World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Single-family wood frame house

Report #	82
Report Date	26-09-2002
Country	CANADA
Housing Type	Timber Building
Housing Sub-Type	Timber Building : Stud-wall frame with plywood/gypsum board sheathing
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Summary

Single-family wood frame construction represents the most common housing construction practice found throughout Canada and constitutes over 50% of the housing stock in British Columbia. A typical Canadian-style modern wood frame house consists of a concrete foundation, upon which a platform is constructed of joists covered with plywood or oriented-strand board (OSB) to form the ground-floor level of the house. This platform is connected

directly to the foundation with anchor bolts, or alternatively, supported by a short wall, a so-called "cripple wall," "pony wall," or "stub wall," which should be connected to the foundation with anchor bolts. On this base, the exterior and interior walls are erected, which consist of a horizontal sill plate with vertical timber studs with board or panel sheathing nailed to the studs on the outside of the building. The roof structure typically consists of prefabricated trusses, which are covered with sheathing and roof tiles (Rainer and Karacabeyli 2000). Because this is generally considered to be a non-engineered construction, the Canadian National Building Code does not usually require direct professional architectural or engineering involvement. Specific seismic construction requirements and calculation/design requirements for seismic resistance are currently not included in Part 9 of the Code, which addresses low-rise residential wood frame construction. There is no evidence of substantial damage to this type of construction in past earthquakes in Canada, which have occurred away from densely populated urban centers. However, recent experimental research studies (Earthquake 99 Project at the University of British Columbia), focused on seismic performance of wood frame construction, have revealed vulnerability in this type of construction to seismic effects, depending on the age and wood construction technology.

1. General Information

Buildings of this construction type can be found in all parts of Canada: However, this contribution describes the construction practice typical for the Canadian West Coast, mainly the Province of British Columbia. According to the Census of Canada, single-family dwellings constitute 56% of the dwelling stock in the Province of British Columbia. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 200 years.

Currently, this type of construction is being built. Based on the historical development of wood frame construction in British Columbia, one could define three distinctive age classes of construction: Pre-1940, 1940-1980, and Post-1980. Each of these age classes results in a corresponding change in expected seismic performance based on the wood product technology in use in the building at the time, since seismic code provisions for buildings of this class were, and continue to be, largely non-existent. Pre-1940 buildings were primarily built from wood boards and full-dimensioned lumber and generally were well connected with nails driven by hand and other fasteners. Early examples of wood frame construction in the area (mainly found in Victoria and Vancouver) were built in the second half of the nineteenth century. Some of these older houses were of log construction, but the vast majority was wood frame construction made out of lumber. Many of these buildings have since become heritage buildings, and are typical period examples of residential construction. Historic development of wood frame construction is documented in Victoria (1978), Ovanin (1984) and Kalman (1979). In the pre-1920 period, housing demand made popular the purchase and erection of prefabricated home kits on prepared footings on a site. The 1940-1980 class reflects a shift in sheathing products from boards to panels such as plywood with a resultant change in wall racking performance. Framing continued to use lumber, however in newer standardized but slightly smaller cross-sections. Concrete was used almost exclusively as a foundation material, with most foundations being a cast slab-on-grade with strip footings placed in the ground at a depth of two feet. Some of the styles and trends popular at the time were: post and beam homes of the 1950's, hybrid plywood beam/stressed skin homes first exhibited at the Pacific National Exhibition in the early 1960's, traditional log homes, the "Vancouver Special" of the late 1950's to mid 1960's, "monster homes" of the 1980's, etc. (Kalman, et al.1978, 1993, NorthVan 1993). According to Taylor (1996), balloon framing as a framing style was not that very common in Vancouver. Finally, the Post-1980 class reflects the transition to engineered wood products encompassing a wide range of panel and framing products that are continuing to gain widespread use in order to optimize the wood resource. A change to pneumatic connection methods such as air gun nailing also occurred during this period, and this effect continues to be a matter of concern and industry research.

Figure 1: A contemporary two-story wood frame house

Figure 2: Modern Canadian style single-family woodframe construction with OSB sheathing

Figure 3: A heritage wood house in Victoria, British Columbia

Figure 4: A typical 1950's stuccoed house with the basement

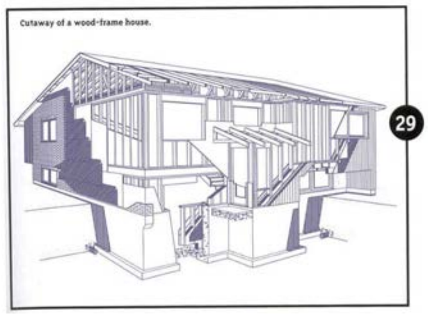

Figure 5: Key load-bearing elements: wood-frame house (Source: CMHC 2001)

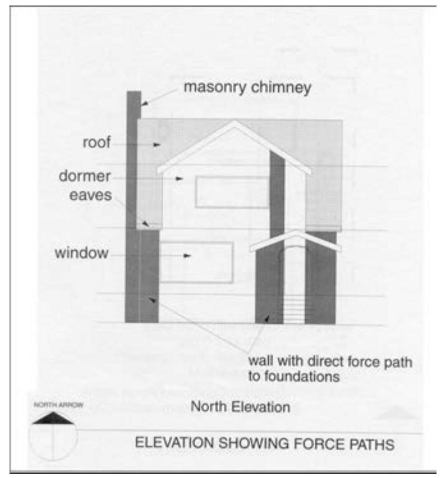

Figure 6: North elevation showing force paths (Source: CMHC)

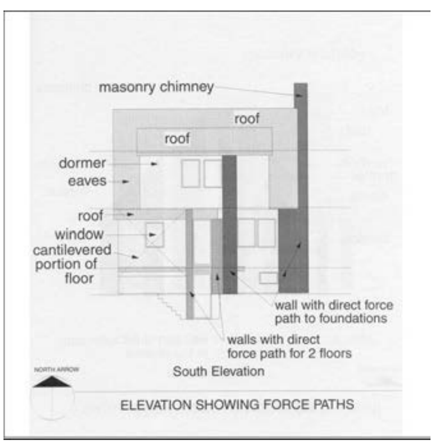

Figure 7: South Elevation showing force paths (Source: CMHC)

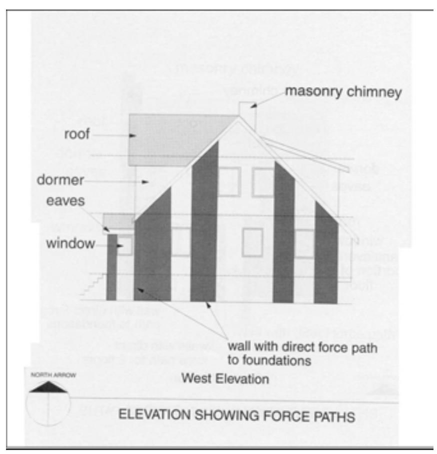

Figure 8: West elevation showing force paths (Source: CMHC)

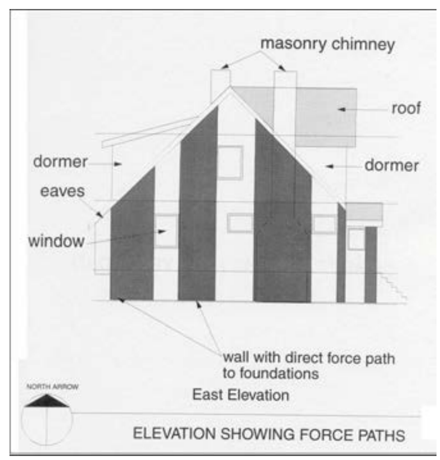

Figure 9: East elevation showing force paths (Source: CMHC)

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 3 meters.

2.2 Building Configuration

Building plan in older buildings of this type (pre-1980 construction) is generally regular i.e. rectangular and "T" or "L"-shaped in some cases. In buildings of more recent construction the shape of the building plan is often irregular due to the modern architectural design trends. An estimate for the overall window and door area as a fraction of the overall wall surface area depends on the age of construction. The total area of openings is on the order of 25-40% in the older construction whereas it is in the range of 50-80% for the contemporary construction.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. For single-story buildings, the means of escape from the buildings of this type is the main door and an additional door (usually in the rear part of the building). In general, there is only one staircase in a two-storey building.

2.4 Modification to Building

In older houses of this type, the basement ceiling has been raised in some cases to increase the floor height. Other modifications include moving the interior (partition) walls as a part of the renovation.

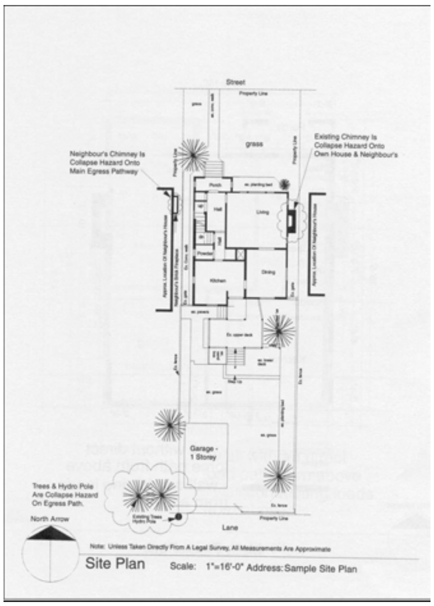

Figure 10: A sample site plan indicating some exterior hazards (Source: CMHC)

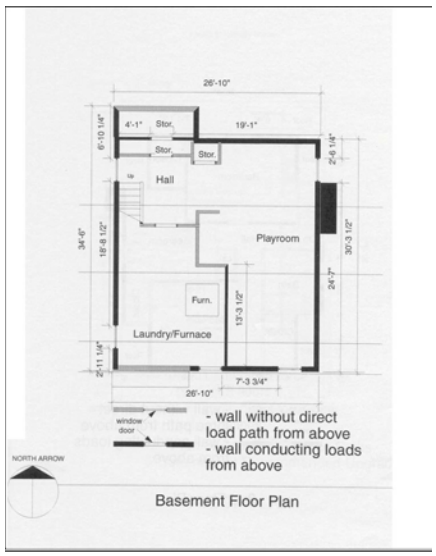

Figure 11: Typical basement floor plan (Source: CMHC)

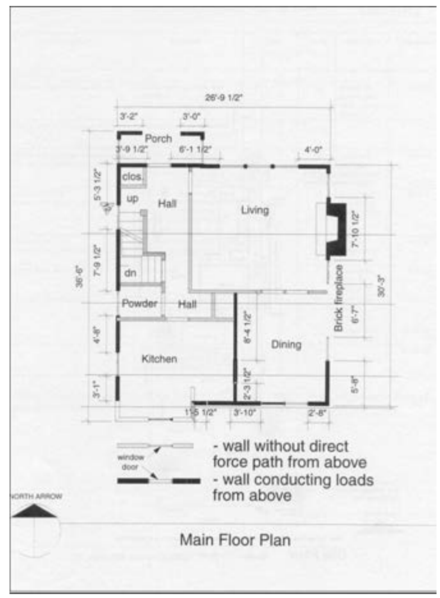

Figure 12: Typical main floor plan (Source: CMHC)

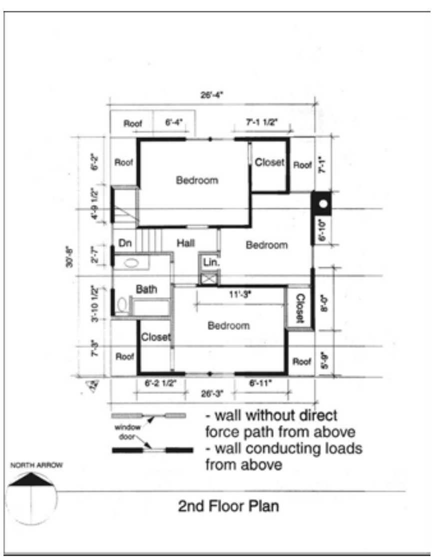

Figure 13: Typical second floor plan (Source: CMHC)

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐

	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☑
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is timber frame. Gravity load is carried by the wall system, which consists of a horizontal sill plate with vertical timber studs of one storey height spaced at 30 to 60 cm on centre. Gravity loads are transferred from the walls to the foundation or the stub walls.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is timber frame. Lateral load-resisting system in wood frame construction includes horizontal elements (roof and floors) and vertical elements (walls). A Canadian style modern wood-frame house consists of a concrete foundation or a basement, on top of which a platform is constructed of joists covered with plywood or oriented strand board (OSB) to form the floor of the ground level of the house. This platform is connected directly to the foundation with anchor bolts, or through a short so-called "cripple wall", #pony wall# or "stub wall" (this short wall may or may not be connected to the foundation with anchor bolts). On this base, the exterior and interior walls are erected. The walls consist of a horizontal sill plate with 38 x 89 mm (2# by 4#) or 38 x 140 mm (2# by 6#) vertical timber studs of one storey height at a spacing of typically 30 to 60 cm. A double top plate from 38 mm thick dimension lumber provides the base for the next floor structure. Board or panel sheathing is then nailed to the studs on the outside of the building, while the inside spaces are filled with thermal insulation and then covered with a vapour barrier and gypsum board as the interior finishing. This is the general configuration of a typical woodframe shear wall which resists the lateral loads of the system. The nailing amount and the type of sheathing and boarding largely affect the effectiveness of the lateral load-resisting system (Ventura et al. 2002).

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 12 and 18 meters, and widths between 12 and 18 meters. The building has 1 to 3 storey(s). The typical span of the roofing/flooring system is 3 meters. Typical Plan Dimensions: These houses are usually characterized with a total built-up plan area less then 600 m.sq. Typical Span: span could be 3 to 4 meters. The typical storey height in such buildings is 2.7 meters. The typical structural wall density is none. Wall density is widely variable.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
	Vaulted	☐	☐

Masonry	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☐
	Wood shingle roof	☐	☑
	Wood planks or beams that support clay tiles	☐	
	Wood planks or beams supporting natural stones slates	☐	☐
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☑
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☑	☐
Other	Described below	☑	☑

The floor is usually considered to be a flexible diaphragm.

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☑
	Reinforced-concrete isolated footing	☐
	Reinforced-concrete strip footing	☑
	Mat foundation	☑
	No foundation	☐
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☑
	Steel bearing piles	☐
	Steel skin friction piles	☑
	Wood piles	☐
	Cast-in-place concrete piers	☑
	Caissons	☐
Other	Described below	☐

It consists of reinforced concrete skin-friction piles, steel skin-friction piles and cast in-place reinforced concrete piers. Other: Concrete block masonry strip footing.

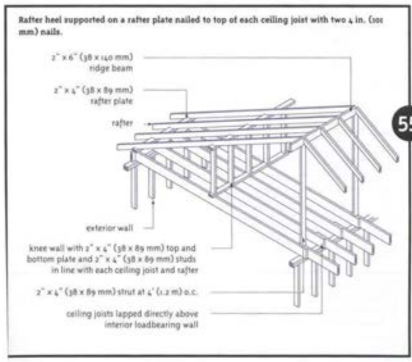

Figure 14: Critical structural details: roof trusses (Source: CMHC 2001)

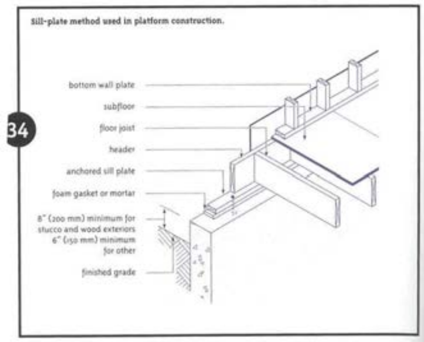

Figure 15: Critical structural details : sill plate construction (Source: CMHC 2001)

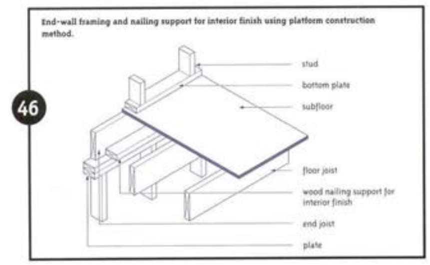

Figure 16: Critical structural details: end wall framing (Source: CMHC 2001)

Figure 17: Key seismic deficiency: no blocking between joists at interior load-bearing wall

Figure 18: Key seismic deficiency: a typical shear wall without holddown

Figure 19: Key seismic deficiency: a typical shear wall without horizontal blocking

Figure 20: Key seismic deficiency: finger joint and discontinuous studs

Figure 21: Key seismic deficiency: rear wall of a house - use of horizontal boards

Figure 22: Key earthquake-resistant feature: installation of hold-downs in shear walls

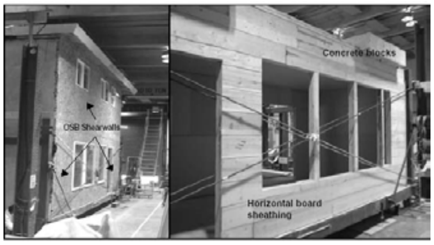

Figure 23: Full-scale model of a two-storey house with OSB shearwalls (left) and one-storey subsystem with horizontal board sheathing (Earthquake 99 Project, Source: Kharazzi 2002)

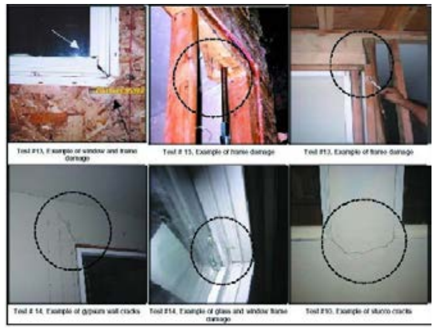

Figure 24: Damage to the two-storey wood frame building specimens tested on the shaking-table: test #13 - 1995 Kobe earthquake, nonengineered building; test 14- 1995 Kobe earthquake, engineered building (Earthquake 99 Project, Source: Kharazzi 2002)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 units in each building. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is 5-10.

4.2 Patterns of Occupancy

Typically, a single family occupies one house. Less often, there are cases in which a house is shared among 4 to 6 individual occupants (case of larger rental houses).

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☐
b) low-income class (poor)	☐
c) middle-income class	☑
d) high-income class (rich)	☐

Economic Level: For Middle Class the ratio of Housing Price Unit to their Annual Income is 4:1.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☐
4:1	☑
3:1	☐
1:1 or better	☐

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	☐
Personal savings	☐
Informal network: friends and relatives	☐
Small lending institutions / micro-finance institutions	☑

Commercial banks/mortgages	☑
Employers	☐
Investment pools	☐
Government-owned housing	☑
Combination (explain below)	☐
other (explain below)	☐

In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) including toilet(s).

Typically there are up to 3 bathrooms in a single family house. Number of bathrooms depends on size of house. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership and ownership with debt (mortgage or other).

Type of ownership or occupancy?	Most appropriate type
Renting	☑
outright ownership	☑
Ownership with debt (mortgage or other)	☑
Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	☐	☑	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	☑	☐	☐
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area.	☐	☑	☐
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☑	☐	☐

Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	☐	☐	☑
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☐	☑	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	☐	☐	☑
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☑	☐	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☑	☐	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☑	☐	☐
Additional Comments	There is a concern that this construction type will experience excessive lateral drift (movement of the building relative to the foundations) because of inadequate wall-foundation anchorage i.e. absence of holddowns.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	- Use of horizontal board sheathing in the construction of exterior shear walls (low-cost construction); - Lack of anchorage and/or holddowns to foundations; - Lack of horizontal blocking in the walls; - Joints over interior load-bearing walls are commonly not blocked; the lack of blocking minimizes any effective load transfer from the floor diaphragm to the wall. - Absence of effective shear walls in non-engineered wood buildings.	- High density of wooden shear walls and stucco; - Provision of holddowns in engineered wood buildings.	No significant damage reported in the past earthquakes in Canada - see Additional Comments below
Frame (Columns, beams)	- Potential loss of gravity load-carrying capacity in walls with finger-jointed studs, since finger joints were never designed for high flexural stresses that can develop in the walls with large lateral deformations.		No significant damage reported in the past earthquakes in Canada - see Additional Comments below
Roof and floors	- Absence of blocking in the roof and/or floors; - Inadequate shear studs in the roof openings.	-Blocking of roof and/or floors; -Design of adequate shear studs for openings;	No significant damage reported in the past earthquakes in Canada - see Additional Comments below
Other			

The expected seismic performance of wood frame housing was recently studied at the University of British Columbia in Vancouver through the Earthquake 99 Woodframe House Project. The main focus of the project was the study of the expected seismic response of residential wood-frame construction in the region. The ultimate goal of this project was to develop procedures for improved design and retrofit. The first part of the project was mainly concentrated on current construction in California and on new proprietary framing systems, while the second part was focused on existing residential (non-engineered) construction in British Columbia (BC). A total of 31 uni-axial shake table tests were conducted on full-scale one and two storey houses with a footprint of 6.1 m (20 ft) by 7.6 m (25 ft). For the California construction tests, records from the 1994 Northridge Earthquake records were used, while selected crustal and subduction earthquake records, adapted to the local geological setting, were used for the BC tests. For each shaking test complementary forced vibration and ambient vibration tests were conducted to evaluate the dynamic properties of the house before and after the simulated earthquake (Kharrazi 2001). The need for this research arose from the current construction practice in British Columbia that has resulted in many forms of contemporary residential housing being substantially more vulnerable to heavy earthquake damage than housing that was built 100 years ago. The project was completed in 2001. The key conclusions of this project were: 1. Non-structural materials such as stucco and gypsum wallboard play a major role in reducing the earthquake damage, and their contributions need to be recognized in the design. 2. There are several forms of high-risk residential construction practice in BC that need to be addressed immediately. Seismic deficiencies studied in the experimental part of the project included the use of horizontal board sheathing, absence of wall anchorages and hold downs and the lack of effective shear walls. The results of the experimental study clearly indicate that measures to address these high-risk construction practices will substantially reduce earthquake damage. 3. The use of an inelastic drift control approach to seismic design is strongly advocated in contrast to the current empirical quasi-elastic force method. Drift control of actual building deflections under real earthquakes is the best method for predicting earthquake damage and ensuring the reliable seismic performance. 4. Sophisticated software for the inelastic time history analysis has been developed to predict building drift levels for an arbitrary earthquake ground motion. The results of the laboratory test program have been used to refine the modeling methods.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is E: LOW VULNERABILITY (i.e., very good seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☑	☐	☐	☑	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1918	Vancouver Island Earthquake, British Columbia	7	MMI=
1946	Vancouver Island Earthquake (Courtenay), British Columbia	7.3	MMI=VI FOR GREATER VICTORIA (GSC)MMI=V FOR GREATER VANCOUVER (GSC)
1949	Queen Charlotte Islands, British Columbia	8.1	MMI=
2001	Nisqually, Washington (USA)	6.8	MMI=VI FOR GREATER VICTORIA (GSC)

Wood frame construction had generally not been exposed to the effects of damaging earthquakes in Canada, however experimental studies were recently conducted to study the expected seismic response of residential wood-frame construction in the region and to explore practical alternatives for seismic retrofit. For more details on the studies see Section 5.3. For more information on the Canadian earthquakes see:

http://www.pgc.nrcan.gc.ca/seismo/hist/list.htm.

Figure 25: Typical earthquake damage to a wood frame house in Comox, BC in the 1946 earthquake (Source: Natural Resources Canada www.pgc.nrcan.gc.ca/seismo/hist/list.htm)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	OSB Plywood Board	Depends to the species and / or composite wood product type. Wood Species such as S-P-F and D-Fir (Soft Wood Lumber)	Wood Species such as SPF and DF (Soft Wood Lumber)	
Foundation	Concrete		concrete mix 1:2:4 (cement:sand:aggregate)	
Frames (beams & columns)	Soft Wood Lumber	Wood Species such as S-P-F and D Fir (Soft Wood Lumber)usually f (bending)=5 to 16 MPa and f (shear) = 0.5 to 1.0 MPa and f(compression parallel to grain) = 4.0 to 16.0 dependent to the species. E(0.05)=3500 to 6000. For more information see the Canadian Wood Council's Wood Frame Construction Guide (CWC, 2001)	horizontal sill plate with 38 x 89 mm (2" by 4") or 38 x 140 mm (2" by 6") vertical timber studs of one storey height at a spacing of typically 30 to 60 cm	For further information see CMHC "Residential Guide to Earthquake Resistance"
Roof and floor(s)		Same as Frame	Different type of joist and blocking with many available sizes	For further information see CMHC "Residential Guide to Earthquake Resistance"

6.2 Builder

It is typically built by developers.

6.3 Construction Process, Problems and Phasing

The platform and baloon method of framing are two ways of constructing wood frame houses in Canada. Baloon framing was the most common method of wood-frame construction in the latter part of the 19th century, and early part of the 20th century. Platform framing has dominated since the late 1940s and today represents conventional practice in Canada. The chief advantage of platform construction is that the floor system, assembled independently from the walls, provides a platform or working surface upon which walls and partitions may be assembled and erected. Since the studs are one storey high, walls can easily be prefabricated off the site or assembled on the subfloor in sections and erected one storey at a time without using heavy lifting equipment. The bottom and top plates, which are an integral part of the wall framing, provide fire stops at the floor and ceiling and also nailing support for wall sheathing and interior finish. Baloon framing differs from platform framing in that the studs used for exterior and some interior walls are continuous, passing through the floors and ending at the top plates which support the roof framing. Since the connections between the floor joists and studs in baloon framing do not lend lend themselves to prefabrication or easy assembly on the site, this method of framing houses is rarely used (CMHC 2001). The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

The level of expertise of all parties involved in the design and construction process are as follows: - Licensed and Qualified Contractor for homes of area less than 600 m.sq.; - Licensed (professional) Engineer (and Architects if required) for homes of area greater than 600 m.sq. Construction of most residential wood frame buildings with less than 600 m.sq. in floor area and four stories in building height should follow Part 9 of the National Building Code (NBC) - Housing and Small Buildings, and generally do not require direct professional architectural or engineering involvement. Explicit seismic provisions related to wood frame structures have never been provided in the NBC. General nailing schedules for wall sheathing attachment and framing were provided, however specific seismic construction requirements, or calculation/design requirements for seismic resistance did not appear in Part 9. The Vancouver Code has recently been modified to require seismic design of all wood frame buildings except for one- and two-family dwellings, which are required to be constructed according to the simplified requirements of the Canadian Wood Council's Wood Frame Construction Guide (CWC, 2001).

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. National Building Code Canada 1995 and City By-Law / Provincial Building Code. The year the first code/standard addressing this type of construction issued was 1941. National Building Code of Canada 1995. The most recent code/standard addressing this construction type issued was 2001. Title of the code or standard: National Building Code Canada 1995 and City By-Law / Provincial Building Code Year the first code/standard addressing this type of construction issued: 1941 National building code, material codes and seismic codes/standards: National Building Code of Canada 1995 When was the most recent code/standard addressing this construction type issued? 2001.

Requirements for plans, permits and inspections vary across Canada; however, most municipalities conform to the basic requirements described in the National Building Code of Canada for plans. Building permit needs to be issued in the pre-construction stage, based on the building plans. Several inspections are performed in the construction stage, such as framing inspection that verifies the quality of construction. Once the construction is complete, completion inspection (interior and exterior) needs to be performed. Finally, a certificate of occupancy is issued. The inspections are performed by the inspectors on behalf of the building department of the municipality the building site belongs to. The chart showing approvals, permits and inspections process for new houses is included in this contribution.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

On the order of CAD 100/ft.sq. Normally, about 4 months is required from start to finish of the construction. Average size of a wood-frame dwelling in Canada is approximately 1200 ft.sq. (CMHC 2001).


Figure 26: A contemporary two-story wood house under construction


Figure 27: A modern wood frame house under construction (photo courtesy of Dr. G. Taylor)

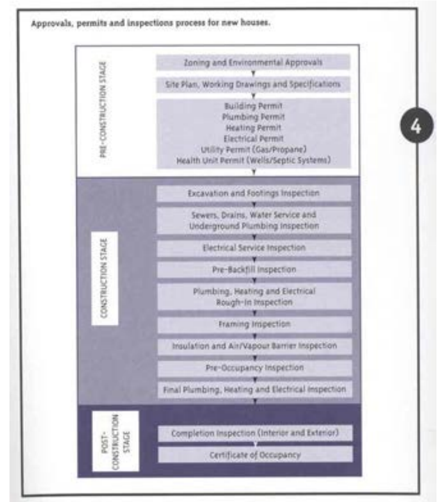

Figure 28: Process for building code enforcement: approvals, permits and inspection process for new houses (Source: CMHC 2001)

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. In case of single-family houses, insurance covers the insured contents and the structure. The deductible is usually 5 to 6% of the insured value (depending on the insurance agency), irrespective of the type of the building and the location.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Absence of wall-foundation anchorage	Install holddowns
Inadequate lateral resistance	Installation of Oriented strand board (OSB) or plywood sheathing
Flexible diaphragm	Installation of blocking
Inadequate wall stiffness	Installation of blocking

The Vancouver Building Bylaw has recently been modified to require seismic design of all new wood frame buildings except for one- and two-family dwellings, which are required to be constructed according to the simplified requirements of the Canadian Wood Council's Wood Frame Construction Guide (CWC, 2001).

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?

Yes. Some retrofit projects of heritage and older wood frame buildings have been performed in the Vancouver area.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?

The work was done as a mitigation effort on an undamaged building.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?

Yes, the construction was inspected in the same manner as new construction.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

Generally, the contractor performed the construction and an architect or engineer were involved.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

The performance of retrofitted building has not been tested under severe shaking.

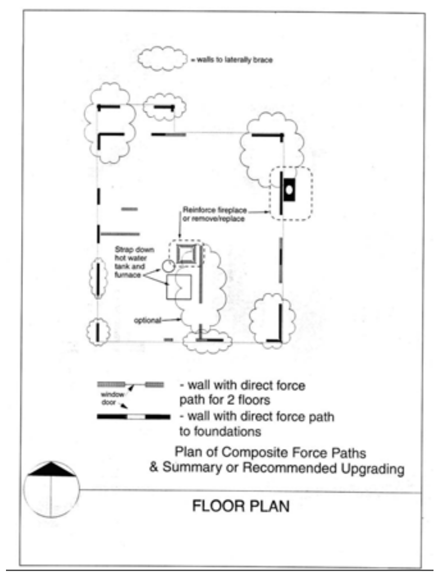

Figure 29: Seismic strengthening technologies: plan of composite force paths and recommended upgrading

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