

THIRD EDITION

BUILDING CONSTRUCTION

Principles,
Materials,
and Systems



Madan Mehta
Walter Scarborough
Diane Armpriest

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Principles, Materials, and Systems Third Edition

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PREFACE

The authors gratefully acknowledge the overwhelming response of the academic and professional communities of architecture, engineering, and construction to the first two editions of this text in recognition of its unique pedagogical philosophy and distinguishing features. We hope that this full-color third edition, which retains the book's uniqueness and includes several revisions to update it to the current state of professional practice, will continue to meet or exceed the expectations of the readers.

As stated in the preface to previous editions, 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 source of information on building products often comes 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 and science 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 resilient 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 the 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 the authors 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, it is 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 and the ability to apply knowledge gained from a 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 titled *Principles in Practice*. These sections provide the opportunity for the interested reader (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 in various chapters of Part 2 called *Focus on Sustainability*. *Appendix B: Preliminary Sizing of Structural Members*, which provides rules of thumb for determining the 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.

As the reader will observe, 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.

Several architectural drawings and details have been retained in the original two-dimensional black-and-white format.

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 approximately 95% 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 kept to a minimum and carefully chosen to ensure relevance and their conformance with the best contemporary construction practices.

WHAT IS NEW IN THE THIRD EDITION

As previously mentioned, several revisions have been made in this edition while retaining the book's distinctiveness. Virtually every chapter has been revised to some degree. Chapters 1, 5, 6, 7, 10, 20, 33, and 36 have been completely revised with entirely new manuscripts. Chapters 2, 13, 15, 26, 28, 29, and 37 contain substantial manuscript revisions.

Various factors have contributed to revisions. Some of these are due to the continuous upgrading of our knowledge in the science and principles of materials and construction. Other revisions are the result of changes in means, methods, and the technologies related to construction, such as the widespread use of virtual construction. Some chapters have been reworked and provided with enhanced graphics to improve content accessibility. New products and assemblies that show promise of successful future applications have been added.

A major factor, however, that has prompted revisions in several chapters is the updates in codes and standards, particularly in the International Building Code (IBC), the International Energy Conservation Code (IECC), the International Green Construction Code (IGCC), and the United States Green Building Council's (USGBC) LEED rating system. Owing to their roots in the science of construction, the updates in these documents have led to revisions in both Part 1 and Part 2 chapters. For example, the new requirement in IECC to provide continuous envelope insulation is based on studies that testified to an unduly large reductions in insulation effectiveness caused by seemingly small thermal bridges. Consequently, the IECC update has led to revisions in Chapter 5 (Thermal Properties) and also in chapters that cover the detailing of wall cladding assemblies (Chapters 27 through 29).

Similarly, the new version (version 4) of USGBC's LEED rating system has completely revised its Materials and Resources (MR) section. This change in the rating system is expected to contribute significantly to sustainability efforts as an increasingly large number of jurisdictions adopt the IGCC to ensure that the jurisdiction's entire building stock has some minimum level of sustainability. The default sustainability rating is set by several jurisdictions to correspond to a specified number of points in LEED rating system.

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, and construction management. The size and 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.

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An Overview of the Building Delivery Process

(How Buildings Come into Being)

CHAPTER OUTLINE

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| 1.2 PREDESIGN PHASE | 1.12 POSTCONSTRUCTION PHASE: PROJECT CLOSEOUT |
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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 conditions.

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 various stakeholders (personnel involved in the design and construction of the 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* or *programming 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 is, the easier it is to proceed to the subsequent phases. Some of the important predesign tasks are:

- Details of the project's program.
- Economic feasibility assessment, including the project's overall budget and financing.
- Site assessment and selection, including the verification of the site's appropriateness, and determining its designated land use (see Chapter 2).
- Governmental constraints assessment, for example, building code and zoning constraints (see Chapter 2) and other legal aspects of the project.
- Sustainability rating—whether the owner would like the project to achieve sustainability rating, such as 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.

Although the owner must provide the program details to the architect, it is not unusual for the owner to involve the architect in preparing the program for some architecturally complex projects. In this instance, the architect may be hired early during the predesign phase. Note that the architect’s role in the preparation of the building program is not considered a part of the architect’s “basic” services, but as an “additional” service, compensated separately [Ref. 1.1].

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, landscape architect, civil and structural consultants, and mechanical, electrical, and plumbing (MEP) 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, 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.

ARCHITECT’S LIABILITY FOR WORK DONE BY OWNER-CONTRACTED CONSULTANT

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 the design of site drainage system), 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.

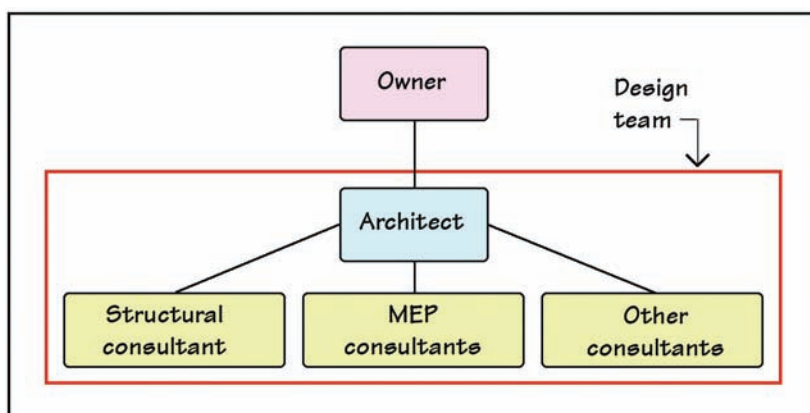


FIGURE 1.1 Members of a typical design team, and their interrelationships with each other and the owner in a traditional contractual set-up. A line in this illustration indicates a contractual relationship between parties. (“MEP consultants” is an acronym for mechanical, electrical, and plumbing consultants.)

NOTE

Building (Project) Program

The American Institute of Architects (AIA) Document B141-1997, *Standard Form of Agreement Between Owner and Architect*, defines the building program: “A program is a written statement setting forth design objectives, constraints, and criteria for a project A program includes space requirements and relationships, flexibility and expandability, special equipment and systems, and site requirements. If a comprehensive program is not available at the outset of the project, the owner may obtain the architect’s assistance in developing one as an expansion of services”.

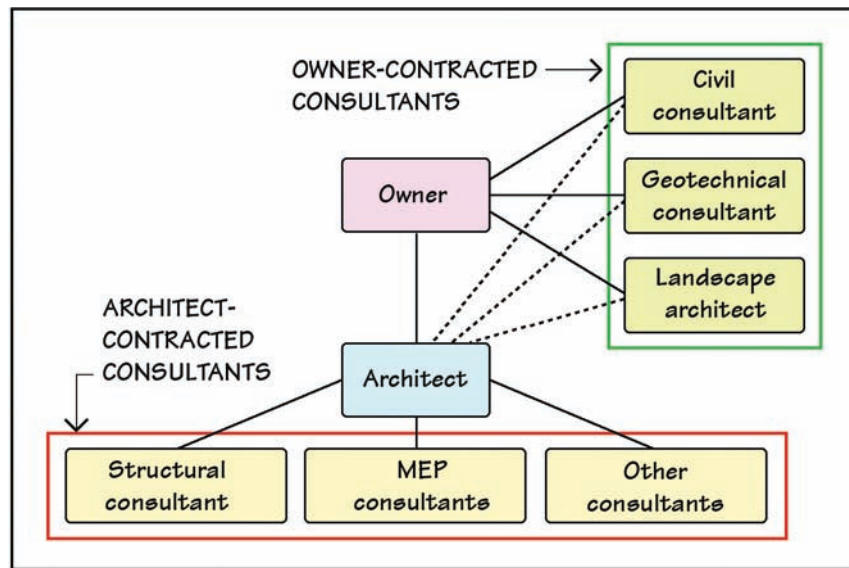


FIGURE 1.2 Members of a typical design team, and their interrelationships with each other and the owner in a project where some consultants are contracted directly by the owner. A solid line in this illustration indicates a contractual relationship between parties. A dashed line indicates a communication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

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

ENGINEER AS PRIME DESIGN PROFESSIONAL

In some cases, an engineer or another professional may coordinate the design process. This generally occurs where architectural design 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.

1.4 THREE SEQUENTIAL STAGES IN DESIGN PHASE

In most building projects, the design phase consists of three stages, which occur in the following sequence:

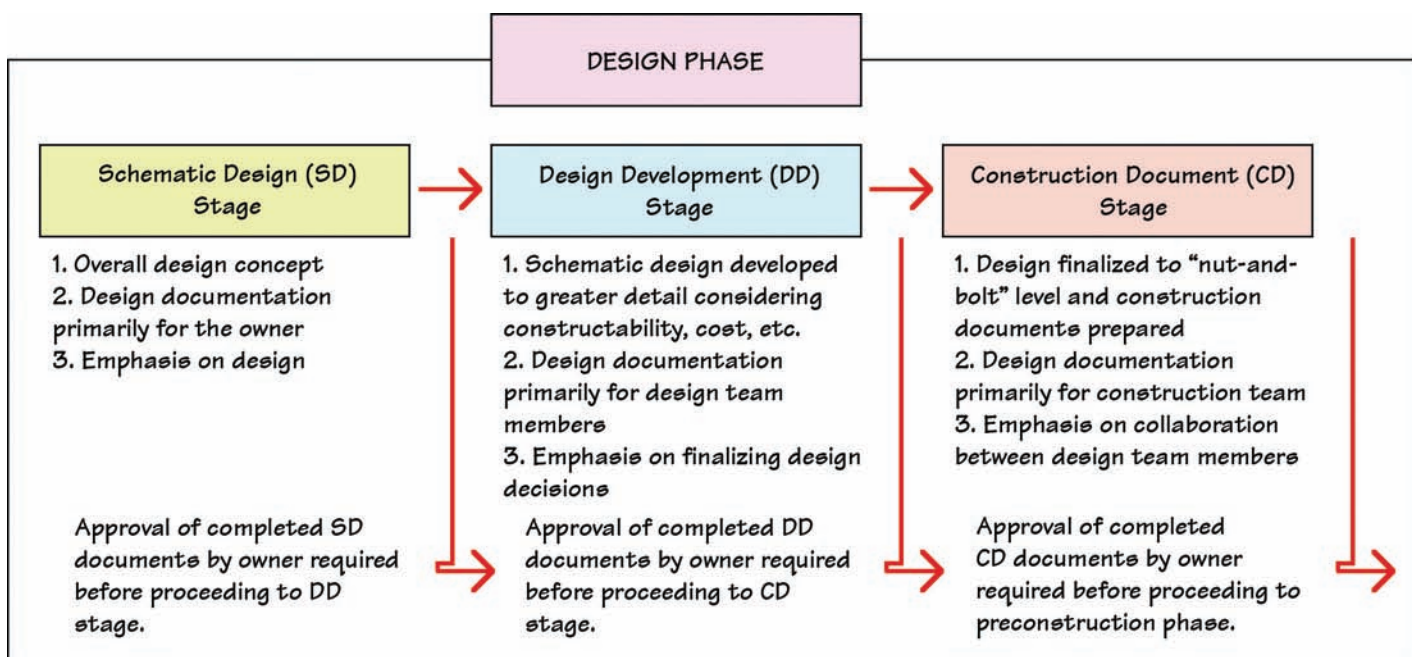


FIGURE 1.3 Three sequential stages (steps) of the design phase and the important tasks accomplished in each stage.

- Schematic design (SD) stage
- Design development (DD) stage
- Construction document (CD) stage

Figure 1.3 illustrates the sequence and the important tasks accomplished in each stage. Note that at the end of each stage, a written approval from the owner is required before proceeding to the next stage, or from the design phase to the preconstruction phase.

SCHEMATIC DESIGN STAGE—EMPHASIS ON DESIGN

The schematic design gives graphic shape to the project program. It is an overall concept that illustrates key ideas of the design solution. The major player in this stage is the architect, who develops the design scheme (or several design options), generally with 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 for communicating the architect's design intent to the owner 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 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, pragmatic, and constructible solutions for the exterior envelope, structure, fenestration, interior systems, MEP 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 ranges from broad design aspects to finer 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 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 items:

- 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, MEP construction drawings, landscape construction drawings, and so on.

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*.

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” (means, methods, and sequencing) of construction 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.

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 can be so stated in the owner-contractor agreement.

EXPAND YOUR KNOWLEDGE

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

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. Because the specifications are in text format (not as drawings), they are bound in book format. A few other items are also included in this document at a later stage, and the entire bound document is called the *project manual*, described in Section 1.7. The construction drawings plus the specifications constitute the construction document set, Figure 1.4 (see also Figure 1.11). Although hardcopy drawings and specification are common, their digital versions are being increasingly used.

OWNER'S ROLE DURING DESIGN PHASE

The owner's role in the design phase of the project may not appear as active as in the predesign 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.

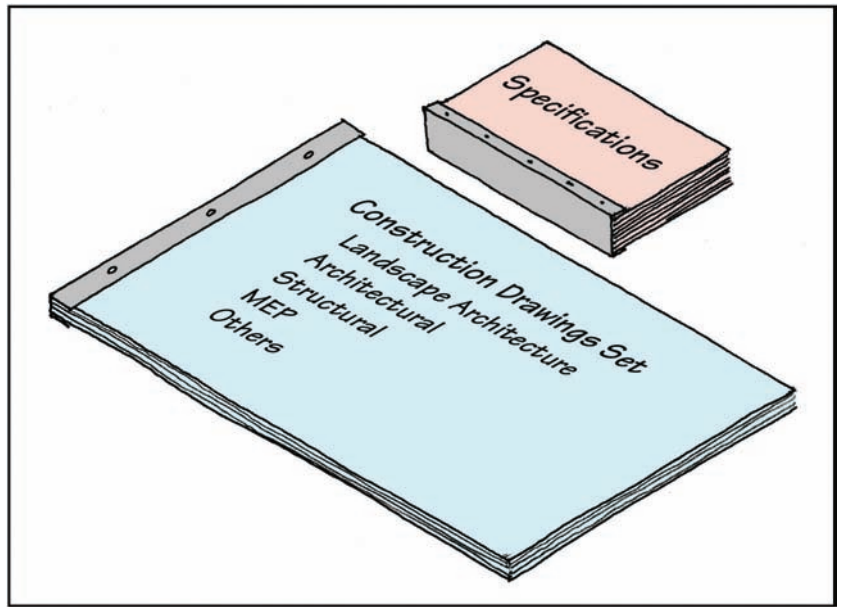


FIGURE 1.4 A construction document set consists of a set of architectural and consultants' construction drawings plus the specifications prepared by the architect and the consultants. The specifications are bound in book format along with other items.

PRACTICE QUIZ

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

- The delivery 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 MEP is an acronym for
 - municipal emergency plan.
 - mechanical, electrical, and plumbing.
 - mechanical, electrical, and piping.
 - mechanical and electrical plans.
 - mechanical and electrical plant.
- The program for a building project is prepared by the
 - owner.
 - general contractor.
 - building official of the city.
 - architect.
 - all of the above collectively.
- 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 the above, 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 and structural drawings.
 - architectural drawings, structural drawings, and MEP drawings.
 - architectural drawings, structural drawings, MEP, and QSA drawings.
 - architectural drawings, structural drawings, and QSA drawings.
 - none of the above.
- The construction document set consists of
 - construction drawings.
 - construction drawings and construction schedule.
 - construction drawings, construction schedule, and owner-contractor agreement.
 - construction drawings, construction schedule, and specifications.
 - construction drawings and specifications.
- The specifications of a typical building project are prepared by the
 - architect.
 - architect in collaboration with the GC.
 - architect in collaboration with the GC and the architect's consultants.
 - architect and the architect's consultants.
 - none of the above.

1.5 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, and 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 is divided into two groups—(i) *Procurement and Contracting Requirements* group and (ii) *Specifications* group, Figure 1.5. The Specifications group is further divided into five subgroups, and each subgroup consists of divisions. The subgroup *General Requirements* comprises one division; *Facilities Construction* subgroup has 18 divisions; and the following three subgroups have 10 divisions each.

The total number of divisions in MasterFormat is 50, 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 1.6 provides a bird’s-eye view of MasterFormat, showing groups, subgroups, and divisions in each subgroup. It also provides additional details of one of the divisions, Division 04—Masonry—as brief illustration of the numbering system. Note that the *Procurement and Contracting Requirements* group is Division 00 and the *Specifications* group consists of Divisions 01 to 49.

Also note that MasterFormat deals with all types of construction (new buildings, renovations, and maintenance). Construction work and products, not directly related with buildings (services, urban infrastructural construction, equipment, etc.) are also included—in Divisions 30 to 49.

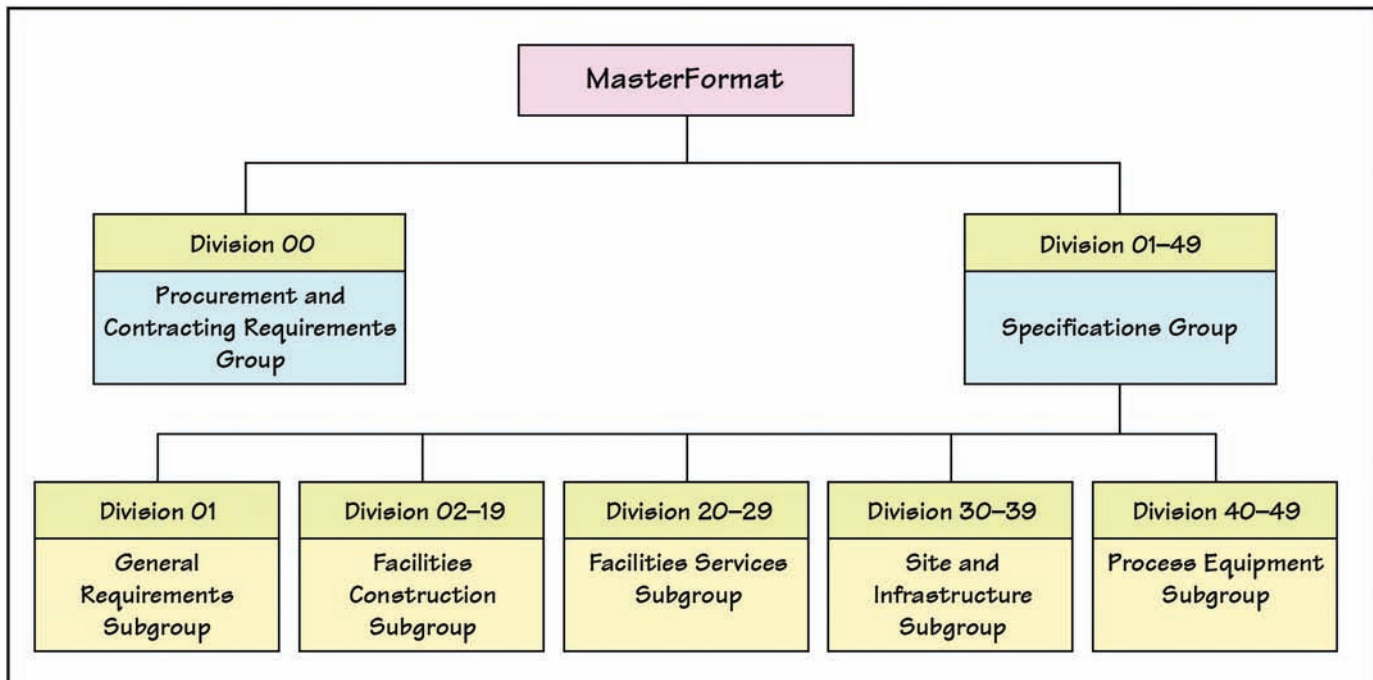


FIGURE 1.5 Structure of the MasterFormat, showing its separation into two groups—(i) Procurement and Contracting Requirements group and (ii) Specifications group. The Specifications group is further divided into five subgroups. Each subgroup is divided into a number of divisions.

50 Divisions of the MasterFormat

PROCUREMENT AND CONTRACTING REQUIREMENTS GROUP

Division 00 Procurement and Contracting Requirements

SPECIFICATIONS GROUP

Div. 01 General Requirements

FACILITIES CONSTRUCTION SUBGROUP

- Div. 02 Existing Conditions
- Div. 03 Concrete
- Div. 04 Masonry
- Div. 05 Metals
- Div. 06 Wood, Plastics, and Composites
- Div. 07 Thermal and Moisture Protection
- Div. 08 Openings
- Div. 09 Finishes
- Div. 10 Specialities
- Div. 11 Equipment
- Div. 12 Furnishings
- Div. 13 Special Construction
- Div. 14 Conveying Equipment
- Div. 15 Reserved for Future Expansion
- Div. 16 Reserved for Future Expansion
- Div. 17 Reserved for Future Expansion
- Div. 18 Reserved for Future Expansion
- Div. 19 Reserved for Future Expansion

FACILITIES SERVICES SUBGROUP

- Div. 20 Reserved for Future Expansion
- Div. 21 Fire Suppression
- Div. 22 Plumbing
- Div. 23 Heating, Ventilating, and Air Conditioning
- Div. 24 Reserved for Future Expansion
- Div. 25 Integrated Automation
- Div. 26 Electrical
- Div. 27 Communications
- Div. 28 Electronic Safety and Security
- Div. 29 Reserved for Future Expansion

SITE AND INFRASTRUCTURE SUBGROUP

- Div. 30 Reserved for Future Expansion
- Div. 31 Earthwork
- Div. 32 Exterior Improvements
- Div. 33 Utilities
- Div. 34 Transportation
- Div. 35 Waterway and Marine Construction
- Div. 36 Reserved for Future Expansion

Level 1 digits
Level 2 digits
Level 3 digits

04	00	00	MASONRY
04	01	00	Maintenance of Masonry
04	03	00	Conservation Treatment for Period Masonry
04	05	00	Common Work Results for Masonry
04	06	00	Schedules for Masonry
04	08	00	Commissioning of Masonry
04	20	00	Unit Masonry
04	21	00	Clay Unit Masonry
04	22	00	Concrete Unit Masonry
04	23	00	Glass Unit Masonry
04	24	00	Adobe Unit Masonry
04	25	00	Unit Masonry Panels
04	26	00	Single-Wythe Unit Masonry
04	27	00	Multiple-Wythe Unit Masonry
04	28	00	Concrete Form Masonry Units
04	29	00	Engineered Unit Masonry
04	40	00	Stone Assemblies
04	41	00	Dry-Placed Stone
04	42	00	Exterior Stone Cladding
04	43	00	Stone Masonry
04	50	00	Refractory Masonry

- Div. 37 Reserved for Future Expansion
- Div. 38 Reserved for Future Expansion
- Div. 39 Reserved for Future Expansion

PROCESS EQUIPMENT SUBGROUP

- Div. 40 Process Interconnections
- Div. 41 Material Processing and Handling Equipment
- Div. 42 Process Heating, Cooling, and Drying Equipment
- Div. 43 Process Gas and Liquid Handling, Purification, and Storage Equipment
- Div. 44 Pollution and Waste Control Equipment
- Div. 45 Industry-Specific Manufacturing Equipment
- Div. 46 Water and Wastewater Equipment
- Div. 47 Reserved for Future Expansion
- Div. 48 Electrical Power Generation
- Div. 49 Reserved for Future Expansion

FIGURE 1.6 MasterFormat divisions. The first few sections (Level 2 details) of Masonry division have been highlighted in a box. Level 3 details would show further divisions of a section. For example, 04 23 13 covers the specifications of vertical glass unit masonry, 04 23 16 covers glass unit masonry floors, and 04 23 19 covers glass unit masonry skylights.

RECOLLECTING MASTERFORMAT DIVISION SEQUENCE

Architectural design typically involves Divisions 02 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 (that are used in virtually all buildings) may be deduced by visualizing the sequence of operations required in constructing the simple building shown in Figure 1.7. The building consists of load-bearing masonry walls, steel roof joists, and wood roof deck.