World Housing Encyclopedia
an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

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HOUSING REPORT
Adobe House

Report #	104
Report Date	25-02-2004
Country	IRAN
Housing Type	Adobe / Earthen House
Housing Sub-Type	Adobe / Earthen House : Adobe block walls
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Summary

This building type is typically one or two stories and used for single-family housing. It is more predominant in the desert, in cold-weather, or other inhospitable climates. It has a large mass and basically no strength, particularly against out-of-plane wall forces. These buildings are the most seismically vulnerable. In the 2003 Bam earthquake, collapse of these buildings was widespread and contributed to many of the 43,000+ deaths. The typical mode of collapse is

out-of-plane failure of the walls, resulting in loss of support for the roof. Adobe construction is widespread throughout Iran, and is used both by wealthy families in luxury residences, as well as by poor families in more modest dwellings.

1. General Information

Buildings of this construction type can be found in the Middle East. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for more than 200 years.

Currently, this type of construction is being built. Adobe construction is widespread throughout Iran, and is used both by wealthy families in luxury residences as well as poor families in more modest dwellings.

Figure 1: Modest adobe house

Figure 2: View of adobe construction with multiple domes

Figure 3: Luxury adobe house

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. The typical separation distance between buildings is more than one meter, if not connected to adjacent buildings

2.2 Building Configuration

It is rectangular in plan. Small windows, one entrance door and one entry for each room. Opening area is about 30 percent of total wall area.

2.3 Functional Planning

The main function of this building typology is single-family house. These buildings can also be found in steep hillside areas, where an individual house is on a flat foundation, but then steps into another house's roof. In a typical building of this type, there are no elevators and no fire-protected exit staircases. There is only one door to exit from the building.

2.4 Modification to Building

No modifications are made to the building.


Figure 4: Historic adobe structure


Figure 5: Section of luxury adobe house.


Figure 6: Ceiling skylight in wealthy adobe dwelling

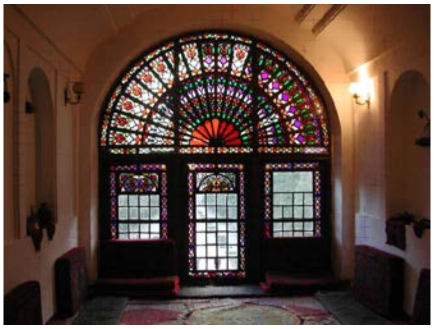
Figure 7: Entryway in wealthy adobe home

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☑
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
			Concrete block masonry in	

		16	cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is earthen walls. The roofs are usually adobe domes or cylindrical arches, supported on adobe walls. Sometimes flat adobe roofs with wood joists are used (as described in section 2, if these buildings are built on hillsides, the ground floor of one building can be the roof for another.).

3.3 Lateral Load-Resisting System

The lateral load-resisting system is earthen walls. The lateral load-resisting elements are adobe walls, typically 3 m high, 4 m wide and 0.80 m thick. The walls do not have any additional system (such as crown beam or pilasters) to restrain their out-of-plane movement. That is one reason why the buildings are so vulnerable in earthquakes. If the walls move out of plane, the roof loses its support, and collapses.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 12 and 12 meters, and widths between 12 and 12 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4 meters. Typical Plan Dimensions: the dimensions can vary, but typically modest homes are 12 meters by 12 meters. Large homes can be very extensive. Typical Number of Stories: typically, these adobe houses are only one story high. Typical Span: a cylindrical or dome-shaped arched roof typically spans 4 meters. More elaborate buildings will have such a vaulted ceiling in the center, flanked by semi-spherical rooms that have domes spanning 3 to 4 meters. A poorer owner may have one cydindrical ceiling. The typical storey height in such buildings is 3 meters. The typical structural wall density is more than 20 %. The typical structural wall density varies from 10% to 35%. The walls are very thick, typically +/- 70-80 cm.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☑	☑
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
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 shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☐
	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	Described below	☑	☑

The roofs (and walls) typically have a 5 cm (2 inch) layer of straw reinforced mud to provide protection against rain.

3.6 Foundation

Type	Description	Most appropriate type
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	☐
	Mat foundation	☐
	No foundation	☐
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

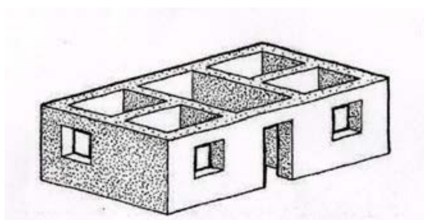

Figure 8: Perspective of a typical modest adobe dwelling. Cylindrical roof goes over rectangular center space, domes are used for the square rooms.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). There is only one unit in each building. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5.

4.2 Patterns of Occupancy

Just one family, possibly with married son and daughter-in-law, lives in each unit.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☑
b) low-income class (poor)	☑
c) middle-income class	☑

d) high-income class (rich)	☐

The ratio of price of each housing unit to the annual income can be 10:1 for very poor and poor families, and 20:1 for middle class families.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☑
4:1	☐
3:1	☐
1:1 or better	☐

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	☑
Personal savings	☑
Informal network: friends and relatives	☑
Small lending institutions / micro-finance institutions	☑
Commercial banks/mortgages	☐
Employers	☐
Investment pools	☐
Government-owned housing	☐
Combination (explain below)	☐
other (explain below)	☐

In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) including toilet(s).

Bathrooms or latrines are in separate structures. .

4.4 Ownership

The type of ownership or occupancy is outright ownership and ownership with debt (mortgage or other).

Type of ownership or occupancy?	Most appropriate type
Renting	☐
outright ownership	☑
Ownership with debt (mortgage or other)	☑
Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	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 from the building to the foundation.	☐	☑	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
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.	☐	☑	☐
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.	☐	☑	☐
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.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal 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);	☑	☐	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☐	☐	☑
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	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.	☑	☐	☐
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☐	☑	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☐	☑	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☐	☑	☐
Additional Comments				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	They are weak in the out of plane direction.	There are no earthquake resistant features.	The walls tips over or bend outwards.
Frame (Columns, beams)			
Roof and floors	It is made of weak materials.	The roof consists of arches and domes which provide integrity	If the walls move out of plane, the roof collapses.
Other			

If the adobe walls can be kept in place, the seismic performance of the building will improve significantly.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is A: HIGH VULNERABILITY (i.e., very poor seismic performance), the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☑	☐	☐	☐	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1990	Manjil	7.7	
1997	Ardekul	7.3	
2003	Bam	6.6	

Iran has a long history of devastating earthquakes that have affected adobe structures. In the 2003 Bam earthquake, over 40,000 people died; in 1997 over 1,568 people died and in the 1990 earthquake in Manjil over 40,000 people died. In the Bam area, there have also been other significant earthquakes: in the Gisk-Zarand 1977 earthquake--665 people were killed; in the 1981 Golbaf earthquake--between 1,000 and 3,000 people were killed; in the 1981 Sirch earthquake--1300 people killed. Many people were killed in adobe structures.


Figure 9: Key Seismic Deficiency--buildings not well-tied together. Example of building collapse in Bam earthquake

Figure 10: Aerial view of roofs after Bam earthquake--multiple domes of each house are visible.

Figure 11: Key Seismic Deficiency: walls are not tied to roof, and can move out-of-plane in an earthquake

Figure 12: Aerial view of complete destruction of adobe dwelllings in Bam earthquake

Figure 13: Aerial view of neighborhood with widespread damage to adobe structures in Bam earthquake

Figure 14: If walls can be kept in-plane, building typically survives. Adobe house in Bam earthquake.

Figure 15: Bam earthquake: Damage to a traditional adobe house. Nonbearing walls collapsed, bearing walls are still standing.

Figure 16: Bam earthquake: collapsed adobe structures

Figure 17: Bam earthquake: debris cleared from roadway, partially collapsed adobe structures, tents

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Adobe is used to make walls.	No information is available on this.	No information is available on this.	
Foundation				
Frames (beams & columns)				
Roof and floor(s)	Adobe is used to make walls.	No information is available on this.	No information is available on this.	

6.2 Builder

Builder Occupied.

6.3 Construction Process, Problems and Phasing

Sun dried adobe units are used to build walls and roof. A 2-inch layer of straw-reinforced mud covers the walls and roof for rain protection. Every 4 to 6 years, this layer is washed away from the roof and requires replacement. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

No special expertise. None.

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not authorized as per development control rules. Building permits are not required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

$20/m2 (this is a rough estimate. A lot of people build their own houses, using their own dirt to make adobe blocks.). It takes about 100 days for 2-3 persons (200-300 person days) to complete the construction.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Weak walls	In other countries, particularly Peru, add reinforced concrete, or add rope stitching

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Weak walls	Dimensional constraints, bamboo reinforcement (Peru) or reinforced concrete overlay.

8.2 Seismic Strengthening Adopted

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

None in Iran.

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

Not applicable.

8.3 Construction and Performance of Seismic Strengthening

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

Not applicable.

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

Not applicable.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

Not applicable.

Figure 18: Basic gravity strengthening technique used for several hundred years--iron rod across vaulted space, tying walls together (increases gravity resistance, not seismic resistance)

Reference(s)

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