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
Reinforced Clay/Concrete Block Masonry Building

Report #	5
Report Date	30-06-2002
Country	CHILE
Housing Type	Reinforced Masonry Building
Housing Sub-Type	Reinforced Masonry Building : Concrete block masonry in cement mortar
Author(s)	Ofelia Moroni, Cristian Gomez, Maximiliano Astroza
Reviewer(s)	Sergio Alcocer

Summary

This is a rather recent construction practice followed since 1970, and it has been widely used for dwellings and up to 4-story-high apartment buildings. Buildings of this type can be found both in urban and rural areas of Chile. The main load-bearing elements are masonry walls

reinforced with vertical steel reinforcement bars and placed in the hollow cores of clay masonry units (hollow clay tiles) or concrete blocks. Horizontal reinforcement bars are placed in horizontal bed joints. Masonry shear walls are tied together at floor levels by means of reinforced concrete beams in a regular structural layout. Stiffness distribution both in plan and elevation is uniform. Prior to 1986, there was no seismic design code for this structural type. During the March 3, 1985 Llolleo earthquake, performance of buildings of this type was rather poor, mainly due to construction problems, such as partial grouting in the hollow cores with reinforcement, poor quality of the mortar, and lack of horizontal reinforcement. Following the earthquake, the Chilean Design Code NCh1928 code was published based on the U.S. Uniform Building Code (UBC-1979) and on the seismic performance of this construction type reported in previous earthquakes. Since 1993, when the last version of NCh1928 was published, and more restricted requirements were enforced, the use of this type of construction has been less frequent, in part because of economic reasons.

1. General Information

Buildings of this construction type can be found in throughout Chile. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 25 years.

Currently, this type of construction is being built. Construction practice followed in the last 25 years. Due to economic reasons its use has declined in the last years.

Figure 1: Typical building

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. Buildings of this type are located close together, conforming what is called "conjuntos", "poblaciones" or "villas". They represent several buildings of the same type with some space left for garden or communities activities that most of the time nobody cares about them, ending filled with garbage or at the most as an earth soccer field When separated from adjacent buildings, the typical distance from a neighboring building is 5 meters.

2.2 Building Configuration

The typical shape of a building plan is rectangular. In each facade there may be 3 to 4 openings of 0.8 to 1.5 m width probably equally spaced.

2.3 Functional Planning

The main function of this building typology is multi-family housing. There are many single family houses and mixed use in this building type as well. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. If single-story building, there is an additional door besides the main entry. If more than one floor, there is not an additional exit stair besides the main stairs.

2.4 Modification to Building

Typical patterns of modification observed are infill balconies or hillocks on the top floor.

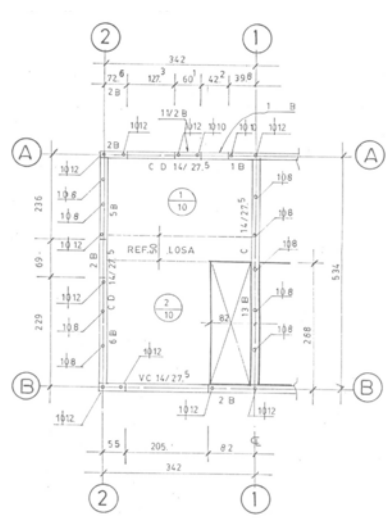

Figure 2: Plan of a typical building

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	☐
			Concrete blocks, tie columns	

		13	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)	☐

Walls are made of day or concrete block masonry, being most used the day hollow units.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is reinforced concrete structural walls (with frame). Shear walls in both directions. Reinforced concrete slab; thickness varies between 8 to 17 cm.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced masonry walls. The main load bearing elements are masonry walls reinforced with vertical steel reinforcement bars placed in the hollow cores of clay masonry units (hollow clay tiles) or concrete blocks. Horizontal reinforcement bars are placed in horizontal bed joints. Although the cores and voids containing reinforcement should be filled with grout, this is not always done. Most of the time cores and voids are filled only with the same mortar used in the horizontal joints. In addition, the size of the hollow in the ceramic unit is quite small so it is difficult to fill it. Concrete blocks, mostly used in the northern part of Chile, have larger hollow cores, however they are experiencing water leakage problems and since 1997 the use of these blocks has been banned in Central Chile. Masonry shear walls are tied together at floor levels by means of reinforced concrete beams, in a regular structural layout. In most cases, wall layout is symmetrical with regards to at least one axis. Stiffness distribution both in plan and elevation is uniform. The Chilean code for reinforced masonry building specifies the size and the minimum quantity of vertical and horizontal bars that must be used in a reinforced masonry walls. The sum of the areas of horizontal and vertical reinforcement shall be at least 0.0015 times the gross-sectional area of the wall and the minimum area of reinforcement in either direction shall not be less than 0.0006 times the gross cross-sectional area of the wall. The spacing of reinforcement shall not exceed 120 cm or 6 times the thickness of the wall. The diameter of the vertical reinforcement shall not be less than 8 mm and the horizontal bar shall not exceed 0.5 times the thickness of the horizontal mortar joint.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 6 and 12 meters, and widths between 10 and 20 meters. The building has 1 to 3 storey(s). The typical span of the roofing/flooring system is 6 meters. Corresponding area is 44 m^2. Typical span may be 5.0 - 6.0 m. The typical storey height in such buildings is 2.3 meters. The typical structural wall density is none. Total wall area/plan area (for each floor) 2.0 to 3.5 % in each direction.

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	☑	☑

In the analysis the floor is considered to be a rigid 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	☐

Usually the foundation does not have reinforcement, unless the soil is day or silt.

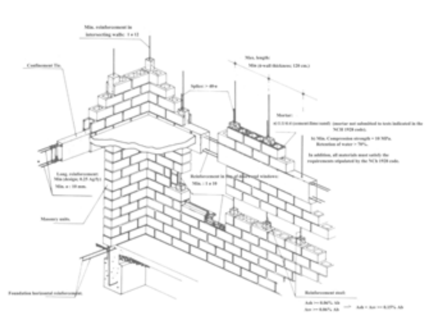

Figure 3: Key load-bearing elements

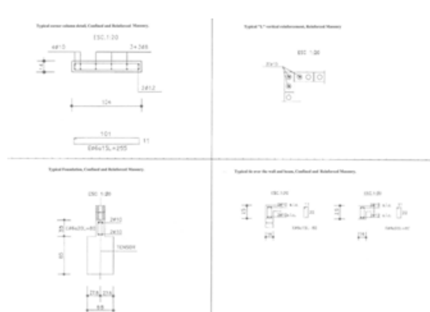

Figure 4A: Critical structural details: reinforced masonry wall and footings

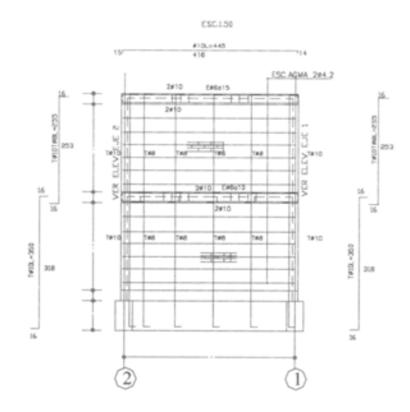

Figure 4B: Vertical elevation through a masonry wall

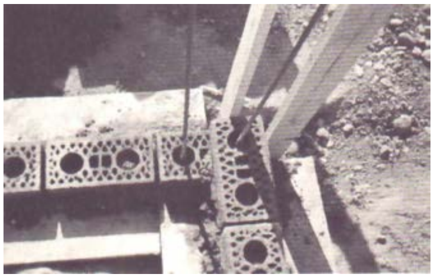

Figure 4C: Typical masonry units

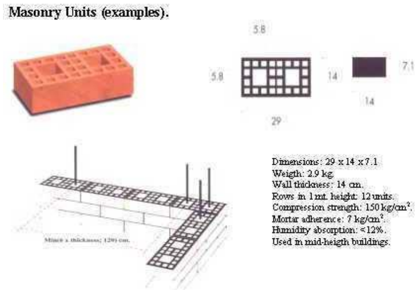

Figure 4D: Typical masonry units

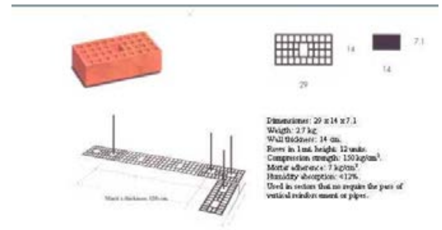

Figure 4E: Typical masonry units

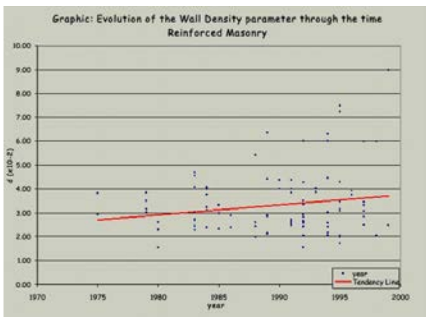

Figure 5: Key seismic features: high wall density

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 5-10 housing unit(s). 8 units in each building. Buildings may be from 1 to 4 floors. One-floor houses may be isolated or grouping up to 4 units. Two floor houses may be isolated or grouping up to 8 units. Up to 6 units per floor may exist in higher buildings. The number of inhabitants in a building during the day or business hours is 11-20. The number of inhabitants during the evening and night is more than 20. At present, the average size of a family is 5.5 persons, so if one unit is occupied by up to 3 families, the number of inhabitants in a building may be quite high.

4.2 Patterns of Occupancy

Typically one family occupies one housing unit. However, poor families may shelter 1 or 2 families more called "allegados".

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 prices are expressed in US$. The poorest quintile has an average annual income of US$ 2,010. They pay for a 45 m² dwelling that is subsidized by the State between US$ 5,445 to 10,885. The next quintile has an average annual income of US$ 4,020, but they live in the same dwellings of the poorest group. The third quintile has an average annual income of US$ 6,150, and they may choose larger or better quality housing. Common prices are between US$ 10,885 to 27,000. Subsides may be between 15 to 25% of the total cost. Economic Level: For Very Poor Class the

Housing Unit Price Unit is 10,000 and the Annual Income is 2,000. For Poor Class the Housing Price Unit is 10,000 and the Annual Income is 4,000. For Middle Class the Housing Unit Price is 20,000 and the Annual Income is 6,150.

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)	☑

Governmental subsidies. In each housing unit, there are 2 bathroom(s) without toilet(s), no toilet(s) only and 2 bathroom(s) including toilet(s).

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		
		True	False	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	Average story height is 2.3 m and the thickness brick most used is 14 cm, so the ratio height to thickness is less than 30.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Low shear strength, so it is difficult to get flexural ductile failure. It is difficult to achieve good anchoring and bonding conditions especially if poor quality masonry units and poor mortar instead of grout are used. Hollow sizes in clay units are inappropriate. Vertical reinforcements without grouting are ineffective. Lack of reinforced concrete horizontal tie-beams may cause out-of-plane bending effects. Lack of appropriate reinforcement at opening edges.	Relatively high wall density In general these buildings are quite stiff, they must resist a base shear of 10-22% depending on the seismic zone and the story drift must be equal or less than 0.002.	- Shear cracks in walls, spandrel part of the walls and window piers - Vertical cracks at the wall bottom due to compression failure - Horizontal cracks at the joints between masonry walls and reinforced concrete floors or foundation - Cracks in window piers and walls due to out-of-the-plane action.
Frame (columns, beams)			
Roof and floors			

Up to 1986 there was not any seismic design code for this structural type, so its behavior during March 3, 1985 earthquake was quite bad, mainly due to construction problems, partial grouting in the hollow with reinforcement, bad quality of the mortar and lack of horizontal reinforcement. After that, the NCh1928 code was published based on the UBC-1979 and the seismic behavior shown by those structures in previous earthquakes. Since 1993, when the last version of NCh1928.Of93 was published, and more restricted requirements were in force, the use of this type of construction has been less frequent, in part due to economic reasons.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), the lower bound (i.e., the worst possible) is C: MEDIUM VULNERABILITY (i.e., moderate 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
1985	Llolleo, V Region	7.8	VIII (MMI)
1997	Punitaqui, IV Region	6.8	VI-VII (MMI)

After the 1985 earthquake the Ministry of Housing appointed an especial committee to review the seismic effects on social dwellings. About 12,000 units were reinforced masonry type and 44% of them had some type of damage. A 100% of the 3 or more story buildings (2800 units) were severely damaged. The following characteristic damage patterns were observed: - shear cracks in walls, spandrel part of the walls and window piers, - vertical cracks at the wall bottom due to compression failure, - horizontal cracks at the joints between masonry walls and reinforced concrete floors or foundation, - cracks in window piers and walls due to out-of-the-plane action. Some damage occurred in houses located in Illapel during 1997 earthquake due to differential settlement in a slopped terrain.

Figure 6A: march 3, 1985 earthquake in Central Chile. Damage to masonry buildings in Santiago.

Figure 6B: Failure of masonry walls in March 3, 1985 Llolleo earthquake

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Clay bricks or concrete blocks	6-12 MPa or 3-10 MPa	14 x 29 or 19 x 39 x 19 / 14 x 39 x 9	Absorption: 10-20 % or 5-12 %
Foundation				
Frames (beams & columns)	Beams: Concrete H18, Steel A44-28H	18 MPa, 280 MPa		
Roof and floor(s)				

6.2 Builder

The state hired construction companies to build it.

6.3 Construction Process, Problems and Phasing

One contractor builds large quantities of this type of building, so project management and control techniques are used in order to increase productivity and to diminish cost. When constructing the vertical reinforcing bars are usually first placed into position before laying the masonry units. Then, the horizontal bars can be placed in horizontal mortar joints. Finally, vertical reinforcement is grouted as the work progresses. With respect to equipment the following is commonly used: concrete mix, trucks, traveling crane, winch, pneumatic cramp. 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 structural engineer will have 6 years of 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. There is not compulsory inspection during the construction and no peer revision of the structural project, but when inspection does exist larger masonry compression strength are allowed. The designer may visit the construction site once or twice during the construction. As it was explained in section "Construction Expertise" architects and engineers design and build these buildings.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. NCh1928.Of93 Albañilería Armada-Requisitos para el diseño y cálculo. The year the first code/standard addressing this type of construction issued was 1986, although provisionally dispositions to design this type of buildings existed since 1981. NCh433.Of96 Seismic Design of Buildings. The most recent code/standard addressing this construction type issued was 1993, however at present time it is in a revision process. NCh1928.Of93 Albañilería Armada-Requisitos para el diseño y cálculo Year the first code/standard addressing this type of construction issued: 1986, although provisionally dispositions to design this type of buildings existed since 1981. National building code, material codes and seismic codes/standards: NCh433.Of96 Seismic Design of Buildings When was the most recent code/standard addressing this construction type issued? 1993, however at present time it is in a revision process.

The building design must follow the NCh433.of96 code and NCh1928.of93. SERVIU a governmental office in charge of social dwellings has a professional staff to review the projects and to inspect during construction. In case of damage an arbitrage process may take place at the court of justice.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and not 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), Tenant(s) , No one and others.

6.8 Construction Economics

According to Bravo and Martínez (1993) the total cost of this type of building can be blotted out in site 15%, construction cost 40%, urbanization 17%, operating cost 13% and profit 15%. The cost of one unit is 200 to 400 UF (area 45 m²), $78,000 to $140,000 /m² (US$ 135 - US$ 245 /m²). Better quality unit may cost up to $174,000 /m² (US$ 300/ m²). At present, depending on technology used, the construction may take 2-3 stories per month of several units simultaneously built.

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. Earthquake insurance is available as supplement of other insurance (fire, robbery) and people living in these buildings do not have money to pay for that. Repairs to same condition as before the earthquake.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Lack of appropriate reinforcement	Addition of new tie-columns

The strengthening procedure consist in confining the masonry wall with reinforced concrete tie-column and tie-beam. This may cost up to 20% of the original cost. With this procedure ductility is also improved. When only some bricks have been damaged, they have been replaced; the same occurs when cracks appeared in the mortar joints.

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?

If new constructions follow the design code, none strengthening scheme is needed.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
As it was pointed out in Section 6, after the 1985 earthquake a committee chaired by Rodrigo Flores was appointed by the Ministry of Housing in order to review the damaged buildings, to prepare restoration projects and supervise its execution.

8.3 Construction and Performance of Seismic Strengthening

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

Yes.

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

Contractors hired by the government. Engineers were involved.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
As of 2001, there was no opportunity to observe the performance of the retrofitted buildings as Central Chile did not experience any earthquakes since 1985.

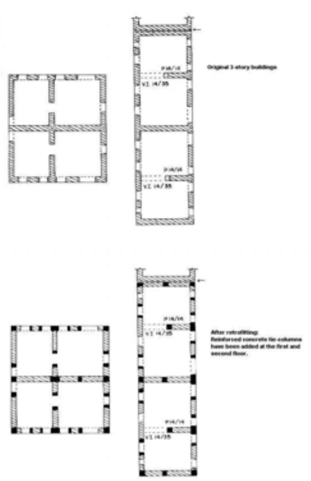
Figure 7A: Illustration of seismic strengthening techniques

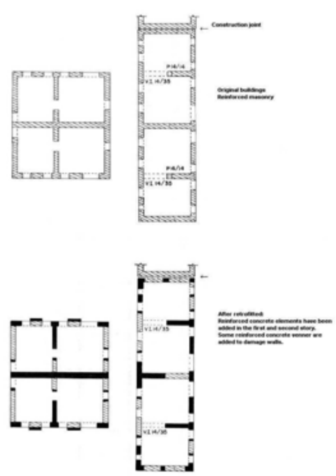
Figure 7B: Illustration of seismic strengthening techniques

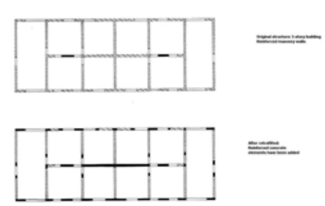
Figure 7C: Illustration of seismic strengthening techniques

Reference(s)

1. Construcciones de Alba

M. Astroza and F. Delf
Cap 5 del libro "El sismo de Marzo de 1985, Chile," (Ed) J. Monge 1985

2. Chile, 50 a
   L. Bravo and C. Martinez
   Universidad de Valpara 1993

3. Caracter
   J. Giadalah
   Civil Engineer Thesis, Universidad de Chile 2000

4. Edificios de Alba
   P. Hidalgo
   (Ed.) Por R. Flores, Editorial Hachette 1993

5. Construcci
   ICH
   Serie Cartilla de Recomendaciones B 1987

6. Apuntes de Curso: CI 52-H. Dise
   M. Astroza
   Divisi 2000

Author(s)

1. Ofelia Moroni
   Civil Engineer/Assistant Professor, University of Chile
   Casilla 228/3, Santiago , CHILE
   Email:mmoroni@cec.uchile.cl FAX: 562-6892833

2. Cristian Gomez
   Civil Engineer/Research Assistant, University of Chile
   Casilla 228/3, Santiago 228/3, CHILE
   Email:crgomez@cec.uchile.cl FAX: 562-6892833

3. Maximiliano Astroza
   Civil Engineer/ Associate Professor, University of Chile
   Casilla 228/3, Santiago , CHILE
   Email:mastroza@cec.uchile.cl FAX: 562-6892833

Reviewer(s)

1. Sergio Alcocer
   Director of Research
   Circuito Escolar Cuidad Universitaria, Institute of Engineering, UNAM
   Mexico DF 4510, MEXICO
   Email:salcocerm@iingen.unam.mx FAX: +52 (55) 56162894