EARTHQUAKE-RESISTANT HOUSING

A Wood-Frame Building Performance Fact Sheet

Canadian and Japanese engineers performing a shake table test of a two-storey shear wall at Japan's National Research Institute for Earth Science and Disaster Prevention.

One of the proven features of Canadian wood-frame construction is its excellent life safety performance in earthquakes. Compared to other forms of house construction, a platform-frame wood house is one of the safest places to be in a quake.

In the past fifty years, our understanding of the risks posed by earthquakes and our ability to survive them have improved. But at the same time, soaring populations and growing urban densities have increased humanity's earthquake risk.

An earthquake is a sudden release of energy from the motion of geologic plates. Some parts of the world, such as the west coast of North America, are high risk areas. Buildings there must resist strong earthquake forces. These forces depend on the strength of the quake, how far away it originated, what type of geological event caused the earthquake, and the geology immediately adjacent to a given building.

Each structure, with its own unique set of characteristics such as stiffness and strength, reacts differently to earthquake stresses. Earthquakes subject a building to both vertical and horizontal shaking. The horizontal forces, also called lateral or shear forces, are the real challenge for seismic design.

A lateral force is a sideways motion that can make a building rack (as shown), overturn or slip off its foundation.

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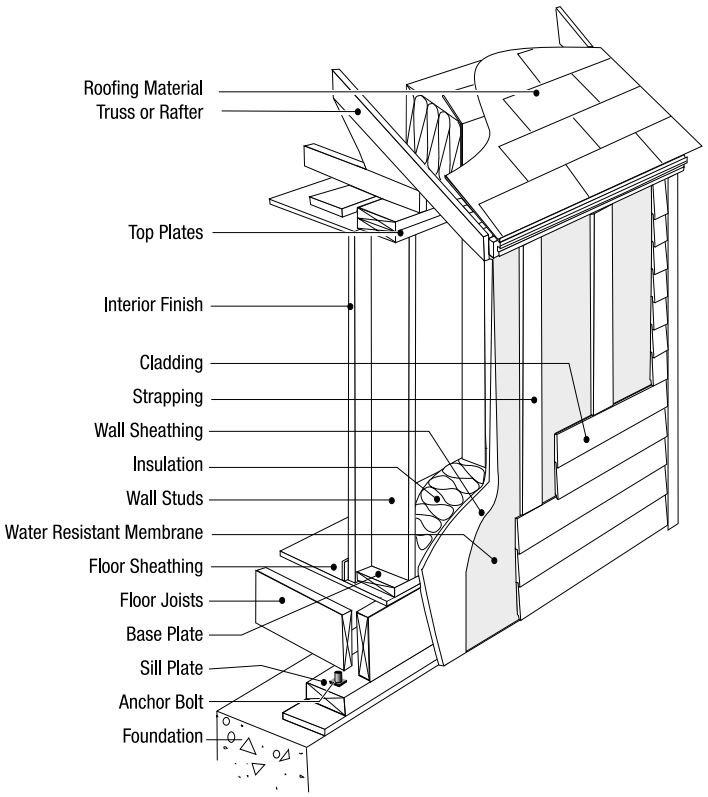
Wood can take the shaking

As a structural material, wood offers some key advantages over other materials in earthquake performance. Wood is strong yet lightweight, hence ground accelerations do not generate as much energy in wood buildings as in other buildings. As an added advantage, wood-frame systems flex more than other materials, absorbing and dissipating energy.

When wood is used for construction in Canada, it is most often used in a light-frame style called platform or western framing. In this type of construction, wood members are thin, of standard size, and closely spaced. Floors are built one at a time, so that each floor becomes the building platform for the new one taking shape above. Three components form most of the framing: *studs* run vertically and form the skeleton of the walls; *joists* run horizontally and form the floors; and *rafters or trusses* underpin the roof. When a wall is braced with diagonal wood members or enclosed with lightweight wooden panels, it now has lateral resistance and becomes a *shear wall* system — light, strong and structurally efficient. All of the pieces work together to hold up the building against gravity, wind and earthquakes.

Light-frame wood construction was invented in North America in the early 1800s. Its track record, both in building performance and the expertise of the trades in assembling it, has been well-established over that time. Many wood buildings across Canada, built at the turn of the 20th century, are standing proof of the reliability of this system.

Canadian wood-frame housing has also proven to perform equally well in other parts of the world. One of the most damaging modern quakes occurred in 1995 in Kobe, Japan. At 6.8 on the Richter scale, a death toll of 6000, and over US$100 billion in loses, this was a torture-test for all buildings, subjecting them to severe lateral and vertical stresses. Older homes built in the traditional Japanese post-and-beam style which had minimal lateral resistance were shattered by this quake. Newer homes built to Canadian seismic standards were virtually unaffected.



Typical Canadian wood-frame design uses small dimension lumber closely spaced, and includes shear walls, which contain components that resist lateral forces. This is most typically accomplished by attaching a wood panel product such as plywood or oriented strandboard as sheathing over the framing studs, using a code-prescribed nailing pattern. Anchor bolts hold the structure firmly on its foundation. Hold-downs (not shown) are metal connectors that tie studs to the foundation. These are often used at the ends of shear wall segments, to resist the overturning forces that result from an earthquake or wind.

Photo credit: Hans Rainer

Three undamaged modern Canadian-style wood-frame buildings in background, collapsed older building in foreground, after Japan's 1995 Kobe earthquake.

Photo credit: Hans Rainer

Failure at a weak first storey, from the 1971 San Fernando (California) earthquake.

Decades of field testing

Forintek, Canada's national institute for wood products research, developed reliable statistics on roughly half a million wood buildings involved in major earthquakes around the world over the last 40 years. The study revealed that North American-style wood-frame structures do well in earthquakes, regardless of their age. In the seven quakes studied, only 34 people in total died due to failure of platform-frame buildings. By contrast, the1999 earthquake in Turkey killed 40,000 by devastating areas in which masonry and concrete were widely used. This is not to say that masonry and concrete are unsuitable for seismic zones, however, these building systems require particularly careful adherence to design and construction standards for good seismic resistance. Experience has shown that wood systems are more forgiving.

Forintek's survey showed that collapse of North American-style wood buildings in earthquakes is very rare. The few collapses observed generally resulted from weak first storeys in multistorey buildings. Many modern houses have large openings in their first floor exterior walls (for big windows, patio doors, and garage doors) which can weaken these walls, no matter what kind of construction. Using good engineering judgement in design and construction, and carefully following the latest building codes and standards, will eliminate a weak first storey problem.

Designing for safety

Here are a few key features that should be included in good seismic design, whether new construction or a retrofit to bring an existing structure up to current standards.

- Special attention to potential weak first storeys.
- A strong foundation on stable ground.
- Walls well tied to the foundation.
- Lateral resistance in key walls, including cripple walls. (These are short walls between the ground and the first floor, forming a crawl space or part of the basement walls).
- Proper nailing of other wood components to the studs.

No building can be completely earthquake-proof, but good seismic design will minimize structural damage, and, most importantly, safeguard the lives of the occupants during a major seismic event. Seismic resistance is best achieved by following modern building codes and standards and, in large or complex buildings, using the services of a professional structural engineer.

Forintek Canada Corp.

Forintek is Canada's wood products research institute. Established as a private, not-for profit corporation in 1979, Forintek is an amalgamation of two former public laboratories whose history dates back to 1913. To this day, Forintek continues to provide leading-edge technical support to the solid wood products industry. As part of a broad research program, Forintek's scientists are among North America's leading experts on wood-frame seismic performance and technologies. Visit www.forintek.ca.

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Canada Mortgage and Housing Corporation is the Federal government's housing agency. For over 50 years, CMHC has been helping provide Canadians with housing quality, affordability and choice. CMHC is also the Canadian housing industry's export partner, bringing Canadian expertise to foreign markets. In addition, CMHC is Canada's largest publisher of housing information. Visit www.cmhc-schl.gc.ca.

For more information

- *Wood-frame Building Construction in Earthquakes*, by Hans Rainer and Erol Karacabeyli, provides more detail on the information in this fact sheet. This publication is available for a fee in English, French, Chinese or Japanese, from Forintek Canada Corp. Telephone 604-224-3221, Fax 604-222-5690. Web: www.forintek.ca

- For seismic design guidance in new construction projects, see *The Canadian Wood Council Guide on Wood-frame Construction*. Telephone 1-800-463-5091. Web: www.cwc.ca

- For help in evaluating the seismic resistance of an existing house or other structure, and on recommended seismic upgrade measures, see *Residential Guide to Earthquake Resistance*, available from Canada Mortgage and Housing Corporation. Telephone 1-800-668-2642 (in Canada), 613-748-2003 outside Canada. Web: www.cmhc-schl.gc.ca

This document is also available in French.
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