

World Housing Encyclopedia

A Resource on Construction in Earthquake Regions



an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Stonework building with wooden timber roof

Report#	114
Last Updated	
Country	Iran
Author(s)	Masoud N. Ahari, Alireza Azarbakht,
Reviewers	Svetlana N. Brzev ,

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

General Information

Building Type:	Stonework building with wooden timber roof
Country:	Iran
Author(s):	Masoud N. Ahari Alireza Azarbakht
Last Updated:	
Regions Where Found:	<p>Buildings of this construction type can be found in most villages in the mountain regions of Alborz and Zagros (Figure 7). This type of housing construction is commonly found in rural areas. This kind of building is not practiced in major cities but only in rural cities and mountainous villages. The major reason for the popularity of this form of construction is that in mountainous regions, stone mines are easily accessible. Two kind of stones are used in these stonework buildings: 1-Rubble stone, a by-product of the mining industry (Figure 15). 2- Carcass stone, which comes from riverbeds (Figure 14).</p>
Summary:	<p>Stonework buildings are a common type of rural construction in many parts of Iran (Figure 7). It is widely used in the mountainous areas because of the ease of attaining the building material. More than 71,000 stonework buildings were built in 1968-1972 in comparison to 54,000 brick masonry buildings in these years [1]. Unfortunately these buildings are often found in highly seismic parts of Iran (see maps on WHE webpage for Iran). Buildings of this type are up to two stories high, with height/width aspect ratio on the order of 0.3-0.5. The building materials consists of stone, wood, mud mortar and straw. The major elements of these systems are stonewalls which carry both gravity and lateral loads. These walls consist of stone or stone ballast with mud mortar and straw. For reasons of thermal insulation the thickness of these walls is not less than 50 centimeters (usually 70 centimeters). Details of wall are shown in Figures 14 to 23. The roof includes wooden joists and a set of secondary joists which are plastered with a thick layer of mud (Figures 24 and 25). Different views of this kind of building are shown in Figures 1 to 5. Also a typical building view, plan and layout are shown in Figures</p>

6 and to 12. Weak points of this construction type are: the presence of a heavy roof; inadequate behavior of the walls under out-of-plane forces (Figures 23 and 24); poor shear capacity of the mortar; inadequate connection between roof and walls; inadequate connection between intersecting walls; and lack of diaphragm action in floors and roof where the roof elements (wooden beams) do not work together in earthquakes and may collapse (Figures 26 through 29). In general, this kind of structure is frequently used as a house and stable in mountainous villages, but its earthquake performance is not acceptable. Any proper rehabilitation techniques may save many people's lives.

Length of time practiced:	More than 200 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	1-2
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	Usually this kind of building is used for living but sometimes when the building is located at the foot of a slope, the ground s

Features

Plan Shape	Other
Additional comments on plan shape	A typical plan of this kind of building is shown in figure 3.
Typical plan length (meters)	
Typical plan width (meters)	
Typical story height (meters)	2.5-3
Type of Structural System	Masonry: Stone Masonry Walls: Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)

<p>Additional comments on structural system</p>	<p>The vertical load-resisting system is confined masonry wall system. The roof of the building is constructed with joists spaced at 20-50 centimeters which transfer loads from the roof to the walls (500-600 kilogram per square meter) and then walls transfer loads to the ground directly. Wall thickness is between 45-70 centimeters. These walls have no foundations. The lateral load-resisting system is confined masonry wall system. Walls carry the inertia forces produced by the roof mass. These loads must be transferred from the walls to the ground by in-plane behavior of the walls, but usually there is no proper path for adequately transferring these seismic loads to the ground in stonework buildings. Floors and roofs do not work as rigid diaphragms and there is rarely connection between the roof components (joists and secondary joists). Heavy floors and roofs are supported on walls without any connection (Figure 24). These deficiencies may cause separation and collapse of roof components as shown in Figures 30, 31 and 32. 1- Walls collapse under out of plane loads. 2- Improper arrangement of stone units may cause buckling of outer stones in walls (Figures 18, 21 and 26). 3- Walls collapse because of poor shear capacity of mortar; also there is not enough cohesion between stone units and mud mortar.</p>
<p>Gravity load-bearing & lateral load-resisting systems</p>	
<p>Typical wall densities in direction 1</p>	<p>>20%</p>
<p>Typical wall densities in direction 2</p>	<p>>20%</p>
<p>Additional comments on typical wall densities</p>	<p>The typical structural wall density is none.</p>
<p>Wall Openings</p>	<p>Most windows are about 120X120 centimeters and doors are 200X100 centimeters.</p>
<p>Is it typical for buildings of this type to have common walls with adjacent buildings?</p>	<p>Yes</p>
<p>Modifications of buildings</p>	<p>Usually there is no modification.</p>
<p>Type of Foundation</p>	<p>Shallow Foundation: Wall or column embedded in soil, without footing</p>
<p>Additional comments on</p>	

foundation

Type of Floor System

Other floor system

Additional comments on floor system

Type of Roof System

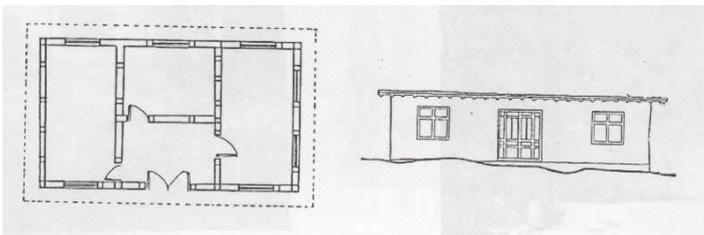
Roof system, other

Additional comments on roof system

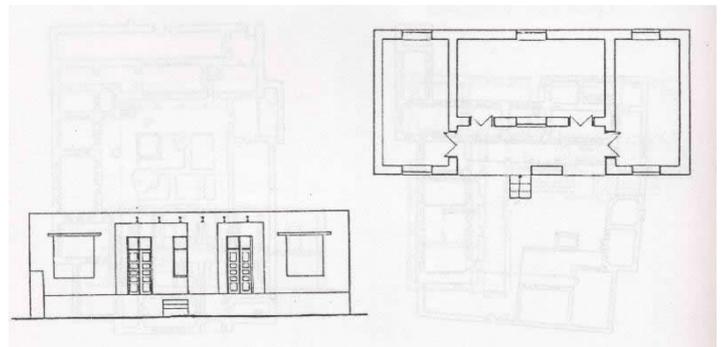
The roof includes wooden joists and a set of secondary joists which are plastered with a thick layer of mud (Figures 24, 25 and 5).

Additional comments section 2

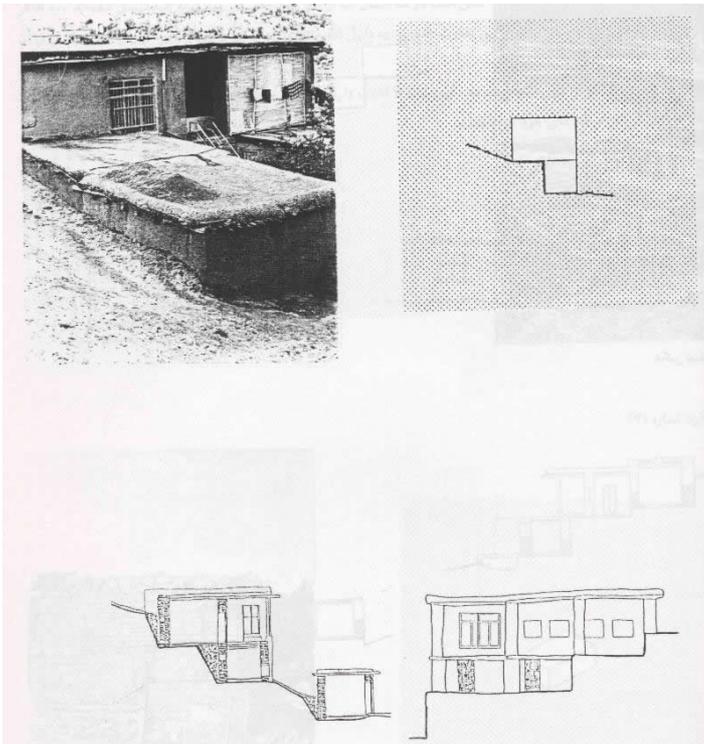
Usually they are constructed side by side and there is no distance between them.



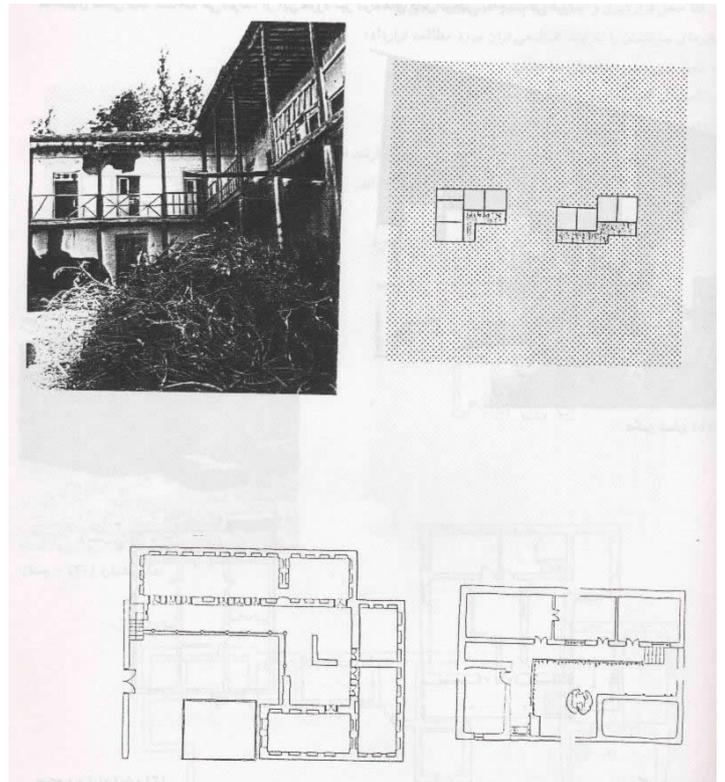
Elevation and a Plan of a Typical Building [7]



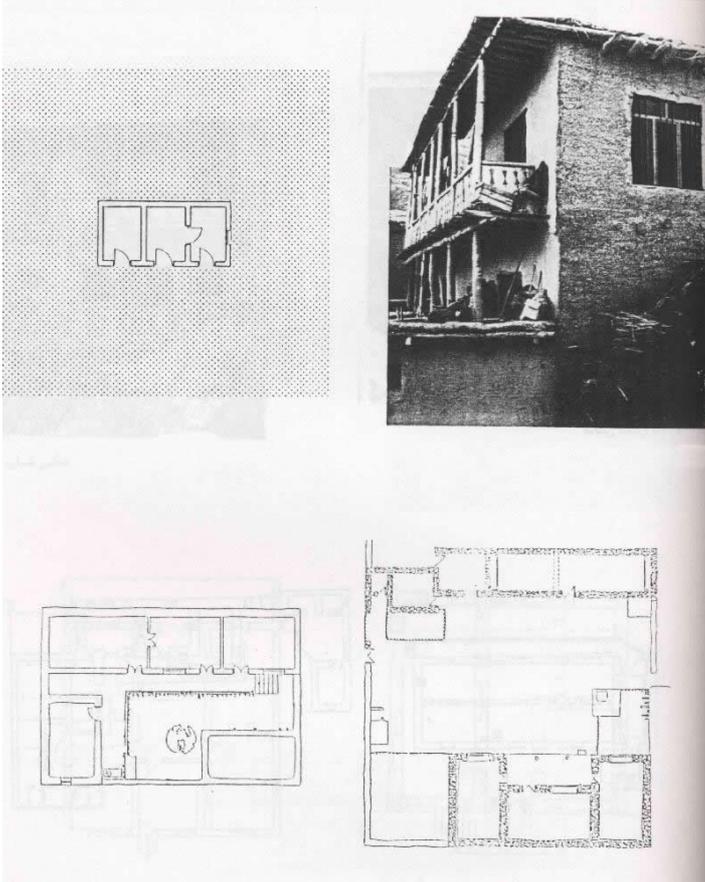
Elevation and a Plan of a Typical Building [7]



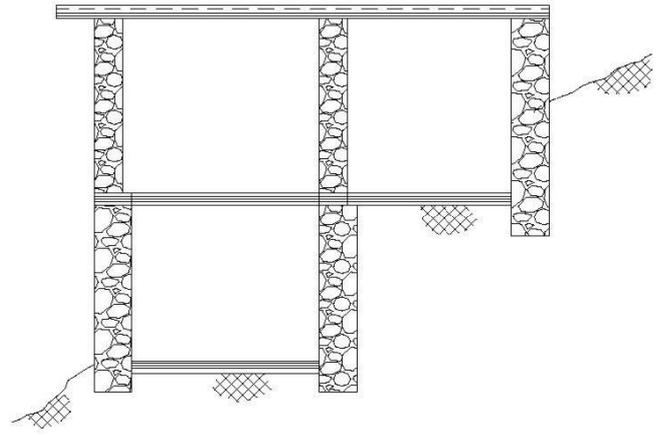
Elevation of a Typical Building [7]



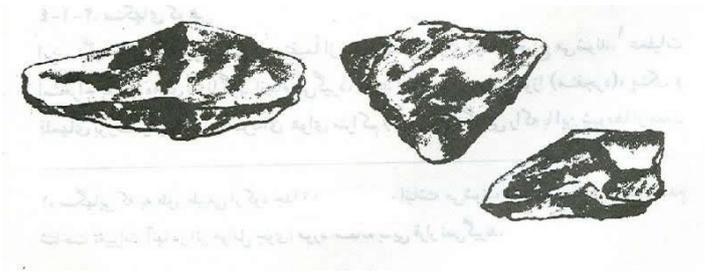
View and Plan of a Typical Building [7]



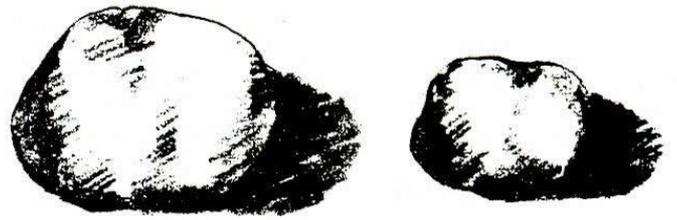
View and Plan of a Typical Building [7]



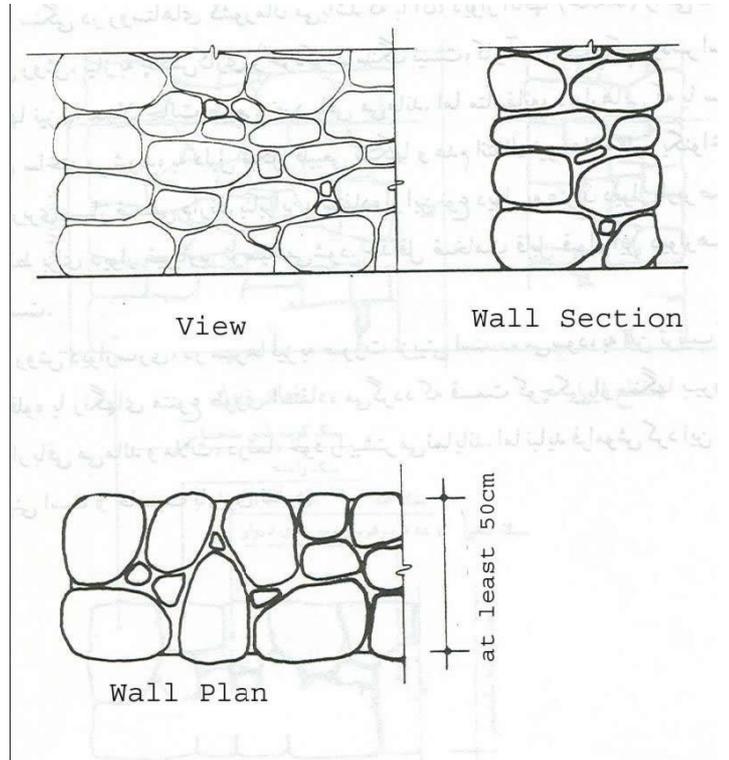
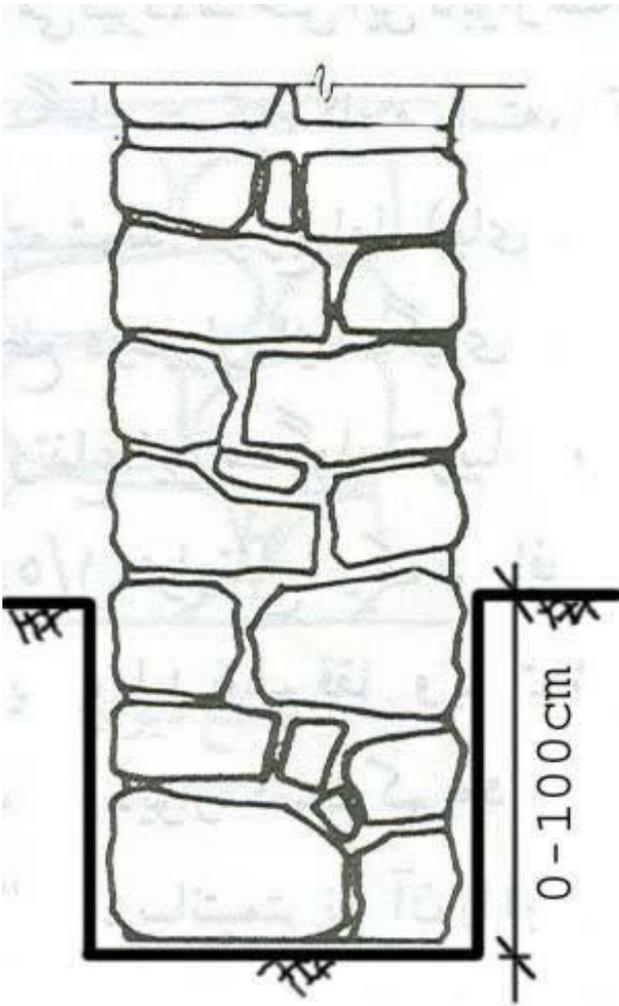
Two story stone masonry house on a slope



Carcass Stone [1]

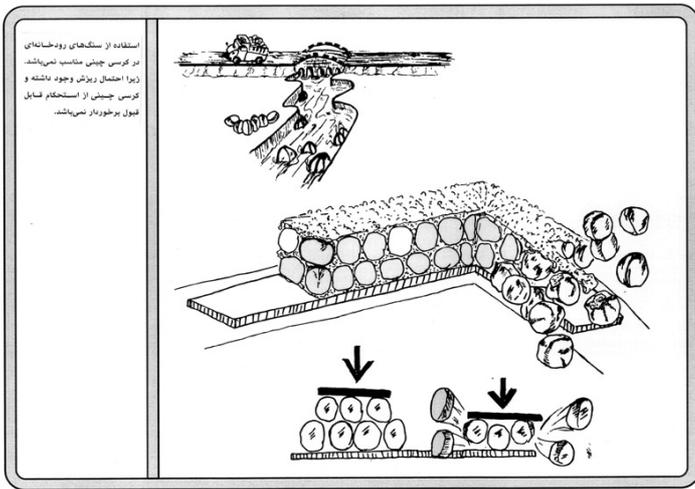


Rubble Stone [1]

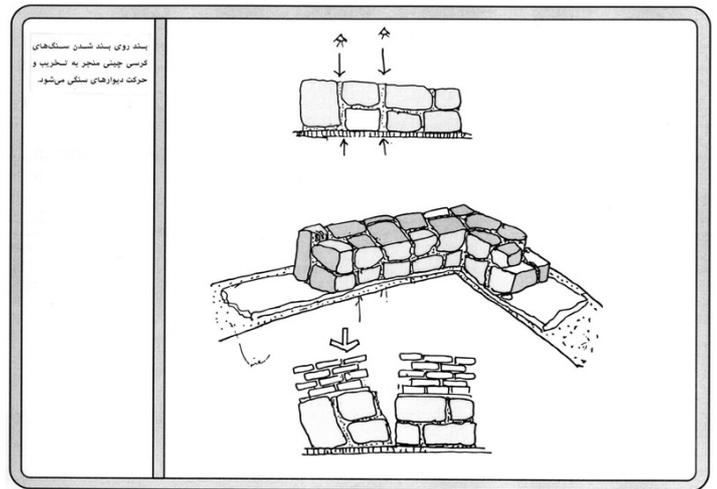


Walls with Rubble Stone [1]

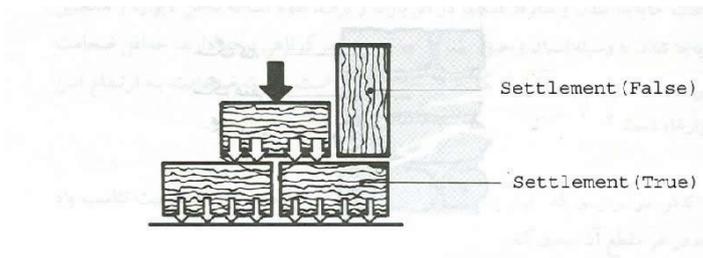
Stone Walls Foundation



Seismic Behavior of Rubble Stone [9]

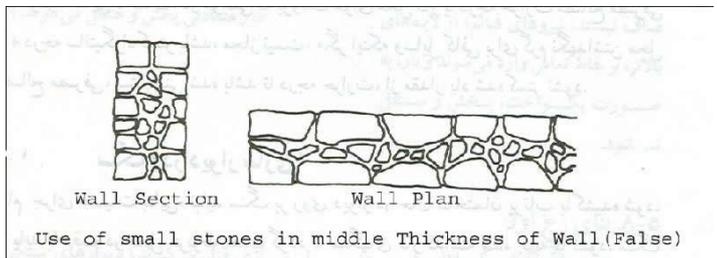


Seismic Behavior of Carcass Stone [9]

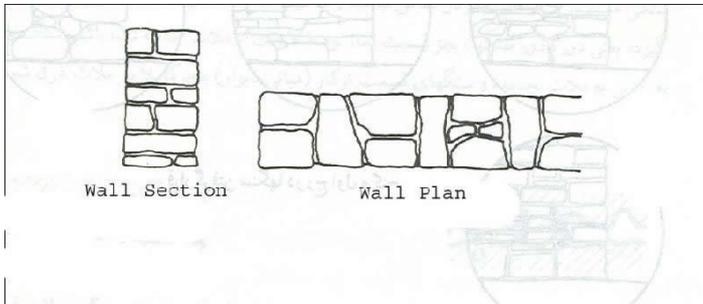


Laods sould be perpendicular to stone fibres

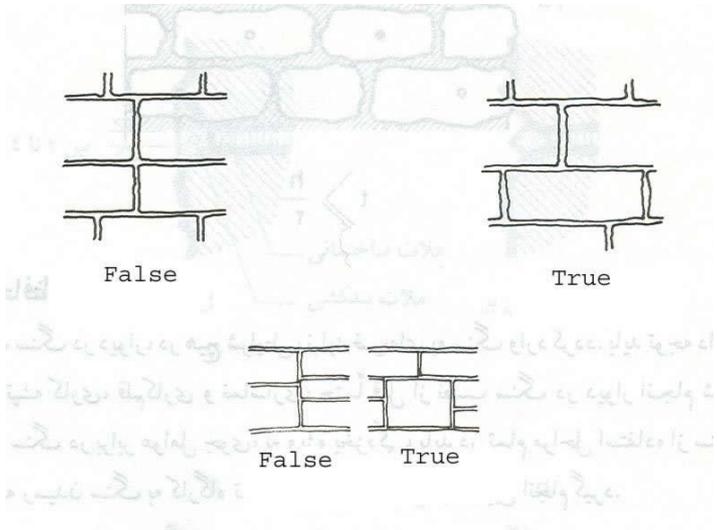
Stone Settlement [1]



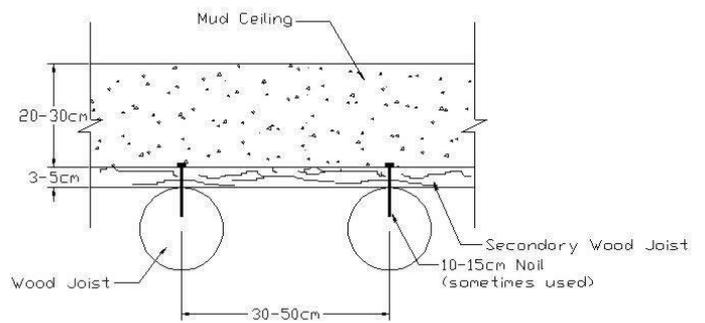
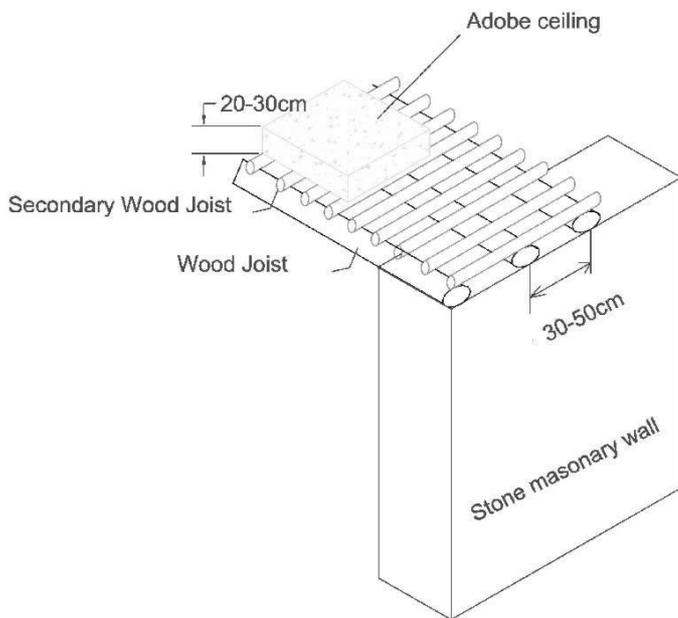
Vulnerable Walls (Buckling of outer stones) [1]



Adequate walls [1]



Stone Units Arrangements [1]



Roof Details (using secondary wood joists)

Typical Detail of Connection between Wall and Roof

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	(wall) Stone; No frame.	
Foundations	No foundation.	
Floors	Joists with mud mortar and straw	
Roof	Joists with mud mortar and straw	
Other		

Design Process

Who is involved with the design process?	Other
Roles of those involved in the design process	Engineers or architects are not present in the design/construction of this housing type.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Builder
Roles of those involved in the building process	The builder lives in this construction type.
Expertise of those involved in building process	This kind of building is constructed by people lacking formal construction expertise. Sometimes expert bricklayers build these buildings with some special architectural features in the walls and roof but they are not certified.
Construction process and phasing	First, the ground is excavated with a width of 80-100 centimeters and a depth of 50-100 centimeters for the wall perimeter. Next, the walls are constructed from bottom of this cavity. On rare occasions, a wooden column is used at the intersection of stone walls. Wooden beams are then placed on top of walls at a 20-50 centimeter spacing distance. The top surface of the beams is covered with thinner wooden beams or board(plank). Finally the roof is plastered with mud in two separate stages to achieve a total thickness of 20-30 centimeters. The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size. There is no special design & drawings for this kind of construction.
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?	Yes
Is this typically informal construction?	Yes

Is this construction typically authorized as per development control rules?	No
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Additional comments on building permits and development control rules	These buildings are old. Building permits are required to build this housing type.
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Building Maintenance and Condition

Typical problems associated with this type of construction	
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Who typically maintains buildings of this type?	Owner(s)
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Additional comments on maintenance and building condition	
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Construction Economics

Unit construction cost	per m2 of built-up area expressed using a currency used in the region, and, if possible, an equivalent amount in \$US in the brackets e.g. 200 Rs/m2 (5 \$US/m2).
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Labor requirements	
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Additional comments section 3	
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Socio-Economic Issues

Patterns of occupancy	Typically there is one family per housing unit that may sometimes include grandparents.
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Number of inhabitants in a typical building of this construction type during the day	<5
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Number of inhabitants in a typical building of this construction type during the evening/night	5-10
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Additional comments on	
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number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)
Additional comments on economic level of inhabitants	Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Owner financed
Additional comments on financing	Because this kind of building is placed in mountainous areas, the owners of them are usually peasants or shepherd.
Type of Ownership	RentOwn outright
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
1985	Ardabil
1990	Manjil
1992	Lordekan

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type

Additional comments on earthquake damage patterns

During earthquakes in the mountainous regions of Iran, there is extensive damage and many casualties in these buildings due to wall collapses. Figures 26 through 24 show typical damage of stone walls from earthquakes. After wall failure, the heavy roof generally collapses. Figures 30, 31 and 32 show evidence of this phenomenon.

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 $\frac{1}{2}$ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than $\frac{1}{3}$ of the distance between the adjacent cross walls; For precast concrete wall structures: less than $\frac{3}{4}$ 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)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan.	FALSE

	(Specify in 5.4.2)	
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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	FALSE
Wall-Roof Connections	Exterior walls are	FALSE

anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.

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	The roof consists of a mud-straw mix about 20-30 centimeters thick, which makes the roof very heavy. The walls are not connected together or to the roof with adequate connections. There are no tie beams or columns in these buildings. The walls do not have enough strength to resist out-of-plane forces. The mortar also has inadequate strength. Usually these buildings are placed on steep slopes in mountainous areas which have a high potential for landslides.	
Vertical irregularities typically found in this construction type	Other	
Horizontal irregularities typically found in this construction type	Other	
	The combination of stone and mortar has low tensile and shear strength, especially for out-of-plane seismic effects. Sometimes openings such as	

Seismic deficiency in walls	walls and windows reduce the strength of the bearing walls. The perimeter walls are not sufficiently connected at the corners, and behave as separate elements, which causes damage in the wall corner connections.
Earthquake-resilient features in walls	
Seismic deficiency in frames	No Frame exists.
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Usually they consist of heavy materials that behave as flexible diaphragms in earthquakes, which undermines the connections between the stone walls and the diaphragm. Also there is not a tie beam for integrity.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

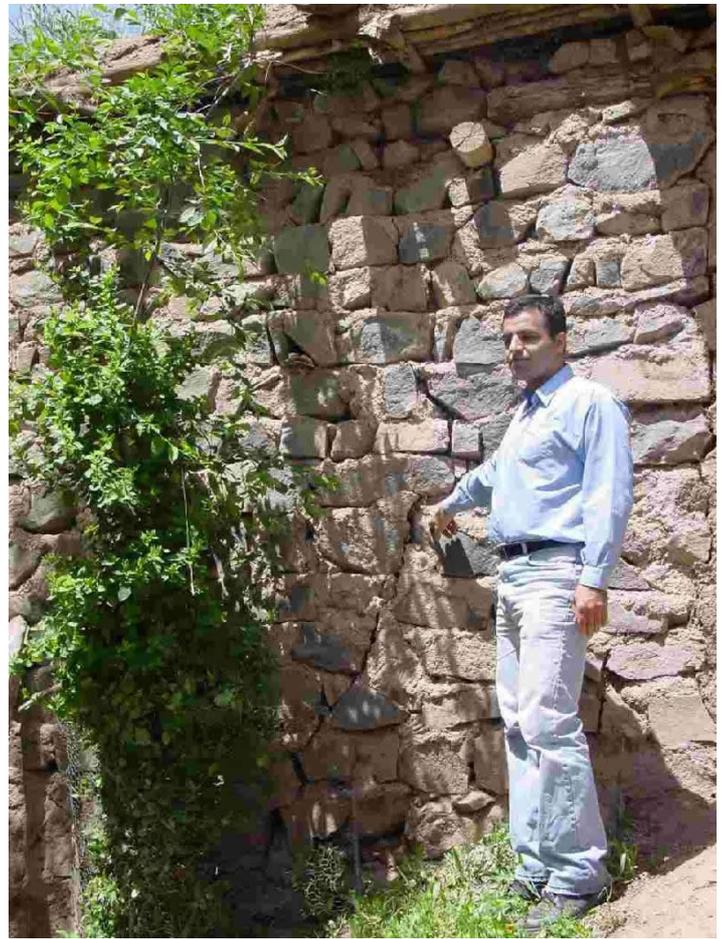
Seismic Vulnerability Rating

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	0					



Typical external walls damage in Firoozabad-Kagoor earthquakes [3]



Typical external walls damage in Firoozabad-Kagoor earthquakes [3]



Typical internal walls damage in Firoozabad-Kagoor earthquakes [3]



Typical internal walls damage in

Firoozabad-Kagoor earthquakes [3]



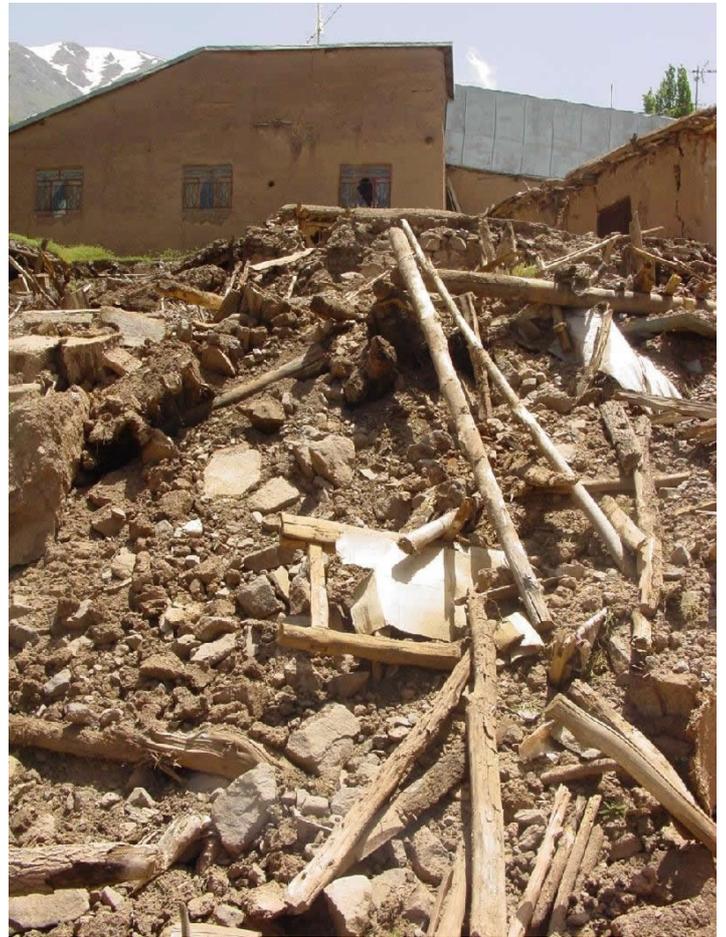
Typical roof damage in Firoozabad-Kagoor earthquakes [3]



Typical roof damage in Firoozabad-Kagoor earthquakes [3]



Typical roof damage in Firoozabad-Kagoor earthquakes [3]

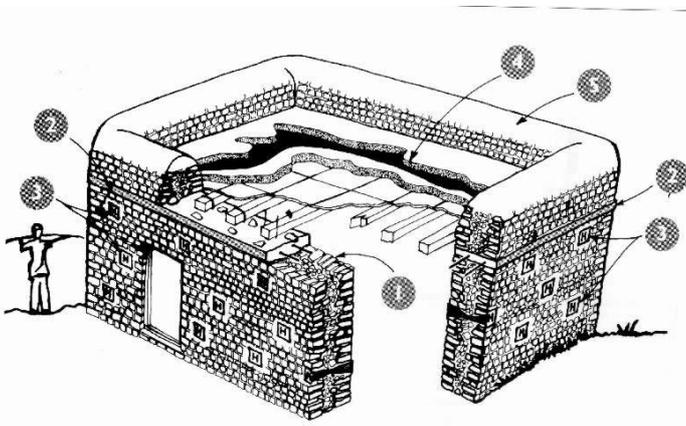


Total collapse of stonework building in Firoozabad-Kagoor earthquakes [3]

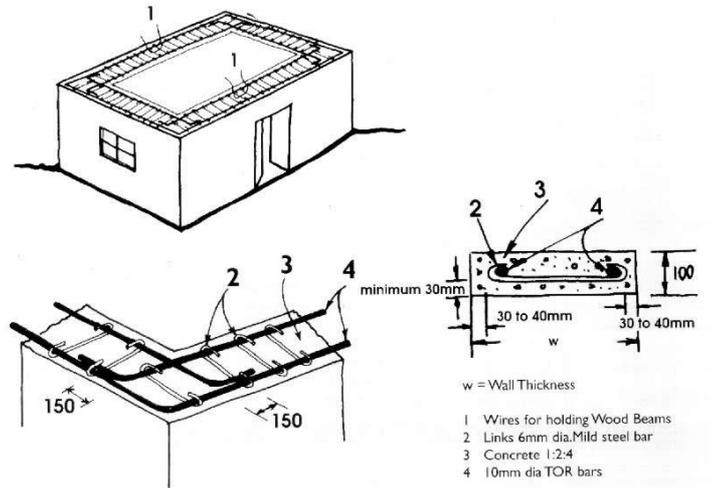
Retrofit Information

Description of Seismic Strengthening Provisions

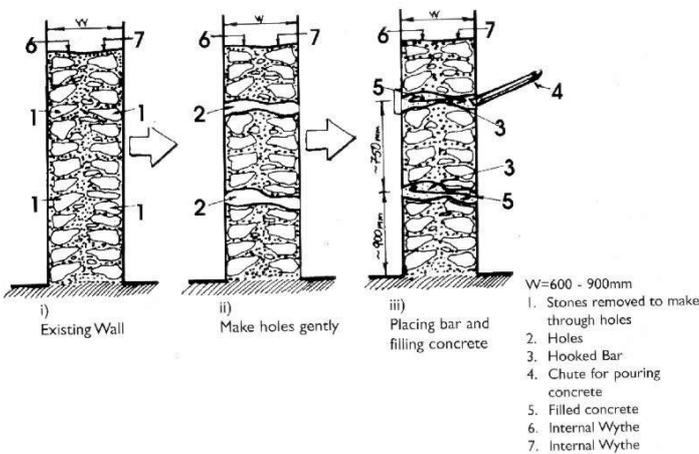
Structural Deficiency	Seismic Strengthening
Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
Was the construction 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	



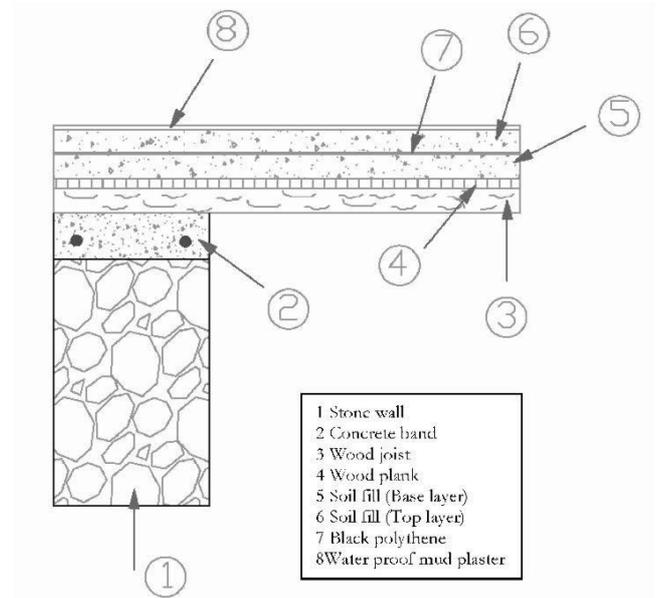
Retrofitting components



R.C. Band below Roof Beams



Providing R.C.



Polythene sheet placements

References

Stone Walls (Report in Persian) Iranian Management and Planning Organization 1376

Retrofitting of Stone Houses in Marathwada Area of Maharashtra Arya, A.S. University of Roorkee, March 1994

Firoozabad-e-Kojour earthquake reconnaissance report Eshghi, S. and Zare, M. International Institute of Earthquake Engineering and Seismology, 1383 (In preparation)

Lordekan earthquake report Chahar Mahal va Bakhtiary and F. Nateghi Elahi International Institute of Earthquake Engineering and Seismology, 1370

Manjil earthquake report Roodbar, S.E. International Institute of Earthquake Engineering and Seismology, 1369

Golestan-Ardebil earthquake report Ashtiani, M.G. International Institute of Earthquake

Engineering and Seismology, 1377

Building and housing types of Zanjan according to architects and materials Bonyade maskane enghelabe eslami, 1372

Building and housing types of Gilan according to architects and materials Bonyade maskane enghelabe eslami, 1372

A simple pictorial guideline for resistance construction of rural houses against earthquake (Report in Persian) Hosseini,B., Alemi,F. and Khaki,A. International Institute of Earthquake Engineering and Seismology 2005

Maps referred to "Geology Survey of Iran"

Seminars, Conferences, Personal communications and practical involvements

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