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
Concrete shear wall highrise buildings

Report #	79
Report Date	17-07-2002
Country	CANADA
Housing Type	RC Structural Wall Building
Housing Sub-Type	RC Structural Wall Building : Moment frame with in-situ shear walls
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Summary

This concrete shear wall high-rise represents a contemporary residential and commercial construction commonly found in downtown areas of Canadian cities. This multi-family building contains 100 to 200 units and provides housing for 300 to 500 inhabitants. The height of these buildings is variable and usually ranges from 12 to 35 stories. The lateral load-resisting system consists of reinforced concrete shear walls and concrete floor slabs. The

gravity load is carried mainly by concrete columns. Seismic detailing of shear walls in medium-to-high seismic regions is mandatory per the Canadian Concrete Code. Exterior walls are clad in stucco backed by cold-form steel framing or masonry veneer, steel/glazing panels, or precast panels. There is no report on the damage sustained by this building type in past earthquakes in Canada. However, because these buildings are designed according to state-of-the-art seismic codes, their seismic performance is expected to be satisfactory in an earthquake of design intensity (per the seismic design requirements of the National Building Code of Canada).

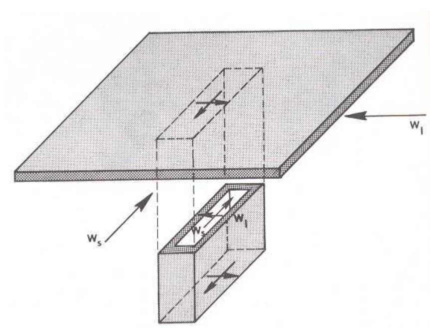
1. General Information

Buildings of this construction type can be found in major Canadian cities: Toronto, Montreal, Vancouver, etc. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 25 years.

Currently, this type of construction is being built. This is a rather recent construction practice, resulting from the population growth in Canadian urban areas in the last few decades.

Typical Building

Typical Building



Key Lateral Load-Resisting Elements: Floor Diaphragm and Elevator Core

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 10 meters.

2.2 Building Configuration

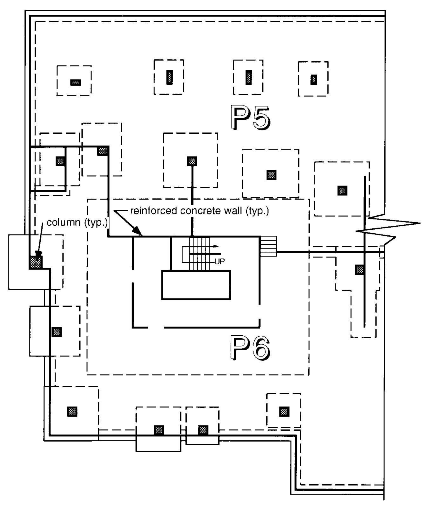
In general, buildings of this type are characterized with a regular plan. A typical building plan characteristic for residential high-rises of post-1970s construction is so-called "point block" system. Point block is characterized with a symmetrical plan (square, circular, hexagonal) with a centrally located elevator core, and the apartments are planned along all sides in a ring pattern around the core (Macsai 1976). Shear wall buildings are usually regular in elevation. However, in some buildings located in the downtown areas, lower floors are used for the commercial purposes and the buildings are characterized with larger plan dimensions; these are so-called "podium-type" buildings. In other cases, there are setbacks at higher floor levels. In the buildings of this type, concrete shear walls are often perforated with openings. Interior walls are perforated with door openings, whereas elevator cores usually have openings on one or more sides (e.g. elevator doors, services etc). A typical size of door openings in the elevator core is 4'-6" (width) by 7'-4" (height).

2.3 Functional Planning

The main function of this building typology is multi-family housing. In a typical building of this type, there are 1-2 elevators and 1-2 fire-protected exit staircases. In a typical building of this type there are 1-2 elevators and two additional means of egress (fire protected exit stair shafts).

2.4 Modification to Building

Except for the removal or modification of light partition walls (usually dry walls), structural modifications in the buildings of this type are not very common. If such modifications are performed, building permit must be issued based on the advice of design professionals (architects and engineers).



Typical Foundation Plan

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	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	☐
		7	Brick masonry in mud/lime	

Masonry	Unreinforced masonry walls		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)	☐
			Stud-wall frame with	

		41	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 reinforced concrete moment resisting frame. The main elements of gravity load-resisting system are concrete columns (which form so-called "gravity frame"). The columns are typically supported by concrete flat slab structures or two-way slabs with beams. Shear walls also carry gravity loads, according to their respective tributary areas.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete structural walls (with frame). The main lateral load-resisting system in this scheme consists of the reinforced concrete elevator core and additional concrete shear walls located elsewhere in the building as required. Shear walls have a dual role of transferring both gravity and lateral loads. Wall thickness ranges from 500 mm at the bottom gradually reducing to 350 mm at the upper floors. The core houses the corridor leading to the residential units, the elevator shaft and stair wells, as well as mechanical and electrical conduits. Typical core plan dimensions are approximately 10 m by 6 m. The core is typically perforated with the openings and designed as ductile wall system according to the Canadian concrete design code. The coupling beams above the openings are designed with diagonal reinforcement provided to ensure ductile seismic response. The base of the core is designed to yield first, thereby forming a plastic hinge in this region. Shear wall structures are addressed by the National Building Code of Canada 1995 (NBCC 1995) and the Canadian Concrete Code A23.3-94 Design of Concrete Structures (CSA 1994). In terms of the seismic design, NBC 1995 classifies shear wall buildings into the following two categories: nominally ductile and ductile wall systems, with the corresponding force modification factor (R) values of 2 and 3.5 respectively. It should be noted that R factor reflects the structural ability to perform in a ductile manner under seismic loads (elastic systems are characterized with R value of 1.0). The latest edition of the Canadian Concrete Code was published in 1994, with the previous editions in 1984, 1977, 1973 (limit state design) and 1970, 1966, and 1959 editions (working stress design). Since 1973 the concrete code includes special seismic provisions for shear wall structures. The provisions include requirements for the amount and detailing of horizontal and vertical wall reinforcement. In case of ductile shear walls (R=3.5), in addition to the distributed reinforcement (in both horizontal and vertical directions) with the required ratio of 0.25 % or higher, the code requires the use of concentrated reinforcement with minimum 4 bars at the ends of walls and coupling beams. The required area of concentrated reinforcement (at each end of the wall) is equal to 0.25% of the wall area. The philosophy of code provisions regarding ductile shear walls is based on the expected development of plastic hinges over the lower part of their height; this applies to the walls with no abrupt changes of the strength and stiffness. The provisions for coupled ductile shear walls (walls with openings) recommend the provision of diagonal reinforcement in coupling beams (also called headers) to ensure ductile behavior and energy absorption capacity in the coupled wall system. The code provisions for nominally ductile shear walls (R=2.0) are less stringent, however the distributed reinforcement ratio (in vertical and horizontal directions) of 0.25% or higher is still required. Dynamic characteristics and seismic response of a typical Canadian shear wall high-rise building were studied by Ventura (White 2001). Nondestructive dynamic ambient vibration testing of a 30-storey tower with the overall height of 85 m was performed as a part of the study. The test has shown that the fundamental period of the structure was equal to 1.83 sec, whereas the periods for the second and third vibration mode were 1.55 sec and 0.78 sec respectively. The linear damping ratios corresponding to the first three vibration modes were 8.0 %, 6.8% and 6.0 % respectively. The testing was performed while building was under construction and therefore damping ratios reflect the structural damping levels only.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 20 and 20 meters, and widths between 20 and 20 meters. The building has 12 to 35 storey(s). The typical span of the roofing/flooring system is 6 meters. Typical Story Height: The above value is typical storey height for residential buildings of this type. However, the story height for the first floor (lobby) area is 4.0 m. Typical Span: The above number refers to centre-to-centre distance between the shear walls. A typical column span is 7 m. The typical storey height in such buildings is 2.6 meters. The typical structural wall density is none. variable wall density.

3.5 Floor and Roof System

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

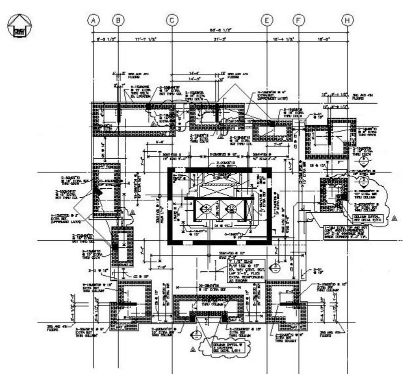
Floor structures are of flat plate construction. Floor structures are considered in the design as rigid diaphragms. Roof structures are of flat plate construction.

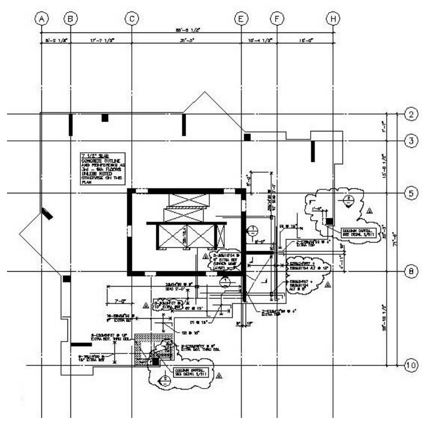
3.6 Foundation

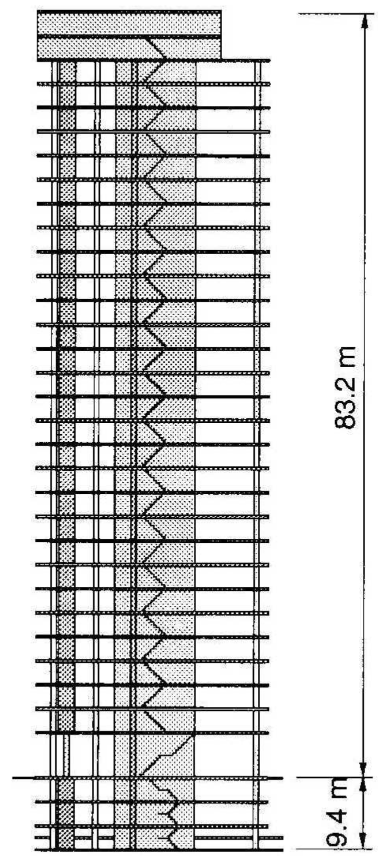
Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	Reinforced-concrete isolated footing	☑
	Reinforced-concrete strip footing	☑
	Mat foundation	☑
	No foundation	☐
	Reinforced-concrete bearing piles	☑
	Reinforced-concrete skin	☐

Deep foundation	friction piles	
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

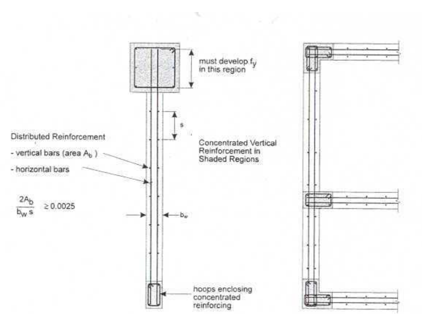
It consists of reinforced concrete end-bearing piles.


Plan of a Typical Building - Lower Floor Levels

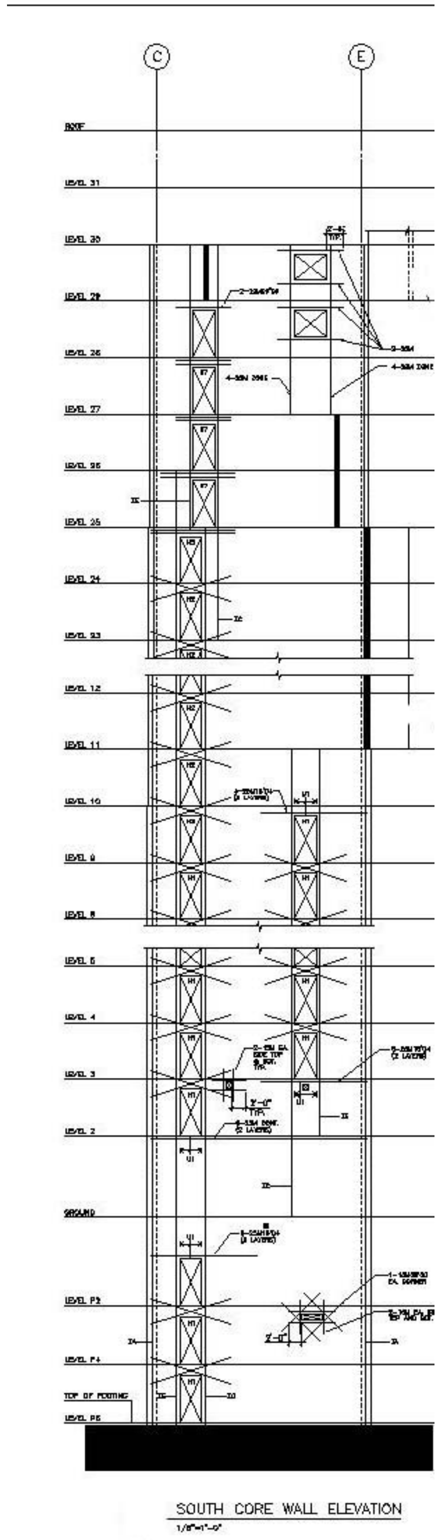

Typical Building Plan - Upper Storey Levels



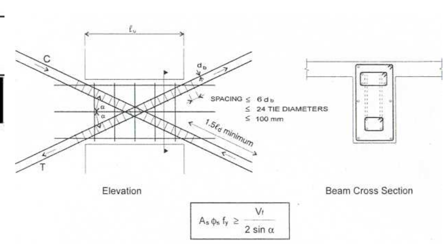
Building Elevation



Wall Seismic Detailing (Source: CSA 1994)



Elevator Core Reinforcement Details



Header Reinforcement Detailing (Source: CSA 1994)

A Typical Building Under Construction

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has more than 100 housing unit(s). 100-200 units in each building. The number of housing units depends on the size of the building (plan dimensions, number of stories, etc.) The number of inhabitants in a building during the day or business hours is more than 20. The number of inhabitants during the evening and night is others (as described below). In general, 300 to 500 inhabitants occupy one building.

4.2 Patterns of Occupancy

One family typically occupies one housing unit i.e. apartment. In case of smaller housing units, one person occupies one housing unit.

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)	☑

The two main categories of inhabitants in buildings of this type are: families with lower income who cannot afford to own a single-family house (this is mainly the case with rental buildings) and younger professionals/couples who desire to live in an urban area (this applies both to the case of rental buildings and condominiums). Economic Level: The ratio of Housing Price Unit to middle dass annual Income is 3:1.

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 1 bathroom(s) including toilet(s).

In general, there is 1 bathroom in a 1-bedroom unit and 2 bathrooms in a 2-bedroom unit. .

4.4 Ownership

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

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				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	- Inadequate amount of vertical reinforcement in the wall end zones (boundary elements); - Inadequate lap	-If properly reinforced (with distributed and end zone reinforcement), ductile seismic behaviour is expected, characterized	-Shear failures corresponding to diagonal tension, web crushing, or sliding shear (if shear strength is less than flexural strength); - Shear cracking around wall openings; - Buckling of longitudinal bars in boundary regions of plastic hinge zones (in case of inadequate lateral confinement); -

	splices causing non-ductile flexural failure;	with the yielding of flexural reinforcement in the plastic hinge zone	Flexural failure due to insufficient reinforcement lap lengths in the wall end zones (slip of lap splices)
Frame (Columns, beams)			Information not available
Roof and floors			Information not available
Other			Information not available

Seismic deficiencies and earthquake damage patterns described in the above table are not expected to occur in case of shear wall structures designed according to building code requirements.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *E: LOW VULNERABILITY (i.e., very good seismic performance)*, the lower bound (i.e., the worst possible) is E: LOW VULNERABILITY (i.e., very good seismic performance), and the upper bound (i.e., the best possible) is *F: VERY LOW VULNERABILITY (i.e., excellent 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

Buildings of this type have not been subjected to the effects of damaging earthquakes in Canada so far.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Reinforced concrete	Concrete compressive strength (fc')= 25-35 MPa Steel yield strength fy= 400 MPa		Concrete compressive strength based on the cylinder strength
Foundation	Reinforced concrete	Concrete compressive strength (fc')= 25 MPa Steel yield strength fy= 400 MPa		Concrete compressive strength based on the cylinder strength
Frames (beams & columns)	Reinforced concrete	Concrete compressive strength (fc')= 40 MPa (lower floors) to 30 MPa (upper floors) Steel yield strength fy= 400 MPa		Concrete compressive strength based on the cylinder strength
Roof and floor(s)	Reinforced concrete	Concrete compressive strength (fc')= 30 MPa Steel yield strength fy= 400 MPa		Concrete compressive strength based on the cylinder strength

6.2 Builder

Buildings of this type are typically built by developers.

6.3 Construction Process, Problems and Phasing

The main advantage of this type of "concrete core/flat plate" cast-in-place concrete high rise residential tower is it can be constructed very quickly. Typical floor-to-floor cycle is one week, however three-day cycles are often achievable. The concrete core and columns are formed by "gang forms" that can be stripped and hoisted up to the next floor and reassembled within a few hours. The flat plate floor slabs are formed by forming tables, usually called "fly forms". When the concrete is set, the "fly forms" can be loosened, lowered and "flown" to the next level. An entire floor can be "flown" in a few hours. The primary hoisting equipment required is a tower crane that is positioned within the slab floor area. As the building height increases with the construction of each floor, the tower crane would climb with the building by jacking up at the base of the crane mast. The building exterior envelope may commence the erection prior to completion of the structure (typically the construction of the exterior envelope will commence after about 10 floors of the structure are complete). 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

Architectural design for buildings of this type is developed by certified architects with a university degree in architecture (M. Arch), who are also the members of the Architectural Institute of British Columbia (AIBC), or other similar associations elsewhere in Canada. Structural design is performed by structural engineers, who are holding a university degree in civil engineering from a recognized university and are the members of the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC). In order to become a member of the APEGBC, it is required to practice for at least 4 years. Engineering technologists (college graduates) are also involved in the design process. Construction professionals include a project manager (usually with a civil engineering degree), and construction labor - tradesmen: carpenters, rebar placers, and concrete placers. This is a fully engineered construction and architects and engineers are involved both in the design phase, in which they are playing a major role, and the construction phase, in which they are performing regular inspection as per the requirements of the APEGBC and the municipalities.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. CSA A23.3-94 Design of Concrete Structures. The year the first code/standard addressing this type of construction issued was 1959. National Building Code of Canada 1995 (seismic provisions for buildings are included in Section 4) CSA A23.3-94 Design of Concrete Structures (seismic provisions for shear wall structures included in Section 21). The most recent code/standard addressing this construction type issued was 1994. Title of the code or standard: CSA A23.3-94 Design of Concrete Structures Year the first code/standard addressing this type of construction issued: 1959 National building code, material codes and seismic codes/standards: National Building Code of Canada 1995 (seismic provisions for buildings are included in Section 4) CSA A23.3-94 Design of Concrete Structures (seismic provisions for shear wall structures included in Section 21) When was the most recent code/standard addressing this construction type issued? 1994.

Building design in Canada must be performed according to the local building bylaws, which may be different for various municipalities. These bylaws usually refer to provincial building codes (e.g. British Columbia Building Code), or (if provincial codes are not available) to the National Building Code of Canada. Once the construction documents have been prepared, construction drawings are submitted for the approval to the municipality in which the building is located. The drawings are reviewed for compliance with the BC Building Code, as well as City Zoning and Development and Building regulations. For large and complex buildings, plumbing and mechanical systems are also reviewed. During the construction, building inspectors (employees of the municipality) are responsible for inspecting the various stages of building construction to ensure compliance with all applicable codes and bylaws. Once the construction is completed, building occupancy permit is issued (provided that the construction was completed in a satisfactory way).

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) and Tenant(s).

6.8 Construction Economics

Unit cost for the structural part only is around CAN$ 220/m² ($US 140/m²), and the cost of the competed building with finishes (excluding the underground parking) is approximately CAN$ 880/m² ($US 560/m²). The construction progresses at a pace of approximately 1 floor/week, however in some cases the construction pace is as fast as 1 floor in 4 days. The construction crew (for concrete part) typically includes 20 people.

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 apartment buildings, insurance covers the insured contents. 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

Seismic strengthening of newer buildings of this type had not been performed in practice, as it is considered that these buildings meet the code requirements and would be able to resist the effects of possible earthquakes.

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?

No.

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

Not applicable.

8.3 Construction and Performance of Seismic Strengthening

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

Not applicable.

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

Not applicable.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
Not applicable.

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