her choices are critical for its success.

Table 3.3 CDM Dutyholders and their responsibilities

DUTYHOLDER	RESPONSIBILITIES
Client	An organisation or individual who requires the building work to be undertaken and is responsible under CDM for its overall management. The client must make suitable arrangements for the appointment of other dutyholders who will undertake actual responsibility for design and construction
Principal Designer	Plan, manage, monitor and coordinate health and safety in the pre-construction phase where more than one designer is involved in the construction work
Designer/s	Prepare the design
Principal Contractor	Plan, manage, monitor and coordinate health and safety in the construction phase. Appointed where the project involves more than one contractor
Contractor/s	Plan, manage and monitor the construction work under their control
Workers	People who work for or under the control of contractors

HSE guidance states that the responsibilities of the client include:

1. *Appointing the right people (i.e. dutyholders at the right time)*
2. *Ensuring that there are arrangements in place for managing and organising the project*
3. *Allowing adequate time for the project to be completed safely*
4. *Providing information to the designer and the contractor*
5. *Communicating with the designer and the contractor*
6. *Ensuring that there are adequate welfare facilities on site*
7. *Ensuring a construction phase plan is in place*
8. *Keeping a health and safety file (this should be provided at the end of the project by the principal designer or, failing him/her, the principal contractor*
9. *Protecting members of the public including its own employees*
10. *Ensuring workplaces are designed correctly (where the work involves a new workplace or alteration of an existing one)*

CDM 2015 recognises that domestic clients, e.g. house owners or occupiers, will normally have no experience of construction works and will normally transfer their duties to a contractor or principal contractor.

Wildlife and Countryside Act 1981

This complicated statute consolidated a number of previous statutes. Together with other statutes and regulations, it protects certain species of birds (including when a bird is nesting) and other wild creatures (e.g. amphibians, badgers, bats, otters, red squirrels, reptiles) as well as wild plants, making it illegal and a criminal offence to kill or disturb them. Further legal protection is also given to some species, e.g. badgers by the **Protection of Badgers Act 1992** and bats by the **Conservation (Natural Habitats, &c.) Regulations 1994**.

If any development of a site or an existing building is affected by the presence of a protected animal or plant, the procedures set out in the statutes and the relevant regulation need to be followed. A full physical investigation of any existing building or a proposed building site should be carried out at an early stage as part of the pre-development/construction procedures.

Access to Neighbouring Land Act 1992

This Act came into force on 31 January 1993 and was introduced to deal with those situations where an owner or occupier needs to get onto adjoining land to undertake essential works to his/her own property, but is denied access to do so by the neighbour. This is because there is no right of access for repair in Common Law.

The statute gives a county court the power to grant an Access Order to a landowner or occupier as long as it does not unreasonably inconvenience the neighbour. The Order allows a person access to neighbouring land only for the purpose of carrying out reasonable and necessary works for the preservation of their own land and buildings. Such work includes repairs to a building, decoration, necessary alterations to preserve land and/or buildings, cleaning or repairs of sewers and drains, filling in a ditch, felling a diseased tree or shrub that is posing a threat to property.

The applicant will be obliged to make good any damage to the adjoining land. The court may also require the applicant to pay the neighbour a 'fair and reasonable sum' for access and pay compensation for any loss of privacy/inconvenience due to the work. If the adjoining landowner unreasonably refuses access, s/he is likely to be ordered to pay the legal costs of court action.

The statute has been little used as its provisions have been largely superseded by the Party Wall etc Act 1996.

Party Wall etc Act 1996

Historically, there have been practical and legal difficulties posed if an adjoining owner wished to frustrate proposed (and, often, highly essential) building works to a party wall between two properties. After the Fire of London, this city had its own legislation to deal with these circumstances but, elsewhere in England and Wales, only Bristol had similar statutory legislation in place. This led to much frustration outside of these cities.

The Party Wall etc Act 1996 applies to the whole of England and Wales. It introduces a system of rights to govern the boundary between two properties and gives protection of each owner's rights. These are known as:

- **The building owner (BO)** who wishes to undertake the building works
- **The adjoining owner (AO)** who is the owner of land, buildings or rooms adjoining those of the BO and of whom there may be more than one.

The statute allows works of construction or reconstruction on or near a party wall to be undertaken by a BO once (A) the required notice has been issued to any affected AO, (B) the statutory time periods have been met and (C) the general procedures set out in the statute have been followed. The statute uses a number of key terms as set out in Table 3.4.

Table 3.4 Key terms under the Party Wall etc. Act 1996

TITLE USED IN THE ACT	DESCRIPTION
Party Wall	A wall between two buildings which are under separate ownership
Party Fence Wall	A garden wall on a legal boundary
Party Structure	A floor or wall between two flats/apartments or common area
Excavations (the etc. part of the Act)	For new foundations that might affect a building on adjoining land under separate ownership

The statute covers works to all of the above. The Act also provides a mechanism for the resolution of any dispute that arises between the BO and any AO as a result of the intention to carry out work to a party wall. These mandatory procedures avoid the need to take the dispute to the courts and they must be followed by the BO and the AO.

The statute allows the BO and AO to come to an informal agreement over the proposed works (this is best set out in writing). If no such agreement over the works can be reached by the BO and AO, they are automatically assumed to be in dispute and the statutory procedures have to be applied. The parties must now appoint **Party Wall Surveyors (PWS)** to represent them. Each PWS is a building professional rather than a lawyer, as the former tends to have a more practical approach to the construction and legal problems presented. The PWSs and not the BO or AO then resolve the dispute.

Table 3.5 The role of the Party Wall Surveyors (once a dispute has arisen)

PARTY WALL SURVEYOR	ROLE
Agreed Surveyor	BO and AO agree to a single PWS to act for both
BO PWS	Appointed by the BO if no agreement
AO PWS	Appointed by the AO if no agreement (normally at BO expense)
Third Surveyor	Nominated by the two PWS to act if they cannot agree

The PWS's legal duty is to the party wall and not the disputing parties and they should be wholly independent once appointed. After appropriate discussion, the PWSs (any two or just the Third Surveyor, if no agreement is reached) prepare a written agreement, known as an **Award**. The Award sets out how and when the building work is to be carried out as well as other essential information, such as costs, provisos and restrictions.

Once the Award has been finalised and agreed by the PWSs, the proposed building works can take place. The Act gives the BO (and his/her PWS and contractor) a statutory right of entry onto the land of the AO to carry out the party wall works. The BO is required to give the AO 14 days' notice of the start of the works. It also makes it an offence for the AO to prevent such entry, with prosecution in a Magistrate's Court leading to a criminal record and a £1,000 fine.

Water Regulations 1999

The laws governing water supply are different for each of the home countries with separate regulations and byelaws for each country. The regulations safeguard the supply to each home and ensure that it is potable at the point of delivery. In England, the **Water Supply (Water Fittings) Regulations 1999** (as amended) apply from the point at which the water supplier's supply enters the property (normally the stop-tap or water meter on the property boundary) to the discharge point (e.g. a tap). The regulations do not apply when a property has its own water supply, e.g. an artisan well. (See also Chapter 20: Cold water services and Chapter 22: Hot water services for more detailed discussion.)

BS 7671: 2018: Requirements for Electrical Installations. IET Wiring Regulations (18th Edition)

Apart from the requirements of Part P of the Building Regulations (Electrical Safety – Dwellings), there is also the UK national standard for all new electrical installations. This is set out in the **18th Edition of the IET Wiring Regulations**, published by the Institution of Engineering and Technology (IET) in conjunction with the British Standards Institution (BSI). These Regulations (650 pages long) apply to the design of all new electrical installations, including those in domestic buildings, from 1 January 2019. They cover wholly new installations as well as additions and alterations to existing installations.

Once all work on an installation is completed, the electrical engineer is to issue an appropriate certificate, such as an Electrical Installation Certificate (EIC) or a Minor Electrical Installation Works Certificate (MEIWC). The certificate includes test results and a schedule of inspection.

It is recommended that all electrical installations are checked every five years against British Standard BS 7671 (which is regularly updated). (See Chapter 24 for a more detailed discussion of electrical installations.)

Section Three: Other authoritative organisations

Introduction

There are a number of sources which offer authoritative advice and guidance on good building practice. A number of the most important organisations are discussed briefly below.

National House-Building Council

Most volume house builders/developers are members of the National House-Building Council (NHBC) which sets out minimum standards of construction for new housing and produces regular bulletins and guidance relating to those standards and also to building defects.

The NHBC was established (under another name) about 70 years ago to raise standards in the housebuilding industry and to provide consumer protection. It achieves these aims by maintaining: (A) a register of qualified house builders/developers of new homes; (B) a model specification for new homes which is regularly updated and is now known as **NHBC Standards**; (C) by the inspection and certification of new homes under the NHBC **Buildmark Scheme**. The NHBC is also an Approved Inspector in terms of Building Regulations.

The critical factor underpinning the NHBC Buildmark Scheme is that members of the Council of Mortgage Lenders (CML) will not grant a mortgage on a new property unless it is the subject of a new home warranty, such as the Buildmark Scheme. Alternatively, CML will accept a Professional Consultant's Certificate, where a qualified building professional provides a certificate of quality and completion for a new home.

The Buildmark Scheme provides cover for new houses and flats, but it does not cover extensions or improvements to existing dwellings. It provides a quality guarantee or warranty that covers: (A) the initial new home purchaser for a 10-year period after construction as well as (B) any subsequent purchaser acquiring the freehold of the property within that 10-year period. The subsequent purchaser can make a claim providing that the defect was not evident at the time when the purchase was made, as such defects should have been considered in the sale agreement.

The NHBC 10-year guarantee period begins on the issue of a 10-year Notice (issued within one month of the completion of the building works of the property). The key points of the guarantee are set out in Table 3.6.

Table 3.6 Details of the NHBC 10-year guarantee period

TITLE	PERIOD	DETAILS OF NHBC COVER
Initial Guarantee Period	2 years	**ANY** defects that arise in the building during this period **MUST** be put right at the developer's expense
Structural Guarantee Period	8 years	In the remaining 8 years, the developer **MUST** put right any damage to the property worth more than £500 (this is indexed-linked since 1999). NOTE: Damage under the Scheme is defined as (and limited to) a defect caused by: a) A defect in the structure b) Subsidence, settlement or heave affecting the structure c) Contaminated land or failure of double-glazing.

If a developer fails to perform its duty under the Scheme to make good a relevant defect, the NHBC can step in and arrange for rectification of the defect. The developer can then lose its membership of the Scheme, with the result that the CML would no longer be prepared to offer mortgages on its houses and flats.

British Standards Institution (BSI)

Perhaps the most prolific and significant source of advice and guidance on good building practice is the British Standards Institution. This organisation regularly publishes detailed guidance on a variety of technical matters, key processes and procedures as well as standards for products produced by UK industry generally.

It publishes **British Standards (BS)** which cover such areas as the quality, performance characteristics and dimensions of building materials and components as well as offer essential guidance on building design procedures and the use of appropriate construction methods.

The importance of British Standards can be gauged from the fact that the Building Regulation's set of Approved Documents makes specific reference to them. The BSI now harmonises British Standards with the European Union's Eurocodes (see Section Four below).

Building Research Establishment Group (BRE)

Founded in 1921, the BRE undertakes consultancy, research into and testing of building performance including construction, fire and security which result in the publication of a large range of invaluable reports and digests on all aspects of construction and design. BRE Global is an independent, international certification body of fire, security and environmental products and services plus management processes and other products and systems.

British Board of Agrément (BBA)

This organisation undertakes independent and comprehensive appraisal and testing of manufactured products as well as systems and procedures in terms of quality, safety and reliability. The BBA procedures and the subsequent certificate take into account all relevant national requirements including those of the Building Regulations (Approved Documents), British Standards, Codes of Practice and NHBC. A successful product is awarded an Agrément Certificate and is then reviewed every 6 months by the BBA.

Other organisations

There are a number of trade bodies and other advisory organisations, such as the Brick Development Association (BDA), the Concrete Society, the Lead Development Association (LDA), the Timber Research and Development Association (TRADA), that publish design and technical guidance on the services offered and products produced by their members. Many individual material and component manufacturers also produce excellent individual design and technical guides on specific products.

Section Four: Eurocodes

The European Committee for Standardization (CEN) is an association that brings together the National Standardisation Bodies of 34 European countries including those from the European Union (EU) and the European Free Trade Area (EFTA). Its aim is to harmonise all building practice across the whole of Europe. It does this by means of Eurocodes, with the result that many British Standards have been, or are about to be, superseded by European Standards (EN).

Eurocodes are standardised design codes for building and civil engineering in CEN member states and are intended to become mandatory. For example, Eurocodes have been the main structural design standards for new structures in the UK since 2010, when the British Standards Institution (BSI), which is responsible for UK national standards, withdrew all national standards that conflicted with them. The BSI is now responsible for the implementation of all Eurocodes in the UK.

Eurocodes were introduced to overcome the problems caused by the differing design codes used by each country within the EU. They now provide over-arching technical specifications for the structural design of a range of engineering and construction projects including buildings, bridges, towers and silos. Currently, there are 10 Eurocodes with a total of 58 parts covering key design criteria, e.g. the basis of design; the design of structural elements in concrete, steel, steel and concrete, timber, masonry and aluminium.

The Eurocodes set out principles that must be met by the designer and also contain application rules that offer guidance on how to meet those principles. They are less prescriptive than British Standards and permit more innovation. Whilst not mandatory in the UK, a designer who does not wish to follow them must show that there is 'technical equivalence' to the Eurocode for a design.

Each country is allowed some flexibility in interpretation of the Eurocodes under Nationally Determined Parameters (NDP) which can cover such matters as partial safety factors and country-specific data such as wind and snow maps. These are set out in a National Annex that accompanies each Eurocode and which combines with the National Title Page and the National Forward to form the British Standard which implements the European Standard.

Currently, there is a review of the Eurocodes in operation and a new set is likely to be introduced in the period 2021–2023. This is likely to be easier to use than the present set, allowing greater flexibility of interpretation by those who have sufficient expert knowledge to be design innovative.

As the CEN sits outside of the EU, Brexit does not prevent the UK from continuing its membership of CEN in the future. At the end of 2018, it was agreed that the UK should remain a full member with full voting rights and engagement in all activities after Brexit was achieved. The UK Government has also stated, in the so-called Chequers Plan, that the BSI would not be permitted to push national standards over CEN or EU standards where they exist.

Section Five: Health, safety and deleterious materials

Deleterious materials are those materials that are hazardous to the health and safety of humans and/or buildings. Historically, society used whatever building materials were available locally with little regard to health and safety. The Industrial Revolution led to, firstly, a national trade in such materials and then an international trade, again with little regard to health and safety issues.

In recent years, greater awareness of the health and safety implications of the materials used in buildings has led to much more detailed review and control of both how we construct buildings and the materials and components used. Many materials that are deleterious to the health and safety of buildings and their occupants have been identified and most are now prohibited for use in the construction industry. Others will, undoubtedly, be added to the prohibition list as knowledge of adverse performance and effect is gained.

Table 3.7 Examples of deleterious materials divided into groups based on the problems they lead to

KEY GROUP	EXAMPLES
Materials that are dangerous to human health	• ***Asbestos*** – banned for use in the UK since 1999; a single particle can lead to lung cancer and various other respiratory diseases (some fatal) • ***Fibreglass*** – this fibre-based insulation product can irritate eyes, skin and airways and may lead to long-term health problems, so must be used with suitable protective equipment • ***Lead products*** – this material is still in general use with appropriate precautions, but can lead to brain damage, especially in children. *Note*: Lead in paint is now banned • ***Silica dust*** – found in stone, brick and concrete, this can lead to lung disease (silicosis) through inhalation, so appropriate personal protective equipment (PPE) must be used • ***Volatile organic compounds (VOC)*** – found in paints and other coatings, VOCs are extremely dangerous, causing eye, nose and throat irritation, headaches and nausea. VOCs can also damage the liver, kidney and central nervous system and they are now banned
Materials that cause failure in buildings	• ***High alumina cement (HAC)*** – now banned because the concrete can fail structurally in the presence of gypsum (found in modern plaster) or high levels of moisture, e.g. condensation • ***Marine sea-dredged aggregates not in compliance with BS EN 206:2013*** – such aggregates can contain a high chloride level leading to failure of concrete products • ***Woodwool slabs or cement board*** – in the past, these boards of softwood shavings covered in cement to form low to medium density boards have been used as permanent shuttering to reinforced concrete. However, this has often led to poor cover for the steel reinforcement and there are concerns about its performance
Materials that cause damage to the environment	• ***Chlorofluorocarbons (CFCs)*** – non-toxic non-flammable materials used in the production of plastic foams, but now believed to be a key agent in the destruction of the ozone layer around the planet. Use now banned in the UK and being phased out internationally • ***Polychlorinated Biphenyls (PCBs)*** – used as coolants and lubricants in electrical equipment since the 1920s. However, they do not biodegrade easily and, when burnt, they produce extremely dangerous and toxic dioxins. They were banned internationally in 1986

Unfortunately, many of these materials were extensively used in buildings over long periods before they were recognised as hazardous and a prohibition was applied. This means that many deleterious materials, as well as components containing such products, are still contained within buildings constructed before any prohibition was made.

Many dangerous substances that are used in the construction industry are now subject to the **Control of Substances Hazardous to Health Regulations 2002 (COSHH)** (discussed briefly in Section Two above).

Section Six: Flooding and flood resilient construction

Background

Historically, the weather on the British Isles has been temperate, i.e. mild, moderately wet and warm. Flooding has been a problem at various times in the past, but not excessively so and not for the great majority of the population. People knew not to build on the flood plains of rivers (no doubt, based on bitter experience). Occasionally, very severe weather led to high water levels that overflowed water courses and flooded adjoining land. Sometimes, this adversely affected adjoining properties.

The weather has changed dramatically in the last 30 years and climate change is now accepted as a reality. Its impact is increasing to the extent that, in the winter of 2019–2020, England experienced one-in-a-hundred-year-storms every few weeks and the highest February rainfall on record, with some areas receiving their highest rainfall in 200 years.

This changed pattern of weather, which involves very mild and extremely wet winters with very hot summers (often with big storms) and very high rainfall (in comparative terms), is predicted to be the likely future for the British Isles.

The effects of climate change have been exacerbated by the construction of many thousands of dwellings on flood plains in recent years. Currently, 10 per cent of new homes are built on a site at risk of flooding and the pressure on land use is such that the Environment Agency has predicted that the overall number of properties built on flood plains is likely to almost double over the next 50 years to 4.6 million. The number of dwellings built in the last 10 years that are at risk of becoming uninsurable due to flooding is believed to be approximately 70,000.

Figure 3.1 Examples of localised flooding

Small-scale localised flooding is a very common occurrence. The stream in the left-hand photograph is some 3.5 metres below the houses, but still flooded them when an adjoining culvert became blocked. Generally, the average depth of floodwater is 300mm and this is about the height of the water affecting the cottage in Oxfordshire on the right. It is sufficiently high to cause water damage to the building. Significant damage can be caused by even this shallow depth of water entering a building.

There are three common types of flooding and these are:

- ***Fluvial flooding – rivers****: Flooding created when a stream or river cannot cope with an increase in the volume of water flowing into it.*
- ***Pluvial flooding – surface water****: Flooding that occurs when a local drainage system reaches its capacity. This may be due to extreme rainfall, maintenance problems or fast-flowing surface water that the drainage system cannot absorb.*
- ***Surge flooding – coastal****: Flooding often created when a high tide coincides with a heavy storm. This leads to a rise in sea level and results in coastal flooding.*

Flood information sources

The Environment Agency's *Flood Map for Planning (Rivers and Seas)* identifies the probable level of flooding in a particular area by means of Flood Zones. These are set out in Table 3.8.

Table 3.8 The Environment Agency's Flood Zones

FLOOD ZONE	PROBABILITY OF FLOODING	DESCRIPTION OF THE FLOOD ZONE
Flood Zone 1	**Low probability of flooding**	Land having a less than 1 in 1,000 annual probability of river or sea flooding *(shown as 'clear' on the Flood Map, i.e. all land outside Zones 2 and 3)*
Flood Zone 2	**Medium probability of flooding**	Areas that could be flooded in an extreme flood event – between 1 in 100 and 1 in 1,000 probability of river flooding or between 1 in 200 and 1 in 1,000 probability of sea flooding occurring each year
Flood Zone 3 *(this is divided between two sub-zones)*	**Flood Zone 3a: High probability of flooding** **Flood Zone 3b: The functional flood plain**	Land with 1 in 100 or greater annual probability of river flooding or 1 in 200 or greater probability of sea flooding The land to where water flows or is stored in times of flood

It should be noted that the stated Flood Zones in Table 3.8 take no account of the effects of continuing climate change and, therefore, specific details may change as a result of the flood events of the winter of 2019–2020. The Chief Executive of the Environment Agency now (early 2020) considers that all new-build properties in Flood Zones 2 and 3 should have property-based flood resilience measures applied and also that no new development should take place in a flood plain zone unless 'there is no real alternative' and only with designs that are 'flood-proof'.

Details of flood risk at a particular locality can also be determined by visiting the UK Government's website at https://flood-warning-information.service.gov.uk/long-term-flood-risk/map and entering a post code. Furthermore, any development proposal needs to take account of the local planning authority's Strategic Flood Risk Assessment (SFRA). This considers climate change impact in general and includes an assessment of the impact that any specific land use change and/or development will have on flood risk in its area.

Community-based flood protection

The majority of dwellings in the UK have not been designed or constructed to take account of the possibility of being affected by flooding. This is particularly so for older buildings and most modern dwellings are also not specifically designed to accommodate flooding. Historically, most towns and villages were created close to a water course for reasons of water supply and drainage and this has resulted in them being more liable to suffer flooding, e.g. Carlisle, Hereford, Tewkesbury, Worcester, York. Some properties in York have been subjected to flooding at least a dozen times in the last 15 years. Flooding has often been exacerbated by more recent development on flood plains adjoining these and other towns and villages.

Various community-based flood defence measures have been undertaken to offer protection to buildings against flood water, increasingly so since the Second World War. They consist of a variety of works provided by the Environment Agency and other authorities including:

- *The provision of flood barriers*
- *The creation of local flood water drainage schemes*
- *The regular clearing and dredging of water courses*
- *The provision of emergency barriers and pumping systems that prevent flooding and/or remove it when it overflows a protection scheme*

- *The slowing down of water course flow by planting of trees and hedges, restoring meanders and creating artificial dams that leak*
- *The creation of temporary flood water storage areas on farmland*
- *The de-syncronising of peak flows from tributaries into larger rivers, i.e. slowing down flow in a tributary to reduce a flood peak downstream.*

Flood resilient construction

Flood water will almost certainly be full of contaminants such as sewage, silt, salt and various chemical and biological substances. It can enter a building by various routes. These include entry:

- *Through gaps between doors/windows and frames and any cracks in joint sealant around the opening*
- *Via air bricks (especially those for underfloor ventilation)*
- *Through gaps around pipes and cables (often via ducts in walls and floors)*
- *Through cracks in masonry or its joints or through framed construction of external walls (and/or a party wall) or through permeable masonry*
- *Through or around a damp proof course (DPC) in a wall*
- *Via seepage through and/or around the lowest floor/s (and the walls of a basement)*
- *Via backflow through an overloaded storm or foul drain.*

It needs to be recognised that any new dwelling in an area where there is the possibility of flooding needs to be designed to provide an initial defence against the level of flood water that might occur and to be remediated easily and quickly if those defences are breached. There are different challenges in terms of individual buildings depending on whether they are existing or new buildings.

New dwellings: Recommended works for any newly constructed dwelling in a flood-risk location include the following flood resilient measures that should be applied to any floor level likely to be affected by flooding (based on BRE advice):

- *Water-resistant plaster or lime-based plaster or waterproof magnesium oxide wall boards or plasterboard that is installed horizontally (to reduce replacement requirement)*
- *Concrete rather than timber floors with water-resistant membrane under the floor and in the walls and plastic sheet finishes*
- *Plastic skirtings and architraves or gloss-painted timber*
- *Drain channels beneath the floor of each room to more quickly remove flood water*
- *Water-resistant insulation in the walls, e.g. injected foam cavity insulation*
- *Water-resistant insulation under the floor, e.g. spray-applied polyurethane (PUR) foam*
- *Internal doors fitted with quick-release hinges or of plastic or resin-bonded board construction*
- *Enhanced seals and locks to external doors and windows to enable them to be flood-proof*
- *Removable air brick covers (installed immediately a flood becomes a possibility and removed afterwards to allow continuing underfloor ventilation)*
- *One-way valves in all drains to prevent water from the sewers entering the dwelling together with sealed manhole covers*
- *The provision of an automatic sump and pump to remove any flood water entering the dwelling to above the external flood level – this should be independent of any other drainage system*
- *Electrical sockets and switches installed above any possible flood level with wiring from above and not below*
- *Central heating boilers at high level or on an upper floor*
- *Service meters above the highest flood level*

- *Kitchen units formed from resin-bonded board, plastic or stainless steel with all-ceramic worktops*
- *Fitted kitchen appliances installed above worktop height.*

Other design measures that should also be considered include creating a ground floor that has no residential accommodation, e.g. only garaging and storage areas with unfinished wall surfaces and minimal services. Any oil or liquid gas storage tank should be installed above the potential flood level if possible or have inlet and outlet at high level with appropriate non-return valves and be anchored/restrained so that the tank cannot 'float'.

Externally, adjoining ground should slope away from the building if at all possible and all paved areas and hard standings should be water permeable. In urban areas, where there can be many impermeable external surfaces, rainwater is normally drained via underground pipework to local water courses, often leading to flooding. Sustainable urban drainage systems (SUDS) should be considered. These are carefully designed water management systems that link man-made drainage systems to natural water courses and other water retention features in order to more readily absorb and control water flow and avoid flooding.

Existing dwellings: Many of the above flood resilient measures can also be applied retrospectively to existing dwellings. However, where such buildings have already been subject to flooding, the remedial work and subsequent flood resilience measures must wait until the building has had water-damaged joinery, fittings and finishes stripped out and been allowed to completely dry out, a process that can take many months.

Figure 3.2 The River Avon at Malmesbury in Wiltshire floods regularly

Flood defence measures are in place for this older house that gets regularly flooded (note the water mark on the render). They include both a door guard or barrier and sandbags.

One final point to note is that many properties are flooded because, although flood defence measures have been put in place, the owner/occupier has failed to properly and fully maintain them.

Section Seven: Conclusion

The construction industry is highly regulated by the Government and also by key industry bodies such as the NHBC. Many of its construction processes, materials and components also need to comply with relevant performance and quality standards, such as those set out by the BSI and the BBA. It should also be noted that whether the UK is in the EU or has left, Eurocodes also apply.

Developing a new building or altering an existing building, whether large or small, is a complex process in terms of both design and construction and failure occurs too frequently – sometimes with huge implications, e.g. the Grenfell Tower fire; at other times with (relatively) small impact, e.g. incorrect taps installed. Such failures may be due to key weaknesses in the design and/or construction processes or because of the consequences of inappropriate maintenance, repair or redevelopment. Both design and construction also need to take account of changes in the key factors that influence how buildings are used and perform, e.g. physical and mental disability, sustainability requirements, environmental change.

However well-developed a regulatory system is in place, there will always be the need for further performance and quality standards to be considered and then put in place. The failure of the Grenfell Tower has revealed inherent weaknesses in the statutory system of building controls that cannot be ignored by those who regulate and those who manage the use of buildings. Construction professionals, the construction industry itself and all those bodies who regulate it must ensure that there is no repeat of such a failure.

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4 Sustainable homes

Introduction

This chapter provides an introduction to the extremely important issue of sustainability and housing. It starts by considering the idea of sustainable development and sets out how its three constituent parts – social sustainability, economic sustainability and environmental sustainability – interact. The chapter then concentrates on environmental sustainability. This is because although all three components are key to the very notion of sustainability, environmental issues have the biggest direct impact on the construction of individual dwellings which is the focus of this book.

Sustainable development – an overview

The idea of sustainable development, that is to achieve sustainable outcomes from human activity, has been around for some considerable time. Sustainability can be seen as a rather complex notion that, in detail if not in concept, has become so all encompassing, and can include so many factors, that it is difficult to articulate, never mind measure. One of the consequences is that it is often easier to prove a negative, i.e. that something is not sustainable, rather than a positive, i.e. that something is sustainable. Also the term 'sustain' or 'sustainable' is used, more so now than ever perhaps, in the sense of 'keeping something going or maintaining it'. So you could talk about the need to sustain the market for diesel and petrol cars for example – which is clearly an anti-environmental notion.

The oft-quoted definition of sustainable development by the Brundtland Commission (1987) 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs' is aspirational but does clearly refer to needs rather than wants.

It is important to understand that although the idea of sustainable development can be seen to have emerged from various environmental concerns, it is much wider in scope than just the interaction between development and the environment, because sustainability also encompasses social and economic issues and activities. Sustainable development can be seen to be that which brings the best fit between social, economic and environmental concerns. It aims to maximise all of these three benefit categories as far as possible, but there is also an implication that there may be a trade-off between them. That is, there may be a case where, for example, realising social benefits is justifiable even where there may be some negative effects on the environment – and vice versa. An example might be where the creation of employment opportunities, or a new residential development in an area of housing need, may result in some loss of environmental benefits. Alternatively the necessity to protect the environment in a particular instance may be justifiably at a cost to social and economic benefits. So although as observed, a sustainable approach would be to seek solutions that maximised all three benefits, it may be that some aspects of sustainability are considered, in particular cases, to be more important than others. There is, however, generally an implication that economic benefits should be long term rather than short term, and should not be sought at the cost of social and environmental benefits. It can be seen that a key aspect of sustainability is social sustainability – and that environmental benefits and (some) economic benefits are also, or at least can be, social benefits.

Sustainable development and housing

Sustainable development, and hence the notion of sustainability, then, is concerned with the synthesis and integration of social, economic and environmental benefits.

In the context of housing, sustainable development will require that a variety of issues, including such matters as affordable housing, mixing social and private housing, the development and retention of character and a sense of place, access to facilities, infrastructure and centres of employment, etc., need to be addressed alongside environmental issues.

In relation to housing development and environmental sustainability specifically, issues such as where to build will raise a number of important policy concerns such as, for example, the provision of homes in rural areas, the use of brownfield sites (which essentially 'recycle' land), the capacity of existing infrastructure, access to public transport, etc. So a low energy development which is situated so that people have no choice but to travel by car to shops, places of recreation, work, etc., cannot be considered environmentally friendly. Indeed a common, and valid, criticism of new housing, particularly perhaps in some suburban and semi-rural areas, is that it is very often isolated from sustainable transport options and therefore its occupiers are far too car-dependent.

Within a particular housing development, design issues, such as safety, character, car-free areas, play areas, the provision of green and recreational space, and the encouragement and protection of wildlife habitat, etc., are examples of some of the environmental sustainability factors that should be addressed.

There has also been much emphasis on the risk of flooding in recent years. Ensuring that a housing development is safe from the risk of flooding is an important sustainability issue which relates to whether or not the development is sited in a flood-risk area, and, if it is, how the design of the site and the individual properties can mitigate the risk of flood damage. Another important factor is the need to ensure that new developments are designed so that they do not increase the risk of flooding elsewhere. Therefore sustainable drainage designs (SUDs) are an important contribution to reducing flooding risk (as well as pollution).

The National Planning Policy Framework (NPPF), which only applies in England, was introduced in 2012 with revisions in 2018 and 2019. It replaced Planning Policy Statement 1 – Planning and Climate Change (PPS1). The NPPF states that 'The purpose of the planning system is to contribute to the achievement of sustainable development' and that 'Plans and decisions should apply a presumption in favour of sustainable development.' The policy refers to three over-arching objectives which, as can be seen, reference the three tenets of sustainable development referred to earlier:

> ***an economic objective*** *– to help build a strong, responsive and competitive economy, by ensuring that sufficient land of the right types is available in the right places and at the right time to support growth, innovation and improved productivity; and by identifying and coordinating the provision of infrastructure*
>
> ***a social objective*** *– to support strong, vibrant and healthy communities, by ensuring that a sufficient number and range of homes can be provided to meet the needs of present*