World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Stone Masonry Building : Rubble stone masonry/dressed stone masonry

Report#	176
Last Updated	
Country	Pakistan
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Important

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General Information

Building Type:	Stone Masonry Building : Rubble stone masonry/dressed stone masonry
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 Pakistan. Stone buildings are commonly found in the northern mountainous regions where stone is available in abundance, such as parts of Gilgit-Baltistan and Khyber-Pakhtunkhwa, the northern parts of Baluchistan, and a limited number of sites in Punjab and Sindh. Some stone buildings also exist in colonial cities like Karachi, built by the British for administrative or religious purposes. These structures have now been declared as heritage buildings and are being used for government and administrative offices. This type of housing construction is commonly found in both rural and urban areas. Stone masonry buildings for residential purposes are mostly found in the northern areas as stone is not readily available in Punjab, Baluchistan, and Sindh as a convenient construction material.
Summary:	This report provides an overview of stone masonry housing construction, which is generally found in northern areas of Pakistan. Stone masonry covers 5.2% of the total built environment of Pakistan. Stone masonry construction is the most common type in the northern areas and Kashmir and ranges from one-storey houses to two- to three-storey buildings. The construction is generally carried out without any technical input. There are no guidelines and provisions available to regulate it; therefore, it

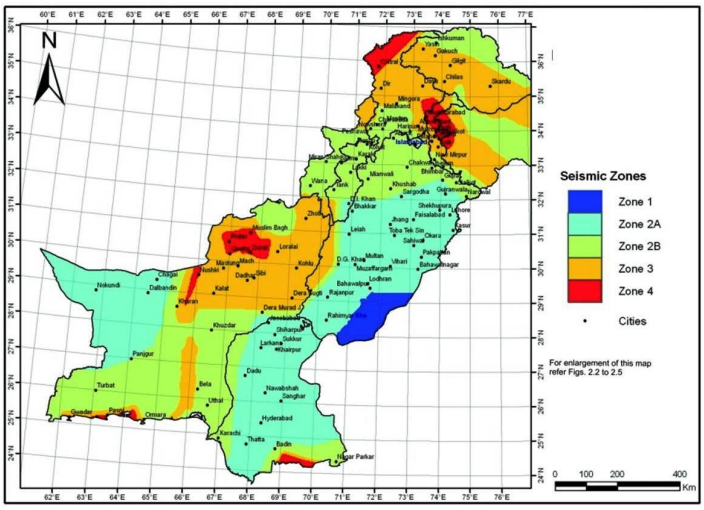
	suffers from a number of weaknesses. This construction type is highly vulnerable to seismic forces.
Length of time practiced:	76-100 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling; Institutional housing
Typical number of stories:	
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	Currently, this type of construction is still being constructed and around 5.2% of the existing building stock of Pakistan compr

Features

Plan Shape	Rectangular, solid; L-shape
Additional comments on plan shape	As stone is a very durable material, various building configurations can be worked out with varying wall thicknesses. It is however always advisable to keep the building as a regular, rectangular shape, with a symmetrical distribution of habitable spaces, as this helps transfer loads more effectively to the foundation, and prevents uneven distribution of lateral loading. L-shaped plans are also common, where the main wing is a longer rectangular section, and a smaller perpendicular appendage exists. Detached rooms may also exist within the large building complex, housing separate functions, like an outhouse, a storage shed, or an animal shelter .Spatial planning within stone masonry houses is rudimentary, and based on direct practical needs. Intimate spaces like bedrooms are docked to the rear, while moresocial, active spaces like dining or a living space are provided closer to the entrance lobby, in a centralized arrangement. A stone house may be as small as one room, which would then contain a bed, kitchenette, and a small sitting area within a shared space. Where the number of rooms is larger, functional planning for exclusive purposes becomes more evident. In a typical building of this type, there are no elevators and no fire-protected exit staircases.
Typical plan length	

Typical plan length (meters)	15-Oct
Typical plan width (meters)	15-May
Typical story height (meters)	3
Type of Structural System	Masonry: Stone Masonry Walls: Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)Masonry: Stone Masonry Walls: Massive stone masonry (in lime/cement mortar)
Additional comments on structural system	The vertical load-resisting system is stone masonry walls. The loads from the roof are transferred to the walls and to the foundations. Sometimes, wooden columns are provided inside the houses, which will be part of the gravity load-resisting system. The lateral load-resisting system is stone masonry walls. The walls have a very low resistance to out of plane forces. In most cases, there is no proper connection between the roof and the walls.
Gravity load-bearing & lateral load-resisting systems	The typical span of the roofing/flooring system is 3-5 meters. The typical storey height in such buildings is 3 meters.
Typical wall densities in direction 1	0-1%
Typical wall densities in direction 2	0-1%
Additional comments on typical wall densities	The typical structural wall density is none.
Wall Openings	Each room has one or two windows that open to the exterior. Windows do not usually open up to interior spaces.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Stone is a heavy, rigid material of construction. It is not common to add more stories to an already existing stone building, but slight adjustments, like the addition of another room to one side of the house, may occur. This usually springs from a need to create additional guest rooms, or as the family expands. It is more common for family members to construct a separate, standalone structure some distance away from the house on the same plot

	rather than construct an adjacent room.
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone strip footing
Additional comments on foundation	The foundations are stone masonry wall footings laid in mud or cement sand mortar, generally wider than the wall. In some cases, the walls may be directly resting on the soil without footing.
Type of Floor System	Other floor system
Additional comments on floor system	Single story stone masonry houses generally have a roof comprising of wooden truss and sheets. Wood planks or beams are also used which are covered with a layer of mud. RC roofs are also being used in urban areas.
Type of Roof System	Roof system, other
Additional comments on roof system	Single story stone masonry houses generally have a roof comprising of wooden truss and sheets. Wood planks or beams are also used which are covered with a layer of mud. RC roofs are also being used in urban areas.
Additional comments section 2	



Seismic zone map of Pakistan

Collapse of stone masonry buildings with hipped roofs in the 2005 Kashmir earthquake [4].

Collapse of roof structures due to the loss of gravity load-bearing capacity of stone walls in the 2005 Kashmir earthquake: reinforced concrete roof [4].

Collapse of roof structures due to the loss of gravity load-bearing capacity of stone walls in the 2005 Kashmir earthquake: reinforced concrete roof [4].

Out-of-plane collapse of walls in northern areas of Pakistan in Kashmir 2005 earthquake [4].

Out-of-plane collapse of stone masonry walls in a building with flexible roof and inadequate wall-to-roof connections in the 2005 Kashmir earthquake [4].

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Stone with mud mortar or cement sand mortar	Mix Proportions 1:10 cement and sand. Walls are made entirely of stone, either rough or dressed. Dressed stone is much more expensive,

		harder to craft, and so is used by the more affluent residents of the region. When using dressed stone, only the internal sides of walls need to be plastered. When using rubble stone, both the interior and exterior sides need plastering. Typical stone masonry walls are shown in Fig 9. Stone walls may or may not employ mortar. Where they do, mud is the primary choice, as it is economical and can be easily acquired. Mud mortar is also preferred for its better insulating capabilities as compared to cement. For this reason, the layer of mud mortar may be up to 4 in. thick. Stone buildings that do not employ mortar in the walls are unsafe for general residential purposes, and so may be used as storage sheds or as animal shelters. The thickness of stone walls can vary according to the size of stones used. Generally, walls are at least 375 mm thick. Construction of walls is a complex task. Double walls may be constructed in colder climates - two horizontal layers of stone are laid, and the residual spaces are filled with smaller stones. Then mortar is applied to bind all the small and large units together. Walls in colder climates are at least 2.5 to 3 m tall.
Foundations	Stone with mud mortar or cement sand mortar	Mix Proportions 1:10 cement and sand. Strip wall foundations are generally used for stone

		masonry construction. The foundation consists of rubble stone, with an average depth of 900 mm. For weaker soils, this depth may increase. The width of the strip foundation ranges from 375 to 450 mm, wider than the walls that rest upon it. The plinth is provided at 600 mm from the ground, and with a thickness similar to that of the foundation. It is more effective to use cement mortar in the foundations and the plinth as it helps to ground the building more firmly. Where cost is an issue, mud mortar may be employed, but it is weaker and so undesirable.
Floors	Wood, steel, earth	RCC slabs can be commonly employed on stone walls due to good compressive strength of stone. Although they cost substantially more than a lightweight roof, they give the structure additional stability, and allow for vertical extensions. Where stone walls do not contain mortar, lighter roofs may be employed. These can be a combination of wooden rafters and layers of soil, or other inexpensive, locally available material like iron sheets, asbestos sheets, or tiles. Wooden posts may be provided beneath such lightweight roofs to support their weight.
Roof	Wood, steel, earth	RCC slabs can be commonly employed on stone walls due to good compressive strength of stone. Although they cost

		substantially more than a lightweight roof, they give the structure additional stability, and allow for vertical extensions. Where stone walls do not contain mortar, lighter roofs may be employed. These can be a combination of wooden rafters and layers of soil, or other inexpensive, locally available material like iron sheets, asbestos sheets, or tiles. Wooden posts may be provided beneath such lightweight roofs to support their weight.
Other		

Design Process

Who is involved with the design process?	Engineer; Architect
Roles of those involved in the design process	There are no design or construction guidelines available for this type of construction. Local masons rely on their past experience and the engineers or architects are not generally involved.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Owner
Roles of those involved in the building process	Stone masonry houses are usually built by owners themselves for their residence. The owner and his relatives/acquaintances may participate in the construction activity, or they may hire the services of experienced masons and craftsmen.
Expertise of those involved in building process	Stone masonry construction is usually carried out by local masons and labourers who rely on their experience. The walls are constructed using stone masonry with mud mortar or cement sand mortar and generally rest directly on ground without proper foundations.

Construction process and phasing	Where foundations are provided, they are wider than the walls at a typical depth of 900 mm. Various types of roofing materials are used which are generally directly resting on the walls without proper connections. 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	
Process for building code enforcement	There are no design or construction guidelines available for this type of construction. Local masons rely on their past experience and the engineers or architects are not generally involved.

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?	Yes
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?	Builder; Owner(s); Renter(s)
	Stone buildings are robust structures and need little

Additional comments on maintenance and building condition	maintenance over time. Light roofs might occasionally cave in in severe weather due to inadequate support from within and would need to be repaired or replaced. Otherwise, stone structures remain relatively intact as compared to other forms of construction.

Construction Economics

Unit construction cost	
Labor requirements	The construction of a typical housing unit takes approximately 3 to 4 months to complete.
Additional comments section 3	

Typical stone masonry walls in northern areas of Pakistan.

Typical stone masonry walls in northern areas of Pakistan.

Socio-Economic Issues

Patterns of occupancy	Houses are used as the primary space for rest and relaxation during the later evenings and night, and remain somewhat vacant during the daytime when men of the house leave for work. Men might work within the village, in which case they return for afternoon meals or other domestic uses. If the men work further away from the village, (e.g. administrative work in a nearby city, or commercial activities which require them to be away from home for extended periods), they may only return on weekends or after a few months. During this time, the house is tended to by the womenfolk. Siblings reside within the same house, some even after marriage. When space starts getting restricted, one

	or more of the married siblings moves out and constructs their own standalone house within close proximity to the family home.
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	10-May
Additional comments on number of inhabitants	Each building typically has 1 housing unit(s). Stone masonry buildings are usually built as single family residences. Sometimes, a larger house may be built for an extended family, and would contain more enhanced spaces for socializing, such as a semi-covered porch, a lawn area with temporary shading structures, and a backyard or vegetable garden. The number of people in one house varies from 4-8.
Economic level of inhabitants	Low-income class (poor); Middle-income class
Additional comments on economic level of inhabitants	Stone houses are built by people from a variety of economic backgrounds. As the choice of material is same, economic differences become evident only in the exterior treatment and the interior adornment of the house. For example, more affluent people would use dressed stone on the walls, and cement mortar in the foundations. Finishing would sometimes go beyond mere plastering and would include ornamental tile work or decorative patterns in the plaster. The ratio of housing unit price to annual income is 5:1 or worse.
Typical Source of Financing	Owner financed; Personal savings; Informal network: friends or relatives
Additional comments on financing	In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).
Type of Ownership	Rent; Own outright; Own with debt (mortgage or other); Units owned individually (condominium)
Additional comments on	The type of ownership or occupancy is renting, outright ownership, ownership with debt (mortgage or other) and individual ownership. Houses are owned by the family that builds them. The houses are not directly inherited by the eldest sons when they get married and the parents pass away, but are viewed as a shared asset of the family and are

Additional comments on ownership	legally divided amongst all the heirs. Though the ownership gets divided, the land remains within the family. Stone houses can also be rented out to other people in the village if the family decides to spend a season in a larger city - not an uncommon practice for some Gilgiti families who come to seek better jobs in Karachi while renting out their village homes to acquaintances.
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	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. Earthquake insurance for this type of construction is not available in Pakistan.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Off
Additional comments on premium discounts	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1668	Samawani, Sindh
1819	Allahnund, Sindh
1827	Lahore, Punjab
1852	Kahan, Balochistan
1889	Jhalawan, Balochistan
1935	Quetta, Balochistan
1945	Pasni, Makran

2008	Ziarat, Balochistan
2011	Dalbandin, Baluchistan
2013	Iran-Pakistan border

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Collapse of wall due to out of plane effects and shear. Collapse of roof due to out of plane failure of walls.
Additional comments on earthquake damage patterns	The 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 the Himalayan mountains. Within the Suleiman, Hindu Kush and Karakoram mountain ranges, the Northern Areas, Chitral district in NWFP, Kashmir including Muzaffarabad, 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 4 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]. In the 2005 Kashmir earthquake, over 74,000 people died, majority of those were buried under the rubble of traditional stone masonry houses [4]. Figures 5 to 8 show the damage and total collapse of stone masonry houses in Kashmir 2005 earthquake.

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.	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.	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);	FALSE
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).	N/A
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, poor quality of construction
Earthquake-resilient features in walls	There are no earthquake resistant features. Some houses have horizontal and vertical wooden bands
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	No connection between roof elements and walls, lack of diaphragm action
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

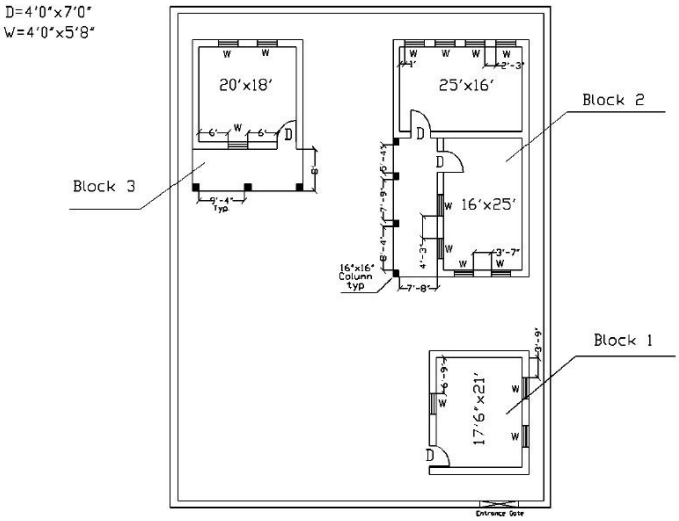
	High vulnerability		**Medium vulnerability**		**Low vulnerability**	
	A	B	C	D	E	F
Seismic vulnerability class	o					

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 stone masonry houses. After the 2005 Kashmir earthquake, a number of houses and buildings were retrofitted but there is no well-defined retrofit scheme, which has been implemented on a large scale. Figure 10 and 11 show the plan and view of a school building in Abbotabad, which has been retrofitted as a case study [5]. There are some guidelines available from Earthquake Relief and Rehabilitation Authority (ERRA) of Pakistan. However, they are not legally binding.
Has seismic strengthening described in the above table been performed?	
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
Was the construction inspected in the same manner as new construction?	
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	
Additional comments section 6	



Plan of case study school building before retrofitting [5].

View of case study school building before retrofitting [5].

Implementation of retrofitting scheme to the case study school [5].

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