World Housing Encyclopedia

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

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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Confined block masonry building

Report #	7
Report Date	05-06-2002
Country	CHILE
Housing Type	Confined Masonry Building
Housing Sub-Type	Confined Masonry Building with Concrete blocks, tie-columns and beams
Author(s)	Ofelia Moroni, Cristian Gomez, Maximiliano Astroza
Reviewer(s)	Sergio Alcocer

Summary

This construction practice started during the 1940s after the 1939 earthquake that struck the mid-southern region of Chile. It is mainly used for dwellings and apartment buildings up to four stories high. Buildings of this type are found in all regions of Chile. This is a confined masonry construction, consisting of load-bearing unreinforced masonry walls (commonly made of clay units or concrete blocks) confined with cast-in-place reinforced-concrete, vertical tie-

columns. these tie-columns are built at regular intervals and are connected with reinforced concrete tie- beams cast after the masonry walls have been constructed. Tie-columns and tie-beams prevent damage due to out-of-plane bending effects and improve wall ductility. Floor systems generally consist of cast-in-place reinforced slabs with a thickness between 100 to 120 mm. Confined masonry walls have limited shear strength and ductility compared to reinforced concrete walls. Nevertheless, typical buildings of this type have good earthquake resistance, because they have high wall densities and because wall layouts are symmetric and regular, both in plan and elevation. Their seismic behavior has been satisfactory, particularly in one- or two-story-high buildings during strong earthquakes [Monge, 1969].

1. General Information

Buildings of this construction type can be found in This housing type is used all over 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 100 years.

Currently, this type of construction is being built. Most of the data in this form refers to 3-4 story buildings for low income people, but this housing type is also used in fancy houses due to its reasonable cost and good isolation characteristics.

Figure 1A: Typical building

Figure 1B: 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. The typical separation distance between buildings is 10 meters 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 free space left for garden or communities activities that most of the time nobody cares about them, ending filled with garbage or at most, as an earth soccer field When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

The typical shape of a building plan is rectangular. In social buildings, in each longitudinal, there may be 3 to 4 openings of 0.8 to 1.5 m wide, probably equally spaced. In the transverse direction there may be one or two openings in each facade and a solid median wall.

2.3 Functional Planning

The main function of this building typology is multi-family housing. 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 no additional exit stair besides the main stairs.

2.4 Modification to Building

Typical modification patterns observed are infill balconies.

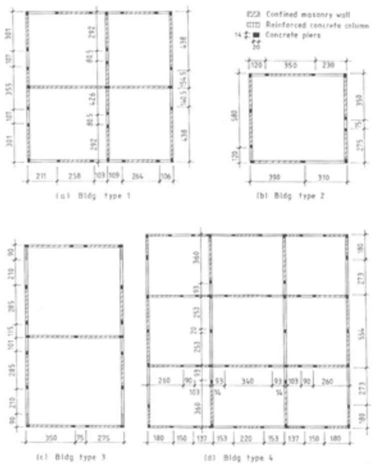

Figure 2A: Plan of a typical building

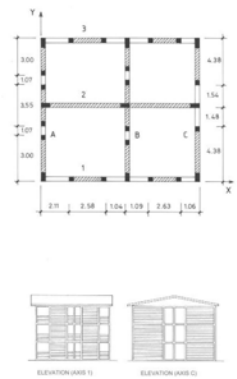

Figure 2B: Plan of a typical building

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	☐
		13	Concrete blocks, tie columns and beams	☑
		14	Stone masonry in cement mortar	☐
			Clay brick masonry in cement	

	Reinforced masonry	15	mortar	☐
		16	Concrete block masonry in cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is reinforced concrete structural walls (with frame). Shear walls in both directions.Reinforced concrete slab.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is confined masonry wall system. This is a confined masonry construction, consisting of load-bearing unreinforced masonry walls (commonly made of day units or concrete blocks) confined with cast-in-place reinforced- concrete vertical tie-columns. These tie-columns are built at regular intervals and are connected with reinforced concrete tie-beams cast after the construction of masonry walls. Tie-columns and tie- beams prevent damage due to out-of-plane bending effects and improve wall ductility. Tie- columns have a rectangular section whose dimensions typically correspond to the wall thickness (150 to 200 mm) and a depth equal to 200 mm. Both tie-columns and tie-beams have minimum four 10 mm diameter longitudinal reinforcement bars and 6 mm diameter stirrups spaced at 100 to 200 mm on centre. The tie-columns have the longitudinal reinforcement necessary to resist overturning moments. Tie-columns and tie-beams prevent damage due to out-of-plane bending effects and improve wall ductility. When any dimension in the building pl an is longer than 20 m, reinforced concrete walls at least 1 m long must be located at each end to avoid cracking in walls due to shrinkage of reinforced concrete elements as slabs and beams. Floor systems generally consist of cast-in-place reinforced slabs with a thickness between 100 to 120 mm. Allowable stress method (working stress design) is used for design according to NCh2123.Of97.

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 is 4 storey high. The typical span of the roofing/flooring system is 6 meters. Typical Plan Dimension: It is average. Corresponding area is 43 m² Plan dimensions ranges : length from 6 m to 12 m, width from 10 m to 20 m. Typical Span: Range of typical span is 5 - 6 meters. 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. The evolution with time is shown in figure 5. However, the wall density per unit weight per floor is a better indicator of the expected seismic behavior for this type of building. To guarantee that the displacement capacity be greater than the displacement demand the wall density per unit weight per floor must be around 0.012 m²/ton. On the other hand, observed structural performance in past earthquakes suggests a wall density per unit weight per floor greater than 0.013 m²/ton in order to ensure the occurrence of only moderate damage (Moroni et al, 2000).

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.

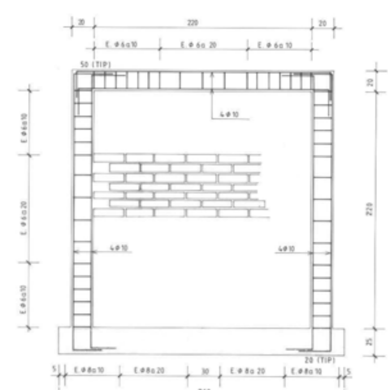

Figure 3: Key load-bearing elements

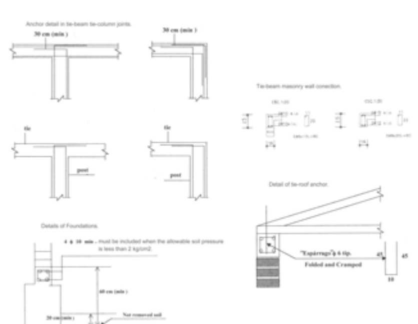

Figure 4: Critical structural details: wall section, foundations, roof-wall connections

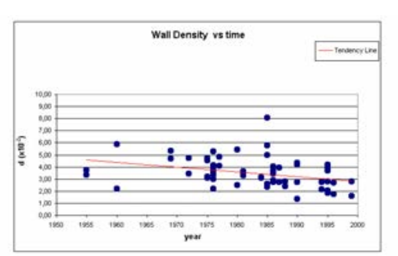

Figure 5: Key seismic feature: large wall density. (The chart illustrates the variation of wall density over time related to this construction type.)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 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 taller buildings. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5. 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 US$ 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 US$27,000. Subsides may be between 15 to 25% of the total cost.

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 the following typical funding modes are presented: # House type 1: Total cost: 320 UF, $ 5,000,000 (US$ 8,700) saving: 13 UF, $ 203,000 (US$ 355) subside: 140 UF, $ 2,200,000 (US$ 3,810) mortgage: 167 UF, $ 2,613,000 (US$ 4,545) monthly payment: 1.67UF (12 years), $26,000 (US$45,5) # House type 2: Total cost: 400 UF, $6,260,000 (US$ 10,885) saving: 20 UF, $ 313,000 (US$ 545) subside: 140 UF, $ 2,200,000 (US$ 3,810) mortgage: 100 UF, $ 1,565,000 (US$ 2,720) monthly payment: 1.18 UF (20 years), $18,500 (US$ 32) # House type 3: Total cost: 650 UF, $10,172,500 (US$ 17,690) saving: 50 UF, $ 782,500 (US$ 1,360) subside: 120 UF, $ 1,878,000 (US$ 3,265) mortgage: 480 UF, $ 7,512,000 (US$ 13,065) monthly payment: 4.8 UF (20 years), $75,100 (US$ 130) These calculations were done in April 2001 and considered $580 = US$1.0. By October 31, 2001 $720 = US$1.0. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and no 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	Usually the roof is made of wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Limited shear strength, so it is difficult to attain a flexural ductile failure. Limited ductility. Lack of tie-columns at all opening sides diminishes shear strength and the post-shear cracking displacement capacity. Excessive spacing between tie-columns or lack of tie-beams may cause out-of-plane damages. Shear cracks propagate through the tie-columns reducing stiffness and strength capacity; to prevent these effects closer stirrups should be used at column ends.	High wall density, confinement of the masonry, closer stirrups at the tie-column and tie-beams ends. This type of buildings has proved to have a good earthquake resistance since 1939 Chilean earthquake.	In-plane shear failure, out of plane bending failure, lack of bond between masonry and concrete elements, damage in column-beam joints, damage in the connection of perpendicular walls.
Frame (columns, beams)			
Roof and floors			

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 D: MEDIUM-LOW VULNERABILITY (i.e., 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
1939	Chillán, VIII Region	7.8	X (MMI)
1965	La Ligua, V Region	7.5	VIII-IX (MMI)
1985	Llolleo, V Region	7.8	VIII (MMI)

According to Del Canto (1940) in Chillán collapsed or partially collapsed 26 (16%) confined masonry houses. About 21,000 masonry houses collapsed and 71,000 had to be repaired after 1965 earthquake. This was an unexpected behavior for confined masonry buildings; although most of them did not have tie-columns. The results were especially bad in houses made of hollow concrete blocks, which were very rigid and the earthquake had a very important high frequency content. Typical patterns of damage were: in-plane shear failure, out-of-plane bending failure, lack of bond between masonry and concrete elements, damage in column-beam joints and separation between walls. (Monge, 1985). After the 1985 earthquake, the Ministry of Housing appointed an especial committee to review the seismic effects on social dwellings, (Flores, 1993). About 84,000 units, mostly located in Santiago, were reviewed, concluding that 50% of the units had some structural damage. Confined masonry buildings represent 16% of the total and 74% of them were lightly damaged, but non-collapsed occurred. In most of the damaged buildings tie-columns were missing at one end of the walls or at the opening extremes. The following characteristic damage patterns were observed: # shear cracks in walls that propagate into the tie-columns. Most of them passed through mortar joints, the initiation of crushing of masonry units has been observed in the middle, most stressed part of the walls. # horizontal cracks at the joints between masonry walls and reinforced concrete floors or foundation # cracks in window piers and cracks in walls due to out-of-the-plane action when they are not properly confined, or the separation between tie-columns is too large. # crushing of concrete at the joints between vertical tie-columns and horizontal bond-beams when their reinforcement was not properly connected. # inadequate quality of material and construction.

Figure 6: Typical earthquake damage: cracking of

concrete posts (1985 Liolleo earthquake)

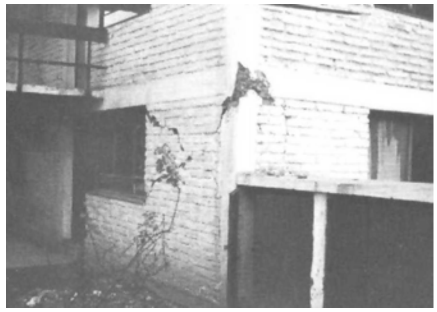

Figure 6B: Typical earthquake damage: cracking of concrete posts and masonry walls (1985 Llolleo earthquake)

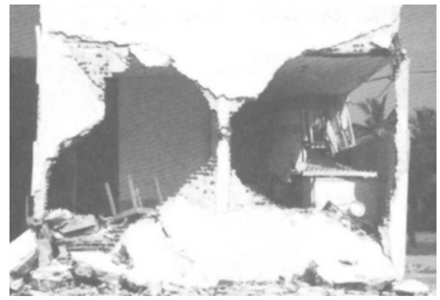

Figure 6C: Typical earthquake damage: collapse of a confined wall (1985 Llolleo earthquake)

Figure 6D: Typical earthquake damage: cracking of masonry walls (1985 Llolleo earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Artisan brick Clay hollow brick concrete block mortar.	2-8 MPa 6-12 MPa 3-10 MPa 10 MPa.	20 X 30 cm 14 X 29 cm 39 X 19 cm 1:1/4/4 (mix)	absorption: 15-40% 10-20% 5-12%masonry shear strength= 0.5 to 1.0 MPa
Foundation				
Frames (beams & columns)	Concrete H-18 Steel A44-28H	18 - 20 MPa 280 MPa		
Roof and floor(s)				

6.2 Builder

No information is available .

6.3 Construction Process, Problems and Phasing

One contractor builds large quantities of this type of buildings, so project management and control techniques are used in order to increase productivity and to diminish cost. With respect to equipment the following is commonly used: concrete mix, trucks, traveling crane, winch. Tie-columns are cast against serrated endings of the masonry walls already built. After that tie- beams, lintels and slab are built simultaneously. 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.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. NCh2123.Of97 Albañilería Confinada-requisitos para el diseño y cálculo. Until 1993, the NCh433.of72 and "Ordenanza General de Construcciones y Urbanización" were in force. The latter since 1949 regulated the construction of 1 or 2 story confined masonry houses, limiting the maximum spacing between tie-columns and tie-beams. 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. The NCh2123 code specifies the allowable shear capacity of a confined masonry wall based on the masonry shear stress and the vertical load applied on it; the size and the minimum quantity of longitudinal reinforcement and amount and spacing of stirrups that must be used in confinement elements; limits wall thickness, tie-column spacing, requires confinement in opening, among others dispositions. The year the first code/standard addressing this type of construction issued was 1949. NCh433.Of96, Diseño sísmico de Edificios. The most recent code/standard addressing this construction type issued was 1997. Title of the code or standard: NCh2123.Of97 Albañilería Confinada-requisitos para el diseño y cálculo. Until 1993, the NCh433.of72 and "Ordenanza General de Construcciones y Urbanización" were in force. The latter since 1949 regulated the construction of 1 or 2 story confined masonry houses, limiting the maximum spacing between tie-columns and tie-beams. 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. The NCh2123 code specifies the allowable shear capacity of a confined masonry wall based on the masonry shear stress and the vertical load applied on it; the size and the minimum quantity of longitudinal reinforcement and amount and spacing of stirrups that must be used in confinement elements; limits wall thickness, tie-column spacing, requires confinement in opening, among others dispositions. Year the first code/standard addressing this type of construction issued: 1949 National building code, material codes and seismic codes/standards: NCh433.Of96, Diseño sísmico de Edificios When was the most recent code/standard addressing this construction type issued? 1997.

The building design must follow the NCh433.of96 code and NCh2123.of97. 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 a panel of experts process may take place at the court of justice.

6.6 Building Permits and Development Control Rules

This type of construction is a non-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

5-12 UF/m² (135-300 US$/m²). At present, depending on technology used, the construction of several units, simultaneously built, may take 2-3 stories per month.

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, although mortgage payment includes this type of insurance. Repair cost.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Partially confinement	New tie-columns are built

Most of the damage that have occurred in confined masonry buildings was due to lack of confinement in some edge or opening, so the strengthening procedure has consisted on completing the confinement of the masonry wall with reinforced concrete tie-column. If the wall was extensively damaged a new wall has been constructed or coated with shotcrete over a wire mesh anchored to the masonry. With this procedure ductility is also improved. When only some bricks have been damaged, they have been replaced; the same occurred when cracks appeared in the mortar joints. This may cost up to 7-8 % of the original cost.

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?
As it was pointed out in 6.1, after the 1985 earthquake a committee was appointed by the Ministry of Housing, in order to review the damaged buildings, to prepare restoration projects and supervise its execution. Most of the strengthening consisted on tie-columns additions and repair of cracks in masonry walls.

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

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?
A contractor, an engineer was involved.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
There has not been any earthquake in Central Chile since 1985. Page 18.

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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