World Housing Encyclopedia Report

Country: Peru

Housing Type: Confined masonry building

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1 General Information

1.1 Country
Peru

1.3 Housing Type
Confined masonry building

1.4 Summary
This is the most common multi-family housing construction type used in urban areas of Peru in 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 they are connected to the tie beams. Confined masonry walls have limited shear strength and ductility, however typically buildings of this type have a good seismic resistance.


FIGURE 1: Typical Building

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 practice has been followed in the last 35 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	X
In rural areas	
In suburban areas	
Both in rural and urban areas	

2 Architectural Features

2.1 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.

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 0.5 meters

2.3 Building Configuration

Rectangular shape.

2.4 Building Function

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

2.5 Means of Escape

Typically, there is only one stair and emergency stair does not exist. A few confined masonry buildings have emergency stairs.

2.6 Modification of Buildings

In some cases owners build additional interior walls as a part of the building extension (new rooms or bathrooms).

3 Socio-Economic Issues

3.1 Patterns of Occupancy

Typically, one family occupies one housing unit. However, in low social classes, two or three families share one housing unit.

3.2 Number of Housing Units in a Building

6 units in each building.

Additional Comments: Usually there are from 4 to 8 units in each building.

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		
5 to 10	X	
10-20	X	X
> 20		X
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 1

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor	X	15000/3500
Middle Class	X	40000/12000
Rich	X	100000/50000

Additional Comments:

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	X
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

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.

4.2 Gravity Load-Bearing Structure

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.

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		

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	
	Reinforced concrete isolated footing	
	Reinforced concrete strip footing	X
	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		

Additional Comments: Usually the foundation is of plain (unreinforced) concrete unless the soil is clay or silt

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			

Additional Comments: In the analysis, the floors are considered to be rigid diaphragms.

4.6 Typical Plan Dimensions

Length: 20 - 20 meters
Width: 20 - 20 meters
Additional Comments: Average plan area is 260 m². Length varies from 15 to 30 m, and the width varies from 5 to 15 m.

4.7 Typical Number of Stories

4 - 6

4.8 Typical Story Height

2.70 meters

Additional Comments: Story height varies from 2.5 meters to 2.8 meters.

4.9 Typical Span

4 meters

Additional Comments: Typical span varies from 3.5-5 m.

4.10 Typical Wall Density

Total wall area/plan area (for each floor) is 3%-5%

4.11 General Applicability of Answers to Questions in Section 4

The information provided is for a typical building, the parameters variation may be of 2 to3%

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	Limited ductility and the absence of tie columns diminishes shear strength	Good transfer of seismic forces	Wall shear cracking that propagates 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 (MMI)
1974	Lima	7.7	VIII (MMI)
1970	Chimbote	7.8	VI (MMI)

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Clay masonry	Compression strength: 12 -16 MPa Shear strength: 0.5 - 0.8 MPa	1:4 / 90 mm X 12 mm X 24 mm	Compression strength depends on the quality of bricks.
Foundations	Concrete	Compression strength: 14 - 18 MPa		
Tie columns and bond beams	Concrete Steel	Compression strength: 21-35 MPa Steel yield stress: 410 MPa		
Roof and floors	Concrete Steel	Compression strength: 21- 35 MPa Steel yield stress: 410 MPa		

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

Construction companies build the buildings of this type and sell them.

7.3 Construction Process

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.

7.4 Design/Construction Expertise

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.

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 in some cases 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	

7.9 Building Maintenance

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

7.10 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 for supervise the construction process.

7.11 Typical Problems Associated with this Type of Construction

-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.

8 Construction Economics

8.1 Unit Construction Cost (estimate)
Unit construction cost may vary from 200 to 300 US$/$m^2$.

8.2 Labor Requirements (estimate)
Depending on the technology used, the construction of a typical building may take 2-3 stories per month..

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: Despite earthquake insurance is available, people living in these buildings do not have enough money to pay it.

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

Cover all costs of damages or the construction of a new building

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	Columns	Installation of additional shear reinforcement in tie columns (Figure 7)
New Construction	Parapets and nonstructural walls	Parapets are confined with tie-columns and bond-beams. When parapets are located between tie-columns, walls are isolated through construction joints.

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 non structural 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.

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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12 Contributors

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13 Figures

FIGURE 1: Typical Building

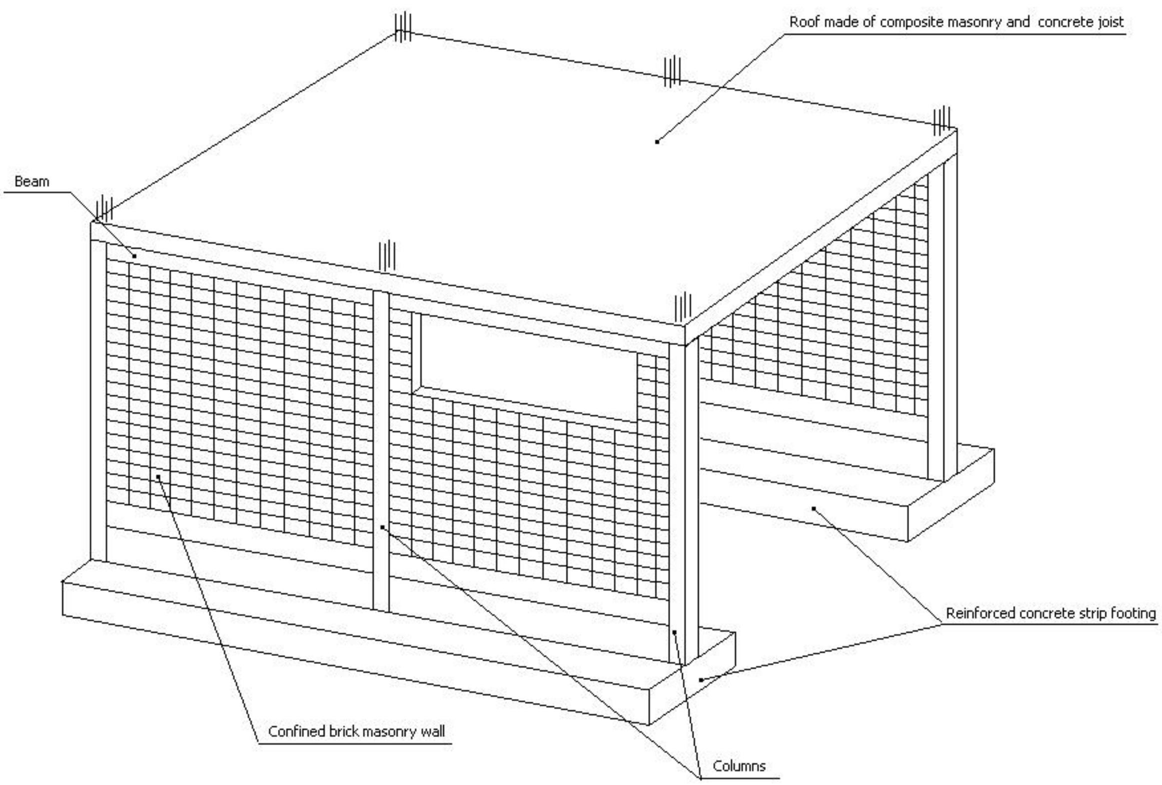

FIGURE 2: Key Load-Bearing Elements

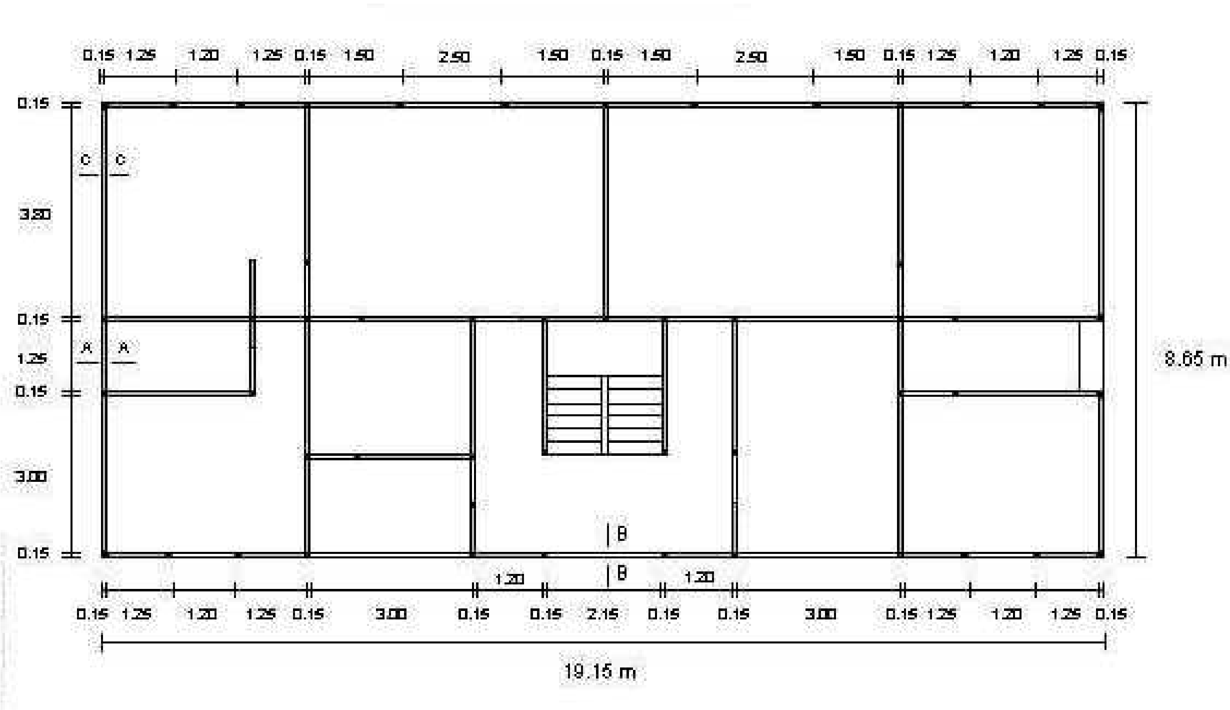

FIGURE 3: Plan of a Typical Building

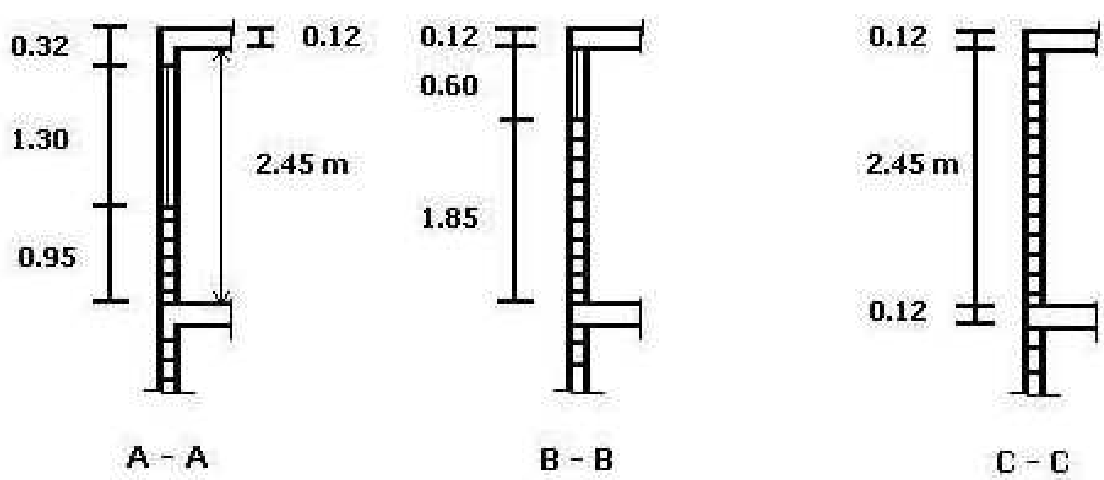

FIGURE 4: Critical Structural Details - Wall Sections

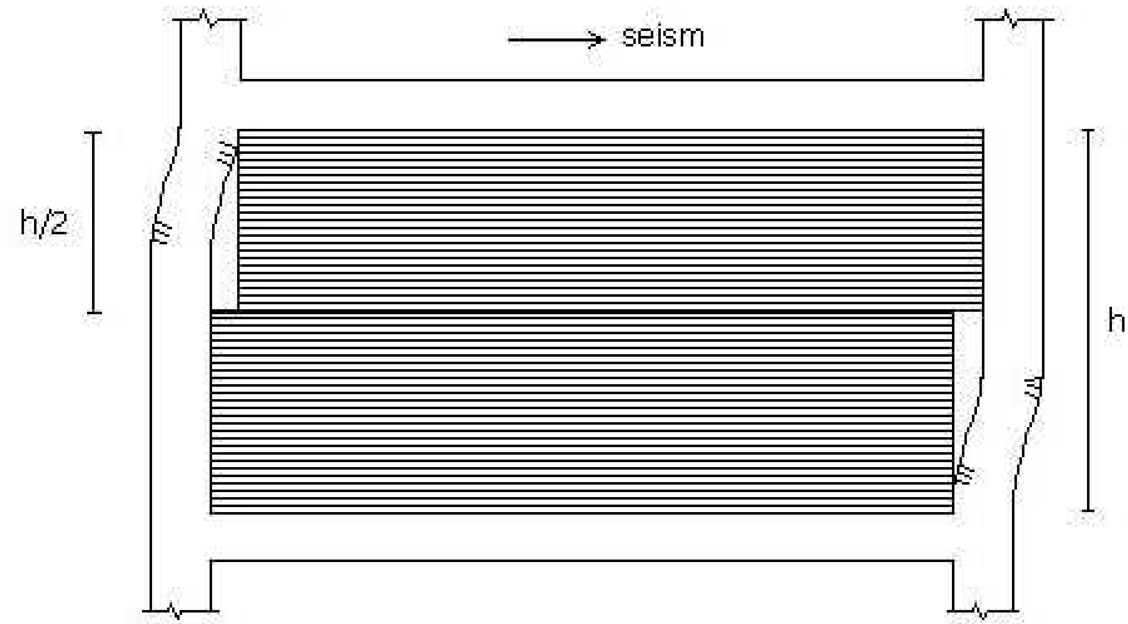

FIGURE 5: An Illustration of Key Seismic Deficiencies

FIGURE 6: A Photograph Illustrating Typical Earthquake Damage

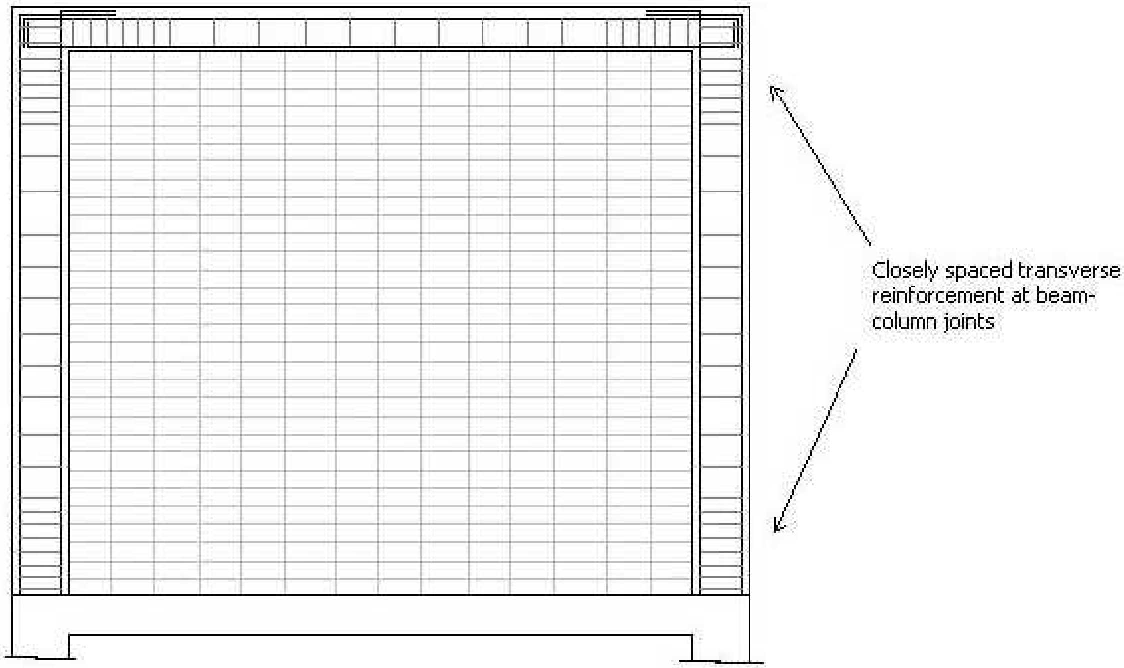

FIGURE 7: Illustration of Seismic Strengthening Techniques