Unit 4

Earthquake Effects

INTRODUCTION

In the last unit, we looked at the causes and characteristics of earthquakes. Now let's take a look at an earthquake's effects on the natural and built environments. Knowing more about the effects of earthquakes helps us understand the mitigation steps that must be taken to protect a community from a seismic event.

Unit 4 covers the following topics:

- What are some effects of earthquakes on the natural and built environments?
- What building characteristics are significant to seismic design?
- How do buildings resist earthquake forces?
- What secondary consequences of earthquakes must we be concerned with?

WHAT ARE SOME EFFECTS OF EARTHQUAKES ON THE NATURAL ENVIRONMENT?

In the last unit, we reviewed the different types of seismic waves that produce the violent ground shaking, or motion, associated with earthquakes. These wave vibrations produce several different effects on the natural environment that also can cause tremendous damage to the built environment (buildings, transportation lines and structures, communications lines, and utilities). Researching potential problems, known as site investigation, is a good first step in reducing damage to the built environment due to earthquakes.

Liquefaction

Strong ground motion during an earthquake can cause water-saturated, unconsolidated soil to act more like a dense fluid than a solid; this process is called liquefaction. Liquefaction occurs when a material of solid consistency is transformed, with increased water pressure, in to a liquefied state. Water saturated, granular sediments such as silts, sands, and gravel that are free of clay particles are susceptible to liquefaction. Imagine what would happen to a building if the soil beneath it suddenly behaved like a liquid. This potential for liquefaction to occur is present in many parts of the United States and in other parts of the world. Liquefaction occurred during the 1811-1812 New Madrid, Missouri, the 1989 Loma Prieta, California, the 1964 Niigata, Japan, and the 1967 Caracas, Venezuela, earthquakes. Figures 4-1 and 4-2 show how buildings can topple when soil assumes the properties of a liquid and loses its bearing capacity.

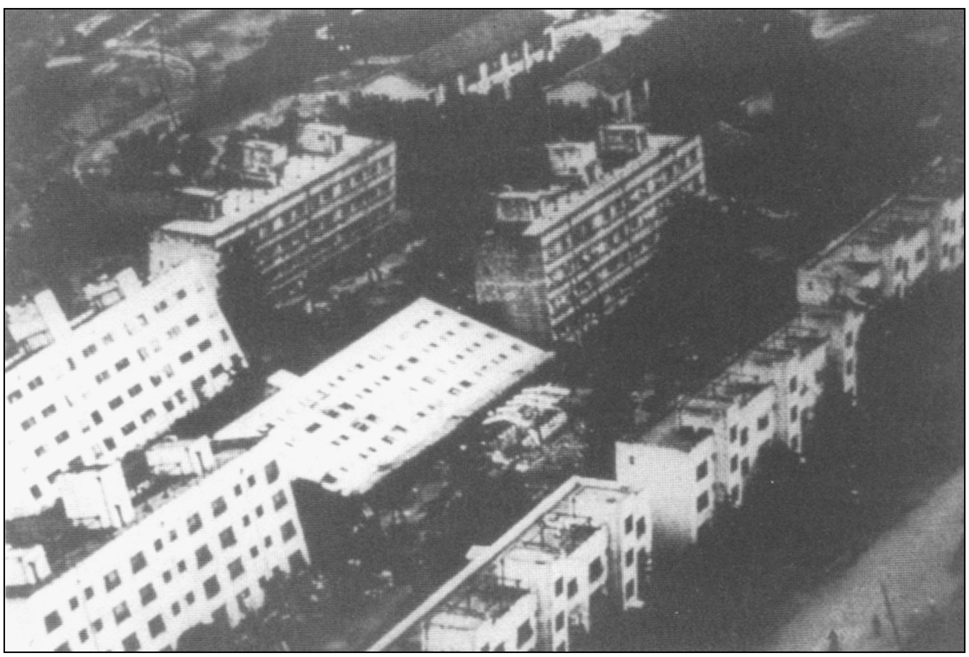


Figure 4-1 *Source: Federal Emergency Management Agency.*

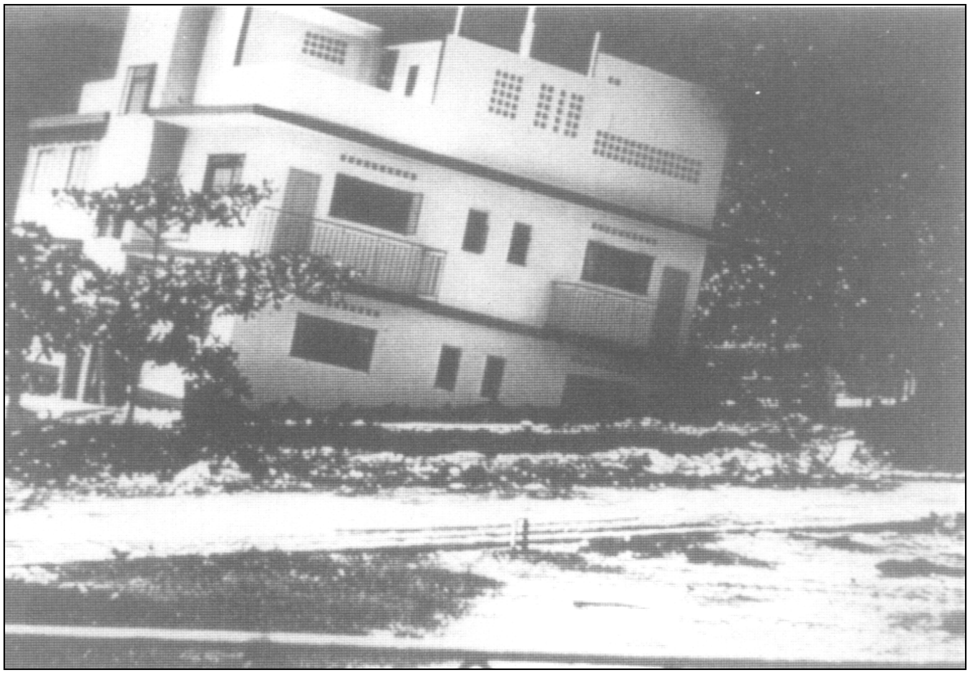


Figure 4-2 *Source: Federal Emergency Management Agency.*

Landslides

Ground motion also can trigger landslides. Careful consideration should be made before developers place a building in a location that could be affected by a landslide. A fire department in California found that out the hard way. During an earthquake in their community, a landslide blocked the exits to the firehouse, and, while the fire equipment was blocked inside, the town suffered millions of dollars in damage from fires caused by the earthquake. Figure 4-3 shows a railroad track that was left hanging on the side of a mountain after the land beneath it slid away.

Tsunamis and Seiche

Tsunami ("Soo na me") is Japanese for tidal wave. A tsunami is caused by an earthquake, landslide, or volcanic eruption on the sea floor. During an earthquake, seismic waves can produce powerful ocean waves. These waves tend to be very deep, with long distance between the peaks. In deep water there may be no noticeable evidence of the tsunami at the surface. However, when the wave enters shallow waters, the energy is forced to the surface and produces a tall wave that travels at high speed and moves far inland. Seaside communities are usually ravaged twice—first, when the water crashes in from the sea and, second, when the water recedes and carries loose objects out to sea. Though tsunamis are not as common as earthquakes, they can cause much more damage. Here in the United States, we can experience tsunamis on the West Coast, Alaska, and Hawaii.

"Seiche" refers to the oscillation (sloshing back and forth) of water in a closed space, such as a lake, reservoir, or swimming pool. This oscillation can cause overtopping of dams and damage to structures near water.

Faults

We saw in the previous unit that ruptures along fault planes or zones sometimes reach the surface. If a building stands on a fault line, little can be done to protect it during an earthquake. It is extremely important to select sites for new buildings that are away from known fault surface traces. Figures 4-4, 4-5, and 4-6 show faults that have risen to the surface.

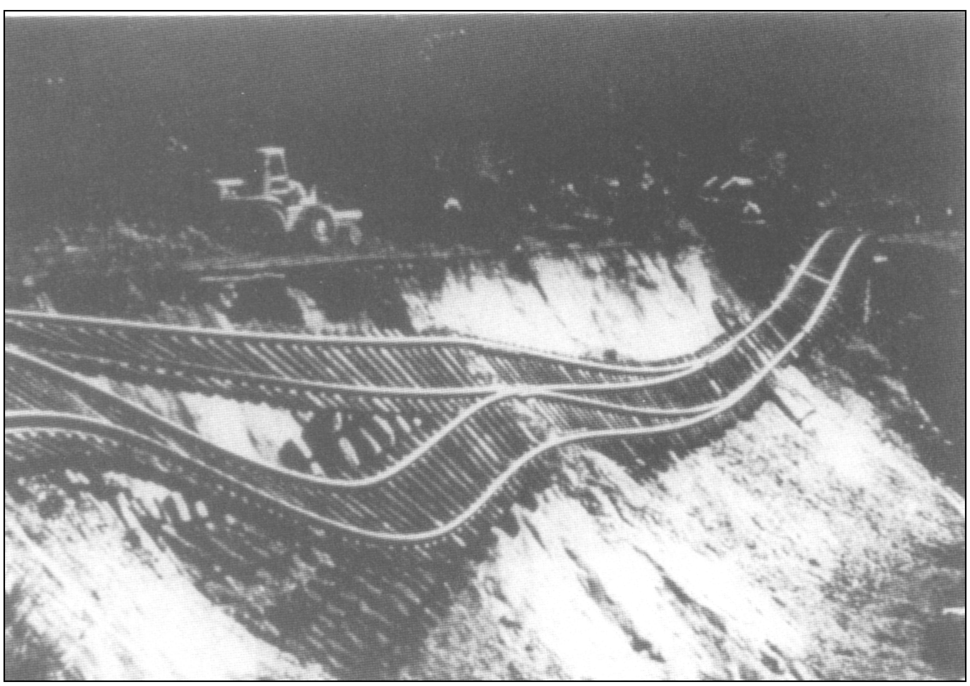


Figure 4-3 *Source: Federal Emergency Management Agency.*

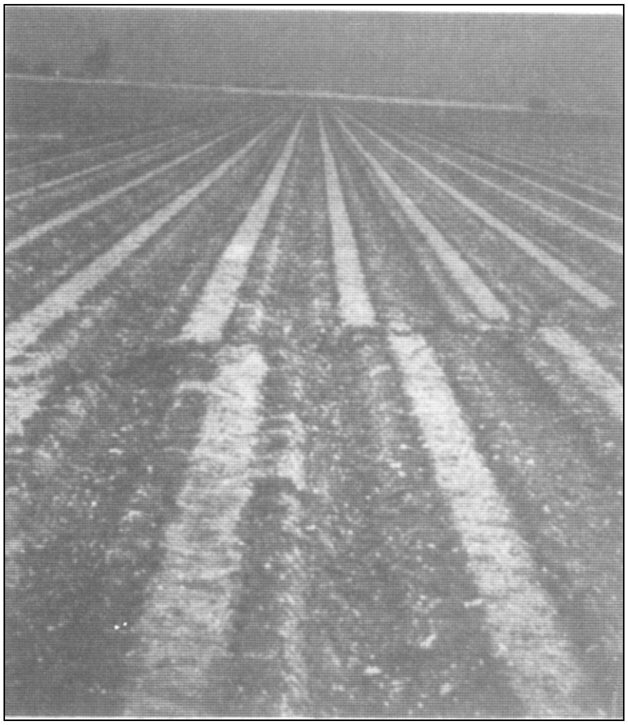


Figure 4-4 *Source: Federal Emergency Management Agency.*

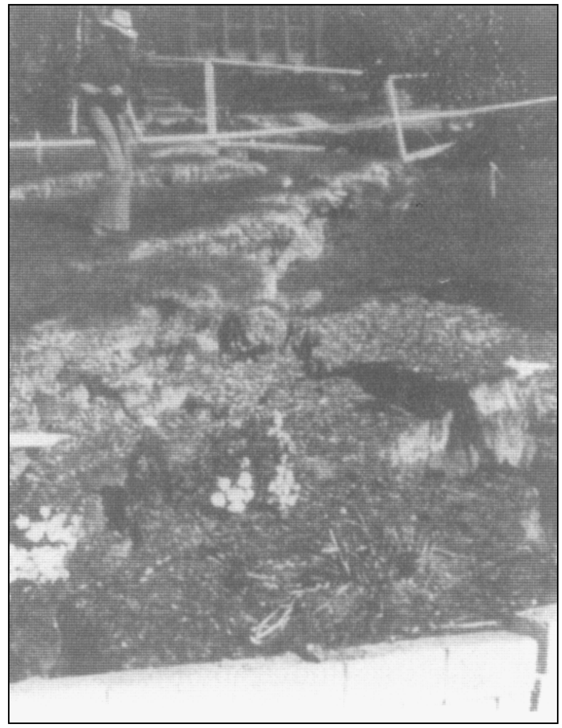


Figure 4-5 *Source: Federal Emergency Management Agency.*

Figure 4-6 *Source: Federal Emergency Management Agency.*

WHAT BUILDING CHARACTERISTICS ARE SIGNIFICANT TO SEISMIC DESIGN?

Several important characteristics of buildings affect performance during an earthquake. Buildings of different construction materials or configurations will respond in different ways to the same ground motion; some may collapse while others survive. Knowing how buildings respond in an earthquake helps architects, engineers, and builders design and construct buildings to withstand ground motion without collapsing. Let's consider some of the structural characteristics of buildings that influence how they behave during an earthquake. These characteristics are natural period, damping, ductility, stiffness, drift, and building configuration.

Natural Period

All objects (including buildings and the ground) have a "natural period," or the time it takes to swing back and forth, from point A to point B and back again. If you pushed the flag pole shown in Figure 4-7, it would sway at its natural period.

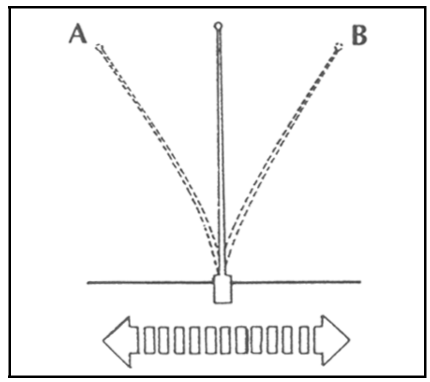


Figure 4-7 *Source: Lagorio. Earthquakes: An Architect's Guide to Nonstructural Seismic Hazards, 1990.*

As seismic waves move through the ground, the ground also moves at its natural period. This can become a problem if the period of the ground is the same as that of a building on the ground. When a building and the ground sway or vibrate at the same rate, they are said to resonate. When a building and the ground resonate it can mean disaster. This is because, as the building and ground resonate, their vibrations are amplified or increased, and greater stress is placed on the building. Think of a building vibrating rapidly; at some point the building will begin to shake apart.

One of the most important factors affecting the period is height. A taller building will swing back and forth more slowly (or for a longer period) than a shorter one. For example, a 4-story building might have a natural period of 0.5 seconds, while a 60-story building may have a period of as much as 7 seconds. Building height can have dramatic effects on a structure's performance in an earthquake. A taller building often suffers more damage than a shorter one because the natural period of the ground tends to match that of buildings nine stories or taller. This explains why some buildings are severely damaged and others are not. During the 1964 earthquake in Anchorage, Alaska, shorter buildings closer to the earthquake's focus suffered less damage than taller buildings up to 75 miles away because the taller, multistory buildings resonated with the long-period ground motions. Buildings resonate only when their natural periods coincide with the period of the ground motions during an earthquake. In the 1985 Mexico City, Mexico, earthquake long-period ground motions were the same as the period of some 9- to 14-story buildings. The results were disastrous for buildings of this size. Buildings taller than 14 stories did not experience resonance and had fewer disastrous effects. Some seismically active areas impose height restrictions on buildings to decrease the possibility of building failure during an earthquake.

Although the phenomenon of resonance can be extremely damaging, its effects can be reduced. In designing seismically safe buildings, an architect or engineer must be concerned with "tuning" a building so that the tendency for its own vibration to be amplified by resonance is reduced or eliminated.

Damping

One way an architect or engineer may decrease the effects of resonance is by constructing buildings so that the vibration of a building is quickly reduced as an earthquake sets it in motion. This is called damping, the termination or retardation of the motion or vibration of a structure. Connections of nonstructural elements such as partitions, ceilings, and exterior walls can dampen a building's vibration. Modern office buildings with open flooring and few partitions tend to be deficient in damping and therefore suffer more damage in an earthquake. It is most advantageous for a building to have a high level of damping characteristics—in effect to be an inefficient vibrator. With damping design, a building is less likely to resonate in tune with the ground.

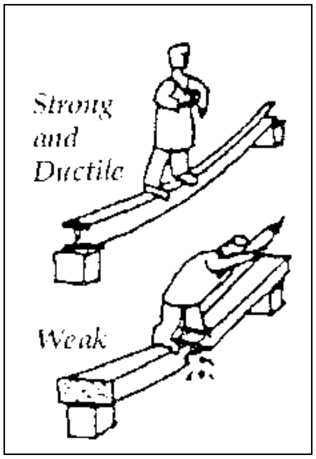


Figure 4-8

Source: Building Seismic Safety Council. Nontechnical Explanation of the NEHRP Recommended Provisions.

Ductility and Strength

Ductility is another factor that can affect the performance of a building during an earthquake. Ductility is the property of certain materials to fail only after large stresses and strains have occurred. Figure 4-8 illustrates what we mean by ductility. Brittle materials, such as non-reinforced concrete, fail suddenly with minimum tensile stresses, so plain concrete beams are no longer used. Other materials, primarily steel, bend or deform before they fail. We can rely on ductile materials to absorb energy and prevent collapse when earthquake forces overwhelm a building. In fact, adding steel rods to concrete can reinforce it and give the concrete considerable ductility and strength. Concrete reinforced with steel will help prevent it from failing during an earthquake.

Stiffness

A building is made up of both rigid and flexible elements. For example, beams and columns may be more flexible than stiff concrete walls or panels. Less rigid building elements have a greater capacity to absorb several cycles of ground motion before failure, in contrast to stiff elements, which may fail abruptly and shatter suddenly during an earthquake. Earthquake forces automatically focus on the stiffer, rigid elements of a building. For this reason, buildings must be constructed of parts that have the same level of flexibility, so that one element does not bend too much and transfer the energy of the earthquake to less ductile elements of the building.

The 1987 failure of a parking structure in Whittier-Narrows, California, was a dramatic illustration of this phenomenon. To accommodate the natural slope of the land on which it was built, the structure was designed with long vertical supports at the front of the building and short columns at the other end, and the roof level was designed as a flat horizontal plane. Figure 4-9 shows a drawing of this structure.

When the earthquake struck, the longer, more flexible columns at the front of the building passed the earthquake forces on to the short, stiffer columns in the back instead of distributing the forces equally among all of the columns. Deflection, the extent to which a structural element moves or bends under pressure, played a major role. The longer columns simply deflected or bent without cracking. The short columns, therefore, were overwhelmed and cracked. The rate of deflection is used as a measure of the stiffness of a structure.

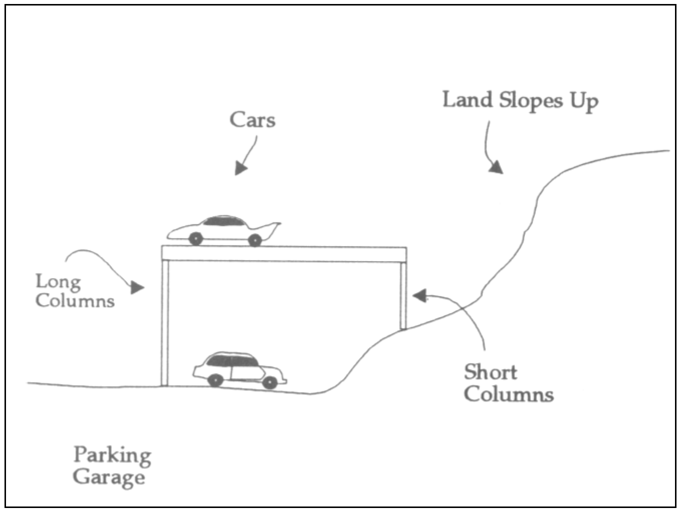


Figure 4-9

Drift

Drift is the extent to which a building bends or sways. Limits are often imposed on drift so a building is not designed to be *so* flexible that the resulting drift or swaying during an earthquake causes excessive damage. Figure 4-10 shows how a building can be affected by drift in an earthquake. If the level of drift is too high, a building may pound into the one next to it. Or the building may be structurally safe but nonstructural components, such as ceilings and walls, could be damaged as the building bends and the ceilings and walls are ripped away from their attachments. Of course, people in the building could be killed or injured from falling debris.

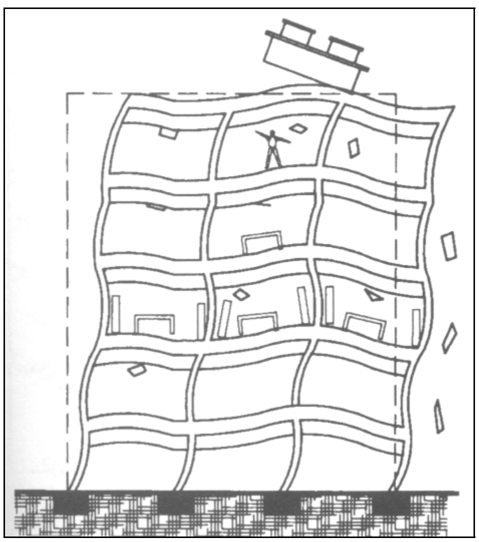


Figure 4-10
Source: Naeim. The Seismic Design Handbook, 1989.

Building Configuration

Configuration of a building determines the ways in which seismic forces are distributed throughout the building. Earthquakes have earned a reputation for their ability to find and exploit the weak link in buildings.

Generally speaking, a building with a symmetrical design and balanced resistance will hold up best. Let's look at several types of buildings that illustrate this point.

L-shaped Buildings

During an earthquake, an L-shaped building will experience increased stress at the point where the wings of the building meet. The difference in stiffness between the two wings causes this stress. To illustrate this point, let's think for a moment about the two wings of our L-shaped building as separate buildings, as shown in Figure 4-11.

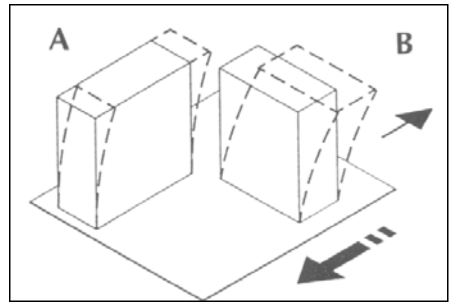


Figure 4-11 *Source: Naeim. The Seismic Design Handbook, 1989.*

Let's say the force of an earthquake travels parallel to building A. The orientation of building A to the earthquake results in it swaying less than building B. This means that the perpendicular building, building B, will sway more than the parallel building, building A. Now let's put the buildings back together into an L shape, as shown in Figure 4-12.

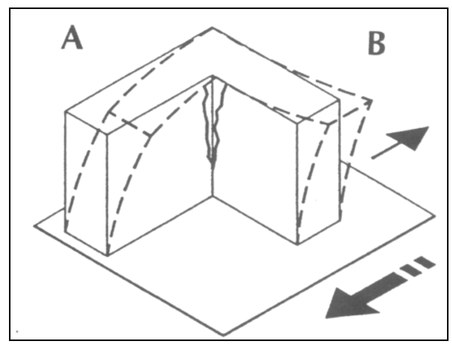


Figure 4-12 *Source: Naeim. The Seismic Design Handbook, 1989.*

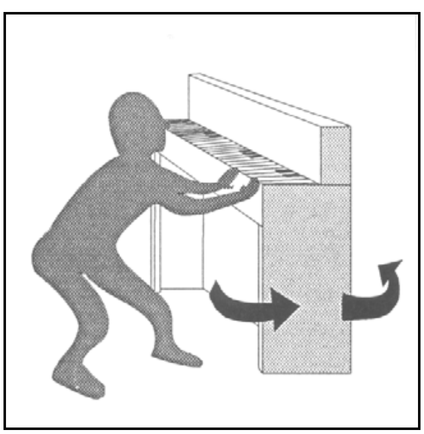


Figure 4-13

In an L-shaped building, the two wings are forced to move together. As the two wings pull and push on each other, high stresses occur at the point where the two wings are joined. This problem also occurs in buildings with a T, H, or + shape.

Torsional forces also affect the way an L-shaped building reacts during an earthquake. Torsional forces are forces that make an object rotate. They are created in a building by a lack of balance in forces. These forces build up as the B wing (perpendicular) attempts to rotate around the stiffer A wing (parallel). Another way to illustrate torsional forces is to think about moving a piano. To move the piano you would be careful to push it from the center. If you pushed at only one end, the piano would rotate around its center of mass, as shown in Figure 4-13. Torsional forces create this rotating effect. The same thing happens to L-, T-, H-, or +-shaped buildings. Torsional forces on these buildings can cause one wing to rotate around the other. If buildings are not designed to resist torsional forces, considerable damage or collapse could occur.

Symmetrical Buildings with Nonsymmetrical Elements

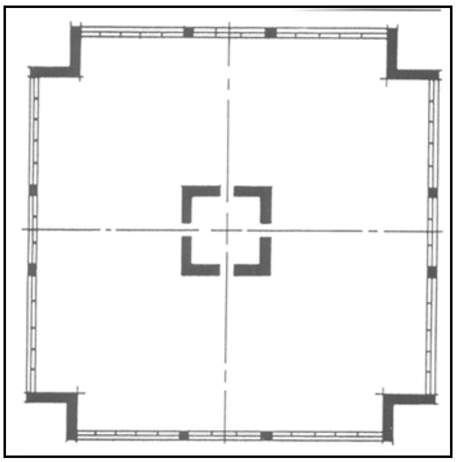


Figure 4-14 *Source: Lagorio. Earthquakes: An Architect's Guide to Non-structural Seismic Hazards, 1990.*

Torsional forces also can be a factor of performance in a symmetrically designed building in which isolated or single structural elements (elevators, etc.) have not been symmetrically distributed. Let's compare damage done to two bank buildings in the 1972 Managua, Nicaragua, earthquake. One bank was symmetrically designed with a stiff elevator core in the center of the building. Figure 4-14 shows the floor plan of this building.

The second bank also was a symmetrically shaped building with its stiff elevator core at one end. Figure 4-15 shows the floor plan of this bank.

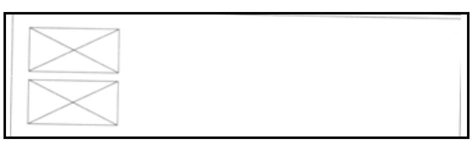


Figure 4-15

The first building (Figure 4-14) suffered little damage during the earthquake. The second building (Figure 4-15) developed unrestrained torsional forces as the free end attempted to rotate around the stiff, off-center elevator core. This building incurred major damage and was demolished.

Soft-story

A soft-story building is a structure with stiffer, more rigid upper stories and an open, flexible first story. This design is found in buildings where the first story contains a parking garage or an open commercial area for stores and the upper floors house offices or apartments. Figure 4-16 illustrates a soft-story building.

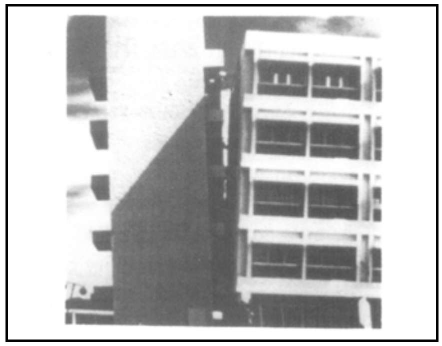


Figure 4-16 *Source: Federal Emergency Management Agency.*

This design creates a discontinuity of strength and stiffness. If all stories are approximately equal in strength, the entire building would bend in an earthquake. If the first story is softer, or more flexible, than the other stories, the bending would concentrate there. Because the first floor is also the most highly loaded, the problem is compounded, thus possibly causing column failure.

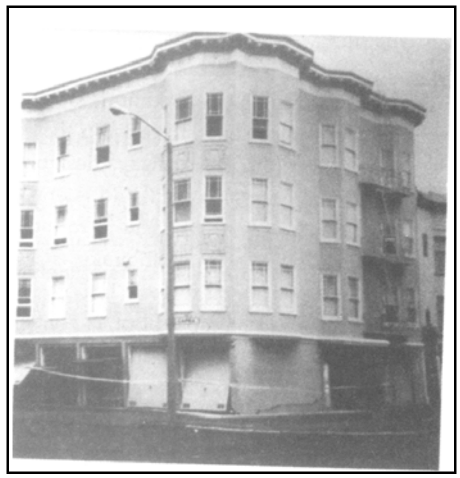


Figure 4-17 *Source: Federal Emergency Management Agency.*

This also will put additional stress on the connection between the first and second stories and can cause the building to collapse. You can see what the stress between the first and second floors did to these soft-story buildings (Figures 4-17 and 4-18) during the 1972 San Fernando and the 1989 Loma Prieta earthquakes. Building configuration can have significant effect on how a building performs in an earthquake.

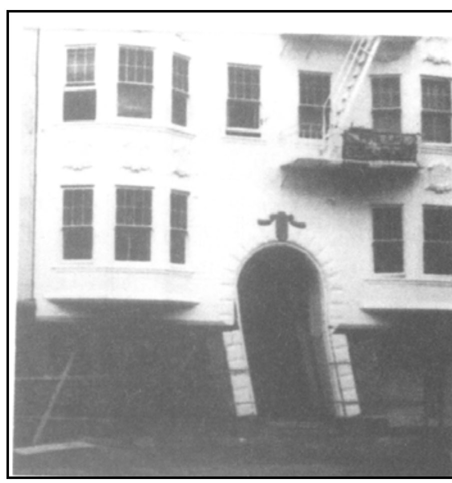


Figure 4-18 *Source: Federal Emergency Management Agency.*

Generally, the simpler the design and the more balanced the building and its structural and nonstructural components, the better the building will perform during an earthquake.

HOW DO BUILDINGS RESIST EARTHQUAKE FORCES?

Now that we have discussed some of the forces that can affect a building and elements of building design that make buildings more or less susceptible to damage by seismic forces, let's look at systems that can be built into a structure to help it resist these forces.

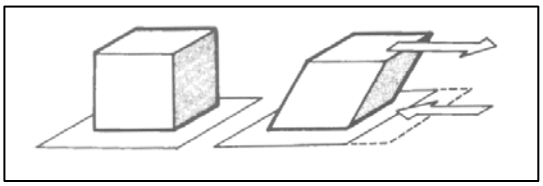


Figure 4-19 *Source: Botsai, et al., Architects and Earthquakes, 1976.*

As a building responds to ground motions produced by an earthquake, the bottom of the structure moves immediately, but the upper portions do not because of their mass and inertia. Figure 4-19 shows the base of a building moving while the upper part lags behind.

The horizontal force, or base shear, created by ground motion resulting from an earthquake must be resisted by the building. The more the ground moves, or the greater the weight of the building, the more force must be resisted by the building. When an architect or engineer designs a building, he or she must determine the maximum force a building might have to resist in the future. Buildings are always designed to handle normal vertical and lateral forces. However, once you introduce the possibility of an earthquake, a building must be designed for extraordinary horizontal or lateral forces. The horizontal (lateral) forces associated with an earthquake can be thought of as a lateral force applied to each floor and to the roof of a building. Figure 4-20 shows the vertical and horizontal forces on a building during an earthquake. Panel (a) shows the direction of gravitational forces on a building, panel (b) shows the horizontal force of seismic waves, and panel (c) shows the combined forces of gravity and an earthquake applied to the floors and roof of a building.

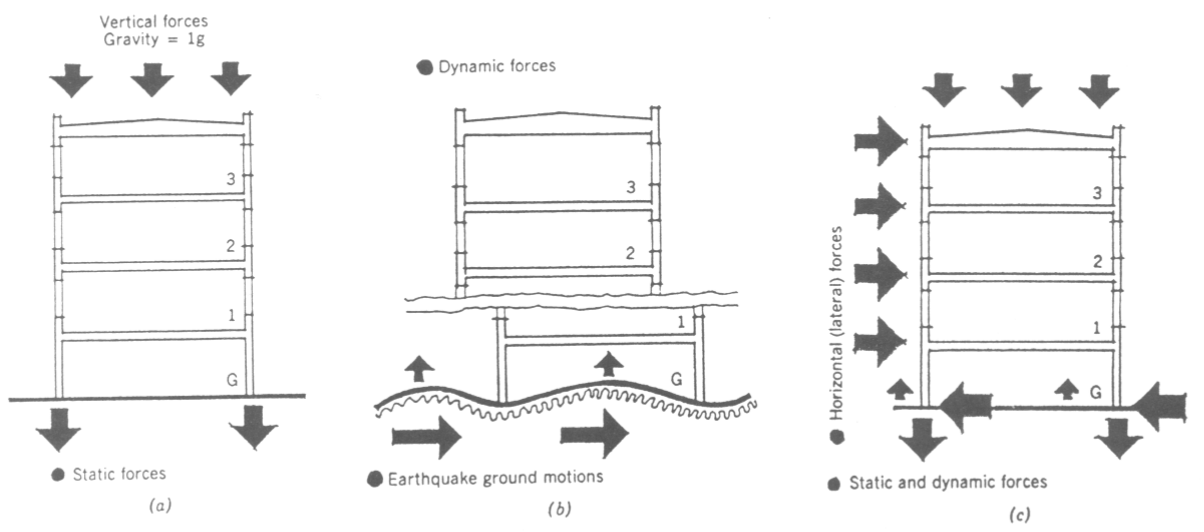


Figure 4-20 *Source: Lagorio. Earthquakes: An Architect's Guide to Nonstructural Seismic Hazards, 1990.*

Horizontal forces accumulate along the floors and roof and then are distributed through the vertical supports into the foundation. A structural engineer must design a building so that lateral forces are distributed throughout the building without a break. Several structural systems, such as floors, walls, and columns, may be used in new buildings to reduce the effects of earthquakes and associated natural disasters.

Diaphragms

The floor and roof systems that distribute an earthquake's lateral forces are referred to as diaphragms. Diaphragms support the gravitational and lateral forces on a building and transfer them to vertical structural elements like shear walls, braced frames, and moment-resistant frames. These vertical elements help resist lateral forces and are therefore called horizontal (or lateral) bracing systems.

Horizontal Bracing Systems

Three horizontal bracing systems can be used to resist earthquake forces. These are:

- Shear wall systems,

- Braced frame systems, and
- Moment-resistant systems.

Shear Wall System

Walls within a building that are designed to receive horizontal forces parallel to the wall are called shear walls. Houses with many rooms separated by structural walls with minimal openings are good examples of shear wall buildings. Figure 4-21 illustrates shear walls.

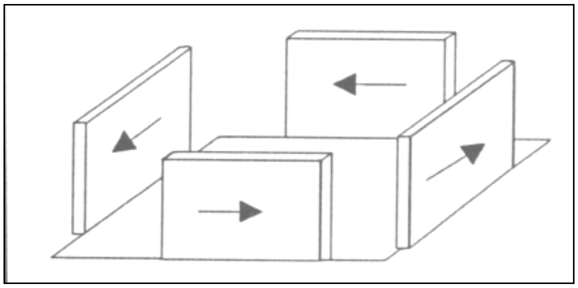


Figure 4-21 *Source: Building Seismic Safety Council. Nontechnical Explanation of the NEHRP Recommended Provisions.*

Braced Frame System

Braced frames act like shear walls but they are somewhat more flexible. In Figure 4-22, the dotted lines show the normal position of a shear wall and a braced frame. The braced frame is more flexible and bends farther from its normal position than the shear wall.

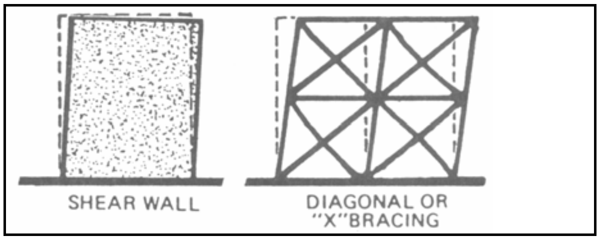


Figure 4-22 *Source: Lagorio. Earthquakes: An Architect's Guide to Nonstructural Seismic Hazards, 1990.*

Moment-Resistant System

This system helps a building resist horizontal (lateral) forces at the joints between the columns and the beams. These joints become highly stressed, so they must be constructed of a strong, ductile material like steel. Figure 4-23 illustrates the moment-resistant system.

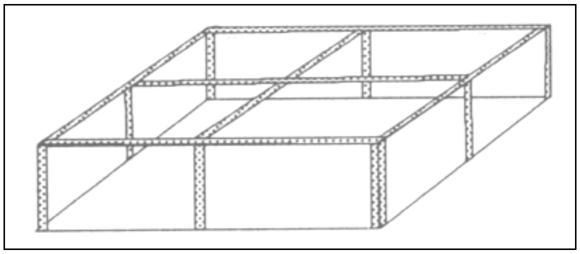


Figure 4-23 *Source: Building Seismic Safety Council. Nontechnical Explanation of the NEHRP Recommended Provisions.*

Dual Systems

Sometimes it is advantageous to use a combination of a moment-resistant frame and a shear wall or braced frame. This combination is called a dual system.

The resisting systems (floors and walls) we have just covered are basic architectural components used in many buildings. In designing a seismically resistant building, the designer must choose some combination of these elements that will provide proper horizontal support. The choices the designer makes will have a major impact on the seismic safety, cost, and architecture of a building.

WHAT SECONDARY CONSEQUENCES OF EARTHQUAKES MUST WE BE CONCERNED WITH?

So far we have talked about the effects of earthquakes on the natural and built environments. These are generally referred to as an earthquake's "primary effects." In this section, we will examine an earthquake's "secondary effects." Secondary effects, such as fire, hazardous material spills, and water main breaks, can cause extensive damage and loss of life.

FIRES AND HAZARDOUS MATERIAL SPILLS

The San Francisco earthquake of 1906 is one of the best illustrations of the problems generated by secondary effects:

> The state-of-the-art city-wide fire alarm system was knocked out of action by the first shock wave. The writhing of the San Andreas fault not only broke telegraph lines and twisted streetcar tracks to stop all transit, it ruptured gas lines and water pipes. The gas fed flames from damaged fireplaces, flues and stove pipes, while the broken water mains rendered fire hydrants pressureless and firemen helpless.

The Day the Earth Shook, Dillon, 1985

Fires burned for 3 days, consuming 508 city blocks. Ground motion caused an estimated 20 percent of all damage to the city, but fire caused the rest.

Certainly California is better prepared for the primary effects of earthquakes today. However, an earthquake can initiate a secondary chain of events involving damage to such lifelines as water supply, gas, and electricity that can turn a moderate seismic event into a catastrophic one. We have only to look at a more recent example to bring this point home:

> In Managua, Nicaragua, an earthquake in 1972 collapsed the second floor of the central fire station, crushing fire apparatus, killing two firemen and injuring others. The communication radio was destroyed and no emergency electric power was available. Fires soon began to break out in the city, where temporary hose lines were laid from the lake and pumps put into place because the local water system failed.
>
> *Bolt, et al., 1977*

Earthquakes also can cause hazardous material incidents that can be dangerous or deadly to a community. These incidents can involve materials such as:

- Poisonous gas,
- Medical materials at clinics and laboratories,
- Sewage,
- Radioactive materials, and
- Carcinogens.

After the 1989 Loma Prieta earthquake, for example, the town of Watsonville, California, was left without running water for weeks after the earthquake broke water and sewer distribution lines, mixing the two together in the trenches where the pipes were located side by side. The cost in time and money to clean and repair the water and sewage lines was tremendous.

LIFELINES

Our previous examples have illustrated the damaging effects a breakdown in lifelines can have following an earthquake. Mitigation plans should consider such lifelines as:

- Water and sewage systems,
- Electric power systems,
- Oil and natural gas systems,
- Communications systems, and
- Transportation systems.

UNIT 4 - SUMMARY

This unit explored some of the effects an earthquake can have on the natural and built environments in a community. In this unit, we have answered the following questions:

- What are some effects of earthquakes on the natural environment?
  - Liquefaction
  - Landslides
  - Faults
  - Tsunamis, flooding, and seiche

- What building characteristics are significant to seismic design?
    - Period and resonance
    - Damping
    - Ductility
    - Stiffness
    - Drift
    - Building configuration
- How do buildings resist earthquake forces?
    - Diaphragms
    - Horizontal bracing systems
    - Moment-resistant systems
- What secondary consequences of earthquakes must we be concerned with?
    - Fires and hazardous material spills
    - Utility lifelines

To check your understanding of this section, complete the Unit Review and check your answers before moving on to the next section.

Unit 4

Earthquake Effects

Unit Review

Directions: For each question, circle the letter of the correct response and check your answers with the Answer Guide at the end of the unit.

1. __________ occurs when loose, sandy soil acts more like a fluid than a solid.

   a. Tsunami
   b. Liquefaction
   c. Resonance
   d. Subduction

2. Three effects an earthquake can have on the natural environment that can cause tremendous damage are:

   a. faults, landslides, and damping.
   b. liquefaction, drift, and tsunamis.
   c. liquefaction, landslides, and tsunamis.
   d. faults, seiche, and damping.

3. The term that refers to the oscillation of water in a closed space is:

   a. tsunami.
   b. liquefaction.
   c. seiche.
   d. subduction.

4. The pendulum of a clock demonstrates the tendency of an object to swing back and forth in its natural _________ .

   a. resonance
   b. ductility
   c. period
   d. torsion

5. If the period of the ground movement and a building are the same, what results?

   a. Resonance
   b. Ductility
   c. Period
   d. Torsion

6. During the 1964 Anchorage, Alaska, earthquake, buildings 75 miles away from the epicenter incurred greater damage than buildings much closer. How did authorities account for this?

   a. The buildings 75 miles away were older.
   b. The buildings 75 miles away had been poorly constructed.
   c. The buildings 75 miles away were taller and resonated with the ground motion.
   d. The buildings 75 miles away were shorter and resonated with the ground motion.

7. The quality of partitions, ceilings, and other nonstructural elements of a building that make it a less efficient vibrator is called:

   a. stiffness.
   b. ductility.
   c. damping.
   d. torsion.

8. Steel has the ability to absorb energy and distort, rather than suddenly break like a more brittle material. This quality is called:

   a. stiffness.
   b. ductility.
   c. damping.
   d. torsion.

9. What could happen to the building pictured below during an earthquake?

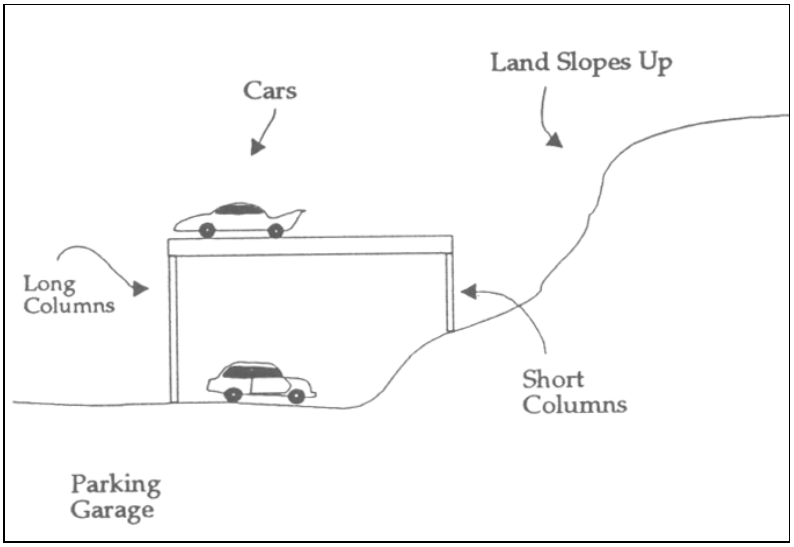


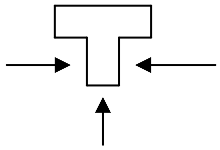
Figure 4-24

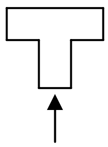
a. Nothing. This is a very strong structure that could withstand a high degree of ground shaking.
b. The longer columns in the front of the structure would receive more of the lateral load and if not properly designed would crack and collapse.
c. The shorter columns in the back of the structure would receive more of the lateral load and if not properly designed would crack and collapse.
d. It is hard to say without knowing the composition of the soil.

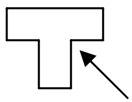
10. Horizontal swaying of a building is called:

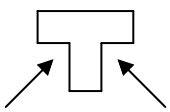
a. torsion.
b. drift.
c. ductility.
d. tectonics.

11. Select the location on a T-shaped building that would suffer the greatest stress during an earthquake.

a. 

b. 

c. 

d. 

12. This illustration shows a building with a stiff elevator core placed at one end. During an earthquake, the free end of the building attempted to rotate around the stiff off-center elevator core. This is an example of what type of force?

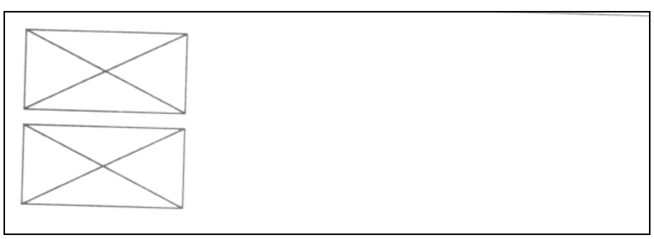


Figure 4-25

a. Velocity
b. Acceleration
c. Torsional
d. Symmetrical

13. This building illustrates what type of structural design problem?

    a. Soft-story
    b. Irregular configuration
    c. Nonuniform mass distribution
    d. Interruption of vertical elements

14. The horizontal force at the base of a building created by an earthquake is often referred to as:

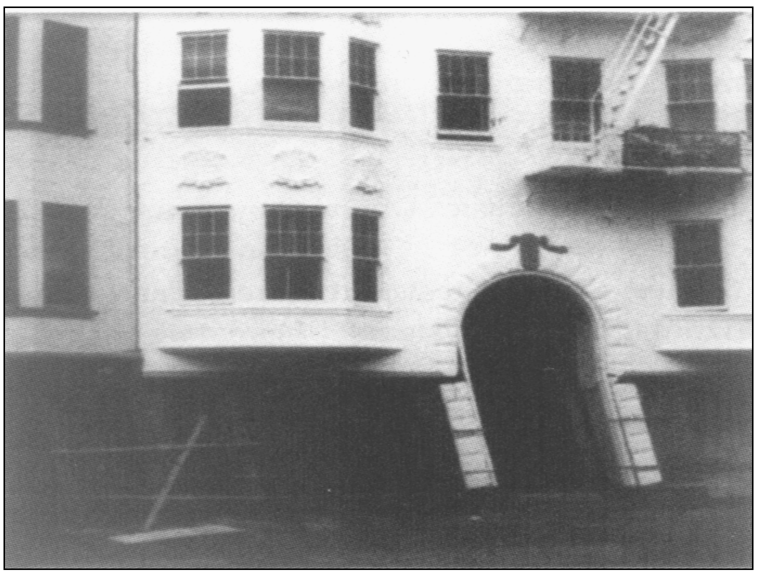


Figure 4-26 *Source: Federal Emergency Management Agency.*

    a. torsional force.
    b. acceleration rate.
    c. base shear.
    d. force of gravity.

15. Diaphragms are the _________ of a building.

    a. shear wall system
    b. lateral bracing systems
    c. floor and roof systems
    d. dual system

16. Buildings resist earthquake forces with basic structural systems, such as:

    a. diaphragms.
    b. horizontal bracing systems (shear walls, braced frames, and moment-resistant systems).
    c. floors and walls.
    d. all of the above.

17. This illustration is an example of what type of horizontal bracing system?

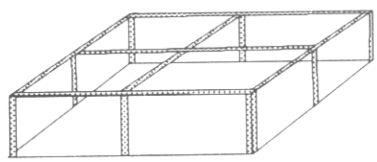


Figure 4-27 *Source: Building Seismic Safety Council. Nontechnical Explanation of the NEHRP Recommended Provisions.*

    a. Shear wall
    b. Braced frame
    c. Moment-resistant system
    d. Dual

18. Houses with many interior walls are a good example of what type of horizontal bracing system?

    a. Shear wall
    b. Braced frame
    c. Moment-resistant system
    d. Dual

19. What makes up the built environment?

    a. Buildings only
    b. Buildings and bridges
    c. Buildings, bridges, and water lines
    d. Buildings, transportation lines and structures, communications lines, and utilities

20. Secondary effects caused by an earthquake do more damage than the damage done by ground motion.

    a. This statement is never true.
    b. This statement is always true.

c. This statement is sometimes true.
d. This statement was true 100 years ago.

Unit 4

Earthquake Effects

Unit Review - Answer Guide

1. _________ occurs when loose, sandy soil acts more like a fluid than a solid.

   b. Liquefaction
   Reference: p. 4-2

2. Three effects an earthquake can have on the natural environment that can cause tremendous damage are:

   c. liquefaction, landslides, and tsunamis.
   Reference: pp. 4-2 and 4-3

3. The term that refers to the oscillation of water in a closed space is:

   c. seiche.
   Reference: p. 4-4

4. The pendulum of a clock demonstrates the tendency of an object to swing back and forth in its natural _________ .

   c. period
   Reference: p. 4-6

5. If the period of the ground movement and a building are the same, what results?

   a. Resonance
   Reference: p. 4-7

6. During the 1964 Anchorage, Alaska, earthquake, buildings 75 miles away from the epicenter incurred greater damage than buildings much closer. How did authorities account for this?

   c. The buildings 75 miles away were taller and resonated with the ground motion.
   Reference: p. 4-7

7. The quality of partitions, ceilings, and other nonstructural elements of a building that make it a less efficient vibrator is called:

   c. damping.
   Reference: pp. 4-7

8. Steel has the ability to absorb energy and distort, rather than suddenly break like a more brittle material. This quality is called:

   b. ductility.
   Reference: p. 4-8

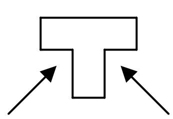
9. What could happen to the building pictured, during an earthquake?

   c. The shorter columns in the back of the structure would receive more of the lateral load and if not properly designed would crack and collapse.
   Reference: pp. 4-8 and 4-9

10. Horizontal swaying of a building is called:

    b. drift.
    Reference: p. 4-9

11. Select the location on a T-shaped building that would suffer the greatest stress during an earthquake.

    d. 
    Reference: pp. 4-10 and 4-11

12. The illustration shows a building with a stiff elevator core placed at one end. During an earthquake, the free end of the building attempted to rotate around the stiff off-center elevator core. This is an example of what type of force?

c. Torsional
Reference: p. 4-11

13. The building illustrates what type of structural design problem?

a. Soft-story
Reference: p. 4-12

14. The horizontal force at the base of a building created by an earthquake is often referred to as:

c. base shear.
Reference: p. 4-13

15. Diaphragms are the _______ of a building.

c. floor and roof systems
Reference: p. 4-14

16. Buildings resist earthquake forces with basic structural systems, such as:

d. all of the above
Reference: pp. 4-13 to 4-16

17. The illustration is an example of what type of horizontal bracing system?

c. Moment-resistant system
Reference: p. 4-15

18. Houses with many interior walls are a good example of what type of horizontal bracing system?

a. Shear wall
Reference: p. 4-15

19. What makes up the built environment?

d. Buildings, transportation lines and structures, communications lines, and utilities.
Reference: p. 4-1

20. Secondary effects caused by an earthquake do more damage than the damage done by ground motion.

c. This statement is sometimes true.

Reference: p. 4-16