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

Confined masonry building

Report#	50
Last Updated	
Country	Peru
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Reviewers	Sergio Alcocer,

Important

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General Information

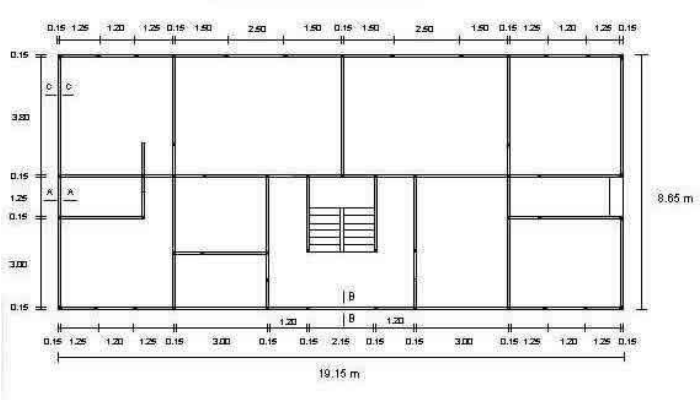
Building Type:	Confined masonry building
Country:	Peru
Author(s):	Cesar Loaiza Marcial Blondet
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in all parts of Peru, particularly in the coastal region. This type of housing construction is commonly found in urban areas.
Summary:	This multifamily housing construction type has been the most commonly used in the urban areas of Peru during the last 35 years. Confined masonry buildings consist of load-bearing unreinforced clay masonry walls confined by cast-in-place reinforced concrete tie columns and beams. Tie columns are cast after the construction of the masonry walls is complete and theyare connected to the tie beams. Confined masonry walls have limited shear strength and ductility; however, buildings of this type typically have a good seismic resistance.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Mixed residential/commercial
Typical number of stories:	4-6
Terrain-Flat:	Typically
Terrain-Sloped:	3
Comments:	Average 6 units in each building; usually there are from 4 to 8 units in each building.

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	

Typical plan length (meters)	20
Typical plan width (meters)	12
Typical story height (meters)	2.7
Type of Structural System	Masonry: Confined Masonry: Concrete blocks, tie columns and beams
Additional comments on structural system	Lateral-load resisting system: The lateral load-resisting system is confined masonry wall system. Confined masonry walls give stiffness to the structure and control lateral drift. Tie columns and post beams prevent damage due to out-of-plane bending effects and improve wall ductility. Tie columns have the longitudinal reinforcement necessary to resist overturning moments. In some cases, reinforced concrete walls are required to avoid cracking of reinforced concrete elements. Gravity load-bearing system: Generally, the same system as described above. Floor and roof structures are composite structures, made of masonry units and concrete joists that transfer the gravity loads to the walls.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	4-5%
Typical wall densities in direction 2	4-5%
Additional comments on typical wall densities	The typical structural wall density is up to 5 %. Total wall area/plan area (for each floor) is 3-5%.
Wall Openings	A typical building has 3 to 4 windows (typically 1 to 2 m wide) in each in the longitudinal direction. In the transverse direction there may be one or two openings per facade.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	In some cases owners build additional interior walls as a part of the building extension (new rooms or bathrooms).
Type of Foundation	Shallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	Usually the foundation is of plain (unreinforced) concrete unless the soil is clay or silt
Type of Floor System	Other floor system
Additional comments on floor system	Composite masonry and concrete joist; in the analysis, the floors are considered to be rigid diaphragms.
Type of Roof System	Roof system, other
Additional comments on roof	

Additional comments on roof system	Composite masonry and concrete joist.
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 0.5-1.0 meters. Average plan area is 260 m.sq. Length varies from 15 to 30 m, and the width varies from 5 to 15 m. Story height varies from 2.5 meters to 2.8 meters.



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Clay masonry	Characteristic Strength: Compression strength: 12 -16 MPa Shear strength: 0.5 - 0.8 MPa Compression strength depends on the quality of bricks. Mix proportions/dimensions: 1:4 / 90 mm X 12 mm X 24 mm
Foundations	Concrete	Characteristic Strength: Compression strength: 14 - 18 MPa
Floors	Concrete Steel	Characteristic Strength: Compression strength: 21- 35 MPa Steel yield stress: 410 MPa
Roof	Concrete Steel	Characteristic Strength: Compression strength: 21- 35 MPa Steel yield stress: 410 MPa

Other	Concrete Steel	Characteristic Strength: Compression strength: 21-35 MPa Steel yield stress: 410 MPa

Design Process

Who is involved with the design process?	EngineerArchitect
Roles of those involved in the design process	Engineers are in charge of the structural design and construction process. Architects are in charge of the architectural design and in some cases in charge of the construction process.
Expertise of those involved in the design process	Both the structural and the construction engineer should have 5 years of study and minimum work experience of 2 years.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	Construction companies build the buildings of this type and sell them.
Expertise of those involved in building process	Both the structural and the construction engineer should have 5 years of study and minimum work experience of 2 years. Commonly, the construction process is inspected. The designer may visit the construction process once or twice during the construction.
Construction process and phasing	Masonry walls are built with serrated endings, then tie columns are cast against them. After that tie beams, lintels and floors are built simultaneously. The equipment commonly used is: concrete mixer, traveling crane, winch, trucks. Typically not built incrementally, buildings originally designed for final constructed size.
Construction issues	-Walls or opening end zones without confinement; -Poor quality of mortar; -Deficient construction joints; -Inadequate reinforcement detailing at the tie-column-to-tie beam joints.

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Seismic Design Standards E-030 (1977) National Construction Standards, Masonry Standards E-070 (1998) The most recent code/standard addressing this construction type issued was 1998.

Process for building code enforcement	Municipal authorities approve the structural and architectural design for the building. It is common that the owner hires a private inspector to supervise the construction process.

Building Permits and Development Control Rules

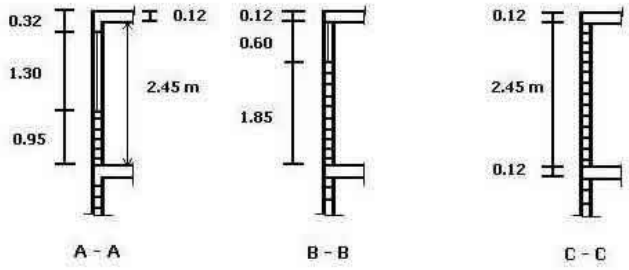
Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes
Additional comments on building permits and development control rules	

Building Maintenance and Condition

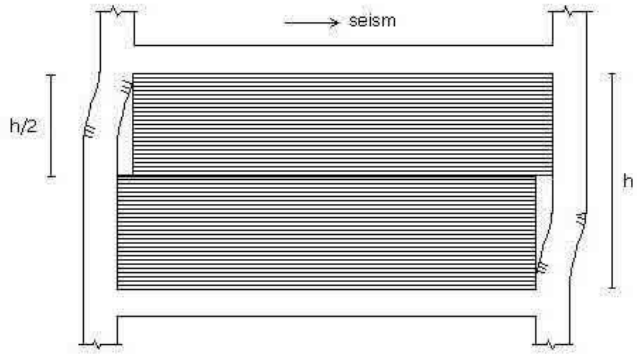
Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	BuilderOwner(s)Renter(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	Unit construction cost may vary from 200 to 300 US$/sq m.
Labor requirements	Depending on the technology used, the construction of a typical building may take 2-3 stories per month.
Additional comments section 3	



Critical Structural Details - Wall Sections



An Illustration of Key Seismic Deficiencies

Socio-Economic Issues

Patterns of occupancy	Typically, one family occupies one housing unit. However, in low social classes, two or three families share one housing unit. Each building typically has 6 housing unit(s). Usually there are from 4 to 8 units in each building.
Number of inhabitants in a typical building of this construction type during the day	5-10
Number of inhabitants in a typical building of this construction type during the evening/night	10-20
Additional comments on number of inhabitants	Inhabitants during the day range from 5-10 to 10-20; inhabitants during the night range from 10-20 to more than 20.
Economic level of inhabitants	Low-income class (poor)Middle-income classHigh-income class (rich)
Additional comments on economic level of inhabitants	Ratio of housing unit price to annual income: 4:1 Economic Level: For Poor Class the Housing Unit Price is 15,000 and the Annual Income is 3,500. For Middle Class the Housing Unit Price is 40,000 and the Annual Income is 12,000. For Rich Class the Housing Unit Price is 100,000 and the Annual Income is 50,000.
Typical Source of Financing	Owner financedPersonal savingsSmall lending institutions/microfinance institutionsCommercial banks/mortgagesGovernment-owned housing
Additional comments on financing	
Type of Ownership	RentOwn outrightOwn with debt (mortgage or other)

Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	Despite earthquake insurance being available, people living in these buildings do not have enough money to pay it. Insurance covers all costs of damages or the construction of a new building.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Yes
Additional comments on premium discounts	
Additional comments section 4	Despite earthquake insurance availability, people living in these buildings do not have enough money to pay for it.

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1970	Chimbote
1974	Lima
1996	Nazca

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Wall shear cracking that propagates through tie columns.
Additional comments on earthquake damage patterns	

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.	N/A
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	TRUE

	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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled 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.	N/A
Wall Openings		TRUE
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).	FALSE

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	Limited ductility and the absence of tie columns diminishes shear strength.
Earthquake-resilient features in walls	Good transfer of seismic forces
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	
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	-|	

A Photograph Illustrating Typical Earthquake Damage

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Columns	Installation of additional shear reinforcement in tie columns (Figure 7)
Parapets and nonstructural walls (new construction)	Parapets are confined with tie-columns and bond-beams. When parapets are located between tie-columns, walls are isolated through construction joints.

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Yes, parapets are confined and non structural walls are isolated from the structure.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	The seismic strengthening was done in a new construction.
Was the construction inspected in the same manner as new construction?	N/A
Who performed the construction: a contractor or	

construction: a contractor or owner/user? Was an architect or engineer involved?	Usually engineers are involved.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Good seismic performance: parapets resist overturning forces and cracking effects were reduced in non structural walls..
Additional comments section 6	

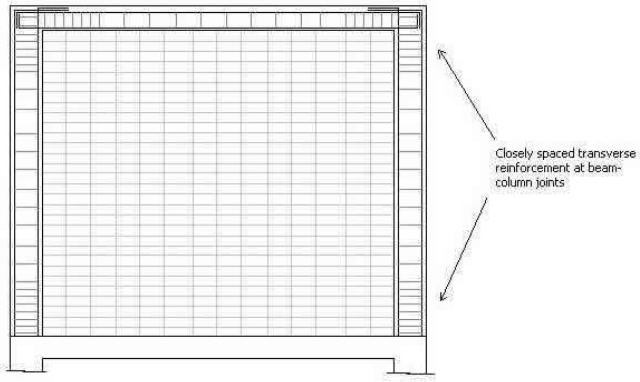


Illustration of Seismic Strengthening Techniques

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