World Housing Encyclopedia Report

Country: Peru

Housing Type: Confined masonry house

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1 General Information

1.1 Country
Peru

1.3 Housing Type
Confined masonry house

FIGURE 1: Typical Building

1.4 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 load bearing 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.

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	
< 50 years	X
< 75 years	
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

Additional Comments: This construction type is followed in the last 45 years.

1.6 Region(s) Where Used
Throughout Peru, particularly in the coastal region.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	
In rural areas	
In suburban areas	
Both in rural and urban areas	X

2 Architectural Features

2.1 Openings

A typical house has 6 to 10 windows per floor, with a total average size of 3.0 m². 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.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		X
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 0.01 meters

2.3 Building Configuration

Rectangular shape or L-shape.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	X
Multiple housing units	
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

2.5 Means of Escape

A typical house has only one main stair used in case of an emergency.

2.6 Modification of Buildings

Commonly, owners build interior walls or additional floors for new rooms.

3 Socio-Economic Issues

3.1 Patterns of Occupancy
Typically, one family occupies one house.

3.2 Number of Housing Units in a Building
1 units in each building.

Additional Comments: In some cases, two families may occupy one house.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5	X	
5 to 10		X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit
Number of Bathrooms: 3
Number of Latrines: 1

Additional Comments: Typically 3 or 4 bathrooms per house.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor		/
Middle Class	X	80000/12000
Rich	X	120000/60000

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	X
Personal Savings	X
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	X
Investment pools	
Combination (explain)	
Government-owned housing	X
Other	

3.7 Ownership

Type of Ownership/Occupancy	
Rent	X
Own outright	X
Own with Debt (mortgage or other)	X
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

4 Structural Features

4.1 Lateral Load-Resisting 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.

4.2 Gravity Load-Bearing Structure

In general, the same system as describe above. Floors/roofs transmits gravity loads to the structural walls.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	X
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

Additional Comments: In some cases, rubble stone and massive stone walls have been used.

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	
	Rubble stone (fieldstone) isolated footing	
	Rubble stone (fieldstone) strip footing	X
	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	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist	X	X
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
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 single roof		
	Wood planks or beams that support clay tiles		
	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			

4.6 Typical Plan Dimensions

Length: 10 - 15 meters
Width: 10 - 15 meters

4.7 Typical Number of Stories

2 - 3

4.8 Typical Story Height

2.60 - 2.80 meters

4.9 Typical Span

3.0 - 4.0 meters

4.10 Typical Wall Density

Typical wall densities for each horizontal direction are 2% and 7%, respectively.

4.11 General Applicability of Answers to Questions in Section 4

The information provided is for a typical building; however, the parameters may vary between 5% and 10%

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	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 form the building to the foundation.		X	
Building configuration	The building is regular with regards to both the plan and the elevation.		X	
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.			X
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.	X		
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.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.			X
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.		X	
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).	X		
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	X		
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).		X	
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	-Inadequate thickness to resist gravity and seismic loads (slender walls). -Inadequate wall density in one direction.	Good seismic force transfer	Shear cracking in the walls (cracks propagate through tie columns).
Frame (columns, beams)			
Roof and floors			

5.3 Seismic Vulnerability Rating

	Vulnerability					
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class			<	0	>	

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1996	Nazca	7.3	VII (MM)
1974	Lima	7.7	VIII (MM)
1970	Chimbote	7.8	VI (MM)

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Brick masonry	Compressive strength (masonry prisms): 13 - 16 MN/m² Shear strength: 0.6 - 0.8 MN/m²	1:4 / 90 mm X 120 mm X 240 mm	Compressive strengths depend on the quality of brick units.
Foundations	Concrete	Compression strength: 10-14 MN/m²		
Frame	Concrete	Compression strength: 18 - 21 MN/m² Steel yield strength: 410 MN/m²	1:2:3	
Roof and floors	Concrete	Compression strength: 21- 35 MN/m² Steel yield strength: 10 MN/m²	1:2:3	

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

It is typically built by developers.

7.3 Construction Process

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.

7.4 Design/Construction Expertise

Both, the structural and the construction engineer will have five years of study and minimum work experience of two years.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

Title of the code or standard: Seismic Design Standards E-030.
Year the first code/standard addressing this type of construction issued: 1977
National building code, material codes and seismic codes/standards: National Construction Standards, Masonry Standards E-070
When was the most recent code/standard addressing this construction type issued? 1998

7.6 Role of Engineers and Architects

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.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required	X	
Informal construction		X
Construction authorized per development control rules	X	

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)		X
Building originally designed for its final constructed size		X

Additional Comments: Buildings are originally designed for a specific number of stories. However, it is common that owners decide to build additional floors some years later.

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	X
Owner(s)	X
Renter(s)	X
No one	X
Other	

7.10 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.

7.11 Typical Problems Associated with this Type of Construction

Inadequate concrete mix proportions.
Poor reinforcement detailing at tie-columns and tie beams joints.
Poor quality of mortar.

8 Construction Economics

8.1 Unit Construction Cost (estimate)
Unit construction cost may vary from 200 to 250 $US/m². This price includes the entire construction cost and could change depending on the quality of finishing materials.

8.2 Labor Requirements (estimate)
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. A typical 2-story house will need approximately 90 days (3 months) to complete the construction.

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available	X	
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features	X	

Additional Comments: It is not common that owners purchase earthquake insurance.

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

It is a total coverage, which includes the price of a new house.

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
New Construction	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.

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

Yes, parapets are confined and nonstructural walls are isolated from the structure.

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

The seismic strengthening was done in a new construction.

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

N/A

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

Usually engineers are involved in the strengthening efforts.

10.6 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.

11 References

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13 Figures

FIGURE 1: Typical Building

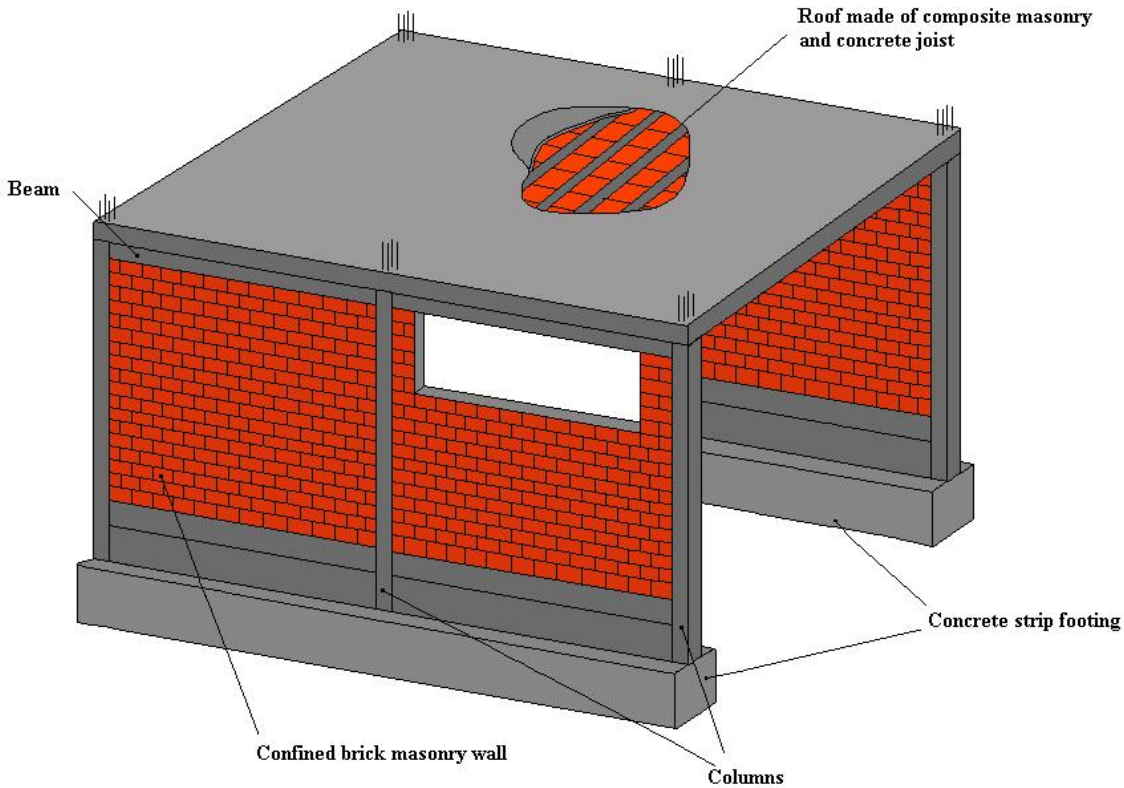

FIGURE 2: Key Load-Bearing Elements

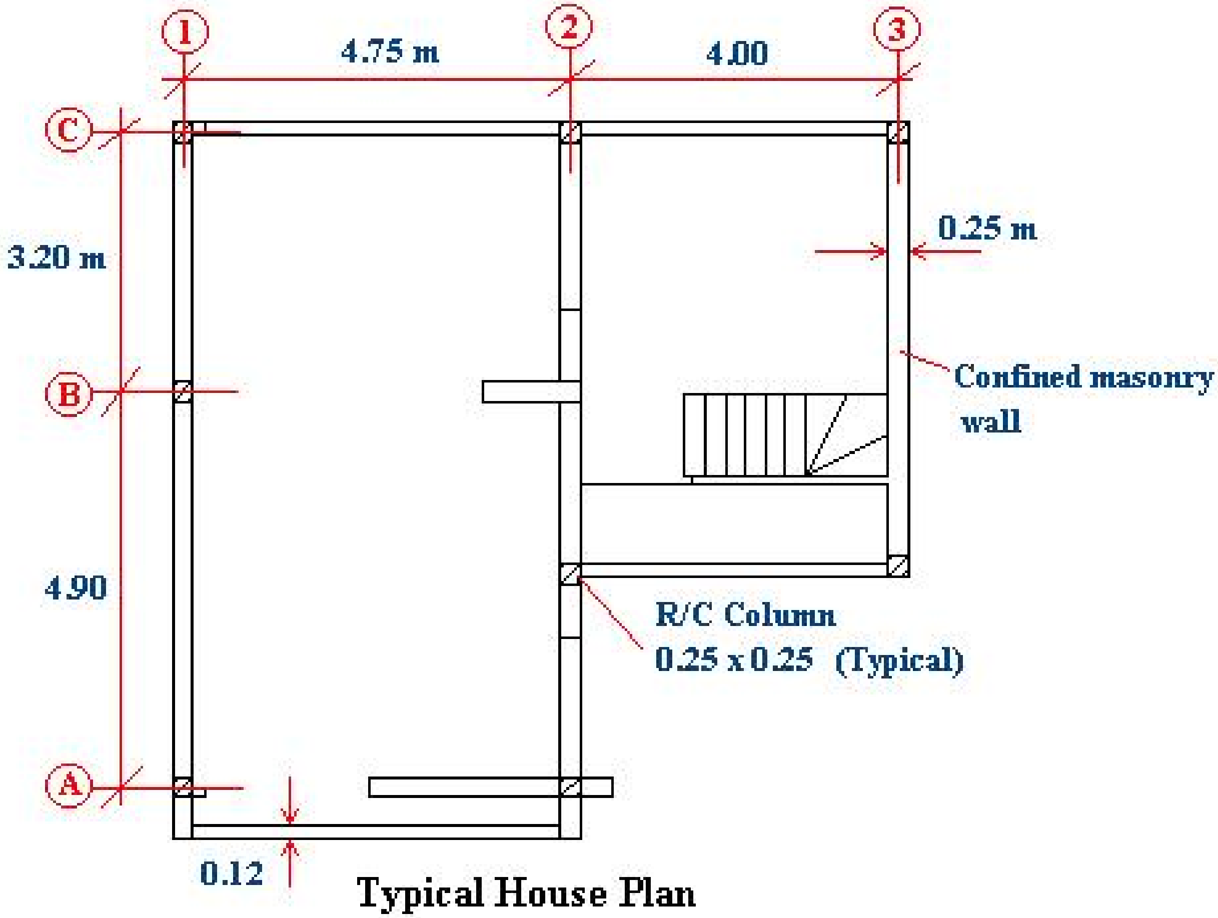

FIGURE 3: Plan of a Typical Building

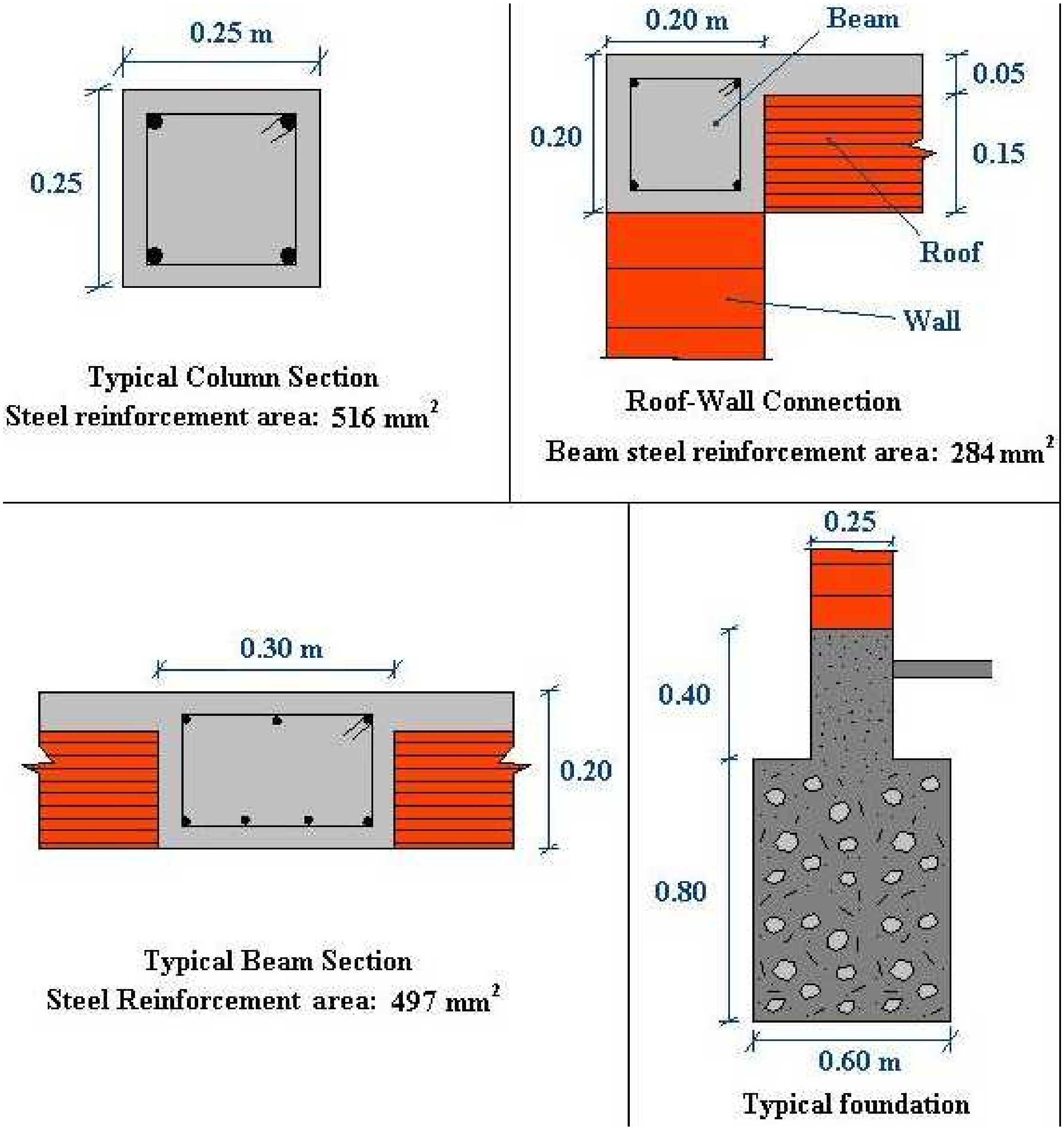

FIGURE 4: Critical Structural Details

FIGURE 5A: Key Seismic Features-Slender Walls

FIGURE 5B: Seismic Deficiencies - Short Column

FIGURE 6: A Photograph Illustrating Typical Earthquake Damage (1996 Nazca earthquake)

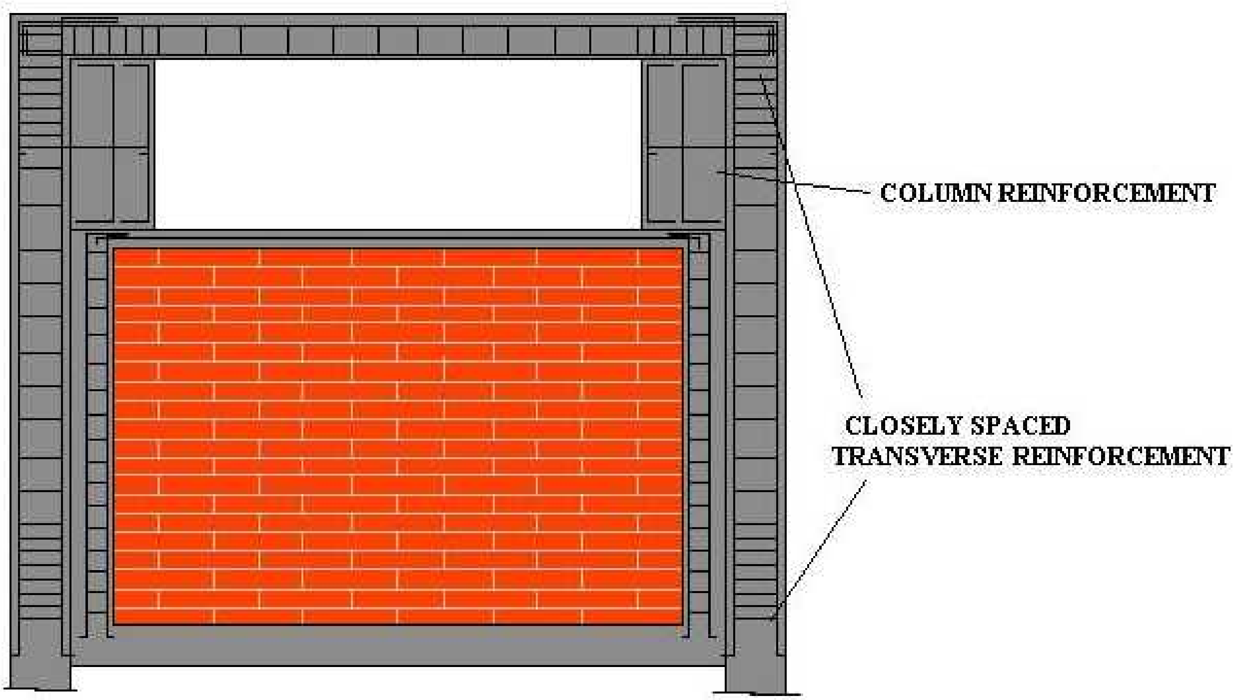

FIGURE 7: Illustration of Seismic Strengthening Techniques