

SECOND EDITION

BUILDING CONSTRUCTION

PRINCIPLES, MATERIALS, AND SYSTEMS

MADAN MEHTA
WALTER SCARBOROUGH
DIANE ARMPRIEST

BUILDING CONSTRUCTION

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Principles, Materials, and Systems Second Edition

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FOREWORD

The pedagogical philosophy of this book continues to be robust and unique. Therefore, it is not surprising that the first edition of the book was well received. The current (second) edition retains the book's original approach but has been substantially enhanced to bring it up-to-date with the current knowledge base and includes full-color photographs, photo-realistic renderings, and line art. I expect that it will become the leading text on construction materials and systems, and I am honored to recommend it to the academic and professional communities with renewed confidence.

As the Chairman and CEO of one of the largest, international architecture and engineering firms, I have come to appreciate the tremendous amount of knowledge today's architects, engineers, and constructors need to produce functional, economical, aesthetically pleasing, and high-performance buildings. Contemporary design and construction professionals cope, on a daily basis, with an exploding amount of information, mesh together a growing range of products, work out increasingly complex assembly details, and coordinate several diverse specialties.

In this second edition of *Building Construction: Principles, Materials, and Systems*, the authors have once again utilized their long experience and diverse expertise to improve upon the first edition and present the complexity of building construction in a more accessible volume. It clearly provides the basics of building science as applied to the art of transforming materials and systems into constructible buildings. Principles that influence building performance provide the background necessary to understand why, as well as how, buildings are assembled as they are.

The book appropriately addresses each of the primary building assemblies—foundations, walls, floors, ceilings, and roofs—and how they join, seal, and integrate with other components. The performance of building enclosures and systems is reviewed in detail, which enhances the reader's understanding of the comprehensive, integrated nature of the building design and construction processes. Almost all building materials and systems have been covered in depth.

The book is unique among the available books on the subject because it is a joint effort of three authors—two of whom are engaged full time in academia and another who has an extensive background in the profession. Together, the authors' combined expertise in architecture, engineering, and construction disciplines provides a holistic treatment of the subject. Although written primarily to educate students of architecture, engineering, and construction, the book will continue to serve as a reference for practitioners.

An exhaustive work, *Building Construction: Principles, Materials, and Systems* uses text and concepts, photographs, and detailed drawings to convey the construction assembly techniques, theory, and technology inherent in architecture. It also highlights the building professionals' involvement, as stewards of the environment, in producing sustainable, purposeful, and high-performance buildings on a life-cycle basis.

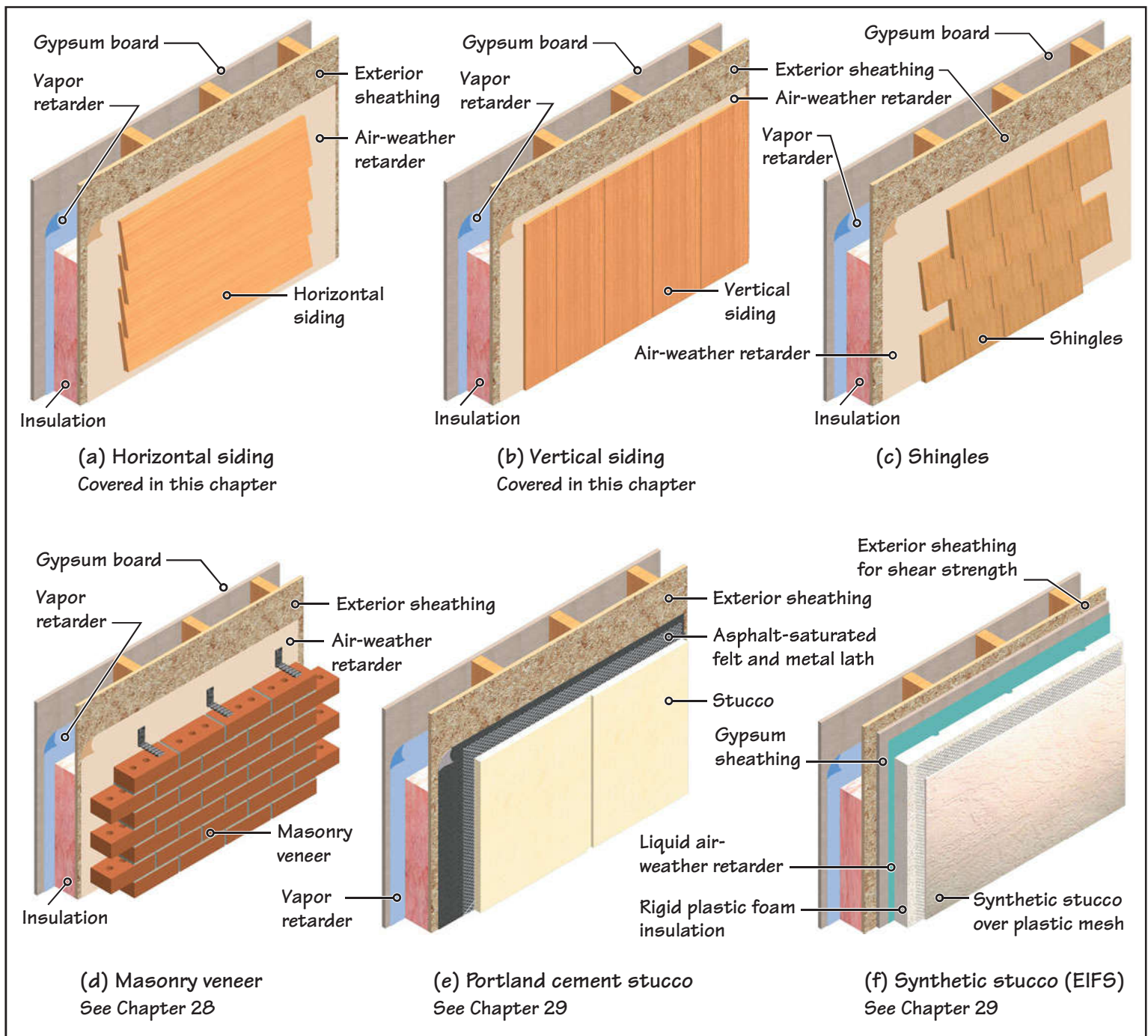


H. Ralph Hawkins, FAIA, FACHA, MPH, LEED AP
Chairman and CEO
HKS Inc.

INTRODUCING THE SECOND EDITION OF THE GROUNDBREAKING *BUILDING CONSTRUCTION:* *PRINCIPLES, MATERIALS, AND SYSTEMS*

Groundbreaking

The *first edition* was groundbreaking in its organization. The first book to focus initially on principles of construction, it gave students a greater understanding before moving on to materials and systems.



Engaging

The *second edition* makes building construction more engaging and accessible than ever before. It is the first truly comprehensive book of its kind to go *full color*.

Hundreds of full-color photos and illustrations make the material even more engaging.



PRINCIPLES IN PRACTICE

With the chalk lines in place, framing the ground floor walls can begin, Figures 5, 6, and 7. Temporary braces stabilize the walls until the frame is complete and the exterior walls are sheathed. When double-height spaces are required, continuous or double studs are used to frame the high segments of the wall.



FIGURE 4 Chalk lines on the slab indicate the location of the walls. Note that plumbing pipes align and are located within the thickness of the wall.



FIGURE 5 Wall assembly under construction.



FIGURE 6 Walls are typically framed on the slab or floor platform and subsequently tilted up into position.

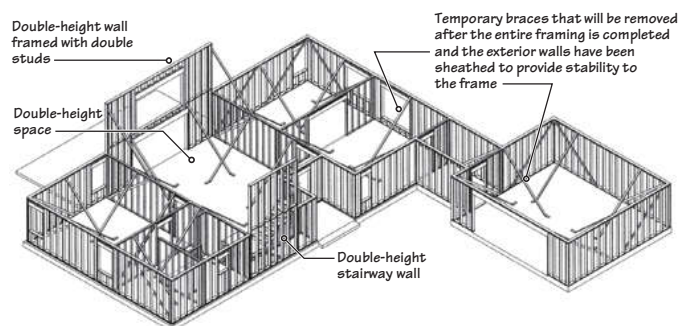


FIGURE 7 Ground-floor wall framing is completed.

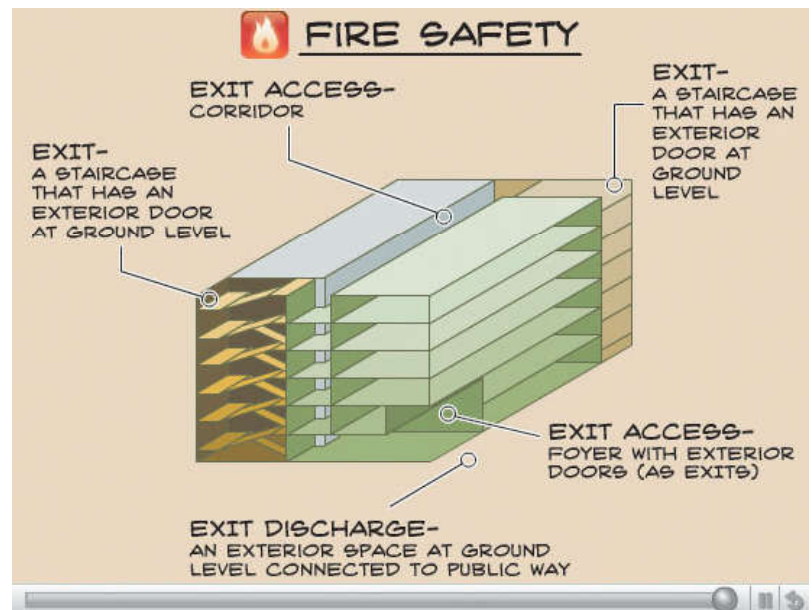
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Principles in Practice demonstrates practical applications of key concepts.

Accessible

This *second edition* has a powerful new online study resource called *MyConstructionKit*, which offers a wealth of tools to engage students.

- Over 150 learning modules provide interactive summaries of key concepts.
- Video links for every chapter bring real-life examples right to the students.
- Self-graded review questions are available for every chapter.
- Over 30 animations bring the art to life.



New Content

- Streamlined content designed to be more accessible
- More end-of-chapter review questions
- Expanded coverage on sustainable manufacturing of modern steel
- New coverage of building information modeling (BIM) and integrated project delivery (IPD)
- Coverage of all-precast concrete construction

Support

No book of this class would be complete without a robust supplement package for instructors and students.

For Instructors

- Instructor's Manual, ISBN-10: 0-13-214872-2
- PowerPoint Presentations, ISBN-10: 0-13-214874-9
- Test Bank, ISBN-10: 0-13- 214876-5

For Students

- Homework and Classroom Assignment Manual, ISBN-10: 0-13-214871-4
- *MyConstructionKit*, ISBN-10: 0-13-214936-2

PREFACE

We gratefully acknowledge the overwhelming response of the academic and professional communities to the first edition of this text in recognition of the text's unique pedagogical philosophy and distinguishing features. We hope that this full-color, updated second edition will continue to meet or exceed the expectations of the readers.

As stated in the preface to the first edition, building construction is a society's most dynamic enterprise, rooted in the inherent desire of humans to continually improve their habitat. The impact of this dynamism on building construction is that new products and construction systems are added to the existing stock in a never-ending process. In addition to new materials, new versions of traditional materials are proliferating. Consequently, today's designers and constructors face an unprecedented challenge as they strive to make well-informed decisions in the face of an expanding number of competing products and systems available for a given application.

The most accessible sources of information on building products often come from those who produce them. Although product testing is generally conducted by independent agencies, the results come to us through the filter of the manufacturers' vested interests and aggressive sales strategies, slanting the information unduly in favor of a specific product.

How do we, as designers and constructors, develop a critical faculty that enables us to sift facts from exaggeration and relevance from insignificance? How do we deal with the immense regional and international diversity of construction? How do we learn to function successfully in an increasingly litigious environment?

The core philosophy of this text is embedded in the belief that the best way for today's designers and constructors to respond successfully to the challenges just cited is for them to be sufficiently grounded in the principles of construction and the related systems. After all, the principles will be sustained, just as the conventional materials and practices will become dated all too soon. Equally important is the belief that architects, engineers, and constructors, well versed in the principles governing the performance of materials and systems, can produce a more wholesome and sustainable built environment.

PARTS 1 AND 2

The study of principles alone is not sufficient to master or fully grasp a subject. The principles must be illustrated by current and traditional practices in order to connect with real-world design and construction. *Building Construction: Principles, Materials, and Systems* aims to do just that. Therefore, the text is divided into two parts:

- Part 1, consisting of 10 chapters, deals primarily with the principles of building materials' and building assemblies' performance.
- Part 2, consisting of 27 chapters, deals primarily with specific materials and assemblies.

The experience of two of the book's authors, who have served in academia for many years, indicates that by introducing the basic principles common to the performance of most materials early in the course, it is possible to preclude or reduce repetition when progressing from one material or system to another. For example, thermal insulation is provided differently in different assemblies, but the thermal behavior of various assemblies is entrenched in the same basic principles. Similarly, all building assemblies must have some measure of fire endurance. Therefore, it makes sense to deal with the general properties and performance requirements of materials and systems in advance of their specifics.

However, there cannot be an absolute separation between the principles and their application. Some reiteration of the fundamentals as one proceeds through various materials and systems is unavoidable—in fact, pedagogically necessary. Additionally, there are certain principles that are limited only to one or two materials or assemblies. Those principles must be discussed in pertinent chapters.

DISTINGUISHING FEATURES

The book has several distinctive features. Each chapter is divided into convenient segments that pause with a set of multiple-choice (*Practice Quiz*) questions. Their purpose is to help the reader gain a broad understanding of the subject and assimilate its highlights. Answers to practice quizzes are provided in the end sheets of the book to facilitate self-testing by the readers. Testing for a detailed understanding of the chapter is accomplished through *Review Questions* provided at the end of each chapter.

A large number of *Margin Notes* expand on critical topics or topics that would stimulate the reader to pursue additional self-directed inquiry. Where a critical topic needs expanded coverage, beyond that given in the main body of the chapter or in margin notes, it is provided in the *Expand Your Knowledge* sections. Almost every chapter has one or more such sections.

Several chapters conclude with a section entitled *Principles in Practice*. These sections provide the opportunity for the interested reader (graduate students, practicing architects and engineers) to pursue in-depth study of the applications of construction principles to design issues without creating an undue burden in the main body of the chapter.

An entire chapter (Chapter 10) is devoted to the *Principles of Sustainable Construction* in Part 1 of the text, and this is followed up with a special section called *Focus on Sustainability* in various chapters of Part 2 of the text.

Appendix B: Preliminary Sizing of Structural Members provides rules of thumb for determining approximate dimensions of structural members of conventional wood, steel, masonry, and concrete structures as one consolidated reference—a handy guide in design studios for students and practitioners.

The book is copiously illustrated. Two-dimensional and three-dimensional line art supplement the text descriptions.

Color in line art has been used only in places where color improves dissemination of information. Most architectural drawings and details have been retained as two-dimensional black-and-white drawings.

Photographs and photorealistic renderings are intended to simulate a live, real-world construction site experience for the reader. Because of the use of color, some photorealistic renderings in this book can be mistaken for photographs. A particularly distinctive feature of the book is that 90% of its 600-plus photographs have been taken from various construction sites by the (primary) author in response to the demands of the text descriptions. Archival photos from manufacturers or industry sources have been carefully chosen to ensure relevance and their conformance with the best contemporary construction practices.

WHAT IS NEW IN THE SECOND EDITION

Several changes have been made in the second edition while retaining the book's distinctiveness. Virtually every chapter has been revised to some degree, and several new renderings, line art, and photographs have been added to supplement the text. Some revisions are in response to the users' feedback, while others are the result of developments in the design and construction industries. The change to a full-color book—with color photos and photorealistic renderings in color—obviously adds substantially to the book's pedagogical message. However, in addition to color, there are other key revisions:

1. The original chapter on Soils and Foundations, has been split into two smaller chapters: "Soils and Excavations" and "Below-Grade Construction: Foundation Systems and Basements". These two chapters have been moved to the beginning of Part 2: Materials and Systems (as Chapters 11 and 12, respectively). New line art and photographs have been added to both chapters to make them more accessible.
2. The original chapter "The Material Steel and Structural Steel Construction" has also been split into two chapters: "The Material Steel and Steel Components" and "Structural Steel Construction" with expanded coverage of sustainable manufacturing of modern steel.
3. Chapter 1 "An Overview of the Building Delivery Process" has been expanded to include coverage of building information modeling (BIM) and integrated project delivery (IPD).
4. A new Expand Your Knowledge section entitled "Wood Construction Prior to Balloon Frame" has been added to Chapter 15, "Wood Light-Frame Construction-I". This section addresses historical timber construction (a system that existed before the invention of the balloon frame), as well as modern timber frame construction, which is used today as an alternative to the more commonly used platform frame construction.
5. Chapter 6 addresses air and water vapor control, and has been completely rewritten and condensed, improving its accessibility and underscoring the impact of these mechanisms on energy use and sustainability.
6. The chapters on Stairs, Floor Coverings, and Ceilings have been rewritten and condensed.
7. The coverage of all-precast concrete construction, an important system for many building types, has been expanded, which further aids in distinguishing between all-precast and mixed-precast concrete construction systems.
8. The answers to practice quizzes have been moved to the end sheets of the book to provide a more serious approach to self-testing by the students. The number of review questions has been increased in every chapter.

ACADEMIC PROGRAMS AND THIS TEXT

Building Construction: Principles, Materials, and Systems, a joint undertaking of two educators and one practitioner, has been written for use in programs in architecture, architectural engineering, construction science, construction management, and landscape architecture. Its size and the extent of its coverage make it an ideal text for a two-semester course sequence. However, it can also be used successfully in other curricular contexts. It can be used in a one-semester introductory class to prepare beginning students for subsequent courses in structures and environmental controls, and it can be used later as a text in a more advanced construction course and as a design studio supplement.

LIMITATIONS

A cursory glimpse of the chapter titles of this text will reveal that building construction is a multidimensional discipline. To develop reasonable competence in this discipline, a fair knowledge of the fundamentals of design, history, art, and building science is necessary. This must be supplemented by careful and frequent observation of the construction process and interaction with contractors, material manufacturers, and assembly fabricators.

In other words, building construction cannot be learned merely by reading a book on the subject, regardless of the book's comprehensiveness. A book provides only the necessary introduction and the opportunities for the reader to explore and pursue the subject further. Although this book includes a large number of illustrations and construction photographs, they should not be regarded as a substitute for the reader's own observation of materials, details, and construction processes.

The book deals with the more commonly used, time-tested materials and assemblies. It does not pretend to cover some of the emerging technologies because of their uncertain future. An authentic test of a building assembly's performance must come from the field, because it is virtually impossible to simulate that in a laboratory.

TEACHING RESOURCES

For Instructors

Instructor's Manual (ISBN-10: 0-13-214872-2) – Complete with lecture notes, references to supplements, and solutions to the lab manual.

PowerPoint Presentations (ISBN-10: 0-13-214874-9) – Redesigned for this edition, the PowerPoints feature lecture notes and full-color images for every chapter.

MyTest Test Bank (ISBN-10: 0-13-214876-5) – A bank of all the questions you will need to teach the class.

To access supplementary materials online, instructors need to request an instructor access code. Go to **www.pearsonhighered.com/irc** to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at <http://247pearsoned.custhelp.com/>.

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Homework and Classroom Assignment Manual (ISBN-10: 0-13-214871-4) – This manual provides a set of homework exercises and projects designed to encourage critical thinking skills—exercises that typically involve the application of the information to design or construction problems. Solutions for the Lab Manual are available with the Instructor’s Manual.

MyConstructionKit (ISBN-10: 0-13-290771-2) – An online study tool with videos, animations, learning modules, and more.

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fiers, and master specification development and maintenance, in addition to being the specifier for major healthcare, sports, detention, municipal, and commercial projects, some valued in the hundreds of millions of dollars. He is active in the Construction Specifications Institute (CSI) at the local level (past president, secretary, and technical director) and national level (Education Committee and Practice Guide Task team), holds several CSI certifications, is Chairman of the Institute's Education Committee, was awarded CSI's prestigious J. Norman Hunter Memorial Award for advancing building sciences and specifications, and is the revision author for CSI's *Project Delivery Practice Guide* and its associated education program.

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An Overview of the Building Delivery Process

(How Buildings Come into Being)

CHAPTER OUTLINE

- 1.1 PROJECT DELIVERY PHASES
- 1.2 PREDESIGN PHASE
- 1.3 DESIGN PHASE
- 1.4 CSI MASTERFORMAT AND SPECIFICATIONS
- 1.5 PRECONSTRUCTION AND BID NEGOTIATION PHASE
- 1.6 GENERAL CONTRACTOR AND PROJECT DELIVERY METHODS
- 1.7 DESIGN-BID-BUILD PROJECT DELIVERY METHOD
- 1.8 CONSTRUCTION PHASE
- 1.9 CONSTRUCTION CONTRACT ADMINISTRATION
- 1.10 POSTCONSTRUCTION (PROJECT CLOSEOUT) PHASE
- 1.11 DESIGN-NEGOTIATE-BUILD PROJECT DELIVERY METHOD
- 1.12 CONSTRUCTION MANAGEMENT-RELATED PROJECT DELIVERY METHODS
- 1.13 DESIGN-BUILD (DB) PROJECT DELIVERY METHOD
- 1.14 FAST-TRACK PROJECT SCHEDULING
- 1.15 THE INTEGRATED PROJECT DELIVERY (IPD) METHOD

Building construction is a complex, significant, and rewarding process. It begins with an idea and culminates in a structure that may serve its occupants for several decades, even centuries. Like the manufacturing of products, building construction requires an ordered and planned assembly of materials. It is, however, far more complicated than product manufacturing. Buildings are assembled outdoors by a large number of diverse constructors and artisans on all types of sites and are subject to all kinds of weather.

Additionally, even a modest-sized building must satisfy many performance criteria and legal constraints, requires an immense variety of materials, and involves a large network of design and production firms. Building construction is further complicated by the fact that no two buildings are identical; each one must be custom-built to serve a unique function and respond to its specific context and the preferences of its owner, user, and occupant.

Because of a building's uniqueness, we invoke first principles in each building project. Although it may seem that we are "reinventing the wheel," we are in fact refining and improving the building delivery process. In so doing, we bring to the task the collective wisdom of the architects, engineers, and contractors who have done so before us. Although

there are movements that promote the development of standardized, mass-produced buildings, these seldom meet the distinct needs of each user.

Regardless of the uniqueness of each building project, the flow of activities, events, and processes necessary for a project's realization is virtually the same in all buildings. This chapter presents an overview of the activities, events, and processes that bring about a building—from the inception of an idea or a concept in the owner's mind to the completed *design* by the architects and engineers and, finally, to the actual *construction* of the building by the contractor.

Design and construction are two independent but related and generally sequential functions in the realization of a building. The former function deals with the creation of the *documents*, and the latter function involves interpreting and transforming these documents into reality—a building or a complex of buildings.

The chapter begins with a discussion of the various personnel involved in a project and the relational framework among them. Subsequently, a description of the two major elements of design documentation—construction drawings and specifications—is provided. Finally, the chapter examines some of the methods used for bringing a building into being, referred to as the *project delivery methods*. From the owner's perspective, these methods are called *project acquisition methods*.

The purpose of this chapter, as its title suggests, is to provide an overall, yet distilled, view of the construction process and its relationship with design. Although several contractual and legal issues are discussed, they should be treated as introductory. A reader requiring additional information on these topics should refer to texts specially devoted to them.

1.1 PROJECT DELIVERY PHASES

The process by which a building project is delivered to its owner may be divided into the following five phases, referred to as the *project delivery phases*. Although there is usually some overlap between adjacent phases, they generally follow this order:

- Predesign phase
- Design phase
- Preconstruction phase
- Construction phase
- Postconstruction phase

1.2 PREDESIGN PHASE

During the *predesign phase* (also called the *planning phase*), the project is defined in terms of its function, purpose, scope, size, and economics. This is the most crucial of the five phases, and is almost always managed by the owner and the owner's team. The success or failure of the project may depend on how well this phase is defined, detailed, and managed. Obviously, the clearer the project's definition, the easier it is to proceed to the subsequent phases. Some of the important predesign tasks are:

- *Building program definition*
- *Economic feasibility assessment*, including the project's overall budget and financing
- *Site assessment and selection*, including verifying the site's appropriateness and determining its designated land use (Chapter 2)
- *Governmental constraints assessment*, for example, building code and zoning constraints (Chapter 2) and other legal aspects of the project
- *Sustainability rating*—whether the owner would like the project to achieve the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) certification at some level (see Chapter 10)
- *Design team selection*

BUILDING (PROJECT) PROGRAM

This includes defining the activities, functions, and spaces required in the building, along with their approximate sizes and their relationships with each other. For a house or another small project, the program is usually simple and can be developed by the owner without external assistance. For a large project, however, where the owner may be an institution (such as a corporation, school board, hospital, religious organization, or governmental entity), developing the program may be a complex exercise. This may be due to the size and

complexity of the project or the need to involve several individuals—a corporation’s board of directors, for example—in decision making. These constituencies may have different views of the project, making it difficult to create a consensus.

Program development may also be complicated by situations in which the owner has a fuzzy idea of the project and is unable to define it clearly. By contrast, experienced owners tend to have a clear understanding of the project and generally provide a detailed, unambiguous program to the architect.

It is not unusual for the owner to involve the architect and a few other consultants of the design team in preparing the program. In this instance, the design team may be hired during the predesign phase. When the economic considerations of the project are paramount, the owner may also consult a construction cost analyst.

Whatever the situation, preparing the program is the first step in the project delivery process. It should be spelled out in writing and in sufficient detail to guide the design, reduce the liability risk for the architect, and avoid its misinterpretation. If a revision is made during the progress of the project, the owner’s written approval is necessary.

1.3 DESIGN PHASE

The *design phase* begins after the selection of the architect. Because the architect (usually a firm) may have limited capabilities for handling the broad range of building-design activities, several different, more specialized consultants are usually required, depending on the size and scope of the project.

In most projects, the design team consists of the architect, civil and structural consultants, and mechanical, electrical, plumbing, and fire-protection (MEPF) consultants. In complex projects, the design team may also include an acoustical consultant, roofing and waterproofing consultant, cost consultant, building code consultant, signage consultant, interior designer, landscape architect, and so on.

Some design firms have an entire design team (architects and specialized consultants) on staff, in which case the owner will contract with a single firm. Generally, however, the design team comprises several different design firms. In such cases, the owner typically contracts the architect, who in turn contracts the remaining design team members, Figure 1.1.

Thus, the architect functions as the prime design professional and, to a limited degree, as the owner’s representative. The architect is liable to the owner for his or her own work and that of the consultants. For that reason, most architects ensure that their consultants carry adequate liability insurance.

In some projects, the owner may contract some consultants directly, particularly a civil consultant (for a survey of the site, site grading, slope stabilization, and site drainage), a geotechnical consultant (for investigation of the soil properties), and a landscape architect (for landscape and site design), Figure 1.2. These consultants may be engaged before or at the same time as the architect.

Even when a consultant is contracted directly by the owner, the architect retains some liability for the consultant’s work. This liability occurs because the architect, being the prime design professional, coordinates the entire design effort, and the consultants’ work is influenced a great deal by the architectural decisions. Therefore, the working relationship

NOTE

Building (Project) Program

The American Institute of Architects (AIA) Document B141, *Standard Form of Agreement Between Owner and Architect*, defines the building program as “the owner’s objectives, schedule, constraints and criteria including space requirements and relationships, special equipment, flexibility, expandability, systems, and site requirements.”

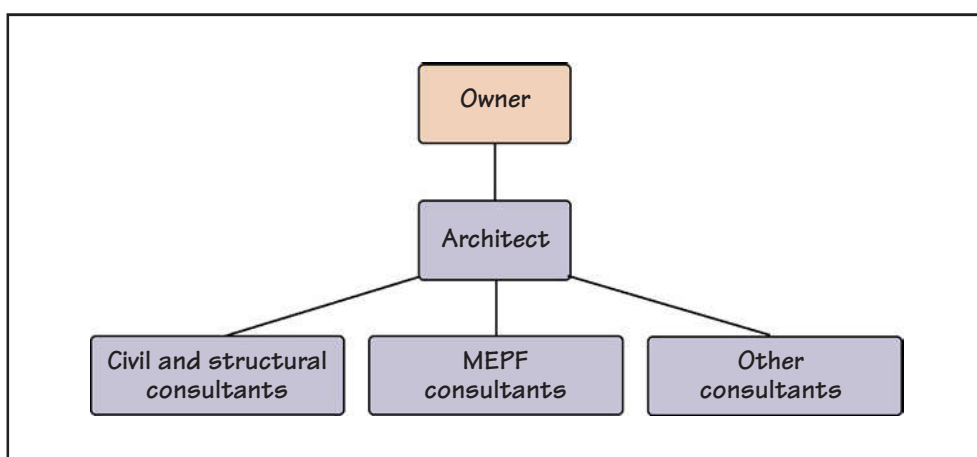


FIGURE 1.1 Members of a typical design team, and their interrelationships with each other and the owner in a traditional contractual setup. A line in this illustration indicates a contractual relationship between parties. (“MEPF consultants” is an acronym for mechanical, electrical, plumbing and fire consultants.)

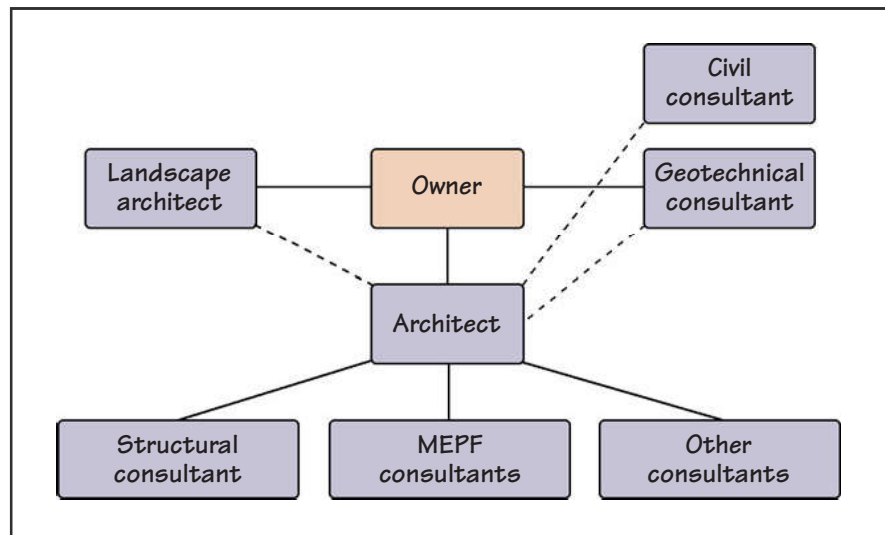


FIGURE 1.2 Members of a typical design team, and their interrelationships with each other and the owner in a project where some consultants are contracted directly by the owner. A solid line in this illustration indicates a contractual relationship between parties. A dashed line indicates a communication link, not a contract.

between the architect and an owner-contracted consultant remains essentially the same as if the consultant were chosen by the architect.

In some cases, an engineer or another professional may coordinate the design process. This generally occurs when a building is a minor component of a large-scale project. For example, in a highly technical project such as a power plant, an electrical engineer may be the prime design professional.

In most building projects, the design phase consists of three stages:

- Schematic design stage
- Design development stage
- Construction documents stage

SCHEMATIC DESIGN (SD) STAGE—EMPHASIS ON DESIGN

The *schematic design* gives graphic shape to the project program. It is an overall design concept that illustrates the key ideas of the design solution. The major player in this stage is the architect, who develops the design scheme (or several design options) with only limited help from the consultants. Because most projects have strict budgetary limitations, a rough estimate of the project's probable cost is generally produced at this stage.

The schematic design usually goes through several revisions, because the first design scheme prepared by the architect will rarely be approved by the owner. The architect communicates the design proposal(s) to the owner through various types of drawings—plans, elevations, sections, freehand sketches, and three-dimensional graphics (isometrics, axonometrics, and perspectives). For some projects, a three-dimensional scale model of the entire building or the complex of buildings, showing the context (neighboring buildings) within which the project is sited, may be needed.

With significant developments in electronic media technology, especially building information modeling (BIM), computer-generated imagery has become common in architecture and related engineering disciplines. Computer-generated walk-through and flyover simulations are becoming increasingly popular ways of communicating the architect's design intent to the owner and the related organizations at the SD stage.

It is important to note that the schematic design drawings, images, models, and simulations, regardless of how well they are produced, are not adequate to construct the building. Their objective is merely to communicate the design scheme to the owner (and to consultants, who may or may not be on board at this stage), not to the contractor.

DESIGN DEVELOPMENT (DD) STAGE—EMPHASIS ON DECISION MAKING

Once the schematic design is approved by the owner, the process of designing the building in greater detail begins. During this stage, the schematic design is developed further—hence the term *design development* (DD) stage.

While the emphasis in the SD stage is on the creative, conceptual, and innovative aspects of design, the DD stage focuses on developing practical and pragmatic solutions for the exterior envelope, structure, fenestration, interior systems, MEPF systems, and so forth. This development involves strategic consultations with all members of the design team.

Therefore, the most critical feature of the DD stage is decision making, which may range from broad design aspects to details. At this stage, the vast majority of decisions about products, materials, and equipment are made. Efficient execution of the construction documents depends directly on how well the DD is managed. A more detailed version of the specifications and probable cost of the project is also prepared at this stage.

CONSTRUCTION DOCUMENTS (CD) STAGE—EMPHASIS ON DOCUMENTATION

The purpose of the *construction documents* (CD) stage is to prepare all documents required by the contractor to construct the building. During this stage, the consultants and architect collaborate intensively to work out the “nuts and bolts” of the building and develop the required documentation, referred to as *construction documents*. All of the consultants advise the architect, but they also collaborate with each other (generally through the architect) so that the work of one consultant agrees with that of the others.

The construction documents consist of the following:

- Construction drawings
- Specifications

CONSTRUCTION DRAWINGS

During the CD stage, the architect and consultants prepare their own sets of drawings, referred to as *construction drawings*. Thus, a project has architectural construction drawings, civil and structural construction drawings, MEPF construction drawings, landscape construction drawings, and so on.

Construction drawings are dimensioned drawings (usually computer generated) that fully delineate the building. They consist of floor plans, elevations, sections, schedules, and various large-scale details. The details depict a small portion of the building that cannot be adequately described on smaller-scale plans, elevations, or sections.

Construction drawings are the drawings that the construction team uses to build the building. Therefore, they must indicate the geometry, layout, dimensions, types of materials, details of assembling the components, colors and textures, and so on. Construction drawings are generally two-dimensional drawings, but three-dimensional isometrics are sometimes used for complex details. Construction drawings are also used by the contractor to prepare a detailed cost estimate of the project at the time of bidding.

Construction drawings are not a sequence of assembly instructions, such as for a bicycle. Instead, they indicate what every component is and where it will be located when the building is completed. In other words, the design team decides the “what” and “where” of the building. The “how” and “when” of the building are entirely in the contractor’s domain.

SPECIFICATIONS

Buildings cannot be constructed from drawings alone, because there is a great deal of information that cannot be included in the drawings. For instance, the drawings will give the locations of columns, their dimensions, and the material used (such as reinforced concrete), but the quality of materials, their properties (the strength of concrete, for example), and the test methods required to confirm compliance cannot be furnished on the drawings. This information is included in the document called *specifications*.

Specifications are written technical descriptions of the design intent, whereas the drawings provide the graphic description. The two components of the construction documents—the specifications and the construction drawings—complement each other and generally deal with different aspects of the project. Because they are complementary, they are supposed to be used in conjunction with each other. There is no order of precedence between the construction drawings and the specifications. Thus, if an item is described in only one place—either the specification or the drawings—it is part of the project, as if described in the other.

For instance, if the construction drawings do not show the door hardware (hinges, locks, handles, and other components) but the hardware is described in the specifications, the owner will get the doors with the stated hardware. If the drawings had precedence over the specifications, the owner would receive doors without hinges and handles.

NOTE

Working Drawings and Construction Drawings

The term *working drawings* was used until the end of the twentieth century for what are now commonly referred to as *construction drawings*.

Relationship Between Construction Drawings and Specifications

Construction Drawings	Specifications
Design intent represented graphically	Design intent represented with words
Product/material may be shown many times	Product/material described only once
Product/material shown generically	Product/material identified specifically, sometimes proprietary to a manufacturer
Quantity indicated	Quality indicated
Location of elements established	Installation requirements of elements established
Size, shape, and relationship of building elements provided	Description, properties, characteristics, and finishes of building elements provided

Generally, there is little overlap between the drawings and the specifications. More importantly, there should be no conflict between them. If a conflict between the two documents is identified, the contractor must bring it to the attention of the architect promptly. In fact, construction contracts generally require that before starting any portion of the project, the contractor must carefully study and compare the drawings and the specifications and report inconsistencies to the architect.

If the conflict between the specifications and the construction drawings goes unnoticed initially but later results in a dispute, the courts have in most cases resolved it in favor of the specifications—implying that the specifications, not the drawings, govern the project. However, if the owner or the design team wishes to reverse the order, it may be so stated in the owner-contractor agreement.

THE CONSTRUCTION DOCUMENT SET

Just as the construction drawings are prepared separately by the architect and each consultant for their respective portions of the work, so are the specifications. The specifications from various design team members are assembled by the architect in a single document called the *project manual*. Because the specifications consist of printed (typed) pages (not graphic images), a project manual is a bound document—like a book.

The major component of a project manual is the specifications. However, the project manual also contains other items, as explained later in this chapter.

The set of construction drawings (from various design team members) and the project manual together constitute what is known as the *construction document set*, Figure 1.3. The construction document set is the document that the owner and architect use to invite bids from prospective contractors.

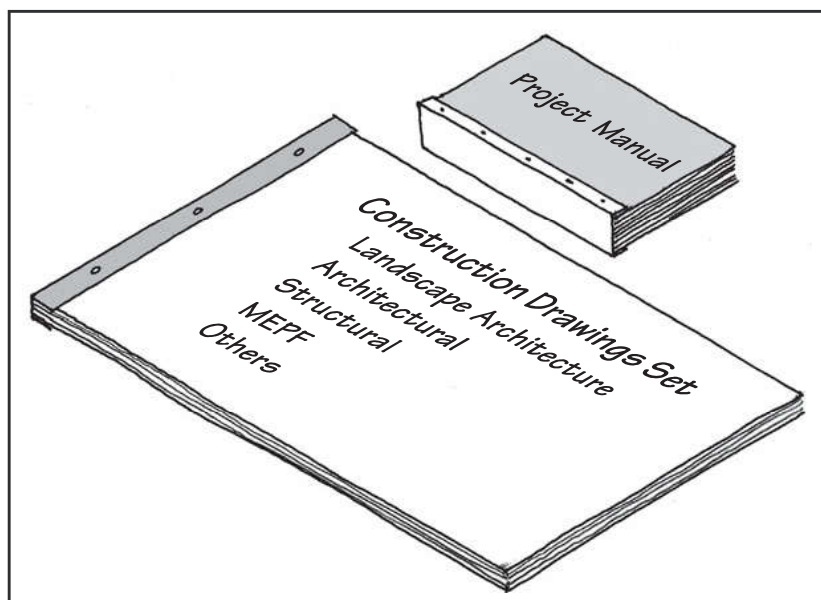


FIGURE 1.3 A construction document set consists of a set of architectural and consultants’ construction drawings plus the project manual. The project manual is bound in a book format.

The owner's role in the design phase of the project may not appear as active as in the pre-design phase, but it is important all the same. In fact, a conscientious owner will be fully involved throughout the entire project delivery process—from the predesign phase through the project closeout phase.

PRACTICE QUIZ

Each question has only one correct answer. Select the choice that best answers the question.

- The realization of a typical building project, as described in this text, may be divided into
 - two phases.
 - three phases.
 - four phases.
 - five phases.
 - six phases.
- Establishing the project's economic feasibility and its overall budget is part of the design phase of the project.
 - True
 - False
- The term MEPF stands for
 - mechanical, electrical, piping, and foundations.
 - mechanical, electrical, plumbing, and foundations.
 - mechanical, electrical, plumbing, and fire.
 - mechanical, electrical, piping, and fire.
- The program for a building project is usually provided by the
 - owner.
 - general contractor.
 - building official of the city.
 - architect.
 - any one of these, depending on the type of building.
- In a typical building project, the coordination of the building's design is done by the
 - owner.
 - general contractor.
 - building official of the city.
 - architect.
 - any one of these, depending on the type of building.
- The construction drawings of a building project are prepared during the
 - SD stage of the project.
 - DD stage of the project.
 - CD stage of the project.
 - preconstruction phase of the project.
 - construction phase of the project.
- The construction drawings of a building project are drawings that the architect uses to explain the design to the owner.
 - True
 - False
- The construction drawings of a building project are generally in the form of
 - freehand sketches.
 - two-dimensional plans, elevations, sections, and details.
 - three-dimensional drawings.
 - photographs of three-dimensional scale model(s).
 - all of the above.
- The construction drawings for a building project generally consist of
 - architectural drawings.
 - structural drawings.
 - MEPF drawings.
 - all of the above.
 - (a) and (b) only.
- The most extensive part of a project manual is
 - construction drawings.
 - construction schedule.
 - owner's program.
 - owner-architect agreement.
 - none of the above.

1.4 CSI MASTERFORMAT AND SPECIFICATIONS

The specification document for even a modest-sized project can run into hundreds of pages. It is used not only by the contractor and the subcontractors, but also by the owner, the material suppliers—in fact, the entire construction team. With so many different people using it, it is necessary that the specifications be organized in a standard format so that each user can go to the section of particular interest without having to wade through the entire document.

The standard organizational format for specifications, referred to as *MasterFormat*, has been developed by the Construction Specifications Institute (CSI) and is the format most commonly used in the United States and Canada. MasterFormat consists of 50 divisions, which are identified using six-digit numbers.

The first two digits of the numbering system (referred to as *Level 1* digits) identify the division number. The 50 division numbers are 00, 01, 02, 03, . . . , 48, and 49. A division identifies the broadest collection of related products and assemblies, such as Division 03—Concrete.

The next two digits of the numbering system (*Level 2* digits) refer to various sections within the division, and the last two digits (*Level 3* digits) refer to the subsections within a section. In other words, Level 2 and Level 3 digits classify products and assemblies into progressively closer affiliations. Thus, Level 1 digits in MasterFormat may be compared to chapter numbers in a book, Level 2 digits to section numbers of a chapter, and Level 3 digits to subsection numbers of a section.

A complete list of MasterFormat titles is voluminous. Figure 1.4 gives the division titles and the additional details of one of the divisions, Division 04—Masonry, as an illustration of the numbering system. Note that apart from the classification in divisions, MasterFormat

is divided into two groups: the *Procurement and Contracting Group* (Division 00) and the *Specifications Group* (Divisions 01 to 49).

Because MasterFormat deals with all types of construction (new facilities, renovations, facility maintenance, services, urban infrastructural construction, equipment, and so forth), the Specification Group has been divided into four subgroups, as shown in Figure 1.4.

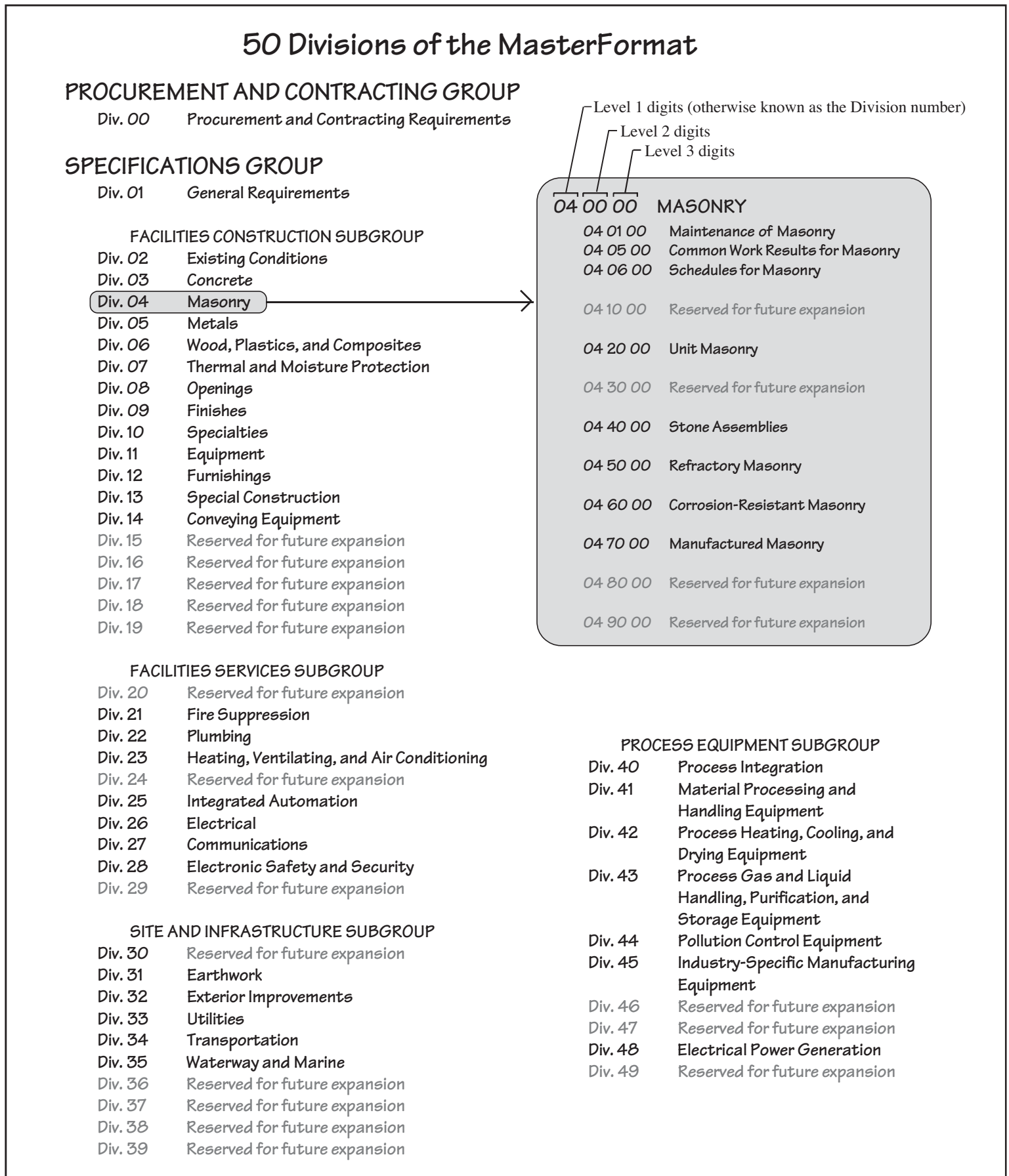


FIGURE 1.4 MasterFormat divisions. The Masonry division has been further elaborated as an illustration.

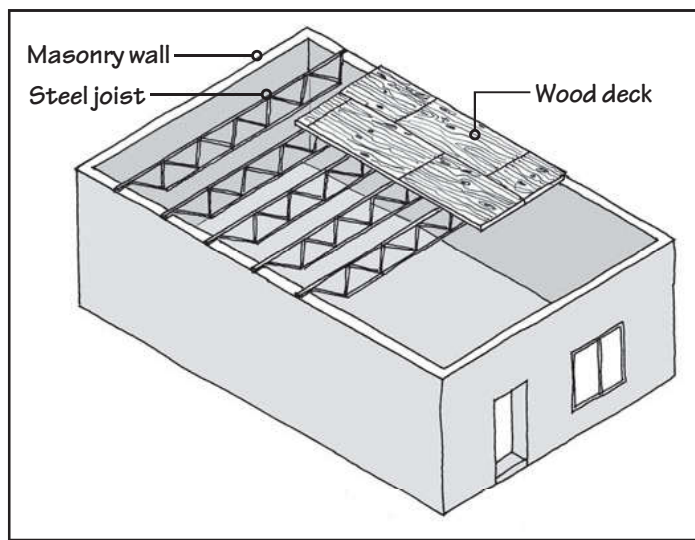


FIGURE 1.5 A simple load-bearing masonry wall building with steel roof trusses and wood roof deck used as an aid to recalling the sequence of the first few (architecturally important) divisions of the MasterFormat.

RECOLLECTING THE MASTERFORMAT DIVISION SEQUENCE

Architectural design typically involves Divisions 2 to 14 of the Facilities Construction Subgroup. Although the basis for sequencing the Divisions in this subgroup is far more complicated, the first few divisions (those that are used in virtually all buildings) may be deduced by visualizing the sequence of postearthwork operations required in constructing the simple building shown in Figure 1.5. The building consists of load-bearing masonry walls, steel roof joists, and wood roof deck.

The first operation is the foundations for the walls. Because foundations are typically made of concrete, *Concrete* is Division 03. After the foundations have been completed, masonry work for the walls can begin. Thus, *Masonry* is Division 04. After the walls are completed, steel roof joists can be placed. Thus, Division 05 is *Metals*. The installation of the wood roof deck follows that of the steel joists. Hence, *Wood, Plastics, and Composites* is Division 06.

After the roof deck is erected, it must be insulated and protected against weather. Therefore, *Thermal and Moisture Protection* is Division 07. Roofing and waterproofing (of basements) are part of this division, as are wall insulation and joint sealants. The next step is to protect the rest of the envelope; hence, Division 08 is *Openings*. All doors and windows are part of this division, regardless of whether they are made of steel, aluminum, or wood.

With the envelope protected, finish operations, such as those involving the interior dry-wall, flooring, and ceiling, can begin. Thus, Division 09 is *Finishes*. Division 10 is *Specialties*, which consists of several items that cannot be included in the previous divisions, such as toilet partitions, lockers, storage shelving, and movable partitions.

Obviously, the building must now receive all the necessary office, kitchen, laboratory, or other equipment. Thus, Division 11 is *Equipment*. Division 12 is *Furnishings*, followed by *Special Construction* (Division 13) and *Conveying Equipment* (Division 14).

Before any construction operation can begin, there must be references to items that apply to all divisions, such as payment procedures, product-substitution procedures, contract-modification procedures, contractor's temporary facilities, and regulatory requirements imposed by the city or any other authority having jurisdiction. This is Division 01, *General Requirements*. Division 00 (*Procurement and Contracting Requirements*) refers to the requirements for the procurement of bids from prospective contractors.

CONSTRUCTION-RELATED INFORMATION

Familiarity with MasterFormat is required to prepare the project manual and write the specifications for the project. It is also helpful in filing and storing construction information in an office. Material manufacturers also use MasterFormat division numbers in catalogs and publications provided to design and construction professionals.

MasterFormat is also helpful when seeking information about a construction material or system, as any serious student of construction (architect, engineer, or builder) must frequently do.

NOTE

Difference Between Specialties (Division 10) and Special Construction (Division 13)

Specialties (Division 10) includes prefabricated items such as marker boards, chalkboards, tackboards, lockers, shelves, grilles and screens, louvers and vents, flagpoles, manufactured fireplaces, and demountable partitions.

Special Construction (Division 13) includes items that are generally site fabricated but are not covered in other divisions, such as air-supported fabric structures, swimming pools, ice rinks, aquariums, planetariums, geodesic structures, and sound and vibration control.

NOTE

Important Items Included in Division 00 (Procurement and Contracting Requirements)

- Advertisements for bids
- Invitation to bid
- Instruction to bidders
- Prebid meetings
- Land survey information
- Geotechnical information
- Bid forms
- Owner-contractor agreement forms
- Bond forms
- Certificate of substantial completion form
- Certificate of completion form
- Conditions of the contract