World Housing Encyclopedia

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

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
Report Date	17-01-2005
Country	IRAN
Housing Type	Stone Masonry House
Housing Sub-Type	Stone Masonry House : Rubble stone without/with mud/lime/cement mortar
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Reviewer(s)	Svetlana N. Brzev

Summary

Stonework buildings are a common type of rural construction in many parts of Iran (Figure 32). 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 centimetres (usually 70 centimetres). Details of wall are shown in Figures 11 to 20. The roof includes wooden joists and a set of secondary joists which are plastered with a thick layer of mud (Figures 21 and 22). Different views of this kind of building are shown in Figures 1 to 3. Also a typical building view, plan and layout are shown in Figures 4 to 10. Weak points of this construction type are: the presence of a heavy roof; inadequate behaviour of the walls under out-of-plain 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 25 and 27). 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.

1. General Information

Buildings of this construction type can be found in In most village buildings in the mountain regions of Alborz and Zagros (Figure 32). This type of housing construction is commonly found 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 12). 2-Carcass stone, which comes from riverbeds (Figure 11).

This construction type which has been in practice for more than 200 years ago, and currently is being practiced. .

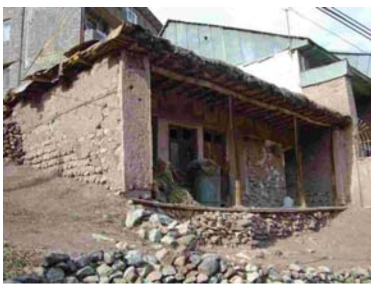

Figure 1a: Typical

Figure 1b: Typical

Figure 2a: Typical

Building View [3]

Building View [3]

Building Wall View [3]

Figure 2b: Typical Building Wall View [3]

Figure 3: Typical Building Roof View [3]

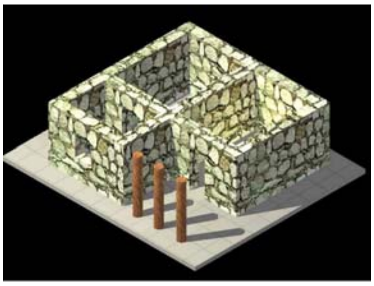

Figure 4: View of common stone masonry house type

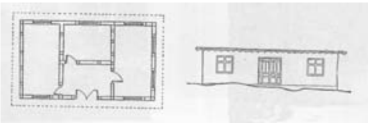

Figure 5: Elevation and a Plan of a Typical Building [7]

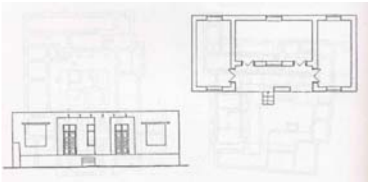

Figure 6: Elevation and a Plan of a Typical Building [7]

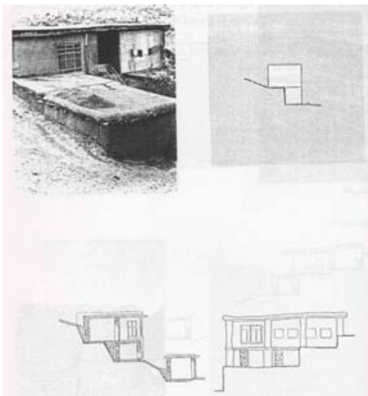

Figure 7: Elevation of a Typical Building [7]

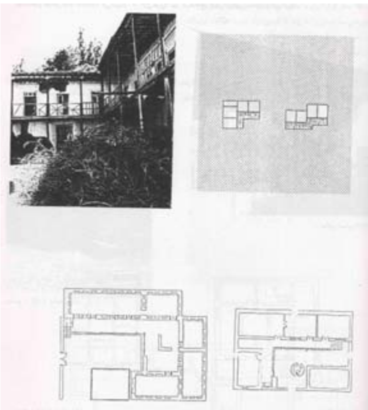

Figure 8: View and Plan of a Typical Building [7]

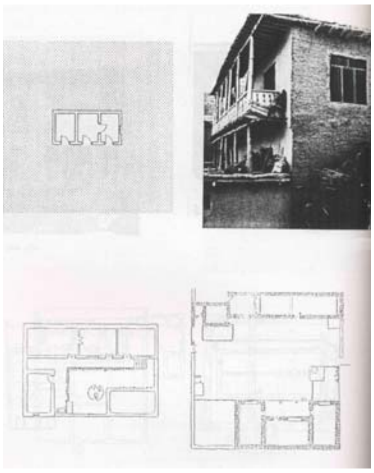

Figure 9: View and a Plan of a Typical Building [7]

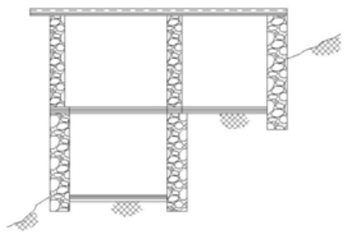

Figure 10: Two story stone masonry house on a slope

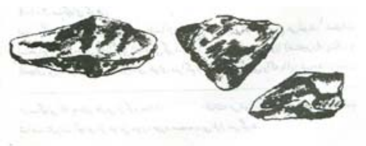

Figure 11: Carcass Stone [1]

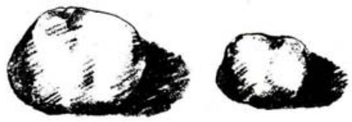

Figure 12: Rubble Stone [1]

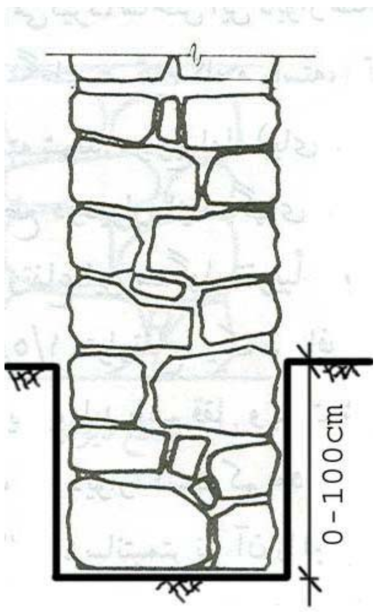

Figure 13: Stone Walls Foundation

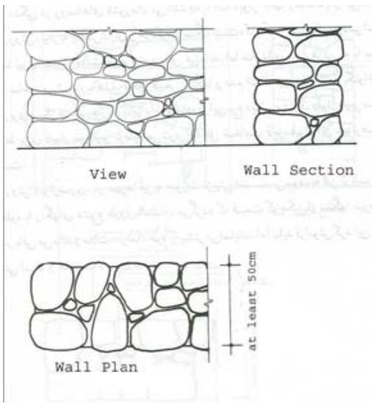

Figure 14: Walls with Rubble Stone [1]

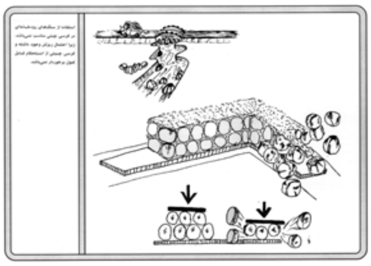

Figure 15: Seismic Behavior of Rubble Stone [9]

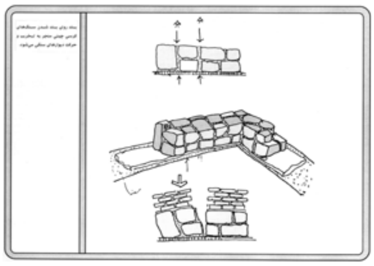

Figure 16: Seismic Behavior of Carcass Stone [9]

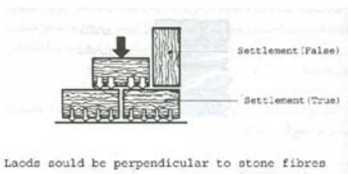

Figure 17: Stone Settlement [1]

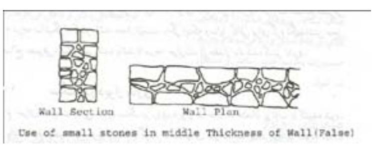

Figure 18: Vulnerable Walls (Buckling of outer stones) [1]

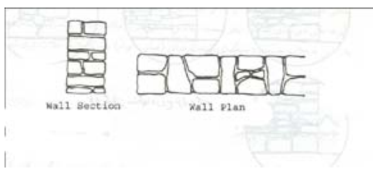

Figure 19: Adequate walls [1]

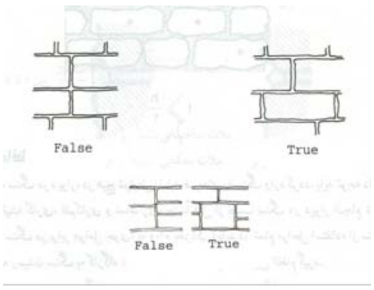

Figure 20: Stone Units Arrangements [1]

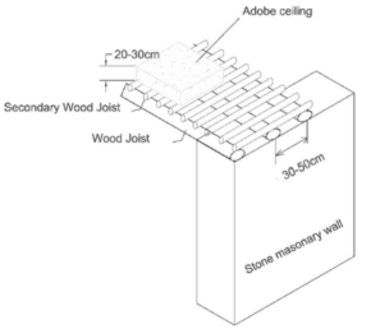

Figure 21: Typical Detail of Connection between Wall and Roof

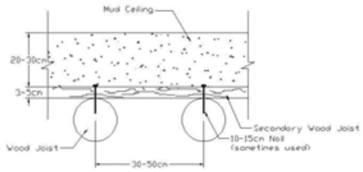

Figure 22: Roof Details (using secondary wood joists)

Figure 23a: Typical external walls damage in Firoozabad-Kagoor earthquakes [3]

Figure 23b: Typical external walls damage in Firoozabad-Kagoor earthquakes [3]

Figure 24a: Typical internal walls damage in Firoozabad-Kagoor earthquakes [3]

Figure 24b: Typical internal walls damage in Firoozabad-Kagoor earthquakes [3]

Figure 25: Typical roof damage in Firoozabad-Kagoor earthquakes [3]

Figure 26a: Typical roof damage in Firoozabad-Kagoor earthquakes [3]

Figure 26b: Typical roof damage in Firoozabad-Kagoor earthquakes [3]

Figure 27: Total collapse of stonework building in Firoozabad-Kagoor earthquakes [3]

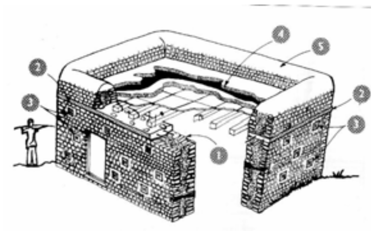

Figure 28: Retrofitting components

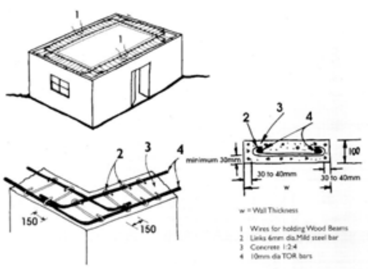

Figure 29: R.C. Band bellow Roof Beams

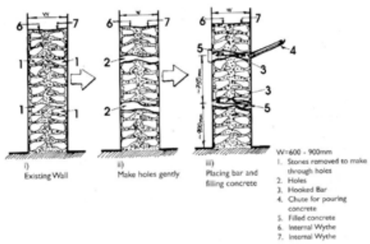

Figure 30: Providing R.C.

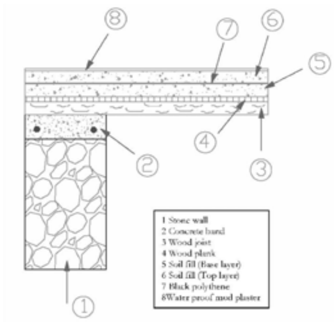

Figure 31: Polythene sheet placements

Figure 32: Distribution of Stonework Buildings in Iran

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrains. They have common walls with adjacent buildings. Usually they are constructed side by side and there is no distance between them.

2.2 Building Configuration

A typical plan of this kind of building is shown in figure 3. Most windows are about 120X120 centemetres and doors are 200X100 centemetres.

2.3 Functional Planning

The main function of these buildings is single family house. Usually this kind of building is used for living but sometimes when the building is located at the foot of a slop, the ground storey has less surface area than the top one and is used for depot reservoir or as a stable. In a typical building of this type, there are no elevators and 1-2 fire protected exit staircases. In one-story buildings there is just one door and in two-story buildings there is one door in front of building and another one behind the building.

2.4 Modification to Building

Usually there is no modification.

3. Structural Details

3.1 Structural System

This is a Stone Masonry House and Stone Masonry House : Rubble stone without/with mud/lime/cement mortar.

3.2 Gravity Load-Resisting System

The vertical load resisting system is confined masonry wall system. The roof of the building is constructed with joists spaced at 20-50 centimetres which transfer loads from the roof to the walls (500-600 kilogram per square meter) and then walls tranfer loads to the ground directly. Wall thickness is between 45-70 centimetres. These walls have no foundations.

3.3 Lateral Load-Resisting System

The lateral load resisting system is confined masonry wall system. Walls carry the inertia forces produced by the roof mass. These loads must be transfered 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 21). These deficiencies may cause separation and collapse of roof components as shown in Figures 25 and 26: 1- Walls collapse under out of plane loads. 2- Improper arrangement of stone units may cause buckling of outer stones in walls (Figures 15, 18 and 23a). 3- Walls collapse because of poor shear capacity of mortar; also there is not enough cohesion between stone units and mud mortar.

3.4 Building Dimensions

The length of the building is 0 m and the width 0 m. The building has 1 to 2 storey (s). The typical span of the roofing/flooring system is 3-4 meters. The typical storey height in such buildings is 2.5-3 meters. The typical structural wall density is none. .

3.5 Floor and Roof System

The flooring system consists of others (described below). The roofing system consists of others (described below). The roof includes wooden joists and a set of secondary joists which are plastered with a thick layer of mud (Figures 21, 22 and 3).

3.6 Foundation

The building has a shallow foundation. It consists of wall or column embedded in soil and without footing.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has less than 10 housing unit(s) 1 unit in each building. The number of inhabitants in a building during the day or business hours is less than 5 persons. The number of inhabitants during the evening and night is less than 5 persons.

4.2 Patterns of Occupancy

Typically there is one family per housing unit that may sometimes include grandparents.

4.3 Economic Level of Inhabitants

Persons living in the housing are very poor and poor. The ratio of the Housing Unit Price to their Annual Income is 1:1 or better. The typical source of financing the purchase of a housing unit in these buildings is owner finance. Because this kind of building is placed in mountainouse areas, the owners of them are ususlly peasants or shepherd. In each housing unit, there are 0 bathrooms (with no toilets), 1 toilets only and 0 bathrooms-cum-toilets.

usually toilet is placed outside of housing unit.

4.4 Ownership

The type of ownership or occupancy is renting and outright ownership.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

The structure does not contain a complete load path for seismic forces in any horizontal direction that transfers inertial forces from the upper portions of the building to its foundation. The building is not regular with regards to its plan and elevation. The roof diaphragm is not rigid and is not expected to maintain its structural integrity during the intensities of earthquakes expected in the area where the buildings are located. The floor diaphragm(s) are not rigid and are not expected to maintain their integrity, during an earthquake of intensity expected in the area where the building is located. There is evidence of excessive foundation movement (e.g., settlement) that would affect the integrity or performance of the building in an earthquake. At least two walls or frames are available in each principal orthogonal direction of the building structure. At each storey level, the height-to-thickness ratio of shear walls is well maintained; the standard is <635mm (25 in) in reinforced concrete walls, <760 mm (30 in) in reinforced masonry walls, and <330 mm (13 in) unreinforced masonry walls. Vertical load-bearing elements (e.g., columns and walls) are not doweled into the foundation. Exterior walls are not anchored into roof and every floor with metal anchors or straps for out-of-plane seismic forces. The total width of door and window openings in a wall is not excessive, i.e., <1/2 the distance between adjacent cross walls in brick masonry walls in cement mortar, <1/3 the distance between adjacent cross walls in adobe masonry, stone masonry & brick masonry in mud mortar, and <3/4 the length of perimeter wall in precast concrete walls. The quality of building materials does not meet the requirements of relevant national codes and standards. And, the quality of workmanship (based on visual inspection of few typical buildings) does not meet the requirements of the relevant national codes and standards. Buildings of this type are generally not well maintained and there are visible signs of deterioration of building materials (e.g., concrete, steel and wood). 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 mountanous areas which have a high potential for landslides.

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	The combination of stone and mortar has low tensile and shear strength, especially for out-of-plane seismic effects. Sometimes openings such as walls and windows reduce the strength of the bearing walls. The perimeter walls are not sufficiently connected at the corners, and behave as seperate elements, which causes damage in the wall corner connections.		During earthquakes in the mountainous regions of Iran, there is extensive damage and many casualties in these buildings due to wall collapses. Figures 23 and 24 show typical damage of stone walls from earthquakes.
Frame (columns, beams)	No Frame exists.	No Frame exists.	No Frame exists.
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.		After wall failure, the heavy roof generally collapses. Figures 25 and 26 show evidence of this phenomenon.
Other			

Total collapse of this kind of building occured during several past earthquakes in Iran. Figure 27 shows one of these catastrophes.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *A: HIGH (i.e., very poor seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *A: HIGH (i.e., very poor seismic performance)*.

5.4 History of Past earthquakes

Year	Epicenter	Magnitude	Intensity
1985	Ardabil	5.8	VII

1990	Manjil	7.6	
1992	Lordekan	5	VII
2004	Firoozabad	6.3	

6. Construction

6.1 Building Materials

Walls: Stone. Unknown.

Foundations: No foundation.

Frames / Beams & Columns: No frame.

Roof and Floor(s): Joists with mud mortar and straw. Unknown.

6.2 Builder

The builder lives in this construction type.

6.3 Construction Process, Problems 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 thiner wooden beams or board(plank). Finally the roof is plastered with mud in two seperate stages to achieve a total thickness of 20-30 centimeters. in a single phase. not designed. There is no special design & drawings for this kind of construction.

6.4 Design and Construction Expertise

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.

6.5 Building Codes and Standards

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

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and not authorized as per development control rules.

These buildings are old. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

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).

7. Insurance

Earthquake insurance for this construction type is typically not available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is not available.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

(CONTINUED: FINISHING THE ROOF AND PARAPETS PROCEDURE) Step FOUR Re-laying the roof on the band 1- Lay the wooden joists and where found necessary, the Ferro-cement channels, on separate rooms as far as possible. 2- Hold these elements to the R.C. band at ceiling level by the wires projecting out of the band (see step two). 3- Build the stone walls to the required height. 4- Affix the wooden planks to the wooden joists with nails. Step FIVE (Figure 31) Finishing the roof The following suggestions are not essential to retrofitting scheme but are desirable for achieving good water proofing of the roof and parapets so that rain water ingression into the walls is prevented. This will maintain the dry strength of mud mortar in the walls. a) Finish the roof by using water proof non-erodible mud plaster as evolved by the CBRI, given below: Cutback is prepared by mixing bitumen 80/100 grade kerosene oil and paraffin wax in the ratio of 100:20:1 for 1.8 kg of cutback, 1.5 kg bitumen is melted with 15 grams of wax and this mixture is poured in a container having 300 ml kerosene oil with constant stirring till all ingredients are mixed. This mixture can now be mixed with 0.03 cubic meters of mud mortar for application as plaster. A plaster thickness of 20-25 mm is suggested. b) The stone parapet top and the walls can be finished on the inside face by using galvanized chicken wire mesh held to the wall by means of nails and plaster over using mud plaster or cement sand 1:6 mix. The galvanized mesh should pass through the space between wooden frames and the walls.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

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   Hosseini,B., Alemi,F. and Khaki,A.
   International Institute of Earthquake Engineering and Seismology 2005

10. Maps refered to "Geology Survey of Iran"

11. Seminars, Conferences, Personal communications and practical involvements

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