Chapter 17
Constructing Structures

Learning Objectives

After studying this chapter, you will be able to:

- List the two types of construction.
- Describe the major types of buildings that are constructed.
- Identify the steps involved in constructing a structure.
- Identify the types of foundations.
- Describe the framework used in buildings.
- Describe how buildings are enclosed.
- Explain the types of utility systems used in buildings.
- Describe materials used in finishing buildings.
- Identify other types of buildings.
- Identify the characteristics of heavy engineering structures.

Human beings have three basic needs: food, clothing, and shelter. Each of these can be satisfied using technology. Agriculture and related biotechnologies help us grow, harvest, and process food. Manufacturing helps us to produce natural and synthetic fibers. These fibers become the inputs to clothing and fabric manufacture. Materials and manufactured goods can be fabricated into dwellings and buildings using construction technology. ***Construction*** uses technological actions to erect a structure on the site where it will be used.

Types of Structures

Construction builds two types of structures. These are buildings and heavy engineering structures, **Figure 17-1.** ***Buildings*** are enclosures to protect people, materials, and equipment from the elements. Buildings also provide security for people and their belongings. ***Heavy engineering structures*** help our economy function effectively.

Buildings

Buildings are grouped into three types: residential, commercial, and industrial, **Figure 17-2.** These groupings are based

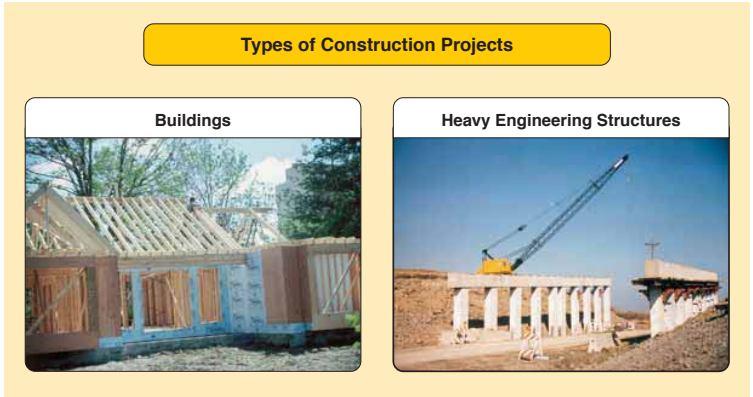

Figure 17-1. Construction erects buildings and heavy engineering structures.

on how the buildings are used. Note, however, that other types of buildings exist. These special buildings follow the same construction steps as the other buildings. This section will describe each of the main types, provide an overview of the other types, and discuss the general steps involved in constructing buildings.

Residential Buildings

Residential buildings are buildings in which people live. These buildings can be single-family or multiple-unit dwellings. The multiple-unit dwellings include apartments, town houses, and condominiums.

A residential building can be either owner occupied or rented from the owner. The owner of a dwelling is responsible for its upkeep. In some types of dwellings, such as condominiums, the costs of upkeep are shared between the owners. Each owner belongs to and pays fees to an association. This group elects officers who manage the maintenance of common areas such as entryways, garages, parking areas, and lawns. The association is also responsible for exterior repairs and insurance on the building. The individual owners maintain their own living quarters and insure their personal belongings against fire and theft.

Commercial Buildings

Commercial buildings are used for business and government purposes. These buildings can be publicly or privately owned. Commercial buildings range in size from small to very large. Retail stores, offices, courthouses, schools, libraries, and warehouses are commercial buildings.

Industrial Buildings

Industrial buildings house the machines that make products. These buildings are used to protect machinery, materials, and workers from the weather. The building supports the machines and supplies the utility needs of the manufacturing process. Many industrial buildings are specially built for one manufacturing process.

Other Types of Buildings

You see commercial, industrial, and residential buildings all around you. If you look around your town or city, however, you will probably see other types of buildings, **Figure 17-3.** These may include:

Figure 17-2. Construction is used to build residential, commercial, and industrial buildings. (Marvin Windows and Doors, Inland Steel Company)

- Monuments: These structures pay tribute to the accomplishments or sacrifices of people or groups.
- Cultural buildings: These buildings house theaters, galleries, libraries, performance halls, and museums. These buildings host musical, dramatic, and dance performances, literary activities, and art exhibits.
- Government buildings: These buildings house government functions. Examples include city halls, post offices, police stations, firehouses, state capitols, courthouses, and government office buildings.
- Transportation terminals: These buildings are used to aid in the loading and unloading of passengers and cargo from transportation vehicles. Examples are airports, train and bus stations, freight terminals, and seaports.
- Sports arenas and exhibition centers: These facilities are used for sporting events, concerts, trade shows, and conventions.
- Agricultural buildings: These structures include barns and storage buildings used to house livestock, shelter machinery, and protect farm products (grain and hay, for example).

As noted earlier, these special buildings are built using the same construction steps used for a single-family home.

A special type of building is the ***manufactured home.*** As you will remember, manufacturing produces products in a factory. The completed product is transported to its place of use. This is exactly how manufactured homes are produced, **Figure 17-4.** Most of the structure is built in a factory. This type of home is usually built in two halves. The floors, walls, and roof are erected; then the plumbing and electrical systems are installed. The structure's interior and exterior is enclosed and finished. This step includes installing flooring, painting walls, setting cabinets and plumbing fixtures, and installing appliances and electrical fixtures.

The two halves of the structure are transported to the site. The foundation is already in place. Each half is lifted from its transporter and placed on the foundation. The two halves are finally bolted together. The final trim that connects the halves is installed. The utilities are hooked up, and the home is ready for the homeowner.

Similar techniques are used to produce temporary classrooms, construction offices, and modular units that can be assembled into motels or nursing homes.

Figure 17-3. Buildings other than the three main types can be found in many forms.

Figure 17-4. Shown here are the steps in building a manufactured home.

Constructing Buildings

Most construction projects follow the same basic steps. These steps, as shown in **Figure 17-5,** include the following:

- Preparing the site
- Setting foundations
- Building the framework
- Enclosing the structure
- Installing utilities
- Finishing the exterior and interior
- Completing the site

Each type of structure needs to have specific actions taken during each step. This helps complete the structure on time. We will look at the steps used to construct a small single-family home. Later in the chapter, other construction activities will be discussed.

A common type of building is a single-family home. It is designed to meet a number of needs of the owners. These needs, as shown in **Figure 17-6,** include protection from the weather, security, and personal comfort. To meet these needs a home must be properly designed and constructed. The construction process starts with locating, buying, and preparing a site.

Preparing the Site

The location for a home needs to be carefully selected. It should meet the needs of the people who will live there. For example, a family with children may think about the schools serving the area. The parents will consider the distance to work, shopping, recreation, and cultural facilities. The condition of other homes in the neighborhood, building codes, and covenants are other factors to consider.

Once the site is chosen, it is purchased from the original owner. This may require working with a real estate agent and obtaining a bank loan or other financing. The financing will probably include the money to erect the home. This is important because most banks will not loan money to build a house on land that is mortgaged.

Next, the site is cleared to make room for the structure. The location of the new building is marked out. Then, that area is cleared of obstacles. When it is possible, the

Figure 17-5. Most construction projects follow the same basic steps. (Gehl Co.)

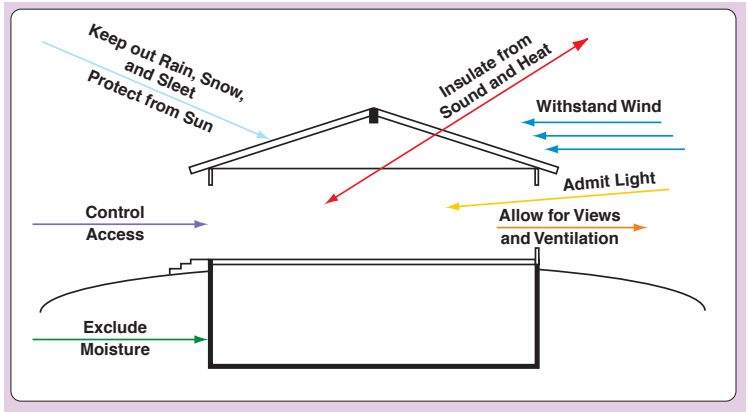

Figure 17-6. This diagram shows some of the needs a home must meet for its owner.

building should be located to save existing trees and other plant life. The site may require grading, **Figure 17-7,** to level the site. Grading prepares areas for sidewalks and landscaping and helps water to drain from the site. These preparations are needed for the next step, setting foundations.

Setting Foundations

The foundation is the most important part of any building project. The foundation serves as the "feet" of the building. Try to stand on just your heels. You will be unstable and wobble. Likewise, a building without a proper foundation will settle unevenly into the ground. It will lean, become unstable, and may fall to the ground. The Leaning Tower of Pisa in Italy is an example of a building that has a poor foundation. Over time, the tower has settled and is leaning several feet to one side.

Figure 17-7. Before a building can be built, the site must be cleared and graded.

A complete foundation has two parts: the footing and the foundation wall, **Figure 17-8.** The footing spreads the load over the bearing surface. The bearing surface is the ground on which the foundation and building will rest. This can be rock, sand, gravel, or a marsh. Each type of soil offers unique challenges for the construction project.

The type of foundation to use is selected to match the soil of the site. Three types, as shown in **Figure 17-9,** are:

- ***Spread foundations:*** These types of foundations are used on rock and in hard soils such as clay. The foundation walls sit on a low flat pad called a footing. On wide buildings, posts support the upper floor between the foundation walls. These posts also rest on pads of concrete called footings.

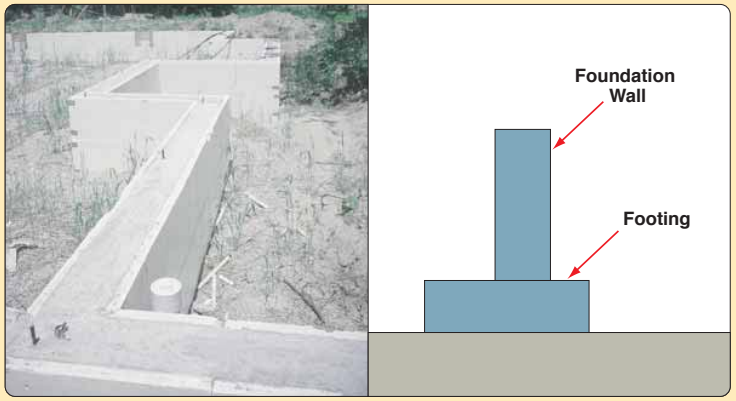

Figure 17-8. The foundation wall and footing spread the building's weight onto the bearing surface. The concrete foundation shown in the photo has been insulated to reduce heat loss.

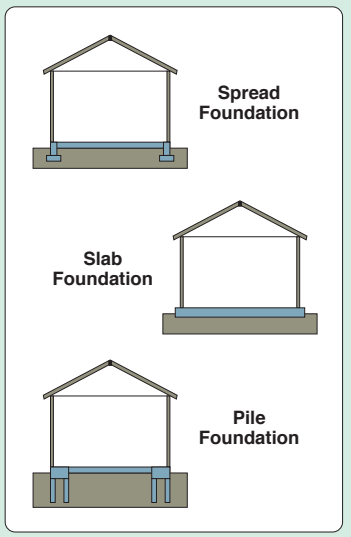

Figure 17-9. Three types of foundations used for buildings are spread, slab, and pile.

- ***Slab foundations:*** These types of foundations are used for buildings that are built on soft soils. They are sometimes called floating slabs. The foundation becomes the floor of the building. Such foundations allow the weight of the building to be spread over a wide area. This type of foundation is used in earthquake areas because it can withstand vibration.
- ***Pile foundations:*** These types of foundations are used on wet, marshy, or sandy soils. Piles are driven into the ground until they encounter solid soil or rock. Piles are large poles made of steel, wood, or concrete. They are widely used for high-rise buildings, marine docks, and homes in areas that flood easily.

Each type of foundation is built in a unique way. Let us consider a spread foundation. The site is surveyed to locate the foundation, **Figure 17-10.** Then the site is excavated in preparation for the footings and the walls. If the building is to have no footings, excavation does not go as deep. Buildings with basements require deeper excavations. Footing forms are set up next. Forms are a lumber frame to hold the wet concrete until it cures (hardens). Forms give the footings or slabs height and shape. Concrete is poured and leveled off. When the concrete is cured, the forms are removed. Walls of poured concrete or concrete block are built atop footings. Slabs are ready for aboveground superstructures. **Figure 17-11** shows an excavation for a pool. Wooden foundations use no concrete for either footings or walls.

Figure 17-10. This worker is surveying a site for a new building. The survey will locate where the foundation will be placed. (Inland Steel Co.)

Figure 17-11. This worker is excavating a hole for a pool.

Career Corner

Carpenters

Carpenters help construct buildings, highways, bridges, factories, and other structures. Some carpenters do all types of work, while others specialize in doing a specific job, such as setting forms for concrete, framing walls and partitions, laying hardwood floors, or installing interior and exterior trim. Carpenters must know local building codes and be able to work from blueprints or instructions from supervisors. Those who remodel homes must be able to do all aspects of a job and, therefore, require a good basic overall training.

Carpentry work is somewhat strenuous and requires standing, climbing, bending, and kneeling. Carpenters must be competent in using tools and power equipment. Carpentry is considered a skilled trade. Most carpenters learn their trade through on-the-job training, vocational education, or apprenticeships.

Figure 17-12. The materials used for framework are lumber, steel, and reinforced concrete.

Building the Framework

The foundation becomes the base for the next part of the building, the framework. Erecting the framework gives the building its size and shape. The framework includes the floors, interior and exterior walls, ceilings, and roof. Also, the location of doors and windows are set up at this time.

The framework can be built out of three different materials, **Figure 17-12.** Small and low-cost buildings have frameworks made from ***lumber.*** Industrial and commercial buildings have either ***steel*** or ***reinforced concrete*** frameworks.

Building the framework involves three steps. First, the floor is constructed, **Figure 17-13.** Homes with slab foundations use the surface of the slab as the floor. Homes with basements or crawl spaces use lumber floors.

Lumber floors start with a wood ***sill*** that is bolted to the foundation. ***Floor joists*** are then placed on the sill. They extend across the structure. Floor joists carry the weight of the floor. The size and spacing of the joists will be determined by the span (distance between outside walls) and the load on the floor. On top of the joists a ***subfloor*** is installed, usually made from plywood or particleboard. After the building is enclosed flooring material will be installed on top of the subfloor.

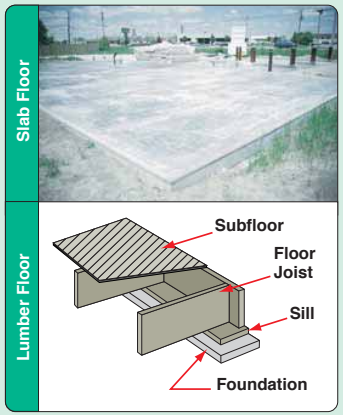

Figure 17-13. The floors in single-family homes are either concrete slabs or lumber.

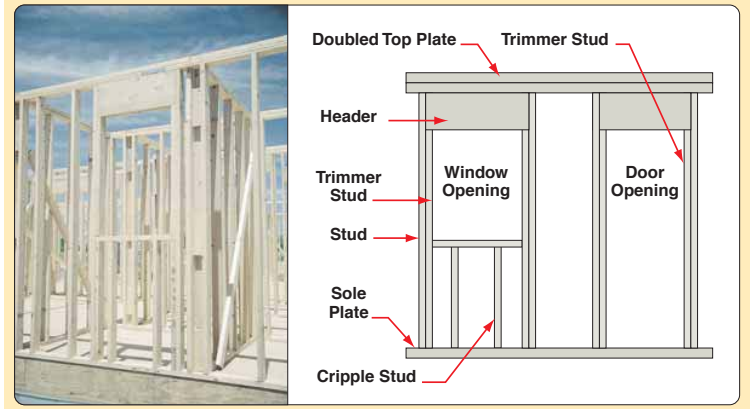

Figure 17-14. This photo shows many of the parts of a wood-framed wall.

The wall frames are placed on top of the floor. These frames support both exterior and interior walls. Wall framing is often made of 2 x 4 or 2 x 6 construction-grade lumber, **Figure 17-14.** A framed wall has a strip at the bottom called the ***sole plate.*** Nailed to the sole plate are uprights called ***studs.*** The length of the studs is set by how high the ceilings will be. At the top of the wall the studs are nailed to double ribbons of 2 x 4s called a ***top plate*** or wall plate. Door and window openings require headers above them. Headers carry the weight from the roof and ceiling across the door and window openings. ***Headers*** are held up by shorter studs called trimmer studs.

The walls support the ceiling and roof, **Figure 17-15.** The ***ceiling*** is the inside surface at the top of a room. The roof is the top of the structure that protects the house from the weather.

Ceiling joists support the ceiling. These joists rest on the outside walls and some interior walls. Interior walls that help support the weight of the ceiling and roof are called load-bearing or bearing walls.

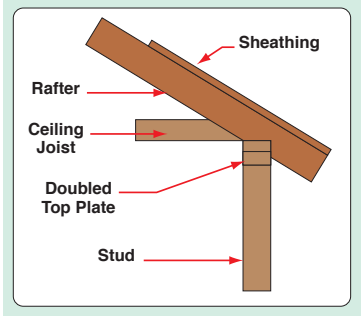

Figure 17-15. This illustration shows how the roof meets the wall frame.

The roof forms the top of the building. There are many types of roofs including flat, gable, hip, gambrel, and shed, **Figure 17-16.** The type of roof is chosen for its appearance and how it withstands the weather. For example, flat roofs are poor choices in areas with heavy snow. This type of roof cannot easily support the weight of deep snow. Likewise, a hip roof would look out of

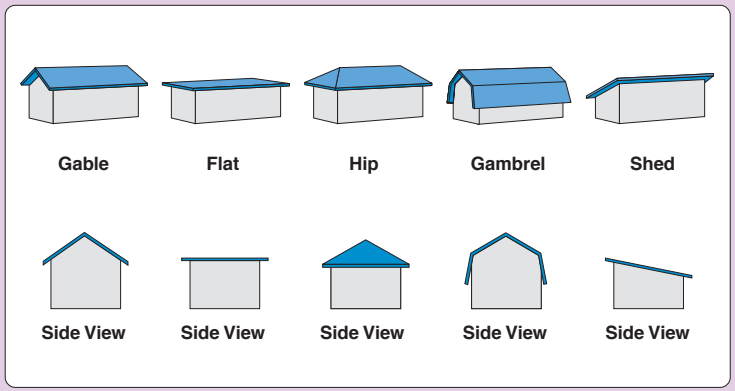

Figure 17-16. Shown here are some popular types of roofs used on homes.

place on Spanish-type homes. This kind of roof would not give the "Spanish-style" look.

Roof construction involves two steps. First, the roof frame is built with rafters. ***Rafters*** are angled boards that rest on the top plate of the exterior walls. Often a special structure called a truss is used. A ***truss*** is a triangle-shaped structure that includes both the rafter and ceiling joist in one unit. Trusses are manufactured in a factory and then shipped to the building site.

The rafters or trusses are covered with plywood or particleboard sheathing. This step completes the erection of the frame.

Enclosing the Structure

After the framework is complete the structure needs to be enclosed. The roof and wall surfaces need to be covered. This process has two steps: enclosing the walls and installing the roof.

With regard to enclosing the walls, we should note that all homes have both interior and exterior wall coverings. These coverings improve the looks of the building and keep out the elements (rain, snow, wind, and sun).

The first step is enclosing the exterior walls, **Figure 17-17.** This involves ***sheathing*** (covering) all the exterior surfaces. Plywood, fiberboard, or rigid foam sheets are used to sheath the walls. Most foam sheets have a reflective backing to improve the insulation value of the sheet. Most homes constructed today have a layer of plastic over the sheathing to prevent air from leaking in.

With regard to roof installation, normally the roof is put in place before the utilities are installed, **Figure 17-18.** The actual roof surface has two parts. Sheathing is applied over the rafters. This sheathing may be plywood or waferboard. Now the roofing material is installed. Builder's felt is often applied over the roof sheathing. Wood or fiberglass shingles, clay tile, or metal roofing is then installed over the sheathing and felt. Flat and shed roofs often use a built-up roof. A built-up roof starts with laying down sheets of insulation. Roofing felt is laid down, followed by a coat of tar, which is covered with gravel.

On many structures the overhang of the roof is also finished. A ***fascia*** board is used to finish the ends of the rafters and the

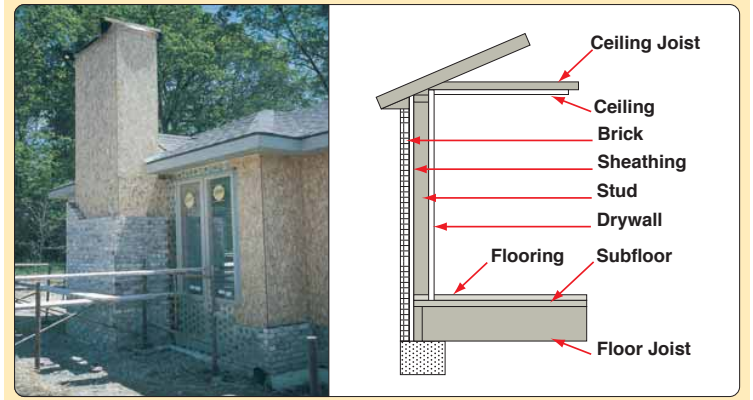

Figure 17-17. This is a cross-section diagram of a finished wall. The photo shows brick being applied as a siding material.

overhang. The ***soffit*** is installed to enclose the underside of the overhang. The soffit can be made of aluminum, vinyl, or plywood. Soffits must have ventilation holes or vents to prevent moisture and heat build up in the attic.

Once the sheathing and roof are installed, the openings for doors and windows are cut out. Then the doors and windows are set in place. Now the house is secure and weather tight.

Installing Utilities

Normally the utilities are installed after the building has been enclosed. This prevents theft and damage from the weather. Some parts of the utilities are installed earlier, such as large plumbing lines. The utility system includes four major systems:

- Electrical
- Plumbing
- Climate control
- Communications

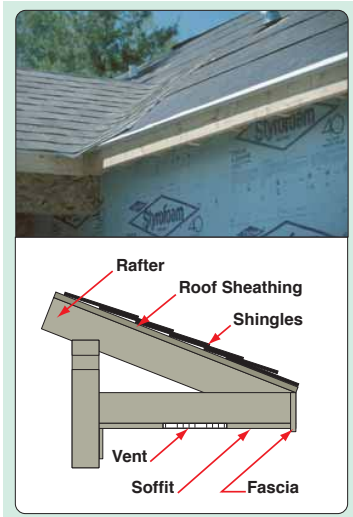

Figure 17-18. These are the parts of a finished roof. The photo shows asphalt shingles being installed on a new roof.

Electrical

The electrical system delivers electrical power to the different rooms of the home. The power is brought into the house through wires to a meter and distribution panel. This panel splits the power into 110-volt and 220-volt circuits. Each circuit has a circuit breaker to protect against current overloads.

Appliances such as clothes dryers, electric ranges, water heaters, and air conditioners require 220-volt power. Circuits for smaller appliances use 110 volts. Outlets may have power fed to them at all times. Outlets can also be controlled by switches. **Figure 17-19** shows a 110-volt circuit with wall (duplex) outlets and a ceiling light. You will note that the outlets will always have power. The circuit to the light has a switch, however.

Most 110-volt circuits are limited to 15 or 20 amps. Therefore, a number of different circuits are required to supply various parts of the home. A kitchen might have one or two circuits because of how many appliances are used there. One circuit might feed two bedrooms because there are few appliances in these rooms.

Plumbing

The plumbing system has two separate parts. One part supplies potable water, **Figure 17-20.** ***Potable water*** is safe for drinking. The other part of the system carries away wastewater. Plumbing fixtures and systems are designed to prevent mixing of potable water and wastewater and to stop sewer gas from leaking into the dwelling.

The potable water system starts with a city water supply or a well for the house. The water enters the house through a shutoff valve. The water may pass through a water conditioner. This device removes impurities such as iron and calcium.

The water line is split into two branches. One line feeds the water heater. The other line feeds the cold water system. Separate hot and cold water lines feed fixtures in the kitchen, bathrooms, and utility room.

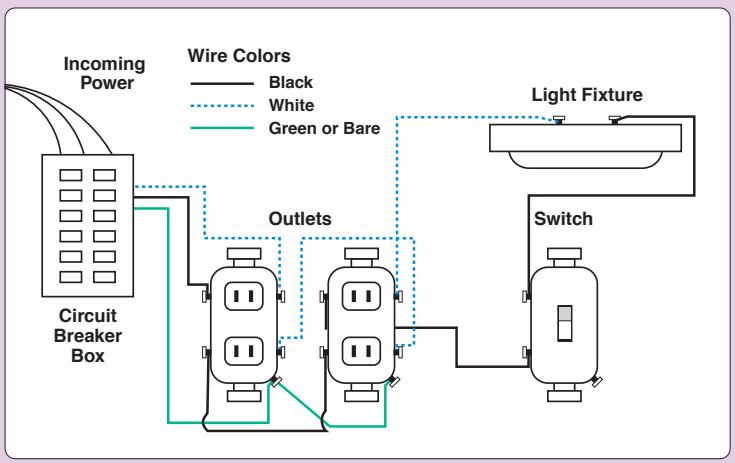

Figure 17-19. This diagram shows a 110-volt electric circuit. Note how the light is controlled by the switch but the outlets are not.

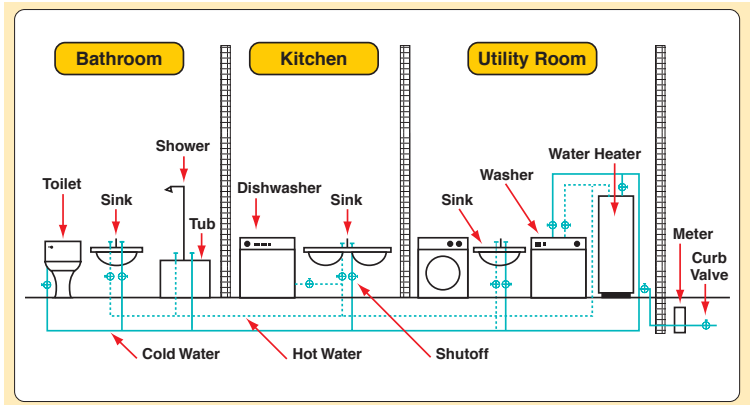

Figure 17-20. This schematic diagram shows the potable water system for a home. Each fixture has a shutoff valve.

Toilets, however, receive only cold water. Most water lines have shutoff valves before they reach the fixture.

For example, the water lines under a sink should have a shutoff valve. The valve allows repairs to be made without stopping the water flow to the rest of the house.

The second part of the plumbing system is the ***wastewater*** system. This system carries used water away from sinks, showers, tubs, toilets, and washing machines. The wastewater is routed to a city sewer line or to a septic system. At each of these fixtures and appliances, a device called a trap is provided. A trap is a U-shaped piece of pipe that remains full of water. The water in the line stops gases from the sewer system from leaking into the home. Wastewater systems have a network of vents to prevent the water from being drawn out of the traps. The vents also allow sewer gases to escape above the roof without causing any harm.

Homes that use natural gas have a third type of plumbing. Gas lines carry natural gas to furnaces, stoves, water heaters, and other appliances. Shutoff valves are installed at the entrance and at the major appliances.

Climate Control Systems

In many homes the climate control system is used to heat the building in winter and cool it in summer. This may be done with a single unit or with separate heating and cooling units.

With regard to heating systems, rooms in a home can be directly or indirectly heated. In a direct heating system, the fuel is used in the room to be heated. Direct heating may use a stove or a fireplace that burns wood or coal. Note, however, that burning wood or coal can be expensive and causes considerable air pollution.

Other direct heating methods use electrical power. These systems use resistance heaters that are installed in the walls or along the baseboards. Also, ceiling radiant wires or panels may supply the heat.

Indirect systems heat a conduction medium such as air or water. This medium then carries the heat to the rooms. The heat is then given off to the air in the room,

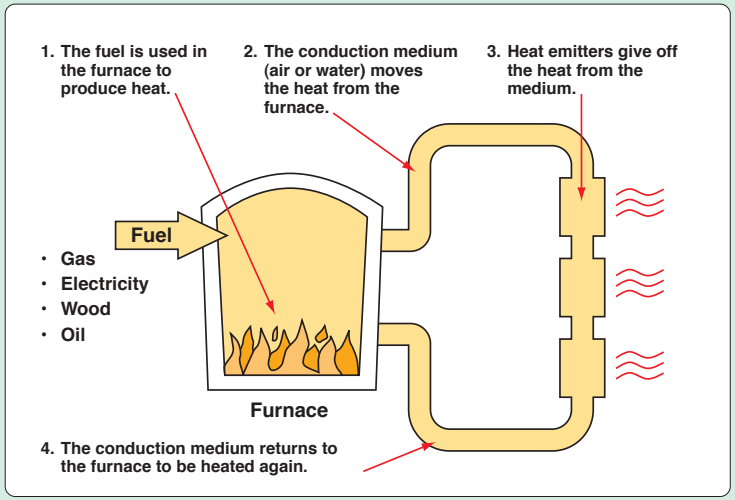

Figure 17-21. Indirect heating systems heat a conduction medium. The resulting heat is then put into the air in the room.

Figure 17-21. The energy sources for these systems are electricity, coal, oil, wood, natural gas, or propane.

Furnaces that heat air as a conduction medium are called ***forced-air heating*** systems. Forced-air furnaces draw air from the room. This air is heated as it moves through the furnace. A fan delivers the heated air through ducts to various rooms.

Hot water heating uses water to carry the heat. The water is heated in the furnace and pumped to various rooms. The water passes through room-heating units that have metal fins that surround the water pipe. The fins dissipate the heat into the room.

Some homes are heated with solar energy. Two types of solar homes exist: active and passive. Passive solar homes use no mechanical means to collect and store heat from the sun. Active solar homes use pumps or fans to move a liquid or air to collect solar heat. After the heat is collected the liquid or air is moved to a storage device. Solar heating systems are very effective in areas that have ample sunshine.

With regard to cooling systems, many buildings have cooling systems to cool the air during the warm parts of the year. Cooling systems use compressors, evaporators, and condensers much like a refrigerator. The system has a fan that draws the air from the room. The air passes over a cold evaporator. This is similar to a forced-air furnace. Instead of the air being heated, it is cooled. The cool air is returned to the room.

Another system used in climate control is a unit called a ***heat pump.*** A heat pump works as a cooling and a heating system. A heat pump can be operated in two directions. Operating in one direction the heat pump acts like an air conditioner. The heat pump takes warmth from inside the house and discharges it outside. In the winter the heat pump works in reverse. It takes warmth from the outside and brings it into the house. Heat pumps can use air, water, or the ground as a heat source. Heat pumps that use air work best in areas that do not get very cold, such as the southern and central United States. Groundwater heat pumps use well water as the heat source. The water is pumped from the well to the heat pump. The water has heat removed or the water receives excess heat, and then the water returns to the well. Ground coil systems are buried in the soil to take or give off heat. Groundwater and ground coil systems can be used in colder climates. Otherwise, heat pumps need a small furnace or other auxiliary heat source as a backup.

Connections to Technology: **Communication**

Word Origins

Probably most people would be happy to have their name become part of everyday language as a result of their invention. John McAdam, a Scottish engineer who experimented with road construction, might be doubly pleased; his work with roads has resulted in two words in common use today.

As described in this chapter, John McAdam developed the crushed stone road. This new type of road had three layers of crushed rock compacted into a solid mass. The road was also made slightly convex. McAdam's design improved roads tremendously because now the traffic load was spread, and rainwater ran off the surface. We are now more familiar with this type of roadway through the use of the term *macadam.*

The other word is even more familiar and is also related to roads. In an effort to improve roads even more, people used tar to bind the crushed rock together. This process was given the name tarmacadam or, as we now call it when we use it on runways, *tarmac.*

Modern roads are still built using John McAdam's principles. Can you find another common word we use today that is based on someone's name and invention?

Communication Systems

Most homes have communication systems such as telephone, radio, and television. These systems require special wiring. Telephone wiring and television cables are normally installed during the construction of the building. Installing them after a building is finished is costly. It takes considerable work to feed the wires through attics, under floors, and inside walls. Some homes have intercom systems that allow two-way communication between rooms. Many intercom systems allow radio programs to be played throughout the house.

Finishing the Exterior and Interior

The final exterior finishing step is installing siding and trim. Siding is the finish covering used on a wood building. Many siding materials are in use. Wood shingles and boards, plywood, hardboard, brick, stone, aluminum, vinyl, and stucco are all used as siding. Look back at Figure 17-17. You will see bricks being installed over plywood sheathing. Trim is the strips of wood that cover the joints between window and door frames and the siding.

The interior walls are the next walls to be finished. Insulation is placed between the studs and around the windows and doors of all exterior walls. Insulation reduces heat loss on cold days and heat gain on hot days. The most common type of insulation is fiberglass. It is available in blankets or batts. A vapor barrier of polyethylene film is attached to the studs over the insulation. The vapor barrier prevents moisture from building up in the insulation.

Once insulation and utilities are in place, the interior wall surfaces can be covered. The most widely used interior wall covering is gypsum wallboard, commonly known as ***drywall.*** Drywall has replaced plaster in most applications. Drywall is a sheet material made of gypsum bonded between layers of paper. The sheets of drywall are nailed or screwed onto the studs and ceiling joists. The fastener heads and drywall seams are then covered with a coating called joint compound. The compound is applied in several thin coats. This is done to make smooth surfaces and joints between the sheets of drywall.

Figure 17-22. This site was finished by grading the lot (top) and planting landscaping (bottom).

The inside and outside of the house are now ready for the finishing touches. Interior wood trim is installed around the doors and windows. Kitchen, bathroom, and utility cabinets are set in place. Floor coverings such as ceramic tile, wood flooring, carpet, or linoleum are installed over the subflooring. Baseboards are installed around the perimeter of all the rooms. The exterior siding and wood trim is painted. Interior trim is painted or stained. The walls are painted or covered with wallpaper or wood paneling. Lighting fixtures, switch and outlet covers, towel racks, and other accessories are installed. The floors and windows are cleaned. Now the home is finished and ready to be occupied.

Completing the Site

Completing the building is the major part of the project. Other work remains to be done, however. The site must be finished. Earth is moved to fill in areas around the foundation. Sidewalks and driveways are installed.

The yard area needs to be landscaped. ***Landscaping*** helps to prevent erosion and improves the appearance of the site. Trees, shrubs, and grass are planted. Landscaping can divide the lot into areas for recreation and gardening. Landscaping can be used to screen areas for privacy, direct foot traffic, and shield the home from wind, sun, and storms.

Look at **Figure 17-22.** The top view shows dirt being moved onto the site for landscaping activities. The bottom view shows a finished landscaped area. Notice how the trees and lawn improve the appearance. Also, note that a grassy mound is used to guide people onto the sidewalk.

Heavy Engineering Structures

Construction activities do not always produce buildings. We need and use many other types of constructed structures. These structures are sometimes called civil structures, or heavy engineering structures. These structures include highways, rail lines, canals, pipelines, power transmission and communication towers, hydroelectric and flood control dams, and airports. They provide the paths for the movement of water, people, goods, information, or electric power. Each of these structures is the result of ***heavy engineering construction.***

These projects can be grouped in various ways. For this discussion, we will group them into transportation, communication, and production structures.

Transportation Structures

Transportation systems depend on constructed structures. These structures include railroad lines, highways and streets, waterways, and airport runways. Other constructed works help vehicles cross uneven terrain and rivers. These structures include bridges and tunnels. Pipelines are land transportation structures that are used to move liquids or gases over long distances.

Let us look at some examples of these constructed works. We will discuss roadways and bridges.

Roadways

Roads are almost as old as civilization. People first used trails and paths to travel. Later, they developed more extensive road systems. The Romans built the first engineered roads more than two thousand years ago. Their influence remained until the 1700s, when modern road building started. Today's roads have their roots in the work of the Scottish engineer John McAdam. He developed the crushed stone road. His roads were built of three layers of crushed rock that was laid in a ribbon about 10″ (25 cm) thick. Later, this roadbed was covered with an asphalt-gravel mix. Asphalt roads are very common today. A more recent development is the concrete roadway.

Building a road starts with selecting and surveying the route. Next, the route is cleared of obstacles such as trees, rocks, and brush. The roadway is graded so that it will drain. Drainage is important to prevent road damage from freezing and thawing. Also, a dry roadbed withstands heavy traffic better than a wet, marshy one. Another reason for grading is to keep the road's slope gentle. Elevation changes are described using the term *grade*. Grades are expressed in percentages. A road with a 5 percent grade would gain or lose 5′ of height for every 100′ of distance. Most grades are kept below 7 percent.

Once the roadbed is established, the layers of the road are built, **Figure 17-23.** The graded dirt is compacted, and a layer of coarse gravel is laid. This is followed with finer gravel that is leveled and compacted. Next, the concrete or asphalt top layer is applied. Concrete roads are laid in one layer. Asphalt is generally applied in two layers: a coarse undercoat and a finer topcoat. Finally, the shoulders or edges of the road are prepared. The shoulders can be gravel or asphalt.

Bridges

Another constructed structure vital for transportation is the bridge. Bridges provide a path for vehicles to move over obstacles. These obstacles include marshy areas, ravines, other roads, or bodies of water. Bridges can carry a number of transportation systems. These systems include highways, railroads, canals, pipelines, and footpaths.

Generally there are two types of bridges: fixed and movable. A fixed bridge does not move. Once the bridge is set in place it stays there. Movable bridges can change

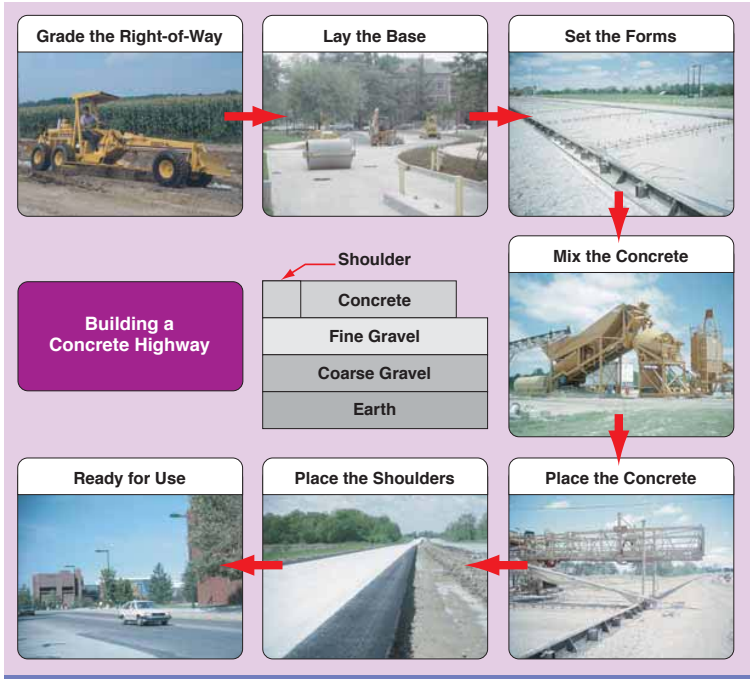

Figure 17-23. Road building is a step-by-step process.

their position to accommodate traffic below it. This type of bridge is used to span ship channels and rivers. The bridge is drawn up or swung out of the way so that ships can pass.

Bridges have two parts, **Figure 17-24.** The substructure spreads the load of the bridge to the soil. The abutments and the piers are parts of the substructure. The superstructure carries the loads of the deck to the substructure. The deck is the part used for the movement of vehicles and people across the bridge.

The kind of superstructure a bridge has indicates the type of bridge. The types of bridges are beam, truss, arch, cantilever, and suspension, **Figure 17-25.**

Beam bridges use concrete or steel beams to support the deck. This type of bridge is widely used when one road crosses another one. Beam bridges are very common on the interstate highway system.

Truss bridges use small parts arranged in triangles to support the deck. These bridges can carry heavier loads over longer spans than beam bridges. Many railroad bridges are truss bridges.

Arch bridges use curved members to support the deck. The arch may be above or below the deck. Arch bridges are used

for longer spans. One of the longest arch bridges spans more than 1650′ (502 m).

Cantilever bridges use trusses that extend out like arms. The ends of the arms can carry small span or hook up to each other. The load is transmitted by the arms to the center. None of the load is carried by the ends of the arms.

Suspension bridges use cables to carry the loads. A large cable is suspended from towers. From the large cable, smaller cables drop down to support the deck. Suspension bridges can span distances as great as 4000′ (1220 m) and longer.

Communication Structures

Most telecommunication technology relies on constructed towers to support antennas. These towers are usually placed on a concrete foundation. A steel tower is built on top of the foundation. Once the tower is complete the signal wiring can be installed. Similar techniques are used to construct towers for power transmission lines, **Figure 17-26.**

Production Structures

Some structures that are used for production activities are not buildings. For example, petroleum refineries are a mix of machinery and pipelines. Irrigation systems are constructed to bring water to farms in dry areas. Evaporation basins are built to recover salt and other minerals from seawater.

Another important production structure is the dam. Dams are used for controlling floods, supplying water, making recreational lakes, or generating electricity.

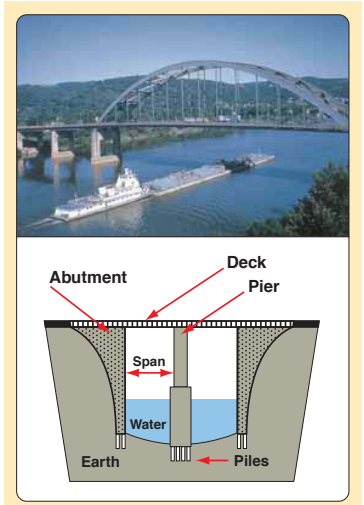

Figure 17-24. This diagram shows the parts of a bridge. An arch bridge is shown in the photo. (American Electric Power Co.)

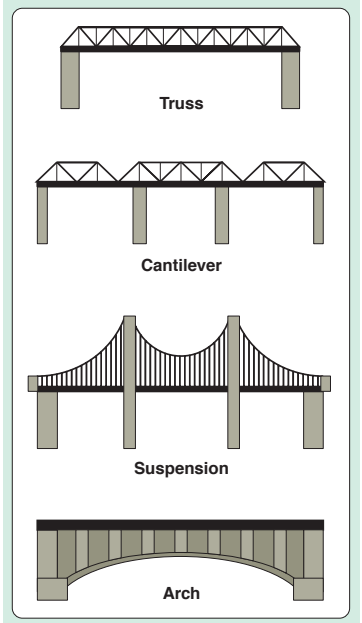

Figure 17-25. Four of the five types of bridges are the truss, the cantilever, the suspension, and the arch. The fifth is the beam bridge.

Figure 17-26. This helicopter is helping to construct a tower for an electricity transmission line. (American Electric Power Co.)

Several types of dams exist. One type is called a ***gravity dam.*** Its lakeside is vertical whereas the other side slopes outward. The sheer weight of the concrete the dam is made from holds the water back. The dam on the left in **Figure 17-27** is a gravity dam.

Two more types of dams are the rock dam and the earth dam. The earth dam is also shown in Figure 17-27. A rock dam looks like two gravity dams placed back-to-back. Both sides slope outward. Rock and earth dams must be covered with a waterproof material to prevent seepage. Clay is often used for this covering.

A ***buttress dam*** uses its structure to hold back the water. This type of dam is not solid. It uses walls of concrete to support a concrete slab or arches against the water.

Tall dams that hold back large quantities of water are called arched dams. The arched shape increases the strength of the dam. The arched shape also spreads the pressure onto the walls of the canyon where the dam is built.

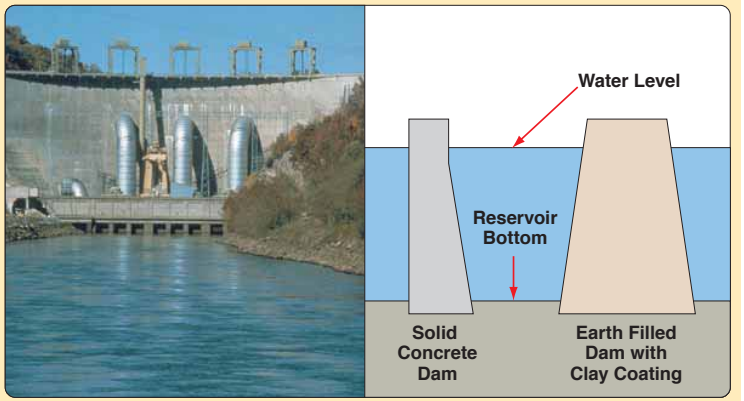

Figure 17-27. The drawing shows two common types of dams. The photo shows a gravity dam. (American Electric Power Co.).

Summary

Construction is a vital production activity. Construction provides us with homes, offices, factories, highways, railroads, pipelines, bridges, dams, and other structures. Construction can be divided into two kinds of projects: those that produce buildings and those that produce heavy engineering structures.

Most buildings are constructed using the same steps. The site is cleared and prepared for construction. The foundation for the structure is set. Then, the framework or superstructure is erected. Utilities are installed, and the structure is enclosed. The building is finished, and the site is landscaped

The construction of heavy engineering structures varies according to type. We can group these kinds of projects into three categories: transportation structures, communication structures, and production structures.

Key Terms

arch bridges
beam bridges
buildings
buttress dam
cantilever bridges
ceiling
ceiling joists
commercial buildings
construction
drywall
fascia
floor joists
forced-air heating
gravity dam
headers
heat pump
heavy engineering construction
heavy engineering structures
hot water heating
industrial buildings
landscaping
lumber
manufactured home
pile foundations
potable water
rafters
reinforced concrete
residential buildings
sheathing
sill
slab foundations
soffit
sole plate
spread foundations
steel
studs
subfloor
suspension bridges
top plate
truss
truss bridges
wastewater

Test Your Knowledge

Write your answers on a separate piece of paper. Please do not write in this book.

1. List the two kinds of constructed works.
2. *True or false?* A condominium is a residential structure that is generally owned by the people living in it.

For Questions 3–15, match the construction step on the right to the correct description on the left. (Note: Some letters will be used more than once.)

Description	Construction Step
3. _____ Sheathing the walls	a. Preparing the site
4. _____ Putting up drywall	b. Setting foundations
5. _____ Grading	c. Building the framework
6. _____ Putting in footings	d. Enclosing the structure
7. _____ Landscaping	e. Installing utilities
8. _____ Putting in heat pump	f. Finishing interior and exterior
9. _____ Installing a subfloor	g. Completing the site
10. _____ Installing the roof	
11. _____ Driving in piles	
12. _____ Marking the building site	
13. _____ Placing floor joists	
14. _____ Adding baseboards	
15. _____ Installing sidewalk	

16. *True or false?* You should use spread foundations on wet or sandy soils.
17. The two types of floors in single-family homes are concrete slab or _____.
18. What is a fascia board used for?
19. The two types of water systems that are part of a plumbing system are called _____ and _____ systems.
20. The most common type of insulation is _____.
21. A home built in a factory is called a(n) _____.
22. What does the term *grade* mean as used in this chapter?
23. *True or false?* Most railway bridges are beam bridges.
24. *True or false?* With cantilever bridges, none of the load is carried by the end of the arms.
25. Tall dams that hold back large quantities of water are called _____ dams.

Applying Your Knowledge

1. Use a chart like the one below to list and describe a few of the constructed structures you see as you travel from your home to school.

Structure	Type of Construction	Description–Use

2. Select one structure that you saw in completing the previous assignment. Make a drawing or model of the structure and label the major parts.

Modular Activity

This activity develops the skills used in TSA's Structural Engineering event.

Structural Engineering

Activity Overview

In this activity, you will create a balsa-wood bridge and determine its failure weight (load at which the bridge breaks).

Materials

- Grid paper
- 20′ of 1/8″ x 1/8″ balsa wood0
- 3″ x 5″ note card
- Glue

Background Information

General. There are several types of bridges: beam, truss, cantilever, suspension, and cable-stayed. The type of bridge used in a particular situation is generally determined by the length of the span and available materials. For this activity, a truss design is considered the most efficient.

Truss bridges. The truss bridge design is based on the assumption that the structural members carry loads along their axes in compression or tension. The members along the bottom of the bridge carry a tensile load. The members along the top of the truss carry a compressive load. The members connecting the top and bottom chords (members) can be in tension or compression.

Gussets. Gussets are plates connected to members at joints to add strength. Gussets are normally used in steel construction. The structural steel members are welded or bolted to the gusset. When designing your bridge, include a gusset at each joint, if possible.

Wood properties. Due to its molecular structure, wood can normally carry a larger load in tension than it can in compression. Also, a shorter member can carry a greater compressive load than a longer member.

Guidelines

- You must create a scale sketch of the bridge before building.
- Two pieces of balsa wood can be glued together along lengthwise surfaces. No more than *two* pieces of balsa can be glued together. You cannot use an excessive amount of glue.
- Gussets cut from the 3″ x 5″ card can be no larger than the diameter of a U.S. quarter coin. A gusset cannot touch another gusset. A gusset cannot be "sandwiched" between two pieces of balsa wood.
- The bridge design must take into account the loading device. Your teacher will provide specific guidelines for bridge length, width, and required details for attachment of a loading device.
- Your bridge will be weighed before being loaded.

Evaluation Criteria

Your project will be evaluated using the following criteria:

- Accuracy of sketch compared to completed bridge
- Conformance to guidelines
- Efficiency (failure weight ÷ bridge weight)