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1

MAKING BUILDINGS

An ironworker connects a steel wide-flange beam to a column.
(Courtesy of Bethlehem Steel Company)

We build because most human activities cannot take place outdoors. We need shelter from sun, wind, rain, and snow. We need dry, level platforms for our activities. Often we need to stack these platforms to multiply available space. On these platforms, and within our shelter, we need air that is warmer or cooler, more or less humid, than outdoors. We need less light by day, and more by night, than is offered by the natural world. We need services that provide energy, communications, and water and dispose of wastes. So, we gather materials and assemble them into the constructions we call buildings in an attempt to satisfy these needs.

Learning to Build

Throughout this book many alternative ways of building are described: different structural systems, different systems of enclosure, and different systems of interior finish. Each system has characteristics that distinguish it from the alternatives. Sometimes a system is distinguished chiefly by its visual qualities, as one might acknowledge in choosing one type of granite over another, one color of paint over another, or one tile pattern over another. However, visual distinctions can extend beyond surface qualities; a designer may prefer the massive appearance of a masonry bearing wall building to the slender look of an exposed steel frame on one project, yet would choose the steel for another building whose situation is different. Again, one may choose for purely functional reasons, as in selecting terrazzo flooring that is highly durable and resistant to water instead of more vulnerable carpet or wood in a restaurant kitchen. One could choose on purely technical grounds, as, for example, in electing to posttension a long concrete beam for greater stiffness rather than rely on conventional steel reinforcing. A designer is often forced into a particular choice by some of the legal constraints identified later in this chapter. A choice is often influenced by considerations of environmental sustainability. And frequently the selection is made on purely economic grounds. The economic criterion can mean any of several things: Sometimes one system is chosen over another because its first cost is less; sometimes the entire life-cycle costs of competing systems are compared by means of formulas that include first cost, maintenance cost, energy consumption cost, the useful lifetime and replacement cost of the system, and interest rates on invested money; and, finally, a system may be chosen because there is keen competition among local suppliers and/or installers that keeps the cost of that system at the lowest possible level. This is often a reason to specify a very standard type of roofing material, for example, that can be furnished and installed by any of a number of companies, instead of a newer system that is theoretically better from a functional standpoint but can only be furnished by a single company that has the special equipment and skills required to install it.

One cannot gain all the knowledge needed to make such decisions from a textbook. It is incumbent upon the reader to go far beyond what can be presented here—to other books, to catalogs, to trade publications, to professional periodicals, and especially to the design office, the workshop, and the building site. There is no other way to gain much of the required information and experience than to get involved in the art and business of building. One must learn how materials feel in the hand; how they look in a building; how they are manufactured, worked, and put in place; how they perform in service; how they deteriorate with time. One must become familiar with the people and organizations that produce buildings—the architects, engineers, materials suppliers, contractors, subcontractors, workers, inspectors, managers, and building owners—and learn to understand their respective methods, problems, and points of view. In the meantime, this long and hopefully enjoyable process of education in the materials and methods of building construction can begin with the information presented in this textbook.

> **Go into the field where you can see the machines and methods at work that make the modern buildings, or stay in construction direct and simple until you can work naturally into building-design from the nature of construction.**
>
> **Frank Lloyd Wright, *To the Young Man in Architecture,* 1931**

Sustainability

In constructing and occupying buildings, we expend vast quantities of the earth's resources and generate a significant portion of the earth's environmental pollution: The U.S. Green Building Council reported in 2008 that buildings account for 30 to 40 percent of the world's energy use and associated greenhouse gas emissions. Construction and operation of buildings in the United States accounted for more than one-third of this country's total energy use and the consumption of more than two-thirds of its electricity, 30 percent of its raw materials, a quarter of its harvested wood, and 12 percent of its fresh water. Building construction and operation is responsible for nearly half of this country's total greenhouse gas emissions and close to a third of its solid waste stream. Buildings are also significant emitters of particulates and other air pollutants. In short, building construction and operation cause many forms of environmental degradation that place an increasing burden on the earth's resources and jeopardize the future of the building industry and societal health and welfare.

Sustainability may be defined as **meeting the needs of the present generation without compromising the ability of future generations to meet their needs**. By consuming irreplaceable fossil fuels and other nonrenewable resources, by building in sprawling urban patterns that cover extensive areas of prime agricultural land, by using destructive forestry practices that degrade natural ecosystems, by allowing topsoil to be eroded by wind and water, and by generating substances that pollute water, soil, and air, we have been building in a manner that will make it increasingly difficult for our children and grandchildren to meet their needs for communities, buildings, and healthy lives.

On the other hand, if we reduce building energy usage and utilize sunlight and wind as energy sources for our buildings, we reduce depletion of fossil fuels. If we reuse existing buildings imaginatively and arrange our new buildings in compact patterns on land of marginal value, we minimize the waste of valuable, productive land. If we harvest wood from forests that are managed in such a way that they can supply wood at a sustained level for the foreseeable future, we maintain wood construction as a viable option for centuries to come and protect the ecosystems that these forests support. If we protect soil and water through sound design and construction practices, we retain these resources for our successors. If we systematically reduce the various forms of pollution emitted in the processes of constructing and operating buildings, we keep the future environment cleaner. And as the industry becomes more experienced and committed to designing and building sustainably, it becomes increasingly possible to do these things with little or no increase in construction cost while creating buildings that are less expensive to operate and more healthful for their occupants for decades to come.

Realization of these goals is dependent on our awareness of the environmental problems created by building activities, knowledge of how to overcome these problems, and skill in designing and constructing buildings that harness this knowledge. While the practice of sustainable design and construction, also called *green building*, remains a relatively recent development in the design and construction industry, its acceptance and support continue to broaden among public agencies, private developers, building operators and users, architectural and engineering firms, contractors, and materials producers. With each passing year, green building techniques are becoming less a design specialty and more a part of mainstream practice.

The Building Life Cycle

Sustainability must be addressed on a life-cycle basis, from the origins of the materials for a building, through the manufacture and installation of these materials and their useful lifetime in the building, to their eventual disposal when the building's life is ended. Each step in this so-called *cradle-to-grave* cycle raises questions of sustainability.

Origin and Manufacture of Materials for a Building

Are the raw materials for a building plentiful or rare? Are they renewable or nonrenewable? How much of the content of a material is recycled from other uses? How much *embodied energy* is expended in obtaining and manufacturing the material, and how much water? What pollutants are discharged into air, water, and soil as a result of these acts? What wastes are created? Can these wastes be converted to useful products?

Construction of the Building

How much energy is expended in transporting a material from its origins to the building site, and what pollutants are generated? How much energy and water are consumed on the building site to put the material in place? What pollutants are associated with the installation of this material in the building? What wastes are generated, and how much of them can be recycled?

Use and Maintenance of the Building

How much energy and water does the building use over its lifetime as a consequence of the materials used in its construction and finishes? What problems of indoor air quality are caused by these materials? How much maintenance do these materials require, and how long will they last? Can they be recycled? How much energy and time are consumed in maintaining these materials? Does this maintenance involve use of toxic chemicals?

Demolition of the Building

What planning and design strategies can be used to extend the useful life of buildings, thereby forestalling resource-intensive demolition and construction of new buildings? When demolition is inevitable, how will the building be demolished and disposed of, and will any part of this process cause pollution of air, water, or soil? Can demolished materials be recycled into new construction or diverted for other uses rather than disposed of as wastes?

One model for sustainable design is nature itself. Nature works in cyclical processes that are self-sustaining and waste nothing. More and more building professionals are learning to create buildings that work more nearly as nature does, helping to leave to our descendants a stock of healthful buildings, a sustainable supply of natural resources, and a clean environment that will enable them to live comfortably and responsibly and to

FIGURE 1.1
The LEED-NC 2009 Project Scorecard. The document shown here was in draft status at the time of this publication. See the U.S. Green Building Council web site for the most current version of this document. ***(Courtesy of U.S. Green Building Council)***

LEED for New Construction and Major Renovation 2009
Project Scorecard

Project Name:
Project Address:

Yes	?	No			
			Sustainable Sites		**26 Points**
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
			Credit 1	**Site Selection**	1
			Credit 2	**Development Density & Community Connectivity**	5
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation,** Public Transportation Access	6
			Credit 4.2	**Alternative Transportation,** Bicycle Storage & Changing Rooms	1
			Credit 4.3	**Alternative Transportation,** Low-Emitting & Fuel-Efficient Vehicles	3
			Credit 4.4	**Alternative Transportation,** Parking Capacity	2
			Credit 5.1	**Site Development,** Protect or Restore Habitat	1
			Credit 5.2	**Site Development,** Maximize Open Space	1
			Credit 6.1	**Stormwater Design,** Quantity Control	1
			Credit 6.2	**Stormwater Design,** Quality Control	1
			Credit 7.1	**Heat Island Effect,** Non-Roof	1
			Credit 7.2	**Heat Island Effect,** Roof	1
			Credit 8	**Light Pollution Reduction**	1
Yes	?	No			
			Water Efficiency		**10 Points**
			Prereq 1	**Water Use Reduction,** 20% Reduction	Required
			Credit 1.1	**Water Efficient Landscaping,** Reduce by 50%	2
			Credit 1.2	**Water Efficient Landscaping,** No Potable Use or No Irrigation	2
			Credit 2	**Innovative Wastewater Technologies**	2
			Credit 3.1	**Water Use Reduction,** 30% Reduction	2
			Credit 3.2	**Water Use Reduction,** 40% Reduction	2
Yes	?	No			
			Energy & Atmosphere		**35 Points**
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance:** 10% New Bldgs or 5% Existing Bldg Renovations	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
			Credit 1	**Optimize Energy Performance**	1 to 19
				12% New Buildings or 8% Existing Building Renovations	1
				16% New Buildings or 12% Existing Building Renovations	3
				20% New Buildings or 16% Existing Building Renovations	5
				24% New Buildings or 20% Existing Building Renovations	7
				28% New Buildings or 24% Existing Building Renovations	9
				32% New Buildings or 28% Existing Building Renovations	11
				36% New Buildings or 32% Existing Building Renovations	13
				40% New Buildings or 36% Existing Building Renovations	15
				44% New Buildings or 40% Existing Building Renovations	17
				48% New Buildings or 44% Existing Building Renovations	19
			Credit 2	**On-Site Renewable Energy**	1 to 7
				1% Renewable Energy	1
				5% Renewable Energy	3
				9% Renewable Energy	5
				13% Renewable Energy	7
			Credit 3	**Enhanced Commissioning**	2
			Credit 4	**Enhanced Refrigerant Management**	2
			Credit 5	**Measurement & Verification**	3
			Credit 6	**Green Power**	2
Yes	?	No			

pass these riches on to their descendants in a never-ending succession.

Assessing Green Buildings

In the United States, the most widely adopted method for rating the environmental sustainability of a building's design and construction is the U.S. Green Building Council's Leadership in Energy and Environmental Design, or *LEED*™, rating system. LEED for New Construction and Major Renovation projects, termed LEED-NC, groups sustainability goals into categories including site selection and development, efficiency in water use, reductions in energy consumption and in the production of atmospheric ozone-depleting gases, minimizing construction waste and the depletion of nonrenewable resources, improving the quality of the indoor environment, and encouraging innovation in sustainable design and construction practices (Figure 1.1). Within each category are specific *credits* that contribute points toward a building's overall assessment of sustainability. Depending on the total number of points accumulated, four levels of sustainable design are recognized, including, in order of increasing performance, Certified, Silver, Gold, and Platinum.

The process of achieving LEED certification for a proposed new building begins at the earliest stages of project conception, continues throughout the design and construction of the project, and involves the combined efforts of the owner, designer, and builder. During this process, the successful achievement of individual credits is documented and submitted to the

Yes	?	No			
			Materials & Resources		**14 Points**
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse,** Maintain 75% of Existing Walls, Floors & Roof	2
			Credit 1.2	**Building Reuse,** Maintain 95% of Existing Walls, Floors & Roof	1
			Credit 1.3	**Building Reuse,** Maintain 50% of Interior Non-Structural Elements	1
			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
			Credit 3.1	**Materials Reuse,** 5%	1
			Credit 3.2	**Materials Reuse,** 10%	1
			Credit 4.1	**Recycled Content,** 10% (post-consumer + ½ pre-consumer)	1
			Credit 4.2	**Recycled Content,** 20% (post-consumer + ½ pre-consumer)	1
			Credit 5.1	**Regional Materials,** 10% Extracted, Processed & Manufactured Regionally	1
			Credit 5.2	**Regional Materials,** 20% Extracted, Processed & Manufactured Regionally	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1
Yes	?	No			
			Indoor Environmental Quality		**15 Points**
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
			Credit 1	**Outdoor Air Delivery Monitoring**	1
			Credit 2	**Increased Ventilation**	1
			Credit 3.1	**Construction IAQ Management Plan,** During Construction	1
			Credit 3.2	**Construction IAQ Management Plan,** Before Occupancy	1
			Credit 4.1	**Low-Emitting Materials,** Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials,** Paints & Coatings	1
			Credit 4.3	**Low-Emitting Materials,** Flooring Systems	1
			Credit 4.4	**Low-Emitting Materials,** Composite Wood & Agrifiber Products	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems,** Lighting	1
			Credit 6.2	**Controllability of Systems,** Thermal Comfort	1
			Credit 7.1	**Thermal Comfort,** Design	1
			Credit 7.2	**Thermal Comfort,** Verification	1
			Credit 8.1	**Daylight & Views,** Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views,** Views for 90% of Spaces	1
Yes	?	No			
			Innovation & Design Process		**6 Points**
			Credit 1.1	**Innovation in Design:** Provide Specific Title	1
			Credit 1.2	**Innovation in Design:** Provide Specific Title	1
			Credit 1.3	**Innovation in Design:** Provide Specific Title	1
			Credit 1.4	**Innovation in Design:** Provide Specific Title	1
			Credit 1.5	**Innovation in Design:** Provide Specific Title	1
			Credit 2	**LEED® Accredited Professional**	1
Yes	?	No			
			Regional Bonus Credits		**4 Points**
			Credit 1.1	**Region Specific Environmental Priority:** Region Defined	1
			Credit 1.2	**Region Specific Environmental Priority:** Region Defined	1
			Credit 1.3	**Region Specific Environmental Priority:** Region Defined	1
			Credit 1.4	**Region Specific Environmental Priority:** Region Defined	1
Yes	?	No			
			Project Totals (Certification Estimates)		**110 Points**
Not Certified			**Certified:** 40-49 points **Silver:** 50-59 points **Gold:** 60-79 points **Platinum:** 80+ points		

Green Building Council, which then makes the final certification of the project's LEED compliance.

The U.S. Green Building Council continues to refine and improve upon LEED-NC and is expanding its family of rating systems to include existing buildings (LEED-EB), commercial interiors (LEED-CI), building core and shell construction (LEED-CS), homes (LEED-H), and other categories of construction and development. Through international sister organizations, LEED is being implemented in Canada and other countries. Other green building programs, such as the Green Building Initiative's *Green Globes*, the National Association of Home Builders' *Green Home Building Guidelines*, and the International Code Council and National Association of Home Builders' jointly developed *National Green Building Standard*, offer alternative assessment schemes.

Some green building efforts focus more narrowly on reducing building energy consumption, a measure of building performance that frequently correlates closely with the generation of greenhouse gas emissions and global warming trends. The American Society of Heating, Refrigerating and Air-Conditioning Engineers' *Advanced Energy Design Guides* and the U.S. Environmental Protection Agency's *Energy Star* program both set goals for reductions in energy consumption in new buildings that exceed current national standards. These standards can be applied either as stand-alone programs or as part of a more comprehensive effort to achieve certification through LEED or some other green building assessment program.

Buildings can also be designed with the goal of zero energy use or carbon neutrality. A *net zero energy* building is one that consumes no more energy than it produces, usually when measured on an annual basis to account for seasonal differences in building energy consumption and on-site energy production. Net zero energy use can be achieved using current technology combining on-site renewable energy generation (such as wind or solar power), passive heating and cooling strategies, a thermally efficient building enclosure, and highly efficient mechanical systems and appliances.

A *carbon-neutral* building is one that causes no net increase in the emission of carbon dioxide, the most prevalent atmospheric greenhouse gas. If emissions due only to building operation are considered, the calculation is similar to that for a net zero energy building. If, however, the embodied carbon in the building's full life cycle—from materials extraction and manufacturing, through building construction and operations, to demolition, disposal, and recycling—is considered, the calculation becomes more complex. Carbon-neutral calculations may also consider the site on which the building resides. For example, what is the carbon footprint of a fully developed building site, including both its buildings and unbuilt areas, in comparison to that of the site prior to construction or in comparison to its natural state prior to human development of any kind? Another possible consideration is, what role, if any, should *carbon offsetting* (funding of off-site activities that reduce global carbon emissions, such as planting of trees), play in such calculations? Questions such as these and the concepts of sustainability and how they relate to building construction will continue to evolve for the foreseeable future.

Considerations of sustainability are included throughout this book. In addition, a sidebar in nearly every chapter describes the major issues of sustainability related to the materials and methods discussed in that chapter. These will be helpful in weighing the environmental costs of one material against those of another, and in learning how to build in such a way that we preserve for future generations the ability to meet their building needs in a reasonable and economical manner. For more information on organizations whose mission is to raise our awareness and provide the knowledge that we need to build sustainably, see the references listed at the end of this chapter.

The Work of the Design Professional: Choosing Building Systems

A building begins as an idea in someone's mind, a desire for new and ample accommodations for a family, many families, an organization, or an enterprise. For any but the smallest buildings, the next step for the owner of the prospective building is to engage, either directly or through a hired construction manager, the services of building design professionals. An architect helps to organize the owner's ideas about the new building, develops the form of the building, and assembles a group of engineering specialists to help work out concepts and details of foundations, structural support, and mechanical, electrical, and communications services.

. . . the architect should have construction at least as much at his fingers' ends as a thinker his grammar.

Le Corbusier, *Towards a New Architecture*, 1927

This team of designers, working with the owner, then develops the scheme for the building in progressively finer degrees of detail. Drawings and written specifications are produced by the architect–engineer team to document how the building is to be made and of what. The drawings and specifications are submitted to the local government building authorities, where they are checked for conformance with zoning ordinances and building codes before a permit is issued to build. A general contractor is selected, either by negotiation or by competitive bidding, who then hires subcontractors to carry out many specialized portions of the work. Once construction begins, the general contractor oversees the construction process while the building inspector, architect, and engineering consultants observe the work at frequent intervals to be sure that it is carried out according to plan. Finally, construction is finished, the building is made ready for occupancy, and that original idea, often initiated years earlier, is realized.

Although a building begins as an abstraction, it is built in a world of material realities. The designers of a building—the architects and engineers—work constantly from a knowledge of what is possible and what is not. They are able, on the one hand, to employ a seemingly limitless palette of building materials and any of a number of structural systems to produce a building of almost any desired form and texture. On the other hand, they are inescapably bound by certain physical limitations: how much land there is with which to work; how heavy a building the soil can support; how long a structural span is feasible; what sorts of materials will perform well in the given environment. They are also constrained by a construction budget and by a complex web of legal restrictions.

Those who work in the building professions need a broad understanding of many things, including people and culture, the environment, the physical principles by which buildings work, the technologies available for utilization in buildings, the legal restrictions on building design and use, the economics of building, and the contractual and practical arrangements under which buildings are constructed. This book is concerned primarily with the technologies of construction—what the materials are, how they are produced, what their properties are, and how they are crafted into buildings. These must be studied, however, with reference to many other factors that bear on the design of buildings, some of which require explanation here.

Zoning Ordinances

The legal restrictions on buildings begin with local *zoning ordinances*, which govern the types of activities that may take place on a given piece of land, how much of the land may be covered by buildings, how far buildings must be set back from adjacent property lines, how many parking spaces must be provided, how large a total floor area may be constructed, and how tall the buildings may be. In larger cities, zoning ordinances may include fire zones with special fire-protection requirements, neighborhood enterprise districts with economic incentives for new construction or revitalization of existing buildings, or other special conditions.

Building Codes

In addition to its zoning ordinances, local governments regulate building activity by means of *building codes*. Building codes protect public health and safety by setting minimum standards for construction quality, structural integrity, durability, livability, accessibility, and especially fire safety.

Most building codes in North America are based on one of several *model building codes*, standardized codes that local jurisdictions may adopt for their own use as an alternative to writing their own. In Canada, the *National Building Code of Canada* is published by the Canadian Commission on Building and Fire Codes. It is the basis for most of that country's provincial and municipal building codes. In the United States, the *International Building Code*® is the predominant model code. This code is published by the International Code Council, a private, nonprofit organization whose membership consists of local code officials from throughout the country. It is the basis for most U.S. building codes enacted at the state, county, and municipal levels. The International Building Code (IBC) is the first unified model building code in U.S. history. First published in March 2000, it was a welcome consolidation of a number of previous competing regional model codes.

Building-code-related information in this book is based on the IBC. The IBC begins by defining *occupancy groups* for buildings as follows:

- Groups A-1 through A-5 are public Assembly occupancies: theaters, auditoriums, lecture halls, nightclubs, restaurants, houses of worship, libraries, museums, sports arenas, and so on.
- Group B is Business occupancies: banks, administrative offices, higher-education facilities, post offices, banks, professional offices, and the like.
- Group E is Educational occupancies: schools for grades K through 12 and day-care facilities.
- Groups F-1 and F-2 comprise industrial processes using moderate-flammability or noncombustible materials, respectively.
- Groups H-1 through H-5 include various types of High Hazard occupancies in which toxic, corrosive, highly flammable, or explosive materials are present.
- Groups I-1 through I-4 are Institutional occupancies in which occupants under the care of others may not be able to save themselves during a fire or other building emergency, such as health care facilities, custodial care facilities, and prisons.
- Group M is Mercantile occupancies: stores, markets, service stations, and salesrooms.
- Groups R-1 through R-4 are Residential occupancies, including apartment buildings, dormitories, fraternity and sorority houses, hotels, one- and two-family dwellings, and assisted-living facilities.
- Groups S-1 and S-2 include buildings for Storage of moderate- and low-hazard materials, respectively.
- Group U is Utility buildings. It comprises agricultural buildings, carports, greenhouses, sheds, stables, fences, tanks, towers, and other secondary buildings.

The IBC's purpose in establishing occupancy groups is to distinguish various degrees of need for safety in buildings. A hospital, in which many patients are bedridden and cannot escape a fire without assistance from others, must be built to a higher standard of safety than a hotel or motel. A warehouse storing noncombustible masonry materials, which is likely to be occupied by only a few people, all of them able-bodied, can be constructed to a lower standard than a large retail mall building, which will house large quantities of combustible materials and will be occupied by many users varying in age and physical capability. An elementary school requires more protection for its occupants than a university building. A theater needs special egress provisions to allow its many patrons to escape quickly, without stampeding, in an emergency.

These definitions of occupancy groups are followed by a set of definitions of *construction types*. At the head of this list is Type I construction, made with highly fire-resistant, noncombustible materials. At the foot of it is Type V construction, which is built from combustible wood framing—the least fire-resistant of all construction types. In between are Types II, III, and IV, with levels of resistance to fire falling between these two extremes.

With occupancy groups and construction types defined, the IBC proceeds to match the two, stating which occupancy groups may be housed in which types of construction, and under what limitations of building height and area. Figure 1.2 is reproduced from the IBC. This table gives values for the maximum building height, in both feet and number of stories above grade, and the maximum area per floor for every possible combination of occupancy group and construction type. Once these base values are adjusted according to other provisions of the code, the maximum permitted size for a building of any particular use and type of construction can be determined.

This table concentrates a great deal of important information into a very small space. A designer may refer to it with a particular building type in mind and find out what types of construction will be permitted and what shape the building may take. Consider, for example, an office building. Under the IBC, a building of this type belongs to Occupancy Group B, Business. Reading across the table from left to right, we find immediately that this building may be built to any desired size, without limit, using Type I-A construction.

Type I-A construction is defined in the IBC as consisting of only noncombustible materials—masonry, concrete, or steel, for example, but not wood—and meeting minimum requirements for resistance to the heat of fire. Looking at the upper table in Figure 1.3, also reproduced from the IBC, we find under Type I-A construction a listing of the required *fire resistance ratings*, measured in hours, for various parts of our proposed office

TABLE 503
ALLOWABLE HEIGHT AND BUILDING AREAS[a]
Height limitations shown as stories and feet above grade plane.
Area limitations as determined by the definition of "Area, building," per story

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HGT(feet)									
GROUP	HGT(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP
H-2[d]	S	UL	3	2	1	2	1	2	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	3,000
H-3[d]	S	UL	6	4	2	4	2	4	2	1
	A	UL	60,000	26,500	14,000	17,500	13,000	25,500	10,000	5,000
H-4	S	UL	7	5	3	5	3	5	3	2
	A	UL	UL	37,500	17,500	28,500	17,500	36,000	18,000	6,500
H-5	S	4	4	3	3	3	3	3	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
I-1	S	UL	9	4	3	4	3	4	3	2
	A	UL	55,000	19,000	10,000	16,500	10,000	18,000	10,500	4,500
I-2	S	UL	4	2	1	1	NP	1	1	NP
	A	UL	UL	15,000	11,000	12,000	NP	12,000	9,500	NP
I-3	S	UL	4	2	1	2	1	2	2	1
	A	UL	UL	15,000	10,000	10,500	7,500	12,000	7,500	5,000
I-4	S	UL	5	3	2	3	2	3	1	1
	A	UL	60,500	26,500	13,000	23,500	13,000	25,500	18,500	9,000
M	S	UL	11	4	4	4	4	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-3	S	UL	11	4	4	4	4	4	3	3
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
R-4	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	3	3	3	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	4	4	4	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2.

UL = Unlimited, NP = Not permitted.

a. See the following sections for general exceptions to Table 503:
   1. Section 504.2, Allowable height increase due to automatic sprinkler system installation.
   2. Section 506.2, Allowable area increase due to street frontage.
   3. Section 506.3, Allowable area increase due to automatic sprinkler system installation.
   4. Section 507, Unlimited area buildings.

b. For open parking structures, see Section 406.3.

c. For private garages, see Section 406.1.

d. See Section 415.5 for limitations.

FIGURE 1.2
Height and area limitations of buildings of various types of construction, as defined in the 2006 IBC. *(Portions of this publication reproduce tables from the* 2006 International Building Code, *International Code Council, Inc., Washington, D.C. Reproduced with Permission. All rights reserved.)*

FIGURE 1.3
Fire resistance of building elements as required by the 2006 IBC. *(Portions of this publication reproduce tables from the* 2006 International Building Code, *International Code Council, Inc., Washington, D.C. Reproduced with Permission. All rights reserved.)*

building. For example, the first line states that the structural frame, including such elements as columns, beams, and trusses, must be rated at 3 hours. The second line also mandates a 3-hour resistance for *bearing walls*, which serve to carry floors or

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[e]	B	A[e]	B	HT	A[e]	B
Structural frame[a]	3[b]	2[b]	1	0	1	0	HT	1	0
Bearing walls Exterior[g] Interior	 3 3[b]	 2 2[b]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[f]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	$1^1/_2$[c]	1[c, d]	1[c, d]	0[d]	1[d]	0[d]	HT	1[c, d]	0

For SI: 1 foot = 304.8 mm.

a. The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads. The members of floor or roof panels which have no connection to the columns shall be considered secondary members and not a part of the structural frame.

b. Roof supports: Fire-resistance ratings of structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

c. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

d. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

e. An approved automatic sprinkler system in accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

f. Not less than the fire-resistance rating required by other sections of this code.

g. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

TABLE 602
FIRE-RESISTANCE RATING REQUIREMENTS FOR EXTERIOR WALLS BASED ON FIRE SEPARATION DISTANCE[a, e]

FIRE SEPARATION DISTANCE = X (feet)	TYPE OF CONSTRUCTION	OCCUPANCY GROUP H	OCCUPANCY GROUP F-1, M, S-1	OCCUPANCY GROUP A, B, E, F-2, I, R, S-2, U[b]
$X < 5$[c]	All	3	2	1
$5 \leq X < 10$	IA Others	3 2	2 1	1 1
$10 \leq X < 30$	IA, IB IIB, VB Others	2 1 1	1 0 1	1[d] 0 1[d]
$X \geq 30$	All	0	0	0

For SI: 1 foot = 304.8 mm.

a. Load-bearing exterior walls shall also comply with the fire-resistance rating requirements of Table 601.

b. For special requirements for Group U occupancies see Section 406.1.2

c. See Section 705.1.1 for party walls.

d. Open parking garages complying with Section 406 shall not be required to have a fire-resistance rating.

e. The fire-resistance rating of an exterior wall is determined based upon the fire separation distance of the exterior wall and the story in which the wall is located.

roofs above. *Nonbearing walls or partitions*, which carry no load from above, are listed in the third line, referring to Table 602, which gives fire resistance rating requirements for exterior walls of a building based on their proximity to adjacent buildings. (Table 602 is included in the lower portion of Figure 1.3.) Requirements for floor and roof construction are defined in the last two lines of Table 601.

Looking across Table 601 in Figure 1.3, we can see that fire resistance rating requirements are highest for Type I-A construction, decrease to 1 hour for various intermediate types, and fall to zero for Type V-B construction. In general, the lower the construction type numeral, the more fire-resistant the construction system is. (Type IV construction is somewhat of an anomaly, referring to *Heavy Timber* construction consisting of large wooden members that are relatively slow to catch fire and burn.)

Once fire resistance rating requirements for the major parts of a building have been determined the design of these parts can proceed, using building assemblies meeting these requirements. Tabulated fire resistance ratings for common building materials and assemblies may come from a variety of sources, including the IBC itself, as well as a from catalogs and handbooks issued by building material manufacturers, construction *trade associations*, and organizations concerned with fire protection of buildings. In each case, the ratings are derived from full-scale laboratory tests of building components carried out in accordance with an accepted standard fire test protocol to ensure uniformity of results. (This test, ASTM E119, is described more fully in Chapter 22 of this book.) Figures 1.4 to 1.6 show sections of tables from catalogs and handbooks to illustrate how such fire resistance ratings are commonly presented.

In general, when determining the level of fire resistance required for a building, the greater the degree of fire resistance, the higher

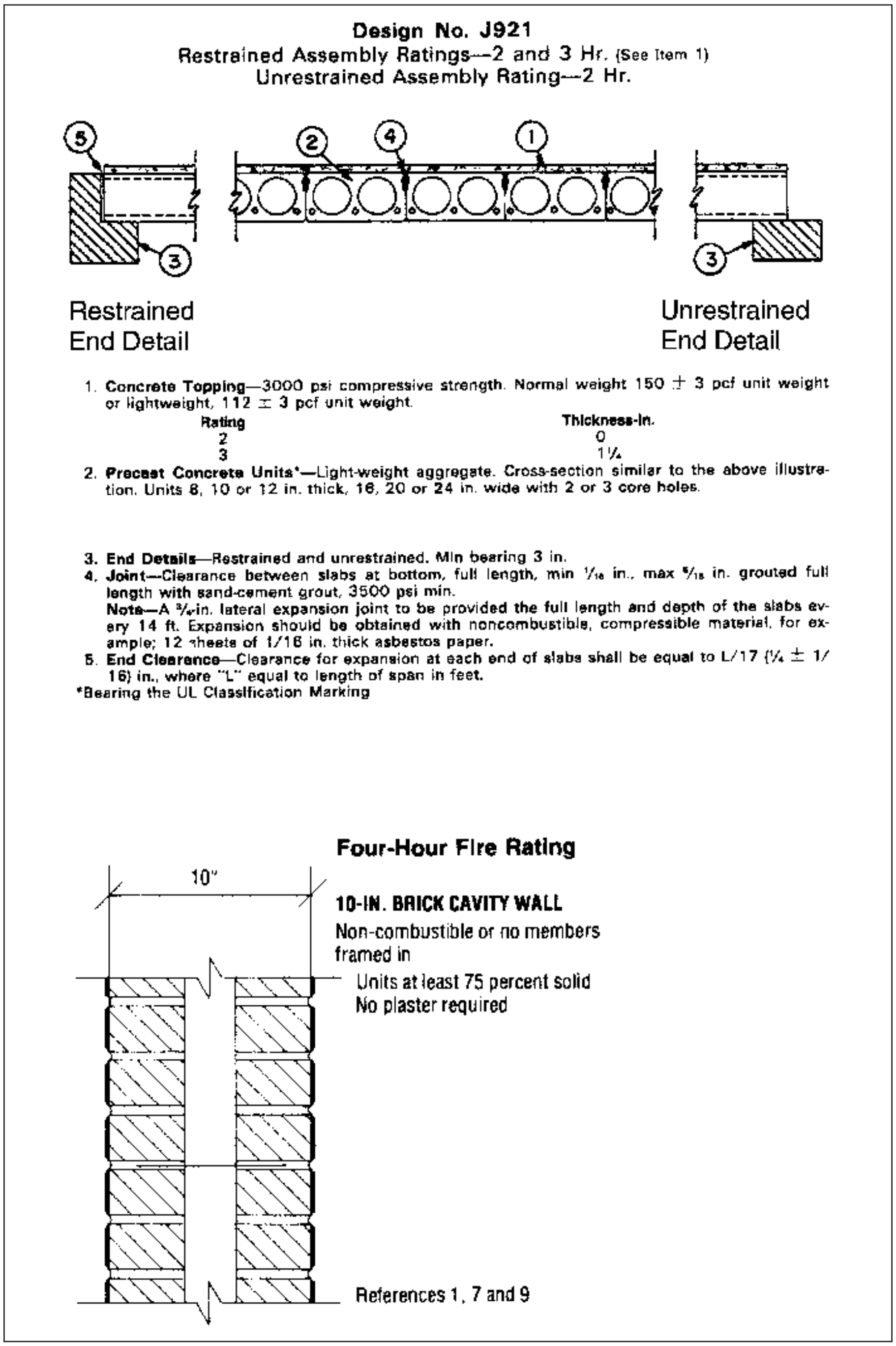
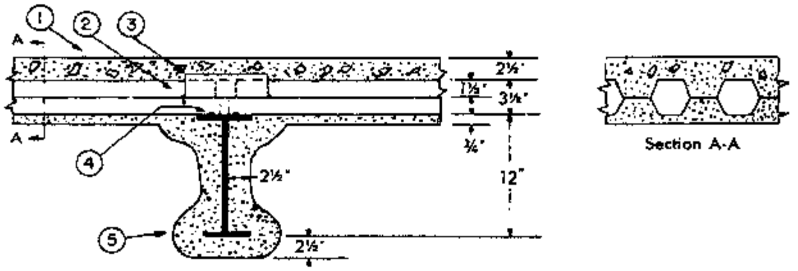


FIGURE 1.4
Examples of fire resistance ratings for concrete and masonry structural elements. The upper detail, taken from the Underwriters Laboratories *Fire Resistance Directory*, is for a precast concrete hollow-core plank floor with a poured concrete topping. *Restrained* and *unrestrained* refer to whether or not the floor is prevented from expanding longitudinally when exposed to the heat of a fire. The lower detail is from literature published by the Brick Institute of America. *(Reprinted with permission of Underwriters Laboratories Inc. and the Brick Institute of America, respectively.)*

Design No. A814
Restrained Assembly Rating—3 Hr.
Unrestrained Assembly Rating—3 Hr.
Unrestrained Beam Rating—3 Hr.



Beam—W12×27, min size.

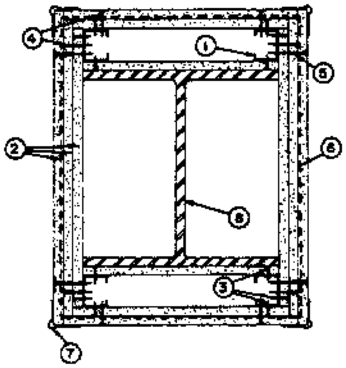
1. **Sand-Gravel Concrete**—150 pcf unit weight 4000 pcf compressive strength.
2. **Steel Floor and Form Units***—Non-composite 3 in. deep galv units. All 24 in. wide, 18/18 MSG min cellular units. Welded to supports 12 in. O.C. Adjacent units button-punched or welded 36 in. O.C. at joints.
3. **Cover Plate**—No. 16 MSG galv steel.
4. **Welds**—12 in. O.C.
5. **Fiber Sprayed***—Applied to wetted steel surfaces which are free of dirt, oil or loose scale by spraying with water to the final thickness shown above. The use of adhesive and sealer and the tamping of fiber are optional. The min and density of the finished fiber should be 11 pcf and the specified fiber thicknesses require a min fiber density of 11 pcf. For areas where the fiber density is between 8 and 11 pcf, the fiber thickness shall be increased in accordance with the following formula:

$$\text{Thickness, in.} = \frac{(11)\ (\text{Design Thickness, in.})}{\text{Actual Fiber Density, pcf.}}$$

Fiber density shall not be less than 8 pcf. For method of density determination refer to General Information Section.

*Bearing the UL Classification Marking.

Design No. X511
Rating—3 Hr.



1. **Steel Studs**—1⅝ in. wide with leg dimensions of 1-5/16 and 1-7/16 in. with a ¼-in. folded flange in legs, fabricated from 25 MSG galv steel, ¾- by 1¾-in. rectangular cutouts punched 8 and 16 in. from the ends. Steel stud cut ½ in. less in length than assembly height.
2. **Wallboard, Gypsum***—½ in. thick, three layers.
3. **Screws**—1 in. long, self-drilling, self-tapping steel screws, spaced vertically 24 in. O.C.
4. **Screws**—1⅝ in. long, self-drilling, self-tapping steel screws, spaced vertically 24 in. O.C., except on the outer layer of wallboard on the flange, which are spaced 12 in. O.C.
5. **Screws**—2¼ in. long, self-drilling, self-tapping steel screws, spaced vertically 12 in. O.C.
6. **Tie Wire**—One strand of 18 SWG soft steel wire placed at the upper one-third point, used to secure the second layers of wallboard only.
7. **Corner Beads**—No. 28 MSG galv steel, 1¼ in. legs or 27 MSG uncoated steel, 1¾ in. legs,

FIGURE 1.5
Fire resistance ratings for a steel floor structure and column, respectively, taken from the Underwriters Laboratories *Fire Resistance Directory*. *(Reprinted with permission of Underwriters Laboratories Inc.)*

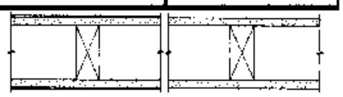
Fire Rating	Sound Rating STC	GA File No.	DETAILED DESCRIPTION	SKETCH AND DESIGN DATA: Fire	SKETCH AND DESIGN DATA: Sound
1 HR	**30 to 34**	**WP 3620**	**Construction Type: Gypsum-Veneer Base, Veneer Plaster, Wood Studs** One layer ½″ type X gypsum veneer base applied at right angles to each side of 2 x 4 wood studs 16″ o.c. with 5d etched nails, 1¾″ long, 0.099″ shank, ¼″ heads, 8″ o.c. Minimum 1/16″ gypsum-veneer plaster over each face. Stagger vertical joints 16″ and horizontal joints each side 12″. Sound tested without veneer plaster. (LB)	 Thickness: 4⅞″ Approx. Weight: 7 psf Fire Test: UC, 1-12-66 Sound Test: G & H IBI-35FT. 5-26-64	

FIGURE 1.6
A sample of fire resistance ratings published by the Gypsum Association, in this case for an interior partition. *(Courtesy of the Gypsum Association)*

the cost. Most frequently, therefore, buildings are designed with the lowest level of fire resistance permitted by the building code. Our hypothetical office building could be built using Type IA construction, but does it really need to be constructed to this high standard?

Let us suppose that the owner desires a five-story building with 30,000 square feet per floor. Reading across the table in Figure 1.2, we can see that in addition to Type I-A construction, the building can be of Type I-B construction, which permits a building of eleven stories and unlimited floor area, or of Type II-A construction, which permits a building of five stories and 37,500 square feet per floor. But it cannot be of Type II-B construction, which allows a building of only four stories and 23,000 square feet per floor. It can also be built of Type IV construction but not of Type III or Type V.

Other factors also come into play in these determinations. If a building is protected throughout by an approved, fully automatic sprinkler system for suppression of fire, the IBC provides that the tabulated area per floor may be quadrupled for a single-story building or as much as tripled for a multistory building (depending on additional considerations omitted here for the sake of simplicity). A one-story increase in allowable height is also granted under most circumstances if such a sprinkler system is installed. If the five-story, 30,000-square-foot office building that we have been considering is provided with such a sprinkler system, a bit of arithmetic will show that it can be built of any construction type shown in Figure 1.2 except Type V.

If more than a quarter of the building's perimeter walls face public ways or open spaces accessible to firefighting equipment, an additional increase of up to 75 percent in allowable area is granted in accordance with another formula. Furthermore, if a building is divided by fire walls having the fire resistance ratings specified in another table (Figure 1.7), each divided portion may be considered a separate building for purposes of computing its allowable area, which effectively permits the creation of a building many times larger than Figure 1.2 would, at first glance, indicate.

TABLE 705.4
FIRE WALL FIRE-RESISTANCE RATINGS

GROUP	FIRE-RESISTANCE RATING (hours)
A, B, E, H-4, I, R-1, R-2, U	3[a]
F-1, H-3[b], H-5, M, S-1	3
H-1, H-2	4[b]
F-2, S-2, R-3, R-4	2

a. Walls shall be not less than 2-hour fire-resistance rated where separating buildings of Type II or V construction.
b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.4 and 415.5.

Figure 1.7
Fire resistance requirements for fire walls, according to the 2006 IBC. *(Portions of this publication reproduce tables from the* 2006 International Building Code, *International Code Council, Inc., Washington, D.C. Reproduced with Permission. All rights reserved.)*

The IBC also establishes standards for natural light, ventilation, means of emergency egress, structural design, construction of floors, walls, and ceilings, chimney construction, fire protection systems, accessibility for disabled persons, and many other important factors. The International Code Council also publishes the *International Residential Code (IRC)*, a simplified model code specifically addressing the construction of detached one- and two-family homes and townhouses of limited size. Within any particular building agency, buildings of these types may fall under the requirements of either the IBC or the IRC, depending on the code adoption policies of that jurisdiction.

The building code is not the only code with which a new building must comply. Health codes regulate aspects of design and operation related to sanitation in public facilities such as swimming pools, food-service operations, schools, or health care facilities. Energy codes establish standards of energy efficiency for buildings affecting a designer's choices of windows, heating and cooling systems, and many aspects of the construction of a building's enclosing walls and roofs. Fire codes regulate the operation and maintenance of buildings to ensure that egress pathways, fire protection systems, emergency power, and other life-safety systems are properly maintained. Electrical and mechanical codes regulate the design and installation of building electrical, plumbing, and heating and cooling systems. Some of these codes may be locally written. But like the building codes discussed above, most are based on national models. In fact, an important task in the early design of any major building is determining what agencies have jurisdiction over the project and what codes and regulations apply.

Other Constraints

Other types of legal restrictions must also be observed in the design and construction of buildings. The *Americans with Disabilities Act (ADA)* makes accessibility to public buildings a civil right of all Americans, and the *Fair Housing Act* does the same for much multifamily housing. These *access* *standards* regulate the design of entrances, stairs, doorways, elevators, toilet facilities, public areas, living spaces, and other parts of affected buildings to ensure that they are accessible and usable by physically handicapped members of the population.

The U.S. *Occupational Safety and Health Administration (OSHA)* controls the design of workplaces to minimize hazards to the health and safety of workers. OSHA sets safety standards under which a building must be constructed and also has an important effect on the design of industrial and commercial buildings.

An increasing number of states have limitations on the amount of *volatile organic compounds (VOCs)* that building products can release into the atmosphere. VOCs are organic chemical compounds that evaporate readily. They can act as irritants to building occupants, they contribute to air pollution, and some are greenhouse gases. Typical sources of VOCs are paints, stains, adhesives, and binders used in the manufacture of wood panel products.

States and localities have conservation laws that protect wetlands and other environmentally sensitive areas from encroachment by buildings. Fire insurance companies exert a major influence on construction standards through their testing and certification organizations (Underwriters Laboratories and Factory Mutual, for example) and through their rate structures for building insurance coverage, which offer strong financial incentives to building owners for more hazard-resistant construction. Building contractors and construction labor unions have standards, both formal and informal, that affect the ways in which buildings are built. Unions have work rules and safety rules that must be observed; contractors have particular types of equipment, certain kinds of skills, and customary ways of going about things. All of these vary significantly from one place to another.

Construction Standards and Information Resources

The tasks of the architect and the engineer would be impossible to carry out without the support of dozens of standards-setting agencies, trade associations, professional organizations, and other groups that produce and disseminate information on materials and methods of construction, some of the most important of which are discussed in the sections that follow.

Standards-Setting Agencies

ASTM International (formerly the American Society for Testing and Materials) is a private organization that establishes specifications for materials and methods of construction accepted as standards throughout the United States. Numerical references to ASTM standards—for example, ASTM C150 for portland cement, used in making concrete—are found throughout building codes and construction specifications, where they are used as a precise shorthand for describing the quality of materials or the requirements of their installation. Throughout this book, references to ASTM standards are provided for the major building materials presented. Should you wish to examine the contents of the standards themselves, they can be found in the ASTM references listed at the end of this chapter. In Canada, corresponding standards are set by the Canadian Standards Association (CSA).

The *American National Standards Institute (ANSI)* is another private organization that develops and certifies North American standards for a broad range of products, such as exterior windows, mechanical components of buildings, and even the accessibility requirements referenced within the IBC itself (ICC/ANSI A117.1). Government agencies, most notably the U.S. Department of Commerce's *National Institute of Science and Technology (NIST)* and the National Research Council Canada's *Institute for Research in Construction (NRC-IRC)*, also sponsor research and establish standards for building products and systems.

Construction Trade and Professional Associations

Design professionals, building materials manufacturers, and construction trade groups have formed a large number of organizations that work to develop technical standards and disseminate information related to their respective fields of interest. The Construction Specifications Institute, whose MasterFormat™ standard is described in the following section, is one example. This organization is composed both of independent building professionals, such as architects and engineers, and of industry members. The Western Wood Products Association, to choose an example from among hundreds of *trade associations*, is made up of producers of lumber and wood products. It carries out research programs on wood products, establishes uniform standards of product quality, certifies mills and products that conform to its standards, and publishes authoritative technical literature concerning the use of lumber and related products. Associations with a similar range of activities exist for virtually every material and product used in building. All of them publish technical data relating to their fields of interest, and many of these publications are indispensable references for the architect or engineer. A considerable number of the standards published by these organizations are incorporated by reference into the building codes. Selected publications from professional and trade associations are identified in the references listed at the end of each chapter in this book. The reader is encouraged to obtain and explore these publications and others available from these various organizations.

MasterFormat

The *Construction Specifications Institute* (*CSI*) of the United States and its Canadian counterpart, *Construction Specifications Canada (CSC)*, have evolved over a period of many years a comprehensive outline called *MasterFormat* for organizing information about construction materials and systems. MasterFormat is used as the outline for construction specifications for the vast majority of large construction projects in these two countries, it is frequently used to organize construction cost data, and it forms the basis on which most trade associations' and manufacturers' technical literature is cataloged. In some cases, MasterFormat is used to cross-reference materials information on construction drawings as well.

MasterFormat is organized into 50 primary *divisions* intended to cover the broadest possible range of construction materials and buildings systems. The portions of MasterFormat relevant to the types of construction discussed in this book are as follows:

Procurement and Contracting Requirements Group
- Division 00 — Procurement and Contracting Requirements

Specifications Group
- General Requirements Subgroup
  - Division 01 — General Requirements
- Facility Construction Subgroup
  - Division 02 — Existing Conditions
  - Division 03 — Concrete
  - Division 04 — Masonry
  - Division 05 — Metals
  - Division 06 — Wood, Plastics, and Composites
  - Division 07 — Thermal and Moisture Protection
  - Division 08 — Openings
  - Division 09 — Finishes
  - Division 10 — Specialties
  - Division 11 — Equipment
  - Division 12 — Furnishings
  - Division 13 — Special Construction
  - Division 14 — Conveying Equipment
- Facilities Services Subgroup
  - Division 21 — Fire Suppression
  - Division 22 — Plumbing
  - Division 23 — Heating, Ventilating, and Air Conditioning
  - Division 25 — Integrated Automation
  - Division 26 — Electrical
  - Division 27 — Communications
  - Division 28 — Electronic Safety and Security
- Site and Infrastructure Subgroup
  - Division 31 — Earthwork
  - Division 32 — Exterior Improvements
  - Division 33 — Utilities

These broadly defined divisions are further subdivided into *sections*, each describing a discrete scope of work usually provided by a single construction trade or subcontractor. Individual sections are identified by six-digit codes, in which the first two digits correspond to the division numbers above and the remaining four digits identify subcategories and individual units within the division. Within Division 05 – Metals, for example, some commonly referenced sections are:

- Section 05 10 00 — Structural Steel Framing
- Section 05 21 00 — Steel Joist Framing
- Section 05 31 00 — Steel Decking
- Section 05 40 00 — Cold-Formed Metal Framing
- Section 05 50 00 — Metal Fabrications

Almost every chapter in this book gives MasterFormat designations for the information it presents to help the reader know where to look in construction specifications and other technical resources for further information. The full MasterFormat system is contained in the volume referenced at the end of this chapter.

MasterFormat organizes building systems information primarily according to work product, that is, the work of discrete building trades, making it especially well suited for use during the construction phase of building. Other organizational systems, such as *Uniformat*™ and *OmmiClass*™, offer a range of alternative organizational schemes suitable to other phases of the building life cycle and other aspects of building functionality. See the references at the end of this chapter for more information about these systems.

The Work of the Construction Professional: Constructing Buildings

Providing Construction Services

An owner wishing to construct a building hopes to achieve a finished project that meets its functional requirements and its expectations for design and quality, at the lowest possible cost, and on a predictable schedule. A contractor offering its construction services hopes to produce quality work, earn a profit, and complete the project in a timely fashion. Yet, the process of building itself is fraught with uncertainty: It is subject to the vagaries of the labor market, commodity prices, and the weather; despite the best planning efforts unanticipated conditions arise, delays occur, and mistakes are made; and the pressures of schedule and cost inevitably minimize the margin for miscalculation. In this high-stakes environment, the

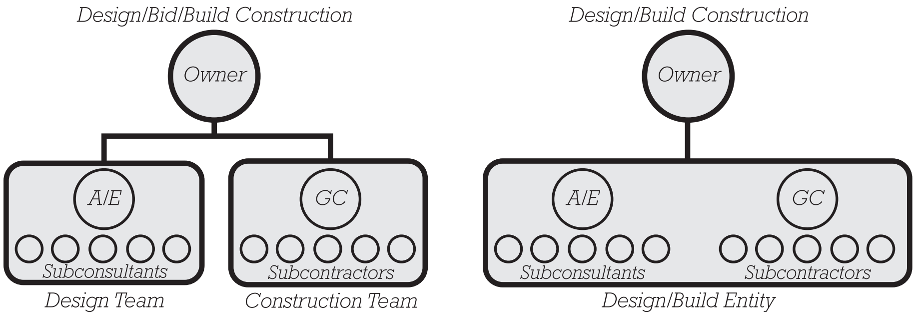


Figure 1.8
In design/bid/build project delivery, the owner contracts separately with the architect/engineer (A/E) design team and the construction general contractor (GC). In a design/build project, the owner contracts with a single organizational entity that provides both design and construction services.

relationship between the owner and contractor must be structured to share reasonably between them the potential rewards and risks.

Construction Project Delivery Methods

In conventional *design/bid/build* project delivery (Figure 1.8), the owner first hires a team of architects and engineers to perform design services, leading to the creation of drawings and technical specifications, referred to collectively as the *construction documents*, that comprehensively describe the facility to be built. Next, construction firms are invited to bid on the project. Each bidding firm reviews the construction documents and proposes a cost to construct the facility. The owner evaluates the submitted proposals and awards the construction contract to the bidder deemed most suitable. This selection may be based on bid price alone, or other factors related to bidders' qualifications may also be considered. The construction documents then become part of the construction contract, and the selected firm proceeds with the work. On all but small projects, this firm acts as the *general contractor*, coordinating and overseeing the overall construction process but frequently relying on smaller, more specialized *subcontractors* to perform significant portions or even all of the construction work. During construction, the design team continues to provide services to the owner, helping to ensure that the facility is built according to the requirements of the documents as well as answering questions related to the design, changes to the work, payments to the contractor, and similar matters. Among the advantages of design/bid/build project delivery are its easy-to-understand organizational structure, well-established legal precedents, and ease of management. The direct relationship between the owner and the design team ensures that the owner retains control over the design and provides a healthy set of checks and balances during the construction process. Also, with design work completed before the project is bid, the owner starts construction with a fixed construction cost and a high degree of confidence regarding the final costs of the project.

In design/bid/build project delivery, the owner contracts with two entities, and design and construction responsibilities remain divided between these two throughout the project. In *design/build* project delivery, one entity ultimately assumes responsibility for both design and construction (Figure 1.8). A design/build project begins with the owner developing a conceptual design or program that describes the functional or performance requirements of the proposed facility but does not detail its form or how it is to be constructed. Next, using this conceptual information, a design/build organization is selected to complete all remaining aspects of the project. Selection of the designer/builder may be based on a competitive bid process similar to that described above for design/bid/build projects, on negotiation and evaluation of an organization's qualifications for the proposed work, or on some combination of both. Design/build organizations themselves can take a variety of forms: a single firm encompassing both design and construction expertise, a construction management firm that subcontracts with a separate design firm to provide those services, or a joint venture between two firms, one specializing in construction and the other in design. Regardless of the internal structure of the design/build organization, the owner contracts with this single entity throughout the remainder of the project, which assumes responsibility for all remaining design and construction services. Design/build project delivery gives the owner a single source of accountability for all aspects of the project. It also places the designers and constructors in a collaborative relationship, introducing construction expertise into the design phases of a project and allowing the earliest possible consideration of constructability, cost control, construction scheduling, and similar matters. This delivery method also readily accommodates fast track construction, a scheduling technique for reducing construction time that is described below.

Other delivery methods are possible: An owner may contract separately with a design team and a *construction manager*. As in design/build construction, the construction manager participates in the project prior to the onset of construction, introducing construction expertise during the design stage. Construction management project delivery can take a variety of forms and is frequently associated with especially large or complex

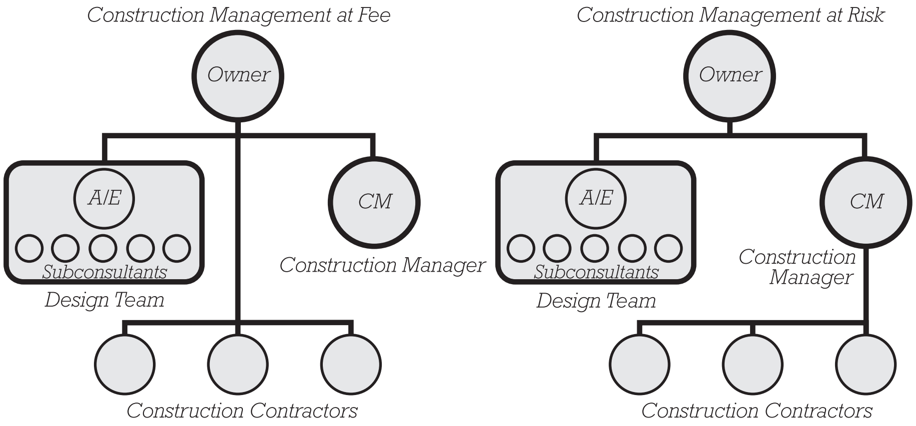


Figure 1.9
In its traditional role, a construction manager (CM) *at fee* provides project management services to the owner and assists the owner in contracting directly for construction services with one or more construction entities. A CM at fee is not directly responsible for the construction work itself. A CM *at risk* acts more like a general contractor and takes on greater responsibility for construction quality, schedule, and costs. In either case, the A/E design team also contracts separately with the owner.

projects (Figure 1.9). In *turnkey* construction, an owner contracts with a single entity that provides not only design and construction services, but financing for the project as well. Or design and construction can be undertaken by a *single-purpose entity*, of which the owner, architect, and contractor are all joint members. Aspects of these and other project delivery methods can also be intermixed, allowing many possible organizational schemes for the delivery of design and construction services that are suitable to a variety of owner requirements and project circumstances.

Paying for Construction Services

With *fixed fee* or *lump sum* compensation, the contractor or other construction entity is paid a fixed dollar amount to complete the construction of a project regardless of that entity's actual costs. With this compensation method the owner begins construction with a known, fixed construction cost and assumes minimal risk for unanticipated increases in cost. On the other hand, the construction contractor assumes most of the risk of unforeseen costs but also stands to gain from potential savings. Fixed fee compensation is most suitable to projects where the scope of the construction work is well defined at the time that the construction fee is set, as is the case, for example, with conventional design/bid/build construction.

As an alternative, compensation may be set on a *cost plus a fee* basis, where the owner agrees to pay the construction entity for the actual costs of construction—whatever they may turn out to be—plus an additional fee. In this case, the construction contractor is shielded from most cost uncertainty, and it is the owner who assumes most of the risk of added costs and stands to gain the most from potential savings. Cost plus a fee compensation is most often used with projects where the scope of construction work is not fully known at the time that compensation is established, a circumstance most frequently associated with construction management or design/build contracts.

With fixed fee compensation, the builder assumes most of the risk related to unanticipated construction costs; with cost plus a fee compensation, the owner assumes most of this risk. Between these two extremes, many other fee-structuring arrangements can be used to allocate varying degrees of risk between the two parties.

Sequential versus Fast Track Construction

In *sequential construction* (Figure 1.10), each major phase in the design and construction of a building is completed before the next phase begins. Sequential construction can take place under any of the project delivery methods described previously. It is frequently associated with design/bid/build construction, where the separation of design and construction phases fits naturally with the contractual separation between design and construction service providers.

Phased construction, also called *fast track construction*, aims to reduce the time required to complete a project by overlapping the design and construction of various project parts (Figure 1.10). By allowing construction to start sooner and by overlapping the work of design and construction, phased construction can reduce the time required to complete a project. However, phased construction also introduces its own risks. Since construction on some parts of the project begins before all design is complete, an overall cost for the project cannot be established until a significant portion of construction is underway. Phased construction also introduces more complexity into the design process and increases the potential for costly design errors (for example, if foundation design does not adequately anticipate the requirements of the not yet fully engineered structure above). Phased construction can be applied to any construction delivery method discussed above. It is frequently associated with design/build and construction management project delivery methods, where the early participation of the construction entity provides resources that are helpful in managing the complex coordination of overlapping design and construction activities.

Construction Scheduling

Constructing a building of any significant size is a complex and costly endeavor, requiring the combined efforts of countless participants and the coordination of myriad tasks. Managing this process requires an in-depth understanding of the work required, of the ways in which different aspects of the work depend upon each other, and of the constraints on the sequence in which the work must be performed.

Figure 1.11 captures one moment in the erection of a tall building. The process is led by the construction of the building's central, stabilizing core structures (in the photograph, the pair of concrete towerlike structures extending above the highest floor levels). This work is followed by the construction of the surrounding floors, which rely, in part, on the previously completed cores for support. Attachment of the exterior skin can follow only after the floor plates are in place and structurally secure. And as the building skin is installed and floor areas become enclosed and protected from the weather, further operations, such as the roughing in of mechanical and electrical systems, and eventually, the installation of finishes and other elements, can proceed in turn. This simple example illustrates considerations that apply to virtually every aspect of building construction and at every scale from a building's largest systems to its smallest details: Successful construction requires a detailed understanding of the tasks required and their interdependencies.

The construction project schedule is used to analyze and represent construction tasks, their relationships, and the sequence in which they must be performed. Development of the schedule is a fundamental part of construction project planning, and regular updating of the schedule throughout the life of the project is essential to its successful management. In a *Gantt chart*, a series of horizontal bars represent the duration of various tasks or groups of tasks that make up the project. Gantt charts provide an easy-to-understand representation of construction tasks and their relationships in time. They can be used to provide an overall picture of a project schedule, with only a project's major phases represented (Figure 1.10), or they can be expanded to represent a larger number of more narrowly defined tasks at greater levels of project detail (Figure 1.12).

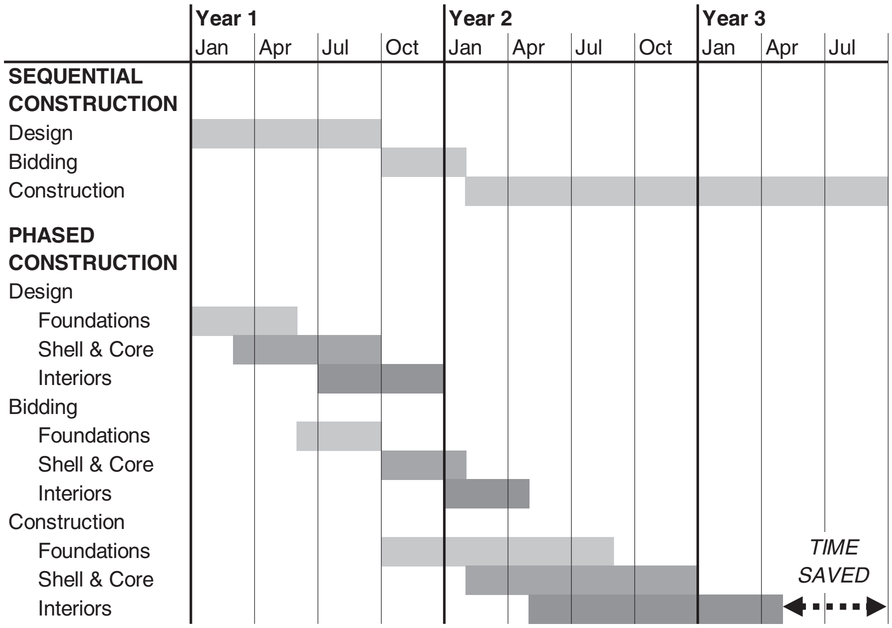


Figure 1.10
In sequential construction, construction does not begin until design is complete. In phased construction, design and construction activities overlap, with the goal of reducing the overall time required to complete a project.

The *critical path* of a project is the sequence of tasks that determines the least amount of time in which a project can be completed. For example, the construction of a building's primary structural system is commonly on the critical path of a project schedule. If any of the tasks on which the completion of this system depends—such as design, shop drawing production and review, component fabrication, materials delivery, or erection on site—are delayed, then the final completion date of the project will be extended. On the other hand, other systems not on the critical path have more flexibility in their scheduling, and delays (within limits) in their execution will not necessarily impact the overall project schedule.

The *critical path method* is a technique for analyzing collections of tasks and optimizing the project schedule to minimize the duration and cost of a project. This requires a detailed breakdown of the work involved in a project and the identification of dependencies between the parts (Figure 1.13). This information is combined with considerations of cost and resources available to perform the work, and then analyzed, usually with the assistance of computer software, to identify optimal scheduling scenarios. Once the critical path of a project has been established, the elements on this path are likely to receive a high degree of scrutiny during the life of the project, since delays in any of these steps will directly impact the overall project schedule.

Managing Construction

Once a construction project is underway, the general contractor or

Figure 1.11
In this photo, the construction sequence of a tall building is readily apparent: A pair of concrete core structures lead the construction, followed by concrete columns and floor plates and, finally, the enclosing curtain wall.

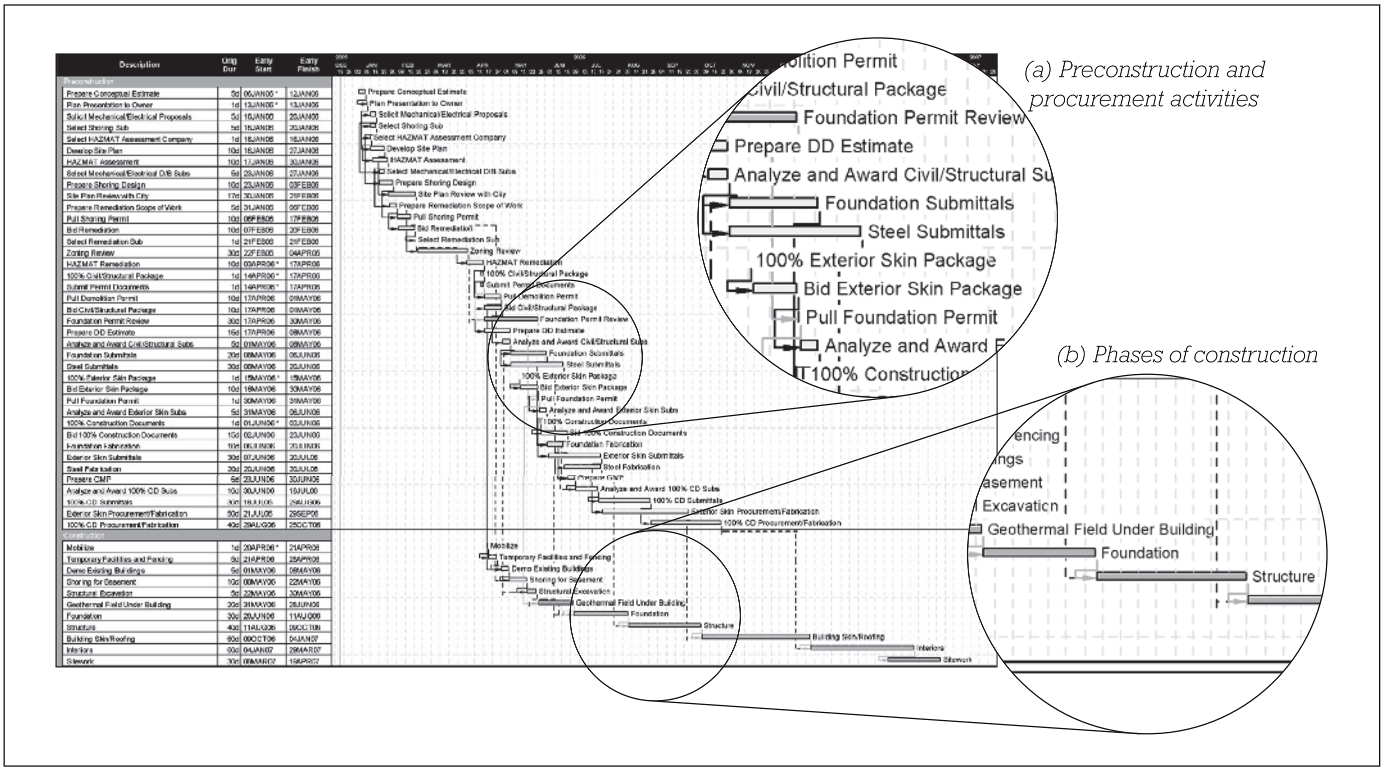


FIGURE 1.12
In a Gantt chart, varying levels of detail can be represented. In this example, roughly the top three-quarters of the chart is devoted to a breakdown of preconstruction and procurement activities such as bidding portions of the work to subtrades, preparing cost estimates, and making submittals to the architect (*a*). Construction activities, represented more broadly, appear in the bottom portion (*b*).

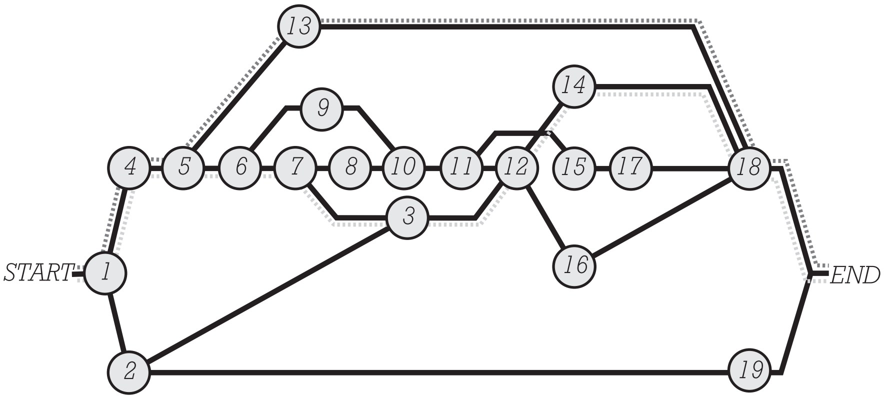


FIGURE 1.13
The critical path method depends on the detailed analysis of work tasks and their relationships to generate an optimal construction schedule. Shown here is a schematic network diagram representing task dependencies. For example, task 6 cannot begin until tasks 1, 4, and 5 are completed, and tasks 7 and 9 cannot begin until task 6 is finished. The dashed lines on the diagram trace two of many possible paths from the start to the end of the diagram. To determine the critical path for this collection of tasks, all such paths must be identified and the time required to complete each one calculated. The path requiring the most time to complete is the critical path, that is, the sequence of activities that determines the least time in which the collection of tasks as a whole can be completed.

construction manager assumes responsibility for day-to-day oversight of the construction site, management of trades and suppliers, and communications between the construction team and other major parties, such as the owner and the designer. On projects of any significant size, this may include responsibility for filing construction permits, securing the project site, providing temporary power and water, setting up office trailers and other support facilities, providing insurance coverage for the work in progress, managing personnel on site, maintaining a safe work environment, stockpiling materials, performing testing and quality control, providing site surveying and engineering, arranging for cranes and other construction machinery, providing temporary structures and weather protection, disposing or recycling of construction waste, soliciting the work of subtrades and coordinating their efforts, submitting product samples and technical information to the design team for review, maintaining accurate records of the construction as it proceeds, monitoring costs and schedules, managing changes to the work, protecting completed work, and more.

Trends in the Delivery of Design and Construction Services

Improving Collaboration Among Team Members

The design and construction industry continues to evolve, testing innovative organizational structures and project delivery methods in which designers, builders, and owners assume less adversarial and less compartmentalized roles. Such approaches share characteristics such as:

- Contractual relationships and working arrangements that foster collaboration between project members
- Participation of the construction contractor during the design phases of a project
- Overlapping of design and construction activities to reduce the "time to market"
- Expanded definitions of project services to encompass the full life cycle of a project—from its original conception, through planning, design and construction, to postconstruction occupancy—to better serve the needs of the building owner

The growth of design/build in the construction marketplace is one example of this trend: Between 1980 and 2005 the share of private, nonresidential construction work performed as design/build construction increased from roughly 5 percent of the total market to an estimated 30 to 40 percent. Alternatives to traditional design/bid/build project delivery have gained increased acceptance in the public construction sector as well. Other new practice models, with such names as *teaming*, *concurrent design*, *integrated practice*, or *alliancing*, combine efficient project delivery methods with innovations in team member relationships in a variety of ways, with the aim of aligning all parties' efforts with the shared goal of a finished product of the highest possible quality and value to the owner.

Improving Efficiency in Production

Other efforts within the construction industry focus on improvements in the efficiency of construction methods themselves. Unlike factory production, much building construction takes place outdoors, is performed within constrained and often physically challenging work areas, and is executed by a highly fragmented workforce. Despite the differences in these production environments, the construction industry is looking to lessons learned in factory production for approaches to improving the quality and efficiency of its own processes. Such so-called *lean construction* methods attempt to:

- Eliminate wasteful activities
- Structure the methods of production and the supply chain of materials and products to achieve the quickest and most reliable workflow
- Decentralize information and decision making so as to put control of construction processes into the hands of those most familiar with the work and most capable of improving it

Current estimates of labor inefficiency in building construction run as high as 35 to 40 percent, and estimates of materials wastage are 20 percent or more. The challenge of lean construction is to restructure the way in which construction materials and building components are manufactured, delivered, and assembled so as to reduce these inefficiencies and improve the quality of the delivered product.

Improving Information Management

Developments in information technology also are influencing the way buildings are designed and constructed. Most notable is *building information modeling (BIM)*, the computerized, three-dimensional modeling of building systems. Unlike the two-dimensional representation of building systems characteristic of conventional *computer-aided design (CAD)*, BIM involves an intelligent model. Components are not only represented geometrically, but are also linked to data describing their intrinsic properties and their relationships to other components. Originally developed for use in highly capital-intensive industries such as aerospace and automobile manufacturing, this modeling technology is now finding increased application in the design and construction of buildings.

BIM has the potential to impact many aspects of the building life cycle. It can aid the design team with the visualization and realization of complex geometries. It can improve coordination between design disciplines—for example, searching out "collisions" between mechanical system ductwork and structural framing or other such physical interferences between systems—and it can facilitate the modeling of building energy use and the performance of other building systems. For the builder, BIM can be used to improve coordination of trades, to drive the automated fabrication or preassembly of building components, and to integrate cost and schedule data more closely with building design. For the building owner, information accumulated in the model during design and construction can be carried forward for use with postconstruction building operations and facilities planning.

As the implementation of BIM matures, it is expected to have a profound impact as a communication tool used to improve the coordination and sharing of information among all of the parties to a project. As the integrated building model is shared across the traditional boundaries of disciplines and project phases, the boundaries of responsibility between the designers, constructors, and owners will also blur, and new, more integrated relationships between these parties will likely be required to fully enable the potential of this technology.

Recurring Concerns

Certain themes are woven throughout this book and surface again and again in different, often widely varying contexts. These represent a set of concerns that fall into two broad categories: building performance and building construction.

The performance concerns relate to the inescapable problems that must be confronted in every building: fire; building movement of every kind, including foundation settlement, structural deflections, and expansion and contraction due to changes in temperature and humidity; the flow of heat and air through building assemblies; water vapor migration and condensation; water leakage; acoustical performance; aging and deterioration of materials; cleanliness; building maintenance; and others.

The construction concerns are associated with the practical problems of getting a building built safely, on time, within budget, and to the required standard of quality: division of work between the shop and the building site; optimum use of the various building trades; sequencing of construction operations for maximum productivity; convenient and safe worker access to construction operations; dealing with inclement weather; making building components fit together; and quality assurance in construction materials and components through grading, testing, and inspection.

To the novice, these matters may seem of minor consequence when compared to the larger and often more interesting themes of building form and function. To the experienced building professional, who has seen buildings fail both aesthetically and physically for want of attention to one or more of these concerns, they are issues that must be resolved as a matter of course before the work of a building project can be allowed to proceed.

CSI/CSC

MasterFormat Sections for Procurement of Construction and General Project Requirements

00 10 00	SOLICITATION
00 11 00	Advertisements and Invitations
00 30 00	AVAILABLE INFORMATION
00 40 00	PROCUREMENT FORMS AND SUPPLEMENTS
00 41 00	Bid Forms
00 50 00	CONTRACTING FORMS AND SUPPLEMENTS
00 52 00	Agreement Forms
00 70 00	CONDITIONS OF THE CONTRACT
01 10 00	SUMMARY
01 11 00	Summary of Work
01 30 00	ADMINISTRATIVE REQUIREMENTS
01 31 00	Project Management and Coordination
01 32 00	Construction Progress Documentation Construction Progress Schedule
01 40 00	QUALITY REQUIREMENTS
01 41 00	Regulatory Requirements
01 50 00	TEMPORARY FACILITIES AND CONTROLS
01 70 00	EXECUTION AND CLOSEOUT REQUIREMENTS
01 80 00	PERFORMANCE REQUIREMENTS
01 81 00	Facility Performance Requirements Sustainable Design Requirements

Selected References

1. Allen, Edward. *How Buildings Work* (3rd ed.). New York, Oxford University Press, 2005.

What do buildings do, and how do they do it? This book sets forth in easily understandable terms the physical principles by which buildings stand up, enclose a piece of the world, and modify it for human use.

2. U.S. Green Building Council. New Construction & Major Renovation, Version 2.2, Reference Guide. Washington, DC, 2006.

This guide is an essential reference for building designers wishing to comply with the Green Building Council's LEED for New Construction rating system. As the standard continues to be revised, look for updated versions.

3. Williams, Daniel E. *Sustainable Design: Ecology, Architecture, and Planning*. Hoboken, NJ, John Wiley & Sons, Inc., 2007.

This book provides a comprehensive treatment of the ecological, social, and economic basis for sustainable design in architecture.

4. ASTM International. *ASTM Standards in Building Codes*. Philadelphia, updated regularly.

This volume contains most of the ASTM standards referenced in standard building construction practice.

5. The Construction Specifications Institute and Construction Specifications Canada. *MasterFormat™ 2004 Edition*. Alexandria, VA, and Toronto, 2004.

This handbook lists the full set of MasterFormat numbers and titles under which construction information is most commonly organized.

6. International Code Council, Inc. *International Building Code®*. Falls Church, VA, updated regularly.

This is the predominant U.S. model building code, used as the basis for the majority of U.S. state, county, and municipal building codes.

7. Canadian Commission on Building and Fires Codes. *National Building Code of Canada*. Ottawa, National Research Council of Canada, updated regularly.

This is the model building code used as the basis for most Canadian provincial and municipal building codes.

8. Allen, Edward, and Joseph Iano. *The Architect's Studio Companion* (4th ed.). Hoboken, NJ, John Wiley & Sons, Inc., 2007.

This designer's reference tabulates building code requirements, simplifying determination of the allowable heights and areas for any building under the IBC or the Canadian Building Code. It explains clearly what each construction type means, relating it to actual construction materials and structural systems, and it gives extensive rules of thumb for structural systems, mechanical systems, and egress planning.

9. Halpin, Daniel W. *Construction Management* (3rd ed.). Hoboken, NJ, John Wiley & Sons, Inc., 2005.

This book covers the full range of contemporary construction management topics.

10. Elvin, George. *Integrated Practice in Architecture*. Hoboken, NJ, John Wiley & Sons, Inc., 2007.

How is the design industry responding to the evolution of design practice models and building delivery methods? This book provides case studies and insights into these recent trends.

11. Allen, Edward and Patrick Rand. *Architectural Detailing* (2nd ed). Hoboken, NJ, John Wiley & Sons, Inc., 2007.

How are the many functional, constructional, and aesthetic requirements of building resolved in the detailing of building systems? This book presents a systematic treatment of the principles and practice of design and the detailing of building assemblies.

Web Sites

Making Buildings

Author's supplementary web site: **www.ianosbackfill.com/01_making_buildings**

Whole Building Design Guide: **www.wbdg.org**

Sustainability

AIA Sustainability Resource Center: **http://www.aia.org/susn_rc_default**

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Engineering for Sustainability: **www.engineeringforsustainability.org**

Architects/Designers/Planners for Social Responsibility: **www.adpsr.org**
Canada Green Building Council: **www.cagbc.org**
Climate Change, Global Warming, and the Built Environment—Architecture 2030: **www.architecture2030.org**
Green Building Initiative (GBI): **www.thegbi.com**
Green Globes: **www.greenglobes.com**
NAHB, Green Home Building Guidelines: **www.nahbrc.org/greenguidelines**
NAHB Research Center, National Green Building Standard: **www.nahbgreen.org**
National Renewable Energy Laboratory (NREL), Buildings Research: **www.nrel.gov/buildings**
Sustainable Buildings Industry Council (SBIC): **www.sbicouncil.org**
U.S. Environmental Protection Agency Energy Star Program: **www.energystar.org**
U.S. Green Building Council (USBGC): **www.usgbc.org**

The Work of the Design Professional: Choosing Building Systems

American Institute of Architects (AIA): **www.aia.org**
American Planning Association (APA): **www.planning.org**
Canadian Codes Centre: **irc.nrc-cnrc.gc.ca/codes**
International Code Council (ICC): **www.iccsafe.org**
U.S. Department of Justice, Americans with Disabilities Act (ADA): **www.ada.gov**

Construction Standards and Information Resources

American National Standards Institute (ANSI): **www.ansi.org**
ASTM International: **www.astm.org**
Canadian Standards Association (CSA): **www.csa.ca**
Construction Specifications Canada (CSC): **www.csc-dcc.ca**
Construction Specifications Institute (CSI): **www.csinet.org**
National Institute of Building Sciences (NIBS): **www.nibs.org**
National Research Council Canada, Institute for Research in Construction (NRC-IRC): **irc.nrc-cnrc.gc.ca**
Underwriters Laboratories, Inc. (UL): **www.ul.com**
U.S. Department of Commerce, National Institute of Standards and Technology (NIST): **www.nist.gov**
U.S. Department of Energy, Building Energy Codes: **www.energycodes.gov**

The Work of the Construction Professional: Constructing Buildings

Associated General Contractors of America (AGC): **www.agc.org**
Building Owners and Managers Association (BOMA): **www.boma.org**
Construction Management Association of America (CMAA): **cmaanet.org**
The Construction Users Roundtable (CURT): **www.curt.org**
Design-Build Institute of America (DBIA): **www.dbia.org**

Key Terms

sustainability
green building
cradle-to-grave
embodied energy
LEED
LEED credit
Green Globes
Green Home Building Guidelines
National Green Building Standard
Advanced Energy Design Guides
Energy Star program
net zero energy
carbon-neutral
carbon offsetting
zoning ordinance
building code
model building code
National Building Code of Canada
International Building Code (IBC)
occupancy group
construction type
fire resistance rating
bearing wall
nonbearing wall, partition
Heavy Timber construction
trade association
International Residential Code (IRC)
Americans with Disabilities Act (ADA)
Fair Housing Act
access standard
Occupational Health and Safety Administrations (OSHA)
volatile organic compound (VOC)
ASTM International
American National Standards Institute (ANSI)
National Institute of Science and Technology (NIST)
Institute for Research in Construction (NRC-IRC)
trade association
Construction Specifications Institute (CSI)
Construction Specifications Canada (CSC)
MasterFormat
specification division
specification section
Uniformat
OmmiClass
design/bid/build
construction document
general contractor
subcontractor
design/build
construction manager
turnkey
single-purpose entity
fixed fee compensation, lump sum compensation
cost plus a fee compensation
sequential construction
phased construction, fast track construction
Gantt chart
critical path
critical path method
teaming
concurrent design
integrated practice
alliancing
lean construction
building information modeling (BIM)
computer-aided design (CAD)

Review Questions

1. Who are the members of the typical team that designs a major building? What are their respective roles?

2. What are the major constraints under which the designers of a building must work?

3. What types of subjects are covered by zoning ordinances? By building codes?

4. In what units is fire resistance measured? How is the fire resistance of a building assembly determined?

5. Compare and contrast design/bid/build and design/build construction. What is the difference between a construction manager and a general contractor? What is the difference between lump sum and cost plus a fee compensation? What is fast track construction, and what types of contracts and fee compensation is it mostly commonly associated with?

6. If you are designing a five-story office building (Occupancy Group B) with 35,000 square feet per floor, what types of construction will you be permitted to use under the IBC if you do not install sprinklers? How does the situation change if you install sprinklers? In each case, what level of fire protection is required for the structural frame of the building?

Exercises

1. Have each class member write to two or three trade associations at the beginning of the term to request their lists of publications, and then have each send for some of the publications. Display and discuss the publications.

2. Repeat the above exercise for manufacturers' catalogs of building materials and components.

3. Obtain copies of your local zoning ordinance and building code (they may be in your library). Look up the applicable provisions of these documents for a specific site and building. What setbacks are required? How large a building is permitted? What construction types may be employed? What types of roofing materials are permitted? What are the restrictions on interior finish materials? Outline in complete detail the requirements for emergency egress from the building.

4. Arrange permission to "shadow" an architect or CM during visits to a construction site or during project meetings related to a construction project. Take notes. Interview the architect or CM about their role and the challenges they have encountered. Report back to the class what you have learned