

SEVENTH EDITION



CONSTRUCTION

PRINCIPLES, MATERIALS, AND METHODS

H. LESLIE SIMMONS, RA, CSI

Previous Editions Developed by HAROLD B. OLIN, FAIA

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H. Leslie Simmons, RA, CSI

Previous Editions Developed By:

Harold B. Olin, FAIA

with contributions from

John L. Schmidt, AIA

Walter H. Lewis, FAIA



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Preface

Construction: Principles, Materials, and Methods is a widely adopted course text in nearly 200 colleges and universities offering architectural and building technology curricula. It is also becoming a standard reference source in professional offices.

This seventh edition is the result of almost 40 years of research and editorial effort costing several million dollars. During the book's first 19 years, much of this work was carried out in an ongoing membership education program initiated by the United States League of Savings Institutions in 1964. The sixth edition was the result of that research and a major program carried out during the 3 years prior to its publication by its publisher at that time, Van Nostrand Reinhold. This program consisted of completely revising the data in the previous edition to reflect the many changes that had occurred in the field and to bring that data up to date with latest industry standards. Furthermore, new data was added to introduce construction materials and methods not in general use when the previous edition was prepared. Materials and construction methods that relate to commercial construction, including high-rise buildings, were also included. Previous editions had primarily covered residential construction. The sixth edition addressed materials and methods used in both.

The seventh edition has been written to further develop the book as a modern teaching and research tool for residential, commercial, and institutional building construction. To this end, the seventh edition contains more than 1100 pages divided into 16 chapters. The organization and names of these chapters are similar to those used in *MasterFormat*[™], which makes this edition easier to relate to the specifications and data filing formats currently being used in the construction industry. A list of applicable *MasterFormat*[™] sections has been in-

cluded as a subsection in each chapter. The numbers and titles listed there are from *MasterFormat* (1995 edition), which is published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC) and is used with permission from CSI, 1999. For those interested in a more in-depth explanation of *MasterFormat*[™] and its use in the construction industry, contact:

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Alexandria, VA 22314
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CSINet URL: www.csnet.org

An attempt has been made in the seventh edition to cover every principle, material, and method used to design and construct both large and small buildings of most types. The information presented includes the background and history of the materials and systems described. In each case, materials and their manufacture are discussed first, followed by the methods of construction used to erect these materials.

Earlier editions of this book, which were directed primarily toward the home construction portion of the construction industry, included coverage, much of it extensive, of wood construction; masonry; interior and exterior finishes; heating, ventilating, and air conditioning; plumbing; electrical systems; and many other subjects as they related to small residential construction. The sixth edition included most of these as well, but supplemented them with information about materials and methods used in the construction of other building types. The construction systems covered included those of both precast and cast-in-place concrete, steel, wood, and masonry. The discussions of mechanical and electrical systems were still limited to requirements for residential construction. Other subjects covered in earlier edi-

tions were expanded to address most kinds of commercial, larger residential, and institutional buildings. As a result, the sixth edition introduced materials and systems used in most types of building construction.

The sixth edition text also covered doors and windows; glazed curtain walls; glazing; and finishes, including plaster, gypsum board, tile, terrazzo, acoustical ceilings and other acoustical treatment, wood flooring, resilient flooring, carpet, and painting and finishing.

Coverage was given to industry standards, codes, land surveys and descriptions, properties of materials, barrier-free design, metrication, sitework (including excavation, grading, shoring, sheeting, and other earthwork), and sound control in buildings.

The seventh edition covers most of the subjects addressed in the sixth edition, but supplements it with much new data. New subjects in the seventh edition include a discussion of the architect's role in building design and construction, including the development of construction documents, and the architect's responsibilities during the bidding and negotiation phase and during the construction phase of a building construction project. The sections on codes and standards have been expanded to include discussion of their effect on building design. Additional subjects include glass-fiber-reinforced concrete, concrete toppings, cement-based underlayment, glass unit masonry, miscellaneous metal fabrications, heavy timber framing, finish carpentry, wood siding, metal roofing, door hardware, stone flooring, resinous flooring, wall coverings, fire protection specialties, residential appliances, unit kitchens, elevators, and fire sprinkler systems. The discussions of mechanical systems have been greatly expanded to include information related to buildings other than residences. For example, there is coverage of the different types of HVAC systems, including heating systems (forced air, air-water, steam, water,

electrical), components (boiler types, furnaces, controls, finned tube radiators, radiant heaters and panels, heat recovery systems, ducts, pipes, diffusers, grilles, and registers), and fuels (coal, gas, electricity). Cooling systems are also covered, including discussions of the refrigeration cycle, cooling components, heat pumps, direct refrigeration, and delivery systems (fan coil units, unit ventilators). The discussion of electrical systems has been expanded to include commercial lighting and cable distribution systems.

In addition, some chapters have been reorganized to make the data they contain more easily usable. For example, Chapter 5 now separates steel materials from steel products. Some material has been relocated to a chapter corresponding to its location in *MasterFormat*™.

Metric equivalents have been added to measurements throughout the book. To avoid changing copyrighted figures, however, metric measure has not generally been added to them. Instead, Figure 1.8-27 is included, which lists metric conversions that are applicable to these figures.

Each chapter now has a section called "Additional Reading" that lists sources of additional information about the subjects discussed in that chapter. To make it easier for a reader to find data, the tables and other data in Appendix A of the sixth edition have instead been placed in the various chapters where the particular subjects are discussed. To enable a reader to more easily find references for the sources of information in the book, the data in the sixth edition's Appendix B, "References," has been moved to a section entitled "Acknowledgments and References" at the end of each relevant chapter.

In Appendix A, the seventh edition contains a list of the names, addresses, telephone numbers, e-mail addresses, and Web sites (where applicable) of the organizations, associations, and agencies that contributed either directly or indirectly to the book. Appendix B is an extensive glossary of terms used in the book.

Acknowledgments

It takes the help of many people and organizations to produce a book such as this, which include all of those who prepared previous editions. First and foremost of these are the original authors, Harold B. Olin, John L. Schmidt, and Walter H. Lewis, without whom this book would not exist. The preface for the fifth edition, written by the three authors, acknowledges the contributions of several persons. Included are Senior Research Associate Christina Farnsworth, for her contribution in revising old chapters and in authoring chapters on barrier-free design, home security and safety, air plenum systems, and metrication; Richard Laya, who prepared the chapters on heat control, passive solar heating, and pole foundations; and Production Specialist Betsy Pavichevich who was responsible for the typing, layout, and preparation of graphics.

Even though the material these people prepared was, in most cases, extensively revised in the sixth edition and has been further revised in the seventh edition to bring it up to date with current materials, methods, and standards, the contribution of these people in producing the original data is to be commended.

My work on the sixth edition was aided immensely by Brenda Bertozzi, my primary research associate, who located sources and obtained permission to use their materials, and by Irene Demchyshyn, who helped me gather the research data necessary to update and expand this book.

I am indebted also to the professionals, both practicing architects and teachers, who lent their time, energy, and expertise to review the sixth edition manuscript so that it would be more accurate and more useful as a text for students of architecture and allied fields. These include Harold B. Olin, FAIA, the original primary editor of previous editions; Daniel W. Halpin, Ph.D., Professor and Head, Division of Construction Engineering and Management, Purdue University; Larry Grosse,

Ph.D., Associate Professor, College of Architecture, Texas A&M University; and Terry L. Patterson, AIA, Professor, College of Architecture, University of Oklahoma, whose extensive, well-informed, and detailed comments contributed greatly to making this book as good as it could be. Professor Patterson was also the author of the sixth edition *Student Workbook* and *Instructor's Manual*.

ACKNOWLEDGMENTS FOR THE SEVENTH EDITION

To determine the needs of the readers of *Construction: Principles, Materials, and Methods*, the sixth edition was reviewed by current users, including teaching professionals and architects in practice. Their comments were of immeasurable help in developing the seventh edition. Among them were the aforementioned Harold B. Olin and Terry Patterson; and Atilla Lawrence, University of Nevada, Department of Architecture; Dana S. Mosher, Professor of Building Construction Technology, NHCTC/Manchester; Robert O. Segner, Jr., Professor of Construction Science, Department of Construction Science, College of Architecture, Texas A&M University; Khalid T. Al-Hamdouni, Rogers University School of Engineering; Maryrose McGowan, AIA, IIDA; and the late Tim Kirby, consultant to the construction industry,

I would like to gratefully acknowledge the contributions of the many manufacturers, trade and professional associations, standards-setting bodies, government agencies, periodicals, book publishers, and individuals who provided valuable research material and illustrations, as well as text reviews and comments. Without their help, this book would not have been possible. The names of most are listed in the "Acknowledgments and References" sections at the ends of the chapters.

I would also like to thank my wife, Nancy, whose help and support have been invaluable.

I am also indebted to the professionals, both practicing architects and teachers, who lent their time, energy, and expertise to review the manuscript for the seventh edition so that it would be more accurate and more useful as a text for students of architecture and allied fields and as a reference for professionals in practice. They include: Harold B. Olin, William C. Mason, Owens Community College, Toledo, OH; Linda Swoboda, University of Nebraska; John Lebduska, Hope, NJ; Harold Tepper, New Jersey Institute of Technology; Felix Rospond, West Orange, NJ; and Anthony Abbate, Florida Atlantic University.

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The information in this book was derived from data published by trade associations, standards-setting organizations, manufacturers, and government organizations and statements made to the author by their representatives; model codes; and related books and periodicals. The author and publisher have exercised their best judgment in selecting data to be presented, have reported the recommendations of the sources consulted in good faith, and have made every reasonable effort to make the data presented accurate and authoritative. However, neither the author nor the publisher warrants the accuracy or completeness of the data nor assumes liability for its fitness for a particular purpose. Users are expected to apply their own professional knowledge and experience or to consult with someone who has such knowledge and experience when using the data contained in this book. Users are also expected to consult the original sources of the data, obtain additional and updated information as needed, and seek expert advice when appropriate.

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CHAPTER

1

General Requirements

Introduction

Applicable *MasterFormat*™ Sections

Building Design

Construction Documents

Bidding and Negotiation

Construction Contract Administration

Industry Standards

Codes

Barrier-Free Design

The Metric System of Measurement

Land Surveys and Descriptions

Properties of Materials

Additional Reading

Acknowledgments and References

Introduction

Many factors influence an architect's work related to building design. In addition to architectural design, an architect must be aware of and conversant in site, structural, mechanical, and electrical design. He or she must also be aware of the legal constraints, such as codes, laws, and regulations, and of the many industry standards that influence design and construction. An architect must also be knowledgeable and conversant in the production of construction documents and must understand the means and methods used in constructing buildings. He or she must understand the construction process and be able to render an architect's services during the construction phase of a building project. He or she must understand the financial constraints on building construction, and be able to design within those constraints. And in all of these, an architect must not be just a jack-of-all-trades, he or she must be a master of them all.

Chapters 2 through 16 of this book address construction materials and methods of design and construction of which an architect must be knowledgeable.

The first four parts of this chapter dis-

cuss some of the services architects provide related to a building construction project. The American Institute of Architects (AIA) has divided an architect's services into the categories *basic* and *additional*.

Basic services are those included in standard services contracts developed by AIA and included in the architect's basic fee for services.

Additional services are optional and are performed only when agreed to by the architect and the owner, with additional compensation to the architect.

Following the flow of a project from conception to the completion of the warranty period (one year after construction completion) an architect's services can be broken down into *predesign* services, *design* services, *construction* services, *postconstruction* services, and *supplemental* services.

Predesign services are additional services. They include such acts as programming, existing facilities studies, project budgeting, and site analysis.

Basic services include *design* and *construction* services. Design services (see Section 1.1) are further broken down into

schematic design, *design development* (a further refinement of schematic design documents), and *construction documents* services (see Section 1.2).

Construction services include services performed during the *bidding and negotiation* phase (see Section 1.2) and those performed during the *construction contract administration* phase (see Section 1.4).

Postconstruction services are additional services performed after substantial completion of the building (see Section 1.4). They include such acts as maintenance and operational programming, record drawings, start-up assistance, and warranty review.

Supplemental services are additional services. They include such items as renderings, models, life cycle cost analysis, quantity surveys, graphic design, and many others.

The rest of this chapter covers some additional facets of the building design and construction process that an architect must understand to be able to carry out the architect's responsibilities in the design and construction of buildings.

Applicable MasterFormat™ Sections

The following *MasterFormat* Level 2 sections are applicable to this chapter.

00100 Bid Solicitation
00200 Instructions to Bidders
00300 Information Available to Bidders
00400 Bid Forms and Supplements
00490 Bidding Addenda

00500 Agreement
00600 Bonds and Certificates
00700 General Conditions
00800 Supplementary Conditions
00900 Addenda and Modifications
01100 Summary
01200 Price and Payment Procedures
01300 Administrative Requirements

01400 Quality Requirements
01500 Temporary Facilities and Controls
01600 Product Requirements
01700 Execution Requirements
01800 Facility Operation
01900 Facility Decommissioning

1.1 Building Design

An architect's first and primary contractual responsibility related to building construction is design. Building design requires training, experience, an aesthetic sense, and an understanding of certain basic principles. Among these principles are (1) the objectives good design should strive for, (2) an architect's responsibilities related to design, (3) basic building

use and shape types, and (4) available construction systems and methods.

1.1.1 DESIGN OBJECTIVES

An architect's primary design objective should be to produce buildings that serve their intended purpose and that permit the activities that take place in them to proceed

with appropriate dispatch and ease. They should be efficient in their use and operation. In addition, commercial buildings should be capable of producing a profit.

An architect's buildings should be of good quality construction, and should be able to be built at as low a cost as is practicable. An architect's designs should produce individual buildings that are aes-

thetically pleasing and that do not diminish the beauty of the natural environment around them.

1.1.2 THE BUILDING CONSTRUCTION TEAM

Many organizations and individuals must work together to produce buildings. These include owners, architects and their consultants, constructors, and supporting professions and industries.

Owners are the architect's clients. They are not necessarily the users of a building, but they begin, finance, and usually own the project.

A *design professional* is a person or organization who designs a construction project. The *prime design professional* is the design professional who is hired by the owner to lead the design team. In building construction projects, the prime professional is usually an architect. An engineer may be the prime design professional on some primarily engineering projects—for example, in the construction of bridges or in the major renovation of an existing heating, ventilating, and air conditioning system. In this section, it is assumed that the project being considered is a building and that the prime design professional is an architect. In other project types, the chores here delineated as the responsibility of the architect may fall to an engineer, as the prime design professional for a particular project.

It is ordinarily the architect's responsibility to (1) determine the legal, financial, and other constraints on project design, (2) program and design the project, (3) produce contract documents, (4) provide professional services during the bidding or negotiation phase, and (5) provide construction contract administration services. For a residence or other small building, an architect may carry out these functions alone. Larger and more complicated buildings often present design problems that are beyond the expertise of most architects. For these more complicated *building construction projects*, an architect functions as a member, usually as the leader, of a team of design professionals that includes structural, mechanical, civil, and electrical engineers, and interior designers, who function as consultants to the architect.

The architect and each of the architect's consultants will design, produce construction documents, and provide construction contract administration for that

one portion of a building's components that fall within his or her field of expertise. The architect coordinates the activities of all team members.

The construction process often also requires input from a second group of design professionals working as consultants, either to the owner directly or to one of the team members. These other professionals include, but are not limited to, those with special knowledge about schools, hospitals, food service facilities, laboratories, industrial complexes, computer systems, communication systems, furniture, specialized equipment, and many other components. The architect usually coordinates the activities of these other professionals.

Constructors, also called *builders*, are usually a group of organizations that together erect construction projects. They consist of many types of *contractors*, including, but not limited to, *general contractors*, who oversee the work of, and usually hire, the others; and specialty, or *trade*, contractors, such as those who provide sitework, excavation, concrete, masonry, steel, carpentry, casework, moisture protection, doors, windows, finishes, specialties, equipment, and conveying, plumbing, electrical, and mechanical systems. Supporting these contractors are suppliers, who provide construction equipment, such as cranes, and product suppliers who furnish the materials, products, systems, and equipment that go into a building.

Supporting professions and industries include, but are not limited to, legal professionals; accountants; lenders and investors, who provide construction money and long-term loans that permit construction projects to be erected; insurance providers; testing and research agencies, which develop new products and test existing ones; regulators, including code and law writers and enforcers, who control health and safety issues, aesthetics, environmental issues, zoning, utilities, financial institutions, and design professionals' licensing and practices.

1.1.3 BUILDING USE TYPES

Construction projects can be identified by their use (residential, commercial [stores, office buildings, etc.], institutional [hospitals, schools, jails, etc.], industrial [manufacturing, laboratories, etc.], and nonbuilding types [bridges, towers, etc.]). From this point forward, this chapter addresses only those building construction

projects for which an architect is the primary professional. In such projects, it is the architect's job to determine the design requirements specific to each use. For example, there is little resemblance between the requirements for a single-family residence and those of a hospital. There may be major differences even within a group. There are great differences, for example, between the requirements for a single-family residence and a high-rise apartment building. A local jail will probably bear little resemblance to a federal prison.

Some buildings are designed for *common use*, meaning that they have more than one use type in the same structure. Street-front stores may have residential or office spaces above them. High-rise buildings may house commercial uses on the lower floors, office uses on intermediate floors, and apartments on the upper floors.

1.1.4 BUILDING SHAPE TYPES

Buildings take many forms and shapes, depending on their use, the materials used to build them, the needs and desires of the owner, the construction budget, the building's potential operating costs, and the designer's preferences. Buildings other than single-family residences and townhouses are so varied in size and shape as to make simplification of their types difficult (Fig. 1.1-1). However, some basic types and

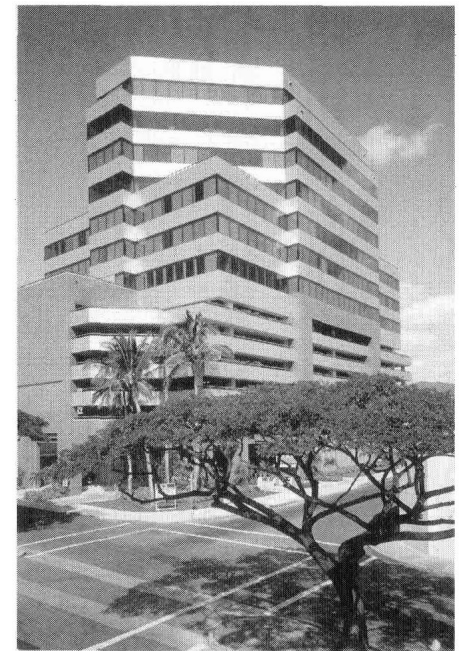


FIGURE 1.1-1 Modern buildings are seldom rectangles. (Honvest Corporation, Honolulu, Hawaii. Architect Leo A. Daly and Associates. Photo courtesy Bethlehem Steel Corporation.)

construction methods can be identified (Fig. 1.1-2).

The simplest building is a 1-story, single-span, slab-on-grade structure with a flat roof (Fig. 1.1-2a). Similar buildings with basements are also commonly built (Fig. 1.1-2b). Single-story structures with more than one structural span (Fig. 1.1-2c), in which one or more intermediate rows of walls or columns supports the roof structure, *enclose more space per unit of exterior wall cladding than do smaller buildings.*

Single-story buildings may also have full or partial basements. The structural systems in buildings of this type may be concrete, masonry, steel-framed, or wood-framed bearing walls with steel, concrete, or wood roof framing systems; steel, concrete, or wood interior and exterior columns with steel, concrete, or wood roof framing; or a combination of these

systems. Foundations are usually poured concrete, but treated wood foundations are sometimes used (see Section 6.4). The roof of a single-story building may be either flat or any of a wide variety of shapes (Fig. 1.1-2d, 1.1-2e, and 1.1-2f). Roof decks may be of wood, steel, or concrete. Basements may have either poured concrete or reinforced masonry walls, depending on the level of the earth against the wall and the height and the hydrostatic head of adjacent underground water. Floors above basements may be steel framed with a concrete or wood floor, concrete framed with a concrete floor, steel framed with a concrete floor, wood framed with a wood floor, or a combination of these systems.

The same principles apply to multistory structures (Fig. 1.1-2g). The construction materials and structural systems in multistory structures and the height of

such buildings are usually dictated by economic factors, such as land cost, but may be affected by codes and laws that restrict building height, land area coverage, or the materials that may be used. Fire codes, for example, may restrict the types of construction systems and the materials that may be left exposed. Many fire codes do not permit wood construction or the exposure of wood finishes on the exterior of buildings in certain locations.

Multistory buildings require less roof surface than single-story buildings with the same floor area. This results in a savings in the cost of roofing materials. In addition, multistory buildings require less land per unit of usable space. Because of their higher ratio of interior space to building shell area, they are also generally more energy efficient than single-story buildings. Except in rare instances, these advantages increase with the number of

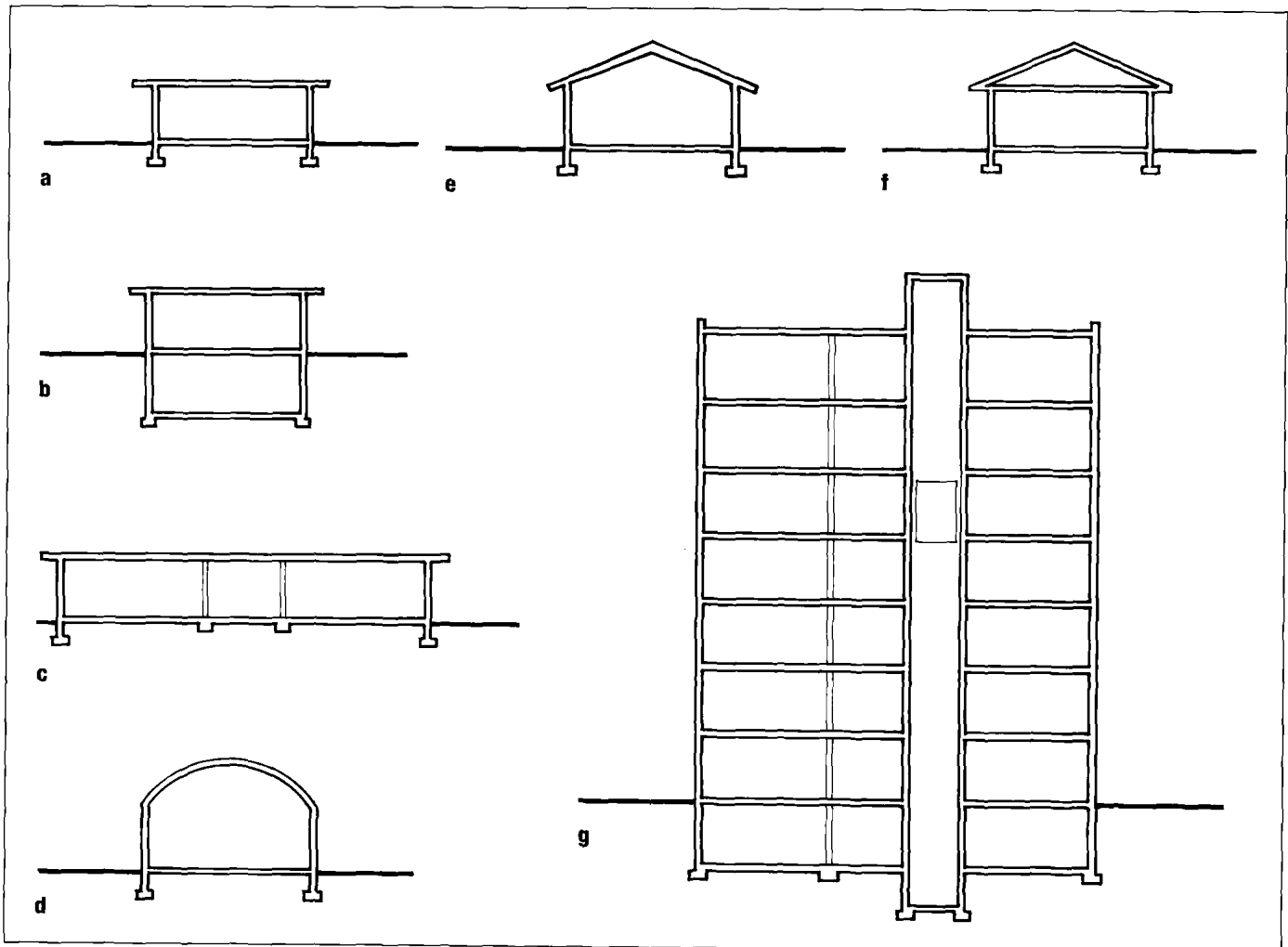


FIGURE 1.1-2 Basic building types for other than single-family residential buildings: (a) one-story; (b) one-story with basement; (c) one-story with multiple framing bays; (d, e, and f) typical roof shapes; and (g) multistory. (Drawings by HLS.)

stories. The lower costs are somewhat offset by the increased costs for maintenance of the exterior surfaces of multistory buildings, the relatively high costs of materials that can be used there, and the increased cost of construction associated with moving materials to high levels and working with them far above ground level.

Low-rise multistory buildings may be of steel or concrete construction or a combination of these. Some even have masonry bearing walls. Steel columns and concrete floors are common. Foundations are usually poured concrete spread footings, although poor soil conditions sometimes dictate the use of piles or caissons.

High-rise buildings are usually framed in steel, with thin concrete floor slabs, because concrete structures of great height have heavier and larger framing members than steel structures, which reduces the amount of usable space and increases the cost of construction. Some recent very high buildings have been designed as a series of steel shells or tubes that extend for the entire height of the building; others have been designed using the same principles as tall radio and television towers. Foundations are either poured concrete footings or pads, piles, or caissons, depending on the soil conditions and the size and load imposed on the soil by the building.

Sometimes the desire to create a statement for ego-enhancing or advertising

purposes affects the size, height, and appearance of a building. For example, a corporation may wish to use its headquarters building as a symbol or may just want to own the tallest, largest, or most spectacular building in town.

Multistory buildings need elevators or escalators to make their use practicable. In addition, in most types of uses, federal accessibility laws and rules make elevators or wheelchair lifts a legal requirement in every building that is not inherently accessible to the handicapped (see Section 1.7), which, of course, includes every multistory building. The additional cost of this vertical transportation must be considered in deciding whether to construct a multistory building.

The basic building types used in single-family and townhouse construction are easier to define. Figure 1.1-3 shows some common types. Most of these types are also used for buildings other than single-family homes or townhouses, however, so they should not be thought of for only these restricted applications. The most prevalent of these is a 1-story building (Fig. 1.1-3a), because this type provides the most size and shape variations. These buildings may or may not contain a basement. Their roofs may be sloped, as shown, or flat.

One-and-one-half-story buildings, with or without basements (Fig. 1.1-3b), are sometimes used for housing. They offer

more living space than single-story buildings with a minimum of additional cost. The second-floor space varies with the building size and roof slope. Light, ventilation, and view can be provided by dormers. One-and-one-half-story buildings are seldom built for other types of uses because their inherently small second-floor rooms, with their sloped ceilings, while adequate for sleeping rooms, often do not make satisfactory work spaces.

Two-story (Fig. 1.1-3c) or taller buildings, with or without basements, provide the maximum usable area at relatively low cost. Two- and three-story single-family houses and townhouses are common. These types of buildings can reduce construction cost, depending on the value of the land. When they must be accessible to the handicapped (see Section 1.7), buildings of more than 1 story require elevators, as described earlier for multistory buildings.

Bilevel buildings (Fig. 1.1-3d) are well suited for single-family houses, townhouses, or small commercial buildings in hillside locations. They provide habitable space at both grade levels when connected with full flights of stairs. In certain types of uses, accessibility restrictions may require that elevators be included. This configuration can also be used for two different occupancies, such as an apartment on one level and a small store on the other. In this case, both levels can be easily made

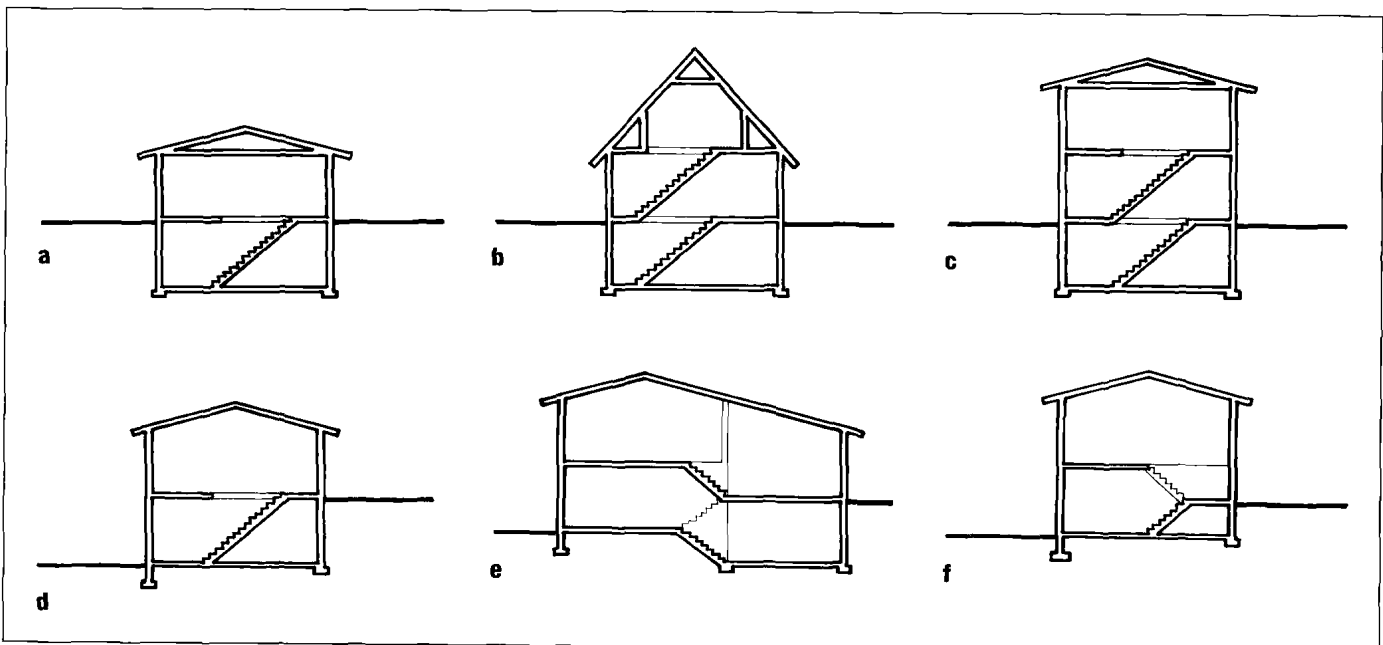


FIGURE 1.1-3 Basic single-family residential building types: (a) single-story; (b) one-and-one-half-story; (c) two-story or higher; (d) bilevel; (e) split-level; and (f) bilevel/split-entry. (Drawings by HLS.)

independently accessible to the handicapped. Roofs may be either sloped, as shown, or flat.

Split-level (Fig. 1.1-3e) and bilevel/split-entry (Fig. 1.1-3f) buildings are used mostly for single-family houses and townhouses. They are infrequently used for other purposes because of the difficulty of making them accessible to the handicapped. Split-level houses offer distinct separation of functions, either on three levels or four, including a basement. These are best suited for sloping lots. They offer numerous design possibilities, but can have awkward proportions if not carefully designed.

Bilevel/split-entry buildings are also best suited to sloping lots. They are characterized by a split foyer between two full living levels. This configuration can provide either a sunken 2-story (or more) house without a basement or a raised one-story (or more) house with a finished basement.

1.1.5 CONSTRUCTION SYSTEMS AND METHODS

The selection of construction methods and systems that produce the basic building types shown in Figures 1.1-2 and 1.1-3 is usually governed by three criteria: functional requirements, cost, and the desired appearance.

These basic criteria may require a consideration of climate, site topography, initial costs, maintenance costs, building codes, zoning ordinances, or other laws, availability of materials and labor, builder resourcefulness and size, owner taste, local custom, and other factors.

The selection of methods and systems is further complicated by the thousands of materials, products, and construction system choices available, many of which are interdependent. Sometimes the relationship of these building elements to each other will create situations in which the construction method or system is the major influence on a building's design. For example, the selection of a dome as the means to roof a coliseum may dictate that the shape of the building be circular or near-circular. Conversely, design requirements may dictate the framing system. A dome, for example, may be a poor choice for roofing a theater because of the inherent acoustical difficulties of a dome, and because a circular building may not be preferable for the kind of theater that is desired. The cost and availability of very large laminated wood (gluelam) structural

elements, as compared with smaller gluelam units, may influence the width or even the shape of a church, or the way in which the gluelam units are fitted together to make a roof structure. The permissible span of the available wood decking may further influence the spacing of these gluelam units or the design of the roof structure and the placement of purlins.

Although there have been experiments with a few revolutionary construction systems since World War II, most new homes and many small commercial and institutional buildings in the United States are still built using conventional light-wood-platform framing (see Chapter 6), often with wood-truss-framed roofs. In many areas, the use of preassembled components, such as those discussed in Chapter 6, is common. In the future, advanced industrialization techniques using new materials and methods may offer new construction forms far different from those typical today.

Other basic systems in use today include wood-post-and-beam framing and wood-pole construction (see Chapter 6); masonry bearing-wall construction (see Chapter 4), sometimes with concrete floors (see Chapter 3), often supported on metal framing or bar joists; concrete-framed construction; and steel-framed construction (see Chapter 5).

In small construction, conventional wood framing still offers many advantages. As a complete construction system, it still is one of the most economical ways to build. The ease of working and fastening wood together with simple tools provides flexibility, which permits job changes without extensive reengineering. Wood framing is still the basis for most building codes and labor practices and will probably remain so for some time to come. Conventional framing is adaptable to site fabrication by the smallest builder handling each member piece by piece, as well as to off-site fabrication of individual pieces into larger preassembled components that require additional manpower or machinery for erection.

1.1.6 THE FUTURE

Further industrialization, using more and larger prefinished and prefabricated components, appears essential to help offset the rising costs of land, labor, and materials. Off-site fabrication permits maximum utilization of labor and materials under factory-controlled conditions with little

loss in on-site time owing to bad weather. Efficiency may be increased with the use of power tools and machinery; volume purchasing of materials and stockpiling of finished parts is possible; greater convenience for workers and better protection for finished materials is provided; and site erection of components can usually be accomplished more economically and in less time by semiskilled or even unskilled labor.

To save costs, mechanical components for small buildings have been developed that combine a furnace, air conditioner, water heater, and electric power panel in one package. Larger mechanical components include completely furnished kitchens and bathrooms. The concept of prefinishing complete rooms has been extended to prefabricating as much as half a small building, such as a house, so that upon setting and joining two halves, an entire building is completed. Future developments may include assembling an entire building and completely finishing it prior to site placement.

Some future building construction methods will be highly sophisticated and closely integrated systems. For instance, integrated floor and ceiling systems available for use in commercial construction include structure, lighting, acoustical control, heating, cooling, and air distribution in a single system.

Components should be capable of satisfying varying design requirements, should permit simple modifications in the field in case of errors, and should be sized for ease of shipping, storage, and assembly. As component size increases, design and construction problems increase and design flexibility is lessened. The dimensions of large units are restricted to what can be transported physically and legally over the highways, and larger components usually require more manpower and larger erection equipment at the site.

Accordingly, the design, engineering, or selection of preassembled components requires judgments between size and flexibility. The most useful systems will combine the advantages of fully standardized factory-built modular units, which capitalize on the inherent savings resulting from repetitive production, and those that offer the design advantages of custom fabrication in the field.

Unfortunately, there are also certain disadvantages associated with prefabrication that have so far limited its use. For example, to be profitable, large compo-