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BARRY'S INTRODUCTION TO CONSTRUCTION OF BUILDINGS

Third edition

Stephen Emmitt
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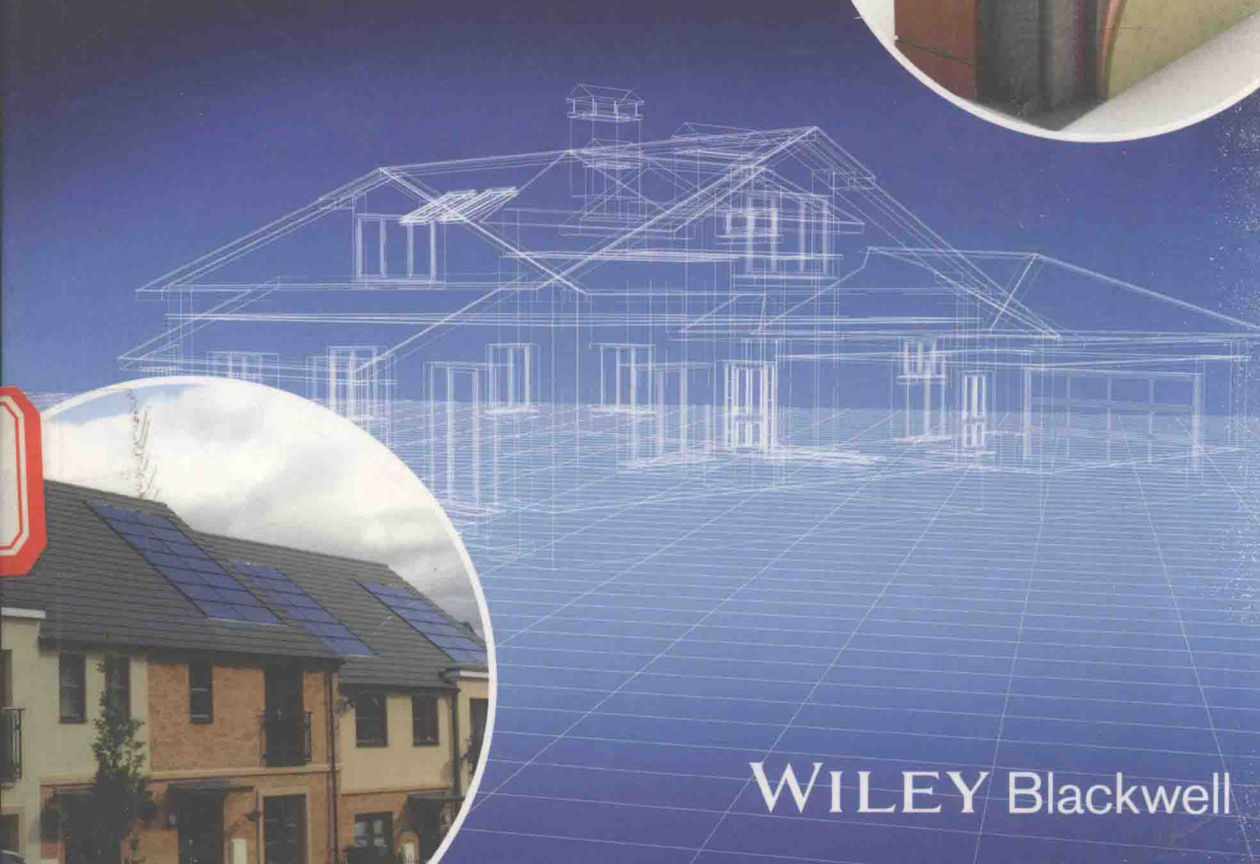

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Preface

Robin Barry's *The Construction of Buildings* was first published in 1958 and quickly became an established source of information for students of building design and construction. When we became involved the initial task was to embark on a major redesign and updating exercise, taking five volumes of the work and distilling it into two comprehensive books: *Barry's Introduction to Construction of Buildings* and *Barry's Advanced Construction of Buildings*. The intention was, and still is, that the 'introduction' volume deals with topics normally taught in the first year of a student's studies and the 'advanced' volume addressed topics usually covered in the second year. Our philosophy remains the same: to provide informative and engaging material that will help students of building design and construction understand the fundamentals of how we construct sustainable buildings. Once again we have tried to do this in a way that represents exceptional value to the reader.

In the third editions of the books, we have made the books easier to navigate by repositioning some of the material. For example, all of the content relating to services has been included in the *Introduction* volume, which has allowed some space to better address indoor climate (Chapters 11 and 12). We have also added a new chapter that deals with heat loss and heat loss calculations (Chapter 13). *Barry's Advanced Construction of Building* contains a new chapter on obsolescence and revitalisation of our building stock (Chapter 11). Combined the two books cover the entire life cycle of buildings underpinned by an environmentally sustainable ethos.

Application of fundamental principles of building will be coloured by prevailing national and international legislation and, to a certain extent, local traditions of building: we feel that this is how it should be, rather than slavishly copying the details and information in the *Barry* books. Although we have continued to make reference to the Building Regulations for England and Wales to help explain some of the issues, we have tried to remain faithful to Robin Barry's original philosophy and describe building elements in relation to their function. Thus the contents are applicable to readers, regardless of specific location.

Stephen Emmitt
Christopher A. Gorse

Acknowledgements

Over the years our students have continued to be the inspiration for writing books and they deserve our heartfelt credit for helping to keep our feet firmly on the ground by asking the 'why' and 'how' questions. Feedback from our readers and reviewers also helps us to keep the *Barry* series relevant and topical. It would, of course, be an impossible task to write this book without the support and assistance of our colleagues in academia and constant interaction with industry, for which we are extremely grateful. We would like to mention and thank Mike Armstrong (Shepherd Group), Joanne Bridges (Yorkon), Mikkel Kragh (Dow Corning), Shaun Long (Rossi Long Consulting), Karen Makin (Roger Bullivant), Jennifer Muston (Rockwool B.V. / Rockpanel Group), Gordon Throup (Big Sky Contracting) and Paul Wilson (Interserve). We would also like to thank the numerous other individuals and organisations, many of whom have been very generous with their time, allowing access for photography and giving valuable advice. We trust a 'global' acknowledgement of our gratitude will go some way to acknowledge their collective help.

About the Companion Website

This book's companion website is at *www.wiley.com/go/barrysintroduction* and offers invaluable resources for students and lecturers:

Contents

1 Introduction

The aim of this short introductory chapter is to highlight some of the factors that determine how buildings are constructed and also to provide some context to the chapters that follow. Related issues are dealt with in the introduction to *Barry's Advanced Construction of Buildings*. A brief overview of the function and performance of buildings leads into a discussion about environmental factors and sustainable building. This is followed by a description of the general principles of construction, concluding with some comments on legislation, sources of information and making informed choices.

1.1 The function and performance of buildings

Buildings are constructed, altered, upgraded, restored or demolished for a variety of reasons. Whether the aim is simply to provide more space or to make a financial gain from speculative development, all building projects need to fulfil a function and meet set performance criteria, no matter how fundamental or sophisticated the client's requirements may be. Buildings, regardless of function, will have an impact (either positive or negative) on the environment throughout their entire life. Environmental impact will be influenced by many factors, such as the responsible sourcing and manufacturing of environmentally sustainable materials and building products; the decisions taken during the construction process; the actions of owners and occupants through a long period of use, reuse, alteration and repair; through to deconstruction at the end of the building's useful life. At this 'final' stage many materials and components can be recovered and reused, or recycled for use in new building products, helping to reduce the amount of material sent to landfill and improving the environmental impact of buildings. Environmental performance of buildings is an important consideration for all building projects, be they new build or work to existing structures.

Function

The primary function of a building is to provide shelter from our weather, a container for living, working and playing in. The principal functional requirements include:

- ❑ Shelter
- ❑ Security

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- Safety (and comfort)
- Ease of use and operation (functionality)
- Ease of maintenance, periodic repair and replacement/upgrading
- Adaptability and durability
- Ability to reuse and recycle materials and components at a future date

The overall goal is to achieve these functions in an economical, safe and timely fashion using the most appropriate resources available and with minimal negative impact on the environment. These primary functional requirements are explored in the chapters that follow in relation to specific building elements.

Performance

The performance of the building will be determined by a number of interrelated factors set by the client, legislation and society. Clients' performance requirements will vary from project to project. However, the main considerations are likely to be:

- Space, determined by a figure for floor area and/or volume (and related to anticipated use)
- Thermal and acoustic performance (the quality of the indoor climate)
- Design life and service life of the building and specific building elements
- Cost of construction, cost in use and cost of demolition/deconstruction and recycling
- Quality of the finished building (functionality and durability)
- Appearance of the finished building
- Environmental impact

Other specific performance criteria will relate to the use of the building, for example the provision of special work surfaces for catering establishments. Legislative performance requirements are set out in building codes and regulations (see 'Building Control and Building Regulations'). Specific performance requirements, for example the thermal insulation of walls and fire protection of doors, must be met or bettered in the proposed construction method.

Quality

Function and performance will influence the quality of the building. The quality of the completed building, as well as the process that brings it about, will also be determined by the quality of thought behind the design process, the quality of the materials and products specified, and the quality of the work undertaken. There are a number of different quality issues:

(1) Quality control is a managerial tool that ensures both work and products conform to predetermined performance specifications. Getting the performance specification right is an important step in getting the required quality, be it for an individual component or the whole building.

(2) Quality assurance is a managerial system that ensures quality service to predetermined parameters. The ethos of total quality management aims at continual improvement and greater integration through a focus on client satisfaction. Manufacturers, contractors and professional consultants use this.
(3) Quality of the finished artefact will be determined by a number of variables constant for all projects, namely, the:
   - Interaction and characteristics of the participants engaged in design, manufacture and assembly
   - Effectiveness of the briefing process
   - Effectiveness of the design decision-making process and resultant information
   - Effectiveness of the assembly process
   - Effectiveness of communications
   - Time constraints
   - Financial constraints
   - Manner in which users perceive their built environment

The required quality of materials and workmanship will be set out in the written specification. Good quality materials and good quality work tend to carry a higher initial cost than lower quality alternatives; however, the overall feel of the building and its long-term durability may be considerably improved: we tend to get what we pay for. When making decisions about the materials and components to be used it is important to consider the whole life cost of the materials, not just their initial capital cost and the cost of labour to assemble the materials.

Economics

The building site and the structures constructed on the land are economic assets. In addition to the cost of the land there are three interrelated costs to consider. The first is the initial cost, the cost of designing and erecting the building. This is usually the primary and sometimes the only concern of clients and developers. It covers professional fees and associated costs involved in land acquisition and permissions, the capital cost of materials and components and the labour costs associated with carrying out the work.

The second cost to consider is the cost of the building in use, i.e. the costs associated with routine maintenance and replacement and the costs associated with heating and servicing the building over its life. These costs can be reduced by sensitive design and detailing, for example designing a building to use zero energy and to be easy to maintain will carry significant cost benefits over the longer term (not to mention benefits to the environment). All materials and components have a specified design life and should also have a specified service life. Designers and contractors need to be aware of these factors before starting work, thus helping to reduce defects and maintenance requirements before construction commences.

The third cost is the cost of materials recovery at the end of the life of the building, i.e. the cost of demolition, recycling and disposal. All three areas of cost associated with building should be considered within a whole life cost model, from which decisions can be made about the type of materials and components to be used and the manner in which they are to be assembled (and subsequently disassembled). This links with issues concerning maintenance, repair renovation and recycling.

1.2 Environmental factors

There is an extensive literature concerning the environmental impact of building materials, products and components, construction activities and the use (and misuse) of buildings during their lifetime. We know that we must do more to respect our planet and build in a way that has a positive impact on our environment. From a construction perspective consideration should be given to the method of construction, maintenance and repair, future adaptability of the structure and the recycling of materials as and when the building is demolished or substantially remodelled. This is particularly important at the detailing and specification stage when materials and components are selected. There are many ways in which we can improve the relationship between our artificial environment and our natural one. For example, detailing buildings so as to reduce unnecessary waste during production not only helps to reduce landfill, it also saves time and money. Similarly, detailing and constructing a building in such a way as to make it easy to disassemble at the end of its service life will enable precious components and materials to be recovered with minimal damage, and hence minimal waste.

Climate change

There continues to be considerable speculation as to the future impact of climate change. In the UK the general consensus is that the average temperature will continue to rise, as will the amount of rainfall and the average wind speed. The message from the weather forecasters is wetter, warmer and windier. This has given rise to a number of concerns about the suitability of the existing building stock and also to the technologies being employed for the erection of new buildings. How, for example, do these predicted changes impact on the way in which we detail the external fabric of buildings? Are existing Codes, Standards and building practices adequate? The general consensus is that we should adopt a cautious approach, although we would urge against over-detailing and over-specifying, which may be wasteful.

Some concern has been expressed about new buildings, especially homes that are built from lightweight materials, such as timber-framed, steel-framed, modular and other lightweight construction systems. The fear is that with an expected increase in temperatures the internal temperature of lightweight construction may become too high during the summer, thus necessitating air conditioning (increased energy demands) and/or better shading and natural ventilation. Buildings constructed of heavy walls, with small windows and sun shading devices (e.g. shutters, verandas) are less susceptible to temperature fluctuation. However, there are plenty of places around the world that have a warmer climate than the UK and where lightweight construction is used successfully. The answer to the problem is not so much about the type of construction used, rather the manner in which the building is designed to respond better to its immediate environment (e.g. verandas and shading devices).

Passive design includes the selection of energy-efficient building materials so that there is very little or no need to provide renewable technologies. This is sometimes referred to as 'fabric first'. A good example is *Passivhaus* (Passive House), which effectively eliminates the need for space heating through a highly insulated building fabric. Taking this concept a little further the *Activhaus* (Active House) concept aims to design and construct a building that generates more energy than it uses. Buildings that are constructed using straw bales and rammed earth also adopt the fabric first philosophy to eliminate the need for space heating. Level 6 of the Code for Sustainable Homes equates to a property with no net CO_2 emissions.

Environmental impact

There are a wide variety of approaches to the construction of buildings, and with increased attention focussed on ecologically friendly construction a number of different approaches are possible. Some have their roots in vernacular architecture and others in technological advancement, although most approaches combine features present in both old and new construction techniques. Strategies adopted can include, for example, the reuse of salvaged components and recycled materials from redundant buildings, designing buildings that may be disassembled with minimal damage to the components used, buildings that are designed to decompose after a predetermined time frame, incorporation of renewal energy sources, and so on. Care is required as many of these methods are largely untried (or the techniques have been forgotten) and it will take some time before we can really know for certain how they perform in situ. We do, however, urge all readers to consider the impact on the environment of their preferred construction method by adopting a whole life approach to the design, construction use and reuse/recycling of buildings (see also *Barry's Advanced Construction of Buildings*).

Energy efficiency and environmental performance

The environmental performance of buildings has long been a cause for concern, but it is an area in which it is difficult for the building owner to get reliable information. Designers and builders must make a greater effort to provide buildings with:

- ❑ Lower running costs
- ❑ Enhanced air quality and natural daylight
- ❑ Use of low-allergy materials
- ❑ Use of environmentally friendly materials
- ❑ Water efficiency (and recycling) measures
- ❑ Ease of adaption and alteration
- ❑ Future proofing (easy upgrading of energy-efficient technologies)

If these (and related) factors are addressed at the conceptual and detailed design phases then the initial cost of the construction is likely to be similar to a project that is less energy efficient and less environmentally friendly. Add to this the considerable cost savings over the life of the building and it is difficult to understand why buildings are still being constructed with such scant regard for the whole life performance of the constructed works.

Our existing building stock is a little more problematic, simply because it may be a challenge to make improvements to the building fabric and services to improve their low carbon credentials. With an estimated 27 million older homes needing to be upgraded to meet energy efficiency targets, the challenge is substantial. The ability to upgrade the building fabric and retrofit appropriate technologies is addressed in Chapter 11 of *Barry's Advanced Construction of Buildings.*

1.3 General principles of construction

Whatever approach taken to the design and erection of our buildings there are a number of fundamental principles that hold true. The building has to resist gravity and hence remain safe throughout its design life and substantial advice is provided in regulations and standards. Every building is composed of some common elements:

- Foundations (see Chapters 2 and 3)
- Floors (see Chapter 4)
- Walls (see Chapter 5)
- Roof (see Chapter 6)
- Windows and doors (see Chapters 7 and 8)
- Stairs and ramps (see Chapter 9)
- Surface finishes (see Chapter 10)
- Services (see Chapters 11 and 12)

It is vital for the success of the building project and the use of the constructed building that an integrated approach is adopted. It is impossible to consider the choice of, for example, a window without considering its interaction with the wall in which it is to be positioned and fixed, maintained and eventually replaced. It follows that the window should exhibit the same, or very similar, thermal and acoustic performance characteristics as the wall. The same argument holds for all building services, which should be integrated with the building structure and fabric in such a way as to make access for routine maintenance, repair and upgrading a safe and straightforward event which does not cause any damage.

It is common to classify construction methods as either loadbearing or framed construction.

Loadbearing construction

Masonry loadbearing construction is well established in the British building sector and despite a move towards more prefabrication, loadbearing construction tends to be the preferred option for many house builders and small commercial buildings (see Chapter 5). There is a heavy reliance on the skills of the site workers and on wet trades, e.g. bricklaying, plastering, and so on. Quality control is highly dependent upon the labour used and the quality of the supervision on site.

In a typical loadbearing cavity wall construction the main loads are transferred to the foundations via the internal loadbearing wall. The external skin serves to provide weather protection and aesthetic quality. Primarily 'wet' construction techniques are employed.

Framed construction

Framed construction has a long pedigree in the UK, starting with the framed construction of low-rise buildings from timber and followed by early experiments with iron and reinforced concrete frames. Subsequent development of technologies and advances in production have resulted in three main materials being used for low-rise developments: timber, steel and concrete (see also *Barry's Advanced Construction of Buildings* for additional information). Framed construction is better suited to prefabrication and off-site manufacturing than masonry loadbearing construction. Dry techniques are used and quality control is easier because the production process is repetitive and a large amount of the work is carried out in a carefully controlled environment. Site operations are concerned with the correct placement and connection of individual component parts in a safe and timely manner.

In a typical framed cavity wall construction the main loads are transferred to the foundations via the structural frame. The external skin serves to provide weather protection and aesthetic quality. It is common practice in most of the UK to clad timber- and steel-framed buildings with brickwork; thus from external appearances it might be impossible to determine whether the construction is framed or loadbearing.

Design and constructability

The functional and performance requirements will inform the design process, from the initial concepts right through to the completion of the detailed designs and production of the information (drawings, schedules and specifications) from which the building will be constructed. The design of the junction between different materials, i.e. the solution for how different parts are assembled, is crucial in helping to meet the performance and functional requirements of the overall building. Good design and detailing will help the contractor and subcontractors to assemble the building safely and economically. Good design and detailing, combined with good workmanship, will contribute to the durability and ease of use of the building over its life.

The manner in which materials are joined together will be determined by their material properties, shapes and sizes available, type of joint required, construction method (e.g. framed or loadbearing) and the safe sequence of assembly (and anticipated disassembly). Interfaces between materials and components can be quite complex and will be specific to particular materials and components, although in simple terms the following methods are used widely to join separate parts, either in isolation or in combination.

- Gravity. The simple placing of materials so that they stay in place due to their mass (e.g. stone on stone) or shape (e.g. interlocking roof tiles) is common, although it tends to be used in conjunction with an adhesive joint or mechanical fixing. Masonry is usually laid in mortar in loadbearing construction and roof tiles need to be clipped in position at regular intervals.