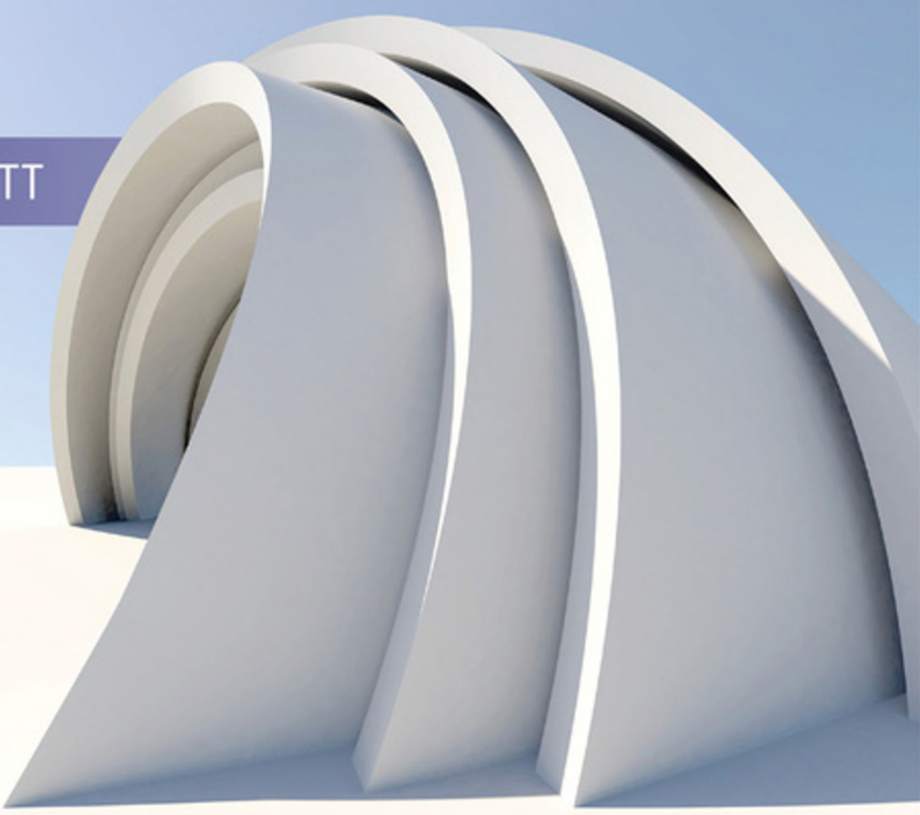
4TH EDITION

BARRY'S ADVANCED CONSTRUCTION OF BUILDINGS

STEPHEN EMMITT



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Fourth Edition

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Preface

Robin Barry's *Construction of Buildings* first appeared in print in 1958 and eventually grew into five volumes. When I took on the task of revising and updating the Barry books, a decision was taken to condense the work into two volumes to make it more accessible to readers. This was a big task and it required the input of a former colleague, Christopher Gorse, and the help of many individuals and companies, for which I remain extremely grateful.

Working on the books continues to be a process of addition and subtraction to keep the content topical and informative to a wide readership. Now as a solo authored work it has been possible to further simplify and clarify the content while making the latest round of revisions. This has resulted in repositioning of material and new features, such as 'How to navigate this book' and the 'At a glance' fact sheets. The repositioning of material, from one volume to another, and within volumes, has helped to ensure a more logical flow of information that better reflects the process of construction. The main changes to each volume are as follows:

The *Introduction* volume has retained the same chapter structure, with changes made within chapters to improve readability. The introductory chapter has been rewritten to better explain the process of construction and to place greater emphasis on the environmental impact of construction. The material on timber framed construction has been moved to this volume, which has allowed for simplification, rewriting and renaming of Chapter 5 to better reflect the content on loadbearing wall construction. Scaffolding can now be found in the *Introduction* volume and the material on foundations has been restructured in both volumes to remove repetition.

This volume has been restructured. Offsite construction has been rewritten and moved to the front of the book (Chapter 2), as the majority of material in the volume is concerned with prefabricated and preassembled construction. There is a new chapter on Framed Timber Construction (Chapter 5), thus the three main materials for framed construction – timber, concrete and steel – are now in the same volume, making it easier for readers to draw comparisons. The material relating to existing buildings, demolition and recycling has been moved to Chapter 11, thus completing the entire building lifecycle.

In making these revisions the original philosophy of Robin Barry – to address the functional requirements of building elements – has been retained. Regardless of building type, the functional requirements for the main elements remain relevant. Similarly, the underpinning construction principles remain much the same, despite ever changing building codes, regulations, guidance and better awareness of the environmental impact of buildings.

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How to Navigate this Book

The Barry books are presented in two volumes, *Introduction* and *Advanced*, with the volumes designed to complement one another. The titles are used to reflect the stage at which these subjects are taught in colleges and universities in the UK. *Introduction* covers the first year, primarily dealing with loadbearing construction and domestic scale developments. It is also cover the common elements found in most buildings. The *Advanced* volume includes material usually taught in the second to third year, primarily dealing with offsite techniques and framed construction for larger buildings. Combined, the two volumes take the reader through the entire life cycle of a building, from inception and construction, to the building in use and eventual demolition, recycling and reuse of valuable resources.

An overview of the chapters in each volume is provided in Table 1, as an aid to navigation of the books.

Chapters are designed so that they can be read from front to back or they can be dipped into as the need arises. Each chapter or section introduces the primary functional requirements and then the reader is introduced to an increasing level of detail. The illustrations and photographs are provided to enhance our understanding of the main principles. At a glance sheets are used for each chapter to address the main what, why, how and when questions.

Table 1 Overview of the chapters

Chapter	*Introduction*	*Advanced*
1	Introduction	Introduction
2	Site Analysis, Set-Up, Drainage and Scaffolding	Offsite Construction
3	Ground Stability and Foundations	Pile Foundations, Substructures and Basements
4	Floors	Single Storey Frames, Shells and Lightweight Coverings
5	Loadbearing Walls	Structural Timber Frames
6	Roofs	Structural Steel Frames
7	Windows	Structural Concrete Frames
8	Doors	Envelopes to Framed Buildings
9	Stairs and Ramps	Lifts and Escalators
10	Surface Finishes	Fit Out and Second Fix
11	Internal Environment and Energy Supply	Existing Buildings: Pathology, Upgrading and Demolition
12	Water Supply and Sanitation	

If readers are studying, for example, loadbearing construction, then they will need to read the *Introduction* volume and focus on specific chapters to supplement their learning in the classroom. In this situation the reader will need to read chapters all the way through in the first instance, perhaps returning to specific issues, such as the position of damp-proof course. Similarly, if readers are studying framed construction, the *Advanced* volume will be a valuable resource, supplemented with material on, for example, doors and windows from the *Introduction* volume. When it comes to revising for examinations in construction technology, the 'At a glance' feature will be useful in prompting one's memory, prior to revisiting key issues within the chapter.

When readers use the books to help detail their building designs, dipping into chapters to see solutions to typical detailing problems will help with understanding. It is, however, important that we understand the principles underlying the construction of buildings – what needs to be achieved and why. Thus the details and photographs provided give an indication of how it could be done; not how it should be done.

1 Introduction

In *Barry's Introduction to Construction of Buildings* we provided an introductory chapter that set out some of the requirements and conditions relevant to all building projects, regardless of size and complexity. We continue the theme in this chapter, with some additional requirements. 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 by 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 context to the chapters that follow.

1.1 The function and performance of buildings

Structure and fabric

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:

(1) *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.

Barry's Advanced Construction of Buildings, Fourth Edition. Stephen Emmitt.

(2) *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.

(3) *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 (the structural frame) and the foundations. This needs to be done in conjunction with the design of the building envelope.

Structural frames

Timber, steel and reinforced concrete are the main materials used for structural frames (Photograph 1.1). 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). Combining two or more materials is known as hybrid construction. 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

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 and adaptability

Designing and detailing a building to be flexible and adaptable 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 (repositioning).

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 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 walls and roof or the structural frame and floors and roof. The primary system is a long-term investment and is difficult to change without considerable cost and disruption.
- *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 vertical circulation systems such as lifts and escalators. The secondary system is a medium-term investment and should be capable of replacement or adaptation through disassembly and reassembly. The shorter the service life of components, the greater the need for replacement, hence the need for easy and safe access.
- *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.

Applying this strategy to a development of, for example, 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 (see also Chapter 2).

Security

Security of buildings and their contents (goods and people) is 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. The desire to keep the building users and contents safe has to be balanced with the need to allow safe evacuation in the case of a fire or an emergency. 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. 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 wellbeing

Various approaches have been taken to improve the health, safety and wellbeing 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:

(1) *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 via the Safety in Design (http://www.safetyindesign.org).

(2) *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.

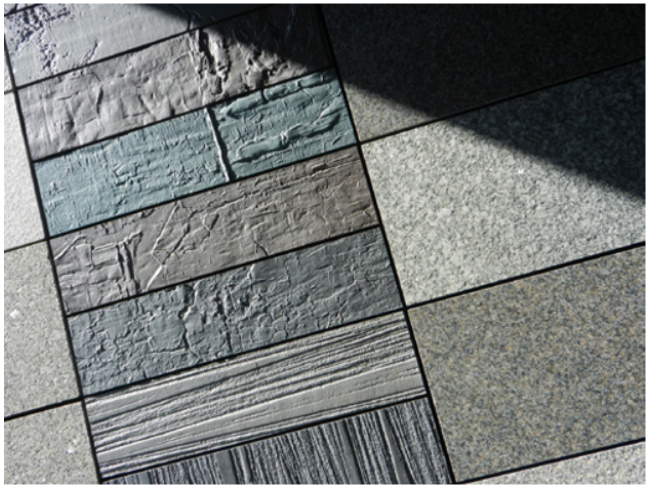
(3) *During use*. Routine maintenance and repair is carried out throughout the life of a building. Even relatively simple tasks such as changing a light bulb can become a potential hazard if the light fitting is difficult to access. Elements of the building with short service lives (and/or with high maintenance requirements) must be accessed safely.

(4) *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 demolition and disassembly strategy are required at the design stage.

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 requirements); changing technologies (e.g. new cladding systems); the trend towards greater use of off-site production (e.g. volumetric system build); advances in building services (e.g. provision of broadband); a move to the use (and reuse) of recycled materials (e.g. products manufactured from recycled material, see Photograph 1.2); and the drive for low or zero carbon construction, which has stimulated renewed interest in natural materials and their innovative use. Many of the changes are, however, quite subtle as manufacturers make gradual technical 'improvements' to their product portfolio. This could be as simple as gradually increasing the amount of recycled content in their products. Gradual innovations are often brought about by the use of a new production plant and automated production and/or are triggered by competition from other manufacturers, with manufacturers seeking to maintain and improve market share through technical innovation. In the vast majority of cases, this results in building products with improved performance standards and improved environmental credentials.

Combined with changing fashions in architectural design and manufacturers' constant push towards the development of new materials and products, we are faced with a very wide range of systems, components and products from which to choose All contributors to the design and erection of buildings, from clients and architects to contractors and specialist



Photograph 1.2 Artificial stone made entirely from recycled rubber tyres (left of picture, rough texture) adjacent to natural stone (right of picture, smooth texture).

subcontractors, will have their own attitude to new products. Some are keen to use new products and/or new techniques, while others are a little more cautious and tend to stick to what they know. Whatever one's approach, it is important to keep up to date with the latest product developments and to investigate those products and methods that may well prove to be beneficial. Maintaining relationships with product manufacturers is one way of achieving this; indeed we would urge readers to visit manufacturers and talk to them about their products. This should be balanced against independent research reports relating to specific or generic product types.

Compliance and performance monitoring

Whatever approach is taken to the use of innovative materials, components and structural systems, it is important to remember that compliance is required with the Building Regulations and appropriate Codes and Standards. And, once built and operational, it is important to monitor the performance of products in relation to the overall building performance. This applies equally to buildings constructed on site and to those produced in whole or in part in factories.

The Building Regulations and supporting guidance (*Approved Documents* in England and Wales, and in Northern Ireland; *Guidance Documents* in Scotland) are structured in such a way as to encourage the adoption of innovative approaches to the design and construction of buildings. This is done through setting performance standards, which must be achieved or bettered by the proposed construction. Acceptance of innovative proposals is in the hands of the building control body handling the application; thus applicants must submit sufficient information on the innovative proposal to allow an accurate assessment of its performance. This is done by supplying data on testing, certification, technical approvals, CE marking and compliance with the Construction Products Directive (CPD), Eurocodes and Standards, calculations, detailed drawings and written specifications where appropriate.

Monitoring, testing and analysing the performance of new products and especially the overall performance of buildings are an important function. This has become particularly pertinent recently in our drive for carbon neutral buildings and the use of many innovative approaches to design and construction. Although new building products and systems will have been tested by manufacturers under laboratory conditions, we can never be sure how they will perform in relation to the entire building, which will be subject to variations in local climate and patterns of use. Thus it is necessary to monitor and analyse the performance of buildings and to feed that information back to manufacturers, designers and constructors.

1.3 Product selection and specification

Both the quality and the long-term durability of a building depend upon the selection of suitable building products and the manner in which they are assembled. This applies to buildings constructed on the site and to off-site production. The majority of people contributing to the design and construction of a building are, in some way or another, involved in the specification of building products; that is making a choice as to the most appropriate material or component for a particular situation. Architects and engineers will usually specify products by brand name (a prescriptive specification) or through the establishment of performance criteria (a performance specification), which is discussed in more detail later. These choices are linked to the way in which the building is detailed and the process of construction, be it offsite or onsite. Contractors and subcontractors will be involved in the purchase and installation of the named product or products that match the specified performance requirements; that is, they will also be involved in assessing options and making a decision. Similarly, designers working for offsite manufacturers will also be involved in material and product selection; here the emphasis will be on secure lines of supply and a transparent and ethical supply chain.

The final choice of product and the manner in which it is built into the building will have an effect on the overall quality and performance of the building. Traditionally, the factors affecting choice of building products have been the characteristics of the product (its properties, or 'fitness for purpose'), its initial cost and its availability. However, a number of other factors are beginning to influence choice, some of which are dependent on legislation, others of which are also dependent upon product safety (during construction, use and replacement/recycling and ethical resourcing) and environmental concerns as to the individual and collective impact of the materials used in the building's construction. Selection criteria will cover the following areas; the importance of one over another is dependent on the location of the product and the type of building project:

- ❏ Aesthetics
- ❏ Availability
- ❏ Compatibility (with other products)
- ❏ Compliance with legislation
- ❏ Cost (whole life costs)
- ❏ Durability
- ❏ Ease of installation (buildability)
- ❏ Environmental impact (low-carbon materials)
- ❏ Fire safety
- ❏ Health and safety

❑ Replacement and recyclability
❑ Risk (associated with the product and the manufacturer)

For very small projects, it is common for contractors to select materials and products from the stock held by their local builders' merchant, choice being largely dependent upon what the merchant stocks (availability) and initial cost. For larger projects, there is a need to confirm specification decisions in a written document, the specification.

The written specification

Specifications are written documents that describe the requirements to which the service or product has to conform; such as its defined quality. It is the written specification, not the drawings, which defines and hence determines the quality of the finished work. The term specification tends to be used in the singular, which is a little misleading. In practice, the work to be carried out will be described in specifications written by the different specialists involved in the construction project. The structural engineer will write the specification for the structural elements, such as foundations and steelwork, whereas the architect will be concerned with materials and finishes. Similarly, there will be a specification for the electrical and mechanical services provision. This collection of multi-authored information is known as 'the specification'.

People from different backgrounds will use the written specification for a number of quite different tasks. It will be used during the pre-contract phase to help prepare costings and tenders. During the contract, operatives and the site managers will read the specification to check that the work is proceeding in accordance with the defined quality. Postcontract, the document will form a record of materials used and set standards, which is useful for alteration and repair work and as a source of evidence in disputes. In more recent projects this information will be held within the Building Information Models (BIMs), and will be accessible for maintenance and future repair work.

Specifying quality

Trying to define quality is a real challenge when it comes to construction, partly because of the complex nature of building activity and partly because of the number of actors who have a stake in achieving quality. The term quality tends to be used in a subjective manner and, of course, is negotiable between the project stakeholders. In terms of the written specification, quality can be defined through the quality of materials and the quality of workmanship. Designers can define the quality of materials they require through their choice of proprietary products or through the use of performance parameters and appropriate reference to standards and codes. Designers do not tell the builder how to construct the building; this is the contractor's responsibility, hence the need for method statements. The specification will set out the appropriate levels of workmanship, again by reference to codes and standards, but it is the people doing the work, and to a certain extent the quality of supervision, that determines the quality of the finished building.

Specification methods

There are a number of methods available for specifying. Some methods allow the contractor some latitude for choice and therefore an element of competition in the tendering process, while others are deliberately restrictive. The four specification methods are:

(1) *Descriptive specifying*: where exact properties of materials and methods of installation are described in detail. Proprietary names are not used; hence this method is not restrictive.
(2) *Reference standard specifying*: where reference is made to established standards to which processes and products must comply, e.g. a national or international standard. This is also non-restrictive.
(3) *Proprietary specifying*: where manufacturers' brand names are stated in the written specification. Here the contractor is restricted to using the specified product unless the specification is written in such a way to allow substitution of an equivalent. Proprietary specification is the most popular method where the designer produces the design requirements and specifies in detail the materials to be used (listing proprietary products), methods and standard of workmanship required.
(4) *Performance specifying*: where the required outcomes are specified together with the criteria by which the chosen solution will be evaluated. This is non-restrictive and the contractor is free to use any product that meets the specified performance criteria. Performance specification is where the designer describes the material and workmanship attributes required, leaving the decision about specific products and standards of workmanship to the contractor.

The task is to select the most appropriate method for a particular situation and project context. The type of funding arrangement for the project and client preferences usually influences this decision. Typically, projects funded with public funds will have to allow for competition, so proprietary specifying is not usually possible. Projects funded from private sources may have no restrictions, unless the client has a preference or policy of using a particular approach. Obviously the client's requirements need to be considered alongside the method best suited to clearly describe the design intent and the required quality, while also considering which method will help to get the best price for the work and, if desired, allow for innovation. In some respects, this also concerns the level of detail required for a project or particular elements of that project. Although one method is usually dominant for a project, it is not uncommon to use a mix of methods for different items in the same document.

It has been argued that performance specifications encourage innovation, although it is hard to find much evidence to support such a view. The performance approach allows, in theory at least, a degree of choice and hence competition. The advantage of one approach over another is largely a matter of circumstance and personal preference. However, it is common for performance and prescriptive specifications to be used on the same project for different elements of the building.

National Building Specification

Standard formats provide a useful template for specifiers and help to ensure a degree of consistency, as well as saving time. In the UK, the National Building Specification (NBS) and the National Engineering Specification (NES) are widely used. This commercially available suite of specification formats includes *NBS Building, NBS Engineering Services* and *NBS Landscape*. Available as computer software, it helps to make the writing of specifications relatively straightforward, because prompts are given to assist the writer's memory. Despite the name, the NBS is not a national specification in the sense that it must be used; many design offices use their own particular hybrid specifications that suit them and their type of work.

NBS Building is available in three different formats to suit the size of a particular project, ranging from Minor Works (small projects) to Intermediate and Standard (large projects). It is an extensive document containing a library of clauses. These clauses are selected and/or deleted by the specifier, and information is added at the appropriate prompt to suit a particular project.

With the uptake of BIM many specification decisions are tied to the product libraries held with the digital model(s) used by designers and specialist subcontractors.

Green specifications

The National Green Specification (NGS) is an independent organisation, partnered by the Building Research Establishment (BRE), to host an Internet-based resource for specifiers. It provides building product information plus work sections and clauses written in a format suitable for importing into the NBS, thus helping to promote the specification of green products.

Coordinated Project Information

Coordinated Project Information (CPI) is a system that categorises drawings and written information (specifications). CPI is used in British Standards and in the measurement of building works, the Standard Method of Measurement (SMM7). This relates directly to the classification system used in the NBS.

One of the conventions of CPI and Uniclass is the ‘Common Arrangement of Work Sections’ (CAWS). CAWS lists around 300 different classes of work according to the operatives who will do the work; indeed the system was designed to assist the dissemination of information to subcontractors. This allows bills of quantities to be arranged according to CAWS.

Table 1.1 CAWS contents

A	Preliminaries
B	Complete buildings / structures / units
C	Demolition / alteration / renovation
D	Groundwork
E	In situ concrete / large precast concrete
F	Masonry
G	Structural / carcassing metal / timber
H	Cladding / covering
J	Waterproofing
K	Linings / sheathing / dry partitioning
L	Windows / doors / stairs
M	Surface finishes
N	Furniture / equipment
P	Building fabric sundries
Q	Paving / planting / fencing / site furniture
R	Disposal systems
S	Piped supply systems
T	Mechanical heating / cooling / refrigeration systems
U	Ventilation / air conditioning systems
V	Electrical supply / power / lighting systems
W	Communications / security / control systems
X	Transport systems
Z	Building fabric reference specification
	Additional rules – work to existing buildings
	Appendices

Table 1.2 NRM2 contents

1	Preliminaries
2	Offsite manufactured materials, components and buildings
3	Demolitions
4	Alterations, repairs and conservation
5	Excavating and filling
6	Ground remediation and soil stabilisation
7	Piling
8	Underpinning
9	Diaphragm walls and embedded retaining walls
10	Crib walls, gabions and reinforced earth
11	In situ concrete works
12	Precast/composite concrete
13	Precast concrete
14	Masonry
15	Structural metalwork
16	Carpentry
17	Sheet roof coverings
18	Tile and slate roof and wall coverings
19	Waterproofing
20	Proprietary linings and partitions
21	Cladding and covering
22	General joinery
23	Windows, screens and lights
24	Doors, shutters and hatches
25	Stairs, walkways and balustrades
26	Metalwork
27	Glazing
28	Floor, wall, ceiling and roof finishings
29	Decoration
30	Suspended ceilings
31	Insulation, fire stopping and fire protection
32	Furniture, fittings and equipment
33	Drainage above ground
34	Drainage below ground
35	Site works
36	Fencing
37	Soft landscaping
38	Mechanical services
39	Electrical services
40	Transportation
41	Builder's work in connection with mechanical, electrical and transportation installations
	Appendices

The system also makes it easy to refer items coded on drawings, in schedules and in bills of quantities back to the written specification. The main categories are shown in Table 1.1 (note there is no 'I', 'O' or 'Y'). The main sections are further divided into sub-sections.

The recent introduction of the New Rules of Measurement (NRM) has brought a move away from CAWS to a new indexing system that aims to better reflect developments in building technologies (e.g. offsite and recycling). This numbered system contains 41 sections and no longer makes reference to CPI, as shown in Table 1.2.

Offsite Construction: Chapter 2
AT A GLANCE

What? The term ‘offsite’ construction refers to the process of producing buildings, or parts of buildings, in factories remote from the building site. The manufacturing process is usually highly automated, resulting in prefabricated and preassembled components, panelised units (2D) and modular (3D, volumetric) systems. The prefabricated and preassembled units and modules are transported to site when required and craned into position on pre-prepared foundations or slotted into a structural frame. This is primarily a dry method of construction, although some wet trades may be employed to complete the building in some circumstances.

Why? Offsite construction offers the potential to better control the quality of workmanship, remove the uncertainties associated with working in variable weather conditions on site, improve health, safety and wellbeing of workers, significantly reduce the amount of time spent working on the site, make financial savings through the repetitive production of units, and in many cases improve the environmental impact of buildings by reducing waste. Offsite construction is ideally suited to buildings with a repetitive element, such as hotels, housing, hospitals, schools, offices, shops and industrial developments. The techniques are also well suited to the preassembly of services, such as modular electrical cabling and services pods. Producers of modular and system building offer a range of modules/elements that can be scaled from a small building to a very large development.

When? Using offsite preassembly methods changes the design and construction process. The design must be finalised (‘design freeze’) before production starts. The design process is influenced by the possibilities and constraints of offsite production, which are specific to the technologies being used. The sequence of construction will vary, depending upon the amount of prefabrication and offsite construction required. It is common to deliver the preassembled units when required to eliminate the need for onsite storage.

How? The preassembled components, panels and modules will be manufactured in factories, usually to suit specific design requirements and with regard to manufacturing constraints. These preassembly factories manage the purchasing and handling of materials, production and delivery. Some manufacturers also offer an on site assembly service. Off the shelf systems are available, in which case designers and engineers need to work within the constraints of the system. Once manufactured, the units are delivered to site, craned into position and connected to adjacent units and/or the loadbearing structural frame. Thus the construction skills, assisted with automation and robotics, are located in a factory, not on the building site.