World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Adobe houses

Report#	166
Last Updated	
Country	PAKISTAN
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Important

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General Information

Building Type:	Adobe houses
Country:	PAKISTAN
Author(s):	Sarosh Hashmat Lodi Abdul Jabbar Sangi Adam Abdullah
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in all over the country (Figure 1) and range in scale and techniques of construction from seasonal family shelters in arid desert areas of Thar, to the more permanent rural family houses of the Indus plains, to the relatively sturdy yet seismically prone multi-level residences in the Gilgit-Baltistan region. They are more common where good quality clay is readily available, such as the alluvial plains of Punjab and Sindh, and, in a limited quantity, the hilly regions of Gilgit-Bultistan or Kashmir. Adobe construction comprises a surprisingly large percentage of the built environment of Pakistan, standing at 14.6% [1] . This type of housing construction is commonly found in both rural and urban areas . Building with adobe is amongst the least expensive forms of construction in the country, and hence widely popular with the rural population of Pakistan. Although they contain absolutely no engineering input and are increasingly prone to earthquakes and floods, adobe houses are still the abode of choice for a large proportion of the rural population. Local masons and craftsmen have great expertise in handling adobe. Apart from its construction cost, adobe is also popular because of its exceptional properties of insulation, and so is used both in very hot as well as very cold regions. Figure 2 and 3 show the adobe bricks used in upper Sindh and typical adobe house in Larkana, Sindh, respectively. The external walls of adobe houses can be covered in a variety of finishes. These include plastering (in mud or cement), whitewashing on the plaster, and coating with lime or organic materials such as manure mixed with straw The aim of the external treatment is twofold to help bond the individual adobe blocks together against a smooth surface, and to protect the adobe blocks from absorbing heat directly. This layer of finish generally requires periodic repairs as wind, water, or extreme heat causes it to disintegrate and spall off. Despite these economic factors that influence the heavy usage of adobe in rural construction, adobe has some serious drawbacks. Apart from being seismically

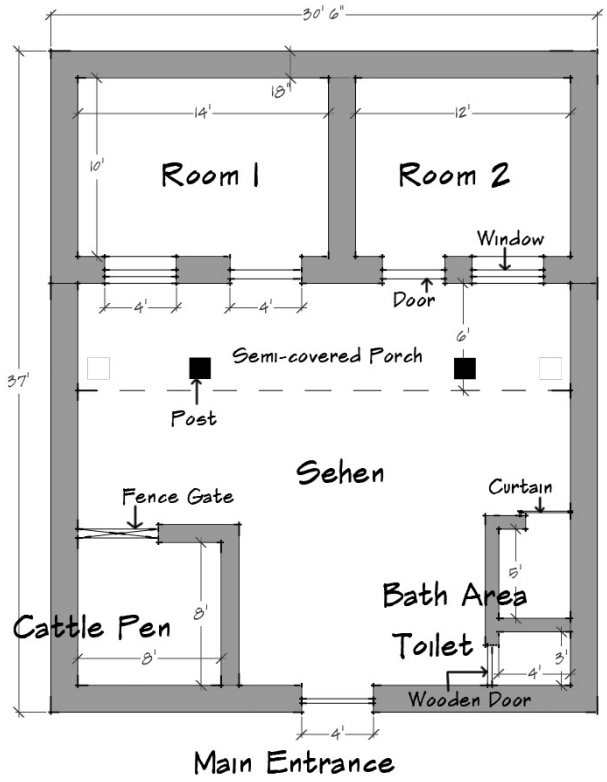
	inadequate, adobe structures tend to be highly prone to abrasion by wind and erosion by rising water levels. The seepage of subterranean moisture tends to weaken their foundations and plinth. Also, it is uncommon to see adobe structures beyond a single story height, except in the northern hilly regions, as adobe blocks have limited strength and can only support a lightweight roof. In Pakistan, adobe is the material of choice for the poorer rural population, who has a limited choice of material when it comes to economical construction.
Summary:	This report provides an overview of adobe housing construction, which is widely distributed all over the country. Adobe construction covers 14.6% of the total built environment of Pakistan. Majority of adobe houses comprise of single storey structures with adobe masonry walls and timber roofs with mud covering. The construction is carried out without any technical input and suffers from a number of weaknesses. Therefore, this construction type is highly vulnerable to seismic forces.
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:	Typically
Comments:	Adobe construction is limited to the rural areas of Pakistan. It may also be present in substantial numbers within the outskirts

Features

Plan Shape	Rectangular, with an opening in plan
Additional comments on plan shape	Adobe buildings normally have a rectangular or linear plan arrangement. The rooms are divided symmetrically on either side of the main axis, with a limited number of small and well-placed openings on walls. These features make the adobe house a robust, compact structure, but one that may still require seismic strengthening. Local appendages to adobe houses include an outhouse (separate toilet and bathroom), a sehen/verandah, and a semi-covered porch space in front of the main entrance, with an extension of roof beams that shade the porch. Figure 4 illustrates the plan of a typical adobe house in the rural areas of Sind and Punjab .

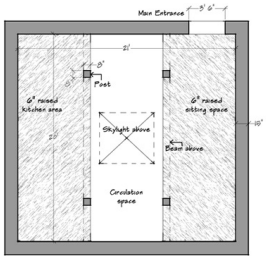
Typical plan length (meters)	4-5
Typical plan width (meters)	4-5
Typical story height (meters)	2.5
Type of Structural System	Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Adobe block walls
Additional comments on structural system	The vertical load-resisting system is earthen walls . The loads from the roof are transferred to the walls (adobe block masonry or earthen) and to the foundations . The lateral load-resisting system is earthen walls . The walls have a very low resistance to out-of-plane forces. There is no proper connection between the roof and the walls .
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	10-15%
Typical wall densities in direction 2	15-20%
Additional comments on typical wall densities	The typical structural wall density is up to 20 % . More precisely, typical structural wall density ranges from 10 to 15% .
Wall Openings	
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Buildings are open to incremental modification as resources become available, or as functional or climatic improvements including seasonal repairs after floods or earthquakes. It is not possible to add vertically to an adobe house, especially those with a light roof (chick reeds or plastic sheets). A small room or storage area may be added to one side-wall of the house, but care should be taken that it does not lean upon the main wall and cause it to tilt inwards .
Type of Foundation	Shallow Foundation: Wall or column embedded in soil, without footing
Additional comments on foundation	
Type of Floor System	Other floor system
Additional comments on floor system	
Type of Roof System	Roof system, other

Additional comments on roof system	The roof of a typical adobe house usually comprises of timber or bamboo with mud layer (Figure 7). Timber rafters covered with a layer of wooden reeds (chick), act as the main horizontal supporting members. A typical 100-150 mm thick layer of mud is applied. Where wood in not available, generally bamboo is used. New constructions may employ I-beams or steel girders instead of wooden planks with bamboo stalks. Another alternative roofing material is galvanized iron (GI) sheets supported on a light wooden truss system .
Additional comments section 2	Adobe construction is limited to the rural areas of Pakistan. It may also be present in substantial numbers within the outskirts of secondary cities or market towns as residences for daily wage workers and labourers. More precisely, adobe structures can be built on flat as well as moderately hilly terrain, but only rarely on rugged or steep slopes. Hence, it is common to find adobe houses in the villages of the Gilgit-Baltistan and Chitral region. The abundance of suitable clay in the vast alluvial plains of the Indus River makes adobe houses a common sight in Punjab and interior Sindh. Adobe houses are also built in parts of Baluchistan as rudimentary, semi-permanent shelters. Each adobe house is an independent unit. Adjacent houses are placed a considerable distance apart, and do not share common walls. Often, a group of houses may be clustered together and surrounded by a crude palisade wall made of dried grass or twigs. This organizes the colony into a single consolidated arrangement, complete with an enclosed communal space for children, women, and elders, keeping strangers and stray animals out of the enclosure When separated from adjacent buildings, the typical distance from a neighboring building is more than 10 meters.



Typical adobe house in rural areas of Sind and Punjab.

Typical adobe house in Village Vikia Sangi, Larkana.



Typical living room of an adobe house in Gilgit.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Adobe bricks with mud mortar	Not available 1:10:1 (Sand, Clay, Straw). The blocks are available in different sizes described below Detailed description given below .
Foundations	Adobe or Rubble stone or baked bricks	Not available Not available Detailed description given below .

Floors		
Roof	Roof is constructed from timber or bamboo with layer of mud.	Not available Not available Detailed description given below .
Other		

Design Process

Who is involved with the design process?	None of the above
Roles of those involved in the design process	Architects and engineers have no role in the design or construction of this housing type .
Expertise of those involved in the design process	This type of construction is generally carried out by unskilled persons and villagers without any technical input. Mostly, the construction is carried out by the owners themselves. In some cases local masons are involved who have acquired the basic knowledge through experience. However, there is no engineering or design involved.

Construction Process

Who typically builds this construction type?	Owner
Roles of those involved in the building process	Adobe houses are constructed by poor rural folk. They have little engineering knowledge but have mastered the art of mass-producing and laying adobe blocks using appropriate mortar and finishes. The builder is usually the owner of the house, who occupies it with his family when it is completed . Mostly, the construction is carried out by the owners themselves. In some cases local masons are involved who have acquired the basic knowledge through experience
Expertise of those involved in building process	This type of construction is generally carried out by unskilled persons and villagers without any technical input.
Construction process and phasing	Adobe houses are quite weak against the action of water, either in the form of heavy precipitation or flooding which erode the walls and damage the roof, or a rising water table which weakens the foundations and the plinth. The lower portion of walls is now constructed using baked brick in cement mortar, with a finish of cement based plaster. This helps reduce the disintegration of the plinth and lower wall when there is stagnant water. The rest of the wall can be mud brick with mud mortar and plaster. Furthermore, the walls can be made of burnt brick on the exterior face, and mud brick on the interior. Generally, a simple mud plaster is not an efficient binding agent. In this case, an external finish of cement sand plaster helps reduce abrasion. Adding lime to the plaster makes it more

	water resistant, as well as helps reflect heat back to the exterior . The construction of this type of housing takes place incrementally over time . Typically, the building is originally not 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	There is no specific code available to address this construction type.
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	Adobe houses are quite weak against the action of water, either in the form of heavy precipitation or flooding which erode the walls and damage the roof, or a rising water table which weakens the foundations and the plinth. Generally, a simple mud plaster is not an efficient binding agent. In this case, an external finish of cement sand plaster helps reduce abrasion. Adding lime to the plaster makes it more water resistant, as well as helps reflect heat back to the exterior . The most affected part of an adobe structure over the period of a year are its walls, the surfaces of which become cracked as plaster (or mud overlapping) dries or wears off, or becomes weak due to the action of rising water or erosion by wind. Foundations are also affected badly by rising water tables or stagnant water after heavy rainfall or a flood season, and need to be checked after the water has been drained. Roofs of adobe houses, containing a number of layers of different materials, are completely exposed to the adversities of nature, including the action of wind currents, harsh sunlight, and direct contact with precipitation, which

	reduces their stability as the year progresses.
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	The most affected part of an adobe structure over the period of a year are its walls, the surfaces of which become cracked as plaster (or mud overlapping) dries or wears off, or becomes weak due to the action of rising water or erosion by wind. Foundations are also affected badly by rising water tables or stagnant water after heavy rainfall or a flood season, and need to be checked after the water has been drained. Roofs of adobe houses, containing a number of layers of different materials, are completely exposed to the adversities of nature, including the action of wind currents, harsh sunlight, and direct contact with precipitation, which reduces their stability as the year progresses. Walls and roofs of adobe houses need to be periodically repaired, which means applying a fresh layer of plaster to the walls and roof in parts where plaster has cracked or withered away, to ensure that the house poses no imminent threat to human inhabitancy.

Construction Economics

Unit construction cost	The cost of construction is roughly Rs. 1,000 per m2 (US$ 10.00) .
Labor requirements	The construction of a typical housing unit takes approximately 2 to 3 months to complete.
Additional comments section 3	

Adobe house roof - interior. Timber planks with bamboo stalks supporting wooden chick.

Socio-Economic Issues

Patterns of occupancy	Each building typically has 1 housing unit(s). Adobe houses act as single family residence only or may house a small extended family, as each house usually has just one or two rooms (bed/store). The number of inhabitants in a building during the day or business hours is others (as described below) . The number of people in each house varies from 2-8, ranging over two or three generations. As sons in the family grow to a marriageable age, they may choose to build a separate unit for themselves, either as an appendage to the existing building or an independent structure a small distance away from it . An adobe house contains one rural family, which typically consists of a few working men, womenfolk, and elders. The house is inhabited by womenfolk and the elderly during the daytime, while children use the attached semi-covered or open court as play space. The external court is also used by women for additional household chores like washing and drying out laundry, and cooking if an appropriate indoors cooking space is not available. This helps in the elimination of harmful fumes from the interior living spaces as well. Men arrive later in the evening or towards nightfall, and the family spends time socializing in the open verandah till dusk. Activities include eating, drinking tea, smoking hookah pipes, and exchanging the day s stories. The inhabitants move into the covered interior spaces as night closes in. During severe climatic conditions, like extreme heat or heavy rain, inhabitants retreat indoors. Otherwise, the indoor spaces are used primarily for sleeping and storage of precious belongings .
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	5-10
Additional comments on number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)
Additional comments on economic level of inhabitants	Adobe houses are the primary choice of residence for low income households of single families. Men build new houses for themselves as they marry and become independent from their extended family. The new house is usually located within close proximity to the original family home, which eventually results in a cluster of single-family homes on the same parcel of land, sometimes enclosed

	by a rudimentary boundary wall made out of dead or dried branches .
Typical Source of Financing	Owner financedPersonal savingsInformal network: friends or relatives
Additional comments on financing	
Type of Ownership	Own outrightOwn with debt (mortgage or other)Units owned individually (condominium)
Additional comments on ownership	Men (heads of the family) own the house, and it is common practice for the sons to build their own houses once independent, as space is very limited within an adobe house (2-3 rooms). In some rural areas, the landlord owns all the land that the worker family lives on, and so a new house may be built on lease or with loans from the landlord. The house then remains the property of the landlord, being leased to the occupants for a defined period of time (e.g. for the harvest season, or for one summer, etc.). These kinds of temporary houses may employ lighter roofs or vertical supports such as bamboo stalks, items that the family can carry away to rebuild somewhere else once their agreement with the landlord expires .
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
1819	Allahbund, Sindh

1852	Kahan, Balochistan
1892	Qilla Abdullah, Balochistan
1909	Sibi, Balochistan
1931	Sharigh Valley, Balochistan
1935	Quetta, Balochistan
1945	Pasni, Makran
2005	Kashmir
2008	Ziarat, Balochistan
2011	Dalbandin, Baluchistan

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Indian plate upon which Pakistan, India and Nepal lie, is continuously moving northward and sub-ducting under the Eurasian plate, thus triggering earthquakes in the process and forming Himalayan mountains. Within the Suleiman, Hindu Kush and Karakoram mountain ranges, the Northern Areas and Chitral district in NWFP, Kashmir including Muzaffarabad, and Quetta, Chaman, Sibi, Zhob, Khuzdar, Dalbandin, the Makran coast including Gwadar and Pasni in Balochistan are located in high or very high risk areas. Cities of Islamabad, Karachi and Peshawar are located on the edges of high risk areas. Figure 8 shows the seismic zoning map of Pakistan, which was developed after 2005 Kashmir earthquake [2]. A large number of major earthquakes have hit Pakistan in 20th Century including: 1935 Quetta earthquake, 1945 Makran coast earthquake, 2001 Bhuj earthquake and 2005 Kashmir earthquake [3]. Figure 9 and 10 show the total collapse of adobe houses in Ziarat 2008 Earthquake and Dalbandin 2011 earthquake in Balochistan. .

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 foundation.	FALSE
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.	N/A
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.	FALSE
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 elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	FALSE
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		FALSE
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

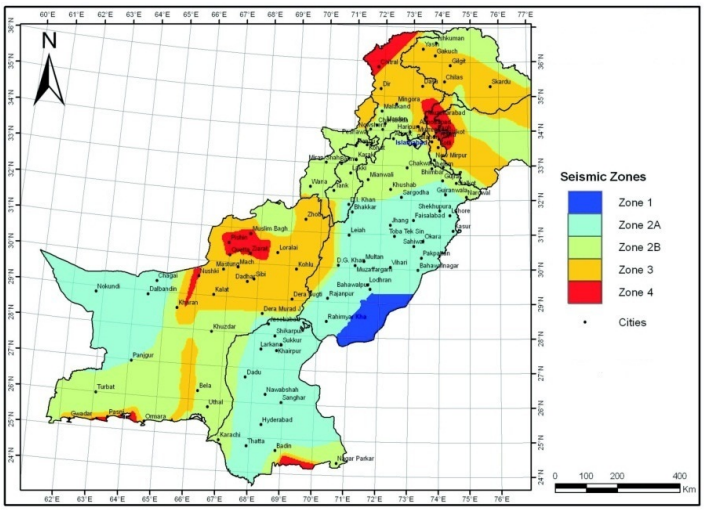
Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Poor lateral resistance, weak in out of plane direction, no lintel band, improper opening proportions Earthquake Damage Patterns: Collapse of wall due to out of plane effects and shear

Earthquake-resilient features in walls	There are no earthquake resistant features.
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Heavy dead loads (5-6 inch mud layer usually topped up every year), no connection between roof elements and walls, lack of diaphragm action. Earthquake Damage Patterns: Collapse of roof due to out of plane failure of walls.
Earthquake resilient features in roof and floors	
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					



Seismic zoning map of Pakistan [2].

Total collapse of adobe houses during the Ziarat earthquake in 2008.


Typical damage caused by the Dalbandin earthquake in 2011.

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening

Additional comments on seismic strengthening provisions	There are no specific set of provisions available for seismic strengthening and retro-fitting of adobe houses .
Has seismic strengthening described in the above table been performed?	Not applicable.
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	

References

Seismic Vulnerability Assessment of Existing Buildings of Pakistan Lodi, S.H., N. Alam, and M. Ahmed (2012) Earthquake Model for Middle East Region (EMME) - Work Package 4 - Department of Civil Engineering, NED University of Engineering & Technology, Karachi, Pakistan (Unpublished).

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