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

Adobe / Earthen House

Report#	104
Last Updated	
Country	IRAN
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Important

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General Information

Building Type:	Adobe / Earthen House
Country:	IRAN
Author(s):	Mehrdad Mehrain Farzad Naeim
Last Updated:	
Regions Where Found:	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.
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.
Length of time practiced:	More than 200 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	4
Comments:	Adobe construction is widespread throughout Iran, and is used both by wealthy families in luxury residences as well as poor fami

Features

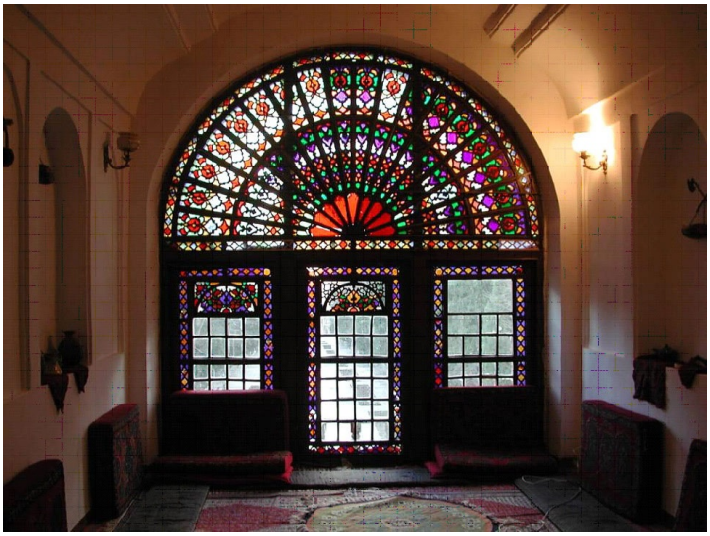
Plan Shape	Rectangular, with an opening in plan
Additional comments on plan shape	Small windows, one entrance door and one entry for each room.
Typical plan length (meters)	12
Typical plan width (meters)	12
Typical story height (meters)	3
Type of Structural System	Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Adobe block walls
Additional comments on structural 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 1.9, if these buildings are built on hillsides, the ground floor of one building can be the roof for another.) . 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 .
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	The typical structural wall density varies from 10% to 35%. The walls are very thick, typically +/- 70-80 cm.
Wall Openings	Small windows, one entrance door and one entry for each room. Opening area is about 30 percent of total wall area .
Is it typical for buildings of this type to have	

of this type to have common walls with adjacent buildings?	Yes
Modifications of buildings	No modifications are made to the building .
Type of Foundation	Shallow Foundation: Wall or column embedded in soil, without footingShallow Foundation: Rubble stone, fieldstone strip footing
Additional comments on foundation	
Type of Floor System	Vaulted masonry floorOther floor system
Additional comments on floor system	
Type of Roof System	Vaulted masonry roofRoof system, other
Additional comments on roof system	The roofs (and walls) typically have a 5 cm (2 inch) layer of straw reinforced mud to provide protection against rain .
Additional comments section 2	The typical separation distance between buildings is more than one meter, if not connected to adjacent buildings.

Historic adobe structure

Section of luxury adobe house.

Ceiling skylight in wealthy adobe dwelling



Entryway in wealthy adobe home

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Adobe is used to make walls.	No information is available on this.
Foundations		
Floors		
Roof		
Other		

Design Process

Who is involved with the design process?	None of the above
Roles of those involved in the design process	
Expertise of those involved in the design process	No special expertise . None .

Construction Process

Who typically builds this construction type?	Other

Roles of those involved in the building process	
Expertise of those involved in building process	No special expertise . None .
Construction process 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.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	No
Applicable codes or standards	
Process for building code enforcement	

Building Permits and Development Control Rules

Are building permits required?	No
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	

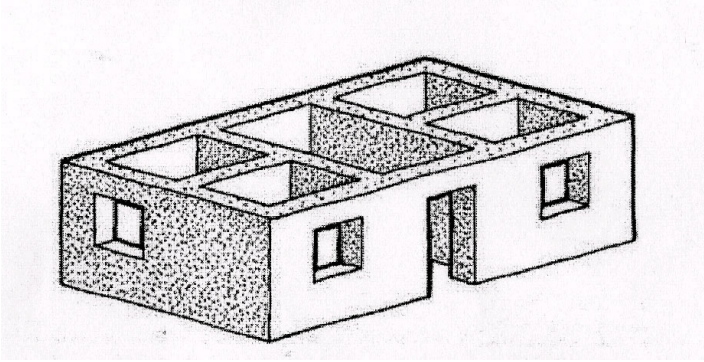
Building Maintenance and Condition

Typical problems associated with this type	

of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

Construction Economics

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



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

Socio-Economic Issues

Patterns of occupancy	Just one family, possibly with married son and daughter-in-law, lives in each unit .
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
Additional comments on number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	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 .
Typical Source of Financing	Owner financedPersonal savingsInformal network: friends or relativesSmall lending institutions/microfinance institutions
Additional comments on financing	
Type of Ownership	Own outrightOwn with debt (mortgage or other)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on premium discounts	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter

1990	Manjil
1997	Ardekul
2003	Bam

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	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 .
Additional comments on earthquake damage patterns	

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	FALSE

	foundation.	
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	FALSE
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.	FALSE
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	N/A

	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.	FALSE
Wall Openings		TRUE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
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	They are weak in the out of plane direction. The walls tips over or bend outwards.
Earthquake-resilient features in walls	There are no earthquake resistant features. If the adobe walls can be kept in place, the seismic performance of the building will improve significantly .
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	It is made of weak materials. If the walls move out of plane, the roof collapses.
Earthquake resilient features in roof and floors	The roof consists of arches and domes which provide integrity.
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					

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

Aerial view of roofs after Bam earthquake--multiple domes of each house are visible

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

Aerial view of complete destruction of adobe dwelllings in Bam earthquake

Aerial view of neighborhood with widespread damage to adobe

If walls can be kept in-plane, building typically survives. Adobe

structures in Bam earthquake

Bam earthquake: Damage to a traditional adobe house. Non-bearing walls collapsed, bearing walls are still standing

house in Bam earthquake

Bam earthquake: collapsed adobe structures

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

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Weak walls	In other countries, particularly Peru, add reinforced concrete, or add rope stitching
Weak walls	Dimensional constraints, bamboo

	reinforcement (Peru) or reinforced concrete overlay.

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	None in Iran .
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Not applicable .
Was the construction inspected in the same manner as new construction?	Not applicable .
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Not applicable .
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Not applicable .
Additional comments section 6	

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

References

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