World Housing Encyclopedia Report

Country: Argentina

Housing Type: Traditional adobe house with reinforcement

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1 General Information

1.1 Country
Argentina

1.3 Housing Type
Traditional adobe house with reinforcement

1.4 Summary
This construction type is a single-family house. In general, it is a single-story building, an isolated construction found in the rural areas of San Juan and Mendoza. The traditional adobe block masonry walls are reinforced with foundations and plinth structure, which provide structural strength. A deficiency in this type of construction is that the adobe blocks deteriorate due to prolonged exposure to humidity.

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	
< 75 years	X
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

Additional Comments: This is a traditional construction practice that has been practiced in San Juan for many years, but since 1948 it has been practiced following the seismic standards.

1.6 Region(s) Where Used
Rural areas in the province of San Juan.

1.7 Urban vs. Rural Construction

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

Additional Comments: The building code allows this type of construction only in rural areas. However, as the city has grown, the current urban area now includes adobe block constructions that were built in the past (when the area was rural).

2 Architectural Features

2.1 Openings

The typical house has approximately seven openings, with an average area of 1.60 m². These openings are: 5 (five) windows, placed in the middle of the walls, and 2 (two) doors. The doors are placed to one side of the wall. The opening area is about 10.40% of the whole wall area.

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?		

The typical separation distance between buildings is 5 meters

2.3 Building Configuration

The typical shape of a building plan for this housing type is rectangular.

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

Usually, there are 2 doors to one side in building.

2.6 Modification of Buildings

Typical patterns of modification is erection of additional parts, generally without any professional input.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

In general, there is a single family in a housing unit.

3.2 Number of Housing Units in a Building

1 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	X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 0

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor	X	12000/7200
Middle Class		/
Rich		/

Additional Comments: 1. Below are the general guidelines related to the economic status of the inhabitants: Very Poor= lowest 10% of the population (per GDP) Poor= lowest 30% of the population Middle Class= from the lowest 30% up to the top 20% of the population Rich= top 20% of the population Values are variable: the adobe blocks may be manufactured by the owner of the house and the masonry may also be made by the owner; canes grow on the banks of the water channels in the area. All this results in a notable reduction of the overall construction cost.

3.6 Typical Sources of Financing

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

Additional Comments: In the '50s, a part of the cost was paid by the government, in the form of a non-repayable contribution or grant, and the rest of the money was financed by a bank. Nowadays, the construction is completely owner financed; the owners are doing the construction by themselves.

3.7 Ownership

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

Additional Comments: The information in this chart reflects the period after the 1944 earthquake. After 1960, houses of this construction type were built directly by the owners, without any kind of external financing.

4 Structural Features

4.1 Lateral Load-Resisting System

Earthquake-resistant system consists of adobe block walls of 40 cm thickness, which generally meet the quality standards and architectural requirements (small openings, heights shorter than 3.00 m). In general, the roofs are light (weight less than 150 kg/m^2). On the upper part of the wall there is a reinforced concrete bond beam, and on the bottom there are foundations and plinth structure.

4.2 Gravity Load-Bearing Structure

The same as seismic resistant structure - adobe block 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	X
		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	
	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: 40-cm-thick block walls joined using mud mortar.

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: Concrete, with a minimum cement of 180 kg/m³ and 30% of stone. The top of the plinth is 30cm above the ground level.

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
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	Mud and cane roof with exterior finishing of clay tiles supported by round logs.		X

Additional Comments: The roof is considered to be a flexible diaphragm with a maximum weight of 150 kg/m²

4.6 Typical Plan Dimensions

Length: 12 - 12 meters
Width: 12 - 12 meters

4.7 Typical Number of Stories

1

4.8 Typical Story Height

3.00 meters

Additional Comments: Variation of story height is 2.8 m - 3 m.

4.9 Typical Span
4.00 meters

4.10 Typical Wall Density
0.215
In the direction X the wall density is 0.153
In the direction Y the wall density is 0.11

4.11 General Applicability of Answers to Questions in Section 4
This contribution is not based on a case study of one building.4.

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	The resistance of adobe masonry in this construction type is weakened by the following factors: 1. The openings- due to the following factors: a) the big size of the two windows (1.60 m²) in the main face of the construction. b) The position of the doors in the angles formed by the meeting of walls. c) The great percentage of opening surface (31%) in the front and back walls. 2. The vulnerability of the adobe due to humidity		In general, during the 1977 earthquake, the adobe block construction built in Caucete using the standards of 1948, suffered moderate damage (economically repairable); those built in the capital city of San Juan, under the same standards, were not damaged at all. Traditional adobe block houses, built without any kind of earthquake-resistant requirements, were seriously damaged during the same earthquake.
Frame (columns, beams)	No buttresses provided at the wall intersections.		
Roof and floors	Flexible 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)
1977	Caucete 100 km to the east of San Juan Capital city	7.4	IX MMI

Additional Comments: In the Capital city of San Juan, located at approximately 100 km distance from the epicenter, the intensity was between VII MMI and VIII MMI. It is important to mention that a wide area of about 1000 km² experienced liquefaction.

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Adobe blocks	10 kg/cm² 3 kg/cm²	Clay soil and thatch	Joined with mud (1) resistance to compression (2) resistance to flection
Foundations	Concrete with stone	150 kg/cm²	1:3:5 and 3 (cement - sand - pebble and stone)	Minimum 180 kg/cm² 30% stone
Frame	Reinforced concrete	200 kg/cm² 2400 kg/cm²	1:3:3 (cement-sand-gravel)	Top reinforced concrete beam as wide as the wall (4) resistance of concrete to compression (5) resistance of steel to tension
Roof and floors	Round logs with cane and mud roof		Round log Æ 16 cm Every 60 cm	Roof maximum weight: 150 kg/m²

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

When this construction was first used, the builder did not live in this construction type. However, later on it was built by the owners themselves; in general, owners of this type of construction are people without any chances of building their houses with other building materials (due to their high cost).

7.3 Construction Process

The owner of the house usually carries out the construction. It begins with the manufacturing of adobe, the filling in of foundations and plinth construction. After that, the adobe block masonry is built, caring that the blocks are perfectly joined. Then, the frame of the top reinforcement concrete beam is made, and the iron bars are placed to fasten the round logs of the roof. The frame is filled in with concrete. The round logs are placed and fastened every 60 cm. After that a 5cm-wide coat of cane and mud is placed. This coat is later made waterproof with asphalt, finishing the process with the placement of Spanish tiles. The tools and equipment typically used are: wheelbarrows, grub hoe, and matrix for the manufacturing of adobe blocks; spatulas, shovels, hoes, baskets, saws, pliers, levels, cement mixers, etc., are used in the whole process.

7.4 Design/Construction Expertise

This construction began to be practiced after the 1944 earthquake, as an alternative to improve the seismic behavior of the traditional adobe block construction. The design of adobe construction was largely based on the local building experience related to this kind of construction. This experience and the new information gained after the earthquake helped in improving the adobe construction practice. This construction proved to be an economic solution as the local material and skills were used and the traditional construction practice was followed.

7.5 Building Codes and Standards

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

Title of the code or standard: 1951 Building Code of the Province of San Juan, Earthquake-proof Norms Concar 70, Argentinean Earthquake-proof Norms 80 and 1990 INPRES CIRSOC Norms.

7.6 Role of Engineers and Architects

In the beginning, this type of construction was designed and built by engineers and general builders, but later the same construction began to be made by the owners.

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

Additional Comments: This construction is subject to regulations and the approval of plans.

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: This type of construction is generally designed for its final constructed size, but the owner also builds additional parts, generally without any professional input.

7.9 Building Maintenance

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

Additional Comments: Usually, it is the owner who maintains the building, but given the low economic levels of the owners there is generally little or no maintenance and over time the construction deteriorates.

7.10 Process for Building Code Enforcement

The construction process is controlled by the corresponding state authorities.

7.11 Typical Problems Associated with this Type of Construction

The only problem associated with this type of construction is that the adobe blocks deteriorate due to a prolonged exposure to humidity.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

Unit construction cost per m² of built-up area is approximately US$ 137.

8.2 Labor Requirements (estimate)

380 man-days (assuming 8 working hours/day).
Experience in the selection of the land
Knowledge about the adequate mix proportions to manufacture the adobe blocks
Knowledge about foundations, plinth structure, top reinforcement beam, round log.
The tools needed in this construction type are not many: shovels, baskets, hoes, pliers, spatulas, etc.

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: Insurance policies for buildings make explicit that disasters are not covered.

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

Not available.

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used

Additional Comments: This type of construction has emerged as a proposal to strengthen the traditional adobe block construction which had an unsatisfactory performance during the 1944 earthquake. This construction has been built in San Juan under the Adobe Construction Regulations of 1948, however it is only allowed in rural areas. During the 1977 Caucete earthquake, this construction has a satisfactory performance so no seismic strengthening has been done since that time. It should be noted that some traditional adobe construction (not following the 1948 Regulations) is still being practiced in rural areas.

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

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

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

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

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

11 References

Adobe Construction Regulations

The 1951 Building Code of the Province of San Juan

Adobe Block Housing in Dry Areas by the engineers Hugo Giuliani and José Herrera Cano.

1991 National Survey on Population and Housing. (INDEC) Nº18

Research Project: Interrelations Between Architectural Design and Structural Design in High Seismic Risk Areas (building level San Juan, 1989 - San Juan - Argentina)

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13 Figures

FIGURE 1: Typical Building

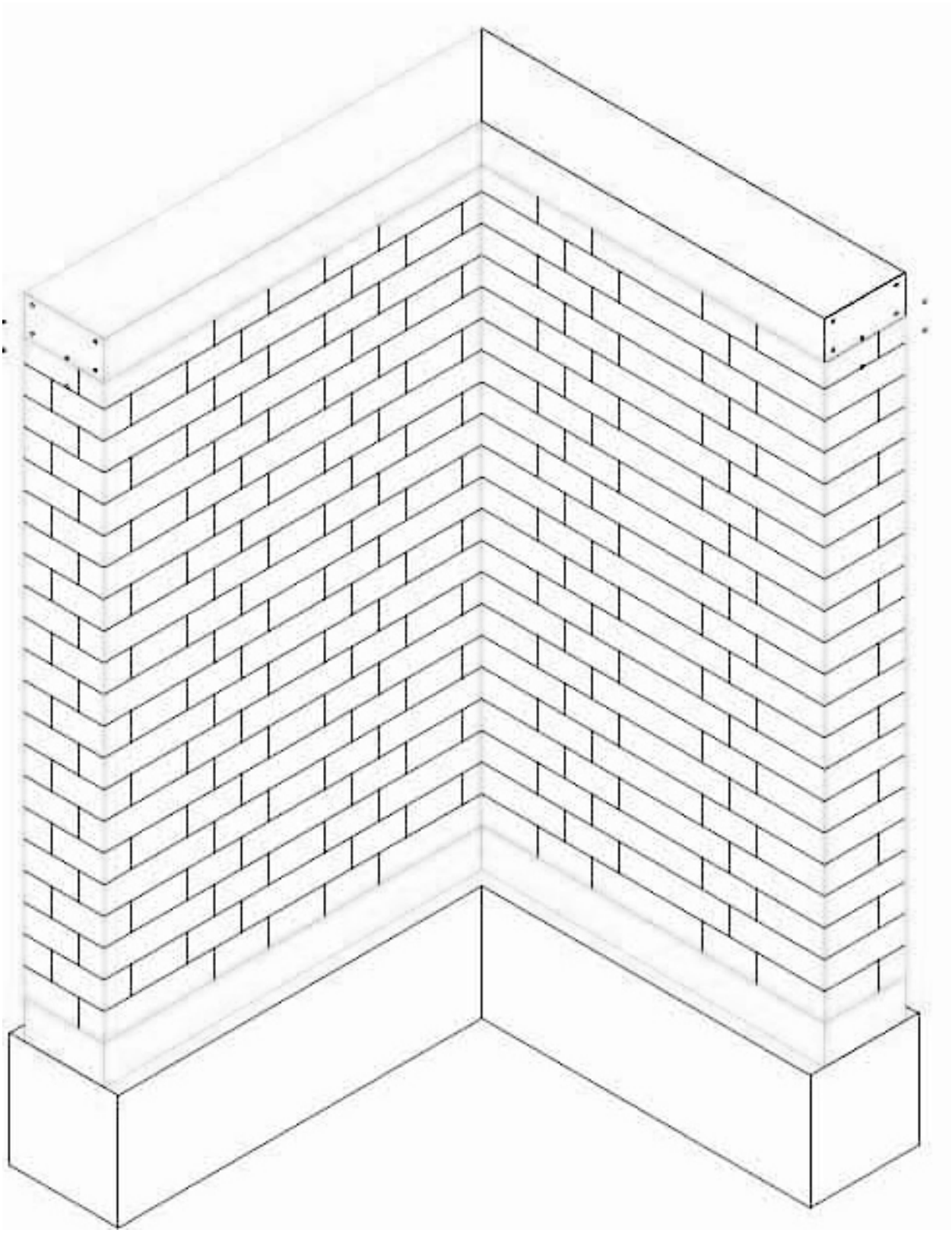

FIGURE 2: Key Load bearing Elements

FIGURE 3: Plan of a Typical Building

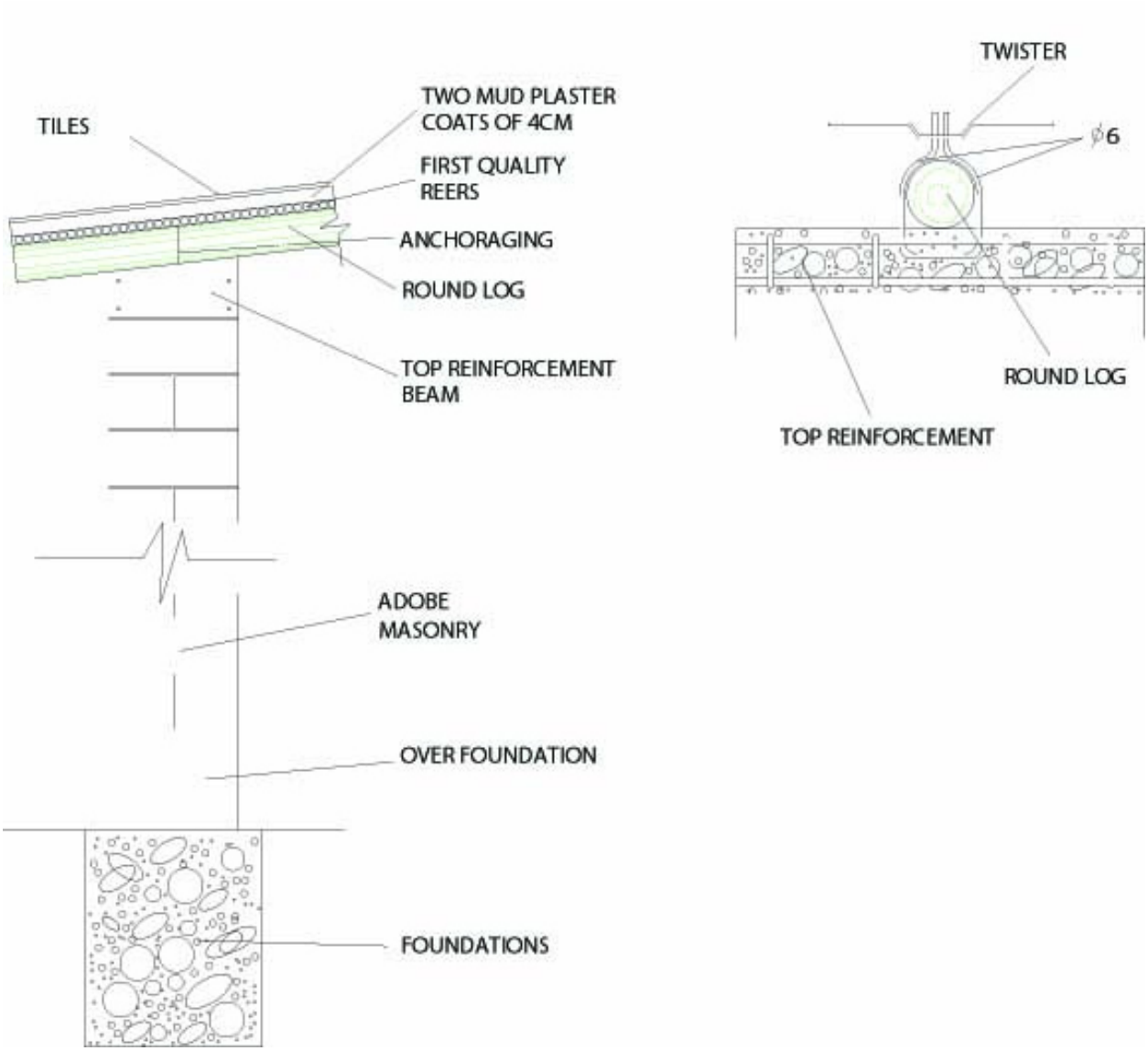

FIGURE 4: Critical Structural Details

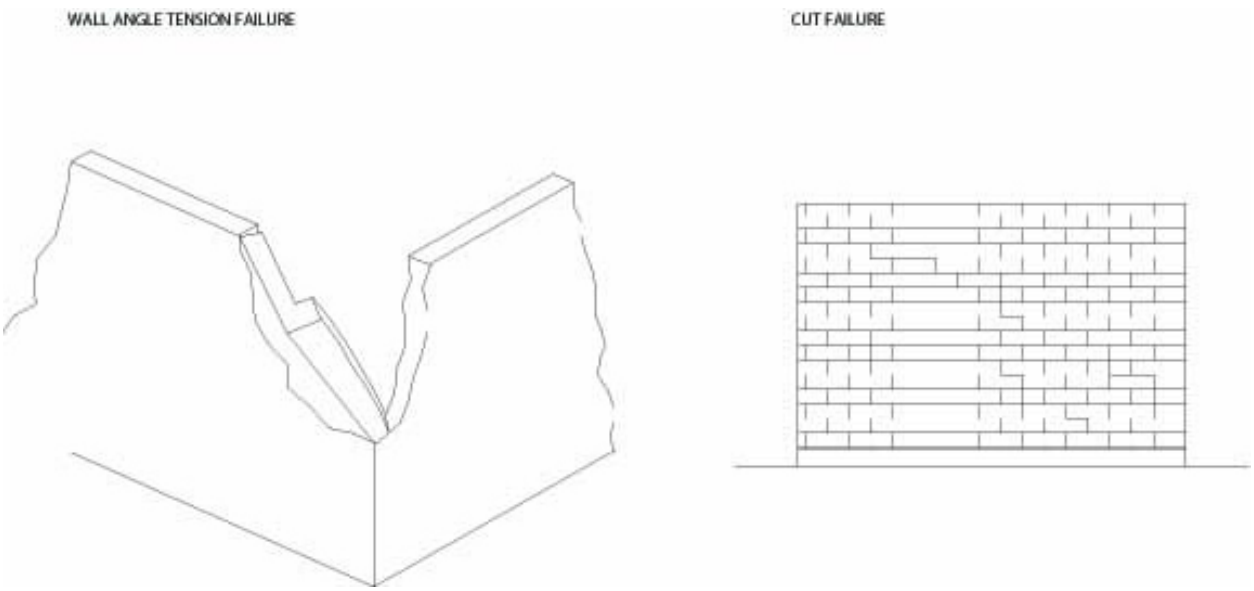

FIGURE 5: An Illustration of Key Seismic Features and/or Deficiencies

FIGURE 6A: Photograph Illustrating Typical Earthquake Damage

FIGURE 6B: A Photograph Illustrating Typical Earthquake Damage