with website

BARRY'S ADVANCED CONSTRUCTION OF BUILDINGS

Third edition

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Christopher A. Gorse

WILEY Blackwell

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This edition first published 2014

Registered office: John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

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Library of Congress Cataloging-in-Publication Data
Emmitt, Stephen.
Barry's advanced construction of buildings / Stephen Emmitt and Christopher A. Gorse. – Third edition.
1 online resource.
Includes bibliographical references and index.
Description based on print version record and CIP data provided by publisher; resource not viewed.
ISBN 978-1-118-87071-6 (ePub) – ISBN 978-1-118-87083-9 (Adobe PDF) – ISBN 978-1-118-25549-0 (pbk.) 1. Building. I. Barry, R. (Robin) II. Gorse, Christopher A. III. Title. IV. Title: Advanced construction of buildings.
TH146
690–dc23

2014002857

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image courtesy of the authors and iStock Photo
Cover design by Andy Meaden

Set in 10/12 pt Minion Pro Regular by Toppan Best-set Premedia Limited
Printed and bound in Malaysia by Vivar Printing Sdn Bhd

1 2014

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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:

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1 Introduction

In *Barry's Introduction to Construction of Buildings* we provided an introductory chapter that set out some of the basic requirements and conditions relevant to all building projects, regardless of size and complexity. In this volume the emphasis shifts from domestic to larger-scale buildings, primarily residential, commercial and industrial buildings constructed with loadbearing frames. This is supported with information on fit out and second fix, lifts and escalators, and off-site construction. Many of the principles and techniques set out in the introductory volume are, however, still appropriate to this volume. Similarly, many of the technologies described here are also used in smaller buildings. Thus we would urge readers to consult both volumes of the *Barry* series. In this introductory chapter we start to address some additional, yet related, issues, again with the aim of providing some context to the chapters that follow.

1.1 The function and performance of buildings

In *Barry's Introduction to Construction of Buildings*, we set out some of the fundamental functional and performance requirements of buildings. We continue the theme here with some additional requirements applicable to the construction of buildings, regardless of type, size or complexity.

Structure and fabric

Structure and building fabric have a very special relationship. It is the combined performance of the structure and building fabric, together with the integration of services, which determines the overall performance of the building during its life. In loadbearing construction, the materials forming the structural support also provide the fabric and hence the external and internal finishes. In framed structures, the fabric is independent of the structure, with the fabric applied to the loadbearing structural frame.

Loading

Buildings need to accommodate the loads and forces acting on them if they are to resist collapse. One of the most important considerations is how forces are transferred within the structure. Buildings are subject to three types of loading:

Barry's Advanced Construction of Buildings, Third Edition. Stephen Emmitt and Christopher A. Gorse.

- Dead loads. Dead loads remain relatively constant throughout the life of a building, unless it is remodelled at a future date. These loads comprise the combined weight of the materials used to construct the building. Loads are transferred to the ground via the foundations. Because the weight of individual components is known, the dead load can be easily calculated.
- Live loads. Unlike dead loads, the live loads acting on a building will vary. Live loads comprise the weight of people using the building, the weight of furniture and equipment, etc. Seasonal changes will result in (temporary) live loading from rainfall and snow. Structural design calculations assume an average maximum live load based on the use of the building (plus a safety factor). If the building use changes, then it will be necessary to check the anticipated live loading against that used at the design stage.
- Wind loads. All buildings are subject to wind loading. Maximum wind loads (gusts) are determined by considering the maximum recorded wind speed in a particular location and adding a safety factor. Wind loading is an important consideration for both permanent and temporary structures. It is also an important consideration when designing and installing temporary weather protection to protect building workers and work in progress from the elements.

When the total loading has been calculated for the proposed building, it is then possible to design the building structure, fabric and foundations.

Structural frames

Timber, steel and reinforced concrete are the main materials used for structural frames (Photograph 1.1). The benefits of one material over another need to be considered against a wide variety of design and performance parameters, such as the following:

- Extent of clear span required
- Height of the building
- Extent of anticipated loading
- Fire resistance and protection
- Embodied energy and associated environmental impact
- Ease of fixing the fabric to the frame (constructability)
- Availability of materials and labour skills
- Extent of prefabrication desired
- Site access (restrictions)
- Erection programme and sequence
- Maintenance and ease of adaptability
- Ease of disassembly and reuse of materials
- Life cycle costs

In some cases, it is common to use one material only for the structural frame, e.g. timber. In other situations, it may be beneficial to use a composite frame construction, e.g. concrete and steel.

Dimensional stability

Stability of the building as a whole will be determined by the independent movement of different materials and components within the structure over time – a complex interaction determined by the dimensional variation of individual components when subjected to changes in moisture content, changes in temperature and not forgetting changes in loading:

Photograph 1.1 Framed building under construction.

- Moisture movement. Dimensional variation will occur in porous materials as they take up or, conversely, lose moisture through evaporation. Seasonal variations in temperature will occur in temperate climates and affect many building materials. Indoor temperature variations should also be considered.
- Thermal movement. All building materials exhibit some amount of thermal movement because of seasonal changes in temperature and (often rapid) diurnal fluctuations. Dimensional variation is usually linear. The extent of movement will be determined by the temperature range the material is subjected to, its coefficient of expansion, its size and its colour. These factors are influenced by the material's degree of exposure, and care is required to allow for adequate expansion and contraction through the use of control joints.
- Loading. Dimensional variation will occur in materials that are subjected to load. Deformation under load may be permanent; however, some materials will return to their natural state when the load is removed. Thus live and wind loads need to be considered too.

Understanding the different physical properties of materials will help in detailing the junctions between materials and with the design, positioning and size of control joints. Movement in materials can be substantial and involve large forces. If materials are restrained in such a way that they cannot move, then these forces may exceed the strength of the material and result in some form of failure. Control joints, sometimes described as 'movement joints' or 'expansion joints', are an effective way of accommodating movement and associated stresses.

Designers and builders must understand the nature of the materials and products they are specifying and building with. These include the materials' scientific properties, structural properties, characteristics when subjected to fire; interaction with other materials, anticipated durability for a given situation, life cycle cost, service life, maintenance requirements, recycling potential, environmental characteristics such as embodied energy, health and safety characteristics, and, last but not least, their aesthetic properties if they are to be seen when the building is complete. With such a long list of considerations, it is essential that designers and builders work closely with manufacturers and consult independent technical reports. A thorough understanding of materials is fundamental to ensuring feasible constructability and disassembly strategies. Consideration should be given to the service life of materials and manufactured products, since any assembly is only as durable as the shortest service life of its component parts.

Tolerances

In order to be able to place individual parts in juxtaposition with other parts of the assembly, a certain amount of dimensional tolerance is required. Construction involves the use of labour, either remote from the site in a factory or workshop, or on site, but always in combination. Designers must consider all those who are expected to assemble the various parts physically into a whole, including those responsible for servicing and replacing parts in the future, so that workers can carry out their tasks safely and comfortably.

With traditional construction, the craftsmen would deal with tolerances as part of their craft, applying their knowledge and skill to trim, cut, fit and adjust materials on site to create the desired effect. In contrast, where materials are manufactured under carefully controlled conditions in a factory, or workshop, and brought to site for assembly, the manufacturer, designer and contractor must be confident that the component parts will fit together since there is no scope to make adjustments to the manufactured components. Provision for variation in materials, manufacturing and positioning is achieved by specifying allowable tolerances. Too small a tolerance and it may be impossible to move components into position on site, resulting in some form of damage; too large a tolerance will necessitate a degree of 'bodging' on site to fill the gap – for practical and economic reasons both situations must be avoided. There are three interrelated tolerances that the designer must specify, which are related specifically to the choice of material(s).

(1) *Manufacturing tolerances.* Manufacturing tolerances limit the dimensional deviation in the manufacture of components. They may be set by a standard (e.g. ISO), by a manufacturer and/or the design team. Some manufacturers are able to manufacture to tighter tolerances than those defined in the current standards. Some designers may require a greater degree of tolerance than that normally supplied, for which there may well be a cost to cover additional tooling and quality control in the factory.

(2) *Positional tolerances.* Minimum and maximum allowable tolerances are essential for convenience and safety of assembly. However, whether the tolerances are met on site will depend upon the skills of those doing the setting out, the technology employed to erect and position components and the quality of the supervision.
(3) *Joint tolerances.* Joint tolerances will be determined by a combination of the performance requirements of the joint solution and the aesthetic requirements of the designer. Functional requirements will be determined through the materials and technologies employed. Aesthetic requirements will be determined by building traditions, architectural fashion and the designer's own idiosyncrasies.

As a general rule, the smaller (or closer) the tolerance, the greater the manufacturing costs and the greater the time for assembly and associated costs. Help in determining the most suitable degree of tolerance can be found in the technical literature provided by trade associations and manufacturers. Once the tolerances are known and understood in relation to the overall building design, it is possible to compose the drawings and details that show the building assembly. Dimensional coordination is important to ensure that the multitude of components fit together correctly, thus ensuring smooth operations on site and the avoidance of unnecessary waste through unnecessary cutting. A modular approach may be useful, although this may not necessarily accord with a more organic design approach.

Flexibility and the open building concept

The vast majority of buildings will need to be adjusted or adapted in some way to accommodate the changing needs of the building users and owners. In domestic construction, this may entail the addition of a small extension to better accommodate a growing family, conversion of unused roof space into living accommodation or the addition of a conservatory. Change of building owner often means that the kitchen or bathroom (which may be functional and in a good state of repair) will be upgraded or replaced to suit the taste and needs of the new building owners. Thus, what was perfectly functional to one building user is not to another, necessitating the need for alterations.

In commercial buildings, a change of tenant can result in major building work, as, for example, internal partition walls are moved to suit different spatial demands. Change of retailer will also result in a complete refitting of most shop interiors. These are just a few examples of the amount of alterations and adaptations made to buildings, which, if not planned and managed in a strategic manner, will result in a considerable amount of material waste. Emphasis should be on reusing and recycling materials as they are disassembled and, if possible, the flexibility of internal space use.

Although these are primarily design considerations, the manner in which materials and components are connected can have a major influence on the ease, or otherwise, of future alterations.

Flexibility

Designing and detailing a building to be flexible in use presents a number of challenges, some of which may be known and foreseen at the briefing stage, but many of which cannot be predicted. Thought should be given to the manner in which internal, non-loadbearing walls are constructed and their ease of disassembly and reuse. Similarly, the position of services and the manner in which they are fixed to the building fabric need careful thought at the design and detailing stage. For example, a flexible house design would have a structural shell with non-loadbearing internal walls (movable partitions, folding walls, etc.), zoned underfloor space heating (allowing for flexible use of space) and carefully positioned wet and electrical service runs (in a designated service zone or service wall).

Open building

The open building concept aims to provide buildings that are relatively easy to adapt to changing needs with minimum waste of materials and little inconvenience to building users. The main concept is based on taking the entire life cycle of a building and the different service lives of the building's individual components into account. Since an assembly of components is dependent upon the service life of its shortest-living element, it may be useful to view the building as a system of time-dependent levels. Terminology varies a little, but the use of a three-level system, primary, secondary and tertiary, is becoming common. Described in more detail the levels are:

- The primary system. Service life of approximately 50–100 years. This comprises the main building elements such as the loadbearing structure, the external fabric, building services structure, etc. The primary system is a long-term investment and is difficult to change without considerable cost and disruption. This is sometimes described as the building 'shell'.
- The secondary system. Service life of approximately 15–50 years. This comprises elements such as internal walls, floor and ceiling finishes, building services installations, doors and mechanical vertical circulation systems such as lifts and escalators. The secondary system is a medium-term investment and should be capable of adaptation through disassembly and reassembly.
- The tertiary system. Service life of approximately 5–15 years. This comprises elements such as fittings and furniture and equipment associated with the building use, e.g. office equipment. The tertiary system is a short-term investment and elements should be capable of being changed without any major building work.

The shorter the service life of components, the greater the need for replacement, hence the need for easy and safe access. Applying this strategy to a development of apartments, the structure and external fabric would be the primary system. The secondary system would include kitchens, bathrooms and services. The tertiary system would cover items such as the furniture and household appliances. If a discrete, modular system is used, then it is relatively easy to replace the kitchen or bathroom without major disruption and to recycle the materials. This 'plug-in' approach is certainly not a new concept but has started to become a more realistic option as the sector has started to adopt off-site production.

Maintenance and repair

It is currently estimated that over 60% of the building stock in England is more than 40 years old. Approximately six million houses are classified as unfit to live in because of problems with damp and inadequate thermal insulation. Combined with the desire of building owners to upgrade their properties, this means that a large proportion of building work is concerned with existing buildings. Many of the principles described in this current *Barry* series will, of course, be relevant to work to existing buildings. Chapter 11 addresses some of the factors relating to the upgrading of existing buildings in greater detail. For readers concerned with restoration and repair work, some of the earlier editions of *Barry* (which date back to 1958) may be useful in helping to describe some of the main techniques used at the time.

Security

Security of buildings and their contents (goods and people) has become a primary concern for the vast majority of building sponsors and owners. In residential developments, the primary concern is with theft of property, with emphasis on the integrity of doors and windows. In commercial developments, the concern is for the safety of the people using the building and for the security of the building's contents. Doctors' surgeries and hospitals have experienced an increase in attacks on staff and patients, leading to the installation of active security measures in an attempt to deter crime. Theft from retail stores and warehouses continues to be a major concern for businesses. Where buildings are located away from housing areas, it may be possible to enclose the site with a secure fence and controlled entrance gates, but for the buildings located in urban and semi-urban locations isolating the building from its neighbours is rarely a realistic option. Vandalism and the fear of terrorist attacks are additional security concerns, leading to changes in the way buildings are designed and constructed. Measures may be passive, active or a combination of both.

Passive security measures

A passive approach to security is based on the concept of inherent security measures, where careful consideration at the design and detailing phase can make a major difference to the security of the building and its contents. Building layout and the positioning of, for example, doors and windows to benefit from natural surveillance need to be combined with the specification of materials and components that match the necessary functional requirements. The main structural materials and the method of construction will have a significant impact on the resistance of the structure to forced entry. For example, consideration should be given to the ease with which external cladding may be removed and/or broken through, and depending on the estimated risk, an alternative form of construction may be more appropriate. Unlawful entry through roofs and rooflights is also a potential risk and building designers must consider the security of all building elements.

Ram raiding, the act of driving a vehicle through the external fabric of the building to create an unauthorised means of access and egress for the purposes of theft, has become a significant problem for the owners of commercial and industrial premises. Concrete and steel bollards, set in robust foundations and spaced at close centres around the perimeter of the building, are one means of providing some security against ram raiding, especially where it is inappropriate to construct a secure perimeter fence.

Active security measures

Active security measures, such as alarms and monitoring devices, may be deployed in lieu of passive measures or in addition to inherent security features. For new buildings, active measures should be considered at the design stage to ensure a good match between passive and active security. Integration of cables and mounting and installation of equipment should also be considered early in the detailed design stage. Likewise, when applying active security measures to existing buildings, care should be taken to analyse and utilise any inherent features. Some of the active measures include:

- Intruder alarm systems
- Entrance control systems in foyers/entrance lobbies
- Coded door access
- CCTV monitoring
- Security personnel patrols

Health, safety and well-being

Worldwide the construction sector has a poor health and safety record. Various approaches have been taken to try to improve the health, safety and well-being of everyone involved in construction. These include more stringent legislation, better education and training of workers, and better management practices. Similarly, a better understanding of the sequence of construction (a combination of constructability principles and detailed method statements) has helped to identify risk hazards and to minimise or even eliminate them. This also applies to future demolition of the building, with a detailed disassembly strategy serving a similar purpose. There are four main, interrelated stages to consider. They are:

- Prior to construction. The manner in which a building is designed and detailed, i.e. the materials selected and their intended relationship to one another, will have a significant bearing on the safety of operations during construction. Extensive guidance is available on the Safety in Design homepage (http://www.safetyindesign.org).
- During construction. Ease of constructability will have a bearing on safety during production. Off-site manufacturing offers the potential of a safer environment, primarily because the factory setting is more stable and easier to control than the constantly changing construction site. However, the way in which work is organised and the attitude of workers towards safety will have a significant bearing on accident prevention.
- During use. Routine maintenance and repair is carried out throughout the life of a building. Even relatively simple tasks such as changing a light bulb can become a potential hazard if the light fitting is difficult to access. Elements of the building with short service lives (and/or with high maintenance requirements) must be accessed safely.
- Demolition and disassembly. Attention must be given to the workers who at some time in the future will be charged with disassembling the building. Method statements and guidance on a suitable and safe disassembly strategy are required.

1.2 New methods and products

An exciting feature of construction is the amount of innovation and change constantly taking place in the development of new materials, methods and products, many of which are used in conjunction with the more established technologies. Some of the more obvious areas of innovative solutions are associated with changing regulations (e.g. airtightness