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Structural Geology
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As America's homes are built more rapidly and economically, they are fortunately under the supervision of engineers to assure the integrity of safe construction ethics are upheld, specifically with growing emphasis on earthquake survivability. Homes undergo tremendous forces in response to seismic wave driven ground acceleration. Updated construction practices are trying to offset these forces focusing primarily on strengthening shear walls. What are these dynamic forces that wood frame shear walls experience, and how are they counteracted?

How Earthquakes Cause Damage

Earthquakes are vibrations in the lithosphere produced by the release of stress within the subsurface (Ambrose *et al.* 1999). Theoretically, earthquakes can occur in any region, but are localized around places with past seismic activity. The vibrations that are created in these regions are transmitted through the Earth's crust in the form of various waves, each distinctive in their motion and importance (Ambrose *et al.* 1999). These vibrations affect foundations in all directions, while the horizontal, or shear, waves tend to dominate. Shear waves are transferred into the building through the foundation in the form of kinetic energy, causing the building to sway, thus producing strain on the shear walls. This phenomenon is known as drift, and is more prevalent in taller multistory structures, but is still applicable for all wood frame buildings (Lagorio 1990).

Acceleration

Acceleration is the change in velocity of the Earth's surface over time and is a result of seismic activity (USGS 2008). Larger measurements of acceleration usually reflect more damage done to man-made structures. The maximum acceleration is an important value that is used to construct building codes, referred to as peak acceleration (USGS 2008).

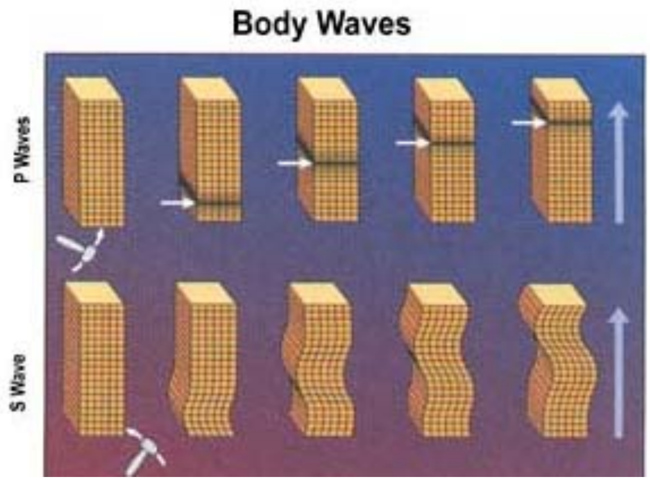
Intensity

Intensity is a measure of the severity of an earthquake in terms of structural damage (Lee 2002). The method of measuring intensity pertains to the observable effects during and following an earthquake. A numerical value is assigned to the area affected by the earthquake representing these descriptions (Lee 2002). Along with intensity, the strength of an earthquake diminishes as the distance from the epicenter increases. This decaying effect is known as attenuation (USGS 2008).

Body Waves

Body waves are the division of seismic waves that transmit through the Earth's interior (Stein 2003). A type of body wave that exists within the subsurface is a compressional wave, or P-wave. These waves travel by rocks moving back and forth in the direction which the wave is advancing (Stein 2008). Due to their compressive nature, they are capable of traveling much faster than any other wave. As they leave the focus of the earthquake and interact with the surface of the earth, vertically oscillating waves are transferred to the foundation. The overall impact is negligible considering all woodframe structures inherently withstand vertical stress (Jaume 2008).

The waves that follow P-waves are S-waves, which travel by propagating through the earth's crust at right angles with respect to their direction of motion. (Stein 2003) This shearing motion has a profound effect when it reaches the immediate surface. The ground surface oscillates back and forth horizontally. This ultimately causes the foundations of buildings to be displaced similarly in motion, creating a shearing action between the foundation and the roof (Jaume 2008).

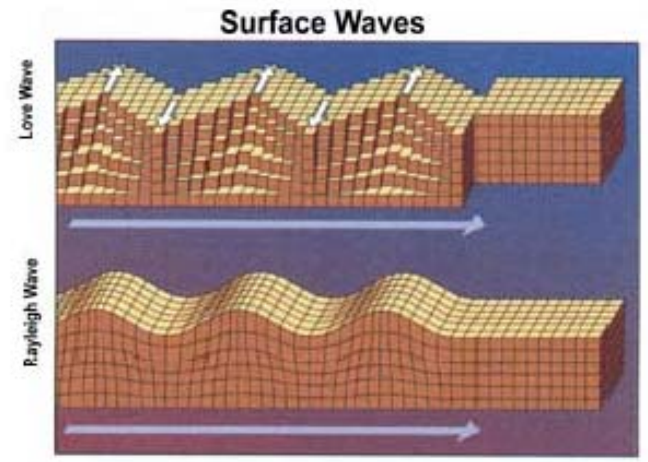


"Seismic Waves." USGS. Nov 2008.

Surface Waves

Surface waves are concentrated at the Earth's surface and spread two-dimensionally from the source while decaying as distance increases (Stein 2003). Love shear waves are the faster of the two surface waves and when propagating in a vertical plane, they appear on the transverse component (Stein 2003). Rayleigh waves, while similar, differ by traveling on the vertical and radial component (Stein 2003).

Rayleigh waves cause the most damage due to their combination of motions. The elliptical motion of the waves spread in a rolling manner displacing homes in the same direction. When these waves initially reach a home one side of the home, is lifted upwards displacing it from the other side. Stress is focused on a distance in between, finding a weakness in the architecture (Doyle 2008). The walls at right angles to these walls are either displaced upward or downward and do not usually experience shearing. The release of stress is often visible as a fracture in the roof that is perpendicular to the direction of the wave's path (Doyle 2008).



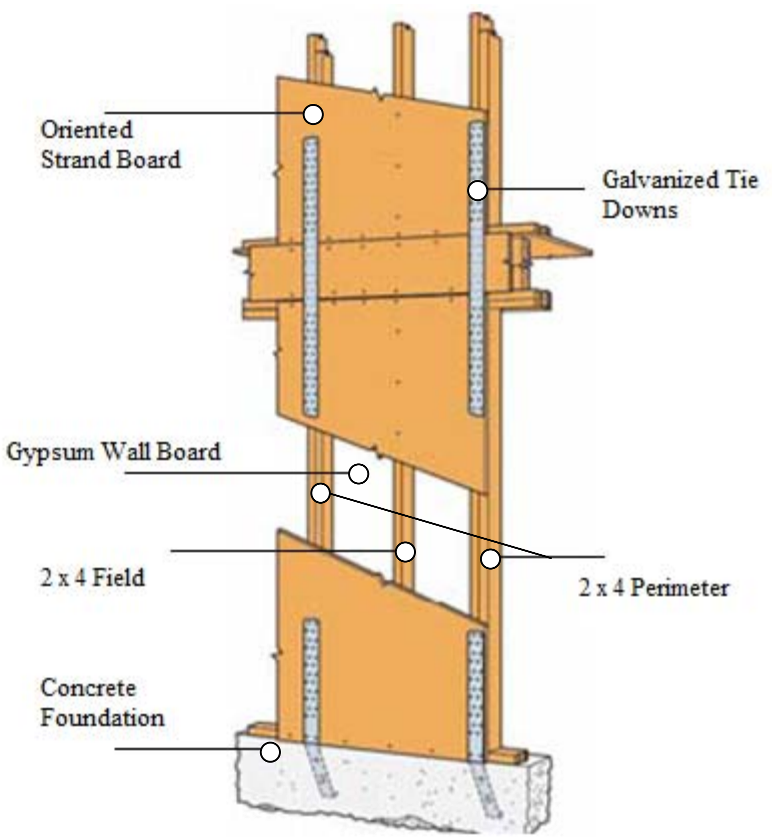
"Seismic Waves." USGS. Nov

Secondary Effects

Seismic waves are responsible for some of the damage seen within engineered structures, though in other cases the predominant cause of damage is seen within the secondary effects that follow an earthquake (Ambrose *et al.* 1999). The most common of site failures are cracks and minor subsidence from shifting or consolidating of fills (Ambrose *et al.* 1999). These are generally minor, often occurring in the absence of earthquakes and pose no serious hazard to the building's infrastructure. In contrast, liquefaction can cause major failure of concrete, masonry, and wood frame structures. Soil liquefaction is comprised of numerous elements but is more prevalent after earthquakes in areas with high ground water levels, artificial fill, and reclaimed swamps, lakes and waterways (Ambrose *et al.* 1999). When the soil is exposed to irregular motion, water within the pore spaces of grains move upward, causing grains to settle downward. The result is a soil with high amounts of water at the immediate surface providing poor support for any foundation (Stein 2003). Although, developing a residential home strong enough to endure one of these secondary failures is virtually impossible. The best alternative is to avoid building a structure that relies solely on the integrity of unconsolidated soils (Ambrose *et al.* 1999).

How are Homes Built to Withstand Lateral Forces?

When a structure experiences any force derived from ground acceleration, the force is directed to the stiffest points within the building. For wood frame homes, the concerned forces are lateral and the stiffest portions are the shear walls (Ambrose 1999).



Shackleford, Randy. Design Solutions for Wood-Frame Multi-Story. Nov 2008.

Shear walls are exterior or interior walls engineered to sustain and counteract the effects of lateral loads parallel to the ground surface. These types of forces are observed in earthquakes and from high winds. Numerous methods are used to prevent the shifting of these load-bearing or non-load bearing walls (Lagorio 1990). Shear walls in typical residential home construction are composed of 1.5 inch x 3.5 inch framed walls (Lindt 2005). Adding sheathing to the outer walls and gypsum wallboard to the inner walls are common methods used to resist lateral forces and therefore reduce drift (Lindt *et a.l* 2007).

When considering the characteristics of a shear wall in a wood structure and its response to force actions, it is important to recognize both the methods of fastening along with the basic properties of the wood itself. This includes the fastener dimensions and spacing along with such irregularities and natural flaws such as knots and the grain within the lumber (Ambrose 1999).

The detailed construction of these shear walls are vastly important to the performance of the wall during a seismic event. Building codes for residential homes in earthquake prone areas are similar across the board. (Note: For the purpose of this section, California building codes will be used for the shear wall description). The most common form of sheathing used is Oriented Strand Board usually measuring between 5/16 inch and 3/8 inch. Nail sizes range from 6d to 8d using the latter for larger thicknesses of OSB. A maximum diaphragm ratio of 2:1 exists to ensure the strength of the shear wall and informs one of why all sheathing exists as 4’x8’ (CBC 2008). The first noticeable difference in shear wall integrity exists within the nail spacing used to fasten it. Along the perimeter of the wall, closer spacing ranges from 3 inch on center (o.c.) to 6 inch o.c. and is much larger for the studs within the field, usually 12 inch o.c.

Shake table and actuator tests reveal that by reducing this nail spacing from 6 inches to 3 inches, on walls with OSB sheathing only, as much as 20% less drift can be observed (Lindt 2005). When Gypsum Wall Board is attached, similar if not greater results can be expected (Lindt 2005). Lastly, when considering the drift of a building and ultimate deformation, the weight of the overlying roof is of major importance. It has been shown that by increasing the weight of the roof by as much as 25%, the overall drift increases by 100% (Lindt *et al.* 2007). This is explained by the same acceleration affecting the structure but multiplied by a larger mass, increasing the applied force (Lindt *et al.* 2007).

Conclusion

Understanding the forces and where stress is localized within the shear walls of structures, one can gauge the survivability of a building. Seismic events trigger waves that travel along the surface and within the interior of the Earth, all which eventually reach the foundation of wood frame residences within the vicinity. One factor that is somewhat beyond a homeowner’s control is the soil characteristics below their foundation. Something that is within their control is the construction and design of their home. Building integrity is dependent upon proper construction methods. Through proper engineering techniques, the use of lightweight woods and laminated particles can be revolutionary in creating enduring homes.

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