Seismic Design and Construction of Dwellings and Townhouses According to the International Residential Code (IRC-2024a)

An Online Continuing Education Course for Engineers

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Seismic Design and Construction of Dwellings and Townhouses According to the International Residential Code (IRC-2024a)

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1. Introduction

This course presents a plain-language overview of design and construction provisions important to the earthquake performance of one- and two-family detached dwellings and townhouses (referred to as dwellings and townhouses in this guide) constructed under the International Residential Code (IRC) (ICC, 2024a). The primary intended audiences for this course are homebuilders, tradespeople working in the home building industry, and building department plan checkers and inspectors. Secondary audiences include architects, engineers, and homeowners with construction knowledge.

2. Fundamental Concepts of Earthquake-Resistant Design

This section explains fundamental concepts of earthquake-resistant design applicable to most buildings, including dwellings and townhouses designed in accordance with the IRC. The topics covered include building response to earthquake ground shaking, site and soil characteristics, load path, and configuration irregularities.

2.1 Building Response to Earthquake Ground Shaking

It is useful to start the discussion of fundamental concepts with a basic description of how buildings respond to earthquake ground shaking. The series of drawings in Figure 2-1 illustrates how a building responds. Before the earthquake occurs, the building is stationary, resisting only the vertical or gravity loads associated with the weight of the building, its occupants, and its contents. When the ground starts to move during an earthquake, the foundation of the building moves sideways, but the roof and upper stories try to remain stationary due to the inertia of the building. By the time the roof starts to move in the direction of the foundation, the foundation is already moving back toward its initial position. Therefore, the roof and foundation are moving in opposite directions. This cycle repeats until the earthquake ends, and the building movements slow and then stop. If the shaking has been severe enough, the building may be damaged and may have a residual lean.

To perform adequately in an earthquake, a building must be both strong enough and stiff enough. Strength allows the building to resist earthquake forces, and stiffness prevents the building from deflecting too much under those forces. The strength of the building resists the forces exerted by earthquake ground motion, whereas the stiffness of the building resists the deflection. An analogy that can be used for this is a fishing pole. The amount the pole bends is dependent on how stiff the pole is; whether the pole breaks or not is dependent on how strong the pole is. A strong building is unlikely to fall, but if it lacks stiffness, it could deflect significantly and sustain considerable damage as a result. Stiffness is measured in buildings in terms of the horizontal drift, a measure of deflection, in a particular story (Figure 2-2). The stiffer the dwelling or townhouse, the less it will move or deflect during an earthquake. The less a building deflects, the less damage there will be to finishing materials, resulting in lower repair costs.

Actual earthquakes can generate forces (Figure 2-3, green line) considerably higher than those used for the code-prescribed design (Figure 2-3, blue line). In Figure 2-3, the vertical axis is a measure of the earthquake forces experienced by the building, and the horizontal axis measures the building period, which is proportional to its height. Nevertheless, the design for code earthquake forces has generally prevented loss of life and, therefore, satisfies the purpose of the code. Remember that the primary goal of the building code is to prevent loss of life; damage due to earthquakes should be expected. There are two items to consider related to expected damage.

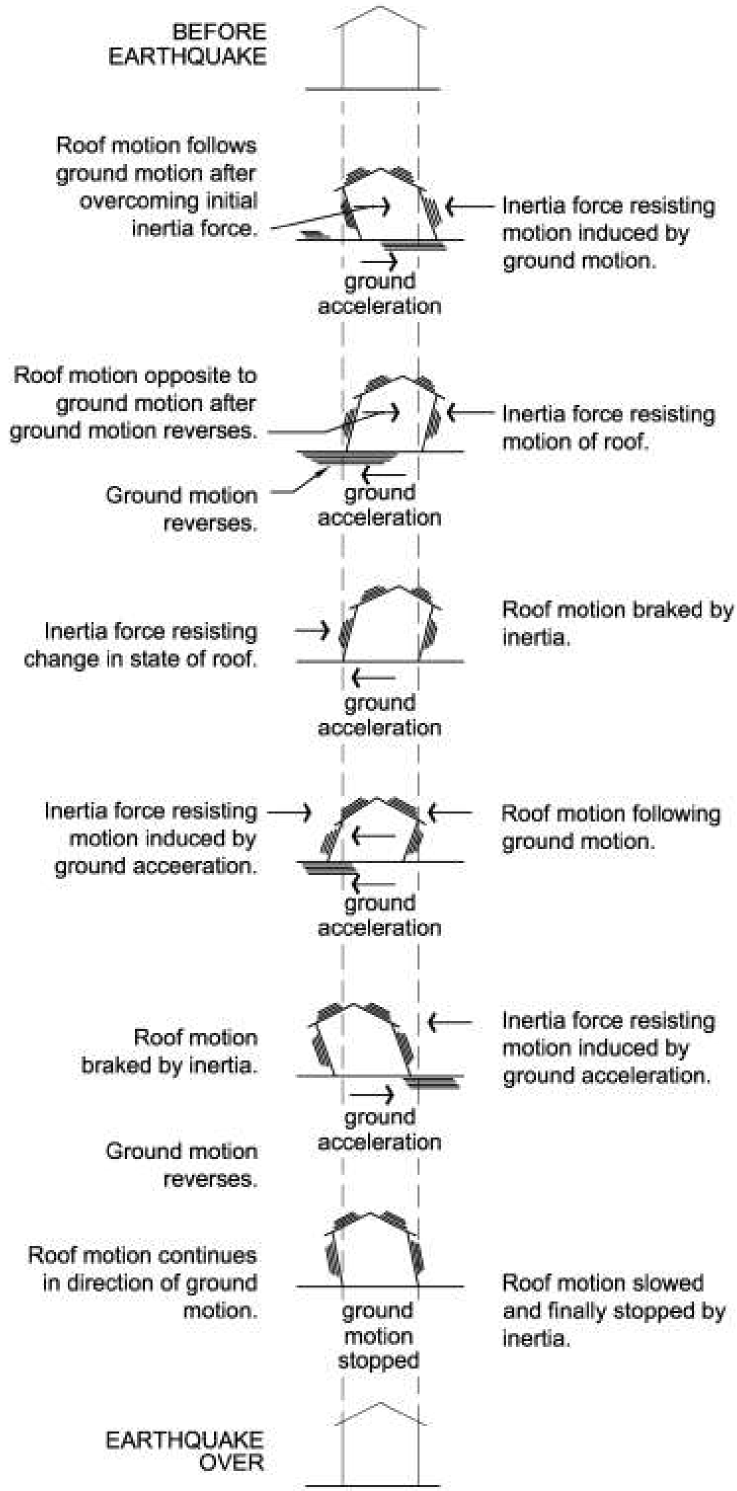


Figure 2-1 Forces induced in a dwelling due to earthquake ground motion

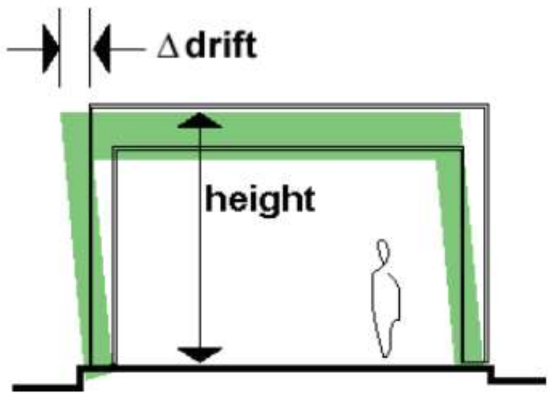


Figure 2-2 Illustration of building drift

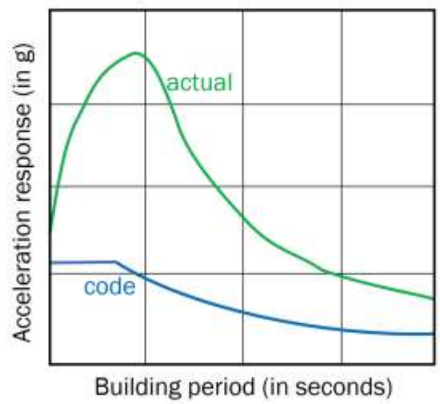


Figure 2-3 Concept of actual vs. code earthquake forces

First, dwellings and townhouses tend to generally perform well in earthquakes even when designed to the minimum code forces because they are typically stronger than recognized in code-level design, and they are often constructed with ductile earthquake-resisting systems. In residential construction, the wall finish materials and interior walls often add significant strength in addition to the strength provided by the required bracing materials. In contrast, the weight of floors and roofs bearing on bracing walls helps to resist overturning loads. Dwellings and townhouses constructed from ductile earthquake-resisting systems generally perform well during earthquakes because they can deform without breaking. An example of ductility is given in Figure 2-4. The ductile metal spoon bends while the brittle plastic spoon breaks. Non-ductile (i.e., brittle) materials like poorly reinforced concrete can break or fail without warning. Ductility is the characteristic of a material like steel that fails only after considerable deformation has occurred.

Second, it is because of expected damage that this guide presents above-code recommendations that describe techniques intended to improve the performance of a dwelling or townhouse during an earthquake and result in less damage and reduced cost of repair. Because increased stiffness also generally results in increased earthquake forces, the above-code recommendations made in this guide simultaneously increase both strength and stiffness.

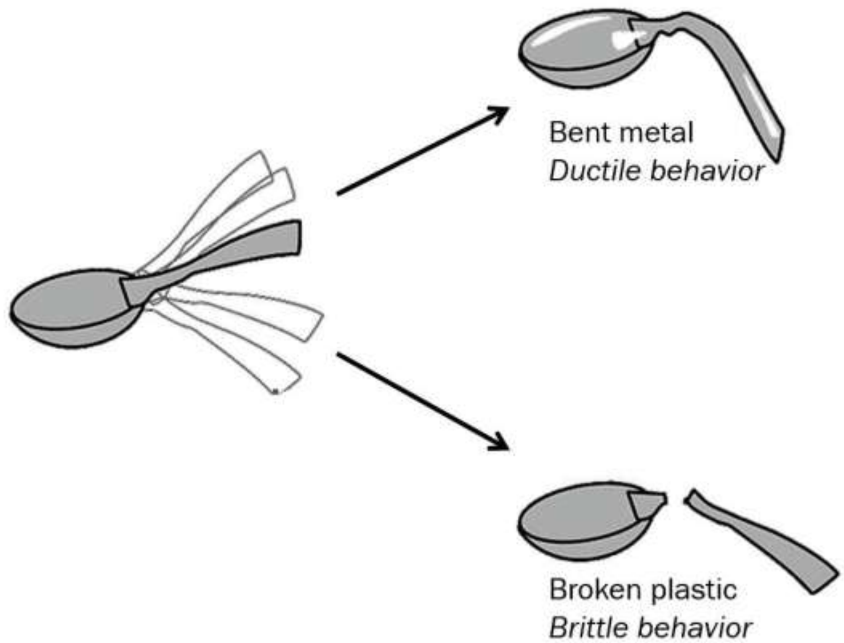
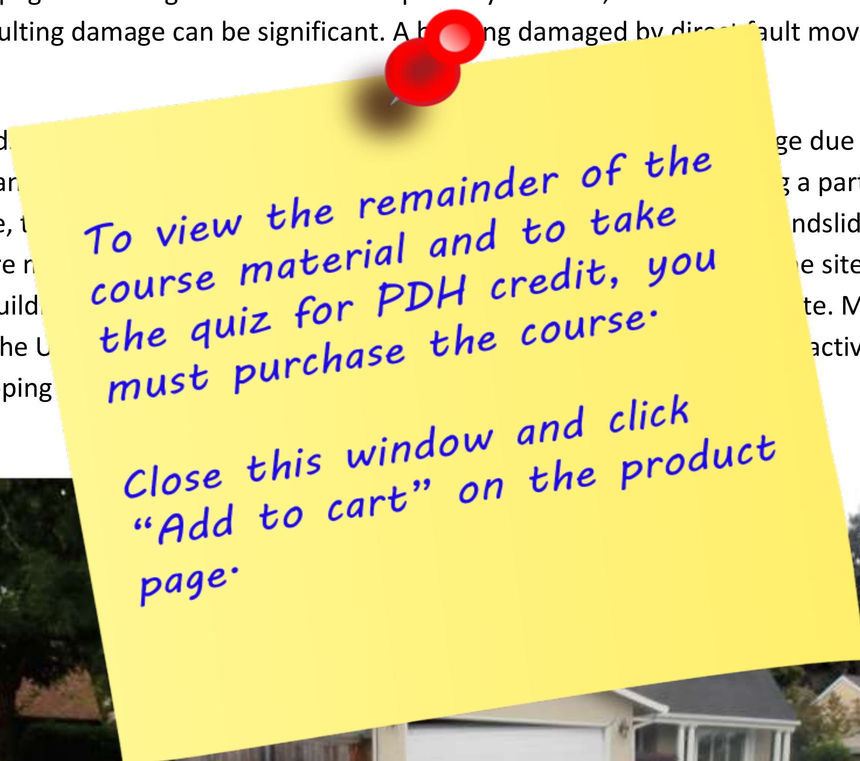


Figure 2-4 Concept of ductility

2.2 Site and Soil Characteristics

Characteristics of the lot or site on which a building is constructed also affect how the building will perform during an earthquake. Certain types of soil amplify earthquake ground motions, which in turn amplify the shaking experienced by the building. Some types of soil slide, liquefy, densify, or settle due to earthquake ground motions, all of which will result in loss of vertical support for the building and vertical settlement. Some soil on hillsides can cause landslides that similarly result in loss of vertical support for the building. Fault rupture on a site can result in both horizontal and vertical offsets of the supporting ground. It is desirable to build lots or sites with stable, solid geologic formations. Deep and unbroken rock formations, referred to as bedrock, minimize earthquake damage. Deep, soft sedimentary soils result in larger earthquake forces and deflections being transferred to the dwelling or townhouse.

Sites located above known faults and in landslide-prone areas warrant special attention. No matter how well-designed, a building cannot accommodate earthquake ground motions at a site directly on top of an earthquake fault where the ground on either side of the fault moves in opposite directions horizontally or vertically. Check with the local building department or online maps published by the U.S. Geological Survey (USGS) to determine where known faults are located. New buildings are generally not built within 50 feet of a known fault; when they are built in this zone, additional investigation and restrictions on building location may apply. This is partially due to uncertainty regarding where the fault rupture will propagate to the ground surface and partially because, even at a distance of 50 feet, ground shaking and resulting damage can be significant. A b ng damaged by dir ault movement is shown in Figure 2-5



Sites where land ge due to a hillside collapsing in a lar a particular building site. In that case, t ndslide, liquefaction, and fault rupture n e site, or checking with the local build te. Maps are available from the U active states provide site hazard mapping

Figure 2-5 A dwelling damaged due to fault movement in the 2014 South Napa Earthquake. (from Geotechnical Extreme Events Reconnaissance, GEER)