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 house

Report#	51
Last Updated	
Country	Peru
Author(s)	Cesar Loaiza, Marcial Blondet, Papa Simona,
Reviewers	Sergio Alcocer,

Important

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John A, Martin & Associates, Inc. or the

participant’s organizations.

General Information

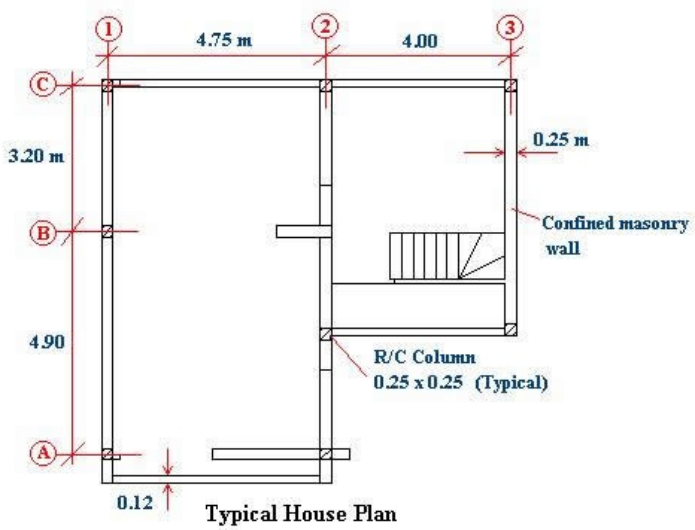
Building Type:	Confined masonry house
Country:	Peru
Author(s):	Cesar Loaiza Marcial Blondet Papa Simona
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in all parts of Peru, particularly in the coastal region. This type of housing construction is commonly found in both rural and urban areas.
Summary:	This is the most common single-family housing construction practice followed both in urban and rural areas of Peru in the last 45 years. Confined masonry buildings consist of loadbearing unreinforced masonry walls made of clay brick units, confined by cast-in-place reinforced concrete tie columns and beams. These buildings do not have a complete load path in both horizontal directions required for adequate lateral load resistance. However, in spite of that typical houses may show a good seismic performance.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	2-3
Terrain-Flat:	Typically
Terrain-Sloped:	3
Comments:	Total number of housing units depends on the number of building sections. Typically, for the three-section building, the number

Features

Plan Shape	Rectangular, solidL-shape

Additional comments on plan shape	Rectangular shape or L-shape.
Typical plan length (meters)	10-15
Typical plan width (meters)	5-10
Typical story height (meters)	2.6 - 2.8
Type of Structural System	Masonry: Confined Masonry: Clay brick masonry with concrete posts/tie columns and beams
Additional comments on structural system	The lateral load-resisting system is confined masonry wall system. Masonry shear walls give stiffness to the structure and control lateral drifts. Tie columns and bond beams provide adequate confinement and ductility to the masonry walls. Typical houses have a good wall density in one horizontal direction, but a lower wall density in the other. This makes the house particularly vulnerable in the horizontal direction where the density is lowest. Tie columns have enough longitudinal reinforcement to resist overturning moments. Closely spaced transverse reinforcement at beam-column joints provides adequate ductility to resist seismic forces. Floors/roofs can consider to be rigid diaphragms in the analysis. Typical wall thickness is 150 mm or 250 mm. In general, the same system as describe above. Floors/roofs transmits gravity loads to the structural walls.
Gravity load-bearing & lateral load-resisting systems	In some cases, rubble stone and massive stone walls have been used.
Typical wall densities in direction 1	1-2%
Typical wall densities in direction 2	4-5%
Additional comments on typical wall densities	Typical wall densities for each horizontal direction are 2% and 7%, respectively.
Wall Openings	A typical house has 6 to 10 windows per floor, with a total average size of 3.0 sq m. The position of these openings is variable, but usually is approximately 0.8 to 1.0 m from the floor level in rooms and from 1.8 to 2.0 m in bathrooms.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Commonly, owners build interior walls or additional floors for new rooms.
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone isolated footing
Additional comments on	In buildings close to rivers, fieldstone strip footing can be

foundation	found.
Type of Floor System	Other floor system
Additional comments on floor system	
Type of Roof System	Roof system, other
Additional comments on roof system	
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 0.01 meters.



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Brick masonry	Compressive strength (masonry prisms)=13-16 MN/sq m Shear strength= 0.6 - 0.8 MN/sq m 1:4 / 90mm x 120mm x 240mm Compressive strengths depend on the quality of brick units.
Foundations	Concrete	Compression strength 10-14 MN/sq m
Floors	Concrete	Compression strength: 21- 35

		MN/sq m Steel yield strength: 410 MN/sq m 1:2:3
Roof	Concrete	Compression strength: 21- 35 MN/sq m Steel yield strength: 410 MN/sq m 1:2:3
Other	Concrete	Compression strength 18 - 21 MN/sq m Steel yield strength 410 MN/m 1:2:3

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 could be in charge of the construction process.
Expertise of those involved in the design process	Both, the structural and the construction engineer will have five years of study and minimum work experience of two years.

Construction Process

Who typically builds this construction type?	Contractor
Roles of those involved in the building process	It is typically built by developers.
Expertise of those involved in building process	
Construction process and phasing	Masonry walls are built with serrated edges, and then the tie-columns are cast against them. After that, bond beams, lintels and floors are built simultaneously. Concrete is mixed in machine mixers and taken with wheelbarrows to fill the wood formwork. Tools and equipment used are: hammers, spatulas, wheelbarrows, concrete vibrator and concrete mixers. The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size. Buildings are originally designed for a specific number of stories. However, it is common that owners decide to build additional floors some years later.
Construction issues	#NAME?

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
Process for building code enforcement	Municipal authorities approve the structural and architectural design for the building. It is a common practice that owners retain a building supervisor to oversee the construction process. In order to start the construction, it is necessary to get a building permit. Municipal authorities are in charge of giving this permit to builder companies. Each project must have four types of technical drawings: structural drawings, architectural drawings, hydraulic installation drawings, and power installation drawings. Municipal authorities need to approve this technical information to issue a building permit.

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	

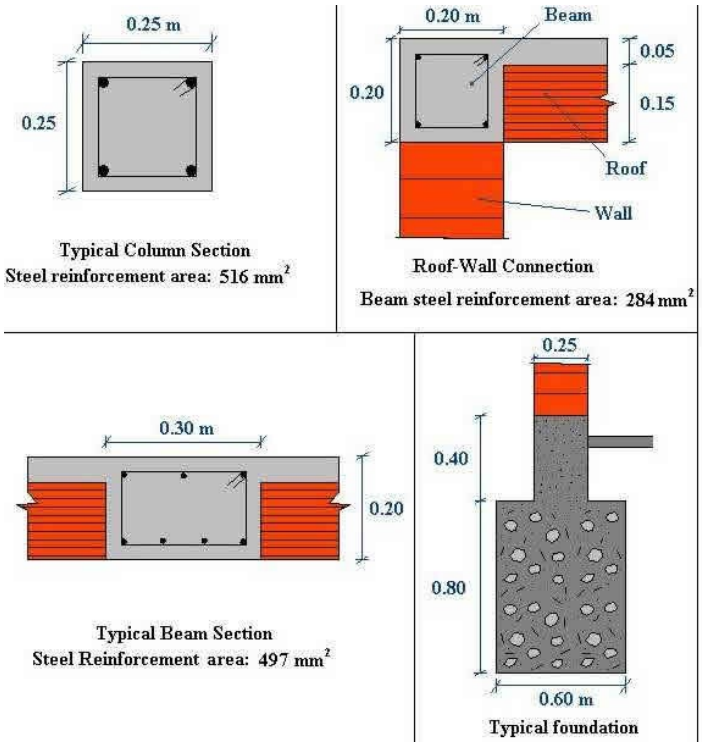
Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	BuilderOwner(s)Renter(s)No one
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	Unit construction cost may vary from 200 to 250 $US/sq m. This price includes the entire construction cost and could change depending on the quality of finishing materials.
Labor requirements	A typical 2-story house will need approximately 90 days (3 months) to complete the construction.
	These buildings were constructed using the following

Additional comments section 3	construction materials: 2. Exterior walls (2 layers); one layer is made using regular concrete and the other one is made of lightwight concrete (for the purpose of heat insulation). 3. Interior walls are made of regular concrete.



Critical Structural Details

Key Seismic Features-Slender Walls

Seismic Deficiencies - Short Column

Socio-Economic Issues

Patterns of occupancy	Typically, one family occupies one house. In some cases, two families may occupy one house.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	
Economic level of inhabitants	Middle-income classHigh-income class (rich)
Additional comments on economic level of inhabitants	Economic Level: For Middle Class the Housing Unit Price is 80,000 and the Annual Income is 12,000. For Rich Class the Housing Unit Price is 120,000 and the Annual Income is 60,000. Ratio of housing unit price to annual income: 5:1 or worse
Typical Source of Financing	Owner financedPersonal savingsCommercial banks/mortgagesGovernment-owned housing
Additional comments on financing	At present time, the Government does not support any new construction of this type.
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	It is not common that owners purchase earthquake insurance. It is a total coverage, which includes the price of a new house.
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	

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	
Additional comments on earthquake damage patterns	Shear cracking in the walls (cracks propagate through tie columns).

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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE

Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
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 direction is greater than or equal to 2.	TRUE
Wall Proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are 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		FALSE
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	-Inadequate thickness to resist gravity and seismic loads (slender walls). -Inadequate wall density in one direction.
Earthquake-resilient features in walls	Good seismic force transfer.
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 (1996 Nazca earthfquake)

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Parapets and nonstructural walls	Parapets and nonstructural walls are confined with tie columns and bond beams. When parapets are located between tie columns, they are isolated with a construction joint.

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Yes, parapets are confined and nonstructural 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?	Yes
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Usually engineers are involved in the strengthening efforts.
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	

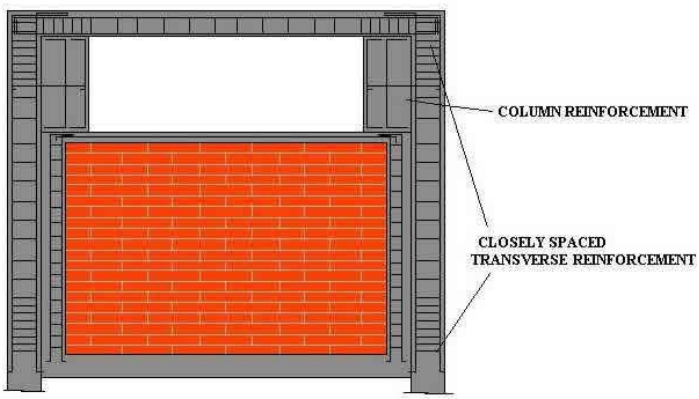


Illustration of Seismic Strengthening Techniques

References

Harmsen T. y Mayorca, 1997, de Estructuras de Concreto Armado, Pontificia Universidad Catolica del Peru.

Norma Peruana de Albanileria E-070, 1998, Capitulo Peruano del ACI.

Norma Peruana de Sismorresistente E-070, 1998, Capitulo Peruano del ACI.

Quiun, San Bartolome, Torrealva, Zegarra, 1997, El Terremoto de Nasca del 12 de Noviembre de 1996, Pontificia Universidad Catolica del Peru.

San Bartolome, 1994, Construcciones en Albanileria, Pontificia Universidad Catolica del Peru.

San Bartolome, Munoz, Rodriguez, 2001, Fuerzas as de para Edificaciones de Albanileria, Pontificia Universidad Catolica del Peru.

Authors

Name	Title	Affiliation	Location	Email
Cesar Loaiza	Professor	Civil Engineering Department, Catholic University of Peru	San Bartolome, Munoz, Rodriguez, 2001, Fuerzas as de para Edificaciones de Albanileria, Pontificia Universidad Catolica del Peru.	cloaiza@pucp.edu.pe
Marcial Blondet	Professor	Civil Engineering Department, Catholic University of Peru	POB 1761, Lima 32 , PERU	mblondet@pucp.edu.pe
Papa Simona	Architect	KazNIISSA	53, Mynbayeva str, Almaty, Republic of Kazakhstanoff. # 305	

Reviewers

Name	Title	Affiliation	Location	Email
Sergio Alcocer	Director of Research	Circuito Escolar Cuidad Universitaria, Institute of	Mexico DF 4510, MEXICO	salcocerm@iingen.unam.mx

		Engineering, UNAM		