World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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

HOUSING REPORT

Steel frame buildings with shear walls

Report#	3
Last Updated	
Country	Chile
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Reviewers	Ofelia Moroni,

Important

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General Information

Building Type:	Steel frame buildings with shear walls
Country:	Chile
Author(s):	Elias Arze L.
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in mainly large cities like Santiago, Concepcion, Valdivia, Temuco, Villarrica. Percentage of total area built is below 2 %. This type of housing construction is commonly found in urban areas.
Summary:	These buildings are modern steel composite structures ranging from 3 to 24 stories. The buildings have a rigid steel frame with floor diaphragms made of post-tensioned concrete slabs or composite steel decking, with or without a concrete slab covering. Additional lateral force-resisting elements are added to the steel moment-resisting frame to stiffen the structure and enhance the seismic performance. These elements are steel #X# or concentric braces and reinforced concrete shear walls. The seismic performance for these composite structures is very good. Most of these buildings are used as apartments or offices.
Length of time practiced:	76-100 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 50+ units
Typical number of stories:	3 to 5 and 6 to 24
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	This construction type has been used since 1965-70. Some buildings include commercial ground floor too.

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	
Typical plan length (meters)	10-20
Typical plan width (meters)	20-30
Typical story height (meters)	3
Type of Structural System	Steel: Moment Resisting Frame: With cast in-situ concrete walls
Additional comments on structural system	The vertical load-resisting system is steel braced frame. Steel deck slabs, prestressed concrete slabs, reinforced concrete slabs. Steel beams, normally composite. Steel columns and shear walls. The lateral load-resisting system is steel structural walls. Dual construction, shear walls combined with rigid steel frame. Up to 5 stories x or v or ^ braced shear walls. Over 5 stories - reinforced concrete slip or jump formed walls.
Gravity load-bearing & lateral load-resisting systems	Typical buildings have shear wall, light weight partitions and some concentric brace frames.
Typical wall densities in direction 1	1-2%
Typical wall densities in direction 2	1-2%
Additional comments on typical wall densities	
Wall Openings	20 to 30%
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	
Type of Foundation	Shallow Foundation: Reinforced concrete isolated footingShallow Foundation: Reinforced concrete strip footingShallow Foundation: Mat foundationDeep Foundation: Reinforced concrete

	bearing pilesDeep Foundation: Steel bearing pilesOther Foundation
Additional comments on foundation	It consists of reinforced concrete end-bearing piles and steel end-bearing piles. Reinforced concrete isolated footing. Reinforced concrete strip footing. Mat foundation. Reinforced concrete bearing piles. Steel bearing piles. Floating deep foundations.
Type of Floor System	Composite steel deck and concrete slabOther floor system
Additional comments on floor system	Other: Post-tensioned slabs, composite steel deck without concrete slab. Floors and roofs are considered as rigid diaphragms.
Type of Roof System	Composite steel roof deck and concrete slabRoof system, other
Additional comments on roof system	Other: composite steel deck without concrete slab. Floor and roof are considered as rigid diaphragm.
Additional comments section 2	Buildings are widely spaced, at a minimum of 10 meters.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Reinforced concrete rebars Structural steel frames	25-30 MPa 420-280 MPa steel: 250 MPa (36 ksi)
Foundations		
Floors	RC slabs Steel beams	25-30 MPa 250 MPa
Roof	RC slabs Steel beams	25-30 MPa 250 MPa
Other		

Design Process

Who is involved with the design process?	EngineerArchitectOther
Roles of those involved in the design process	Developer hires architects, engineers and construction firms. Architects and engineers must visit the job and provide general supervision. They usually must approve construction contracts.

Expertise of those involved in the design process	Architects have 5 university years and typically over 5 years of experience. Engineers have 6 university years and typically over 5 years of experience. Construction companies are headed by engineers or architects. Experience about 10 years. The same for fab shops. In steel frame buildings, review of design and independent inspection are typical.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	Developer hires architects, engineers and construction firms.
Expertise of those involved in building process	Construction companies are headed by engineers or architects. Experience about 10 years. The same for fab shops. In steel frame buildings, review of design and independent inspection are typical.
Construction process and phasing	Construction of this type typically takes place over time, buildings are originally designed for their final constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Chilean seismic codes NCh433.Of96 & NCh2369 are mandatory. AISC and ACI codes corrected to meet seismic codes are applied. Code/standard addressing this type of construction was first issued 1957. National building code, material codes and seismic codes/standards: NCh433.Of96, seismic design for buildings; NCh2369.Of01 seismic design of industrial buildings, NCh428.Of57code design for steel structures. Most recent code/standard addressing this construction type was issued: 1957, but now there is a draft to modify that code that partially follows AISC and AISI.
Process for building code enforcement	Design review by peers (may belong to design firm) is normal. Independent inspection is normal in steel framed buildings.

Building Permits and Development Control Rules

Are building permits	

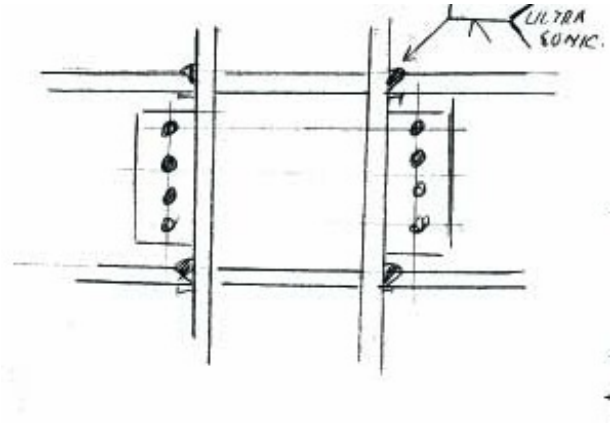
Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes
Additional comments on building permits and development control rules	

Building Maintenance and Condition

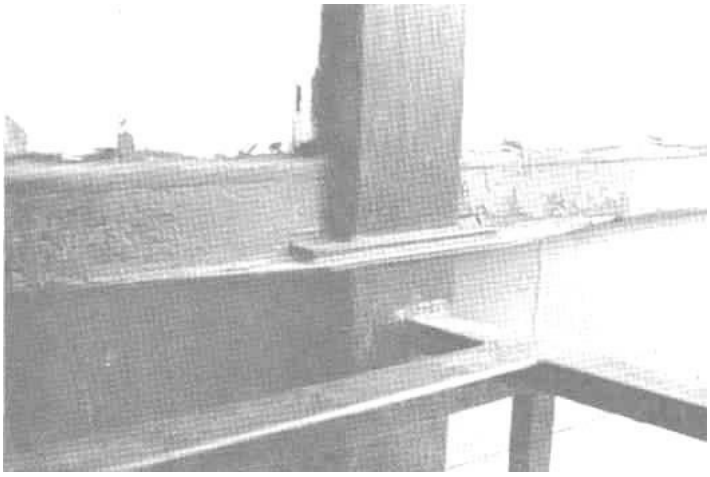
Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)Renter(s)
Additional comments on maintenance and building condition	

Construction Economics

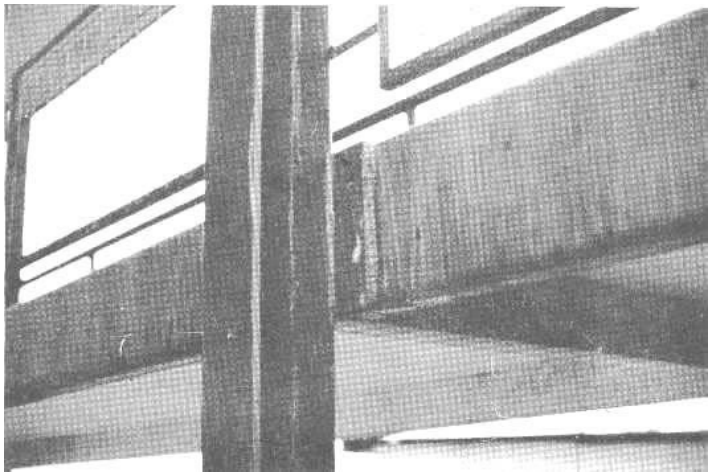
Unit construction cost	Low cost apartments, up to 5 floors, UF 10/sq m (US $300/sq m). Normal, up to 5 floors, UF 20/sq m (US $600/sq m). High-rise, 30/sq m (US$ 900/sq m).
Labor requirements	1.5 to 2.5 floors per month.
Additional comments section 3	



Critical structural details



Critical structural details: beam-column connection. THe beam stringer is welded to the column at the top, so that onsite welding is done outside high risk zones.



Critical structural details: connections

Socio-Economic Issues

Patterns of occupancy	One family per unit. Each building typically has 51-100 housing unit(s). For buildings up to 5 floors: 15 - 20 units. For those up to 20 floors: 150 - 200 units.
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	>20

Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income classHigh-income class (rich)
Additional comments on economic level of inhabitants	House Price/Annual Income ratio: Poor: 4.0 - 4.5, Middle Class: 2.5 - 3.0, Rich: 2.5 - 3.0 Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Owner financedPersonal savingsCommercial banks/mortgagesOther
Additional comments on financing	Ministry of Housing gives low interest loans for poor or low middle class owners.
Type of Ownership	RentOwn with debt (mortgage or other)Units owned individually (condominium)Owned by group or pool
Additional comments on ownership	Some buildings may belong to an institution
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	Repairs to same conditions before the earthquake. Occasionally, time lost.
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	It is on average. Up to 5 floors, 15-20 units. Up to 20 floors, 150-200

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1960	Valdivia
1985	Llolleo

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	There were many connections of the type that failed in Northridge, Loma Prieta and Kobe. No damage in any of them. Probable causes: # Chilean Building Code allows maximum drift about 1/2 of USA. # Periods are approximately 0.05N instead of 0.1N (N=floors) # No jumbo W sections are used # Beams and columns are welded to stress relieved plates. A good example of good behavior are the seven 4 story-buildings from Poblacion Republica Popular China, located in Vina del Mar. They are 46 X 10.6 m in plan, have moment resisting frames in both directions and 12 cm reinforced concrete slab. In the longitudinal direction the span is 4.6 cm. The buildings were designed according to NCh428.Of 57 with A42-27ES steel.
Additional comments on earthquake damage patterns	No damage in serious earthquakes in 1960 (M9.5) and in 1985 (M7.8)

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 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.

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 structure in an earthquake.	TRUE
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	TRUE

	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.	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 elements (concrete, steel, timber).	TRUE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	None

Earthquake-resilient features in walls	Regular buildings in plan and height good design and construction practice
Seismic deficiency in frames	None
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	None
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					|-	o

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening

Additional comments on seismic strengthening provisions	It has not been required in steel framed buildings
Has seismic strengthening described	

in the above table been performed?	
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
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?	
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	
Additional comments section 6	

References

Edificios de Acero J.Monge, S.Campino, and R.Sharpe a Chapter in "El Sismo de Marzo 1985, Chile", (Ed.) J.Monge 1985

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