Wisconsin Contractors Institute

Continuing Education

<u>Waters Heaters Systems</u>

<u>(Course #13200) – 4 hours</u>

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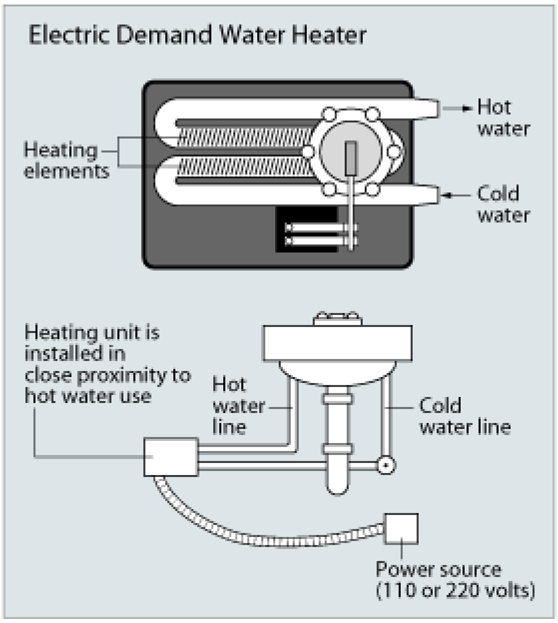
Demand (Tankless or Instantaneous) Water Heaters

Demand (tankless or instantaneous) water heaters provide hot water only as it is needed. They don't produce the standby energy losses associated with storage water heaters, which can save money. In the course you'll find basic information about how they work, whether a demand water heater might be right for your client's home, and what criteria to use when selecting the right model.



How They Work

Demand water heaters heat water directly without the use of a storage tank. Therefore, they avoid the standby heat losses associated with storage water heaters. When a hot water tap is turned on, cold water travels through a pipe into the unit. Either a gas burner or an electric element heats the water. As a result, demand water heaters deliver a constant supply of hot water. You don't need to wait for a storage tank to fill up with enough hot water. However, a demand water heater's output limits the flow rate.

Typically, demand water heaters provide hot water at a rate of 2–5 gallons (7.6–15.2 liters) per minute. Gas-fired demand water heaters produce higher flow rates than electric ones. Sometimes, however, even the largest, gas-fired model cannot supply enough hot water for simultaneous, multiple uses in large households. For example, taking a shower and running the dishwasher at the same time can stretch a demand water heater to its limit. To overcome this problem, you can install two or more demand water heaters, connected in parallel for simultaneous demands of hot water. You can also install separate demand water heaters for appliances—such as a clothes washer or dishwater—that use a lot of hot water in the home.

Other applications for demand water heaters include the following:

- Remote bathrooms or hot tubs
- Booster for appliances, such as dishwashers or clothes washers
- Booster for a solar water heating system.

Although gas-fired demand water heaters tend to have higher flow rates than electric ones, they can waste energy if they have a constantly burning pilot light. This can sometimes offset the elimination of standby energy losses when compared to a storage water heater. In a gas-fired storage water heater, the pilot light heats the water in the tank so the energy isn't wasted. The cost of operating a pilot light in a demand water heater varies from model to model. Ask the manufacturer how much gas the pilot light uses for the model you're considering. If you purchase a model that uses a standing pilot light, you can always turn it off when it's not in use to save energy. Also consider models that have an intermittent ignition device (IID) instead of a standing pilot light. This device resembles the spark ignition device on some gas kitchen ranges and ovens.

For homes that use 41 gallons or less of hot water daily, demand water heaters can be 24%–34% more energy efficient than conventional storage tank water heaters. They can be 8%–14% more energy efficient for homes that use a lot of hot water—around 86 gallons per day. You can achieve even greater energy savings of 27%–50% if you install a demand water heater at each hot water outlet.

Selecting a Demand Water Heater

Demand water heaters cost more than conventional storage water heaters. However, you may find that a demand water heater may have lower operating and energy costs, which could offset its higher purchase price.

Before buying or installing a demand water heater, you also need to consider the following:

- Size
- Fuel type and availability.
- Energy efficiency (energy factor)
- Estimate costs.

Installation and Maintenance

Proper installation and maintenance of a demand water heater can optimize its energy efficiency.

Proper installation depends on many factors. These factors include fuel type, climate, local building code requirements, and safety issues, especially concerning the combustion of gas-fired water heaters.

Most tankless water heaters have a life expectancy of more than 20 years. They also have easily replaceable parts that extend their life by many more years. In contrast, storage water heaters last 10–15 years. Periodic water heater maintenance can significantly extend the water heater's life and minimize loss of efficiency. Read the owner's manual for specific maintenance recommendations.

Sizing a Demand (Tankless or Instantaneous) Water Heater

Demand (tankless or instantaneous) water heaters are rated by the maximum temperature rise possible at a given flow rate. Therefore, to size a demand water heater, you need to determine the flow rate and the temperature rise you'll need for its application (whole house or a remote application, such as just a bathroom) in the home.

First, list the number of hot water devices you expect to use at any one time. Then, add up their flow rates (gallons per minute). This is the desired flow rate you'll want for the demand water heater. For example, let's say you expect to simultaneously run a hot water faucet with a flow rate of 0.75 gallons (2.84 liters) per minute and a shower head with a flow rate of 2.5 gallons (9.46 liters) per minute. The flow rate through the demand water heater would need to be at least 3.25 gallons (12.3 liters) per minute. To reduce flow rates, install low-flow water fixtures.

To determine temperature rise, subtract the incoming water temperature from the desired output temperature. Unless you know otherwise, assume that the incoming water temperature is 50ºF (10ºC). For most uses, you'll want your water heated to 120ºF (49ºC). In this example, you'd need a demand water heater that produces a temperature rise of 70ºF (39ºC) for most uses. For dishwashers without internal heaters and other such applications, you might want your water heated at 140ºF (60ºC). In that case, you'll need a temperature rise of 90ºF (50ºC).

Most demand water heaters are rated for a variety of inlet temperatures. Typically, a 70ºF (39ºC) water temperature rise is possible at a flow rate of 5 gallons per minute through gas-fired demand water heaters and 2 gallons per minute through electric ones. Faster flow rates or cooler inlet temperatures can sometimes reduce the water temperature at the most distant faucet. Some types of tankless water heaters are thermostatically controlled; they can vary their output temperature according to the water flow rate and inlet temperature.

EXAM QUESTIONS:

1.) **Demand water heaters heat water directly without the use of a storage tank.**
   a. True
   b. False

2.) **Typically, demand water heaters provide hot water at a rate of _____ gallons per minute.**
   a. 1 -3
   b. 2-5
   c. 4-7
   d. 6-10

3.) **Electric demand water heaters produce higher flow rates than gas-fired demand water heaters.**
   a. True
   b. False

4.) **Applications for demand waters heaters include the following:**
   a. Hot tubs
   b. Booster for appliances
   c. Remote bathrooms
   d. All of the above

5.) **For homes that use ____ gallons or less of hot water daily, demand water heaters can be 24%–34% more energy efficient than conventional storage tank water heaters.**
   a. 24
   b. 34
   c. 41
   d. 86

6.) **Demand water heaters cost more than conventional storage water heaters.**
   a. True
   b. False

7.) Before installing a demand water heater, the following needs to be considered.

a. Size
b. Fuel type
c. Energy efficiency
d. All of the above

8.) Most tankless water heaters have a life expectancy of more than ____ years.

a. 10
b. 20
c. 30
d. 40

9.) If you simultaneously run a hot water faucet with a flow rate of 0.50 gallons per minute and a shower head with a flow rate of 2.25 gallons per minute, what is the flow rate for a demand water heater?

a. 0.50
b. 2.25
c. 2.75
d. 3.25

10.) Assuming the incoming water temperature is 60ºF and you want the water heated to 140 ºF, what is the temperature rise needed for a demand water heater?

a. 60º
b. 70º
c. 80º
d. 90º

Solar Water Heaters

Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water for the home. They can be used in any climate, and the fuel they use—sunshine—is free.

How They Work

Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.

Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater. In one-tank systems, the back-up heater is combined with the solar storage in one tank.

Three types of solar collectors are used for residential applications:

- **Flat-plate collector**

  Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors—typically used for solar pool heating—have a dark absorber plate, made of metal or polymer, without a cover or enclosure.

- **Integral collector-storage systems**

  Also known as ICS or *batch* systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.

- **Evacuated-tube solar collectors**

  They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.

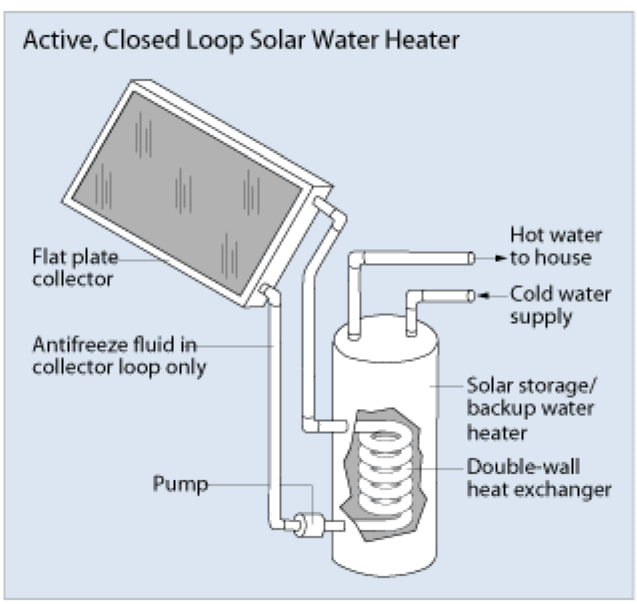
There are two types of active solar water heating systems:

- **Direct circulation systems**

  Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

- **Indirect circulation systems**

  Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.



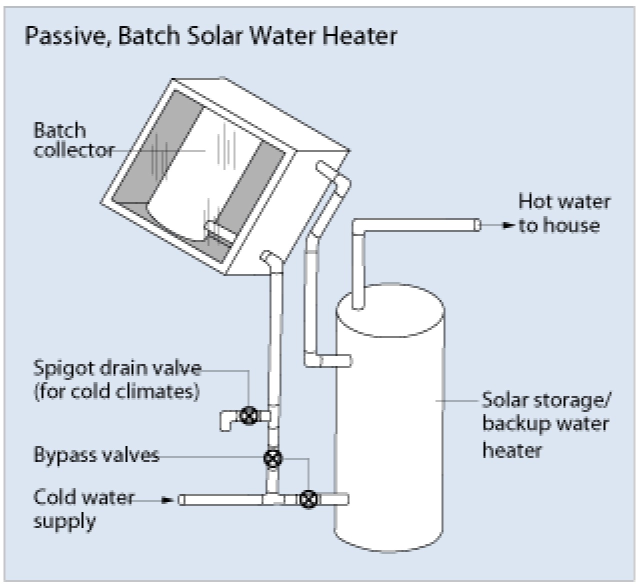
Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

- **Integral collector-storage passive systems**

  These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

- **Thermosyphon systems**

  Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.



Solar water heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosyphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a demand (tankless or instantaneous) water heater for backup.

Heat Exchangers for Solar Water Heating Systems

Solar water heating systems use heat exchangers to transfer solar energy absorbed in solar collectors to the liquid or air used to heat water or a space.

Heat exchangers can be made of steel, copper, bronze, stainless steel, aluminum, or cast iron. Solar heating systems usually use copper, because it is a good thermal conductor and has greater resistance to corrosion.

Types of Heat Exchangers

Solar water heating systems use two types of heat exchangers:

- **Liquid-to-liquid**

  This heat exchanger uses a heat-transfer fluid that circulates through the solar collector, absorbs heat, and then flows through a heat exchanger to transfer its heat to water in a storage tank. Heat-transfer fluids, such as antifreeze, protect the solar collector from freezing in cold weather. Liquid-to-liquid heat exchangers have either one or two barriers (single wall or double wall) between the heat-transfer fluid and the domestic water supply.

  A single-wall heat exchanger is a pipe or tube surrounded by a fluid. Either the fluid passing through the tubing or the fluid surrounding the tubing can be the heat-transfer fluid, while the other fluid is the potable water. Double-wall heat exchangers have two walls between the two fluids. Two walls are often used when the heat-transfer fluid is toxic, such as ethylene glycol (antifreeze). Double walls are often required as a safety measure in case of leaks, helping ensure that the antifreeze does not mix with the potable water supply. An example of a double-wall, liquid-to-liquid heat exchanger is the "wrap-around heat exchanger," in which a tube is wrapped around and bonded to the outside of a hot water tank. The tube must be adequately insulated to reduce heat losses.

  While double-wall heat exchangers increase safety, they are less efficient because heat must transfer through two surfaces rather than one. To transfer the same amount of heat, a double-wall heat exchanger must be larger than a single-wall exchanger.

- **Air-to-liquid**

  Solar heating systems with air heater collectors usually do not need a heat exchanger between the solar collector and the air distribution system. Those systems with air heater collectors that heat water use air-to-liquid heat exchangers, which are similar to liquid-to-air heat exchangers.

EXAM QUESTIONS:

11.) Passive solar water heating systems have circulating pumps and controls.

a. True
b. False

12.) Which type of solar collector is typically used for solar pool heating?

a. Unglazed flat-plate collectors
b. ICS systems
c. Evacuated tube solar collectors
d. None of the above

13.) This type of solar collector is more frequently used for commercial applications.

a. Unglazed flat-plate collectors
b. ICS systems
c. Evacuated tube solar collectors
d. None of the above

14.) **This type of solar collector should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.**

a. Unglazed flat-plate collectors
b. ICS systems
c. Evacuated tube solar collectors
d. None of the above

15.) **Indirect circulation systems are popular in climates prone to freezing temperatures.**

a. True
b. False

16.) **Passive solar water heating systems are typically more expensive than active systems.**

a. True
b. False

17.) **Which of the following is a passive solar water heating system?**

a. Direct circulation system
b. Indirect circulation system
c. Thermosyphon system
d. All of the above

18.) **Solar water heating systems almost always require a backup system for cloudy days and times of increased demand.**

a. True
b. False

19.) **This heat exchanger uses a heat-transfer fluid that circulates through the solar collector, absorbs heat, and then flows through a heat exchanger to transfer its heat to water in a storage tank.**

a. Liquid-to-liquid
b. Air-to-liquid
c. Coil-in tank
d. All of the above

Heat Exchanger Designs

There are many heat exchanger designs. Here are some common ones:

- **Coil-in-tank**

  The heat exchanger is a coil of tubing in the storage tank. It can be a single tube (single-wall heat exchanger) or the thickness of two tubes (double-wall heat exchanger). A less efficient alternative is to place the coil on the outside of the collector tank with a cover of insulation.

- **Shell-and-tube**

  The heat exchanger is separate from (external to) the storage tank. It has two separate fluid loops inside a case or shell. The fluids flow in opposite directions to each other through the heat exchanger, maximizing heat transfer. In one loop, the fluid to be heated (such as potable water) circulates through the inner tubes. In the second loop, the heat-transfer fluid flows between the shell and the tubes of water. The tubes and shell should be made of the same material. When the collector or heat-transfer fluid is toxic, double-wall tubes are used, and a non-toxic intermediary transfer fluid is placed between the outer and inner walls of the tubes.

- **Tube-in-tube**

  In this very efficient design, the tubes of water and the heat-transfer fluid are in direct thermal contact with each other. The water and the heat-transfer fluid flow in opposite directions to each other. This type of heat exchanger has two loops similar to those described in the shell-and-tube heat exchanger.

Sizing

A heat exchanger must be sized correctly to be effective. There are many factors to consider for proper sizing, including the following:

- Type of heat exchanger
- Characteristics of the heat-transfer fluid (specific heat, viscosity, and density)
- Flow rate
- Inlet and outlet temperatures for each fluid.

Usually, manufacturers will supply heat transfer ratings for their heat exchangers (in Btu/hour) for various fluid temperatures and flow rates. Also, the size of a heat exchanger's surface area affects its speed and efficiency: a large surface area transfers heat faster and more efficiently.

Installation

For the best performance, always follow the manufacturer's installation recommendations for the heat exchanger. Be sure to choose a heat-transfer fluid that is compatible with the type of heat exchanger you will be using. If you want to build your own heat exchanger, be aware that using different metals in heat exchanger construction may cause corrosion. Also, because dissimilar metals have different thermal expansion and contraction characteristics, leaks or cracks may develop. Either of these conditions may reduce the life span of the heat exchanger.

Heat-Transfer Fluids for Solar Water Heating Systems

Heat-transfer fluids carry heat through solar collectors and a heat exchanger to the heat storage tanks in solar water heating systems. When selecting a heat-transfer fluid, you should consider the following criteria:

- Coefficient of expansion – the fractional change in length (or sometimes in volume, when specified) of a material for a unit change in temperature
- Viscosity – resistance of a liquid to sheer forces (and hence to flow)
- Thermal capacity – the ability of matter to store heat
- Freezing point – the temperature below which a liquid turns into a solid
- Boiling point – the temperature at which a liquid boils

- Flash point – the lowest temperature at which the vapor above a liquid can be ignited in air.

For example, in a cold climate, solar water heating systems require fluids with low freezing points. Fluids exposed to high temperatures, as in a desert climate, should have a high boiling point. Viscosity and thermal capacity determine the amount of pumping energy required. A fluid with low viscosity and high specific heat is easier to pump, because it is less resistant to flow and transfers more heat. Other properties that help determine the effectiveness of a fluid is its corrosiveness and stability.

Types of Heat-Transfer Fluids

The following are some of the most commonly used heat-transfer fluids and their properties. Consult the local authority having jurisdiction to determine the requirements for heat transfer fluid in solar water heating systems in your area.

- **Air**

  Air will not freeze or boil, and is non-corrosive. However, it has a very low heat capacity, and tends to leak out of collectors, ducts, and dampers.

- **Water**

  Water is nontoxic and inexpensive. With a high specific heat, and a very low viscosity, it's easy to pump. Unfortunately, water has a relatively low boiling point and a high freezing point. It can also be corrosive if the pH (acidity/alkalinity level) is not maintained at a neutral level. Water with a high mineral content (i.e., "hard" water) can cause mineral deposits to form in collector tubing and system plumbing.

- **Glycol/water mixtures**

  Glycol/water mixtures have a 50/50 or 60/40 glycol-to-water ratio. Ethylene and propylene glycol are "antifreezes."

- **Hydrocarbon oils**

  Hydrocarbon oils have a higher viscosity and lower specific heat than water. They require more energy to pump. These oils are relatively inexpensive and have a low freezing point. The basic categories of hydrocarbon oils are synthetic hydrocarbons, paraffin hydrocarbons, and aromatic refined mineral oils. Synthetic hydrocarbons are relatively nontoxic and require little maintenance. Paraffin hydrocarbons have a wider temperature range between freezing and boiling points than water, but they are toxic and require a double-walled, closed-loop heat exchanger. Aromatic oils are the least viscous of the hydrocarbon oils.

- **Refrigerants/phase change fluids**

  These are commonly used as the heat transfer fluid in refrigerators, air conditioners, and heat pumps. They generally have a low boiling point and a high heat capacity. This enables a small amount of the refrigerant to transfer a large amount of heat very efficiently. Refrigerants respond quickly to solar heat, making them more effective on cloudy days than other transfer fluids. Heat absorption occurs when the refrigerant boils (changes phase from liquid to gas) in the solar collector. Release of the collected heat takes place when the now-gaseous refrigerant condenses to a liquid again in a heat exchanger or condenser.

For years chlorofluorocarbon (CFC) refrigerants, such as Freon, were the primary fluids used by refrigerator, air-conditioner, and heat pump manufacturers because they are nonflammable, low in toxicity, stable, noncorrosive, and do not freeze. However, due the negative effect that CFCs have on the earth's ozone layer, CFC production is being phased out, as is the production of hydro chlorofluorocarbons (HCFC). The few companies that produced refrigerant-charged solar systems have either stopped manufacturing the systems entirely, or are currently seeking alternative refrigerants. Some companies have investigated methyl alcohol as a replacement for refrigerants.

Since July 1, 1992, intentional venting of CFCs and HCFCs during service and maintenance or disposal of the equipment containing these compounds is illegal and punishable by stiff fines. Although production of CFCs ceased in the U.S. in 1996, a licensed refrigeration technician can still service your system. You may wish to contact your service professional to discuss the possible replacement of the CFC refrigerant with methyl alcohol or some other heat transfer fluid.

Ammonia can also be used as a refrigerant. It's commonly used in industrial applications. Due to safety considerations it's not used in residential systems. The refrigerants can be aqueous ammonia or a calcium chloride ammonia mixture.

- **Silicones**

  Silicones have a very low freezing point, and a very high boiling point. They are noncorrosive and long-lasting. Because silicones have a high viscosity and low heat capacities, they require more energy to pump. Silicones also leak easily, even through microscopic holes in a solar loop.

Solar Water Heating System Freeze Protection

Solar water heating systems, which use liquids as heat-transfer fluids, need protection from freezing in climates where temperatures fall below 42ºF (6ºC).

Don't rely on a collector's and the piping's (collector loop's) insulation to keep them from freezing. The main purpose of the insulation is to reduce heat loss and increase performance. For protecting the collector and piping from damage due to freezing temperatures, you basically have two options:

- Use an antifreeze solution as the heat-transfer fluid.
- Drain the collector(s) and piping (collector loop), either manually or automatically, when there's a chance the temperature might drop below the liquid's freezing point.

Using an Antifreeze Solution

Solar water heating systems that use an antifreeze solution (propylene glycol or ethylene glycol) as a heat-transfer fluid have effective freeze protection as long as the proper antifreeze concentration is maintained. Antifreeze fluids degrade over time and normally should be changed every 3–5 years. Since these systems are pressurized, it is not practical for the average homeowner to check the condition of the antifreeze solution.

Draining the Collector and Piping

Solar water heating systems that use only water as a heat-transfer fluid are the most vulnerable to freeze damage. "Draindown" or "drainback" systems typically use a controller to drain the collector loop automatically. Sensors on the collector and storage tank tell the controller when to shut off the circulation pump, to drain the collector loop, and when to start the pump again.

Improper placement or the use of low-quality sensors can lead to their failure to detect freezing conditions. The controller may not drain the system, and expensive freeze damage may occur. Make sure that the sensor(s) have been installed according to the manufacturer's recommendations, and check the controller at least once a year to be sure that it is operating correctly.

To ensure that the collector loop drains completely, there should also be a means to prevent a vacuum from forming inside the collector loop as the liquid drains out. Usually an air vent is installed at the highest point in the collector loop. It is a good practice to insulate air vents so that they do not freeze. Also make sure that nothing blocks the airflow into the system when the drain cycle is active.

Collectors and piping must slope properly to allow the water to drain completely. All collectors and piping should have a minimum slope of 0.25 inches per foot (2.1 centimeters per meter).

In integral collector storage or "batch" systems, the collector is also the storage tank. Placing large amounts of insulation around the unglazed parts of the collector and covering the glazing at night or on cloudy days will help to protect the collector from cold temperatures. However, water in the collector can freeze over extended periods of very cold weather. The collector supply and return pipes are also susceptible to freezing, especially if they run through an unheated space or outside. This can happen even when the pipes are well insulated. It is best to drain the entire system before freezing temperatures occur to avoid any possible freeze damage.

Selecting a Solar Water Heater

Before you purchase and install a solar water heating system, you want to do the following:

- Consider the economics of a solar water heating system
- Evaluate your site's solar resource
- Determine the correct system size
- Determine the system's energy efficiency
- Estimate and compare system costs
- Investigate local codes, covenants, and regulations.

Installing and Maintaining the System

The proper installation of solar water heaters depends on many factors. These factors include solar resource, climate, local building code requirements, and safety issues.

After installation, properly maintaining the system will keep it running smoothly. Passive systems don't require much maintenance. For active systems, discuss the maintenance requirements with the system provider, and consult the system's owner's manual. Plumbing and other conventional water heating components require the same maintenance as conventional systems. Glazing may need to be cleaned in dry climates where rainwater doesn't provide a natural rinse.

Regular maintenance on simple systems can be as infrequent as every 3–5 years. Systems with electrical components usually require a replacement part or two after 10 years.

Sizing a Solar Water Heating System

Sizing your solar water heating system basically involves determining the total collector area and the storage volume you'll need to meet 90%–100% of your household's hot water needs during the summer.

Collector Area

Contractors usually follow a guideline of around 20 square feet of collector area for each of the first two family members. For every additional person, add 8 square feet if you live in the U.S. Sun Belt area or 12–14 square feet if you live in the northern United States.

Storage Volume

A small (50- to 60-gallon) storage tank is usually sufficient for one to two three people. A medium (80-gallon) storage tank works well for three to four people. A large tank is appropriate for four to six people.

For active systems, the size of the solar storage tank increases with the size of the collector—typically 1.5 gallons per square foot of collector. This helps prevent the system from overheating when the demand for hot water is low. In very warm, sunny climates, some experts suggest that the ratio should be increased to as much as 2 gallons of storage to 1 square foot of collector area.

Other Calculations

Additional calculations involved in sizing your solar water heating system will include the following:

- Evaluation of your building site's solar resource
- Orientation and tilt of the solar collector.

EXAM QUESTIONS:

20.) In this heat exchanger design, the tubes of water and the heat-transfer fluid are in direct thermal contact with each other?

a. Coil-in-tank
b. Shell-and-tube
c. Tube-in-tube
d. None of the above

21.) This heat exchanger design is a coil of tubing in the storage tank.

a. Coil-in-tank
b. Shell-and-tube
c. Tube-in-tube
d. None of the above

22.) Which of the following factors must be considered when sizing a heat exchanger?

a. Type
b. Flow rate
c. Inlet and outlet temperatures for each fluid
d. All of the above

23.) The lowest temperature at which the vapor above a liquid can be ignited in air is called:

a. Freezing point
b. Flash point
c. Boiling point
d. Thermal capacity

24.) Heat-transfer fluids for solar water heating systems exposed to high temperatures, as in a desert climate, should have a high boiling point.

a. True
b. False

25.) Which of the following are types of heat-transfer fluids?

a. Air
b. Water
c. Silicones
d. All of the above

26.) Solar water heating systems, which use liquids as heat-transfer fluids, need protection from freezing in climates where temperatures fall below ____ºF.

a. 22
b. 32
c. 42
d. 52

27.) The main purpose of a collector's and the piping's (collector loop's) insulation is to keep them from freezing.

a. True
b. False

28.) Solar water heating systems that use only _______ as a heat-transfer fluid are the most vulnerable to freeze damage.

a. Water
b. Air
c. Silicones
d. Oils

29.) All collectors and piping for solar systems should have a minimum slope of ____ inches per foot.

a. 0.25
b. 0.50
c. 1.00
d. 1.25

30.) **How much collector area is needed for a solar system assuming you live in Wisconsin and there are 4 family members?**

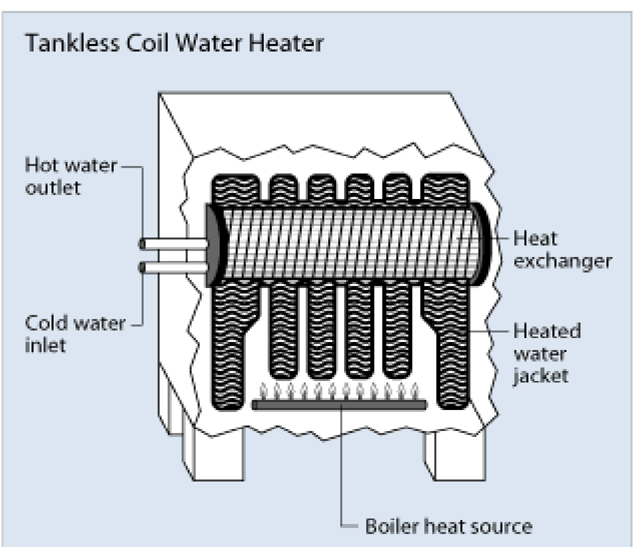
a. 20-20 square feet
b. 28-32 square feet
c. 48-52 square feet
d. 64-68 square feet

Tankless Coil and Indirect Water Heaters

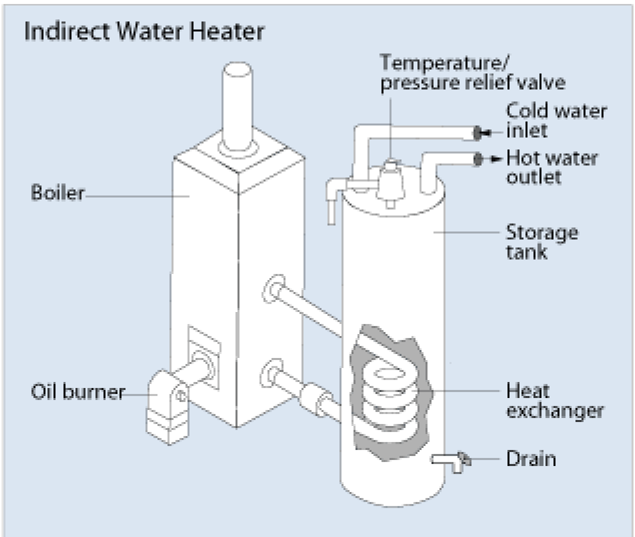
Tankless coil and indirect water heaters use a home's space heating system to heat water. They're part of what's called integrated or combination water and space heating systems.

How They Work

A tankless coil water heater uses a heating coil or heat exchanger installed in a main furnace or boiler. Whenever a hot water faucet is turned on, the water flows through the heat exchanger. These water heaters provide hot water on demand without a tank, like a demand water heater, but because they rely on the furnace or boiler to heat the water directly, tankless coil water heaters work most efficiently during cold months when the heating system is used regularly. That's why they can be an inefficient choice for many homes, especially for those in warmer climates.



Indirect water heaters offer a more efficient choice for most homes, even though they require a storage tank. An indirect water heater uses the main furnace or boiler to heat a fluid that's circulated through a heat exchanger in the storage tank. The energy stored by the water tank allows the furnace to turn off and on less often, which saves energy. Therefore, an indirect water heater is used with a high-efficiency boiler and well-insulated tank can be the least expensive means of providing hot water.



Indirect systems can be fired by gas, oil, propane, electric, solar energy, or a combination of any of these. Tankless systems are typically electric or gas-fired. Also, these integrated or combination water heating systems not only can work with forced air systems but also with hydronic or radiant floor heating systems.

Selecting a Combination Water and Space Heating System

Integrated or combination water and space heating systems usually cost more than a separate water heater and furnace or boiler, but installation and maintenance costs may be less. For example, you won't need multiple utility hook-ups since there's one source of heat. There also aren't as many moving parts to maintain or service. Some of these high efficiency systems may also provide you with lower utility costs.

Most combination water and space heating systems are usually designed for new construction. However, there are some retrofit units available that can work with an existing water heater.

When selecting a system, you need to consider its size. The sizing of a combination system involves some different calculations than those used for sizing a separate water heating or space heating system.

To determine the energy efficiency of a combination water and space heating system, use its combined appliance efficiency rating (CAE). The higher the number, the more energy efficient. Combination appliance efficiency ratings vary from 0.59 to 0.90.

EXAM QUESTIONS:

31.) Tankless coil water heaters work most efficiently during cold months when the heating system is used regularly.

a. True
b. False

32.) Indirect water heaters do not require a storage tank.

a. True
b. False

33.) Indirect systems can be fired by which of the following:

a. Oil
b. Propane
c. Electric or gas
d. All of the above

34.) Integrated or combination water and space heating systems usually cost more than a separate water heater and furnace or boiler.

a. True
b. False

Heat Pump Water Heaters

Most homeowners who have heat pumps use them to heat and cool their homes. But a heat pump also can be used to heat water—either as stand-alone water heating system, or as combination water heating and space conditioning system.

How They Work

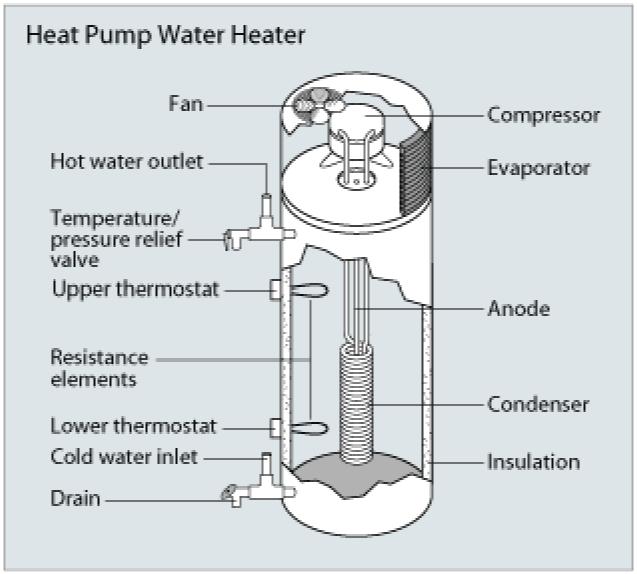
Heat pump water heaters use electricity to move heat from one place to another instead of generating heat directly. Therefore, they can be two to three times more energy efficient than conventional electric resistance water heaters. To move the heat, heat pumps work like a refrigerator in reverse.

While a refrigerator pulls heat from inside a box and dumps it into the surrounding room, a stand-alone *air-source heat pump* water heater pulls heat from the surrounding air and dumps it—at a higher temperature—into a tank to heat water. You can purchase a stand-alone heat pump water heating system as an integrated unit with a built-in water storage tank and back-up resistance heating elements. You can also retrofit a heat pump to work with an existing conventional storage water heater.

Heat pump water heaters require installation in locations that remain in the 40º–90ºF (4.4º–32.2ºC) range year-round and provide at least 1,000 cubic feet (28.3 cubic meters) of air space around the water heater. Cool exhaust air can be exhausted to the room or outdoors. Install them in a space with excess heat, such as a furnace room. Heat pump water heaters will not operate efficiently in a cold space. They tend to cool the spaces they are in. You can also install an air-source heat pump system that combines heating, cooling, and water heating. These combination systems pull their heat indoors from the outdoor air in the winter and from the indoor air in the summer. Because they remove heat from the air, any type of air-source heat pump system works more efficiently in a warm climate.

Homeowners primarily install geothermal heat pumps—which draw heat from the ground during the winter and from the indoor air during the summer—for heating and cooling their homes. For water heating, you can add a *desuperheater* to a geothermal heat pump system. A desuperheater is a small, auxiliary heat exchanger that uses superheated gases from the heat pump's compressor to heat water. This hot water then circulates through a pipe to the home's storage water heater tank.

Desuperheaters are also available for demand (tankless or instantaneous) water heaters. In the summer, the desuperheater uses the excess heat that would otherwise be expelled to the ground. Therefore, when the geothermal heat pump runs frequently during the summer, it can heat all of your water. During the fall, winter, and spring—when the desuperheater isn't producing as much excess heat—you'll need to rely more on your storage or demand water heater to heat the water. Some manufacturers also offer triple-function geothermal heat pump systems, which provide heating, cooling, and hot water. They use a separate heat exchanger to meet all of a household's hot water needs.



Selecting a Heat Pump Water Heater

Heat pump water heater systems typically have higher initial costs than conventional storage water heaters. However, they have lower operating costs, which can offset their higher purchase and installation prices.

Before buying or installing a heat pump water heating system, you also need to consider the following:

- Size and first hour rating
- Fuel type and availability
- Energy efficiency (energy factor)
- Overall costs.

<u>EXAM QUESTIONS:</u>

35.) Heat pump water heaters use ______ to move heat from one place to another instead of generating heat directly.

a. Water
b. Heat
c. Electricity
d. Gas

36.) Wisconsin has an ideal climate to install a heat pump water heater.

a. True
b. False

37.) Before installing a heat pump water system, you need to consider the following:

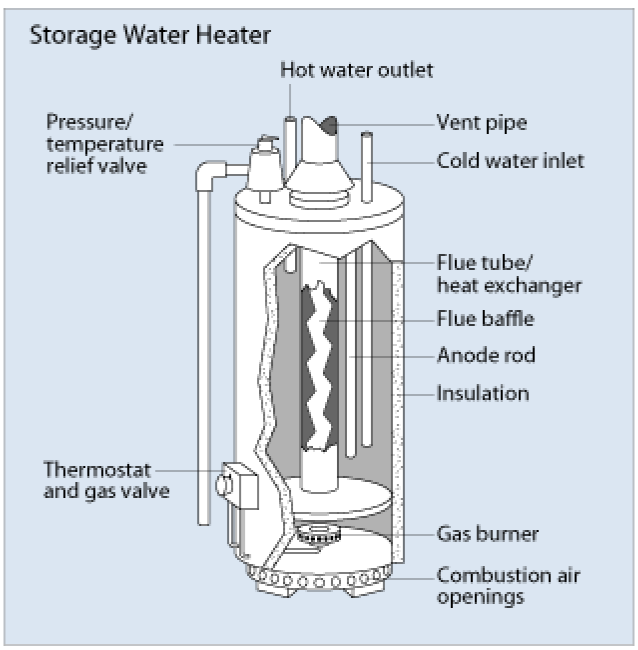
a. Size and first hour rating
b. Fuel type
c. Energy efficiency
d. All of the above

Conventional Storage Water Heaters

Conventional storage water heaters remain the most popular type of water heating system for the home. Here you'll find basic information about how storage water heaters work; what criteria to use when selecting the right model; and some installation, maintenance, and safety tips.

How They Work

A single-family storage water heater offers a ready reservoir—from 20 to 80 gallons—of hot water. It operates by releasing hot water from the top of the tank when you turn on the hot water tap. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full.



Conventional storage water heater fuel sources include natural gas, propane, fuel oil, and electricity. Natural gas and propane water heaters basically operate the same. A gas burner under the tank heats the water. A thermostat opens the gas valve as the water temperature falls. The valve closes when the temperature rises to the thermostat's setpoint. Oil-fired water heaters operate similarly, but they have power burners that mix oil and air in a vaporizing mist, ignited by an electric spark. Electric water heaters have one or two electric elements, each with its own thermostat. With two electric elements, a standby element at the bottom of the tank maintains the minimum thermostat setting while the upper demand element provides hot water recovery when demand heightens.

Because water is constantly heated in the tank, energy can be wasted even when a hot water tap isn't running. This is called *standby heat loss*. Only tankless water heaters—such as demand water heaters and tankless coil water heaters—avoid standby heat losses. However, you can find some storage water heater models with heavily insulated tanks, which significantly reduce standby heat losses, lowering annual operating costs. Look for models with tanks that have a thermal resistance (R-Value) of R-12 to R-25.

Gas and oil water heaters also have venting-related energy losses. Two types of water heaters—a fan-assisted gas water heater and an atmospheric sealed-combustion water heater—reduce these losses. The fan-assisted gas water heater uses a draft-induced fan that regulates the air that passes through the burner, which minimizes the amount of excess air during combustion, increasing efficiency. The atmospheric sealed-combustion water heater uses a combustion and venting system that is totally sealed from the house.

You might also want to consider some less conventional storage water heaters—heat pump water heaters and solar water heaters. These water heaters are usually more expensive but they typically have lower annual operating costs.

Selecting a Storage Water Heater

The lowest-priced storage water heater may be the most expensive to operate and maintain over its lifetime. While an oversized unit may be alluring, it carries a higher purchase price and increased energy costs due to higher standby energy losses.

Installation and Maintenance

Proper installation and maintenance of your water heater can optimize its energy efficiency.

Proper installation depends on many factors. These factors include fuel type, climate, local building code requirements, and safety issues, especially concerning the combustion of gas- and oil-fired water heaters.

Periodic water heater maintenance can significantly extend your water heater's life and minimize loss of efficiency. Read your owner's manual for specific maintenance recommendations.

Routine maintenance for storage water heaters, depending on what type/model, may include:

- Flushing a quart of water from the storage tank every three months
- Checking the temperature and pressure valve every six months
- Inspecting the anode rod every three to four years.

Sizing Storage and Heat Pump (with Tank) Water Heaters

To properly size a storage water heater for a home, use the water heater's first hour rating (FHR). The first hour rating is the amount of hot water in gallons the heater can supply per hour (starting with a tank full of hot water). It depends on the tank capacity, source of heat (burner or element), and the size of the burner or element.

The Energy Guide Label lists the first hour rating in the top left corner as "Capacity (first hour rating)." The Federal Trade Commission requires an Energy Guide Label on all new conventional storage water heaters but not on heat pump water heaters. Product literature from a manufacturer may also provide the first hour rating. Look for water heater models with a first hour rating that matches within 1 or 2 gallons of the peak hour demand—the daily peak 1-hour hot water demand for your home.

Do the following to estimate the peak hour demand:

- Determine what time of day (morning, noon, evening) the most hot water is used in the home. Keep in mind the number of people living in the home.
- Use the worksheet below to estimate your maximum usage of hot water during this one hour of the day—this is your peak hour demand. Note: the worksheet does not estimate total daily hot water usage.

The worksheet example shows a total peak hour demand of 46 gallons. Therefore, this household would need a water heater model with a first hour rating of 44 to 48 gallons.

Worksheet for Estimating Peak Hour Demand/First Hour Rating

Use	Average gallons of hot water per usage		Times used during 1 hour		Gallons used in 1 hour
Shower	12	×		=	
Bath	9	×		=	
Shaving	2	×		=	
Hands & face washing	4	×		=	
Hair shampoo	4	×		=	
Hand dishwashing	4	×		=	
Automatic dishwasher	14	×		=	
Food preparation	5	×		=	
Wringer clothes washer	26	×		=	
Automatic clothes washer	32	×		=	
			Total Peak Hour Demand	=	

EXAMPLE

3 showers	12 × 3 = 36
1 shave	2 × 1 = 2
1 shampoo	4 × 1 = 4
1 hand dishwashing	4 × 1 = 4
Peak Hour Demand	= 46

EXAM QUESTIONS:

38.) The first hour rating is the amount of hot water in gallons the heater can supply per hour (starting with a tank full of hot water).

a. True
b. False

39.) What is the Peak Hour Demand for a household that takes 3 showers, 1 shave, 2 hands & face washing, and 1 food preparation during the daily peak 1-hour?

a. 47
b. 51
c. 54
d. 58

40.) What is the Peak Hour Demand for a household that takes 2 showers, 1 shave, 1 shampoo and 1 hand dishwashing during the daily peak 1-hour?

a. 34
b. 40
c. 46
d. 54

WISCONSIN CONTRACTORS INSTITUTE – ANSWER SHEET

Water Heater Systems – 4 hours

First Name: ____________________ **Last Name:** ____________________________________ **Date:** _________________

Address: ____ **State:** __________ **ZIP:** ________________

WI Customer ID (license #): _________________________ **(e.g. Master Plumber #)**

Phone: ___________________________________ **Email:** ____

Water Heaters		**Water Heaters**	
	T F		T F
1.	ⓐⓑⓒⓓ	21.	ⓐⓑⓒⓓ
2.	ⓐⓑⓒⓓ	22.	ⓐⓑⓒⓓ
3.	ⓐⓑⓒⓓ	23.	ⓐⓑⓒⓓ
4.	ⓐⓑⓒⓓ	24.	ⓐⓑⓒⓓ
5.	ⓐⓑⓒⓓ	25.	ⓐⓑⓒⓓ
6.	ⓐⓑⓒⓓ	26.	ⓐⓑⓒⓓ
7.	ⓐⓑⓒⓓ	27.	ⓐⓑⓒⓓ
8.	ⓐⓑⓒⓓ	28.	ⓐⓑⓒⓓ
9.	ⓐⓑⓒⓓ	29.	ⓐⓑⓒⓓ
10.	ⓐⓑⓒⓓ	30.	ⓐⓑⓒⓓ
11.	ⓐⓑⓒⓓ	31.	ⓐⓑⓒⓓ
12.	ⓐⓑⓒⓓ	32.	ⓐⓑⓒⓓ
13.	ⓐⓑⓒⓓ	33.	ⓐⓑⓒⓓ
14.	ⓐⓑⓒⓓ	34.	ⓐⓑⓒⓓ
15.	ⓐⓑⓒⓓ	35.	ⓐⓑⓒⓓ
16.	ⓐⓑⓒⓓ	36.	ⓐⓑⓒⓓ
17.	ⓐⓑⓒⓓ	37.	ⓐⓑⓒⓓ
18.	ⓐⓑⓒⓓ	38.	ⓐⓑⓒⓓ
19.	ⓐⓑⓒⓓ	39.	ⓐⓑⓒⓓ
20.	ⓐⓑⓒⓓ	40.	ⓐⓑⓒⓓ

Wisconsin Contractors Institute

Construction Codes

(Based on WI Comm 21)

For more information:

Website: www.wcitraining.com

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Construction Codes

This is a summary of many of the main topics in Comm 21. A full copy of the regulations can be found on the Wisconsin Contractors Institutes website.

Subchapter I — Scope

Comm 21.01 Scope.

The provisions of this chapter shall apply to the design and construction of all one− and 2−family dwellings.

Subchapter II — Design Criteria

Comm 21.02 Loads and materials.

Every dwelling shall be designed and constructed in accordance with the requirements of this section.

(1) DESIGN LOAD.

Every dwelling shall be designed and constructed to support the actual dead load, live loads and wind loads acting upon it without exceeding the allowable stresses of the material. The construction of buildings and structures shall result in a system that provides a complete load path capable of transferring all loads from point of origin through the load−resisting elements to the foundation.

(a) *Dead loads.* Every dwelling shall be designed and constructed to support the actual weight of all components and materials. Earth−sheltered dwellings shall be designed and constructed to support the actual weight of all soil loads.

(b) *Live loads.* 1. 'Floors and ceilings.' Floors and ceilings shall be designed and constructed to support the minimum live loads listed in Table 21.02. The design load shall be applied uniformly over the component area.

TABLE 21.02

Component	Live Load (pounds per sq. ft.)
Floors	40
Garage floors	50
Exterior balconies, decks, porches	40
Ceilings (with storage)	20
Ceilings (without storage)	5

2. 'Snow loads.' Roofs shall be designed and constructed to support the minimum snow loads listed on the zone map. The loads shall be assumed to act vertically over the roof area projected upon a horizontal plane.

(c) *Wind loads.* Dwellings shall be designed and constructed to withstand a horizontal and uplift pressure of 20 pounds per square foot acting over the surface area.

(d) *Fasteners.* All building components shall be fastened to withstand the dead load, live load and wind load.
(3) STRUCTURAL STANDARDS. (a) *General.* Design, construction, installation, practice and structural analysis shall conform to the following nationally recognized standards. (b) *Wood.* 1. Except as provided in subd. 1. a. and b., structural lumber, glue−laminated timber, timber pilings and fastenings shall be designed in accordance with the "National Design Specification for Wood Construction" and the "Design Values for Wood Construction," a supplement to the National Design Specification for Wood Construction. a. Section 2.2.5.3. The cumulative effects of short−time loads, such as snow, shall be considered in determining duration of load. For snow load, no greater duration of load factor than 1.15 shall be used. b. Section 4.1.7. The provisions of this section shall also apply to reused lumber. Reused lumber shall be considered to have a duration of load factor of 0.90. 2. Span tables for joists and rafters printed in the appendix or approved by the department may be used in lieu of designing by structural analysis. 3. Sawn lumber that is not graded in accordance with the standards under subd. 1., shall use the NDS published allowable design stresses for the lumber species using grade number 3 when used for studs, stringers, rafters or joists and may use grade number 1 when used for beams, posts or timbers. (c) *Structural steel.* The design, fabrication and erection of structural steel for buildings shall conform to Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design and the provisions of the accompanying commentary as adopted under Table 20.24−3. (d) *Concrete.* Plain, reinforced or pre-stressed concrete construction shall conform to the following standards: 1. ACI Standard 318, "Building Code Requirements for Reinforced Concrete". 2. ACI Standard 318.1, "Building Code Requirements for Structural Plain Concrete". (e) *Masonry.* The design and construction of masonry shall conform to the following standards: 1. ACI 530, Building Code Requirements for Masonry Structures. (f) *Engineered structural components.* Engineered structural components shall be used in

accordance with structural analysis or with load tables supplied by the manufacturer, provided those load tables were developed using structural analysis or load testing.

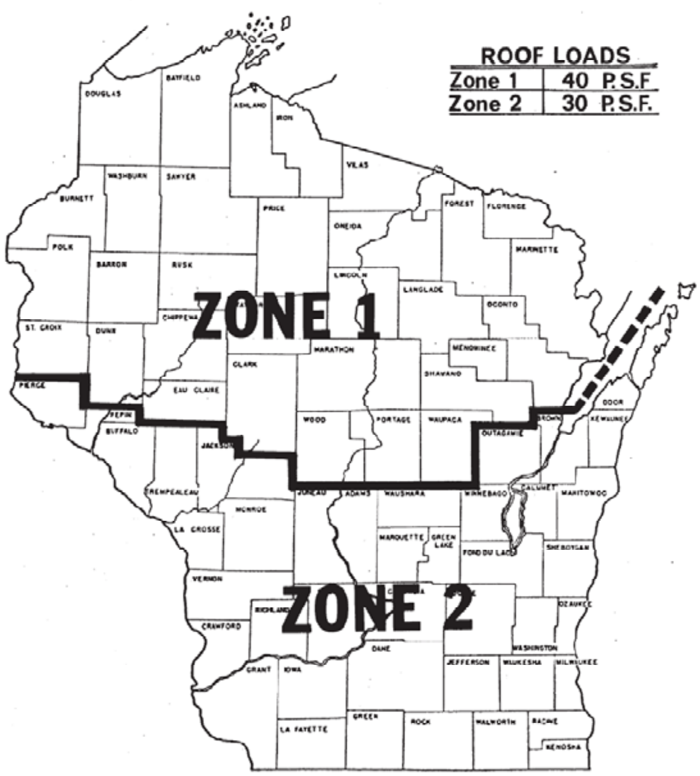
(g) *Whole logs.* Dwellings constructed of whole logs shall conform to the following standards:

1. ILBA Log Building Standards for Residential, Handcrafted, Interlocking, Scribe−fit Construction.

Note: This standard requires the minimum log diameter to be 8 inches.

2. ICC/ANSI 400, Standard on the Design and Construction of Log Structures.

Figure 21.02
ZONE MAP FOR ROOF LOADS



Comm 21.03 Exits.

Exits, doors and hallways shall be constructed as specified in this section.

(1) EXITS FROM THE FIRST FLOOR. (a) Except as allowed under par. (h), every dwelling unit shall be provided with at least 2 exit doors accessible from the first floor.

(b) At least one of the exits shall discharge to grade and may not go through a garage. This exit may include interior or exterior stairs.

(c) An additional exit may discharge to an outside balcony that complies with sub. (8).

(d) An additional exit may discharge into an attached garage provided the garage has an exit door that discharges to grade. An overhead garage door may not be used as an exit door.

(e) Except as allowed under pars. (f) and (h), the 2 required exit doors shall be separated by at least the greater of the following distances:

1. One−third the length of the longest diagonal of the floor in plan view, exclusive of an attached garage.

2. 20 feet.

(f) 1. First floor levels that do not meet the separation requirements under par. (e), shall have at least one egress window complying with sub. (6) on that floor level.

2. An egress window to comply with subd. 1. shall be separated from at least one door on the first floor by one of the distances under par. (e).

3. If first floor levels that do not meet the separation requirements under par. (e) contain one or more sleeping rooms, each sleeping room shall have at least one egress window complying with sub. (6).

(g) 1. The exit separation distance required under par. (e) shall be calculated or measured as a straight line from the midpoint of one doorway to the midpoint of the other doorway.

2. For exiting through an attached garage, the separation distance shall be measured using the door connecting the garage and the dwelling. Distance within the garage shall be ignored.

(h) 1. Dwellings consisting of no more than a first floor with a maximum floor area of 400 square feet and a loft area not exceeding half of the first floor area, shall be provided with at least one exit door leading directly to the exterior and at least one egress window that complies with sub. (6).

2. a. Dwellings that meet the size restrictions under subd. 1., are not required to meet the exit separation requirements under par. (e) or (f).

b. If a dwelling that meets the size restrictions under subd. 1., has more than one room on the first floor, the door and the egress window shall be located in different rooms.

(2) EXITS FROM THE SECOND FLOOR. (a) At least 2 exits shall be provided from the second floor. One of the exits shall be a stairway or ramp and lead to the first floor or discharge to grade. The second exit may be via a stairway or ramp which discharges to grade

or may discharge to a balcony which complies with sub. (8). (b) Except as provided in par. (c), windows which comply with sub. (6) may be provided in each second floor bedroom in lieu of the second exit from the floor. (c) Where the second floor is the lowest floor level in a dwelling unit, as in an up–and–down duplex, windows may not be provided as the second exit from the floor.
(3) EXITS ABOVE THE SECOND FLOOR. (a) Except as provided under pars. (b) and (c), each habitable floor above the second floor shall be provided with at least 2 exits that meet all of the following requirements: 1. The exits shall be stairways or ramps that lead to the second floor or discharge to grade. 2. The exits shall be located such that an exit is accessible to the second floor if another exit is blocked.
1. The dwelling is fully sprinklered in accordance with NFPA13R or NFPA 13D. 2. If a required exit includes an attached garage, the garage shall be sprinklered.
(4) EXITS FROM LOFTS. (a) At least one stairway exit shall be provided, to the floor below, for a loft exceeding 400 square feet in area. (b) At least one stairway or ladder exit shall be provided to the floor below for a loft, 400 square feet or less, in area. **(5)** EXITS FROM BASEMENTS AND GROUND FLOORS. (a) *General.* Except as provided in par. (b), all basements and ground floors shall be provided with at least one exit of the following types: 1. A door to the exterior of the dwelling. 2. A stairway or ramp that leads to the floor above. **(6)** WINDOWS USED FOR EXITING. Windows which are installed for exit purposes shall comply with the requirements of this subsection. (a) The window shall be openable from the inside without the use of tools or the removal of a sash. If equipped with a storm or screen, it shall be openable from the inside.

(b) 1. The nominal size of the net clear window opening shall be at least 20 inches by 24 inches irrespective of height or width. Nominal dimensions shall be determined by rounding up fractions of inches if they are ½ inch or greater or rounding down fractions of inches if they are less than ½ inch.

(7) DOORS USED FOR EXITING. (a) Doors used for exiting from a dwelling shall meet the following dimensions:

1. At least one exit door shall be a swing−type door at least 80 inches high by 36 inches wide.

2. Except as allowed under subds. 3. and 4., other required exit doors shall be at least 76 inches high by 32 inches wide.

3. Where double doors are used as a required exit, each door leaf shall provide a clear opening at least 30 inches wide and be at least 76 inches high.

4. Where sliding doors are used as a required exit, the clear opening shall be at least 30 inches wide and be at least 76 inches high.

(8) BALCONIES. (a) Balconies shall be made of concrete, metal or wood which is treated, protected or naturally decay−resistive in accordance with s. Comm 21.10.

(9) SPLIT LEVEL DWELLINGS. In determining the exit requirement in a split level dwelling, all levels that are to be considered a single story shall be within 5 feet of each other.

(10) TWO−FAMILY DWELLINGS. In a 2−family dwelling, each dwelling unit shall be provided with exits in compliance with this section.

Comm 21.035 Interior circulation.

(1) DOORS AND OPENINGS. All doors and openings to the following areas shall be at least 80 inches high and provide either a net clear opening width of 30 inches or be a 32−inch door:

(a) Except as provided under pars. (b) and (c), all entrances into common use areas.

(b) At least 50% of the bedrooms.

(c) 1. At least one full bathroom, including doors or openings to a sink, toilet and tub or shower. If this bathroom is accessible only through a bedroom, the bedroom door shall meet the minimum width requirements of this section.

(2) HALLWAYS. (a) Except as allowed under par. (b), the clear width of hallways shall be at least 36 inches.

(b) The following are allowed to infringe on the required clear width of a hallway:

1. Door hardware and finish trim.
2. Handrails may infringe into the minimum width of a hallway up to 4 1/2 inches on each side.
3. Heating registers may infringe into the minimum width of a hallway up to 4 1/2 inches and no part of the register may be more than 38 inches above the floor.
4. Ducts, pipes, light fixtures, structural features, and corner treatments that are within 84 inches of the floor may infringe into the minimum width of a hallway by a maximum of 4 1/2 inches on each side.
5. Unlimited infringements are allowed in a hallway more than 84 inches above the floor.

(3) KITCHENS. (a) There shall be at least 30 inches of clearance between a wall, a permanently−installed kitchen island, permanently− installed kitchen cabinets and the following kitchen appliances, if provided:
1. A range, cook top or oven.
2. A sink, refrigerator or freezer.

(b) Measurements shall be taken from the face of the wall, island, cabinet or appliance, ignoring knobs and handles.

Comm 21.04 Stairways and elevated areas.

(2) DETAILS. (a) *Width.* 1. Except for spiral staircases under subd. 2., stairways shall measure at least 36 inches in width. Handrails and associated trim may project a maximum of 4.5 inches into the required width at each side of the stairway.

2. Risers in spiral staircases may not exceed 9.5 inches in height measured vertically from tread to tread.

(c) *Tread depth.* 1. 'Rectangular treads.' Rectangular treads shall have minimum tread depth of 9 inches measured horizontally from nosing to nosing.

(3) HANDRAILS AND GUARDRAILS. (a) *General.* 1. Stair flights with more than 3 risers shall be provided with at least one handrail for the full length of the stair flight.

4. a. Handrails and guardrails shall be designed and constructed to withstand a 200 pound load applied in any direction.

(c) *Guardrails.* 1. 'Application.' a. All openings between floors, and open sides of landings, platforms, balconies or porches that are more than 24 inches above grade or a floor shall be protected with guardrails.

Comm 21.042 Ladders.

Ladders which are used as part of a required exit shall conform to this section.

(1) DESIGN LOAD. Ladders shall be designed to withstand loads of at least 200 pounds.

(2) TREAD OR RUNGS. (a) Minimum tread requirements shall be specified in Table 21.042. Treads less than 9 inches in width shall have open risers. All treads shall be uniform in dimension.

Comm 21.045 Ramps.

(2) SLOPE. Ramps shall not have a gradient greater than 1 in 8 or one foot of rise in 8 feet of run. Walkways with gradients less than 1 in 20 or one foot of rise in 20 feet of run are not considered to be ramps.

(3) SURFACE AND WIDTH. Ramps shall have a slip resistant surface and shall have a minimum width of 36 inches measured between handrails.

Comm 21.05 Natural light and natural ventilation. **(3)** SAFETY GLASS. Except as provided in par. (e), glazing shall consist of safety glass meeting the requirements of CPSC 16 CFR, Part 1201 when installed in any of the following locations: (a) In any sidelight or glazing adjacent to a door that meets all of the following: 1. The nearest point of the glazing is within 2 feet of the door. 2. The nearest point of the glazing is within 5 feet of the floor. 3. The plane of the glazing is within 30 degrees of the plane of the door when the door is in the closed position
Comm 21.06 Ceiling height. All habitable rooms, kitchens, hallways, bathrooms and corridors shall have a ceiling height of at least 7 feet. Habitable rooms may have ceiling heights of less than 7 feet provided at least 50% of the room's floor area has a ceiling height of at least 7 feet. Beams and girders or other projections shall not project more than 8 inches below the required ceiling height.
Comm 21.07 Attic and crawl space access. **(1)** ATTIC. Attics with 150 or more square feet of area and 30 or more inches of clear height between the top of the ceiling framing and the bottom of the rafter or top truss chord framing shall be provided with an access opening of at least 14 by 24 inches, accessible from inside the structure. **(2)** CRAWL SPACES. Crawl spaces with 18 inches of clearance or more between the crawl space floor and the underside of the house floor joist framing shall be provided with an access opening of at least 14 by 24 inches.

Comm 21.08 Fire separation and dwelling unit separation.

TABLE 21.08

Between Dwelling And:	Distance Between Objects[1]	Fire Rated Construction[2,5]
Detached garage or accessory building on same property	Less than 5 feet	3/4−hour wall[3] 1/3−hour door or window[3]
Another dwelling on same property	Less than 5 feet	3/4−hour wall[4] 1/3−hour door or window[4]
Detached garage, accessory building, or other dwelling on same property	5 to 10 feet	3/4−hour wall[3] No requirement on openings
Detached garage, accessory building, or other dwelling on same property	More than 10 feet	No requirements
Property Lines	Less than 3 feet	3/4−hour wall 1/3−hour door or window
Property Lines	3 feet or more	No Requirements
Zero Lot Line	None	Follow sub. (2) (d) requirements

Comm 21.085 Fireblocking.

(1) FIREBLOCKING LOCATIONS.
Fireblocking shall be provided in all of the following locations:

(a) In concealed spaces of walls and partitions, including furred spaces, at the ceiling and floor levels.

(b) At all interconnections between concealed vertical and horizontal spaces including the attachment between a carport and a dwelling.

(c) In concealed spaces between stair stringers at the top and bottom of the run and at any intervening floor level.

(d) At all openings around wires, cables, vents, pipes, ducts, chimneys and fireplaces at ceiling and floor level.

(2) FIREBLOCKING MATERIALS. Fireblocking shall consist of one of the following:

(a) 2−inch nominal lumber.

(b) Two layers of one−inch nominal lumber.

(c) One thickness of 3/4−inch nominal plywood or wood structural panel with any joints backed with the same material.

(d) One thickness of 1/2−inch gypsum wallboard, face nailed or face screwed to solid wood, with any joints backed with the same material.

Comm 21.09 Smoke detectors.

(1) A listed and labeled multiple−station smoke alarm with battery backup shall be installed in all of the following locations:

(a) An alarm shall be installed inside each sleeping room.

(b) On floor levels that contain one or more sleeping areas, an alarm shall be installed outside of the sleeping rooms, within 21 feet of the centerline of the door opening to any sleeping room and in an exit path from any sleeping room.

(c) On floor levels that do not contain a sleeping area, an alarm shall be installed in a common area on each floor level.

Comm 21.095 Automatic fire sprinklers.

(1) Except as allowed under sub. (2), where automatic fire sprinklers using a dedicated water supply system are installed, the design, installation, testing and maintenance shall follow the requirements of NFPA 13D.

(2) Limited area dwelling systems are allowed.

Comm 21.097 Carbon monoxide alarms.

(1) DEFINITIONS.

In this section:

(a) "Fuel−burning appliance" has the meaning given in s. 101.647 (1) (b), Stats. Fuel−burning appliances include stoves, ovens, grills, clothes dryers, furnaces, boilers, water heaters, fireplaces and heaters.

(2) NEW CONSTRUCTION. (a) *General.* Except as provided in sub. (4), listed and labeled carbon monoxide alarms shall be installed and maintained in accordance with s. 101.647 (2) to (6), Stats., in one and 2-family dwellings, for which building permit applications were made or construction commenced on or after February 1, 2011.

(b) *Location.* 1. On floor levels that contain one or more sleeping areas, a carbon monoxide alarm shall be installed outside of the sleeping area, within 21 feet of the centerline of the door opening to any sleeping area and in an exit path from any sleeping area.

2. On floor levels that do not contain a sleeping area, a carbon monoxide alarm shall be installed in a common area on each floor level.

(c) *Electrical service and interconnection.*
1. Except as provided in sub. 2., carbon monoxide alarms shall be continuously powered by the house electrical service, shall have a backup power supply and shall be interconnected so that activation of one alarm will cause activation of all alarms.

2. Dwellings with no electrical service shall be provided with battery-powered carbon monoxide alarms in the locations under par. (b). Interconnection is not required in these dwellings.

Comm 21.10 Protection against decay and termites.

(1) Wood used in any of the applications under this section shall meet all of the following requirements:

(a) The wood shall be labeled and pressure treated with preservative in accordance with an AWPA standard or shall be naturally durable and decay−resistant or shall be engineered to be decay resistant.

(b) The wood shall be pressure treated with preservative or shall be naturally termite−resistant unless additional steps are taken to make the wood termite−resistant.

Comm 21.11 Foam plastic.
(1) (a) *General.* Foam plastic insulation shall have a flame−spread rating of 75 or less and a smoke−developed rating of 450 or less when tested in accordance with ASTM E−84.

(b) *Thermal barrier.* Except as provided in par. (c), foam plastic insulation shall be separated from the interior of the dwelling by one of the following thermal barriers:
1. 1/2−inch gypsum wallboard.
2. 1/2−inch nominal wood structural panel.
3. 3/4−inch sawn lumber with tongue−and−groove or lap joints.
4. 1−inch of masonry or concrete.

Comm 21.115 Installation of elevators or dumbwaiters.

Elevators or dumbwaiters serving dwelling units shall comply with the requirements under ch. Comm 18.

Subchapter III — Excavations

Comm 21.12 Grade.

The finished grade of the soil shall slope away from the dwelling at a rate of at least ½ inch per foot for a minimum distance of 10 feet, or to the lot line, whichever is less.

(2) MANDATED PRACTICES. Specific practices at each site where land disturbing construction activity is to occur shall be utilized to prevent or reduce all of the following:

(a) The deposition of soil from being tracked onto streets by vehicles.

(b) The discharge of sediment from disturbed areas into on− site storm water inlets.

(c) The discharge of sediment from disturbed areas into abutting waters of the state.

(d) The discharge of sediment from drainage ways that flow off the site.

(e) The discharge of sediment by dewatering activities.

(f) The discharge of sediment eroding from soil stockpiles existing for more than 7 days.

Comm 21.126 Storm water management.

Storm water management practices shall be employed in accordance with s. NR 151.12 and maintained when the land disturbing construction activity involves one or more acres.

Comm 21.13 Excavations adjacent to adjoining property.

(1) NOTICE. Any person making or causing an excavation which may affect the lateral soil support of adjoining property or buildings shall provide at least 30 days written notice to all owners of adjoining buildings of the intention to excavate. The notice shall state that adjoining buildings may require permanent protection.

Subchapter IV — Footings

Comm 21.15 Footings.

(1) GENERAL. (a) The dwelling and attached structures, such as decks and garages, shall be supported on a structural system designed to transmit and safely distribute the loads to the soil.

(b) The loads for determining the footing size shall include the weight of the live load, roof, walls, floors, pier or column, plus the weight of the structural system and the soil over the footing.

(c) Footings shall be sized to not exceed the allowable material stresses.

(d) The bearing area shall be at least equal to the area required to transfer the loads to the supporting soil without exceeding the bearing capacity of the soil.

(e) Structures supported on floating slabs or similar shallow foundations may not be physically attached to structures that are supported by footings that extend below the frost line unless an isolation joint is used between the structures. This isolation shall extend for the full height of the structure.

(2) SIZE AND TYPE. Unless designed by structural analysis, unreinforced concrete footings shall comply with the following requirements:

(a) *Continuous footings.* The minimum width of the footing on each side of the foundation wall shall measure at least 4 inches wider than the wall. The footing depth shall be at least 8 inches nominal. Footing placed in unstable soil shall be formed. Lintels may be used in place of continuous footings when there is a change in footing elevation.
Note: Unstable soil includes soils that are unable to support themselves at a 90 degree angle for the full depth of the footing.

(b) *Column or pier footing.*
1. The minimum width and length of column or pier footings shall measure at least 2 feet by 2 feet.

2. The minimum depth of column or pier footings shall measure at least 12 inches nominal.

(c) *Trench footings.* Footings poured integrally with the wall may be used when soil conditions permit. The minimum width shall be at least 8 inches nominal.

Comm 21.16 Frost protection.
(1) GENERAL.
(a) Except as allowed under sub. (2), footings and foundations, including those for ramps and stoops, shall be placed below the frost penetration level or at least 48 inches below adjacent grade, whichever is deeper.

Comm 21.17 Drain tiles.
(1) DETERMINATION OF NEED.
(a) *New construction.* 1. Except as provided under sub. (2), a complete drain tile or pipe

system shall be installed around the foundation of dwellings under construction where groundwater occurs above the bottom of the footing.

Subchapter V — Foundations

Comm 21.18 Foundations.

(1) GENERAL.

(a) *Design.*

Foundation walls shall be designed and constructed to support the vertical loads of the dwelling, lateral soil pressure, and other loads without exceeding the allowable stresses of the materials of which the foundations are constructed.

(b) *Lateral support at base.* Lateral support such as floor slabs or framing shall be provided at the base of foundation walls.

(c) *Lateral support at top.* Lateral support shall be provided at the top of the foundation walls by one of the following:

2. Structural analysis. A system designed through structural analysis.

3. Anchor bolts.

a. Structural steel anchor bolts, at least ½ inch in diameter, embedded at least 7 inches into the [concrete or] grouted masonry with a maximum spacing of 72 inches and located within 18 inches of wall corners.

b. A properly sized nut and washer shall be tightened on each bolt to the plate or sill.

(3) MASONRY FOUNDATION WALLS.

(a) *Dampproofing.* 1. Except as allowed under subd. 3., masonry block foundation walls shall be coated with a layer of minimum 3/8−inch thick type M or S portland cement mortar parging on the exterior of the wall from footing to finished grade.

Subchapter VI — Floors

Comm 21.20 Concrete floors.

(1) When concrete floors are provided, the thickness of the concrete shall measure at least 3 inches.

(2) When a concrete floor is placed in clay soils, a 4−inch thick base course shall be placed in the subgrade consisting of clean graded sand, gravel or crushed stone.

(3) When a concrete floor is placed on sand or gravel soils, the base course may be omitted unless drain tile is installed. If drain tile is installed, the requirements of s. Comm 21.17 shall be met.

Comm 21.203 Garage floors.

(1) MATERIALS. Garage floors shall be constructed of concrete or other noncombustible materials which are impermeable to petroleum products. Slab− on−grade concrete garage floors shall be at least 4 inches thick and placed over at least 4 inches of granular fill.

Comm 21.22 Wood frame floors.

Unless designed through structural analysis, wood frame floors shall comply with the following requirements:

(1) FLOOR JOISTS. (a) *General.*

1. Floor joists shall comply with the structural requirements and live load determination under s. Comm 21.02.

2. Where the joists of a floor system are parallel to, and located between bearing walls above and below, the joists shall be doubled.

(b) *Floor joists on concrete walls.* Where a sill plate is provided for floor joists on poured concrete, the sill plates shall be fastened to the foundation.

(c) *Floor joists on masonry walls with a solid top course.* Where a sill plate is provided for floor joists on solid block top course masonry, the sill plate shall be fastened to the foundation.

(d) *Floor joists on masonry walls with open top course.*

1. Where the masonry wall has an open top course, a sill plate at least as wide as the foundation wall shall be fastened to the foundation.

2. Where anchor bolts are used on masonry walls with an open top course, the minimum width of an individual piece making up the sill plate shall be at least 5.5 inches.

(7) FLOOR OPENINGS. Trimmers and headers shall be doubled when the span of the header exceeds 4 feet. Headers which span more than 6 feet shall have the ends supported by joist hangers or framing anchors, unless the ends are supported on a partition or beam. Tail joists (joists which frame into headers) more than 8 feet long shall be supported on metal framing anchors or on ledger strips of at least 2 inches by 2 inches nominal.

(8) (e) *Planks.* Planks shall be tongue and groove or splined and at least 2 inches, nominal, in thickness. Planks shall terminate over beams unless the joints are end matched. The planks shall be laid so that no continuous line of joints will occur except at points of support. Planks shall be nailed to each beam.

Comm 21.225 Decks.

Decks attached to dwellings and detached decks which serve an exit shall comply with the applicable provisions of this chapter, including but not limited to: **(1)** Excavation requirements of s. Comm 21.14; **(2)** Footing requirements of s. Comm 21.15 (2) (f); **(3)** Frost penetration requirements of s. Comm 21.16; **(4)** Load requirements of s. Comm 21.02; **(5)** Stair, handrail and guardrail requirements of s. Comm 21.04; and **(6)** Decay **protection requirements** of s. Comm 21.10
Subchapter VII — Walls
Comm 21.23 Wall design. **(1)** LIVE AND DEAD LOADS. All walls shall support all superimposed vertical dead loads and live loads from floors and roofs. **(2)** HORIZONTAL WIND LOAD. Walls shall be designed to withstand a horizontal wind pressure of at least 20 pounds per square foot applied to the vertical projection of that portion of the dwelling above grade. No wind load reduction shall be permitted for the shielding effect of other buildings.
Comm 21.24 Exterior covering. **(1)** GENERAL. The exterior walls shall be covered with a permanent weather resistant finish. **(2)** DURING CONSTRUCTION. During construction, wall cavity insulation may not be installed until a water−resistant covering is in place over the wall cavity and windows, doors and a roof with at least underlayment are installed.
(3) FLASHING. (a) Corrosion−resistant flashing shall be installed in the exterior wall to prevent water from entering the wall cavity or coming in contact with the structural framing components. (b) The flashing shall extend to the surface of the exterior wall finish and prevent water from reentering the exterior wall. (c) 1. Any joints between 2 pieces of flashing that form a vertical joint shall be lapped a minimum of 6 inches and sealed.

2. Any joints between 2 pieces of flashing that form a horizontal joint shall be lapped a minimum of 2 inches and sealed unless otherwise specified by the flashing manufacturer. 3. Sealants used for flashing shall be exterior grade and shall be compatible with the materials being sealed. (d) Flashing shall be provided at all of the following locations: 1. At the top of all exterior door and window openings, unless using self−flashing windows that provide at least one inch of flashing around the opening, including the corners. 2. At the intersection of chimneys or other masonry construction with frame walls. 3. Under and at the ends of masonry, wood or metal copings and sills. 4. Continuously above all projecting wood trim. 5. Where porches, decks or stairs attach to a wall or floor assembly of wood frame construction. 6. At wall and roof intersections. 7. At built−in gutters.
(4) WATER−RESISTIVE BARRIER REQUIREMENTS. (a) *General.* 1. Exterior walls of wood or metal frame construction shall be provided with a water−resistive barrier from the highest point to the bottom of the permanent weather−resistant covering. 2. (b) *Material compatibility.* The water−resistive barrier material shall be compatible with the other materials in the wall with which it will come into contact. (d) *Application.* 1. Horizontal seams in sheet or strip material shall be overlapped such that the upper layer extends over the lower layer at least 2 inches. (e) 2. Penetrations of 5 square inches or less with an annular space of no more than 1/2 inch shall be sealed with caulk or similar material. 3. Penetrations of greater than 5 square inches shall be flashed in accordance with sub. (3)

Comm 21.25 Wood frame walls. **(2)** TOP PLATES. (a) *General.* Except as allowed under subd. 3., top plates shall be provided and configured as follows: 1. Studs at bearing walls shall be capped with double top plates. 2. End joints in double top plates shall be offset at least 2 stud spaces. 3. Double top plates shall be overlapped at the corners and at intersections of partitions. 4. The plate immediately above the stud may have a joint only when directly over the stud. (c) *Exceptions.* 1. A single top plate may be used in place of a double top plate provided a rafter is located directly over the studs and the plate is securely tied at the end joints, corners and intersecting walls. Joints may occur in single top plates only when directly over a stud. **(3)** WALL OPENINGS. 1. Headers 3 feet or less in length shall be directly supported on each end by either: a. The single common stud and a shoulder stud; or b. The single common stud with a framing anchor attached. 2. Headers greater than 3 feet but less than or equal to 6 feet in length shall be directly supported on each end by the single common stud and a shoulder stud. 3. Headers greater than 6 feet in length shall be directly supported on each end by the single common stud and 2 shoulder studs.
Comm 21.26 Masonry walls. Masonry walls shall be constructed in accordance with the requirements of this section. **(1)** COLD WEATHER WORK. When ambient air temperature is below 40_F, the cold weather construction procedures under ACI 530.1 shall be followed.

TABLE 21.26−A

TYPES OF MORTAR FOR VARIOUS KINDS OF MASONRY

Kind of Masonry	Types of Mortar
Foundations:	
Footings	M, S
Walls of solid units	M, S, N
Walls of hollow units	M, S
Hollow walls	M, S
Masonry other than foundation masonry:	
Piers of solid masonry	M, S, N
Piers of hollow units	M, S
Walls of solid masonry	M, S, N, O
Walls of solid masonry not less than 12 in. thick or more than 35 ft. in height, supported laterally at intervals not exceeding 12 times the wall thickness	M, S, N, O
Walls of hollow units; load−bearing or exterior, and hollow walls 12 in. or more in thickness	M, S, N
Hollow walls, less than 12 in. thick	M, S, N
Linings of existing masonry, either above or below grade	M, S
Masonry other than above	M, S, N

(9) BEARING

(b) *Continuous loads.* Joists, trusses and beams other than wood, spaced 4 feet or less on center and 40 feet or less in length, slabs or other members causing continuous loads shall be transmitted to masonry with a minimum bearing of 3 inches upon solid masonry at least 2_inches in height, or as indicated for concentrated loads.

Subchapter VIII — Roof and Ceilings

(3) UPLIFT AND SUCTION FORCES.

(a) *General.* 1. Roofs shall withstand a pressure of at least 20 pounds per square foot acting upward normal to the roof surface.

2. Roof overhangs, eaves, canopies and cornices shall withstand an upward wind pressure of at least 20 pounds per square foot applied to the entire exposed area.

(b) *Anchorage.* 1. Roof framing members spanning more than 6 feet measured from the outermost edge of the roof shall be permanently fastened to the top plate of load bearing walls using engineered clips, straps or hangers.

2. Roof framing members spanning 6 feet or less measured from the outermost edge of the roof shall be permanently fastened to the top plate of load bearing walls using toe−nailing or

engineered clips, straps or hangers.

(c) *Boring.* 1. Holes bored within 2 inches of the top or bottom of ceiling joists or rafters may not be located in the middle 1/3 of the span of the member.

2. The diameter of a hole may not exceed 1/3 the depth of the member.

3. A hole may not be bored within 2 inches of a notch or another hole.

4. The distance between adjacent holes may not be less than the diameter of the larger hole.

Comm 21.28 Weather protection for roofs.

(1) GENERAL.

(a) All roofs shall be designed and constructed to assure drainage of water.

(b) All fasteners shall be corrosion resistant.

(2) UNDERLAYMENT FOR SHINGLES. Underlayment consisting of number 15 asphalt−impregnated felt paper or equivalent or other type I material that shows no water transmission when tested in accordance with ASTM D 226 or ASTM D 4869 shall be provided under shingles.

Subchapter IX — Fireplace Requirements

Comm 21.29 Masonry fireplaces. Masonry fireplaces shall be constructed of masonry, stone or concrete. Masonry fireplaces shall be supported on foundations of concrete or masonry. Structural walls shall be at least 8 inches thick.

(1) FLUE SIZE. The fireplace flue size shall be based on the type of flue and the fireplace opening indicated in Table 21.29.

TABLE 21.29

MINIMUM FLUE SIZE FOR MASONRY FIREPLACES

Type of Flue	Minimum Cross−Sectional Area
Round	1/12 of fireplace opening but not less than 75 square inches.
Square or rectangular	1/10 of fireplace opening but not less than 75 square inches.

(2) TERMINATION OF CHIMNEY. Masonry fireplace chimneys shall extend at least 3 feet above the highest point where the chimney passes through the roof and at least 2 feet higher than any portion of the dwelling within 10 feet of the chimney.

(3) FIREBOX MATERIALS. The firebox shall be of the preformed metal type, at least 1/4−inch thick, or listed by a nationally recognized laboratory; or shall be lined with firebrick, at least 2 inches thick and laid in thin joints of refractory cement. The back and sidewalls of the firebox, including the lining, shall be at least 8 inches nominally thick masonry, at least 4 inches of which shall be solid. **(4)** LINTEL. Masonry over the fireplace opening shall be supported by a lintel of steel or masonry.
Comm 21.30 Masonry chimneys. Masonry chimneys shall conform to the following provisions: **(1)** MATERIALS. No masonry chimney shall rest upon wood. The foundation shall be designed and built in conformity with the requirements for foundations. Masonry chimney walls shall be at least 4 inches in nominal thickness. Hollow cored masonry units may be used to meet the 4 inch nominal thickness requirement.
Comm 21.32 Factory−built fireplaces. Factory−built fireplaces consisting of a fire chamber assembly, one or more chimney sections, a roof assembly and other parts shall be tested and listed by a nationally recognized testing laboratory. **(1)** FIREPLACE ASSEMBLY AND MAINTENANCE. The fireplace assembly shall be erected and maintained in accordance with the conditions of the listing. (a) All joints between the wall or decorative facing material and the fireplace unit shall be completely sealed, firestopped or draft−stopped with a noncombustible caulk or equivalent. (b) Doors installed on factory built fireplaces shall conform with the terms of the listing and the manufacturers installation instructions for the fireplace unit. **(2)** DISTANCE FROM COMBUSTIBLES. Portions of the manufactured chimney extending through combustible floors or roof/ceiling assemblies shall be installed in accordance with the distances listed on the chimney in order to prevent contact with combustible materials.
Subchapter X — Construction in Floodplains
(2) ELEVATION. (a) *General.* Except as provided in pars. (b) and (c), all dwellings constructed within a flood fringe area shall be elevated so the lowest floor and all basement floor surfaces are located at or above the base flood elevation.

(b) *Certified floodproof basements.* Floodproof basements may have the top of the basement floor no more than 5 feet below the base flood elevation provided the basement is designed by a registered architect or engineer to be watertight and impermeable. No limitation is placed on the use or occupancy of a certified floodproof basement by the provisions of this subchapter.

Comm 21.34 Construction in coastal floodplains.

(1) GENERAL. All dwellings constructed in coastal floodplains shall be designed by a registered architect or engineer and shall meet the requirements of this section and s. Comm 21.33.

(2) ELEVATION. All dwellings constructed in a coastal floodplain shall be elevated so the lowest portion of all structural members supporting the lowest floor, with the exception of mat or raft foundations, pilings, piling caps, columns, grade beams and bracing, is located at or above the base flood elevation.

Subchapter XI — Installation of Manufactured Homes

Comm 21.40 Installation standards.

(1) (a) The installation of a manufactured home produced on or after April 1, 2007 shall comply with procedures acceptable to the department.

(b) Acceptable installation procedures shall address all of the following:

1. Soil mechanics.
2. Site preparation.
3. Structural support, stabilization and anchorage.
4. Setting.
5. Ventilation of crawl spaces.
6. Connections, plumbing, electrical, HVAC.
7. Joining of home sections.

3. The home site shall be graded to permit water to drain from under the home and away from the home for a minimum of 5 feet from the home.

4. Every pier shall be supported by a footing. Each footing shall be no less than a nominal 16 inches by 16 inches.

Appendix

A5.31 Dwelling contractor financial responsibility certification.

Section 101.654 (2), (2m) and (4) of the statutes reads:

(2) An applicant for a certificate of financial responsibility shall provide to the satisfaction of the department proof of all of the following:

(a) That the applicant has in force one of the following:
1. A bond endorsed by a surety company authorized to do business in this state of not less than $5,000, conditioned upon the applicant complying with all applicable provisions of the one− and 2− family dwelling code and any ordinance enacted under s. 101.65 (1) (a).

2. A policy of general liability insurance issued by an insurer authorized to do business in this state insuring the applicant in the amount of at least $250,000 per occurrence because of bodily injury to or death of others or because of damage to the property of others.

(b) If the applicant is required under s. 102.28 (2) (a) to have in force a policy of worker's compensation insurance or if the applicant is self−insured in accordance with s. 102.28 (2) (b), that the applicant has in force a policy of worker's compensation insurance issued by an insurer authorized to do business in this state or is self−insured in accordance with s. 102.28 (2) (b).

(c) If the applicant is required to make state unemployment compensation contributions under ch. 108 or is required to pay federal unemployment compensation taxes under 26 USC 3301 to 3311, that the applicant is making those contributions or paying those taxes as required.

(2m) If an applicant wishes to use a bond under sub. (2) (a) 1. of less than $25,000 to comply with sub. (2) (a), the applicant shall agree not to perform any work on a dwelling for which the estimated cost of completion is greater than the amount of the bond. The department shall indicate any restriction under this subsection on the certificate of financial responsibility issued under sub. (3).

(4) (a) A bond or insurance policy required under sub. (2) may not be canceled by the person insured under the bond or policy or by the surety company or insurer except on 30 days' prior written notice served on the department in person or by 1st class mail or, if the cancellation is for nonpayment of premiums to the insurer, on 10 days' prior written notice served on the department in person or by 1st class mail. The person insured under the bond or policy shall file with the department proof to the satisfaction of the department of a replacement bond or replacement insurance within the 30−day notice period or 10−day notice period, whichever is applicable, and before the expiration of the bond or policy. The department shall suspend without prior notice or hearing the certificate of financial responsibility of a person who does not file satisfactory proof of a replacement bond or replacement insurance as required by this subsection.

(b) A bond under sub. (2) (a) 1. shall be executed in the name of the state for the benefit of any person who sustains a loss as a result of the person insured under the bond not complying with an applicable provision of the one− and 2−.family dwelling code or any ordinance enacted under s. 101.65 (1) (a), except that the aggregate liability of the surety to all persons may not exceed the amount of the bond.

Final Exam - Construction Codes

Scope and Design Criteria

1.) The provisions of Chapter Comm 21 apply to the design and the construction of
   a. One family dwellings
   b. 2-family dwellings
   c. Commercial buildings
   d. Only a & b

2.) Floors and ceilings are considered:
   a. Dead loads
   b. Live loads
   c. Wind loads
   d. Snow loads

3.) Every dwelling shall be designed and constructed to support the actual weight of all components and materials.
   a. True
   b. False

4.) Earth−sheltered dwellings shall be designed and constructed to support the actual weight of all soil loads.
   a. True
   b. False

5.) All building components shall be fastened to withstand the dead load, live load and wind load.
   a. True
   b. False

6.) For wind loads, dwellings shall be designed and constructed to withstand a horizontal and uplift pressure of _____ pounds per square foot acting over the surface area.
   a. 10
   b. 20
   c. 30
   d. 40

7.) Garage floors should be designed and constructed to support the following minimum live load?
   a. 20 pounds per square foot
   b. 30 pounds per square foot
   c. 40 pounds per square foot
   d. 50 pounds per square foot

8.) Exterior balconies should be designed and constructed to support the following minimum live load?
   a. 20 pounds per square foot
   b. 30 pounds per square foot
   c. 40 pounds per square foot
   d. 50 pounds per square foot

9.) In Milwaukee County (Zone 2) what is the minimum snow load for the roof?
   a. 20 pounds per square foot
   b. 30 pounds per square foot
   c. 40 pounds per square foot
   d. 50 pounds per square foot

10.) In Wisconsin Zone 1, what is the minimum snow load for the roof?
   a. 20 pounds per square foot
   b. 30 pounds per square foot
   c. 40 pounds per square foot
   d. 50 pounds per square foot

11.) Dwellings shall be designed and constructed to withstand a horizontal and uplift pressure of ________ per square foot acting over the surface area.
   a. 20 pounds
   b. 30 pounds
   c. 40 pounds
   d. 50 pounds

12.) All building components shall be fastened to withstand the dead load, live load and wind load.
   a. True
   b. False

13.) Reused lumber shall be considered to have a duration of load factor of ______.
   a. 0.80
   b. 0.90
   c. 1.15
   d. 1.25

14.) Span tables for joists and rafters approved by the department may be used in lieu of designing by structural analysis.
   a. True
   b. False

15.) The design and construction of masonry shall conform to the following standards:

a. ACI 318
b. ACI 400
c. ACI 530
d. ACI 620

16.) The standard for whole logs requires the minimum log diameter to be __________.

a. 6 inches
b. 7 inches
c. 8 inches
d. 9 inches

Exits

17.) In most cases, how many exit doors accessible from the first floor are required?

a. 1
b. 2
c. 3
d. 4

18.) At least one first floor exits must discharge to grade and may not go through a garage.

a. True
b. False

19.) An overhead garage door may be used as an exit door.

a. True
b. False

20.) If the full length of the longest diagonal of the floor in plan view is 90-feet, what is the required distance between the two first floor exits?

a. 20 feet
b. 30 feet
c. 40 feet
d. 50 feet

21.) If the full length of the longest diagonal of the floor in plan view is 50-feet, what is the required distance between the two first floor exits?

a. 20 feet
b. 30 feet
c. 40 feet
d. 50 feet

22.) For exiting through an attached garage, the separation distance shall be measured using the door connecting the garage and the dwelling.

a. True
b. False

23.) Dwellings consisting of no more than a first floor with a maximum floor area of ____________ and a loft area not exceeding half of the first floor area, shall be provided with at least one exit door leading directly to the exterior and at least one egress window.

a. 200 square feet
b. 300 square feet
c. 400 square feet
d. 500 square feet

24.) In most cases, how many exits are required from the second floor?

a. 1
b. 2
c. 3
d. 4

25.) Windows may be provided in each second floor bedroom in lieu of a second exit from the floor.

a. True
b. False

26.) At least one stairway exit shall be provided, to the floor below, for a loft exceeding __________ in area.

a. 300 square feet
b. 400 square feet
c. 500 square feet
d. 600 square feet

27.) A basement is required to have both a door to the exterior and a stairway that leads to the floor above.

a. True
b. False

28.) The nominal size of the net clear window opening, for an appropriate exit, must be at least:

a. 16 inches by 20 inches
b. 20 inches by 24 inches
c. 24 inches by 28 inches
d. 28 inches by 32 inches

29.) A window used as an exit shall be openable from the inside without the use of tools or the removal of a sash.

a. True
b. False

30.) At least one exit door must be a swing-type door at least 80 inches high by 36 inches wide.

a. True
b. False

31.) Where double doors are used as a required exit, each door leaf shall provide a clear opening at least 24 inches wide and be at least 76 inches high.

a. True
b. False

32.) Balconies shall be made of which of the following:

a. Concrete
b. Metal
c. Treated wood
d. Any of the above

33.) In determining the exit requirement in a split level dwelling, all levels that are to be considered a single story shall be within _______ of each other.

a. 3 feet
b. 4 feet
c. 5 feet
d. 6 feet

Interior Circulation

34.) Excluding infringements, the clear width of hallways shall be at least __________.

a. 30 inches
b. 36 inches
c. 42 inches
d. 48 inches

35.) Door hardware and finish trim are allowed to infringe on the required clear width of a hallway.

a. True
b. False

36.) Handrails may infringe into the minimum width of a hallway up to 6 inches on each side.

a. True
b. False

37.) Heating registers may infringe into the minimum width of a hallway up to 4 1/2 inches and no part of the register may be more than ____ inches above the floor.

a. 34 inches
b. 36 inches
c. 38 inches
d. 40 inches

38.) Unlimited infringements are allowed in a hallway more than 84 inches above the floor.

a. True
b. False

39.) Ducts, pipes, light fixtures, structural features, and corner treatments that are within ____ inches of the floor may infringe into the minimum width of a hallway by a maximum of 4 1/2 inches on each side.

a. 54 inches
b. 64 inches
c. 74 inches
d. 84 inches

40.) The minimum distance between a wall and a permanently installed kitchen island must be at least __________.

a. 30 inches
b. 36 inches
c. 42 inches
d. 48 inches

Stairways and elevated areas

41.) Except for spiral staircases, stairways must measure at least _________ in width.

a. 30 inches
b. 36 inches
c. 42 inches
d. 48 inches

42.) Handrails may project a maximum of _______ into the required width at each side of the stairway.

a. 4.5 inches
b. 6.5 inches
c. 8.5 inches
d. 9.5 inches

43.) What is the maximum height for risers in spiral staircases?

a. 4.5 inches
b. 6.5 inches
c. 8.5 inches
d. 9.5 inches

44.) What is the load that handrails and guardrails must be designed to withstand?

a. 100 pounds
b. 150 pounds
c. 200 pounds
d. 250 pounds

45.) All openings between floors, and open sides of landings, platforms, balconies or porches that are more than _______ above grade or a floor shall be protected with guardrails.

a. 24 inches
b. 30 inches
c. 36 inches
d. 42 inches

46.) Rectangular treads shall have minimum tread depth of 12 inches measured horizontally from nosing to nosing.

a. True
b. False

<u>Ladders & Ramps</u>

47.) Ladders which are used as part of a required exit shall be designed to withstand loads of at least _________ pounds.

a. 100 pounds
b. 150 pounds
c. 200 pounds
d. 250 pounds

48.) Ladders used for exits with treads less than 9 inches in width shall have open risers.

a. True
b. False

49.) All treads on ladders used for exits should be uniform in dimension.

a. True
b. False

50.) Ramps must have a minimum width of ________ measured between handrails

a. 30 inches
b. 36 inches
c. 42 inches
d. 48 inches

51.) Ramps shall not have a gradient greater than 1 in 8 or one foot of rise in 8 feet of run.

a. True
b. False

52.) Walkways with gradients less than 1 in 20 or one foot of rise in 20 feet of run are not considered to be ramps.

a. True
b. False

Ceiling Height

53.) Which of the following rooms must have a ceiling of at least 7 feet tall?

a. Kitchens
b. Hallways
c. Bathrooms
d. All of the above

54.) Beams and girders or other projections shall not project more than 12 inches below the required ceiling height.

a. True
b. False

Attics and crawl space access

55.) Assuming an attic is required to have an access opening, the opening must be:

a. At least 14 by 24 inches
b. Accessible from the inside
c. Both a & b
d. None of the above

56.) Assuming a crawl space is required to have an access opening, the opening must be at least:

a. 14 by 24 inches
b. 18 by 24 inches
c. 14 by 30 inches
d. 18 by 30 inches

57.) Crawl spaces with ____ inches of clearance or more between the crawl space floor and the underside of the house floor joist framing shall be provided with an access opening.

a. 12
b. 18
c. 24
d. 30

Fireblocking

58.) Fireblocking is required at all openings around wires, cables, vents, pipes, ducts, chimneys and fireplaces at ceiling and floor level.

a. True
b. False

59.) 2-inch nominal lumber may be used as fireblocking material.

a. True
b. False

Smoke detectors, fire sprinklers and Carbon monoxide alarms

60.) Smoke alarms must be installed in 50% of the sleeping rooms.

a. True
b. False

61.) On floor levels that do not contain a sleeping area, a smoke detector must be installed in a common area on each floor level.

a. True
b. False

62.) On floor levels that contain one or more sleeping areas, a smoke detector alarm shall be installed outside of the sleeping rooms, within ____ feet of the centerline of the door opening to any sleeping room and in an exit path from any sleeping room.

a. 18
b. 21
c. 24
d. 27

63.) Where automatic fire sprinklers using a dedicated water supply system are installed, the design, installation, testing and maintenance shall follow the requirements of NFPA 13D.

a. True
b. False

64.) Which of the following is considered a fuel-burning appliance?
   a. Stove
   b. Furnace
   c. Water heater
   d. All of the above

65.) On floor levels that contain one or more sleeping areas, a carbon monoxide alarm shall be installed outside of the sleeping area, within 21 feet of the centerline of the door opening to any sleeping area and in an exit path from any sleeping area.
   a. True
   b. False

66.) On floors that do not contain a sleeping area, a carbon monoxide alarm shall be installed in a common area on each floor level.
   a. True
   b. False

67.) Which is a true statement about carbon monoxide alarms with dwellings that have electrical service:
   a. Be continuously powered by the house electrical service
   b. Have a backup power supply
   c. Be interconnected with other alarms in the house
   d. All of the above

Protection against decay and termites & Foam plastic

68.) The wood use to protect against termites shall be labeled and pressure treated with preservative in accordance with an AWPA standard or shall be naturally durable and decay–resistant or shall be engineered to be decay resistant.
   a. True
   b. False

69.) Foam plastic insulation shall have a flame-spread rating of _______ or less.
   a. 55
   b. 65
   c. 75
   d. 85

70.) Foam plastic insulation shall have a smoke-developed rating of _____ or less when tested in accordance with ASTME-84.
   a. 350
   b. 450
   c. 550
   d. 650

Subchapter III - Excavations

71.) The finished grade of the soil shall slope away from the dwelling at a rate of at least ½ inch per foot for a minimum distance of ___ feet, or to the lot line, whichever is less.

a. 5
b. 10
c. 15
d. 20

72.) Storm water management practices shall be employed in accordance with s. NR 151.12 and maintained when the land disturbing construction activity involves one or more acres.

a. True
b. False

73.) Any person making or causing an excavation which may affect the lateral soil support of adjoining property or buildings shall provide at least ____ written notice to all owners of adjoining buildings of the intention to excavate.

a. 14 days
b. 30 days
c. 45 days
d. 60 days

Footings

74.) The minimum width and length of column or pier footings shall measure at least:

a. 1 foot by 1foot
b. 2 feet by 2 feet
c. 3 feet by 3 feet
d. 4 feet by 4 feet

75.) Footings may be sized to exceed the allowable material stresses.

a. True
b. False

76.) The minimum depth of column or pier footings shall measure at least 12 inches nominal.

a. True
b. False

77.) The bearing area for footings shall be at least equal to the area required to transfer the loads to the supporting soil without exceeding the bearing capacity of the soil.

a. True
b. False

78.) Structures supported on floating slabs may not be physically attached to structures that are supported by footings that extend below the frost line unless an ________ is used between the structures.

a. Continuous footing
b. Pier footing
c. Isolation joint
d. Column

79.) The minimum width of an unreinforced concrete footing on each side of the foundation wall shall measure at least _______ wider than the wall.

a. 4 inches
b. 6 inches
c. 8 inches
d. 12 inches

80.) Unstable soil includes soils that are unable to support themselves at a 45 degree angle for the full depth of the footing.

a. True
b. False

81.) The minimum width and length of column or pier footings shall measure at least 2 feet by 2 feet.

a. True
b. False

82.) Footings and foundations, including those for ramps and stoops, shall be placed below the frost penetration level or at least ______ below adjacent grade, whichever is deeper.

a. 24 inches
b. 36 inches
c. 48 inches
d. 60 inches

83.) In most cases, a complete drain tile or pipe system shall be installed around the foundation of dwellings under construction where groundwater occurs above the bottom of the footing.

a. True
b. False

Foundations

84.) Structural steel anchor bolts must be embedded how far into the concrete or grouted masonry?

a. 60 inches
b. 72 inches
c. 84 inches
d. 96 inches

85.) Structural steel anchor bolts must be embedded at least _________ into the concrete or grouted masonry foundation.

a. 5 inches
b. 6 inches
c. 7 inches
d. 8 inches

86.) Lateral support such as floor slabs or framing shall be provided at the base of foundation walls.

a. True
b. False

Floors

87.) What is the required thickness of concrete floors in normal soils?

a. 1 inch
b. 2 inches
c. 3 inches
d. 4 inches

88.) When a concrete floor is placed in clay soils, a _____ thick base course shall be placed in the sub grade consisting of clean graded sand, gravel or crushed stone.

a. 4 inch
b. 5 inch
c. 6 inch
d. 7 inch

89.) When a concrete floor is placed on sand or gravel soils, the base course may be omitted unless drain tile is installed.

a. True
b. False

90.) For wood frame floors, where a sill plate is provided for floor joists on poured concrete, the sill plates shall be fastened to the foundation.

a. True
b. False

91.) Garage floors shall be constructed of concrete or other noncombustible materials which are impermeable to petroleum products.

a. True
b. False

92.) Slab– on–grade concrete garage floors shall be at least _______ thick and placed over at least 4 inches of granular fill.

a. 4 inches
b. 5 inches
c. 6 inches
d. 7 inches

93.) Where anchor bolts are used on masonry walls with an open top course, the minimum width of an individual piece making up the sill plate shall be at least _________.

a. 5.5 inches
b. 6.5 inches
c. 7.5 inches
d. 8.5 inches

Walls

94.) All walls shall support all superimposed vertical dead loads and live loads from floors and roofs.

a. True
b. False

95.) Walls shall be designed to withstand a horizontal wind pressure of at least _____ per square foot applied to the vertical projection of that portion of the dwelling above grade.

a. 10 pounds
b. 20 pounds
c. 30 pounds
d. 40 pounds

96.) The exterior walls shall be covered with a temporary weather resistant finish.

a. True
b. False

97.) During construction, wall cavity insulation may not be installed until a water–resistant covering is in place over the wall cavity and windows, doors and a roof with at least underlayment are installed.

a. True
b. False

98.) Any joints between 2 pieces of flashing that form a vertical joint shall be lapped a minimum of ________ and sealed.

a. 6 inches
b. 8 inches
c. 10 inches
d. 12 inches

99.) Sealants used for flashing shall be exterior grade and shall be compatible with the materials being sealed.

a. True
b. False

100.) Flashings are not required at built-in gutters.

a. True
b. False

101.) Flashings shall be provided at the following locations:

a. At the top of all exterior door and window openings
b. At wall and roof intersections
c. Continuously above all projecting wood trim
d. All of the above

102.) Exterior walls of wood or metal frame construction shall be provided with a water‒resistive barrier from the highest point to the bottom of the permanent weather‒resistant covering.

a. True
b. False

103.) Headers greater than 3 feet but less than or equal to 6 feet in length shall be directly supported on each end by the single common stud and a shoulder stud.

a. True
b. False

104.) Headers greater than ____ feet in length shall be directly supported on each end by the single common stud and 2 shoulder studs.

a. 3 feet
b. 4 feet
c. 5 feet
d. 6 feet

Roof and Ceilings

105.) Roofs shall withstand a pressure of at least _______ per square foot acting upward normal to the roof surface.

a. 10 pounds
b. 20 pounds
c. 30 pounds
d. 40 pounds

106.) Roof overhangs, eaves, canopies and cornices shall withstand an upward wind pressure of at least _______ per square foot applied to the entire exposed area.

a. 10 pounds
b. 20 pounds
c. 30 pounds
d. 40 pounds

107.) Roof framing members spanning more than ________ measured from the outermost edge of the roof shall be permanently fastened to the top plate of load bearing walls using engineered clips, straps or hangers.

a. 4 feet
b. 5 feet
c. 6 feet
d. 7 feet

108.) Holes bored within 2 inches of the top or bottom of ceiling joists or rafters may not be located in the middle 1/3 of the span of the member.

a. True
b. False

109.) All roofs shall be designed and constructed to assure drainage of water.

a. True
b. False

Fireplace Requirements

110.) Structural walls of masonry fireplaces must be at least how thick?

a. 6 inches
b. 7 inches
c. 8 inches
d. 9 inches

111.) Masonry fireplace chimneys shall extend at least ______ above the highest point where the chimney passes through the roof.

a. 2 feet
b. 3 feet
c. 4 feet
d. None of the above

112.) Masonry fireplace chimneys shall extend at least _______ higher than any portion of the dwelling within 10 feet of the chimney.

a. 2 feet
b. 3 feet
c. 4 feet
d. None of the above

113.) The back and sidewalls of the firebox, including the lining, shall be at least 8 inches nominally thick masonry, at least 4 inches of which shall be solid.

a. True
b. False

114.) Masonry over the fireplace opening shall be supported by a lintel of steel or masonry.

a. True
b. False

115.) Masonry chimney walls shall be at least 6 inches in nominal thickness.

a. True
b. False

116.) A masonry chimney may rest upon wood.

a. True
b. False

<u>Construction in Floodplains</u>

117.) Dwellings constructed within a flood fringe area shall be elevated so the lowest floor and all basement floor surfaces are located at or above the base flood elevation.

a. True
b. False

118.) Floodproof basements may have the top of the basement floor no more than ______ below the base flood elevation.

a. 4 feet
b. 5 feet
c. 6 feet
d. 7 feet

119.) Floodproof basements must be designed by a registered architect or engineer to be watertight and impermeable.

a. True
b. False

Installation of Manufactured Homes

120.) The installation of a manufactured home produced on or after April 1, ______ shall comply with procedures acceptable to the department.

a. 2005
b. 2006
c. 2007
d. 2008

Construction Codes Final Exam – Answer Sheet

Name: ______________________ **Last Name:** _____________________________________ **Date:**_______________

Address: ____________________________________ **City** __________________ **State:**_____ **ZIP:**________________

WI Dwelling Contractor Qualifier Number: _____________________

Phone: ___________________________________ **Email:** ____

T F	T F	
1. A B C D	21. A B C D	41. A B C D
2. A B C D	22. A B C D	42. A B C D
3. A B C D	23. A B C D	43. A B C D
4. A B C D	24. A B C D	44. A B C D
5. A B C D	25. A B C D	45. A B C D
6. A B C D	26. A B C D	46. A B C D
7. A B C D	27. A B C D	47. A B C D
8. A B C D	28. A B C D	48. A B C D
9. A B C D	29. A B C D	49. A B C D
10. A B C D	30. A B C D	50. A B C D
11. A B C D	31. A B C D	51. A B C D
12. A B C D	32. A B C D	52. A B C D
13. A B C D	33. A B C D	53. A B C D
14. A B C D	34. A B C D	54. A B C D
15. A B C D	35. A B C D	55. A B C D
16. A B C D	36. A B C D	56. A B C D
17. A B C D	37. A B C D	57. A B C D
18. A B C D	38. A B C D	58. A B C D
19. A B C D	39. A B C D	59. A B C D
20. A B C D	40. A B C D	60. A B C D

Construction Codes Final Exam – Answer Sheet (Page2)

T F 61. A B C D	T F 81. A B C D	101. A B C D
62. A B C D	82. A B C D	102. A B C D
63. A B C D	83. A B C D	103. A B C D
64. A B C D	84. A B C D	104. A B C D
65. A B C D	85. A B C D	105. A B C D
66. A B C D	86. A B C D	106. A B C D
67. A B C D	87. A B C D	107. A B C D
68. A B C D	88. A B C D	108. A B C D
69. A B C D	89. A B C D	109. A B C D
70. A B C D	90. A B C D	110. A B C D
71. A B C D	91. A B C D	111. A B C D
72. A B C D	92. A B C D	112. A B C D
73. A B C D	93. A B C D	113. A B C D
74. A B C D	94. A B C D	114. A B C D
75. A B C D	95. A B C D	115. A B C D
76. A B C D	96. A B C D	116. A B C D
77. A B C D	97. A B C D	117. A B C D
78. A B C D	98. A B C D	118. A B C D
79. A B C D	99. A B C D	119. A B C D
80. A B C D	100. A B C D	120. A B C D

Wisconsin Contractors Institute

Continuing Education

Erosion & Sediment Control

Course # 12775 – 2 hours

Wisconsin Contractors Institute

N16 W23217 Stone Ridge Dr., Suite 290

Waukesha, WI 53188

Website: www.wcitraining.com

Phone: 262-409-4282

Erosion & Sediment Control

Comm 21.125 - Erosion control and sediment control.

(1) GENERAL.

(a) Where land disturbing construction activity is to occur erosion and sediment control practices shall be employed, as necessary, and maintained to prevent or reduce the potential deposition of soil or sediment to all of the following:

1. The waters of the state.
2. Adjacent properties.

(b) Land disturbing construction activities, except those activities necessary to implement erosion or sediment control practices, may not begin until the sediment control practices are in place for each area to be disturbed in accordance with the approved plan.

(c) Erosion and sediment control practices shall be maintained until the disturbed areas are stabilized. A disturbed area shall be considered stabilized by vegetation when a perennial cover has been established with a density of at least 70%.

(d) Erosion and sediment control practices shall either be approved by the department or listed by the department of natural resources in accordance with the process under s. NR 151.32 (2).

Exam Questions:

1.) **Land disturbing construction activities may not begin until the sediment control practices are in place for each area to be disturbed in accordance with the approved plan.**

a. True
b. False

2.) **A disturbed area shall be considered stabilized by vegetation when a perennial cover has been established with a density of at least _____.**

a. 50%
b. 60%
c. 70%
d. 80%

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(2) MANDATED PRACTICES. Specific practices at each site where land disturbing construction activity is to occur shall be utilized to prevent or reduce all of the following:

(a) The deposition of soil from being tracked onto streets by vehicles.

(b) The discharge of sediment from disturbed areas into on−site storm water inlets.

(c) The discharge of sediment from disturbed areas into abutting waters of the state.

(d) The discharge of sediment from drainage ways that flow off the site.

(e) The discharge of sediment by dewatering activities.

(f) The discharge of sediment eroding from soil stockpiles existing for more than 7 days.

Exam Questions:

3.) **Specific practices at each site where land disturbing construction activity is to occur shall be utilized to prevent or reduce the discharge of sediment:**

a. By dewatering activities
b. From drainage that flow off the site
c. From disturbed areas into abutting waters of the state
d. All of the above

---

(3) CONTROL STANDARDS. Including the practices under sub.(2) above, additional erosion and sediment control practices shall be employed, as necessary, to accomplish one of the following:

(a) A potential annual cumulative soil loss rate of not more than one of the following:

1. Five tons per acre per year where sand, loamy sand, sandy loam, loam, sandy clay loam, clay loam, sandy clay, silty clay or clay textures are exposed.

2. Seven and a half tons per acre per year where silt, silty clay loam or silt loam textures are exposed.

(b) A reduction of at least 80% of the potential sediment load in storm water runoff from the site on an average annual basis as compared with no sediment or erosion controls for the site when the land disturbing construction activity involves one or more acres.

(c) A reduction of at least 40% of the potential sediment load in storm water runoff from the site on an average annual basis as compared with no sediment or erosion controls for the site where less than one acre of land disturbing construction activity is to occur.

Exam Questions:

4.) **A reduction of at least 80% of the potential sediment load in storm water runoff from the site on an average annual basis as compared with no sediment or erosion controls for the site when the land disturbing construction activity involves _______________.**

a. Less than one acre
b. One or more acres
c. Two or more acres
d. None of the above

5.) **A reduction of at least 40% of the potential sediment load in storm water runoff from the site on an average annual basis as compared with no sediment or erosion controls for the site when the land disturbing construction activity involves _________________.**

a. Less than once acre
b. One or more acres
c. Two or more acres
d. None of the above

The following are designs acceptable by the department to achieve compliance with the control standards of acceptable soil loss or percent reduction of sediment load in runoff from a site.

Less than one acre disturbance (regardless of the lot or property size).

A. Mandated practices:

1. A method to prevent or reduce soil from leaving a site via entries or roads**.** This may include a tracking pad or tire washing stand designed and installed to meet DNR Standard 1057. Other means of compliance include gravel mulch, frozen soil, bedrock or some other physical means to prevent soil from leaving the site on vehicle tires which is equivalent to the tracking pad or tire washing stand.

2. Storm water inlet protection. Inlet protection may be accomplished by using DNR Technical Standard, number 1050, "Storm Drain Inlet Protection for Construction Sites". The protection of stormwater inlets in the code is specific to "on–site" inlets; however an off–site inlet may create a direct conduit to a water of the state, which links any inlet that leads to a water of the state to the #3 mandated practice. In that case, special care should be taken to protect both types of inlets from sediment in runoff from a construction site.

3. Protection of adjoining waters of the state. The installation of practices is necessary if runoff from the disturbance could impact a water of the state. Practices may include channel erosion mats, silt fences, vegetative buffers or any other practices applicable to the specific site.

4. Drainage way protection. Any ditches or drainage ways that flow off–site must be protected with appropriate best management practices (BMPs). This may include but is not limited to ditch checks, channel erosion control mats or riprap.

5. Dewatering activity sediment reduction**.** Any dewatering necessary on the construction site must include measures to reduce the sediment in the water leaving the site. Dewatering BMPs may include filters, fiber rolls or gravel bag berms.

6. Stockpile protection. Any soil stockpiles which are left more than 7 days must be protected by seeding and mulching, erosion mat, silt fencing, covering or other methods. This does not include fill or topsoil piles that are in active use.

Exam Questions:

6.) **Inlet protection for less than one acre of disturbance may be accomplished by using which DNR Technical Standard number?**

a. 1050
b. 1056
c. 1057
d. 1058

7.) **A tracking pad or a tire washing stand is an acceptable practice to prevent or reduce soil from leaving a site via entries or roads.**

a. True
b. False

8.) **Ditch checks, channel erosion control mats or riprap are examples of:**

a. Stockpile protection
b. Storm water inlet protection
c. Drainage way protection
d. None of the above

9.) **Any dewatering necessary on the construction site must include measures to reduce the sediment in the water leaving the site.**

a. True
b. False

10.) **Any soil stockpiles which are left more than ___ days must be protected by seeding and mulching, erosion mat, silt fencing, covering or other methods.**

a. 3
b. 5
c. 7
d. 9

B. In addition to mandated practices, the owner/contractor or designer must choose one or more of the following methods in order to achieve compliance with the standards.

1. The Revised Universal Soil Loss Equation may be used to determine the amount of soil lost from a site in order to stay below the 5 tons/acre/year for sand, loamy sand, sandy loam, loam, sandy clay loam, clay loam, sandy clay, silty clay or clay textures or the 7.5 tons/acre/year soil loss for silt, silty clay loam or silt loam textures. The Commerce–accepted version of an Excel worksheet that is used to calculate the soil loss is available at: http://commerce.wi.gov/SB/SB–SoilErosionControlProgram.html.

2. Silt fence may be placed in accordance with the DNR Technical Standard 1056 and remain on the site until the pervious area is stabilized. This practice, in addition to the mandated practices in part "A" is accepted by the Department of Commerce as compliant with the 40% reduction in sediment load goal.

3. The site may be seeded and mulched, erosion control mat may be installed or polymers may be applied. The erosion control BMPs must be applied within one week of disturbance. Seeding must be accomplished in accordance with DNR Technical Standard 1059 and mulching with DNR Technical Standard 1058. Erosion control mat must be installed in accordance with DNR Technical Standards 1052 and 1053. Polymer application must be done in accordance with DNR Technical Standard 1051. (This method is only acceptable when the maximum slope length is 300 feet and the maximum slope is no more than that specified in Table A−21.125−1 and Table A−21.125−2.)

4. Practices may be included in the erosion and sediment control plan for the site that achieves compliance with the 40% reduction in sediment load in the runoff from the site.

5. A unique design may be submitted with the UDC permit application for review.

One acre or more disturbed (regardless of the lot or property size).

A. Mandated practices:

1. A method to prevent or reduce soil from leaving a site via entries or roads. This may include a tracking pad or tire washing stand designed and installed to meet DNR Standard 1057. Other means of compliance include gravel mulch, frozen soil, bedrock or some other physical means to prevent soil from leaving the site on vehicle tires which is equivalent to the tracking pad or tire washing stand.

2. Storm water inlet protection. Inlet protection may be accomplished by using DNR Technical Standard, number 1060, "Storm Drain Inlet Protection for Construction Sites". The protection of stormwater inlets in the code is specific to "on−site" inlets; however an off−site inlet may create a direct conduit to a water of the state, which links any inlet that leads to a water of the state to the #3 mandated practice. In that case, special care should be taken to protect both types of inlets from sediment in runoff from a construction site.

3. Protection of adjoining waters of the state. The installation of practices is necessary if runoff from the disturbance could impact a water of the state. Practices may include channel erosion mats, silt fences, vegetative buffers or any other practices applicable to the specific site.

4. Drainage way protection. Any ditches or drainage ways that flow off−site must be protected with appropriate best management practices (BMPs). This may include but is not limited to ditch checks, erosion control mats or riprap.

5. Dewatering activity sediment reduction. Any dewatering necessary on the construction site must include measures to reduce the sediment in the water leaving the site. Dewatering BMPs may include filters, fiber rolls or gravel bag berms.

6. Stockpile protection. Any soil stockpiles which are left more than 7 days must be protected by seeding and mulching, erosion mat, silt fencing, covering or other methods. This does not include fill or topsoil piles that are in active use.

Exam Questions:

11.) **Filters, fiber rolls or gravel bag berms are examples of best management practices for:**

a. Stockpile protection
b. Dewatering
c. Storm inlet protection
d. Drainage way protection

12.) **A unique design may NOT be submitted with the UDC permit application for review.**

a. True
b. False

B. In addition to mandated practices, the owner/contractor or designer must choose one or more of the following methods in order to achieve compliance with the standards.

1. The Revised Universal Soil Loss Equation may be used to determine the amount of soil lost from a site in order to stay below the 5 tons/acre/year for sand, loamy sand, sandy loam, loam, sandy clay loam, clay loam, sandy clay, silty clay or clay textures or the 7.5 tons/acre/year soil loss for silt, silty clay loam or silt loam textures. The Commerce−accepted version of an Excel worksheet that is used to calculate the soil loss is available at: http://commerce.wi.gov/SB/SB−SoilErosionControlProgram.html.

2. The site may be seeded and mulched, erosion control mat may be installed or polymers may be applied. The erosion control BMPs must be applied within one week of disturbance. Seeding must be accomplished in accordance with DNR Technical Standard 1059 and mulching with DNR Technical Standard 1058. Erosion control mat must be installed in accordance with DNR Technical Standards 1052 and 1053. Polymer application must be done in accordance with DNR Technical Standard 1051. (This method is only acceptable when the maximum slope length is 300 feet and the maximum slope is no more than that specified in Table A−21.125−1.)

3. Practices may be included in the erosion and sediment control plan for the site that achieve compliance with the 80% reduction in sediment load in the runoff from the site.

4. A unique design may be submitted with the UDC permit application for review.

(4) SOIL LOSS ANALYSIS. Potential soil loss shall be determined using an engineer analytical modeling acceptable to the department.

Note: The Revised Universal Soil Loss Equation II is an example of an acceptable model to determine soil loss.

(5) MONITORING.

(a) The owner or owner's agent shall check the erosion and sediment control practices for maintenance needs at all the following intervals until the site is stabilized:

1. At least weekly.

2. Within 24 hours after a rainfall event of 0.5 inches or greater. A rainfall event shall be considered to be the total amount of rainfall recorded in any continuous 24 hour period.

3. At all intervals cited on the erosion and sediment control plan.

(b) The owner or owner's agent shall maintain a monitoring record when the land disturbing construction activity involves one or more acres.

(c) The monitoring record shall contain at least the following information:

1. The condition of the erosion and sediment control practices at the intervals specified under par. (a).

2. A description of the maintenance conducted to repair or replace erosion and sediment control practices.

Exam Questions:

13.) Potential soil loss shall be determined using an engineer analytical modeling acceptable to the department.

a. True
b. False

14.) The Revised Universal Soil Loss Equation II is an example of an acceptable model to determine soil loss.

a. True
b. False

15.) The owner or owner's agent shall maintain a monitoring record when the land disturbing construction activity involves ________________.

a. Less than one acre
b. One or more acres
c. Two or more acres
d. None of the above

16.) The monitoring record shall contain at least the following information:

a. The condition of the erosion and sediment control practices
b. A description of the maintenance conducted to repair or replace erosion and sediment control practices.
c. All of the above
d. None of the above

---

(6) MAINTENANCE.

(a) 1. Except as provided in subd. 3., off–site sediment deposition resulting from the failure of an erosion or sediment control practice shall be cleaned up by the end of the next day.

Note: Contact the Department of Natural Resources before attempting to clean up any sediment deposited or discharged into the waters of the state.

2. Except as provided in subd. 3., off–site soil deposition, resulting from construction activity, that creates a nuisance shall be cleaned up by the end of the work day.

3. A municipality may enact more stringent requirements regarding cleanup of soil or sediment deposition onto public ways.

(b) 1. Except as required in subd. 2., the owner or owner's agent shall complete repair or replacement of erosion and sediment control practices as necessary within 48 hours of an interval specified under sub. (5).

2. When the failure of erosion or sediment control practices results in an immediate threat of sediment entering public sewers or the waters of the state, procedures shall be implemented immediately to repair or replace the practices.

Exam Questions:

17.) Off–site sediment deposition resulting from the failure of an erosion or sediment control practice shall be cleaned up by the end of the week.

a. True
b. False

18.) The owner or owner's agent shall complete repair or replacement of erosion and sediment control practices as necessary within _____ hours.

a. 24
b. 48
c. 72
d. 96

19.) When the failure of erosion or sediment control practices results in an immediate threat of sediment entering public sewers or the waters of the state, procedures shall be implemented immediately to repair or replace the practices.

a. True
b. False

Silt Fence

One of the most important ways to prevent soil erosion is utilizing a proper silt fence. Here is a summary of the Wisconsin DNR's Conservation Practice Standard.

I. Definition

Silt fence is a temporary sediment barrier of entrenched permeable geotextile fabric designed to intercept and slow the flow of sediment-laden sheet flow runoff from small areas of disturbed soil.

II. Purpose

The purpose of this practice is to reduce slope length of the disturbed area and to intercept and retain transported sediment from disturbed areas.

III. Conditions Where Practice Applies

A. This standard applies to the following applications:

1. Erosion occurs in the form of sheet and rill erosion (see definitions). There is no concentration of water flowing to the barrier (channel erosion).

2. Where adjacent areas need protection from sediment-laden runoff.

3. Where effectiveness is required for one year or less.

4. Where conditions allow for silt fence to be properly entrenched and staked as outlined in the Criteria Section V.

B. Under no circumstance shall silt fence be used in the following applications:

1. Below the ordinary high watermark or placed perpendicular to flow in streams, swales, ditches or any place where flow is concentrated.

2. Where the maximum gradient upslope of the fence is greater than 50% (2:1).

<u>Exam Questions:</u>

20.) _________ is a temporary sediment barrier of entrenched permeable geotextile fabric designed to intercept and slow the flow of sediment-laden sheet flow runoff from small areas of disturbed soil.

a. Sediment ponds
b. Temporary seeding
c. Silt fence
d. All of the above

21.) The purpose of using a silt fence is to reduce slope length of the disturbed area and to intercept and retain transported sediment from disturbed areas.

a. True
b. False

22.) The standard for silt fence applies where adjacent areas need protection from sediment-laden runoff.

a. True
b. False

23.) The standard for silt fence applies where effectiveness is required for two years or more.

a. True
b. False

24.) A silt fence may used where the maximum gradient upslope of the fence is greater than 50%.

a. True
b. False

25.) A silt fence may not be used below the ordinary high watermark.

a. True
b. False

IV. Federal, State, and Local Laws

Users of this standard shall be aware of applicable federal, state, and local laws, rules, regulations, or permit requirements governing the use and placement of silt fence. This standard does not contain the text of federal, state, or local laws.

V. Criteria

This section establishes the minimum standards for design, installation and performance requirements.

A. Placement

1. When installed as a stand-alone practice on a slope, silt fence shall be placed on the contour. The parallel spacing shall not exceed the maximum slope lengths for the appropriate slope as specified in Table 1.

Table 1

Slope	Fence Spacing
< 2%	100 feet
2 to 5%	75 feet
5 to 10%	50 feet
10 to 33%	25 feet
> 33%	20 feet

2. Silt fences shall not be placed perpendicular to the contour.

3. The ends of the fence shall be extended upslope to prevent water from flowing around the ends of the fence.

Exam Questions:

26.) Using Table 1, what is the appropriate fence spacing when the slope is 7%?

a. 25 feet
b. 50 feet
c. 75 feet
d. 100 feet

27.) Using Table 1, what is the appropriate fence spacing when the slope is 1%?

a. 25 feet
b. 50 feet
c. 75 feet
d. 100 feet

28.) Using Table 1, what is the appropriate fence spacing when the slope is 25%?

a. 25 feet
b. 50 feet
c. 75 feet
d. 100 feet

29.) Silt fences shall not be placed perpendicular to the contour.

a. True
b. False

30.) The ends of the silt fence shall be extended upslope to prevent water from flowing around the ends of the fence.

a. True
b. False

B. Height – Installed silt fences shall be a minimum 14 inches high and shall not exceed 28 inches in height measured from the installed ground elevation.

C. Support – Silt fences shall be supported by either steel or wood supports as specified below:

1. Wood supports

a. The full height of the silt fence shall be supported by 1 1/8 inches by 1 1/8 inches air or kiln dried posts of hickory or oak.

b. The silt fence fabric shall be stapled, using at least 0.5-inch staples, to the upslope side of the posts in at least 3 places.

c. The posts shall be a minimum of 3 feet long for 24-inch silt fence and a minimum of 4 feet for 36-inch silt fence fabric.

Exam Questions:

31.) What is the minimum height requirement of an installed silt fence?

a. 10 inches
b. 14 inches
c. 20 inches
d. 28 inches

32.) What is the maximum height requirement of an installed silt fence?

a. 10 inches
b. 14 inches
c. 20 inches
d. 28 inches

33.) Silt fences shall be supported by either steel or wood supports.

a. True
b. False

34.) For wood supports, the silt fence fabric should be stapled using at least 0.5 inch staples, to the upslope side of the posts in at least __________.

a. 1 place
b. 2 places
c. 3 places
d. 4 places

35.) Wood supports made of hickory or oak must be what size?

a. ½ inch by ½ inch
b. ¾ inch by ¾ inch
c. 1 inch by 1 inch
d. 1 1/8 inch by 1 1/8 inch

36.) Wood posts should be a minimum of ____ feet long for a 24-inch silt fence.

a. 2
b. 3
c. 4
d. 5

37.) Wood posts should be a minimum of ____ feet long for a 36-inch silt fence.

a. 2
b. 3
c. 4
d. 5

2. Steel supports

a. The full height of the silt fence shall be supported by steel posts at least 5 feet long with a strength of 1.33 pounds per foot and have projections for the attachment of fasteners.

b. The silt fence fabric shall be attached in at least three places on the upslope side with 50 pound plastic tie straps or wire fasteners. To prevent damage to the fabric from fastener, the protruding ends shall be pointed away from the fabric.

Exam Questions:

38.) The full height of the silt fence shall be supported by steel posts at least ____ feet long.

a. 2
b. 3
c. 4
d. 5

39.) The full height of the silt fence shall be supported by steel posts with a strength of 1.33 pounds per foot.

a. True
b. False

40.) The silt fence fabric shall be attached to steel supports in at least _____ places on the upslope side with 50 pound plastic tie straps or wire fasteners.

a. 2
b. 3
c. 4
d. 5

---

3. The maximum spacing of posts for nonwoven silt fence shall be 3 feet and for woven fabric 8 feet.

4. Silt fence shall have a support cord.

5. Where joints are necessary, each end of the fabric shall be securely fastened to a post. The posts shall then be wrapped around each other to produce a stable, secure joint or shall be overlapped the distance between two posts.

6. A minimum of 20 inches of the post shall extend into the ground after installation.

D. Anchoring – Silt fence shall be anchored by spreading at least 8 inches of the fabric in a 4 inch wide by 6 inch deep trench, or 6 inch deep V-trench on the upslope side of the fence. The trench shall be backfilled and compacted. Trenches shall not be excavated wider and deeper than necessary for proper installation.

Exam Questions:

41.) **The maximum spacing of posts for a nonwoven silt fence shall be 8 feet.**

a. True
b. False

42.) **The maximum spacing of posts for a woven silt fence is:**

a. 3 feet
b. 4 feet
c. 7 feet
d. 8 feet

43.) **A minimum of 10 inches of the post shall extend into the ground after installation.**

a. True
b. False

44.) **A Silt fence should have a support cord.**

a. True
b. False

45.) **It is appropriate to anchor silt fence by spreading at least 8 inches of the fabric in a 4 inch wide by 6 inch deep trench.**

a. True
b. False

On the terminal ends of silt fence the fabric shall be wrapped around the post such that the staples are not visible.

E. Geotextile Fabric Specifications – The geotextile fabric consists of either woven or non-woven polyester, polypropylene, stabilized nylon, polyethylene, or polyvinylidene chloride. Non-woven fabric may be needle punched, heat bonded, resin bonded, or combinations thereof. All fabric shall meet the following requirements as specified in Table 2.

Table 2.

Test Requirement	Method	Value*
Minimum grab tensile strength in the machine direction……….	ASTM D4632	120 lbs. (550 N)
Minimum grab tensile strength in the cross machine direction…	ASTM D4632	100 lbs. (450 N)
Maximum apparent opening size equivalent standard sieve……	ASTM D4751	No. 30 (600µm)
Minimum permittivity. ………………………………………..	ASTM D4491	0.05 scc-1
Minimum ultraviolet stability percent of strength retained after 500 hours of exposure……………………………………….…	ASTM D4355	70%

(WisDOT Standard Specifications for Road and Bridge Construction, 2001)

* All numerical values represent minimum / maximum average roll values. (For example, the average minimum test results on any roll in a lot should meet or exceed the minimum specified values.)

Silt fence shall have a maximum flow rate of 10-gallons/minute/square foot at 50mm constant head as determined by multiplying permittivity in 1/second as determined by ASTM D-4491 by a conversion factor of 74.

F. Removal – Silt fences shall be removed once the disturbed area is permanently stabilized and no longer susceptible to erosion.

VI. Considerations

A. Improper placement as well as improper installation and maintenance of silt fences will significantly decrease the effectiveness of this practice.

Silt fences should be considered for trapping sediment where sheet and rill erosion may be expected to occur in small drainage areas. Silt fences should not be placed in areas of concentrated flow.

B. Silt fences should be installed prior to disturbing the upslope area.

C. Silt fences should not be used to define the boundaries of the entire project. Silt fence should be placed only in areas where it is applicable due to its cost and the fact that it is not biodegradable. For example, silt fence should not be placed in locations where the natural overland flow is from an undisturbed area into disturbed areas of the project. It should also not be used as a diversion.

D. Silt fence should not be used in areas where the silt fence is at a higher elevation than the disturbed area.

E. When placing silt fence near trees, care should be taken to minimize damage to the root system. Avoid compaction and root cutting within 1.5 feet multiplied by the inch diameter of the tree (for example: for 10-inch trees keep out a 15-foot radius from the trunk). Refer to UWEX publication Preserving Trees During Construction for more information.

F. To protect silt fence from damage in areas of active construction or heavy traffic, silt fence should be flagged, marked, or highlighted to improve visibility.

G. Silt fence effectiveness is generally increased when used in conjunction with other upslope erosion control practices. To further strengthen the silt fence, straw / hay bales can be placed on the down slope side.

H. To help ensure effectiveness, silt fence should be inspected and repaired as necessary prior to forecasted rain events.

I. Where installation with wood posts is difficult, such as when hard or frozen ground is encountered, the use of steel post is recommended.

J. Silt fence can be mechanically installed with a plow type device provided that the silt fence is trenched in a manner such that equivalent performance is achieved to that specified in Section V.D.

Exam Questions:

46.) Silt fences shall be removed once the disturbed area is permanently stabilized and no longer susceptible to erosion.

a. True
b. False

47.) Which of the following will decrease the effectiveness of using a silt fence?

a. Improper placement
b. Improper installation
c. Improper maintenance
d. All of the above

48.) Silt fences should be considered for trapping sediment where sheet and rill erosion may be expected to occur in small drainage areas.

a. True
b. False

49.) Silt fences should be placed in areas of concentrated flow.

a. True
b. False

50.) Silt fences should be used to define the boundaries of an entire construction project.

a. True
b. False

51.) A silt fence should not be used in areas where the silt fence is at a higher elevation than the disturbed area.

a. True
b. False

52.) When placing a silt fence near trees, care should be taken to minimize damage to the root system.

a. True
b. False

53.) To protect silt fence from damage in areas of active construction or heavy traffic, silt fence should be flagged, marked, or highlighted to improve visibility.

a. True
b. False

54.) Where installation with wood posts is difficult, such as when hard or frozen ground is encountered, the use of steel post is recommended.

a. True
b. False

VII. Plans and Specifications

A. Plans and specifications for installing silt fence shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. The plans and specifications shall address the following:

1. Location of silt fence
2. Contributory drainage area
3. Schedules
4. Material specification conforming to standard
5. Standard drawings and installation details
6. Restoration after removal

B. All plans, standard detail drawings, or specifications shall include schedule for installation, inspection, and maintenance. The responsible party shall be identified.

VIII. Operation and Maintenance

A. Silt fences shall at a minimum be inspected weekly and within 24 hours after every precipitation event that produces 0.5 inches of rain or more during a 24 hour period.

B. Damaged or decomposed fences, undercutting, or flow channels around the end of barriers shall be repaired or corrected.

C. Sediment shall be properly disposed of once the deposits reach ½ the height of the fence.

IX. References

UWEX Publication A0327 “Preserving Trees During Construction”

X. Definitions

Channel Erosion (III.A.1): The deepening and widening of a channel due to soil loss caused by flowing water. As rills become larger and flows begin to concentrate, soil detachment occurs primarily as a result of shear.

Sheet and Rill Erosion (III.A.1): Sheet and rill erosion is the removal of soil by the action of rainfall and shallow overland runoff. It is the first stage in water erosion. As flow becomes more concentrated rills occur. As soil detachment continues or flow increases, rills will become wider and deeper forming gullies.

Exam Questions:

55.) Plans and specifications for installing silt fence should include which of the following?

a. Location of silt fence
b. Contributory drainage area
c. Schedules
d. All of the above

56.) Damaged or decomposed fences, undercutting, or flow channels around the end of barriers shall be repaired or corrected.

a. True
b. False

57.) Sediment shall be properly disposed of once the deposits reach ____ the height of the fence.

a. Half
b. Equal to
c. Twice
d. None of the above

58.) Sediment shall be properly disposed of once the deposits reach twice the height of the fence.

a. True
b. False

59.) _____________ is the removal of soil by the action of rainfall and shallow overland runoff.

a. Channel erosion
b. Sheet and rill erosion
c. Lake erosion
d. None of the above

60.) ______________ is the deepening and widening of a channel due to soil loss caused by flowing water.

a. Channel erosion
b. Sheet and rill erosion
c. Lake erosion
d. None of the above

Erosion Control Final Exam – Answer Sheet

Name: ______________________ Last Name: __________________________ Date:_______________

Address: _________________________ City __________________ State:_____ ZIP:________________

WI Dwelling Contractor Qualifier Number: _____________________

Phone: _____________________________ Email: ____

T F 1. Ⓐ Ⓑ Ⓒ Ⓓ	T F 21. Ⓐ Ⓑ Ⓒ Ⓓ	41. Ⓐ Ⓑ Ⓒ Ⓓ
2. Ⓐ Ⓑ Ⓒ Ⓓ	22. Ⓐ Ⓑ Ⓒ Ⓓ	42. Ⓐ Ⓑ Ⓒ Ⓓ
3. Ⓐ Ⓑ Ⓒ Ⓓ	23. Ⓐ Ⓑ Ⓒ Ⓓ	43. Ⓐ Ⓑ Ⓒ Ⓓ
4. Ⓐ Ⓑ Ⓒ Ⓓ	24. Ⓐ Ⓑ Ⓒ Ⓓ	44. Ⓐ Ⓑ Ⓒ Ⓓ
5. Ⓐ Ⓑ Ⓒ Ⓓ	25. Ⓐ Ⓑ Ⓒ Ⓓ	45. Ⓐ Ⓑ Ⓒ Ⓓ
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8. Ⓐ Ⓑ Ⓒ Ⓓ	28. Ⓐ Ⓑ Ⓒ Ⓓ	48. Ⓐ Ⓑ Ⓒ Ⓓ
9. Ⓐ Ⓑ Ⓒ Ⓓ	29. Ⓐ Ⓑ Ⓒ Ⓓ	49. Ⓐ Ⓑ Ⓒ Ⓓ
10. Ⓐ Ⓑ Ⓒ Ⓓ	30. Ⓐ Ⓑ Ⓒ Ⓓ	50. Ⓐ Ⓑ Ⓒ Ⓓ
11. Ⓐ Ⓑ Ⓒ Ⓓ	31. Ⓐ Ⓑ Ⓒ Ⓓ	51. Ⓐ Ⓑ Ⓒ Ⓓ
12. Ⓐ Ⓑ Ⓒ Ⓓ	32. Ⓐ Ⓑ Ⓒ Ⓓ	52. Ⓐ Ⓑ Ⓒ Ⓓ
13. Ⓐ Ⓑ Ⓒ Ⓓ	33. Ⓐ Ⓑ Ⓒ Ⓓ	53. Ⓐ Ⓑ Ⓒ Ⓓ
14. Ⓐ Ⓑ Ⓒ Ⓓ	34. Ⓐ Ⓑ Ⓒ Ⓓ	54. Ⓐ Ⓑ Ⓒ Ⓓ
15. Ⓐ Ⓑ Ⓒ Ⓓ	35. Ⓐ Ⓑ Ⓒ Ⓓ	55. Ⓐ Ⓑ Ⓒ Ⓓ
16. Ⓐ Ⓑ Ⓒ Ⓓ	36. Ⓐ Ⓑ Ⓒ Ⓓ	56. Ⓐ Ⓑ Ⓒ Ⓓ
17. Ⓐ Ⓑ Ⓒ Ⓓ	37. Ⓐ Ⓑ Ⓒ Ⓓ	57. Ⓐ Ⓑ Ⓒ Ⓓ
18. Ⓐ Ⓑ Ⓒ Ⓓ	38. Ⓐ Ⓑ Ⓒ Ⓓ	58. Ⓐ Ⓑ Ⓒ Ⓓ
19. Ⓐ Ⓑ Ⓒ Ⓓ	39. Ⓐ Ⓑ Ⓒ Ⓓ	59. Ⓐ Ⓑ Ⓒ Ⓓ
20. Ⓐ Ⓑ Ⓒ Ⓓ	40. Ⓐ Ⓑ Ⓒ Ⓓ	60. Ⓐ Ⓑ Ⓒ Ⓓ

The Cost Benefits of Insulated Concrete Forms

Course #18123 3 Hours

Wisconsin Contractors Institute

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EXECUTIVE SUMMARY

The concept of assessing the value of something is as much an art as it is a science. This observation is particularly true of decisions related to a new home purchase. One person may determine “best” value by lowest cost or highest quality while another makes a decision purely on intangibles (i.e., comfort, aesthetics, “peace of mind”). Regardless of the method to determine value, a homebuyer, builder, or designer should make informed decisions about house construction options. This guide provides for that need by evaluating the costs and benefits of using Insulating Concrete Forms (ICF) in the construction of a home or other similar buildings.

Through several studies of ICF construction costs, it has been determined that using ICF wall construction generally adds about 3 to 5 percent to the total purchase price of a typical wood-frame home and land (about 5 to 10 percent of the house construction cost). In other words, the added cost is about \$2 to \$4 per square foot of the floor area of a typical home. For a typical 2,500 square-foot, two-story home and lot (sale price of \$180,000), the additional cost amounts to about \$7,000. The additional first cost of ICF construction should be weighed against longer-term benefits.

Several benefits of ICFs are discussed in this guide and are quantified to the extent possible based on available technical data and analysis. The benefits of ICF house construction considered in this study are as follows:

> **Structural Safety**. This factor involves the ability of ICF construction to resist damage and protect occupants from fire, wind, earthquakes, and flooding. Of these, the inherent strength of ICF construction against severe wind loads, including hurricanes and tornadoes, are most notable.
>
> **Comfort**. Though somewhat intangible, comfort deals with important issues such as even distribution of air temperature in the home and the quietness or acoustical properties of the home. ICF construction provides improved reduction of "outdoor" noise relative to standard home construction practices.
>
> **Energy Efficiency**. Energy efficiency is the ability to maintain acceptable indoor living conditions (i.e., air conditioning or heating) at a low monthly energy cost. ICF construction, in general, provides improved energy efficiency relative to standard home construction practices.
>
> **Durability**. This factor deals with a building or material’s ability to resist rot, decay, corrosion, pest attack, and other forms of degradation that may occur over time. While concrete is known to be highly resistant to degradation, there is insufficient data to provide meaningful comparisons to standard home construction.

Some benefits of ICF construction help to minimize the monthly cost of home ownership by reducing insurance premiums and energy/utility bills. On the basis of monthly costs to own the typical home described above, ICF construction adds only about \$24 per month (accounting for a decrease in monthly energy cost and insurance premiums) in comparison to a standard wood-frame home. The cost difference can approach $35 per month in comparison to a wood-frame home upgraded to achieve similar energy performance.

The following conclusions address the major findings of this study:

1. ICF construction costs about three to five percent more than a typical new home and land in today's market (about five to ten percent of house-only construction cost).

2. Relative to standard housing construction practices, ICF construction offers several performance benefits.

3. Based on any single benefit of ICF construction, it is generally more economical to consider upgrading standard wood-frame construction to achieve "equivalent" performance.

4. It is generally more economical or practical to consider ICF construction based on the collective benefits.

5. The individual performance attribute which has greatest technical significance to ICF construction is structural safety.

6. Based on the above conclusions, the cost-benefits of ICF construction are most appealing when considered as a "package deal" with special emphasis on structural performance, particularly in extreme wind environments.

1. INTRODUCTION

The concept of assessing the value of something is as much an art as it is a science. This observation is particularly true of decisions related to a new home purchase. One person may determine “best” value by lowest cost or highest quality while another makes a decision purely on intangibles (i.e., comfort, aesthetics, “peace of mind”). Regardless of the method to determine value, a homebuyer, builder, or designer should make informed decisions about house construction options. This guide provides for that need by evaluating the costs and benefits of using Insulating Concrete Forms (ICF) in the construction of a home or other similar buildings.

Three objectives have shaped the content of this guide:

- provide objective information on the cost of typical ICF home construction relative to standard housing construction;

- compile credible information on the benefits of ICF construction relative to standard home construction; and

- evaluate and compare cost benefits of ICF and wood-frame house construction based on the above data.

Many sources of technical and anecdotal information have been considered in fulfilling the above objectives, including some of the latest test data on the strength of ICF wall construction and other benefits such as energy efficiency, wind-debris impact resistance, fire resistance, and noise control. Since ICFs offer many benefits relative to traditional home construction materials and methods, it is important to understand the entire “package” of benefits associated with ICF construction relative to other options, such as standard or up-graded wood-frame construction. Thus, an informed decision can be made regarding the value of ICF construction relative to other choices. Of course, the final assessment of value is for the reader to decide. The intent of this guide is to simply help make that decision an informed decision.

This report begins with a brief survey of housing market perspectives regarding the value of ICF construction (Section 2). In Section 3, data is presented to capture the range of construction costs that have been documented for actual ICF and wood-frame construction. Next, Section 4 presents comparative data on the performance benefits of ICF and standard wood-frame house construction, including structural safety, hazard mitigation, fire resistance, durability, energy efficiency, and noise control. Section 5 provides a cost-benefit evaluation making use of information provided in previous sections. Finally, conclusions are provided in Section 6.

2. HOUSING MARKET PERSPECTIVES

One important factor that is considered in making any purchase is the experience of other users of a product. In this section, the experience and opinions of various builders, designers, and homeowners are presented to assist in judging the costs and benefits of ICF construction. The following information has been gathered from various sources including news articles, reports, web pages, and personal communications. While this information is purely anecdotal, it does represent considerations important to understanding the value of ICF construction as perceived through the actual experience of homebuyers, builders, engineers, and others who have used the product. Negative experiences were not usually found in the available sources, nor were they specifically sought in this study.

- Cost vs. Benefits Testimonials

"*Our highest [utility] bill in a month was $110 in summer. Our neighbors hit $200-$300 in August and September*." (Source: Survey of ICF homeowners conducted by Dr. Pieter VanderWerf at Boston University as reported in Concrete Homes Newsletter, Skokie, IL.) This sentiment is shared by many ICF homeowners who are willing to pay a little extra on the front end for downstream energy cost savings, not to mention the benefits of added safety and comfort.

"*There's a certain degree of protection that you can build into every house*," says Robert Hannon, a plans examiner for the City of Coral Springs in Florida. "*The question is how much the homeowner wants to pay for when they're building the house*." (Source: PBF Magazine, November 15, 1999.)

Recent market data shows evidence of increased use of ICF construction in the housing market and even production builders have made attempts to incorporate ICF construction on the scale of entire developments. One such builder/developer reports that "while ICF construction is viable, the market interest in the benefits of ICF construction [at additional cost] does not appear to generate the volume of sales necessary to support a production building operation".

- Tornado Survival

The house shown in Figure 1 survived a tornado strike and resisted a blow from a snapped tree. Adjacent homes were completely destroyed. This ICF house belongs to a family in Washington, Iowa. The family's two children were in the home when the tornado hit. The owner's response to this experience may be summed up by the statement "*The kids didn't even hear the tree hit the house*." (Source: Reward Wall Systems, www.rwsinc.com/news_tornado.htm.)

Figure 1
Tree impact to an ICF house with no damage to the ICF wall caused by the tornado.
(Photo courtesy of Reward Wall Systems, Omaha, Nebraska, www.rwsinc.com)

The Urbana, Illinois, house shown in Figure 2 survived a direct hit from an F2-F3 tornado which tore a substantial part of the roof apart, but the ICF wall construction remained intact. The ICF walls protected the owners and their pets from the fierce wind and debris even when the roof was gone. Adjacent homes suffered 100 percent damage. "*When the city engineer came out to look, he was absolutely amazed*," stated the owner. (Source: Reward Wall Systems.)

Figure 2
An ICF home survives a direct tornado strike with windows, siding, and roof destroyed.
(Photo of Polysteel ICF home courtesy of Reward Wall Systems, Omaha, Nebraska, www.rwsinc.com)

- Hurricanes

"*I figured it couldn't hurt to learn about a building system that's both strong and energy efficient. On the barrier islands where I build, we feel the effects of almost every hurricane and nor'easter that hits the East Coast…Insulating walls rated to withstand 200-mph winds and promising to cut electric bills in half might sell themselves*," says Ralph Woodard, a builder on North Carolina's Outer Banks. (Source: Journal of Light Construction, June 1998.)

On Long Beach Island, New Jersey, homeowner Stuart Stainecker explains, "*The most prominent reason I chose to build my Barnegat Light home with Blue Maxx™ insulated concrete wall system is because of the product's resistance against tropical storms, hurricanes, and flooding*." (Source: Concretenetwork.com)

"*We have a responsibility to build safe homes for consumers, and this is the safest product to do that with*," says Guy Collins, a developer in Myrtle Beach, SC. (Source: www.pca.org, September 24, 1999, press release, Skokie, IL).

- Floods

In a flood that exceeded the 100-year level for the Gadalupe River in Texas, an ICF home (see Figure 3) withstood rushing flood waters and debris while other homes were torn from their foundations and heavily damaged. "*If this had been a conventional home [the debris] would* *have gone straight through*," said the owner, Earl Roberts, who goes on to say, "*It truly held up well*." (Source: PBF Magazine, April 1, 1999.)

Figure 3
An ICF home withstands flood waters of Guadalupe River, Texas.

- Earthquakes

According to Gene St. Onge, the structural engineer of an ICF home in earthquake-prone California, "*With a little more concrete reinforcement and strengthening of the roof and floor, incurring not that much more expense, a structure can be designed to withstand major quake damage using an ICF system*." (Source: PBF Magazine, August 15, 1999.)

3. COST

3.1 GENERAL

There are essentially two aspects to considering cost or "affordability" in purchasing a house. First cost, including all costs that affect the purchase price of the home, is important to consider because it directly influences the buyer's qualification for mortgage, down payment amount, and monthly mortgage payments. Ownership, or long-term costs, is also important to consider (given that the buyer is able to afford the first cost). Some features that increase first cost may bring future benefits in terms of reduced monthly costs for certain items such as energy consumption, maintenance, and insurance premiums. This section provides information to help assess first (construction) costs of ICF construction and standard wood-frame construction. Monthly or long-term costs are evaluated in Section 5, Cost-Benefit Evaluation.

3.2 CONSTRUCTION COST

First, and foremost, the cost of ICF construction (like any other type of building construction) is very dependent on the familiarity of the contractor and trades people with the product. In most cases, there is a "learning curve" in any new construction process that requires building several houses to eventually economize the overall approach to construction. Therefore, the experience of the contractor is an important factor that will have an impact on cost and quality. Fortunately, ICF construction is a fairly simple method of construction using a system of conventional materials (i.e., concrete, reinforcement, and insulation) and it is easily learned and understood by contractors, trades people, and "do-it-yourselfers".

There are several methods to obtain information on construction cost. One of the most reliable methods is to conduct detailed time-and-motion studies of actual construction. Fortunately, such a study has been done on a number of ICF homes and, in some cases, identical wood-frame homes to give side-by-side comparisons. The findings from this type of study are summarized in Table 1 below. While the costs are specific to the sites studied, some general observations can be made from the data as a whole:

1. ICF Construction does cost more than typical wood-frame home construction;

2. On average, the additional cost of ICF construction (per square foot of floor area) is about $4 when compared to typical wood-frame house construction; and

3. Actual cost differences vary depending on the size and complexity of the home, the type of ICF used, and other site-specific factors; thus, the additional cost of ICF construction relative to wood-frame construction may typically range from $3 to $5 per square foot.

TABLE 1
COST PER SQUARE FOOT
FROM TIME-AND-MOTION AND FIELD COST STUDIES

House Type, Size, and Estimated Sales Price	Cost of Wall Construction (per square foot of wall area) [floor area]		
	ICF	Wood	Difference
Economy One-story/1,008 sq ft $90,000 to $100,000	$4.56 [$6.19]	$2.37 [$3.42]	$2.19 [$2.77]
Custom One-story/two-story mix/3,894 sq ft	$5.95 [$7.79]	$2.25 [$2.95]	$3.70 [$4.84]
Custom One-story/2,775 sq ft	$6.65 [$6.46]	$2.14 [$2.08]	$4.51 [$4.38]
AVERAGE	$5.72 [$6.81]	$2.25 [$2.82]	$3.47 [$3.99]

Sources:
1. Insulating Concrete Forms for Residential Construction – Demonstration Homes, HUD, July 1997
2. Insulating Concrete Forms: Installed Cost and Acoustic Performance, HUD, March 1999.

A second and common method to estimate construction cost is through the use of estimating guide books such as RSMeans Residential Cost Data, 19^{th} Annual Edition. This source of construction cost data allows for a detailed assessment of the cost of house construction. However, it does not necessarily account for the nuances of non-traditional construction methods. Thus, such an approach may often over- or under-estimate actual costs depending on a number of job-specific variables, namely the experience of the contractor with the product, local availability, and cyclic market trends (i.e., demand and supply). For example, RSMeans cost data for a traditional 2x4 wood-frame wall and a traditional concrete wall with furring and insulation are shown in the Table 2. Unlike the data for the test site above, indirect cost impacts to the electric, HVAC, or plumbing installations are not considered. In addition, other design changes such as wall thickness may add cost to windows and doors (i.e., need extension jambs). Therefore, these numbers should not be blindly used for estimating the actual cost of ICF construction for specific cases. The cost estimates are, however, not very different from the cost figures reported in actual field studies. Again, the purpose here is to give a general level of expectation for cost differences between typical wood-frame construction and ICF construction.

TABLE 2
ESTIMATES USING RESIDENTIAL COST DATA[1]

WALL CONSTRUCTION	COST PER SQUARE FOOT OF GROSS WALL AREA
4" thick concrete wall[2]	$5.63
2x4 wood-frame wall[3]	$2.60
Cost Difference	$3.03

Notes:
[1]Table values are based on application of RSMeans, Residential Cost Data, 19th Annual Edition.
[2]Estimate based on lightly reinforced basement wall with thickness adjusted to 4" from 8"wall thickness, 1x2 furring both sides added, form rental/cost not included, two layers of 2" polystyrene insulation added.
[3]Typical wood-frame wall includes 2x4 studs at 16"oc, 7/16" OSB sheathing, and R13 fiberglass batt insulation.

The reader is again reminded that the actual cost for any specific house will depend on a variety of factors which may not be represented by the "ballpark" data outlined above. Therefore, actual costs are ultimately defined by actual bids from real contractors and real homes. However, pricing that varies substantially from the figures shown above should be carefully scrutinized. The above cost data is relevant to the value of money in the 1997-99 time frame and may need adjustment; the proportionate differences should, however, remain relatively constant with time. Other factors that can easily alter the above cost data include significant changes in construction practice, in material attributes, and cost of raw materials (i.e., lumber vs. concrete).

4. BENEFITS

4.1 STRUCTURAL SAFETY AND HAZARD MITIGATION

Understanding Risk

Individuals are subject to a variety of risks or hazards that can result in health problems, injury, or even death. The magnitude of common risks in terms of the chance of any one of them happening over the lifetime of an individual is shown Figure 4. It can be seen that certain risks are much more likely to happen than others. These higher risks are often what drive "calculated" risk-management decisions of the public or individuals. However, for some, risks at the lower end of the scale (often referred to as "Acts of God") are perceived as being important based on unique personal experience or perception. It should be noted that the values in Figure 4 represent a national average, whereas certain individuals, depending on life-style and where they live, may be subject to significantly higher or lower risks in some categories. For example, people living in the mid-western U.S. will not experience a hurricane, but severe thunderstorms and tornadoes are common threats (regional reasons).

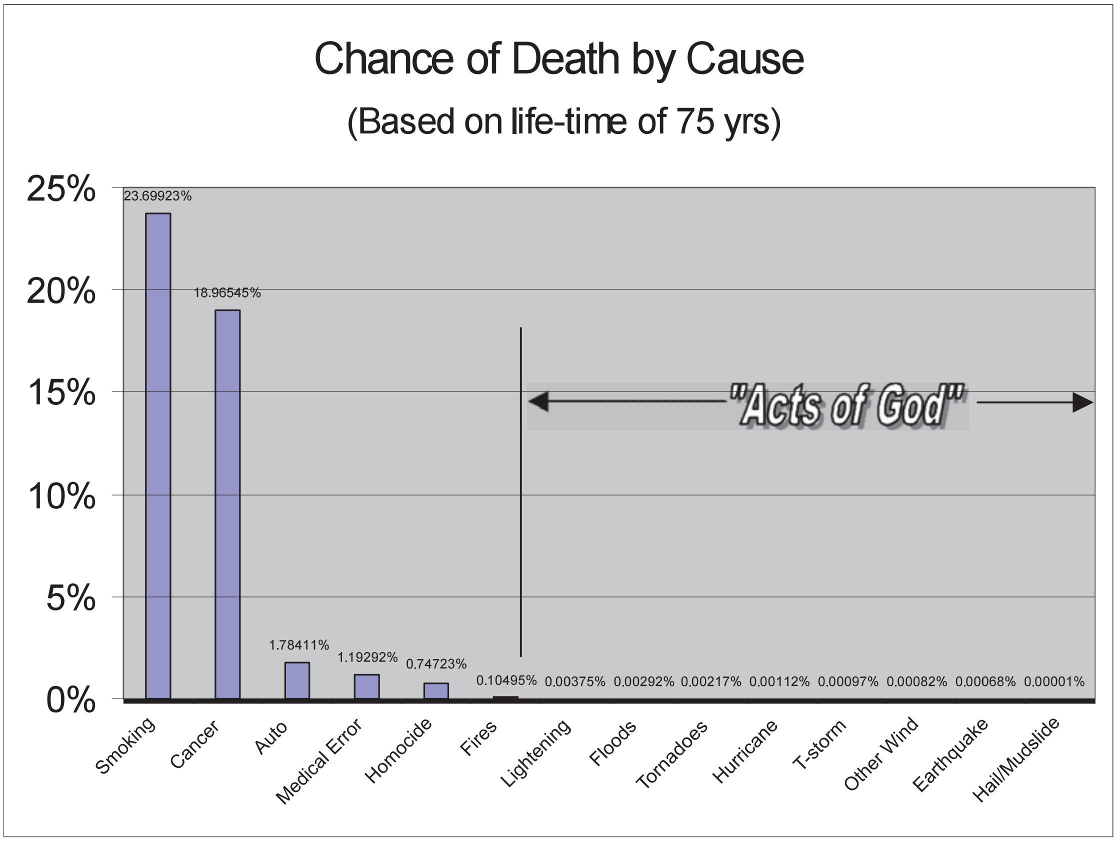
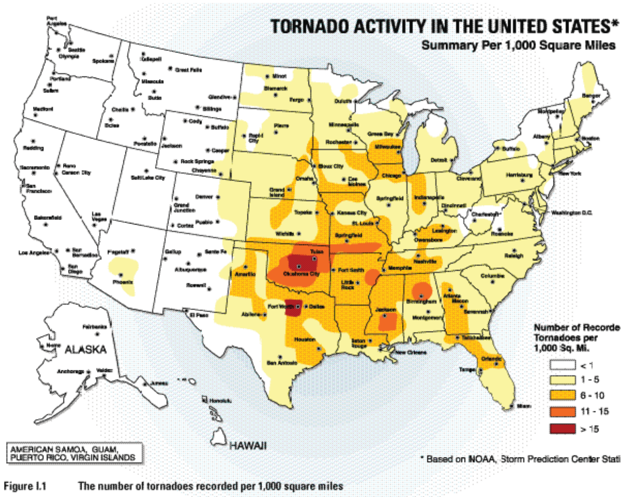


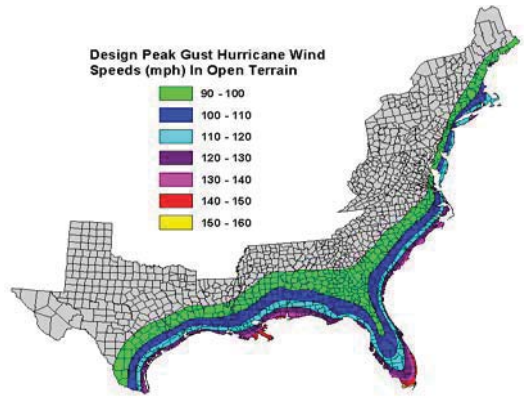
Figure 4
Chart of Various Consumer Risks*
(*Chance of happening per individual life-time based on national averages and a life-expectancy of 75 years; includes deaths unrelated to housing)
Reference: Residential Structural Design Guide (HUD, 2000)

Of similar interest is the chance of injury by cause. While the availability of data is limited, one useful example involves risk of injury due to a tornado. As shown in Figure 4, the estimated chance of death by tornado is about 0.002 percent (i.e., two thousandths of a percent chance in a lifetime of 75 years). However, the chance of experiencing an injury from a tornado incident (over a lifetime of 75 years) is about 0.04 percent (i.e., four hundredths of a percent). Thus, it can be seen that the risk of injury by certain causes may be several times greater than the risk of death by the same cause.

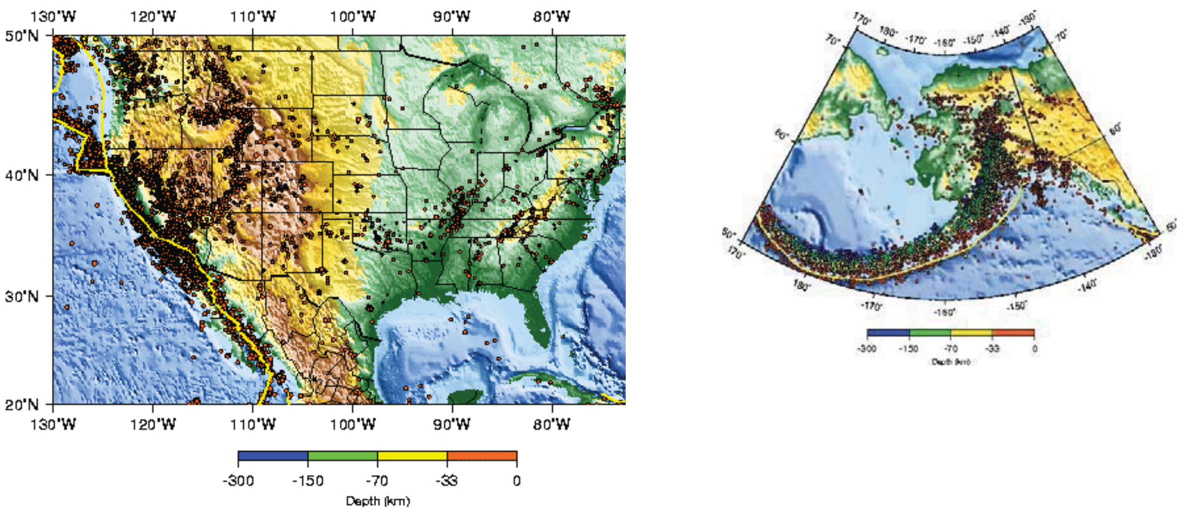
While emotional decisions definitely transfer into the home purchasing process, they cannot be predicted from one individual to the next and the "market" is often fickle in this respect. Conversely, regional differences in certain risks are much more predictable and can be based on historic climatic and geologic data. Regional differences in risk, as related to natural hazards, are shown in Figure 5.



(a) Tornado Activity Map of the United States



(b) Hurricane Design Wind Speed Map (U.S. Atlantic Coast)



(c) Earthquake Occurrence (Seismicity) Map of the United States and Alaska

Figure 5
Regional Variation of Natural Hazard Risk in the United States

The geographic distribution of risk in Figure 5 illustrates why, as a national average, some risks are of little concern to the overall population but have significant local or regional impact. For example, people in the mid-western region known as “tornado alley” may be more inclined to consider a strong house construction method, such as provided by Insulating Concrete Forms. Similar trends in public or individual risk management decisions can be expected for other regional risks, such as hurricanes and earthquakes.

ROLE OF BUILDING CODES:
Building codes are comprised of minimum requirements that represent a balance of many competing interests, not the least of which are affordability and safety. The building code merely establishes a minimum level of risk that is considered to be socially acceptable on national and local or regional scales. It is always possible to build a home that exceeds the minimum building code requirements and, therefore, further reduce certain risks below the accepted norms. However, it must be understood that any and all risks cannot be "zeroed" or eliminated.

Managing Risk

Risk management is really a money management decision regarding the design and purchase of a home. It is perfectly normal to purchase a home that meets the minimum requirements (and implied acceptable risk level) of the local building code. However, additional investment can be made to enhance a building's "survivability" in extreme hazards. This enhancement can be achieved by designing a more resistant structure of a certain construction type or by electing to use a type of construction that is inherently more resistant to certain hazards of interest. In some cases, it may be most practical or economical to use a stronger material or construction technique in only part of the structure (i.e., use of a "hardened room" for an in-home tornado shelter).

IN-HOME TORNADO SHELTERS
For information on the use of ICF construction and other materials for in-home tornado shelters, refer to "Taking Shelter from the Storm: Building a Safe Room Inside Your House" (Publication 320) by the Federal Emergency Management Agency, Washington, DC (www.fema.gov). The document includes construction plans and cost estimates.

Safety and Hazard Mitigation Benefits

There is substantial "real world" evidence that an ICF home has a greater chance of surviving certain natural hazards with less damage (refer to 'Testimonials' section) than a typical wood home. This experience is also confirmed in laboratory structural tests and design theory. This section explores the structural safety benefits of ICF construction.

- Racking Strength

Certain walls in a building experience in-plane shear or "racking" from lateral (i.e., sideways) loads created by wind and earthquakes. The racking strength of these walls prevent the building from collapsing or being pushed over by wind or earthquake forces. Data comparing racking strength of ICF walls and wood-frame walls are shown in Table 3.

TABLE 3
RACKING STRENGTH DATA
(Based on 4-foot long by 8-foot tall wall segments)

WALL CONSTRUCTION	PEAK UNIT SHEAR (pounds per foot of wall length)
Wood-Frame	300 to 2,000
ICF	2,500 to 8,500

Sources:
1. In-Plane Lateral Load Resistance of Wall Panels in Residential Buildings, Portland Cement Association, PCA R&D Serial No. 2403, Skokie, IL, 2000.
2. In-Plane Shear Resistance of Insulating Concrete Form Walls, U.S. Department of Housing and Urban Development, Washington, DC, April 2001.
3. International Building Code, International Code Council, Falls Church, VA, 2000.
4. Residential Structural Design Guide, U.S. Department of Housing and Urban Development, Washington, DC, 2000.

Notes:
1. Comparisons are based on a 4-foot wall segment or "panel" length and an 8-foot wall height.
2. Longer wall segments can result in higher values for both ICF and wood-frame wall constructions. Conversely, shorter (more narrow) wall segments without compensating structural enhancements can result in significantly lower values for both construction types.
3. Values can vary significantly depending on actual wall configuration, amount of supported dead load, amount of openings, and special detailing such as connections in wood framing and reinforcement in ICF walls.

In general, ICF wall construction provides 5 to 10 times the racking resistance of conventional wood-frame walls. To provide resistance comparable to the lowest strength ICF wall construction, a wood-frame wall construction using 3x4 studs, 1/2-inch-thick structural sheathing, 10d common nails at 2 inches on center, and special connection hardware to restrain the walls from overturning is necessary. The construction of such a wall adds about $2.00 per square foot of gross wall area which reduces the average cost difference in comparison to ICF wall construction by more than 50 percent (refer to Table 1). It is not practical or feasible to achieve the higher racking strength capability of ICF walls by further enhancement to light-frame wood construction.

While it is not necessary to have the racking strength potential of ICF walls to meet minimum building code requirements, the added strength does have benefit in terms of safety and protection of building occupants in extreme events. For example, conventional wood-frame buildings often begin to suffer damage at wind speeds typical of severe hurricanes (i.e., 130 mph gust or higher). At wind speeds of 160 mph gust or higher (a "Category 5" or catastrophic hurricane event), conventional and even moderately reinforced wood-frame homes can begin to suffer major structural damage, including collapse.[1] In excessive wind speeds that could be expected in moderate to severe tornadoes, wood-frame homes are frequently totally destroyed.[2] In contrast, with 5 or more times the in-plane shear resistance, a typical home with ICF walls could be expected to withstand "Category 5" hurricane winds (not considering storm surge effects seen by coastal homes) and even a moderate to severe tornado with minimal damage due to wind pressure on the building and the associated racking loads on walls. While the risk-benefit is small because the risk of a direct tornado strike or catastrophic hurricane is relatively low (see Figure 4), the added strength of ICF construction provides exceptional protection against

[1] "Assessment of Damage to Single-Family Homes Caused by Hurricanes Andrew and Iniki," U.S. Department of Housing and Urban Development, Washington, DC, September 1993.

[2] "Midwest Tornadoes of May 3, 1999," Federal Emergency Management Agency, Washington, DC, October 1999.

extreme wind hazards. Similar benefits are found in the resistance of ICFs to forces that may be experienced by buildings located in velocity flow zones of coastal or riverine flood plains. It should be noted, however, that flood areas constitute very unique and localized hazards that can often best be avoided by site selection and appropriate land management practices.

It is also important to note that ICF walls are stiffer than wood-frame walls. Thus, greater racking force is required to deform the wall which helps to protect non-structural components, such as wall finishes, windows, and doors from damage. However, in seismic conditions, heavy and stiff ICF walls generate greater racking loads than wood-frame walls. This effect offsets some of the racking strength benefit of ICF construction relative to light-frame wood construction in regions prone to earthquakes.

- Bending Strength

Building walls experience out-of-plane bending loads from wind, seismic, flood water, and earth pressure (i.e., basement foundation wall). Data on bending strength of ICF walls and wood-frame walls are shown in Table 4.

TABLE 4
COMPARISON OF BENDING STRENGTH
(8-foot wall height)

WALL TYPE	ULTIMATE BENDING LOAD (pounds per square foot)
ICF Construction (various types/thicknesses)	200 to 400
2x4 Wood Construction (various species, facings, and stud spacings)	50 to 100

Sources:
1. Polensek, A. and Atherton, G. H., Compression Bending Strength and Stiffness of Walls with Utility Grade Studs, Forest Products Journal, Vol 26, No 11, November 1976.
2. Design Criteria for Insulating Concrete Form Wall Systems, Portland Cement Association, Skokie, IL, 1996.
3. Stress and Deflection Reduction in 2x4 Studs Spaced 24 inches on Center Due to the Addition of Interior and Exterior Surfacings, NAHB Research Center, Inc., Upper Marlboro, MD, July 1974.

A 200 to 400 psf ultimate bending load can be associated with a 280 to 395 mph (gust) wind event which implies an ability to withstand a severe tornado (i.e., F3 or higher by Fujita tornado scale). A wood-frame wall provides bending resistance comparable to a 140 to 200 mph (gust) wind speed which implies an ability to withstand a moderate tornado (i.e., F2 or less by Fujita tornado scale). While this level of protection is clearly sufficient relative to typical building code requirements, the added strength of ICF walls in bending does provide enhanced protection in extremely rare (i.e., low risk) events such as a direct strike by a severe tornado. While the possibility of a near or direct strike of a tornado exists in many parts of the United States (see Figure 5), the risk of such an incident to any one home is only about once in a hundred thousand years or more on average. The fact that several hundred homes and buildings are affected by tornadoes in any given year is then the result of the millions of existing buildings that each have exposure to this slight risk (see Figure 4).

NOTE ON IMPORTANCE OF CONNECTIONS:

In most buildings, damages associated with wind events are often caused by connections that form a "weak link" in transmitting the loads between structural components that are otherwise capable of resisting the load. The potential impact of connections on house performance is not reflected in the above discussion on bending strength of ICF and wood walls. Given that ICF homes are of monolithic concrete construction (i.e., no joints within walls), connections can be expected to have a minimal effect on a typical ICF home compared to a typical wood home. However, ICF homes are frequently built with wood-frame roofs. Since wood-frame roofs are often the location where wind damage begins in a home, the full benefit of ICF wall construction may not be realized when used with wood-frame roofs that are not additionally reinforced. This reinforcement can be achieved by the use of additional fasteners in roof sheathing and enhanced connections between an ICF wall and a roof system by use of metal tie straps or other similar devices.

- Compressive strength

Building walls experience compressive loads from the weight of the building itself as well as the weight of contents, including people and furnishings. Therefore, the compressive strength of a wall prevents the collapse of a building when heavily loaded with people or contents. Data comparing the compressive strength of ICF walls and wood-frame walls are shown in Table 5. For homes, the compressive strength of ICF walls generally exceeds plausible extreme gravity (compressive) loads that could be experienced in typical homes or similar structures.

TABLE 5
COMPRESSIVE STRENGTH DATA
(based on 8-foot wall height)

WALL CONSTRUCTION	MAXIMUM COMPRESSIVE LOAD (pounds per foot of wall length)
Wood Frame (various 2x4 configurations)	4,500 to 10,000
ICF (4- to 6-inch wall thickness)	60,000 to 100,000

Note:
Values are based on unpublished test data and analysis by NAHB Research Center, Inc.

- Wind-borne Debris Impact Resistance

ICF wall systems have been tested for wind-borne debris resistance by subjecting them to the impact of a 2x4 wood stud traveling at speeds of up to 100 mph. This level of impact is considered to be representative of the nature of impacts that could be expected in a severe tornado (i.e., 250 mph wind speed). Data on the wind-borne debris impact resistance of ICF walls and wood-frame walls is shown in Table 6. While it is possible to upgrade the impact resistance of standard wood-frame wall construction to levels suitable for protection against potential debris in moderate hurricanes and less severe tornadoes, it is impractical to upgrade standard wood-frame wall construction to give comparable performance to ICF walls. It should be noted that the ICF wall data in Table 6 applies to ICF types that result in a "solid" concrete wall.

TABLE 6
WIND-BORNE DEBRIS IMPACT DATA

WALL CONSTRUCTION	IMPACT RESISTANCE
Wood Frame (various typical constructions)	8 to 26 mph (9 lb 2x4)[1]
ICF (4" and 6" flat and waffle-grid)	100+ mph (15 lb 2x4)[2]

Notes:
[1]Based on testing performed by Clemson University for the Region IV Mitigation Division of the Federal Emergency Management Agency, Atlanta, GA.
[2]Based on Investigation of Wind Projectile Resistance of Insulating Concrete Form Homes, Portland Cement Association, Skokie, IL.

4.2 FIRE RESISTANCE

Fire resistance is important to the protection of occupants from fire and to allow sufficient time for warning and evacuation. Concrete walls have superior fire resistance in comparison to most other building materials. Solid concrete ICF walls can generally sustain as much as four hours of extreme fire exposure (as reported at www.rwsinc.com), whereas typical wood-frame walls in houses generally do not exceed a one-hour fire rating. For housing, building codes typically require a minimum 15-minute rating with the exception of special fire separation requirements for multifamily construction, apartments, and townhouse units, where a minimum one- to two-hour fire rating is required between dwelling units.

While building contents are often the initiating source of fuel for fire-related incidents in homes, concrete is not a fuel source that can contribute to fire growth and spread in a building. It is also important to realize that doors, windows, and other penetrations can create a "short-circuit" for fire spread, if not similarly fire-rated in comparison to the walls. Regardless, fire resistance is a recognized benefit of ICF construction and can result in reduced fire insurance premiums.

4.3 DURABILITY

Little data is available to exactly quantify durability benefits in the varying use-conditions of building materials. Therefore, experience is often the most reliable guide. Concrete construction is well-known for its durability in building construction. In particular, concrete used in ICF walls is further protected from moisture and other environmental factors. While wood is similarly protected within the walls of a home, it is susceptible to rot in areas where water often penetrates the exterior weather-resistant barrier of a home, particularly in hot/humid climates. Wood materials are also subject to termite attack which can result in significant structural damage and necessitate structural repairs.

To obtain a higher level of durability in wood-frame construction would require additional costs in protecting the wood, either by design and detailing of the building, or by use of preservative-treated wood or naturally decay-resistant wood species. For example, treated lumber is often used for house construction in Hawaii because of severe termite problems. The cost increase relative to typical house construction with untreated lumber is about $0.50 per square foot of wall or approximately 15 percent of the cost difference between ICF and standard wood construction (see Tables 1 and 2).

In summary, concrete is able to maintain it's structural capabilities over a long period of time and extend the life-expectancy of buildings. Life-expectancy and maintenance of a home is a concern of homebuyers and designers with a long-term perspective.

4.4 ENERGY EFFICIENCY

ICF construction, as a result of the use of insulating form materials (i.e., polystyrene foam), provides an inherently high level of thermal resistance. In field comparisons of similar ICF and wood-frame house constructions, it has been found that ICF wall construction can provide a 20 to 25 percent savings in annual heating and cooling costs[3]. To achieve a similar level of energy performance, a typical wood-frame home would require an "energy upgrade" that adds about $2,640 to an average home cost of $200,000 (or about $1.32 per square foot of living area). This amount is equivalent to about one-third of the cost difference between ICF and typical wood-frame house construction reported in Tables 1 and 2.

4.5 NOISE CONTROL

The ability of a wall to decrease the amount of sound (or noise) passing through is measured by testing the wall to give it a rating. This rating is known as the Sound Transmission Class (STC) and can be used to compare the noise control or privacy afforded by various wall constructions. For ICF wall construction, the primary noise control benefit is in the reduction of noise from outside-the-home sources. Control of inside-the-home noise sources may require special detailing of partition walls and floor systems inside the home and is beyond the scope of this document.

First, it is important to understand the difference between various STC ratings as described in Table 7. Since a tolerable level of noise is dependent on the nature of the noise source (e.g., frequency), the individual perception, and other factors, the descriptions of "privacy afforded" given in Table 7 do not indicate an acceptable level of noise suppression. Such determinations are left up to the reader. As a point of reference, for party walls separating attached dwelling units, U.S. building codes usually require a minimum STC rating of 45.

TABLE 7
SOUND TRANSMISSION CLASS DESCRIPTION

STC RATING	PRIVACY AFFORDED
25	Normal speech easily understood
30	Normal speech heard but not understood
35	Loud speech heard and somewhat understood
40	Loud speech heard but not understood
45	Loud speech barely heard
50	Shouting barely heard
55	Shouting not heard

Source:
Quieting: A Practical Guide to Noise Control, NBS Handbook 119, National Bureau of Standards, U.S. Department of Commerce, Washington, DC, 1976.

[3] *Insulating Concrete Forms: Comparative Thermal Performance*, U.S. Department of Housing and Urban Development, Washington, DC, December 1999.

Data on the STC ratings of ICF and wood walls are summarized in Table 8. ICF construction provides a clear benefit relative to typical wood-frame wall construction. To obtain similar performance from a wood-frame wall, certain enhancements are required (i.e., thicker gypsum board layers, resilient channels, acoustic insulation, etc.). These enhancements can add about $0.70 per gross square foot of wall area, which accounts for about one-fifth of the cost difference between ICF and standard wood-frame construction (refer to Tables 1 and 2).

TABLE 8
SOUND TRANSMISSION CLASS RATINGS

Wall Construction	STC Ratings	FSTC Rating[1]
Typical Wood Wall	35 to 49	35
Enhanced Wood Wall[2]	50 to 54	--
ICF	48 to 58	40

Sources:
1. Fire Resistance Design Manual, Sound Control, Gypsum Systems (GA–600–94), Gypsum Association, Washington, DC, 1994.
2. Insulating Concrete Forms: Installed Cost and Acoustic Performance, U.S. Department of Housing and Urban Development, Washington, DC, March 1999.
3. Manufacturer data.

Notes:
1. FSTC is tested in actual field conditions and may be 1 to 5 points lower than STC rating. The FSTC rating also includes the effect of windows and other sources that can “short-circuit” noise control provided by a wall. Therefore, to maximize the sound deadening benefits of ICF construction, enhanced window and door construction should be considered.
2. Enhanced wood wall includes 2x4 @ 16”oc, resilient channels 24”oc, 5/8” gyp board both sides, and 3-1/2 inch batt insulation.

5. COST-BENEFIT EVALUATION

5.1 General

ICF construction, while generally more expensive than standard wood-frame construction, has several performance benefits that require consideration relative to first cost, monthly (operating) costs, and comparative performance of standard wood-frame construction. Comparative cost-benefits with respect to energy efficiency is addressed in the next section, Monthly Costs. The assignment of a dollar value was found to be difficult for other performance attributes such as structural safety, durability, fire resistance, and noise control for a variety of reasons, including lack of reliable data or the inherent subjective or non-economic "value" associated with a particular performance attribute (i.e., noise control). Recognizing that there are important differences in performance and value, however, a comparison of relative performance and cost to achieve "equivalent" performance is presented in Section 5.3 based on the data presented in Sections 3 and 4.

5.2 Monthly Costs

Since most homes are purchased using mortgages, the monthly cost of home ownership is primarily related to financing. Thus, interest rate and the term of the loan (usually 15 or 30 years) are key factors that govern monthly and overall cost. Any increase in the first cost of a home will directly effect the monthly mortgage payment and the amount paid in principal and interest over the term of the loan. However, certain benefits that come at additional first cost may convey a net cost savings over the term of a mortgage or period of ownership.

Key monthly or periodic costs include:

- mortgage (principal and interest);
- utilities (electric, gas, etc.);
- home owner's insurance (required by mortgager, optional otherwise);
- maintenance (painting, repairs, etc.); and
- taxes.

Maintenance and long-term replacement costs are not factored in to the monthly cost comparison of Table 9 because of the lack of reliable data on this issue, particularly for ICF homes. Table 9 compares a standard wood-frame home to a typical ICF home in terms of monthly housing cost. Also included is a wood-frame home with an upgraded energy package that compares more closely with the energy efficiency of typical ICF construction. Long-term maintenance and repair costs are not included. Monthly maintenance and repair costs for a typical home is about $25 to $50.

TABLE 9
COMPARISON OF TYPICAL MONTHLY COSTS OF HOME OWNERSHIP

	STANDARD WOOD HOME	UP-GRADED WOOD HOME	TYPICAL ICF HOME	COMMENTS
Purchase Price	200,000	202,640	208,000	ICF 4% more
Principal and Interest	1,119	1,133	1,163	7.5% interest/20% down
Taxes	300	304	312	.15% tax rate
Insurance	25	25.33	22.50	10% savings
Energy	145	116	116	20% savings
TOTAL MONTHLY COST	1,589	1,578.33	1,613	ICF is $24 to $35 more per month

Notes:
1. Values for standard wood home and typical ICF home are based on similar data found at www.pca.org.
2. Upgraded wood home includes a typical energy efficiency option of 2x6 studs, R13 fiberglass batt insulation, and 1-inch exterior foam insulation.

5.3 COMPARATIVE PERFORMANCE

A comparison of the relative performance of ICF construction and wood-frame construction is shown in Table 10. While subjective in nature, the comparison is based on quantitative data presented in Section 4.

TABLE 10
COMPARISON OF RELATIVE PERFORMANCE

PERFORMANCE CHARACTERISTIC	ABOVE-GRADE WALL CONSTRUCTION TYPE	
	Concrete (ICF)	Wood-Frame
Safety and Damage Prevention	Excellent	Adequate to Good
Energy Efficiency	Excellent	Adequate to Excellent
Fire Resistance	Excellent	Adequate
Durability	Excellent	Adequate
Sound Control	Excellent	Adequate to Good

5.4 COST COMPARISON BASED ON EQUIVALENT PERFORMANCE

A summary of cost increases to standard wood-frame construction to achieve (or nearly achieve) a level of performance comparable to ICF construction for various performance attributes is shown in Table 11. It can be seen that if comparable performance is desired on all counts, the cost of an upgraded wood-frame home can exceed that of ICF house construction. However, if only one performance attribute is of concern, such as energy efficiency, the option to upgrade wood-frame construction is more economical. Conversely, ICF construction compares most favorably in the area of structural safety where the cost to upgrade wood framing to similar performance is greatest, particularly in areas with high wind hazard.

TABLE 11
COST TO UPGRADE WOOD-FRAME WALL PERFORMANCE[1]

PERFORMANCE CHARACTERISTIC	PERCENTAGE OF COST DIFFERENCE BETWEEN ICF AND STANDARD WOOD CONSTRUCTION
Safety & Hazard Mitigation	50% or more
Fire Resistance	Not considered practical to upgrade
Energy Efficiency	33%
Durability	15%
Sound Control	20%
TOTAL	118%

Notes:
1. Table values are based on data presented within the report.
2. Cost difference between ICF and standard wood construction is found in Tables 1 and 2. This difference is about $3.99 per square foot of floor area, $3.47 per square foot of gross wall area, or about $7,000 for a typical 1,800 sq ft house plan costing an average $208,000.

6. CONCLUSIONS

The following conclusions are based on the findings of this study:

1. ICF construction costs about three to five percent more than a typical new home and land in today's market (about five to ten percent of house-only construction cost).

2. Relative to standard housing construction practices, ICF construction offers several performance benefits.

3. Based on any single benefit of ICF construction, it is generally more economical to consider upgrading standard wood-frame construction to achieve "equivalent" performance.

4. It is generally more economical or practical to consider ICF construction based on the collective benefits.

5. The individual performance attribute which has greatest technical significance to ICF construction is structural safety.

6. Based on the above conclusions, the cost-benefits of ICF construction are most appealing when considered as a "package deal" with special emphasis on structural performance, particularly in extreme wind environments.

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The Cost Benefits of Insulated Concrete Forms
Final Exam

EXECUTIVE SUMMARY

1. What does the acronym ICF stand for?
    a. Insulation Constructed Formula
    b. Insulating Concrete Forms
    c. Insulate Creation Formation
    d. Insulated Construction Factor

2. Through several studies of ICF construction costs, it has been determined that using ICF wall construction generally adds ____ to the total purchase price of a typical wood frame home and land:
    a. 17 percent
    b. About 3 to 5 percent
    c. About 4 to 7 percent
    d. 2 to 3 percent

3. Structural safety involves the ability of ICF construction to resist damage and protect occupants from which of the following:
    a. Fire and wind
    b. Earthquakes and flooding
    c. Hurricanes and tornadoes
    d. All of the above

4. Energy efficiency refers to:
    a. The ability to maintain acceptable indoor living conditions at a low monthly energy cost
    b. The rate at which energy is generated in comparison to alternate means of production
    c. The ratio of energy produced divided by the amount of time elapsed
    d. None of the above

1. INTRODUCTION

5. True or false? Some of the latest test data on the strength of ICF wall construction verify its benefits such as energy efficiency, wind-debris impact resistance, fire resistance, and noise control.
    a. True
    b. False

2. HOUSING MARKET PERSPECTIVES

6. Recent market data shows evidence of ________ use of ICF construction in the housing market.
    a. Excessive
    b. Less
    c. Increased
    d. Decreased

7. ICF homeowners who pay a little extra for building construction on the front end have _______utility bills in comparison to non-ICF homeowners.
    a. Smaller
    b. Larger
    c. Equivalent
    d. Varies by situation

8. With regards to Figure 2, the ICF walls remained intact, whilst adjacent homes lacking such construction suffered ___percent damage.
    a. 50%
    b. 75%
    c. 80%
    d. 100%

3. COST

3.2 CONSTRUCTION COST

9. On average, the additional cost of ICF construction (per square foot of floor area) is about $___ when compared to typical wood-frame house construction.
    a. 2
    b. 4
    c. 6
    d. 8

10. According to Table 1, the cost of wall construction per square foot of wall area for wood on an economy one-story home is:
    a. $2.37
    b. $4.19
    c. $3.33
    d. $3.50

4. BENEFITS

4.1 STRUCTURAL SAFETY AND HAZARD MITIGATION

11. Risks at the lower end of the scale, often referred to as ________, include: lightening, earthquakes, and mudslides among others.
    a. “Forces of Nature”
    b. “Environmental Intervention”
    c. “Acts of God”
    d. None of the above

12. From Figure 4, the highest chance of death is from:
    a. Tornadoes
    b. Medical error
    c. Earthquake
    d. Smoking

13. Regional differences in certain risks can be very predictable and are based on which of the following data:
    a. Historic
    b. Climatic
    c. Geologic
    d. All of the above

14. According to Figure 5, what state has the most heavily concentrated tornado activity?
    a. Texas
    b. Oklahoma
    c. Nebraska
    d. Arkansas

15. The building code merely establishes a ________ level of risk that is considered to be socially acceptable on national and local or regional scales.
    a. Minimum
    b. Maximum
    c. Safe
    d. Appropriate

16. True or false? The racking strength of a wood frame wall is higher than for an ICF wall, according to Table 3.
    a. True
    b. False

17. True or false? An ICF wall can handle a much larger compressive load than a wood frame wall, according to Table
    a. True
    b. False

4.2 FIRE RESISTANCE

18. Solid concrete ICF walls can generally sustain as much as ___ hour of extreme fire exposure, whereas typical wood-frame walls in houses generally do not exceed ___hour(s).
    a. 2, 1
    b. 3, 2
    c. 4, 1
    d. 5, 2

4.3 DURABILITY

19. ________ construction is well-known for its durability in building construction.
    a. Wood
    b. Concrete
    c. Clay
    d. Sand

4.4 ENERGY EFFICIENCY

20. Regarding *energy efficiency*, ICF wall construction can provide a _____ savings in annual heating and cooling costs:
    a. 10 to 15 percent
    b. Negligible
    c. 50 percent
    d. 20 to 25 percent

4.5 NOISE CONTROL

21. What does the acronym STC stand for?
    a. Sound Transmission Class
    b. Sonic Transduction Category
    c. Speech Transferal Classification
    d. Shouting Transducer Classified

22. According to table 7, at an STC rating of 45
    a. Normal speech is easily understood
    b. Loud speech is barely heard
    c. Shouting is barely heard
    d. Shouting is not heard

23. What type of sound enhancement accounts for about one-fifth of the cost difference between ICF and stand wood-frame construction?
    a. Thicker gypsum board layers
    b. Resilient channels
    c. Acoustic insulation
    d. All of the above

5. COST-BENEFIT EVALUATION

5.2 MONTHLY COSTS

24. The monthly cost of home ownership is primarily related to:
    a. Utilities
    b. Maintenance
    c. Insurance
    d. Financing

25. According to Table 9, the energy cost of an up-graded wood home compared to a typical ICF home is________.
    a. Smaller
    b. Larger
    c. Equivalent
    d. Not listed

5.3 COMPARATIVE PERFORMANCE

26. True or false? According to Table 10, the relative performance of an ICF home compared to a wood-frame home with regards to durability is better for an ICF home.
    a. True
    b. False

5.4 COST COMPARISON BASED ON EQUIVALENT PERFORMANCE

27. True or false? If only one performance attribute is of concern, the option to upgrade ICF construction is more economical.
    a. True
    b. False

28. According to Table 11, the difference in cost between ICF and standard wood construction for durability is ___%.
    a. 5
    b. 10
    c. 15
    d. 20

6. CONCLUSIONS

29. True or false? A valid *conclusion* regarding this study could be that it is generally more economical or practical to consider ICF construction based on the collective benefits.
    a. True
    b. False

30. The cost-benefits of ICF construction are most appealing when considered as a "package deal" with special emphasis on structural performance, particularly in environments subject to _______.
    a. Wildfires
    b. Flooding
    c. Extreme wind
    d. Earthquakes

Cost Benefits of Insulate Concrete Forms - Answer Sheet

First Name: _______________ **Last Name:** ____________________________ **Date:** _________________

Address: ____ **State:** __________ **ZIP:** ________________

WI Dwelling Contractor Qualifier License #: __________________________

Phone: ____________________________________ **Email:** _______________________________________

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4.	ⓐⓑⓒⓓ	24.	ⓐⓑⓒⓓ
5.	ⓐⓑⓒⓓ	25.	ⓐⓑⓒⓓ
6.	ⓐⓑⓒⓓ	26.	ⓐⓑⓒⓓ
7.	ⓐⓑⓒⓓ	27.	ⓐⓑⓒⓓ
8.	ⓐⓑⓒⓓ	28.	ⓐⓑⓒⓓ
9.	ⓐⓑⓒⓓ	29.	ⓐⓑⓒⓓ
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