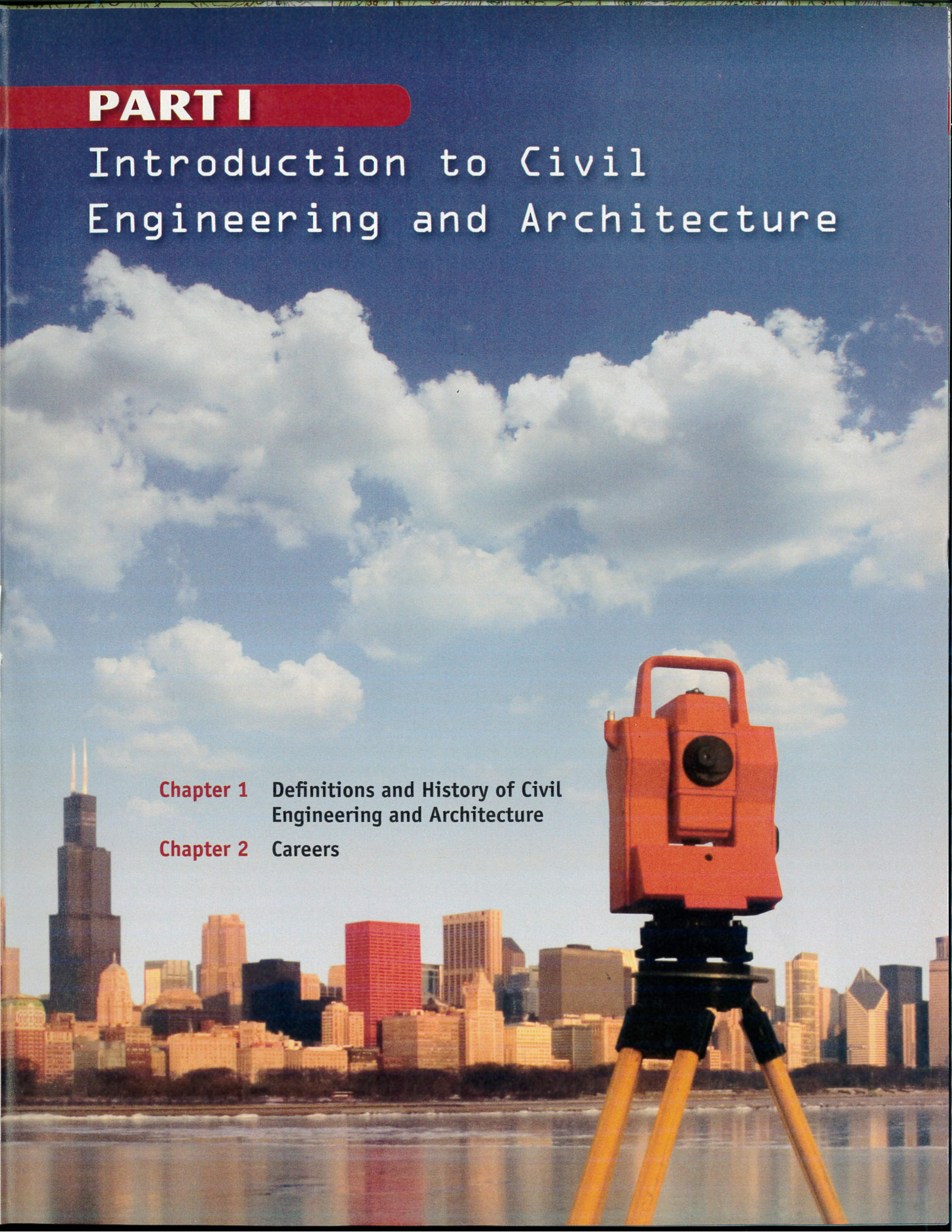
PART I
Introduction to Civil Engineering and Architecture



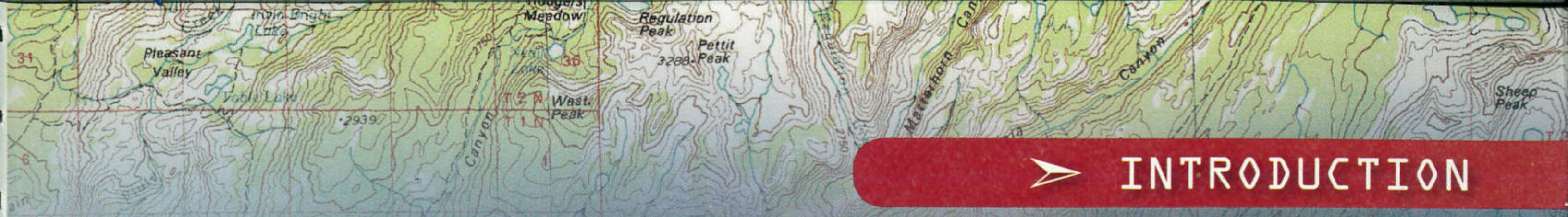
CHAPTER 1

Definitions and History of Civil Engineering and Architecture

Before You Begin

Think about these questions as you study the concepts in this chapter:

1. What are the differences and similarities between Civil Engineering and Architecture?
2. What were the earliest human-made structures? What structural systems were used?
3. How is a building's age determined?
4. How does a building maintain its architectural integrity when the building process extends past the lifetime of the architect?
5. Who were some of the distinguished architects and civil engineers in history and what were their accomplishments?
6. How did architecture and engineering achievements increase land use and urban development?
7. How did innovations in building materials contribute to the evolution of civil engineering and architecture?



INTRODUCTION

Our human-made world is filled with examples of civil engineering and architecture. Just look out any window and you will see that civil engineering and architecture surround us. We travel roads, bridges, and rails to reach our home, school, and workplace. These structures represent the work of civil engineers and architects.

As you read this chapter, you will develop a better understanding of what civil engineers and architects do through study of their work. You will learn how to define the difference between civil engineering and architecture, as you read how these disciplines have contributed, separately and together, to our **built environment** (see Figure 1-1).

Built Environment: the human-made surroundings created to accommodate human activity, ranging from personal residences to large, urban developments.

As we examine a few examples of civil engineering and architecture in today's world, we will take an imaginary trip back in time to explore the history of civil engineering and architecture. Our journey will start in prehistoric times and make several stops on the way back to the present day. During this journey, you will read the stories behind history's most famous architects and civil engineers and their successful works.

Historical architecture provides clues about people, culture, environment, and concerns of the time. Just as architects and civil engineers have shaped our built environment, so has the natural environment shaped the course of architecture and civil engineering. As this chapter guides you on an imaginary journey through time, you'll learn how environmental and societal factors influenced the development of civil engineering and architecture. In turn, you'll discover how the achievements of architects and civil engineers throughout history have led to increased land use and urban development in today's built environment. Just look out any window.

Figure 1-1: *Miami skyline.*

DEFINING CIVIL ENGINEERING AND ARCHITECTURE

Before we begin our journey into the past, we need a clear understanding of the basic differences and similarities between the fields of civil engineering and architecture. Let's first take a look at civil engineering.

What Is Civil Engineering?

Civil engineering has a long history. The first engineer generally accepted by name and achievement is Imhotep, who lived from 2650 to 2600 BC. Imhotep is credited with overseeing the building of the Step Pyramid at Saqqarah in Egypt between 2630 and 2611 BC. We will make a stop during our journey to look at this structure.

The term *civil engineering* was first used in the eighteenth century to distinguish the newly recognized profession from military engineering. Civil engineering gained recognition as a discipline when the Institution of Civil Engineers was founded in London in 1818. This is how the Institution defined civil engineering in its original charter:

> ...the art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange, and in the construction of ports, harbors, moles, breakwaters and lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and application of machinery, and in the drainage of cities and towns.
>
> —*Reprinted from the Institution of Civil Engineers' original charter, 1828*

Point of Interest

The First Civil Engineer

Although the first engineers were military engineers making items for war such as catapults, rams, fortresses, and towers, civil engineering is the oldest of all other engineering disciplines. The first person actually to call himself a civil engineer was John Smeaton. Smeaton designed the first lighthouse to be located in the open sea. The lighthouse, called Eddystone, perched on a group of rocks 14 miles from the Southwest shore of England (see Figure 1-2). To build this structure, Smeaton created a form of cement that would harden in water.

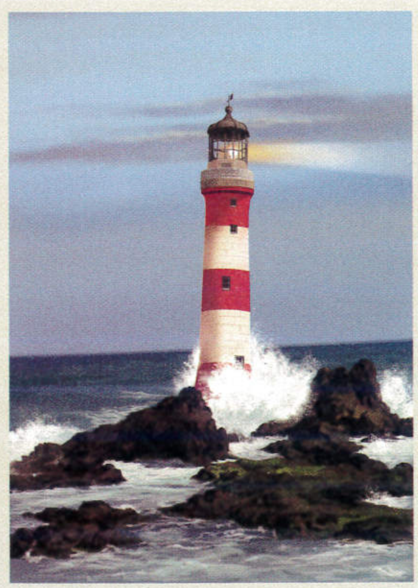


Figure 1-2: The famous Eddystone lighthouse was made to withstand the pounding of waves on the reef using "hydraulic" cement and dovetailed stone blocks.

The American Society of Civil Engineers updated and expanded this definition in the twentieth century to describe how engineers apply their knowledge of math and science to meet human wants and needs:

> Civil Engineering is the profession in which a knowledge of the mathematical and physical sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well-being of humanity in creating, improving, and protecting the environment, in providing facilities for community living, industry and transportation, and in providing structures for the use of humanity.
>
> —*American Society of Civil Engineers, 1961*

Civil Engineering: the profession of designing and providing specifications for structural works that serve the general public, such as roads, bridges, water systems, and public buildings.

Today, we define **civil engineering** as the profession of designing and executing structural works that serve the general public. These structural works include bridges, canals, dams, roads, tunnels, harbors, water systems, and water treatment facilities (see Figure 1-3). Keep in mind that when researching the term *civil engineering,* you might find a variety of definitions.

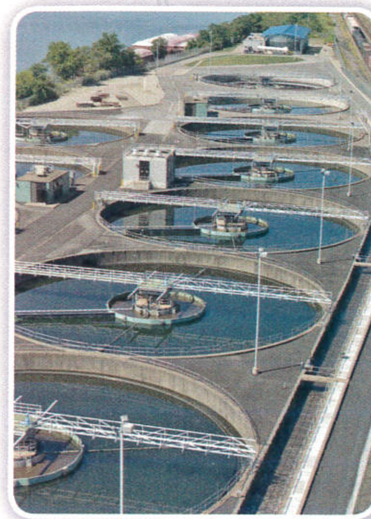


Figure 1-3: Wastewater treatment facility.

Image copyright Wade H. Massey, 2008. Used under license from Shutterstock.com.

What Does a Civil Engineer Do?

Many people think of civil engineering as the design of bridges, but civil engineers provide structural design for a much wider variety of building projects. Today's civil engineers create structural designs for harbors, factories, power plants, transportation facilities, public meeting spaces, water treatment facilities, residential and commercial buildings, and others (see Figure 1-4). There are seven major interrelated branches of civil engineering:

BRANCHES OF CIVIL ENGINEERING

- Construction engineering
- Environmental engineering
- Geotechnical engineering
- Structural engineering
- Transportation engineering
- Urban and community planning
- Water resources engineering

Each branch of civil engineering requires specialized career training. You will read more about preparing for a career in civil engineering in Chapter 2.

Figure 1-4: Civil engineers design complex transportation systems, such as the New York City subway.

© iStock.com/Claudio Divizia.

Identifying Types of Structures

Civil engineers design structures to be safe, reliable, and resilient (see Figure 1-5). Their structures must withstand the vertical force of gravity and lateral (side) forces such as wind and earthquakes. Civil engineers ensure the safety and reliability of their structures by analyzing the bending, compression, and tension capacity of each building member.

As an example, consider the most basic structure of all: a simple wall. Structures built with walls include early stone and brick buildings, log cabins, concrete block, and preformed panels. By itself, a wall may not be very strong.

Figure 1-5: Bridges are designed to provide safe, reliable, and convenient means to cross water. The Brooklyn Bridge, NYC.

© iStockphoto.com/Bill Grove.

You may have noticed that the dug-out area around a new masonry block foundation wall is not backfilled with dirt until the house has been framed, or at the very least, a floor system has been added to the top of the foundation. Without vertical compression or connecting horizontal members, the wall cannot withstand the lateral or side loads from the backfill dirt.

Retaining walls are another structure that must resist the lateral movement of earth (see Figure 1-6). They are built to achieve an extreme change in grade and must withstand additional loads from stormwater.

Figure 1-6: The retaining wall in the foreground of this photo must withstand pressure from the lateral movement of the earth behind it and stormwater runoff.

© iStockphoto.com/Frances Twitty.

Point of Interest

You may have seen a retaining wall that has failed or was about to fail. The Seattle.gov website provides a document highlighting an investigation conducted by the Seattle Public Utilities of a retaining wall that failed in December 2006 during a severe rainstorm. Visual inspection indicated that the concrete failed by torsion or twisting force. The final determination was that the failure was caused by increased water pressure from the rainstorm.

http://www.**seattle**.gov/util/stellent/groups/public/@spu/@esb/documents/webcontent/spu01_002567.pdf

Engineers have identified five basic structural systems based on geometric configurations (see Table 1-1). The reliability of each system can be analyzed by applying loads to its members. Using that information, civil engineers can identify advantages and disadvantages of each structural system, and select the best match for a given project. You will learn more about structural systems in Chapter 14. For the purpose of this chapter, you will identify the structural classification of several historical structures.

Your Turn

The PBS Building Big webpage provides several civil engineering activities.

Access the Public Broadcasting Service website at http://www.pbs.org/wgbh/buildingbig/ to learn about bridges, domes, skyscrapers, dams, and tunnels. Read about engineering wonders of the world and engineers and architects that "build big." Have some fun trying to solve the engineering challenges offered under each category.

You might want to copy the five classifications in your notebook and record the page number for future reference. As you study these classifications, you will begin to see them everywhere!

Table 1-1: Structural Systems

Category	Recognized by	Example	Illustration
Column and beam (post and lintel)	Distance between vertical members (columns/post) is determined by the spanning capacity of horizontal members (beam/lintel)	Post and beam construction	 Column-and-beam construction © iStock.com/laughingmango
Corbel (pronounced *core-bull*)	Corbelling: objects laid in horizontal courses, each projecting slightly beyond the one below	Pyramids	 Corbelled chimney © Cengage Learning 2012
Cantilever (pronounced *can't-ta-leave-r*)	Cantilevered: beams extend beyond their supports to form an overhang	Frank Lloyd Wright's Fallingwater	 Cantilevered roof © iStock.com/Timothy Large
Arch and vault	Wedge-shaped members placed so that they press against each other to become self-supporting. A keystone is located at the top of the arch.	Arch	 Archway © Cengage Learning 2012

(Continued)

Table 1-1: Structural Systems (Continued)

Category	Recognized by	Example	Illustration
Truss and space frame (pronounced *turr-us*)	Short members connected in triangular configurations	Railway bridge	 Railway bridge © iStockphoto/MegapixelMedia
Tensile (pronounced *ten-sul*)	Use of suspended cables to support load	Suspension bridge	 Suspension bridge © iStockphoto.com/Bill Grove

Your Turn

Take a minute to reread the definitions of civil engineering. Make entries in your notebook as to how the profession has evolved over time and the possible contributing factors. What global and human factors impact civil engineering today? Read your local newspaper or listen to a news station to find a local project related to civil engineering. Follow the project's progress and add articles and notes to your notebook. Determine why the project is being done. How will the completed project enhance the community? As you follow the progress of the project, list any problems that occur and how they are addressed. Determine when the project is expected to finish. How will the community be affected during the construction? For example, if a bridge were being replaced due to concerns of structural fatigue, where would the old bridge go? How would construction noise and dust affect the community? Would there be an increase in traffic congestion or accidents? Would traffic detours cause delays? And finally, what new material, design, or process will be used to enhance structure longevity and prevent a future failure? Throughout the review of your local project, continue to make entries in your notebook. When the project is complete determine if the project was finished on time and within budget. Make notes of things you would have done differently if you were "in charge."

What Is Architecture?

Architecture: responsible and purposeful design of functional, sustainable, and aesthetically pleasing buildings.

Unlike civil engineering, architecture is not clearly defined. If you ask a dozen architects to define architecture, you might get a dozen different answers. One might say that architecture exists where form and function come together; another might say that architecture achieves maximum comfort through minimal form; yet another might describe architecture as the form that emerges when we create harmony with the environment. For the purposes of this text, we will define **architecture** as the art and technique of building design through purposeful application of elements and principles of design. The visual elements of design are line, color, form, space, shape, texture, value, and tone. The principles of design are balance, contrast, emphasis, movement, pattern/repetition/rhythm, and unity/harmony. You will read more about the principles and elements of design and how architects apply them in Chapter 4.

Most architecture can be described by spatial relationships and purposeful combination of geometrical shapes. Prisms, pyramids, cones, cylinders, and other geometrical objects have attributes of size and proportion (see Figure 1-7). Their relationship as they touch, intersect, and combine is what creates a building's unique architectural form (see Figure 1-8).

Figure 1-7: An assortment of three-dimensional geometric shapes.

Beyond Form and Function

Architecture is not limited to a building's form and function. In addition to a visually pleasing and serviceable design, the building's architecture must *fit* within the surroundings. Recent architecture shows thoughtful consideration for the occupant's health, owner operation and maintenance cost, building longevity, future expansion, change of use, and the current and future impact on the environment. These factors are considerations of sustainable architecture. Sustainable architecture is achieved by addressing the impact of environmental, economical, and ethical factors. You will read more about green and sustainable architecture and building resiliency in future chapters.

Figure 1-8: How many geometric shapes do you recognize in Richard Meier's High Museum of Art in Atlanta, Georgia?

Point of Interest

An Architect's Definition

My area of study is architecture and its cultural manifestations, and such a quest for historical knowledge, especially of the arts, arises from my own need for a deeper understanding of the essence of architecture. Too frequently, the merely historical understanding of architecture is considered the complete and authentic understanding: whereas the sense of spiritual activity expressed in architectonic forms should be related to speculative interest in the nature of architectural forms more directly than to a historical interest in forms already realized, already claimed by the past. The one affords us the promise of architecture; the other, too often, ends in historicist ideology.

Richard Meier. *Richard Meier, Architect: Buildings and Projects, 1966–1976.* (New York, NY: Oxford University Press, 1976.)

THE HISTORY OF CIVIL ENGINEERING AND ARCHITECTURE: A JOURNEY THROUGH TIME

What were the earliest human-made structures? What types of structural systems were used? Let us begin our journey back in time to find out. Many of you have watched science-fiction movies or read stories of time travel where people are transported back in time through a portal or use of a time-travel device. Imagine that you found such a device similar to a Global Positioning System (GPS), which receives information from satellites to provide navigation. In addition to maps and directions, your time-travel device has a menu option for dates in time (see Figure 1-9).

Humans made dwellings by draping animal hides over bones and stakes.

15,000–10,000 BC

Architecture evolved from the stone-age need to provide shelter toward the societal need to provide security and gathering spaces. **Stonehenge** was built near Salisbury, England, over a period of about a thousand years. Its purpose and means of construction remain a mystery.

3000 BC

Stone Age or Paleolithic | **Mesolithic Age** | **Neolithic Age** | **Early Bronze Age**

300,000 BC

Dwellings found in Nice, France, were made from stakes pushed into the sand and supported by a ring of stones.

8000 BC

The settlement of **Jericho** in the Jordan Valley consisted of circular shaped mud huts surrounded by a wall up to 27 feet thick enclosing almost 10 acres.

Building in Prehistoric Times: 300,000 BC

As you study civil engineering and architecture, you might wonder about the early buildings in history. What were the first human dwellings? What did they look like? What materials were used for construction? Armed with a notebook and pen, you decide to take your first trip back in time. You have always been interested in the prehistoric era, so you enter 300,000 BC, which is in the Paleolithic period. You are quickly transported to a sandy beach in Nice, a city on the Mediterranean coast of southern France. Oval huts ranging in length from 26 to 49 feet, and in width from 13 to 19 feet are built along the shore. These are the earliest known buildings on architectural record. **Thermoluminescence** dating of the hut floors indicate that they were built approximately 380,000 years ago! You explore further to discover central hearths and walls constructed with 3-inch diameter stakes set in sand and braced on the outside by a ring of stones.

Figure 1-9: Imagine discovering a device that would allow you to travel back in time.

During the Paleolithic and Mesolithic periods of the Stone Age, people were mobile. Mammoth bone huts were believed to exist in 20,000 BC in the Ukraine. The foundation was created of mammoth jaws and large bones, and the roof was constructed with tree branches and tusks.

After entering 15,000–10,000 BC into your time-travel device, you discover animal hide tents in France and in the severe climates of Russia and Switzerland pit houses, which were dug into the ground. These ancient pit houses might have been inspiration for today's earth bermed structures built partially underground for energy efficiency.

OFF-SITE EXPLORATION

Find out more about thermoluminescence and other dating technology from the Minnesota State University, Mankato, at *http://www.mnsu.edu/emuseum/archaeology/dating/*.

The straight-sided Great **Pyramid at Giza** originally covered more than 13 acres and stood 481 feet tall. Scholars continue to speculate on how it was built.

2720–2560 BC

The Great Wall of China, stretching for more than 4,000 miles, was built to protect the borders of the Chinese Empire.

250 BC–AD 1500

The Nîmes aqueduct in France stretches about 30 miles from Uzès to Nîmes and includes the **Pont du Gard** bridge.

AD 36–50

Hellenistic Period | **Roman Period**

2750 BC

The builder **Imhotep** constructed the step pyramid of King Djoser in **Ancient Egypt.** Many scholars consider Imhotep to be the first engineer and architect in history to be known by name.

448–432 BC

Greek architecture displays classical design principles of symmetry and balance.

Point of Interest

Thermoluminescence Dating

Thermoluminescence dating, which is used on rocks, minerals, and pottery that existed between the years 300–10,000 BC, is based on the fact that almost all natural minerals are thermoluminescent. Energy absorbed from ionizing radiation frees electrons to move through the crystal lattice, and some are trapped at imperfections. Later heating releases the trapped electrons, producing light. Measurement of the intensity of the luminescence can be used to determine how much time has passed since the last time the object was heated. The light is proportional to the amount of radiation absorbed since the material was last heated. Natural radioactivity causes latent thermoluminescence to build up so the older an object is the more light is produced. Because thermoluminescence technology is still in a developmental stage, it is not considered accurate enough for archaeological standards.

Human populations use environmental resources in order to maintain and improve their existence.

After recording these findings in your notebook, you are off to Jericho in the Jordan Valley, around 8000 BC. The settlement of Jericho consisted of circular shaped mud huts, surrounded by a wall up to 27 feet thick enclosing almost 10 acres (see Figure 1-10). You are surprised to find a circular stone tower at the center of town. It is believed that Jericho reached a population of 2000 by 7000 BC.

Gothic architecture employs a skeletal system featuring arches, rib vaults, and flying buttresses

AD 1140–1520

Renaissance architecture valued formality and classical elements like pediments and circular forms.

AD 1400–1600

Roman Period | Medieval Period

27 BC–AD 25

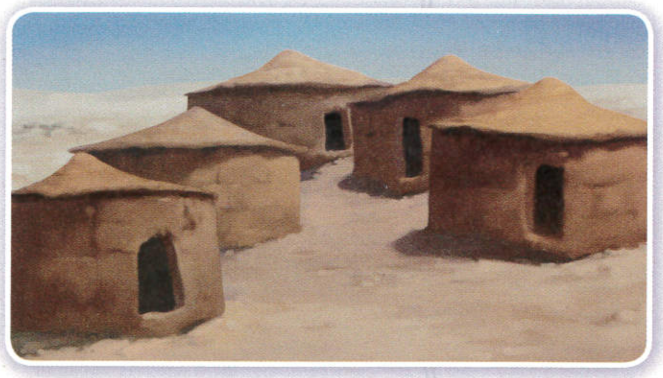
The **Pantheon** displays **Romanesque** style, using a continuous wall to sustain the load

AD 1485–1547

Tudor architecture returned to a plainer, symmetrical style that emphasized horizontal elements; designed to provide luxurious interior comfort.

Before you leave the Stone Age, you make a quick stop at one of the oldest known Neolithic settlements in Europe, around 6220 BC. This settlement featured early timber frame houses approximately 25 feet by 25 feet in size. These mud-walled structures were built by inserting oak saplings into deep footings of mud. You may remember from history class that farming most likely led to the establishment of early urban societies. The agricultural surplus of these areas provided opportunity for some residents to take on roles unrelated to food, such as a religious leader, craftsperson, merchant, or builder.

Figure 1-10: Circular houses built in ancient Jericho with corbelled mud bricks might have looked similar to these structures.



© Cengage Learning 2012

You decide to make a note in your notebook that early hunters and gatherers needed temporary movable shelters, whereas early farmers required more permanent dwellings. Referring back to your structural systems chart, think about which systems may have been applied during the Stone Age. Tents may have employed a tensile system, whereas some of the early huts used a post-and-lintel framework system.

Early structures were not limited to living spaces. As you continue your time travel, you will discover tombs of stacked stone slabs across Europe and Asia. Architecture evolved from addressing the basic needs of shelter, security, or worship. Construction techniques were influenced by whatever materials were readily available.

Building in the Ancient World: 3200 BC to AD 337

Continue on your journey to what many consider the most famous and mysterious relic of prehistory in Europe: Stonehenge (see Figure 1-11). The cover story of the June 2008 *National Geographic* magazine was devoted to the "Secrets of Stonehenge."

Although the purpose of Stonehenge still remains a mystery, there are many theories. Cremation remains have led some to believe it was used as a cemetery. Others believe the stones were purposefully aligned with solar and lunar phenomena to create a temple or astronomical calendar. Whatever the purpose, the magnitude of this project has earned admiration from generations of scholars, tourists, and history buffs alike.

Stonehenge could date back as far as 3000 BC. Circular pits lining the inner edge of the circular ditch and bank of Stonehenge may indicate original wooden pole construction. As the construction of Stonehenge continued through several phases, extending over a period of a thousand years, it is likely that many changes and adaptations occurred during that time. The early bluestones weighing approximately four tons probably appeared around 2500 BC. The stones are thought to have been brought in from Wales, 250 miles away.

Many still wonder about the purpose of Stonehenge and its specific design and layout—a circle of stones 100 feet in diameter that towers approximately 16 feet above ground. The huge stones were shaped and placed in a very precise pattern. How were such large stones raised and placed into position? This very question still intrigues researchers. Some have surmised that construction methods employed a simple machine such as a lever and inclined plane, a sledge and greased track, wooden

Figure 1-11: Stonehenge, located near Salisbury, England.

© iStockphoto.com/Reggie Sanejo.

Figure 1-12: A Stonehenge tenon is seen at the top of the tallest stone. Mortise or openings in the horizontal members were aligned with the vertical tenon, creating the interlocking construction.

© iStockphoto.com/James Robinson.

scaffolds, ropes, and the combined efforts of more than 100 people. We can see that the massive lintels, or horizontal members, are secured to their uprights by mortise-and-tenon joints (see Figure 1-12). This type of joinery is still used in woodworking and construction today (see Figure 1-13). Stonehenge's mortise-and-tenon interlocking construction has enabled this dry stone structure to withstand the elements for almost four thousand years.

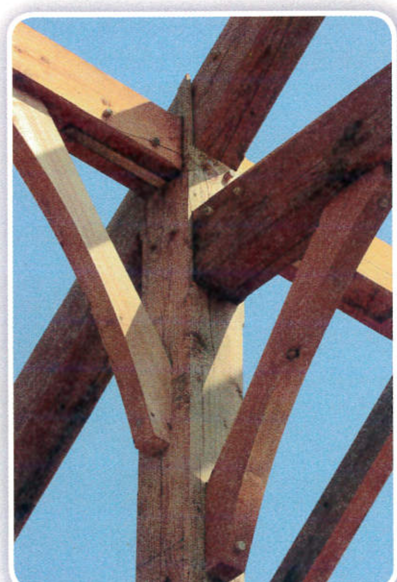
Were these builders some of our first civil engineers? Looking back to your structural systems chart, which systems do you think were applied to the building of Stonehenge?

RECENT DISCOVERIES AND INVESTIGATIONS Recently, an investigation of Stonehenge has led researchers to a nearby Neolithic village at Durrington Walls, dating between 2600 and 2500 BC. Researchers believe that this village may have contained 300 houses, making it one of the largest Neolithic settlements to be found in Britain. It is believed the houses were constructed of wattle and daub, a building material of wooden strips or branches and a combination of wet soil, clay, sand, animal dung, and straw. This building technique has been used for more than 6,000 years, and can still be seen in developing countries. A similar process of lath and plaster, used extensively in the United States up until the late 1950s, might have evolved from the wattle and daub process.

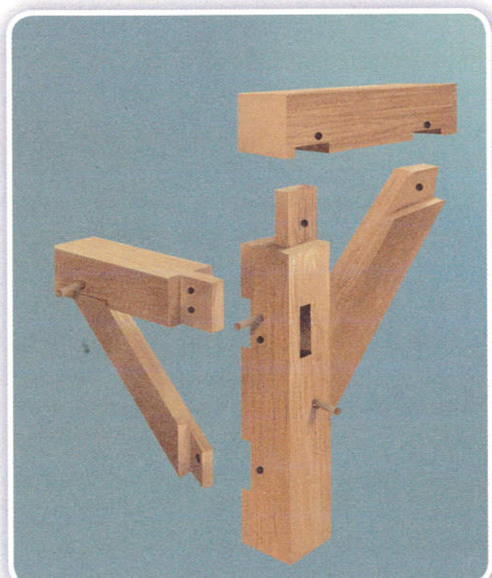
In this text we describe what we currently know and accept as history. However, new discoveries can reveal the existence of other early shelters and settlements that change our perception of history. For example, archeologists recently unearthed a 4,000-year-old temple on the northern coast of Peru. The temple contains a mural of a deer caught in a net. Archeologists used carbon dating to confirm the age of the mural and temple. The temple was made of blocks built from river sediment. This primitive construction material created a stark contrast to the elaborate

Carbon Dating: used by archeologists to estimate the age of organic remains and other substances rich in carbon. Carbon dating can be used on items as old as 60,000 years.

Figure 1-13: Mortise-and-tenon joints were used in this wooden post-and-beam construction.



© iStockphoto.com/troy wuelfing.



© Cengage Learning 2012

Fun Fact

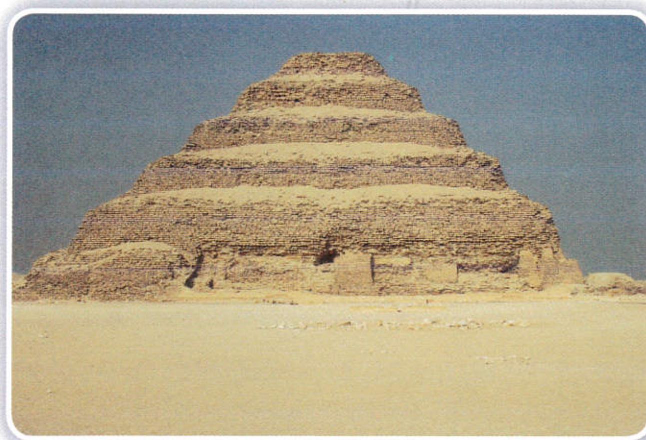
A retired construction worker from Michigan, Wally Wallington, thinks he knows how Stonehenge was moved and erected. To prove his theory, he has made a cement replica of a 16-foot tall stone hedge arch and singlehandedly moved and stood the blocks by applying his knowledge of physics. Using two small stones and a long lever, he was able to move a 1-ton block 300 feet per hour. Gravity, weight, and blocking were then used to stand the 19,200 lb blocks. The feat was taped for the Discovery Channel and can be seen at http://www.theforgottentechnology.com.

mural and structure. Artifacts from the site included shells that might have come from coastal Ecuador, indicating the possibility that the region was a cultural exchange point. You can find out more about this discovery and see photos from the excavation at *http://www.reuters.com/article/newsOne/idUSN1018888320071111.*

Building in Ancient Egypt

The next stop on your journey will be ancient Egypt. During this period, Pharaohs believed they would need their worldly possessions in the afterlife, which led to the design and development of tombs. In your trip back in time, you discover that Mastabas were the first pyramids; however, the shape may surprise you. They were simple flat-roofed rectangular structures made of mud, brick, or stone. You begin to see the evolution of the pyramid in the design of step pyramid, which was comprised of six stacked mastabas, each progressively smaller. Look closely at Figure 1-14 and identify the structural system used to construct the step pyramid. You may be surprised to learn that this pyramid still stands today.

Figure 1-14: The step pyramid of King Djoser was constructed in 2750 BC.



The builder of the step pyramid was Imhotep, whom we mentioned earlier in this chapter as the first engineer to be recognized by name and achievement. Many also consider him to be the first architect in history known by name. Although he was not the first to build with stone, the immense size of the step pyramid, made entirely of stone, is considered a signficant innovation. Imhotep applied simple tools and mathematics of proportion and scale to develop the art of building with stone. Some believe that Imhotep may also be connected to the first use of columns in architecture.

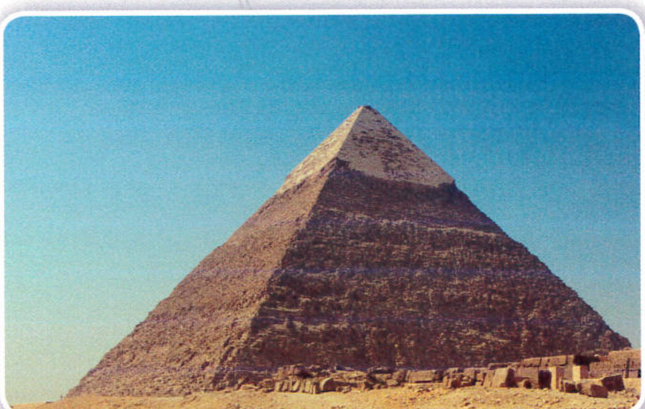
Application of techniques, tools, and formulas to determine measurements and proportions.

When most of us think of a pyramid, we envision triangular forms. The Great Pyramid at Giza (Figure 1-15), built between 2720 and 2560 BC, is a good example. It covered more than 13 acres with sides 755 feet long angled at 51 degrees. Originally, these walls stood 481 feet high. Now standing at 450 feet, its features are so large it can be seen from the moon. Recent computer calculations estimate approximately 500,000 stone blocks, each weighing more than 2 tons, were used to build this pyramid. How were these huge stones moved and placed? Even today, there is much speculation about the construction of the pyramids. Tomb paintings depict huge blocks being moved on sledges over lubricated ground and the use of ramps to bring

Your Turn

Many questions concerning construction of the pyramids are still left unanswered. Even the mortar used remains a mystery. Some believe that analysis could lead to a more definitive dating of the pyramids. Use your Internet search engine to research pyramid mortar to read more about the carbon dating of organic material within the mortar. You may be surprised to learn that the mortar joints of the great pyramid are consistently only 1/50 of an inch.

Figure 1-15: The Great Pyramid at Giza is the sole remnant of the Seven Wonders of the World, with features so large they can be seen from the moon.



the blocks to their position on the pyramid. Revisit your structural systems chart from this chapter. Into which category would you place the Great Pyramid at Giza? You are right if you said corbelling. You can see in Figure 1-15 how each new row of blocks was offset from the previous row.

HISTORY INSPIRES MODERN-DAY DESIGNS Although materials and building construction are much different, the pyramid shape is still used in building design. The famous glass pyramid by Ieoh Ming Pei at the Louvre Museum in Paris (Figure 1-16) was inaugurated in 1989. The pyramid serves as main axis of circulation and provides access to the large reception hall beneath.

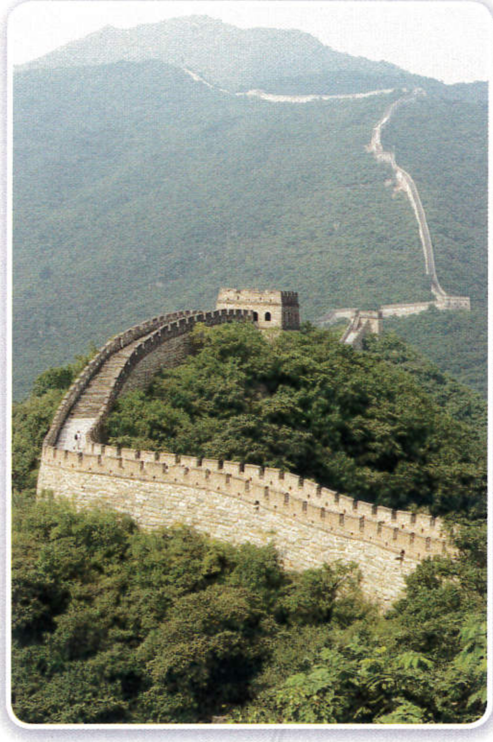
Another modern-day pyramid is the Luxor Hotel and Casino, built in Las Vegas, Nevada (see Figure 1-17). One of its interesting features is an inclinator that is similar

Figure 1-16: The famous glass pyramid at the Louvre Museum in Paris by architect Ieoh Ming Pei.

Figure 1-17: The Luxor Hotel and Casino built in Las Vegas, 1991–1993.

to an elevator but has the ability to move diagonally. The Luxor's inclinator travels 30 floors, moving people at a 39-degree angle from floor to floor. Another unique feature is its 42.3 billion candlepower beam, which projects outward from the upper point of the pyramid. It has been said to be the strongest beam of light in the world and is clearly visible from outer space.

Figure 1-18: Great Wall of China.



Building in Ancient Asia: 250 BC–AD 1500

The next stop on your journey is the Great Wall of China (see Figure 1-18). The Great Wall was built to protect the borders of the Chinese Empire and stretched across 4000 miles. It was originally built using materials readily available near the building site. Stone was used when building in the mountain areas, and compacted earth was used in the plains. Each year, thousands of visitors walk the long and often steep Great Wall of China.

Architecture in Ancient Greece: The Parthenon, 448–432 BC

A trip back in history isn't complete without a stop in Athens to visit one of the most famous examples of classical architecture—the Parthenon (Figure 1-19). Phidias, a famous sculptor, designed the Parthenon, and architects Ictinos and Callicrates supervised its construction between 448 and 438 BC. The structure is approximately 111 feet by 228 feet and stands on a hill called the Acropolis, meaning "high city." The Parthenon, made from 22,000 ton of marble, is a famous example of classical architecture and is easily identified by extensive detail and massive columns. Looking back at your structural systems chart, into which system category would you place the Parthenon? Did you choose post and beam? Why do you think the columns were spaced so close together? If a different material was used for the horizontal or beam pieces, could the columns have been spaced farther apart? What can you conclude about the properties of marble?

COLUMNS USED IN TODAY'S ARCHITECTURE There are many styles of columns in use today. Their function is both decorative and structural. You often see them used as structural members for a front porch or portico. Columns are one of the most distinctive features used to identify building styles. You will read more about architectural styles in Chapter 4: Architectural Design.

Figure 1-19: The Parthenon stands in ruins from damage from a fire during ancient times and an explosion in 1687.

Engineering in Ancient Times

On the next stop of your journey, you will discover the ancient Roman aqueducts. Aqueducts were one of the greatest engineering feats of the ancient world, allowing people to move water over long distances with minimal loss. They were constructed in Persia, India, and Rome, with some dating back to the bronze age of 3500 BC. These irrigation systems supplied water to settlements and agricultural areas in need of water.

Fun Fact

An exact replica of the Parthenon was built in Nashville, Tennessee, in 1897 for the city's 100th anniversary. The building serves as the city's art museum.

The re-creation of the 42-foot statue of Athena is the focus of Nashville's Parthenon, just as it was in ancient Greece. The building and Athena's statue are both full-scale replicas of the Athenian originals.

Originally built for Tennessee's 1897 Centennial Exposition, this replica serves as a monument to what is considered the pinnacle of Classical architecture (see Figure 1-20).

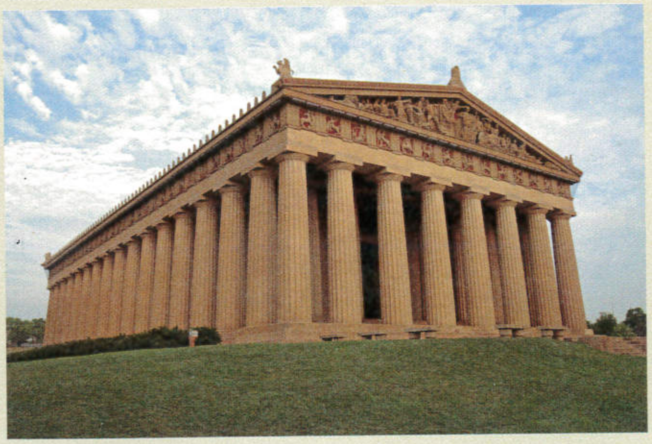
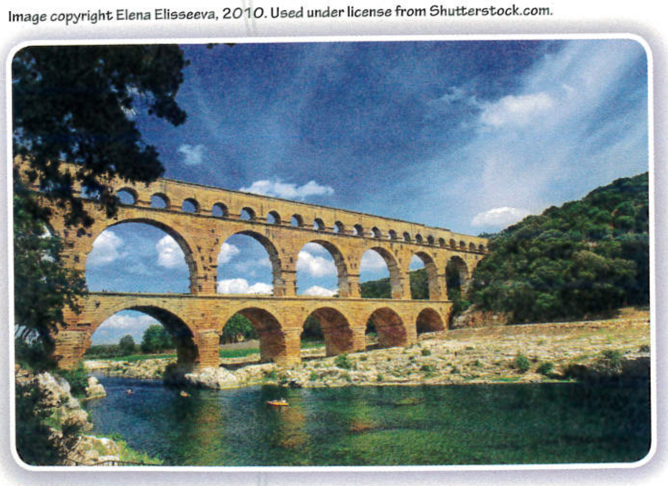


Figure 1-20: The Parthenon replica stands proudly as the centerpiece of Centennial Park, Nashville's premier urban park.

The ancient Romans were the most famous builders of aqueducts (see Figure 1-21). MatThey built eleven major aqueducts between 312 BC and AD 226. Builders used the principle of the arch to support these structures. (Revisit your chart on structural systems and reread the description of the arch.) Arches could span a wide distance and support weight. The early Roman arch used an odd number of bricks to form a semicircular pattern with a keystone or capstone at the very top.

The arch was used in doorways, bridges, gates, palaces, amphitheaters, and monuments. Many variations of the arch evolved, including the Gothic, jack, Tudor, and catenary arches. The catenary arch supports only its own weight. Can you think of a famous example of a catenary arch? You are right if you guessed the Gateway Arch in Saint Louis, Missouri. The Gateway Arch (Figure 1-22) was designed in 1947 and built between 1963 and 1968. The Gateway Arch is 630 feet wide at the base, and stands 630 feet tall.

Figure 1-21: Pont du Gard.



Architecture and Engineering of the Ancient Roman Empire

Your next stop will be the Pantheon in Rome, Figure 1-23. It is often difficult to determine the age of historical buildings like the Pantheon, but fortunately, important clues are often left behind by the architect or builder. The original Pantheon was a rectangular temple and included an inscription on the architrave indicating that it was built under the councilship of Marcus Vipsanius Agrippa. This inscription dates the construction of the original Pantheon between 27 and 25 BC. Building age is often determined by the building materials or construction techniques used. For example, the rebuild of the Pantheon following fires in AD 80 and 110 included bricks containing brickmaker stamps. These marks helped to determine that the restoration date was somewhere between AD 118 and 125. What other techniques are used to determine age of a structure? In this chapter, you have read about using thermoluminescence, carbon dating, and clues such as building materials, techniques, and inscriptions left by the architect or builder. Record this information in your notebook for future reference.

The Pantheon is easily identified by its Corinthian columns, set in a pattern of two rows of four columns each. These massive stone columns, which support the portico, are 39 feet tall by 5 feet in diameter.

Figure 1-22: The gateway in St Louis Missouri is an example catenary arch, and contains a tram system that transports visitors to an observation room at the top.

Gothic Architecture, Twelfth to Sixteenth Century AD 1140–1520

On next stop along your journey you will learn about Gothic architecture. Gothic architecture has been featured in many films and novels. For example, the famous Gloucester Cathedral, built in 1100 and rebuilt in 1331, was the setting for two Harry Potter films. Gothic architecture evolved from Romanesque architecture. The pointed Gothic arch allowed the building to be tall yet still have a large amount of window area for natural light (see Figures 1-25 and 1-26).

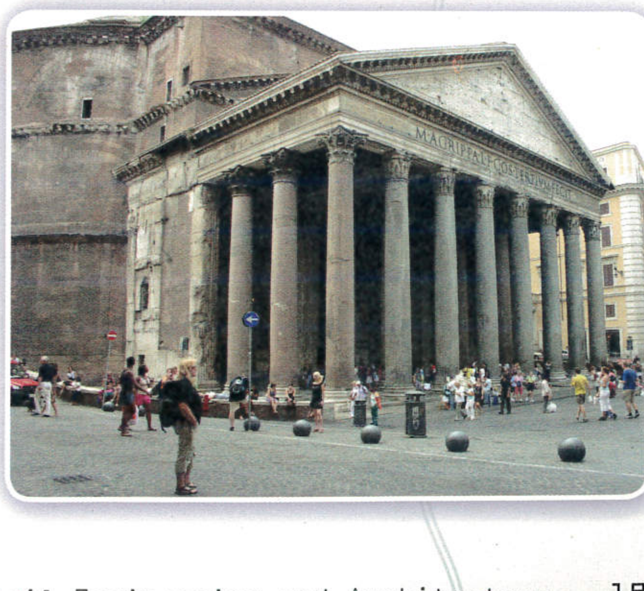
> Because people's needs and wants change, new technologies are developed, and old ones are improved.

Gothic architecture flourished during the medieval period and is seen on many churches, cathedrals, castles, palaces, and university buildings. Although you can find many Gothic-style churches and universities, you will seldom see the style applied to residential structures.

Unlike Romanesque style, where a continuous wall sustains the load, a Gothic structure employs a skeletal system to transfer roof loads down to the ground at specific locations, thus affording huge uninterrupted spaces. The most recognizable features of Gothic architecture are pointed arches, rib vaults, and flying buttresses.

Originating in France, Gothic architecture soon spread to Britain, Germany, Italy, and Spain. In Italy, Gothic architecture was constructed with brick and marble instead of stone. Variations of Gothic architecture emerged, including Rayonnant and Flamboyant style. Rayonnant Gothic structures are known for their rose windows (see Figure 1-27). The more decorative

Figure 1-23: The Pantheon is considered to be the best preserved of all ancient Roman buildings.



Fun Fact

Did you know that the Roman Pantheon has the largest unreinforced solid concrete dome in the world? The dome has a diameter of 142 feet and a height of 142 feet from the floor. The dome has a hole 25.5 feet in diameter, which provides light to the interior. To reduce the weight of the dome, recessed panels and cement made with pumice were used in the upper levels (see Figure 1-24). What structural system is followed to create a dome? If you could slice a dome in half, what would you see?

Figure 1-24: Looking from the inside of the Pantheon dome.

Your Turn

To learn more about Roman architecture, use the Internet to search Roman villa, Roman Forum, amphitheater, Coliseum, Pantheon, Rome triumphal arch, and aqueduct. You might be surprised to learn of an ancient Roman system of central heating called a *hypocaust*, which created heated floors for public baths.

Flamboyant style is easy to recognize by its stone window tracings in the shape of an *S* or flame (see Figure 1-28).

Variations of styles are sometimes found on the same building. One famous example is the two contrasting towers on the west façade of the cathedral of Notre Dame de Chartres. One of the towers was damaged in the 1140s in a fire sparked by lightning. The new spire constructed in the sixteenth century featured a contrasting Gothic Flamboyant style. After examining Figure 1-29, can you tell which tower represents the Flamboyant style? (You are right if you chose the taller one.)

As you look at historical buildings in your own community, remember that there are many variations of architectural styles. Some are the result of availability of building materials, whereas other variations are based on design creativity. When creative designs became distinctively different from the original and gained popularity, the new variations of style were given a more specific, descriptive name, even if they still fell within the original, general style category. This was the case with Gothic architecture. Another such example is the British Perpendicular style of Gothic, which emphasized the vertical lines and elements (see Figure 1-30).

Figure 1-25: The Gothic Architecture of Santa Maria del Mar Church in Barcelona, Spain, provides large interior space and natural light.

Image copyright Jakub Pavlinec, 2010. Used under license from Shutterstock.com.

Figure 1-26: The skeleton construction of Gothic architecture.

© Cengage Learning 2012

In historical perspective, science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.

Figure 1-27: A Rayonnant-style rose window in Notre Dame de Paris.
Image copyright Luca Moi, 2010. Used under license from Shutterstock.com.

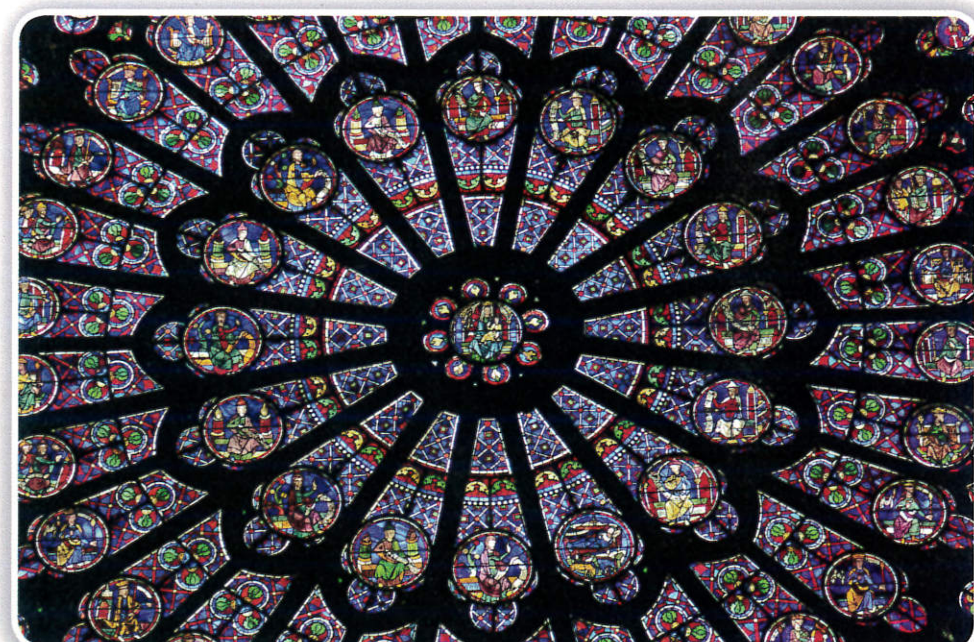


Figure 1-28: Flamboyant-style Gothic window.
Image copyright Peter Zurek, 2010. Used under license from Shutterstock.com.

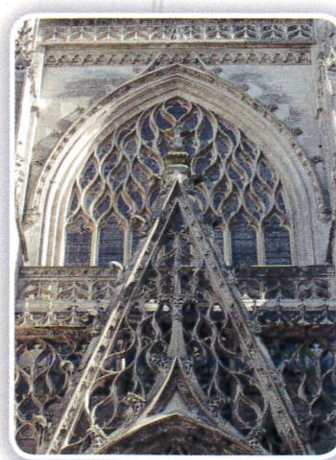


Figure 1-29: The two contrasting towers of Notre Dame Cathedral in Chartres, France.

Figure 1-30: The Classic Perpendicular-style Lady Chapel was built between 1503 and 1512 at the eastern end of Westminster Abbey.

In the past, it took several years to build a structure. In some cases, it took several decades or even centuries! How did the builders maintain a structure's architectural integrity when the building process extended past the lifetime of several architects and designers? One solution was to match the form, materials, and details of the original style. A good example is Westminster Abby in London, England (Figures 1-32 and 1-33). Not much is left of the first structure, which opened in 1065. What you see now is the result of a major rebuild between 1245 and 1517 in the Gothic style. A chapel was added in the early 1500s. The two west front towers were added between 1722 and 1745. Finally, the north part of the building was completed in the nineteenth century. Although Westminster Abbey was built and rebuilt over several centuries, architects retained the building's Gothic style. Compare Figure 1-32 to Figure 1-33. What similarities and differences do you see? Notice the brick pattern? What problems do you think occurred during the process of rebuilding?

As the Gothic style evolved, the arches were flattened and windows were framed with rectangular trim. This evolution inspired the development of Tudor architecture between 1485 and 1547 (see Figure 1-34).

Renaissance Architecture 1400–1600

On the last stop of your historical journey, you will look at Renaissance architecture. This style of architecture was born in Italy following the Gothic period. The symmetrical and proportioned designs of the Renaissance were a stark contrast to the complex asymmetrical Gothic buildings. One of the most famous architects of this period was the Italian architect, Andrea Palladio (1508–1580). Andrea Palladio was known for classical design elements and mathematical order, which have influenced architectural styles for more than 500 years. The Villa Capra (Figure 1-35) is one of Palladio's best-known works.

Two hundred years after Palladio's time, Thomas Jefferson based the design of his famous home, Monticello, on Palladio's classical design principles (see Figure 1-36). Jefferson applied his understanding of geometric shapes

Your Turn

Use the Internet to research the Gloucester Cathedral, which was used in filming the Harry Potter films. Trace the timeline of the building and note the architectural features and changes that have occurred since 1072. Record the architectural style of the building, and print a picture of the fan-vaulted roof to include in your notebook (see Figure 1-31).

Historical buildings often have clues that uncover or document historical developments. See if you can locate a picture of the stained glass on the east wing of the cathedral, which dates back to 1350 and contains an image similar to the game of golf. There has been quite a debate as to where the game of golf originated; some believe it was in Scotland, while others think it was in the Netherlands.

Figure 1- 31: Interior hallway of the Gloucester Cathedral.

Figure 1-32: Westminster Abbey's west towers built between 1720 and 1745.

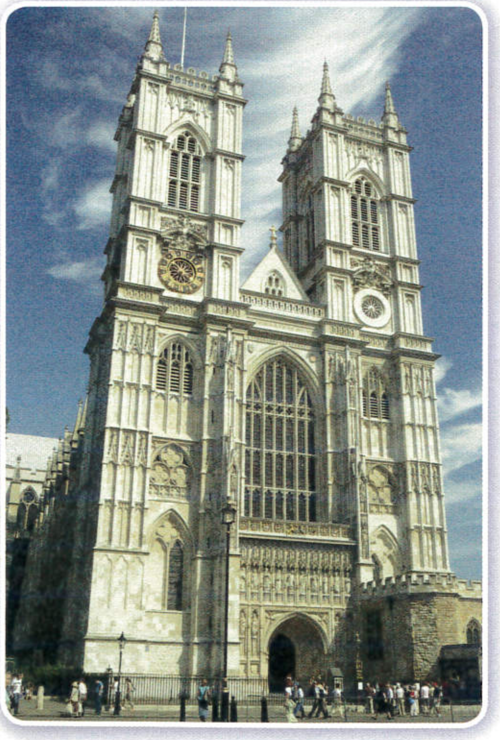


Figure 1-33: The north entrance of Westminster Abbey completed in the nineteenth century.

Figure 1-34: The history behind Hampton Court Palace in London dates back to 1236; however, the Tudor-style construction appeared in 1525.

Point of Interest

Did you know that Hampton Court Palace was once a prison for King Charles I? It has been reported to be haunted by ghosts. Go to http://www.cnn.com/2003/WORLD/europe/12/19/hampton.ghost/index.html?iref=allsearch to hear the story and learn more about the history of this building.

Your Turn

Use the Internet to research the four basic shapes of Gothic arches: Lancet, Equilateral, Flamboyant, and Depressed. Make sketches of them in your notebook and describe their features and the Gothic style they represent. Locate one historical example of each arch and print a copy for to your notebook.

and mathematical proportions to the Classical elements in Monticello. What geometric shapes and similarities do you see when comparing Figure 1-35 to Figure 1-36?

Thomas Jefferson was largely responsible for launching the Neo-Classical movement in architecture in the United States. He based his timeless, Classical design for the University of Virginia on mathematical rules and proportions

Figure 1-35: *Construction of the Rotonda (Villa Capra) by Andrea Palladio began in 1550.*

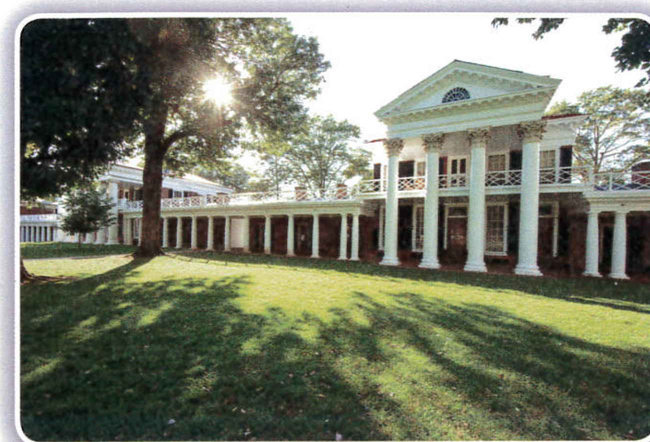
(Figure 1-37). In 1976, the American Institute of Architecture described Jefferson's "academical village" as "the proudest achievement of American architecture in the past 200 years."

You may be surprised to learn that the White House and the U.S. Capitol were also influenced by Palladio's Classical principles. Renaissance architecture is the last stop on your historical journey, at least for now. In Chapter 4, you will study

Figure 1-36: Thomas Jefferson began building his home at Monticello in Virginia in 1769 and continued to work on the structure for 40 years.

Figure 1-37: Jefferson described his design for the University of Virginia as an "academical village." The central Rotunda (a) and extending pavilions and colonnades (b) are among the finest examples of Neo-Classical architecture in the United States.

Courtesy of the University of Virginia Office of Public Affairs.



architectural design, beginning with American Colonial architecture around AD 1600 and continue to present day. In Chapter 4, you will also read about the "revival" of Greek and Gothic architecture.

Famous Buildings

Many buildings constructed in the 1500s and 1600s fell into disrepair due to wars, natural disasters, climate conditions, or lack of maintenance. Several of the survivors are quite famous. Saint Paul's Cathedral, Windsor Castle, and the Palace of Versailles were all built during this time period.

S T E M

Structures require maintenance, alteration, or renovation periodically to improve them or to alter their intended use.

You have most likely heard of the Taj Mahal, which was built in India between 1632 and 1653. The lavish design of this tomb led to its name being used as a synonym for architecture that displays great wealth, extravagance, and detail (see Figure 1-38).

The building shown in Figure 1-39 is recognized worldwide for its unique shapes, detailing, and elaborate color scheme. Can you guess the name of this medieval Russian landmark built between 1555 and 1561?

5 FAMOUS ARCHITECTS

> The ultimate aim of all creative activity is a building.
>
> —*Walter Gropius, director of the Bauhaus School,*
> Bauhaus Manifesto, *1919*

How do architects become famous? If you were to take a survey asking people to name a famous architect, many would name Frank Lloyd Wright. He was an architect, interior designer, writer, educator, and philosopher. Frank Lloyd Wright designed more than 1000 projects, but only 400 were built. He is most remembered

Figure 1-38: Twenty-two thousand laborers and 1,000 elephants contributed to the construction of the Taj Mahal of India. It took them 22 years to build it, beginning in 1631.

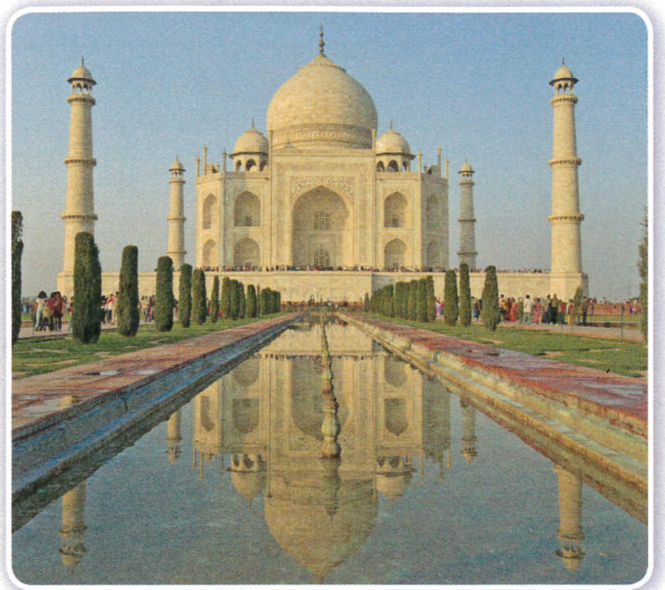
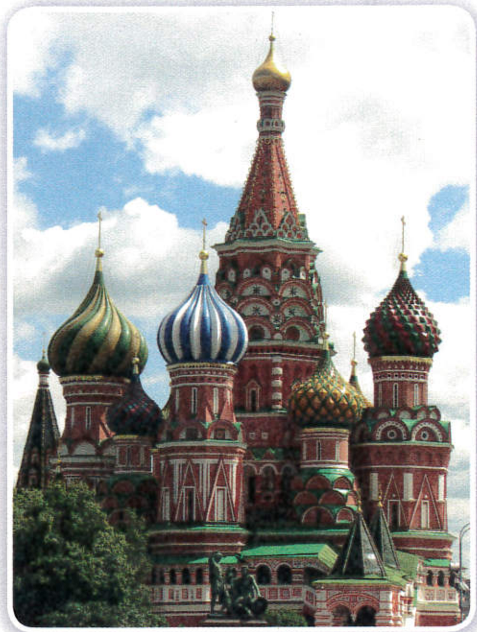


Figure 1-39: Saint Basil's Cathedral was built in Moscow during the 1550s.



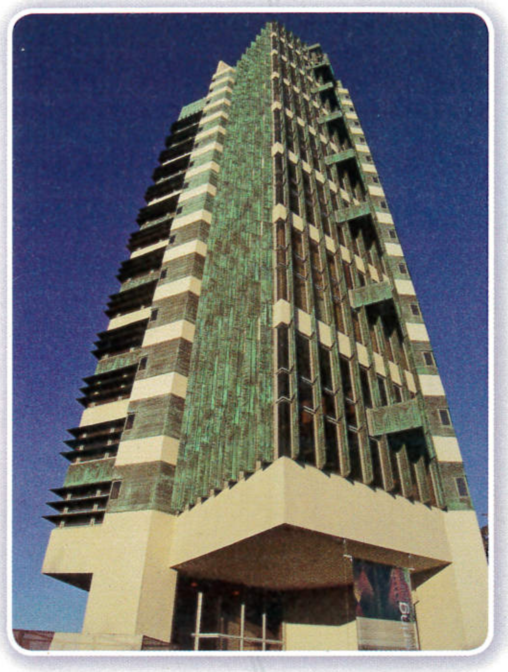
for Fallingwater, in Pennsylvania (see Figure 1-40), and the Guggenheim museum in New York City. When designing a new building, Wright considered even the smallest of details, including furniture and accessories.

During his career, Frank Lloyd Wright made many humorous and insightful remarks about architecture. In a 1953 interview for the *New York Times Magazine,* Wright said, "The physician can bury his mistakes, but the architect can only advise his clients to plant vines." What do you think he meant by that comment? As with any building, Wright's buildings were not perfect. There has been great controversy over the great cracks which formed on the cantilevered portions of Fallingwater. If you want to read about mistakes that plagued Fallingwater, use the Internet to search "Fallingwater cracks." Wright's designs ranged from a popular Prairie-style house made of natural materials to the expressionist modern style of Fallingwater. You might be surprised to learn that he also designed a nineteen story skyscraper in Bartlesville, Oklahoma. The Price Tower (Figure 1-41) was designated as a national historical landmark by the U.S. Department of the Interior in 2007.

Thousands of architects have left their marks on history. The table in Figure 1-46 lists several influential architects whom you might find interesting to research. Each artist has a unique story and a personal vision for architecture. For example, Ludwig Mies van der Rohe is one of the founding fathers of modern architecture. He was known for his simplified architectural designs, or "less is more"

Figure 1-40: Frank Lloyd Wright is one of the most influential architects in American history. Artist Walter DuBois Richards created this rendering of Wright's Fallingwater as part of a 16-stamp series honoring great accomplishments in American architecture. The stamps were issued in 1982.

Figure 1-41: Frank Lloyd Wright's Price Tower was built in 1956 in Bartlesville, Oklahoma.



approach to building. Mies van der Rohe created a "skin and bones" effect with steel framing and ground-to-ceiling plate glass windows. His 38-story Seagram building was erected in 1958 (see Figure 1-42). Notice the unique character achieved with the use of tinted glass, vertical bronze I-beams, and granite pillars.

Architects have made some interesting and thought-provoking comments. What do you think about this comment by architect Philip Johnson: "comfort is not a function of beauty...purpose is not necessary to make a building beautiful...sooner or later we will fit our buildings so that they can be used. Where form comes from I don't know, but it has nothing at all to do with the functional or sociological aspects of our architecture." In 1949, Philip Johnson designed the Johnson House, generally referred to as "the Glass House." Take a look at Figure 1-44. What statement do you think Johnson was trying to make?

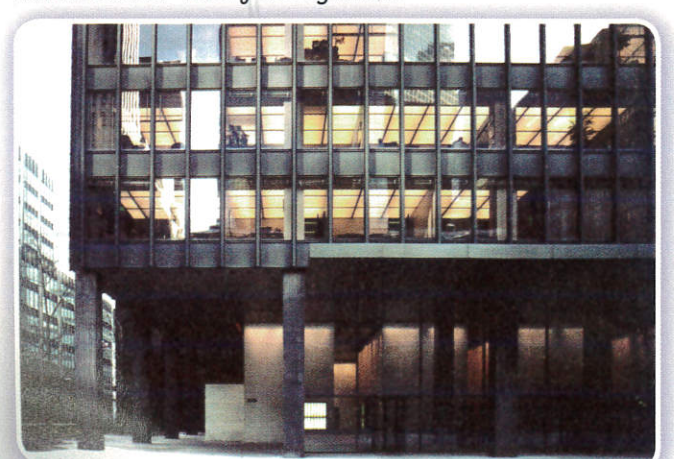
One of the most talked about architects of today is Frank Gehry, a laureate of the Pritzker Architecture Prize. Many believe that he has created his own style of architecture, through his use of Deconstructivism, Expressionism, and Organic Modernism. His "architecture is art" philosophy has resulted in some of the most exciting architecture of our time. He has been described as "refreshingly original and totally American." His designs combine building elements into intriguing sculptures that seem to defy the laws of gravity (see Figure 1-45).

6 MAJOR DEVELOPMENTS IN CIVIL ENGINEERING IMPACT LAND DEVELOPMENT

Innovation and inventions in civil engineering play a major role in the growth of an area. For example, the arch was used to build aqueducts to distribute water over long distances. Aqueducts provided water and irrigation for crops to otherwise uninhabitable areas. The arch was also applied to bridge construction, making travel over large bodies of water possible. On the architectural side, the arch led to the development of large open spaces with high ceilings, ideal for cathedrals, palaces, and amphitheaters.

Even today, an area's growth and land development is controlled by the amount of resources available. Many places would be uninhabitable if they did not receive resources such as utilities from another area. What would it be like to live without electricity, communications, water, or sewage? The presence of roadways also affects land development. Would you buy a piece of land that was not accessible? In the past, new roads have fostered the development of suburban residential areas to alleviate city overpopulation. However, many suburban residents must travel daily back to the city to their place of employment. They depend on well-built and maintained roads and highways (see Figure 1-50).

Figure 1-42: You can catch this view of the base of the Seagram Building at 375 Park Avenue in midtown Manhattan. The famous landmark was designed by Ludwig Mies van der Rohe with Philip Johnson and features a 2^{nd} story roof garden.



Point of Interest

If you visit New York City, you may want to see the Lever building (Figure 1-43). Built in 1952, it set a standard for office building design and was one of the first buildings to use a heat absorbing sealed glass.

In stark contrast to the glass office floors, the top floors are opaque to conceal mechanisms and mechanicals. The structure featured a 24-story building set on a two-story podium, which includes a roof garden. The base is a single-story pedestrian area supported by columns. Interesting features, still in service, include a window-washing mechanism and a mail conveyer to distribute mail to different floors.

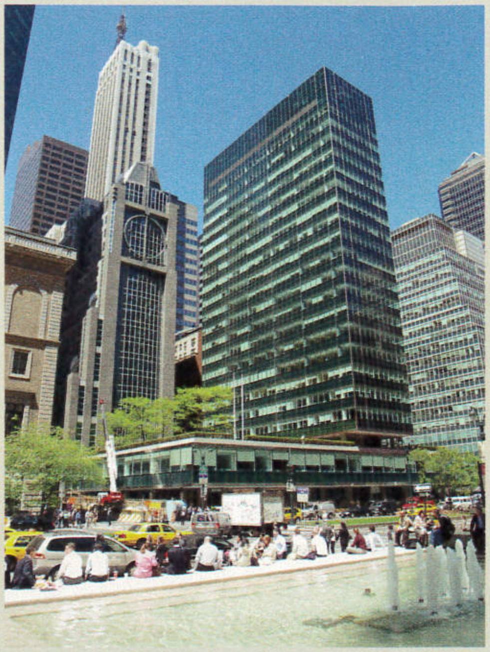


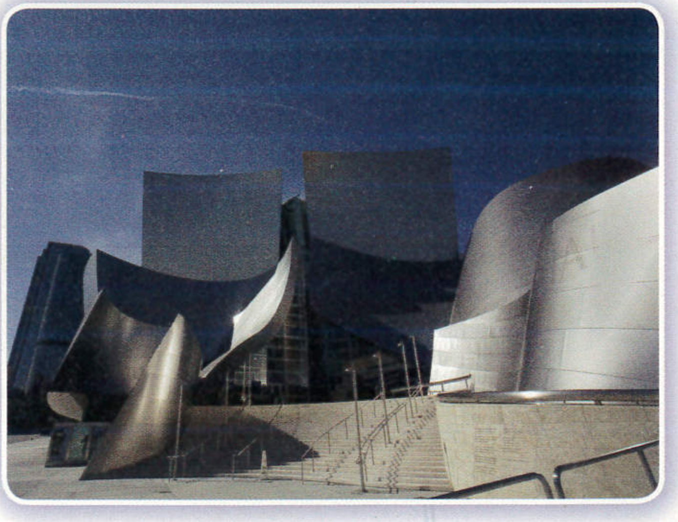
Figure 1-43: The Lever building in New York City features a second-story roof garden.

From http://en.wikipedia.org/wiki/File:Lever_House_by_David_Shankbone.jpg

Figure 1-44: Philip Johnson built the Glass House as his personal residence in 1949. What statement do you think he was trying to make?

Courtesy of the Philip Johnson Museum.

Figure 1-45: Los Angeles Disney Concert Hall by architect Frank Gehry.



Fun Fact

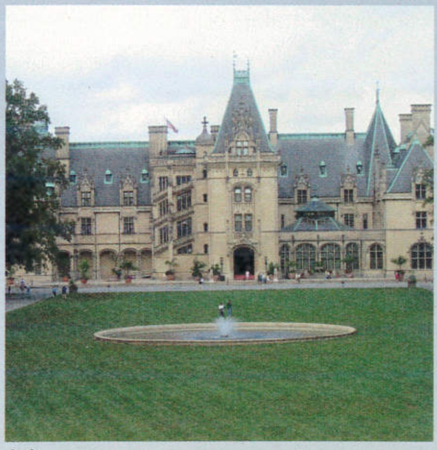
The Los Angeles Disney Concert Hall initially had problems interacting with the environment. The highly reflective metal cladding directed sunlight onto the pavement, creating a fire hazard.

Point of Interest

Did you know that famous architect Frank Gehry appeared as a guest star to design a concert hall for Springfield in an episode of *The Simpsons*? If you enter "Frank Gehry in Simpsons" into your Internet search engine, you might be able to view the episode "The Seven-Beer Snitch" from season 16. For a more serious look at this architect and designer, search for the documentary *Sketches of Frank Gehry* by filmmaker Sydney Pollack. You will hear the architect's own interpretation of his famous buildings, including the home he designed for himself.

Your Turn

The table in Figure 1-46 lists a series of influential architects and important examples of their work. Select one architect from this list to research. Use the Internet to learn the architect's story. What was the vision or mission behind your architect's designs? Print examples of the individual's accomplishments and add notes of interesting details. If possible, identify the date of construction, building type, purpose, architectural style, and materials used. Identify which structural system may have influenced your architect's design.



(a)

(b)

(c)

Figure 1-46: (a) The Biltmore Estate represents the nineteenth-century architectural style of Richard Morris Hunt.

(b) Notre Dame du Haut was completed in Ronchamp, France, in 1955. The hilltop chapel represents Le Corbusier's vision of Postmodern Expressionism.

(c) The wings of the Milwaukee Art Museum's Quadracci Pavilion were designed by Spanish architect Santiago Calatrava to open and close in response to wind speed.

Figure 1-46: Architects to research.

Name	Birth/Death	Significant Work
Richard Morris Hunt	1827–1895	Biltmore Estate, Asheville, North Carolina 
Henry Hobson Richardson	1838–1886	Ames Gate Lodge, North Easton, Massachusetts
Charles Greene	1868–1957	N. Bentz House Santa Barbara, California
Henry Greene	1870–1954	
Le Corbusier (Charles-Édouard Jeanneret-Gris)	1887–1965	Notre Dame du Haut, Ronchamp, France 
Gerrit Rietveld	1888–1964	Schroder House, Utrecht, The Netherlands
Louis I. Kahn	1901–1974	Salk Institute, La Jolla, California
Marcel Breuer	1902–1981	Robinson House, Williamstown, Massachusetts
Charles Eames	1907–1978	Eames House, Pacific Palisades, California
Eero Saarinen	1910–1961	Washington Dulles International Airport, Chantilly, Virginia
John Lautner	1911–1994	Malin Residence (The Chemosphere), Los Angeles, California
Pierre Koenig	1925–2004	Stahl House, Los Angeles, California
Tadao Ando	1941–	Modern Art Museum, Fort Worth, Texas
Santiago Calatrava	1951–	Milwaukee Art Museum, Milwaukee, Wisconsin 

Properties of Materials

In the past, materials of a given region often determined how things were built. It is probable our first builders and architects learned about the properties of these materials by trial and error and then passed along the knowledge to the next generation.

Case Study

Throughout this textbook, we will take a close look at actual building projects. They will be referred to as case studies. One case study will examine the design and build of the Syracuse Center of Excellence, a 55,000-square-foot, five-story research facility (see Figure 1-47). The site was contaminated by previous industrial uses, but has been remediated, restoring the site for construction of the Center of Excellence. The building will house offices for staff, classrooms, public spaces, and research laboratories. The main laboratory is a total indoor environmental quality lab where controlled experiments on the human response to indoor environments will be conducted. Main sustainability features of the Syracuse Center of Excellence include ground-source heating and cooling, rainwater collection, a green roof, and photovoltaic panels.

A second case study will examine a large urban plan development: CityCenter in Las Vegas. CityCenter, a 67-acre urban development in Las Vegas Nevada, includes condominiums, hotels, a casino, and a large retail and entertainment district (see Figure 1-48). The nine billion dollar venture includes six major buildings, along with a fire station, co-generation plant, parking garages, and a people-mover system. The goal of this urban plan is to create the diversity and vitality of a city, with a focus on sophistication. This requires that building designs offer timeless beauty and functionality, yet be different from any others. It was a challenging task to find architects to design such a look. Sven Van Assche, vice president of design, was up to the task. He began by clearly defining the term *contemporary*. Through his research, he determined that *contemporary* was not necessarily a preestablished design style using specific design elements but instead an innovative design that would be both timeless and inviting—a beauty people would enjoy for years to come. Van Assche searched the world for architects who would be able to design this "timeless" urban experience. Due to the project size and its mission—providing unique and distinctive choices that would attract diversity—several creative and experienced architects were needed. Although each would design a different building with its own vision, there was a need for meticulous leadership and collaboration between the professionals to create a dynamic and unified urban experience. Gensler, named the largest architectural firm in the United States by *Building Design+Construction* magazine for the past 24 consecutive years, was chosen as the executive architect of CityCenter. As the owner's representative, Gensler was responsible for collaborating with each of the architectural teams.

Figure 1-47: *Syracuse Center of Excellence under construction in 2008.*
Courtesy of the Syracuse Center of Excellence.

Figure 1-48: *CityCenter ready for opening in December 2009.*

searched world wide for modern architects to design CityCenter's one-of-a kind buildings. When the search concluded, the result was a "dream team" of the world's foremost architects (Figure 1-49).

Pelli Clarke Pelli, architect of the World Financial Center in New York City, competed against Kohn Pedersen Fox to design the ARIA Resort & Casino in the heart of CityCenter. Pelli proposed a building of two intersecting arches of almost curvilinear form. Sunshades framed the glass curtain wall to provide sun protection as well as "make the whole building more graceful" stated Pelli (*Las Vegas Life*/November 2007). Kohn Pedersen Fox was chosen to design the Mandarin Oriental Hotel and condominium tower. Elegance and quality were essential to convey a luxurious feeling, which is signature of the internationally renowned resort brand Mandarin. Helmut Jahn Architects was chosen to design the two residential high rises known

Robert H. (Bobby) Baldwin, MGM MIRAGE's chief design and construction officer, and president and CEO of CityCenter, is credited as the project's visionary. After traveling the world to find the secrets of successful urban settings, he worked with New York's Ehrenkrantz, Eckstut, and Kuhn Architects to develop a master plan. Baldwin and Van Assche

Figure 1-49: *CityCenter's dream team of architects.*

Courtesy of MGM Mirage.

Gensler	Executive Architect	CityCenter
Pelli Clarke Pelli	ARIA Resort & Casino	ARIA/photo
Kohn Pedersen Fox Associates	Mandarin Oriental Las Vegas	Mandarin Oriental/photo
Helmut Jahn Architects	Veer Towers	Veer Towers/photo
Foster + Partners	The HarmonHotel, Spa & Residences	Harmon Hotel/photo
RV Architecture Architecture	Vdara Condo Hotel	Vdara Condo Hotel/photo
Studio Daniel Libeskind and Rockwell Group	Crystals	Crystals/photo

as Veer Towers. Jahn translated energy and excitement into physical form with the design of two angled 37-story glass towers that will shimmer both day and night. London's Foster + Partners, known for beautifully engineered intelligent and efficient buildings, was chosen to design the Harmon Hotel, Spa & Residences. This hotel will provide hip, exclusive living directly on The Strip for those that desire both privacy and profile. Rafael Viñoly was selected to design the soaring 57-story Vdara Condo Hotel deep within CityCenter. Vdara's distinctive crescent shape and skin of pattern glass will feature open floor plans and expansive views of the city and mountains. The retail and entertainment district known as Crystals was created by Studio Daniel Libeskind and Rockwell Group. The Crystals striking exterior features a dazzling and dynamic collection of angled roofs. Its luxurious interior provides a series of striking environments designed to invite, engage, intrigue, and relax.

Figure 1-50: Highway systems provide safe and efficient travel.

They learned that stone and brick were strong under compression but weak under tension, whereas wood, depending on the type, held up under both but was not as durable when exposed to the elements.

Early builders soon discovered that the material needed to be matched to its application. They also needed to use the materials in a way that would maximize their desirable qualities. One such desirable quality was strength. Although new techniques emerged, builders continued to search for stronger materials. A major development of its time was iron. Iron was strong, but brittleness limited how it could be used. In the nineteenth and twentieth centuries, iron was refined into steel, which became a popular building material and was soon applied to wire and cables. Can you imagine the advantages of replacing fiber rope with cables made of steel wire?

Materials were also combined to enhance performance. What do you think happened when concrete was reinforced with steel rebar? You probably guessed it would be stronger, but what else would change? Would the weight be the same? You will learn more about materials when you read Chapter 12: Building Materials and Components.

Innovations in Materials and Processes

7

Materials and applications change over time. Take road materials for example. Roads have gone from dirt, cobbles, brick, and stone to today's popular Macadam, often described as "black top." Most materials have both desirable and undesirable properties. For example, although Macadam provides a smooth traveling surface when new, it must be repeatedly coated or replaced in areas of harsh climates. During the winter months in northern United States, moisture can seep into small roadway cracks and freeze. When the water turns to ice it expands and causes larger cracks, letting even more moisture under the pavement, as shown in Figure 1-51. By spring, many of the roadways show signs of severe damage.

Macadam is designed to seal water out. Although this sounds like a good thing, it creates another problem. Under heavy rains, hydroplaning of automobiles can occur. When the water on the Macadam roadway builds beyond what the tire's tread can handle, cars literally drive on water, and without traction can easily slide off the road.

Another problem comes from rainwater run-off from large parking lots. Where does this water go so that it doesn't cause flooding? You will read more about run off in Chapter 6: Site Planning.

Figure 1-51: Road cracks and pothole.

Point of Interest

Today, civil engineers are working to develop and refine a porous road material to be used in warm climates. Use the Internet to search for the phrases "pervious concrete pavement" and "porous asphalt pavements."

Your Turn

You may be curious about engineering achievements and the engineers behind them. Table 1-2 provides a partial list of notable civil engineers identified by the American Society of Civil Engineers. Choose an engineer and use the Internet to research his or her work. What makes this engineer's life and work "notable?"

Table 1-2: Notable civil engineers

	Name	Major Accomplishment or Notability
1635–1703	ROBERT HOOKE	Hookes law, mechanics of materials
1724–1792	JOHN SMEATON	Eddystone Lighthouse 1759 Research in mechanical power watermills, windmills, and steam engines
1756–1836	JOHN LOUDON MACADAM	Process of roadway design and construction

(Continued)

Table 1-2: (*continued*)

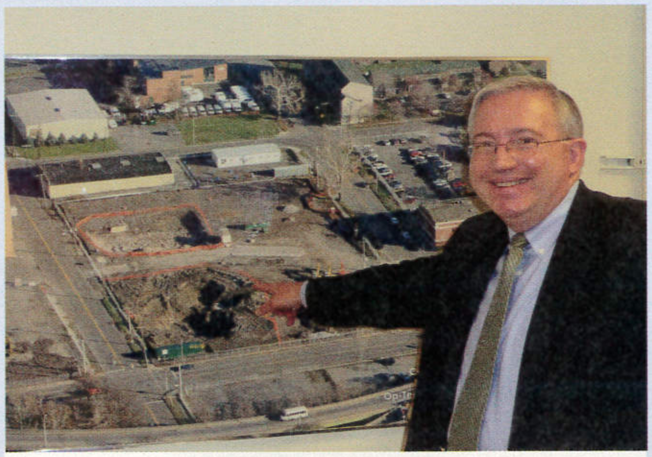
	Name	Major Accomplishment or Notability
1764–1820	BENJAMIN HENRY LATROBE	Contracted by U.S. government to redesign the U.S. Capitol in 1815 Engineering projects included the Philadelphia Waterworks, plans for the Washington Canal, and the New Orleans Waterworks
1768–1849	MARC ISAMBARD BRUNEL	Thames Tunnel–underground tunnel
1772–1822	THEODORE BURR	Waterford style bridge The key feature was the arch that started below the deck at the abutments and ran near the top of the top chord at mid span. This was the first time in the United States that anyone used an arch in combination with a truss in order to provide both stiffness and strength.
1784–1864	STEPHEN H. LONG	Considered to be the first structural engineer in America. Patented Jackson Bridge, first engineer to write about the advantages of pre-loading a truss in order to achieve additional stiffness and the use of the parallelogram of forces
1789–1867	GRIDLEY BRYANT	Eight-wheel railroad car, the portable derrick, the rail switch, and the turntable
179 –1885	JOHN BLOOMFIELD JERVIS	Croton Aqueduct–brought fresh water to island of Manhattan
1798–1856	SIMEON BORDEN	Survey Instrument
1803–1858	HENRI PHILIBERT GASPARD DARCY	Darcy's Law and the Darcy-Weinbach equation
1806–1859	ISAMBARD KINGDOM BRUNEL	Great Western Railway, first tunnel under a navigable river, first propeller driven ocean going iron ship
1806–1869	JOHN AUGUSTUS ROEBLING	Idea of replacing the fiber rope with stronger wire rope for greater safety and economy; in 1841, filed a patent application for a cable made of parallel wires.
1811–1875	JAMES LAURIE	Design of the Warehouse Point Bridge across the Connecticut River on the New York-New Haven railroad line; replaced the older wooden bridge with an iron bridge without interruption of train service.
1813–1886	ELLIS SYLVESTER CHESBROUGH	Chesbrough's Chicago Water Supply
1814–1884	WENDALL BOLLMAN	Iron suspension-truss design railroad bridge
1820–1887	JAMES BUCHANAN EADS	Eads Bridge–Early steel bridge combined road and railway over the Mississippi at St Louis—when constructed it was the longest arch bridge in the world.
1826–1863	THEODORE DEHONE JUDAH	Central Pacific Railroad, Western terminus of America's first transcontinental railroad
1827–1897	ALBERT FINK	On May 9, 1854, received patent No. 10,887 for a truss bridge; received a second patent on April 9, 1867, No. 63,714, for a combination truss with wooden compression members and wrought iron tension members.

1832–1923	ALEXANDRE GUSTAVE EIFFEL	Eiffel Tower–worlds' tallest tower in 1889
1837–1926	WASHINGTON AUGUSTUS ROEBLING	Brooklyn Bridge–steel cable suspension bridge
1842–1911	ELLEN HENRIETTA SWALLOW RICHARDS	First woman to graduate from MIT; expert on water and sewage analysis
1843–1908	WILHELM HILDENBRAND	Suspension bridges and cables
1843–1903	EMILY WARREN ROEBLING	Brooklyn Bridge work; construction foreman at Montauk, Long Island, camp
1850–1935	GUSTAV LINDENTHAL	Smithfield Street Bridge–lenticular truss Queensboro Bridge and Hell Gate Bridge Upon completion the Hell Gate Bridge was the longest and heaviest steel arch bridge.
1855–1932	JOHN RIPLEY FREEMAN	Charles River Dam, Charles River Basin report
1858–1928	GEORGE WASHINGTON GOETHALS	Panama Canal–1914
1879–1965	OTHMAR HERMANN AMMANN	George Washington Bridge
1883–1924	CLIFFORD MILBURN HOLLAND	Holland Tunnel
1892–1989	ABEL WOLMAN	Combined engineering with public health and hygiene into the field that came to be known as sanitary engineering. Developed procedures for water and sewage chlorination and disinfection, and influenced federal policy concerning water pollution control and management.
1900–1989	STEPHEN D. BECHTEL, Sr.	Hoover Dam 1935 monolithic and the Trans Arabian pipeline
1902–1981	ARTHUR CASAGRANDE	Together with colleague Karl Terzaghi built the influential discipline of soil mechanics Earth fill dam design
1903–1994	ANTON TEDESKO	Thin shell concrete roofs, Hayden Planetarium dome, the Hershey Arena and NASA's Vehicle Assembly Building (VAB) at Kennedy Space Center, Florida. When completed in 1966, the VAB enclosed the greatest total volume of any building in the world.
1907–1997	MARIO SALVADORI	Salvadori Educational Center on the Built Environment *Why Buildings Stand Up* was the first of a series of popular works written for the general public.
1921–1996	GEORGE F. SOWERS	Soil Mechanics and Foundations
1922–1989	HARRY BOLTON SEED	Known internationally for his understanding of soil behavior during earthquakes

Source: American Society of Civil Engineers, http://live.asce.org/hh/index.mxml. Accessed 4/19/2010.

Careers in Civil Engineering and Architecture

Looking Back, to the Future



Edward A. Bogucz, Jr.: Executive Director
Syracuse Center of Excellence in Environmental and Energy Systems
Syracuse University

"When you're envisioning the future, the past can be a wonderful inspiration and guide," explains Ed Bogucz, executive director of the Syracuse Center of Excellence in Environmental and Energy Systems (SyracuseCoE). "Our organization develops next-generation energy and environmental systems. We trace our roots back to one of the greatest engineering accomplishments of all time—the design and construction of the Erie Canal. In the early 1800s, it was an audacious idea: connect the Atlantic Ocean to the Great Lakes via a 40-foot-wide canal across 360 miles of wilderness in upstate New York. U.S. President Thomas Jefferson called the idea 'a little short of madness.' Undaunted, New York's state government took on the project. The Erie Canal opened in 1825. It had a profound impact on the development of the U.S. It promoted the flow of people, products and ideas into, and out of, a young and growing country. During the Industrial Revolution, all kinds of new technologies and innovations were developed by companies along the route of the Erie Canal. One of the hubs was Syracuse, which was home to a wide variety of firms. In the early 1900s, Syracuse was known as the 'Typewriter City' because of a cluster of major manufacturers. L.C. Smith and Brothers (which later became Smith Corona) built a manufacturing plant along the Erie Canal in 1902. Simultaneously, L.C. Smith successfully encouraged Syracuse University to start an engineering college. Today, SyracuseCoE is led by Syracuse University and our new headquarters is being constructed on the site of the old Smith Corona plant."

"Without the Erie Canal, there would be no L.C. Smith, no College of Engineering at Syracuse University, and no SyracuseCoE. Our activities today were made possible by a sequence of historical events," says Bogucz. The historical significance of the site continues to challenge and intrigue Bogucz. During the building process, they uncovered mule shoes, plates, bottles, and many other artifacts dating back 200 years. Not all discoveries were welcome. One surprise was the discovery of an underground oil storage tank—made of wood—that dates from the days of the Erie Canal. Costs relating to the unexpected cleanup of this discovery had a major impact on the project's overall budget.

On the Job

Bogucz started his career in academia in 1985 as a junior faculty member at Syracuse University. He was attracted to Syracuse University because of its long history of encouraging faculty to work with industry. Building upon his childhood interest in air conditioning and his college study of heat transfer, the proximity to Carrier Corporation in Syracuse held the possibility of exciting collaboration opportunities. Bogucz explains, "all the planets aligned for me. As a junior faculty member I worked projects with Carrier to design software to help engineers design new air conditioners." Bogucz served eight years as Dean of the L.C. Smith College of Engineering and Computer Science when the school was in a period of rapid change. Bogucz led the development of a strategic plan to guide the future of the college. Energy and environmental systems was one of four different areas chosen for investments in faculty and facilities. Bogucz led teams that developed concepts for collaborations among firms and institutions throughout New York. These efforts culminated in 2002 with the establishment of SyracuseCoE as part of a statewide Centers of Excellence program that is intended to create economic benefits.

Inspirations

Bogucz grew up in northern New Jersey. His father was a mechanical engineer and executive in a company that made heating and cooling systems for homes, schools, and hospitals. He fondly remembers childhood visits to the plant where his father was employed. He remembers seeing molten iron poured to make cast iron boilers. He learned about engineering and how air conditioners work. From an early age, he envisioned following in his father's footsteps in the field of heating, ventilation, and air conditioning (HVAC) engineering. Responding to today's world challenges, HVAC engineers are developing innovations that will conserve energy and natural resources and improve indoor environmental quality for building occupants. As the executive director of SyracuseCoE, Bogucz plays a major role in collaborative efforts to improve the built environment and its interaction with the natural world.

Education

Bogucz recalls his interest in engineering developed in high school, "When I was in high school I had the privilege of taking courses similar to Project Lead The Way. I took two years of mechanical drawing and two years of architectural drawing. I had an interest in buildings and how things worked." As a senior he was torn between mechanical engineering and architecture. HVAC provided an interface between the two fields.

After receiving a Bachelors of Science degree in mechanical engineering from Lehigh University, Bogucz received a scholarship to study abroad at the University of London. It was during that period, working on his Masters degree, he envisioned an academic career. Upon return to the United States, Bogucz went back to Lehigh for his PhD, still interested in how things worked and the new and emerging technologies, which effect heating, cooling, and heat transfer.

Advice for Students

Bogucz challenges students to think about history. Whether the history of a building site, or an engineering marvel, history is important. Think about the Erie Canal, for example. Imagine what a challenge in 1817 it must have been to construct a bridge for the canal to pass over a river. The construction was done by hand, using locally available materials. The canal had to carry water over streams, rivers, and swamps. Bogucz recommends students question how things work; sometimes the knowledge can lead to innovation. Think about ways to conserve energy, or make things work more efficiently and use less energy. Challenge yourself to make a difference, just like innovators throughout history whose creativity inspires us today.