
World Housing Encyclopedia

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



an initiative of
Earthquake Engineering Research Institute (EERI) and
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HOUSING REPORT

Stone masonry residential buildings

Report #	138
Report Date	26-05-2007
Country	PAKISTAN
Housing Type	Stone Masonry House
Housing Sub-Type	Stone Masonry House : Rubble stone without/with mud/lime/cement mortar
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Important

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John A. Martin & Associates, Inc. or the participants' organizations.

Summary

In the Northern part of Pakistan, which mostly consists of mountainous terrain and where building stones are more abundantly available than any of the alternate building material, people commonly construct single story stone masonry buildings for residential purpose. A variety of building typologies are in use. An approximate distribution of common types of such buildings is:- Stone masonry houses without mortar with earthen roof (Fig 1a). 10% Stone

masonry houses in mud mortar with earthen roofs (Fig 1c). 40% Stone masonry houses in cement mortar with earthen roof (Fig 1d). 10% Stone masonry houses in cement mortar with G.I. Sheet roof (Fig 1f). 30% Stone masonry houses with R.C roofing (Fig 1g) 10%. Construction of houses in rubble stone masonry, in dry or in mud mortar, was most common and was generally practiced in the past in these areas. It is still in practice in most construction. Presently, among all, about 50% of the buildings are of this type. In new construction mud mortar is steadily being replaced with cement mortar. Wall thickness in all cases usually varies from 1 to 1 ½ ft. Roofs are usually earthen and generally consist of thatch covered with mud/earth and supported on wooden beams (or logs) and rafters. Some time wooden columns are also provided beneath the beams along the walls or in between the walls to support the roofing. Wooden rafters, planks and G.I. sheets are also used in modern construction for roofing. Any particular or regular layout is not used for construction of these residential buildings. It varies depending on the available space. Size of the building also varies from a single room to more than one room as per requirement of the family (Figs 3a--3c). These structures are considered, from experience, to be strong enough to withstand the applied gravity loads, but their seismic performance has not properly been investigated and is believed to be vulnerable to earthquake of even moderate shaking, particularly when confining elements such as wooden columns are not used. In a typical type of construction, historically known to be well resistant to seismic effects, horizontal and vertical wooden members are provided in the walls. These horizontal and vertical members are inter-connected at corners and other locations through wooden nails. The remaining space of the wall is then built in stone masonry of any type. This type of construction was commonly practiced in remote North parts of this region in the past and is still in practice for improved seismic performance in some of the buildings (figs 5a--5e).

1. General Information

Buildings of this construction type can be found in the Northern mountainous parts of Pakistan where the percentage of this type of construction may exceed 80% of the total residential building stock. This type of housing construction is commonly found in both rural and sub-urban areas.

Stone masonry is basically general practice for residential building construction in both rural and urban areas. The form and type varies with locality. In cities however the new trend is to use RCC frame structures instead of stone masonry.

This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. It is not known exactly as to how long this construction type has been practiced. It is believed that this type has been practiced at least 200 years.



Figure 1 (a): A view of typical stone masonry house constructed in dry (without any mortar) with earthen roof.

Figure 1: Typical stone masonry house, mud



Figure 1 (b): A view of under construction stone masonry house in dry.

Figure 2: Stone masonry without mortar under



Figure 1 (c): A view of typical stone masonry wall constructed in mud mortar.

Figure 3: View of typical stone masonry wall

mortar w with earthen roof.



Figure 1 (d). A view of typical stone masonry house constructed in cement sand mortar with earthen roof.

Figure 4: Typical stone masonry house constructed in cement sand mortar with earthen roof

construction



Figure 1 (f). A view of under construction stone masonry house in cement sand mortar with wooden truss and G.I. Sheet roof.

Figure 5: Stone masonry house under construction with cement sand mortar with wooden truss and G.I. Sheet roof

construction, with mud mortar



Figure 1 (g). A view of stone masonry house constructed with dressed stones in cement sand mortar having R.C.C. roof.

Figure 6: Stone masonry house with dressed stones in cement sand mortar with RCC roof



Figure 7: A wooden column in the center of a room, in addition to the main stone masonry walls, is provided to support roof gravity load

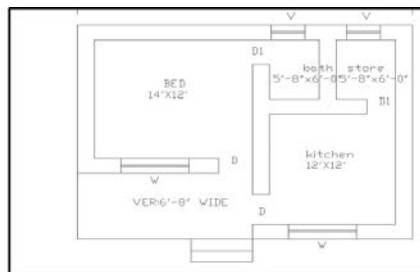


Figure 3 (a). Plan of a typical building-1.

Figure 8: Plan of a typical building

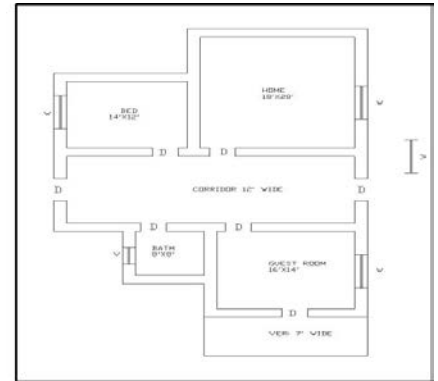


Figure 3 (b). Plan of a typical building-2.

Figure 9: Plan of a typical building-2

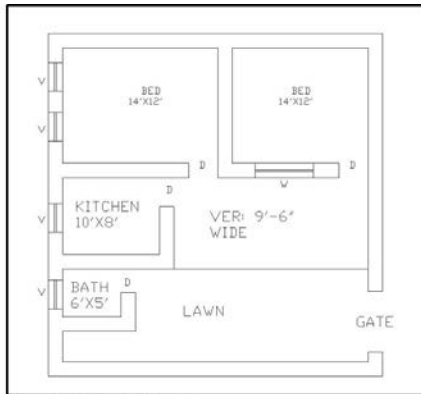


Figure 3 (c). Plan of typical building-3.

Figure 10: Plan of typical building-3

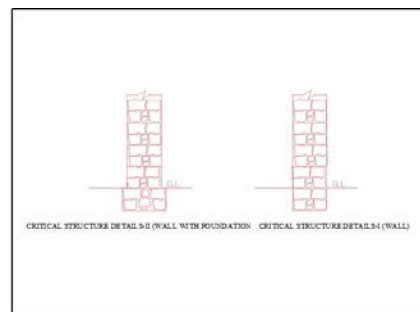


Figure 4 (a). Typical wall section.

Figure 11: Typical wall section



Figure 4 (b). Typical wall section, photo of a damage wall from October 08, 2005 earthquake 2005; two wythes & central portion of wall are clearly visible.

Figure 12: Damaged wall from October 8 2005 earthquake. Two wythes and central portion of wall are clearly visible.

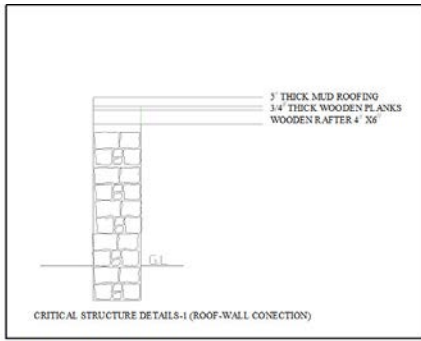


Figure 4 (c): Roof wall connection.

Figure 13: Roof wall connection



Figure 5 (a): An old house with wooden seismic bands.

Figure 14: An old house with wooden seismic bands



Figure 5 (b): A historical three story building, with single room at each floor, well standing the past seismic events.

Figure 15: A historical three story building, with single room at each floor; well standing the past seismic events



Figure 5 (c): A recently built stone masonry house in cement sand mortar and earthen roof; horizontal and vertical wooden bands are clearly visible.

Figure 16: A recently built stone masonry house in cement sand mortar and earthen roof; horizontal and vertical wooden bands are clearly visible



Figure 5 (d): Inner close view of building in fig 5 c.

Figure 17: Inner close view of building in previous figure (fig 5 c)



Figure 5 (e): An under construction house, being built with wooden seismic bands.

Figure 18: A house under construction, being built with wooden seismic bands



Figure 6 (a): Typical corner failure of a stone masonry house in mud mortar with earthen roof; Pakistan earthquake of October 08, 2005.

Figure 19: Typical corner failure of a stone masonry house in mud mortar with earthen roof; Pakistan earthquake of October 08, 2005



Figure 6 (b): Out-of-plane failure of stone masonry in dry; Pakistan earthquake of October 08, 2005

Figure 20: Out-of-plane failure of stone masonry with no mortar; Pakistan earthquake of October 08, 2005



Figure 6 (c): Gable wall failure; Pakistan earthquake of October 08, 2005.

Figure 21: Gable wall failure: Pakistan earthquake of October 08, 2005



Figure 6 (d): Debris of buildings collapsed due to lateral thrust in addition to seismic forces. Note a building in the background with rigid diaphragm is still standing; Pakistan earthquake of October 08, 2005.

Figure 22: Debris of buildings collapsed due to



Figure 6 (e): Out of plane bending failure of masonry walls due to additional thrust from roof trusses; Pakistan earthquake of October 08, 2005.

Figure 23: Out of plane bending failure of masonry walls due to additional thrust from roof trusses; Pakistan earthquake of October 08, 2005



Figure 6 (f): Slippage of top course of masonry; Pakistan earthquake of October 08, 2005.

Figure 24: Slippage of top course of masonry; Pakistan earthquake of October 08, 2005

lateral thrust in addition to seismic forces. Note a building in the background with rigid diaphragm is still standing; Pakistan earthquake of October 08, 2005



Figure 25: Seismic strengthening technique; column repaired after the earthquake

Figure 25: Seismic strengthening technique; column repaired after the earthquake



Figure 26: Seismic strengthening techniques; column repaired after the earthquake

Figure 26: Seismic strengthening techniques; column repaired after the earthquake



Figure 27: Seismic strengthening techniques; horizontal and vertical wooden bands introduced after the earthquake

Figure 27: Seismic strengthening techniques; horizontal and vertical wooden bands introduced after the earthquake

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. A typical separation distance between buildings cannot be specified. Sometimes there may be no separation while in isolated dwellings, separation distance may be up-to 1/2 km or even more.) When separated from adjacent buildings, the typical distance from a neighboring building is 0-500 meters.

2.2 Building Configuration

Variable configurations are used to suit requirements. Rectangular buildings are most common practice. L-shape is also constructed. In some cases isolated rooms on 2 or 3 sides of an open terrace are constructed for a single housing unit. Usually one door and one or two windows in each room are provided. In present day practice standard size doors (3 ft x 7 ft) and windows (3 x 4 to 6 x 4 ft) are provided. In past practice small doors and windows were used. Doors up-to 4 1/2 ft height and windows of 1 x 2 to 2 x 2 ft were commonly used in traditional houses in the remote northern part of this region. A small opening (usually 1 x 1 ft size) in the roof was also provided for the purpose of both lighting and fire smoke ventilation.

2.3 Functional Planning

The main function of this building typology is single-family house. Normally used for single or joint families consisting of families of real brothers or paternal cousins. In a typical building of this type, there are no elevators and no fire-protected exit staircases. The main opening provided for the purpose of access to the room is the only

mean of escape in these buildings.

2.4 Modification to Building

Generally these houses are not modified. Additional rooms are constructed horizontally when so required.

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)	<input checked="" type="checkbox"/>
		2	Dressed stone masonry (in lime/cement mortar)	<input type="checkbox"/>
	Adobe/ Earthen Walls	3	Mud walls	<input type="checkbox"/>
		4	Mud walls with horizontal wood elements	<input type="checkbox"/>
		5	Adobe block walls	<input type="checkbox"/>
		6	Rammed earth/Pise construction	<input type="checkbox"/>
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	<input type="checkbox"/>
		8	Brick masonry in mud/lime mortar with vertical posts	<input type="checkbox"/>
		9	Brick masonry in lime/cement mortar	<input type="checkbox"/>
		10	Concrete block masonry in cement mortar	<input type="checkbox"/>
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	<input type="checkbox"/>
		12	Clay brick masonry, with concrete posts/tie columns and beams	<input type="checkbox"/>
		13	Concrete blocks, tie columns and beams	<input type="checkbox"/>
	Reinforced masonry	14	Stone masonry in cement mortar	<input type="checkbox"/>
		15	Clay brick masonry in cement mortar	<input type="checkbox"/>
		16	Concrete block masonry in cement mortar	<input type="checkbox"/>
Structural concrete	Moment resisting frame	17	Flat slab structure	<input type="checkbox"/>
		18	Designed for gravity loads only, with URM infill walls	<input type="checkbox"/>
		19	Designed for seismic effects, with URM infill walls	<input type="checkbox"/>
		20	Designed for seismic effects, with structural infill walls	<input type="checkbox"/>
		21	Dual system – Frame with shear wall	<input type="checkbox"/>
	Structural wall	22	Moment frame with in-situ shear walls	<input type="checkbox"/>
		23	Moment frame with precast shear walls	<input type="checkbox"/>
		24	Moment frame	<input type="checkbox"/>
		25	Prestressed moment frame with shear walls	<input type="checkbox"/>
		26	Large panel precast walls	<input type="checkbox"/>

	Precast concrete	27	Shear wall structure with walls cast-in-situ	<input type="checkbox"/>
		28	Shear wall structure with precast wall panel structure	<input type="checkbox"/>
Steel	Moment-resisting frame	29	With brick masonry partitions	<input type="checkbox"/>
		30	With cast in-situ concrete walls	<input type="checkbox"/>
		31	With lightweight partitions	<input type="checkbox"/>
	Braced frame	32	Concentric connections in all panels	<input type="checkbox"/>
		33	Eccentric connections in a few panels	<input type="checkbox"/>
	Structural wall	34	Bolted plate	<input type="checkbox"/>
35		Welded plate	<input type="checkbox"/>	
Timber	Load-bearing timber frame	36	Thatch	<input type="checkbox"/>
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	<input type="checkbox"/>
		38	Masonry with horizontal beams/planks at intermediate levels	<input type="checkbox"/>
		39	Post and beam frame (no special connections)	<input type="checkbox"/>
		40	Wood frame (with special connections)	<input type="checkbox"/>
		41	Stud-wall frame with plywood/gypsum board sheathing	<input type="checkbox"/>
		42	Wooden panel walls	<input type="checkbox"/>
Other	Seismic protection systems	43	Building protected with base-isolation systems	<input type="checkbox"/>
		44	Building protected with seismic dampers	<input type="checkbox"/>
	Hybrid systems	45	other (described below)	<input type="checkbox"/>

The most popular practice is to use rubble stone masonry in mud mortar or without mortar (dry masonry) with wooden roofs, with or without using wooden columns to support roofing.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). The masonry walls and wooden columns, if provided, act as load bearing elements. The walls and wooden columns in turn transfer the load to the ground either directly or through the foundation.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). The lateral load resisting system consists of masonry walls and wooden columns also contribute, if they are provided.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 8 and 15 meters, and widths between 5 and 12 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 3.5 meters. The typical storey height in such buildings is 3.2 meters. The typical structural wall density is more than 20%. 15% - 25%.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof

Masonry	Vaulted	<input type="checkbox"/>	<input type="checkbox"/>
	Composite system of concrete joists and masonry panels	<input type="checkbox"/>	<input type="checkbox"/>
Structural concrete	Solid slabs (cast-in-place)	<input type="checkbox"/>	<input type="checkbox"/>
	Waffle slabs (cast-in-place)	<input type="checkbox"/>	<input type="checkbox"/>
	Flat slabs (cast-in-place)	<input type="checkbox"/>	<input type="checkbox"/>
	Precast joist system	<input type="checkbox"/>	<input type="checkbox"/>
	Hollow core slab (precast)	<input type="checkbox"/>	<input type="checkbox"/>
	Solid slabs (precast)	<input type="checkbox"/>	<input type="checkbox"/>
	Beams and planks (precast) with concrete topping (cast-in-situ)	<input type="checkbox"/>	<input type="checkbox"/>
	Slabs (post-tensioned)	<input type="checkbox"/>	<input type="checkbox"/>
Steel	Composite steel deck with concrete slab (cast-in-situ)	<input type="checkbox"/>	<input type="checkbox"/>
Timber	Rammed earth with ballast and concrete or plaster finishing	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams with ballast and concrete or plaster finishing	<input type="checkbox"/>	<input type="checkbox"/>
	Thatched roof supported on wood purlins	<input type="checkbox"/>	<input type="checkbox"/>
	Wood shingle roof	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams that support clay tiles	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams supporting natural stones slates	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	<input type="checkbox"/>	<input type="checkbox"/>
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	<input type="checkbox"/>	<input type="checkbox"/>
Other	Described below	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Rammed Earth . Rammed earth floors in traditional houses and PCC floor in modern houses are normally practiced. Occasionally wooden floor are also constructed in special rooms (i.e. sitting rooms for guests or room used for storage of house commodities etc). Wooden covered with mud and earth.

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	<input checked="" type="checkbox"/>
	Rubble stone, fieldstone isolated footing	<input type="checkbox"/>
	Rubble stone, fieldstone strip footing	<input type="checkbox"/>
	Reinforced-concrete isolated footing	<input type="checkbox"/>
	Reinforced-concrete strip footing	<input type="checkbox"/>
	Mat foundation	<input type="checkbox"/>
	No foundation	<input type="checkbox"/>
Deep foundation	Reinforced-concrete bearing piles	<input type="checkbox"/>
	Reinforced-concrete skin friction piles	<input type="checkbox"/>
	Steel bearing piles	<input type="checkbox"/>
	Steel skin friction piles	<input type="checkbox"/>
	Wood piles	<input type="checkbox"/>
	Cast-in-place concrete piers	<input type="checkbox"/>
	Caissons	<input type="checkbox"/>

Other	Described below	<input type="checkbox"/>
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Walls are directly supported on soil without footings in traditional practice. Wooden columns are directly rested on a stone block of comparatively larger size which in turn rests on soil. In modern practice a regular step footing (one or two steps) is provided on plain concrete bedding.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 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 5-10.

4.2 Patterns of Occupancy

A single family or an extended family typically occupies one house or housing unit. The number of inhabitants in a family (single or extended) in most cases exceeds 10.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	<input checked="" type="checkbox"/>
b) low-income class (poor)	<input checked="" type="checkbox"/>
c) middle-income class	<input checked="" type="checkbox"/>
d) high-income class (rich)	<input type="checkbox"/>

Roughly about 20% of the population falls in the category of very poor, 65% poor and 15% middle class. 1% among middle class may be approximately rated as rich.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	<input type="checkbox"/>
4:1	<input type="checkbox"/>
3:1	<input type="checkbox"/>
1:1 or better	<input checked="" type="checkbox"/>

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

other (explain below)	<input type="checkbox"/>
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Residential buildings are constructed by personal savings in most cases. Relatives and friends contribute in cash, kind, labour and materials in deserving cases. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) including toilet(s).

One bathroom is usually provided with each housing unit particularly for use of female members. Providing latrine in the housing unit is not general practice in rural areas. Open fields in the vicinity of houses are used for the purpose. In the present day practice latrine/bathroom are constructed in the new houses. In cities one or two bathrooms and latrines are constructed as per requirement of the family. .

4.4 Ownership

The type of ownership or occupancy is outright ownership.

Type of ownership or occupancy?	Most appropriate type
Renting	<input type="checkbox"/>
outright ow nership	<input checked="" type="checkbox"/>
Ow nership with debt (mortgage or other)	<input type="checkbox"/>
Individual ow nership	<input type="checkbox"/>
Ow nership by a group or pool of persons	<input type="checkbox"/>
Long-term lease	<input type="checkbox"/>
other (explain below)	<input type="checkbox"/>

The houses are owned as common property of the family and are legally divided among the owners/heirs in accordance with the general rule of law practiced, whenever families are separated. The ownership of the house is thus transferred but remains within the family. Therefore the ownership can be categorized as "owned outright".

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.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Building Configuration	The building is regular with regards to both the plan and the elevation.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
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.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
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.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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);	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than 1/2 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.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Additional Comments				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Poor quality of mud, excessive thick mud joints, and poor quality of construction.	Wooden horizontal bands and vertical wooden posts within the walls	In-plane shear and out-of-plane failure of walls
Frame(Columns, Beams)	N/A	N/A	N/A
Roof and Floor	Parts of the roof are not properly connected so each part acts independently without any integrity.		Collapse
Other			

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
	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1972	Sept.13. Hamaran (Hindu Kush)	6.3	VIII*
1974	Dec. 28. Pateen Valley (Hindu Kush)	5.9	VII*
1981	Sept. 12. Darel Valley (Hindu Kush)	6.1	VII*
2002	Nov. 01 Raikot Valley (Himalayas)	5.3	VI*
2002	Nov20 Raikot valley (Himalayas)	6.5	VIII*
2005	Oct 08 Muzafarabad (Himalayas)	7.6	IX-X

An earthquake of Magnitude $M_w = 7.6$ occurred on October 8, 2005 at 08:50 am local time causing damage and casualties over an area of 30,000 km² in the N-W.F.P. province of Pakistan and parts of Pakistan administered Kashmir. The main event was followed by more than 978 aftershocks of Magnitude $M_w = 4.0$ and above, till October 27, 2005. The epicenter of the main earthquake was located at latitude of 34° 29' 35" N and longitude of 73° 37' 44" E. The focal depth of the main earthquake was determined to be 26 km (USGS). This was the deadliest earthquake in the recent history of the sub-continent with more than eighty thousand casualties, two hundred thousand injured, and more than 4 million people were left homeless. The adverse effects of this earthquake are estimated to be more than those of the tsunami of December 2004. The major cities and towns affected were Muzafarabad, Bagh and Rawlakot in Kashmir and Balakot, Shinkiari, Batagram, Mansehra Abbotabad, Murree and Islamabad in Pakistan. A significant number of casualties and injuries in the affected regions were associated with the total collapse of single story unreinforced stone masonry buildings. The stone masonry walls consisted of irregularly placed undressed stones, mostly rounded, that were laid in cement sand, mud mortar or even dry in some cases.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/ dimensions	Comments
Walls	Stone, mud mortar, cement sand mortar		In case of cement mortar 1:8 to 1:10 is used	No experimental work has been done for determination of mechanical properties of such type of stone masonry.
Foundation	Stone, mud mortar, cement sand mortar		In case of cement mortar 1:8 to 1:10 is used	No experimental work has been done for determination of mechanical properties of such type of stone masonry.
Frames (beams & columns)				No experimental work has been done for determination of mechanical properties of such type of stone masonry.
Roof and floor(s)	Wood, earth			No experimental work has been done for determination of mechanical properties of such type of stone masonry.

6.2 Builder

Usually the owner himself is the builder and typically lives in the same building.

6.3 Construction Process, Problems and Phasing

In most cases the owners arrange material at site. Skilled labour (mason, carpenters etc) and unskilled labour are engaged to do the work on daily wages or lump-sum basis. Walls are generally constructed of stone laid dry, or in mud and rest on soil directly usually at a shallow depth (1-2 ft) without a foundation. A wooden roof rests directly on walls. To add to the stability wooden columns below beams are occasionally provided. 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 takes place over time according to the availability of resources.

6.4 Design and Construction Expertise

Design is not practiced. Skilled labourers for each component of the work are expert in their job through experience and practice. The owner hires these expert 'skilled labourers' to carry out the construction work. No role for either Engineers or Architects.

6.5 Building Codes and Standards

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

No practice or attempt is made to enforce building codes.

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 development control rules do not exist and therefore are not enforced so anyone can construct any type of residential building. 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). Maintenance is usually not required. In the case where any damage occurs, it is repaired. When the building reaches its serviceable life, it is dismantled and reconstructed.

6.8 Construction Economics

2400 - 5400 PRs/m² (40 - 90 \$US/m²). 2 to 5 man-days of skilled labour (mason, carpenter etc) and 8 to 12 unskilled labour will be required per m² of this type of construction.(i.e. if 4 skilled and 10 unskilled labours are engaged to construct a house of this type with 100 m² cover area they will complete it in 2 to 4 months.).

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. No earthquake insurance is available.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

The area is seismically very active. Earthquake in the past have caused damage in different localities. Being scattered, far-flung, and mountainous no documentation of such type of damage in the area is recorded and available. No defined retrofit (or strengthening) practice is known except only making a stronger component than that damaged in the earthquake through reconstruction or new construction, fig 7 (a) though 7 (c).

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?

No design method is practiced. The trend is to make stronger components than those damaged previously.

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

NA.

8.3 Construction and Performance of Seismic Strengthening

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

NA.

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

NA.

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

NA.

Reference(s)

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