

World Housing Encyclopedia

A Resource on Construction in Earthquake Regions



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

HOUSING REPORT

Concrete frame and shear wall building

Report#	6
Last Updated	
Country	Chile
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Important

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General Information

Building Type:	Concrete frame and shear wall building
Country:	Chile
Author(s):	Ofelia Moroni Cristian Gomez
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in all main cities of the country: Iquique, Antofagasta, Concepcion, Temuco, Valparaiso, Vina del Mar and Santiago. This type of housing construction is commonly found in urban areas.
Summary:	Buildings of this type are used mainly for offices or hotels and they are found in the large cities throughout the country. At the present time this building type represents about 15-20% of the highrise building stock in Chile (building more than 10 stories high). The structural system consists of reinforced concrete frames and shear walls. The walls are typically located around the staircases and the elevators, while the frames may be uniformly distributed in plan or at the perimeter only. Most of the lateral load-bearing elements exist along the full building height in the elevation and in both directions of the building plan. In some buildings the walls are perforated with openings and coupled with lintel beams. Some buildings of this type have one or more basement floors. In general, these buildings are quite stiff. Seismic performance is very good, strength and stiffness are controlled, and torsion effects are minimal. Problems that may occur in the future are related to the reduction in the wall density, and introduction of soft storey or torsional effects.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Mixed residential/commercial
Typical number of stories:	10-30

Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	In some buildings commercial ground floor includes a big hall.

Features

Plan Shape	Rectangular, solidOther
Additional comments on plan shape	From rectangular to octagonal.
Typical plan length (meters)	20
Typical plan width (meters)	40
Typical story height (meters)	3.2
Type of Structural System	Structural Concrete: Moment Resisting Frame: Dual system Frame with shear wall
Additional comments on structural system	<p>The vertical load-resisting system is reinforced concrete structural walls (with frame). Shear walls and frames play both role as both the lateral and gravity load-bearing elements. In addition, gravity load-resisting beams may exist. The lateral load-resisting system is reinforced concrete structural walls (with frame). Shear walls provide enough strength and stiffness to control displacements in the lower floors while the frames control displacements in the upper floors. In some cases the walls are coupled with lintel beams, which are able to dissipate energy when subjected to severe earthquakes and are easily repairable afterwards. In general these buildings are quite stiff because they must resist a base shear of 5 - 6.7% depending on the seismic zone and the story drift must be equal or less than 0.002. The facade frames may not be linked to the stair or elevator walls, in which case the slab must transfer lateral loads from one element to the other. Stiffness and mass distribution are regular in plan but some irregularities may appear at the top floors due to reduction in floor area. Most of them may have symmetry axes in at least one direction of the plan. The ratio Total Height/Period (H/T) has been defined as representative of building stiffness, being normal values between 40 to 70 m/sec. However, in the last</p>

	decade this value had diminished and about 7% of the buildings have H/T between 20 to 40 m/sec. This may lead to larger story drift and damage due to earthquakes.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	1-2%
Typical wall densities in direction 2	1-2%
Additional comments on typical wall densities	Ranges from 1.5% to 2.5% in each direction. Only 25% buildings of this type have wall density less than 1.5% but larger than 0.5%. Figure 8 shows the variation with time of the wall density.
Wall Openings	In this country there is not standardization for any element: window, door, etc, so it is not possible to provide any number or size of openings.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	The most popular may be infill balconies.
Type of Foundation	Shallow Foundation: Reinforced concrete strip footing Shallow Foundation: Mat foundation
Additional comments on foundation	Probably the mat foundation is more typical as most of these buildings possess a basement.
Type of Floor System	Other floor system
Additional comments on floor system	Floor system(s): Structural concrete: cast in place solid slabs, post-tensioned slabs, precast solid slabs The floors and the roof are considered as rigid diaphragms for seismic analysis. With post-tensioned slab larger span between the central core walls (elevators and stairs) and some frames can be used.
Type of Roof System	Roof system, other
Additional comments on roof system	Roof system(s): Structural concrete: cast in place solid slab, precast solid slabs; Timber: wood planks or beams with ballast and concrete or plaster finishing, wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles, wood planks or beams supporting

Wall/Frame	Reinforced Concrete	Characteristic Strength- 1.5-4.0/25-35/1.5-2.0 st/f'c/shear strength Mix Proportion/Dimensions- 3:1:0.5
Foundations	Reinforced Concrete	Characteristic Strength: 1.4-2.2/25/1.5 st/f'c/shear strength Mix Proportion/Dimensions: 3:1:0.5
Floors	Reinforced Concrete	Cylinder compressive strength of concrete: 25-30 MPa
Roof	Reinforced Concrete	Cylinder compressive strength of concrete: 25-30 MPa
Other		

Design Process

Who is involved with the design process?	Engineer Architect
Roles of those involved in the design process	The landowner and a construction firm (developer) hire an architectural office and structural engineer to design the building. Modern equipment such as crane, premix concrete, industrial formwork etc. is used in the construction. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.
Expertise of those involved in the design process	The structural engineer typically has a background consisting of 6 years of academic studies and more than 3-5 years of experience. The construction engineer may have 6 years of studies and less experience than the structural engineer. The inspection during the construction is not mandatory and there is no peer review of the structural project. The designer may visit the construction site once or twice during the construction.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	It is built by developers or as initiative of a firm or a hotel.

Expertise of those involved in building process	
Construction process and phasing	This building is not typically constructed incrementally and is designed for its final constructed size.
Construction issues	The main problems are associated to the construction process: construction joints badly done or existence of honeycombs.

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Nch433.of96 Seismic Design Until 1993 the NCh433.of72 was in force. The last two numbers indicates the year since the code is in force. Provisional dispositions to design this type of buildings existed since 1966. The most recent code/standard addressing this construction type was issued 1996. Applicable national building code, material codes and seismic code/standards: Nch 433.of96 Seismic design of Buildings. The design of structural elements follows ACI 318-95, with some exceptions: reduced reinforcement cover, non-confinement at the wall ends, 16 Mpa minimum compressive strength.B.2.1 Appendix of the NCH433.0f96 Seismic Design of Buildings says: "The design of frames in buildings with "Frame with concrete shear walls-dual system", must follow at least ACI318-95 dispositions 21.8.4 and 21.8.5 when the 75% or more of the story shear in any direction of analysis is resisted by the shear walls and any frame individually resists less than 10% of the story shear. The same may apply when the seismic forces acting on the building are calculated with a reduced modification factor".B.2.2 says: "The shear wall design doesn't need to follow dispositions 21.6.6.1 to 21.6.6.4 of ACI318-95."
Process for building code enforcement	The building design must follow the NCh433.of96 code, although nobody checks this. In case of damage an arbitrage process may take place at the court of justice.

Building Permits and Development Control Rules

Are building permits required?	Yes
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Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes
Additional comments on building permits and development control rules	

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)Renter(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	For an standard building construction may be 15 - 30 UF/m ² (400 - 800 US/m ²). Selling price will be 40 - 50 UF/m ² (1,050 - 1,400 \$US/m ²). In the last years, "intelligent buildings" had been constructed that include air conditioning,computer, energy-savings devices, etc. For this case the construction cost may be up to 30-45 UF/m ² (800 - 1,225\$US/m ²). Selling price will be 50 - 70 UF/m ² (1,400 - 1,850 \$US/m ²).
Labor requirements	Nowadays this is quite rapid, probably one or two floors per month.
Additional comments section 3	

Socio-Economic Issues

Patterns of occupancy	These are mainly office buildings and therefore nobody resides in them with the exception of some administrative workers unless the building is used as a hotel.Each building typically has 21-50 housing
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	unit(s). One institution may own one or more floors.
Number of inhabitants in a typical building of this construction type during the day	>20
Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	During the day the building will have complete occupancy, however some buildings may also be occupied in the night (night shifts).
Economic level of inhabitants	High-income class (rich)
Additional comments on economic level of inhabitants	We are identifying the entrepreneurs or the owners of the offices, not the people working in these buildings. Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Owner financed Personal savings Commercial banks/mortgages Investment pools Other
Additional comments on financing	Other: Government owned offices.
Type of Ownership	Rent Own outright Own with debt (mortgage or other) Units owned individually (condominium) Owned by group or pool Long-term lease
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	Earthquake insurance are optional added to fire insurance. In case of damage, this insurance will cover repair work and contents.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on	

premium discounts

Additional comments
section 4

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1960	Valdivia, X Region
1985	Llolleo

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	<p>In the southern part of Chile, buildings of this type did not exist at the time of the 1960 earthquake, and the only reported example of damage is the hospital in Valdivia. In the 1985 earthquake, structural damage was not reported in buildings of this type with the exception of the San Antonio Hospital, located very close to epicenter. Out of plane tilting occurred in some non-structural masonry walls at the third floor level (Figure 9) and some columns, not properly confined, in the first floor were damaged at the top. (Figures 9,10 and 11). In fact there were two building blocks-one of them was 3-story high and one basement with no damage, whereas the other one was 4 story high with a flower stand on the top floor that was damaged. The other photo (Figure 12) represent a 4-story buildings at Valparaiso that had experienced some damage in interior panel and contents.</p>
Additional comments on earthquake damage patterns	<p>Overall damage patterns observed in past earthquakes for this type of construction, in its frame element, were a tilt out of plane of non-structural elements and short column failures.</p>

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is

FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than $\frac{1}{2}$ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than $\frac{1}{3}$ of the distance between the adjacent cross walls; For precast concrete wall structures: less than $\frac{3}{4}$ of the length of a perimeter wall.

Structural/Architectural Feature	Statement	Seismic Resistance
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.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	TRUE
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.	TRUE
Foundation Performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the	TRUE

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.	TRUE
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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	TRUE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	TRUE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	TRUE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building	TRUE

elements (concrete, steel, timber).

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Torsion eccentricity
Horizontal irregularities typically found in this construction type	Soft/weak story Change in vertical structure
Seismic deficiency in walls	None
Earthquake-resilient features in walls	The main characteristic of Chilean buildings is the high wall density ratio.
Seismic deficiency in frames	Non-structural elements not properly separated from the structures.
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Some damage has been reported in slab with openings, i.e. between stairs and elevators, when there are not lintels and the slab works as a coupling element if no special reinforcements have been provided.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

**High
vulnerability**

**Medium
vulnerability**

**Low
vulnerability**

A

B

C

D

E

F

Seismic vulnerability class

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o



San Antonio Hospital, March 3, 1985 Lolleo earthquake



San Antonio Hospital. First floor columns damaged in the 1985 Lolleo earthquake



San Antonio Hospital, close-up damaged in the 1985 Lolleo



Medicine School, University of Valparaiso, 1985 Lolleo earthquake, damage in interior panels and contents

earthquake

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Short column	To separate the non-structural elements from the column
Non-structural elements connections	To provide support against out of plane deformations

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	The hospital at San Antonio was repaired; however, the details are not available.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	This is not a common activity in Chile. The only situation when buildings are repaired is after an earthquake, when some constructive deficiencies appeared. It is normal to observe some small cracks in the concrete.
Was the construction inspected in the same manner as new construction?	
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	A contractor performed the construction, of course an architect and engineer were involved.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Since 2001, no subsequent earthquake has occurred in the central zone of Chile.
Additional comments	

References

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