

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

Unreinforced Masonry Building : Brick masonry in mud/lime mortar

Report#	118
Last Updated	
Country	Iran
Author(s)	Nima T. Bekloo , ,
Reviewers	,

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:	Unreinforced Masonry Building : Brick masonry in mud/lime mortar
Country:	Iran
Author(s):	Nima T. Bekloo
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in throughout the Persian Empire, except places near the sea. This type of housing construction is commonly found in both rural and urban areas. This building type is more common in old and traditional cities.
Summary:	<p>This building structure derives its name from the four earrings that are constructed at the four corners of a rectangular building at the spring level of dome roof. This structural system was developed due to the lack of wood and stone. It was widely constructed more than three thousand years ago, after the invention of the dome-roof structures in the Old Persian Empire (Achaemenian & Sasanian). The main problem with the dome-roof building was transforming the rectangular or polygonal plan of the group of walls into the circular plan at the spring level of dome roof. They used to construct the first row of dome and then construct another row on top of previous one with a little offset closer to the center of the dome circle and so on. That was too difficult to construct. This system was invented to resolve this problem. In this system, once the walls were constructed, four earrings (shekanj) were built upon four corners of walls intersections, and then it was much easier to build a dome over these. It is an ideal system to resist vertical and gravity loads and transform them into horizontal and shear loads. For lateral loads, domes behave like trusses and distribute the load to the other parts of the structure creating a perfect load path.</p>
Length of time practiced:	More than 200 years
Still Practiced:	Yes

In practice as of:	
Building Occupancy:	Residential, unknown typeSingle dwellingMulti-unit, unknown typeResidential, 2 unitsResidential, 3-4 unitsResidential, 5-9 units
Typical number of stories:	1-2
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	The main function of this building typology is single-family house. Sometimes (especially in the old times) thewhole family (inc

Features

Plan Shape	Square, solidSquare, with an opening in planRectangular, solidRectangular, with an opening in plan
Additional comments on plan shape	Building configuration in plan is often rectangular or octagonal, or sometimes even polygon with more arms.
Typical plan length (meters)	5-20
Typical plan width (meters)	5-20
Typical story height (meters)	4-20
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)Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Mud wallsMasonry: Earthen/Mud/Adobe/Rammed Earth Walls: Mud walls with horizontal wood elementsMasonry: Earthen/Mud/Adobe/Rammed Earth Walls: Adobe block wallsMasonry: Earthen/Mud/Adobe/Rammed Earth Walls: Rammed earth/pile constructionMasonry: Unreinforced Masonry Walls: Brick masonry in mud/lime mortarMasonry: Unreinforced Masonry Walls: Brick masonry in mud mortar with vertical posts
Additional comments on	Lateral load-resisting system: The vertical load-resisting system is earthen walls. Load bearing walls

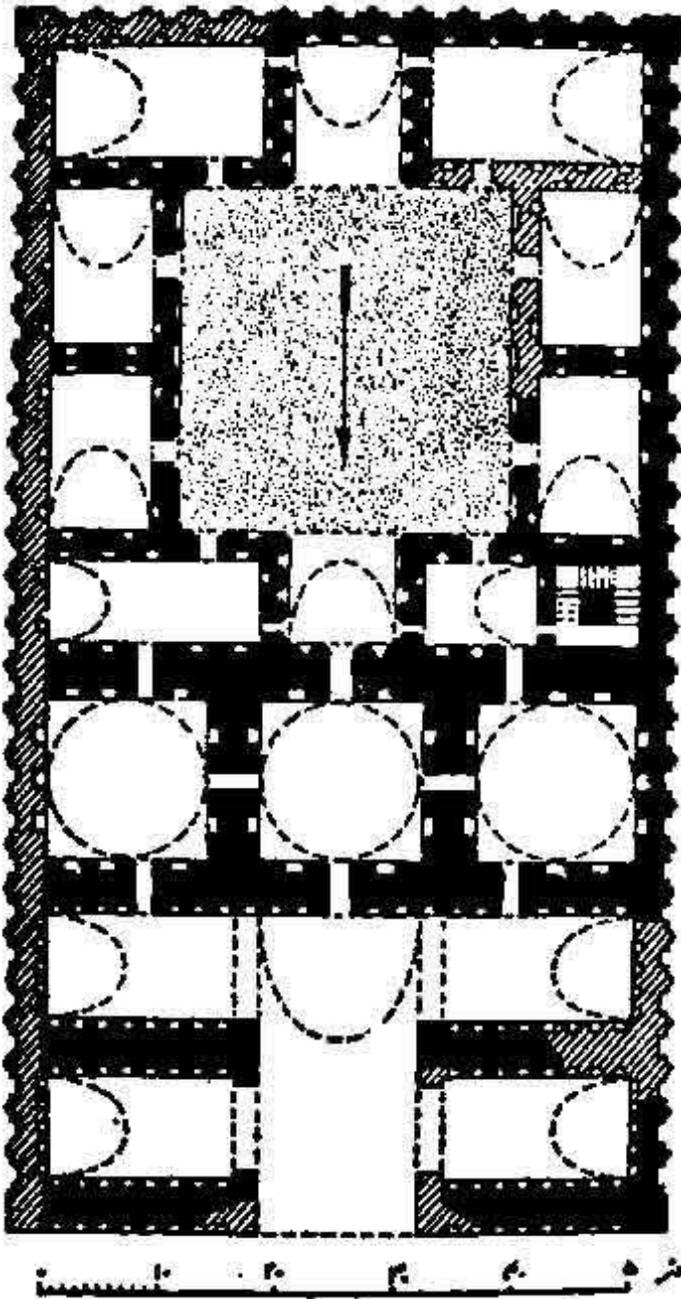
Additional comments on structural system	and dome-roof system Gravity load-bearing system: The lateral load-resisting system is earthen walls. Load bearing walls and dome-roof system.
Gravity load-bearing & lateral load-resisting systems	1. Sometimes walls and dome of the buildings constructed with mud mixed with pebbles as well. 2. Nowadays some people use cement based mortar as well.
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	The typical structural wall density is more than 20 %. (20% to 40%.)
Wall Openings	Due to its load bearing system, it does not have many openings. The openings are usually less than 30% of wall area. Sometimes openings are also provided in the roof as well. These are usually around 50 cm in diameter.
Is it typical for buildings of this type to have common walls with adjacent buildings?	Yes
Modifications of buildings	Because the structural system is the load bearing system, it is possible only to modify some small openings.
Type of Foundation	Shallow Foundation: Wall or column embedded in soil, without footing Shallow Foundation: Rubble stone, fieldstone isolated footing Shallow Foundation: Rubble stone, fieldstone strip footing
Additional comments on foundation	
Type of Floor System	Masonry floor, unknown Vaulted masonry floor Shallow-arched masonry floor Earthen floor, unknown Other floor system
Additional comments on floor system	The construction materials have no ductility. By building it in vault form, the forces are distributed on the surface.
Type of Roof System	Roof material unknown Masonry roof, unknown Vaulted masonry roof Shallow-arched masonry roof Earthen roof, unknown Vaulted earthen roof Wooden roof, unknown Roof system, other
Additional comments on	The construction materials have no ductility. By

Additional comments on roof system

building it in vault form, the forces are distributed on the surface.

Additional comments section 2

The typical plan dimension depend on the building function (residential, barn, mosque etc). The dimensions may vary, but over all the structure have a regular plan shape.



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Brick & adobe	Wall: Characteristic Strength-40-120 kg/cm ² Mix Proportion/Dimensions- 20x10x10 - 50x50x20 cm Varies from places and ages
Foundations	Brick & stone	Characteristic Strength: 40-150 kg/cm ² Mix Proportion/Dimensions: Not much bigger than the walls Varies from places and ages
Floors	Brick & adobe	Characteristic Strength: 40-120 kg/cm ² Mix Proportion/Dimensions: 20x10x10 - 50x50x20 cm Varies from places and ages
Roof	Brick & adobe	Characteristic Strength: 40-120 kg/cm ² Mix Proportion/Dimensions: 20x10x10 - 50x50x20 cm Varies from places and ages
Other		

Design Process

Who is involved with the design process?	ArchitectTechnologistBuilderOther
Roles of those involved in the design process	
Expertise of those involved in the design process	There were no academically qualified engineers or architects and no Standards for design of this type of buildingstructures were available. These are constructed by empiricism or experimentation. However, it is still a topic ofresearch. There are no academically qualified engineers or architects for this type of buildings.

Construction Process

Who typically builds this construction type?	OwnerMasonBuilderOther
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Roles of those involved in the building process	The builder lives in the house. Traditionally every body has a co-operation in construction their own home.
Expertise of those involved in building process	These are constructed by empiricism or experimentation.
Construction process and phasing	It is basically owner built construction where experienced persons, master builders and maybe some local contractors, with help of laborers, built the structure with shovel, hack, float and other old construction equipment. The construction of this type of housing takes place in a single phase. Typically, the building is originally 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	

Building Permits and Development Control Rules

Are building permits required?	No
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	This type of construction is a non-engineered, and not authorized as per development control rules. This type can only be seen in small villages and old towns nowadays. Building permits are not required to build this housing type.

Building Maintenance and Condition

Typical problems	
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typical problems associated with this type of construction

Since These types are ancient, sometimes they clash with urban development

Who typically maintains buildings of this type?

BuilderOwner(s)Other

Additional comments on maintenance and building condition

Often, the whole family workstogether for the maintenance of the building.

Construction Economics

Unit construction cost

Approximately US\$ 80.

Labor requirements

For construction of an average size of house, 4-8 people work for about 6 months.

Additional comments section 3



Critical structural details



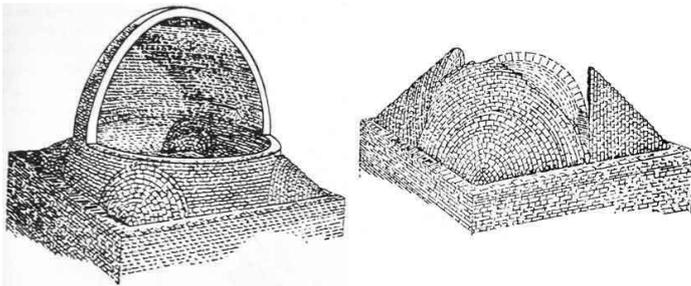
Critical structural details



Critical structural details



Critical structural details



Critical structural details



Critical structural details



Key seismic feature

Socio-Economic Issues

Patterns of occupancy	Houses of this type are mostly occupied by a single family.
Number of inhabitants in a typical building of this	~20

construction type during the day	<20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor) Low-income class (poor) Middle-income class High-income class (rich)
Additional comments on economic level of inhabitants	Nowadays very small number of people live in this type of building. Economic Level: The ratio of price of housing unit to the annual income can be 1:1 for poor class families.
Typical Source of Financing	Owner financed Personal savings Informal network: friends or relatives Government-owned housing
Additional comments on financing	
Type of Ownership	Rent Own outright Units owned individually (condominium) Owned by group or pool Long-term lease
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	Earthquake insurance is included in fire insurance and is based on the value of the building. It depends on the owner capital demand, usually for every US\$ 5000 additional coverage, it costs about US\$ 6/year added to the fire insurance.
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Yes
Additional comments on premium discounts	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type

As stated above, this type has been constructed thousands of years ago, so there must be many other earthquakes especially historical ones that affected these buildings. However, no exact information is available.

Additional comments on earthquake damage patterns

Overall damage patterns observed in past earthquakes for this type of construction included- (walls): Vertical and diagonal cracks in walls, more often along mortar joints (roof and floors): No significant damage except that caused by wall damage especially when walls under the dome slip leaving the dome roof without any support (other): Crushable brick material, weak mortar band

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	TRUE

	direction that serves to transfer inertial forces from the building to the foundation.	
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.	TRUE
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.	TRUE
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.	TRUE
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	TRUE

than 13 (unreinforced masonry walls);

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 anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	N/A
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).	TRUE
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	These are special type of structures which are not covered by the National Building Code	
Vertical irregularities typically found in this construction type	Other	

Horizontal irregularities typically found in this construction type	SetbackOther
Seismic deficiency in walls	Constructed of low strength brittle materials, the structural elements are unreinforced, walls are large and heavy
Earthquake-resilient features in walls	Well defined load path, high rigidity, continuous bearing (Shear) walls
Seismic deficiency in frames	Brittle material, mostly no confinements
Earthquake-resilient features in frame	Vaulted roof and massive masonry piers.
Seismic deficiency in roof and floors	Constructed of low strength brittle materials, heavy in weight, the roof is unreinforced, opening in the roof, slipping of the roof over walls large span,
Earthquake resilient features in roof and floors	well defined load path, perfect distribution of forces and stresses
Seismic deficiency in foundation	Lack of Lateral resistance
Earthquake-resilient features in foundation	N/A

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

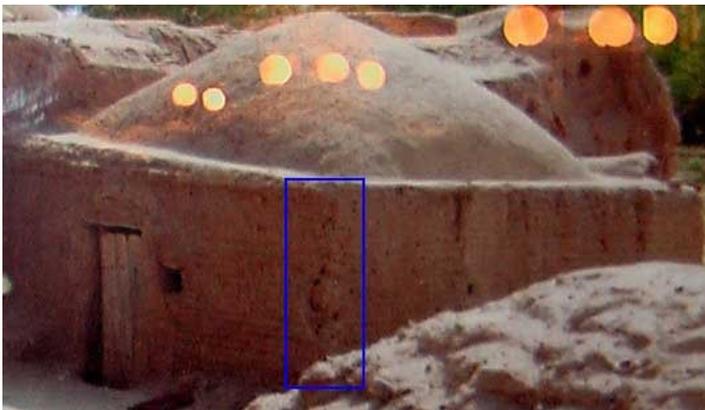
	High vulnerability		Medium vulnerability		Low vulnerability	
	A	B	C	D	E	F
Seismic vulnerability class	0					



Typical earthquake damage



Typical earthquake damage



Typical earthquake damage

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Not enough distance between adjacent buildings	For buildings with different heights: 1. Destroy some common part of the adjacent walls to reach distance of 1% wallheight. 2. Join all the buildings in an area to make them behave as a one single structure.
Damages in load path (exterior walls)	1. Add a shear wall to the system. 2. Embed some materials to maintain the wall. 3. Fill the cracks by plaster, cement
Opening in roof	Strengthening all around the opening by wood

	or steel bars.
Heavy weight	Remove the heavy weight materials of the roof and replace them with light new materials.
#NAME?	#NAME?

Additional comments on seismic strengthening provisions	Iranian codes stated that they are not suitable for monuments.
Has seismic strengthening described in the above table been performed?	No.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Both intervention options have been used; they are used for both matters.
Was the construction inspected in the same manner as new construction?	No.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Owner, local masons without any no academic background in engineering.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	N/A
Additional comments section 6	

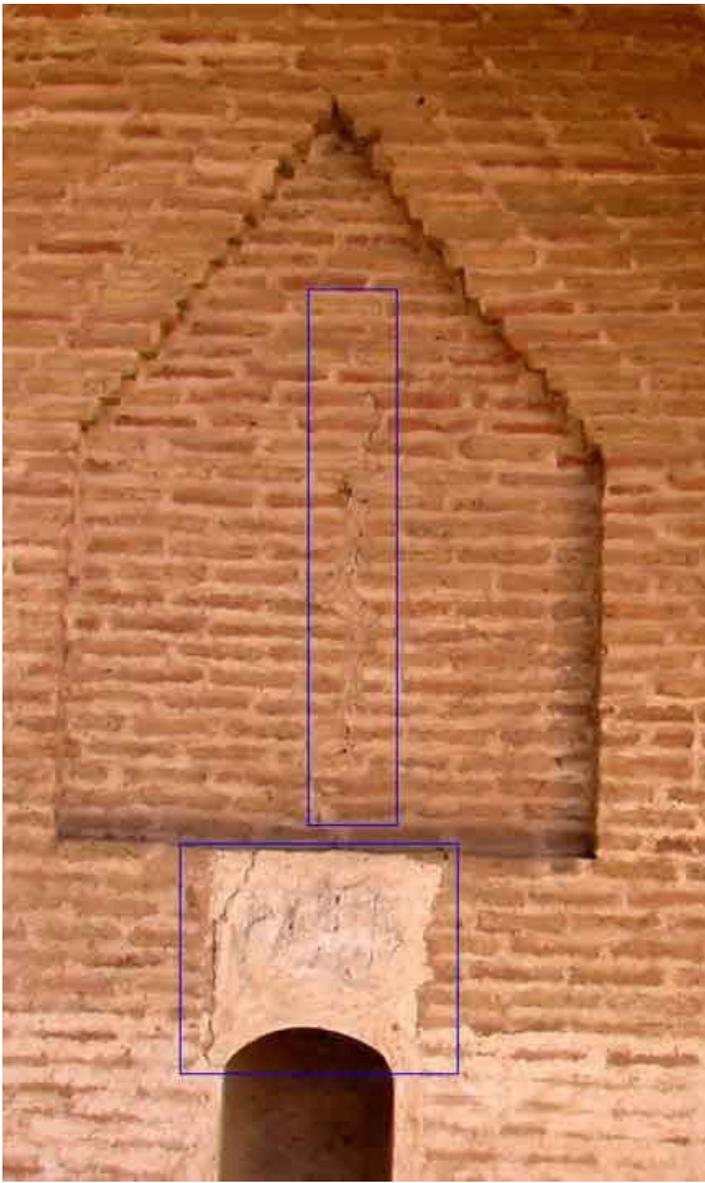
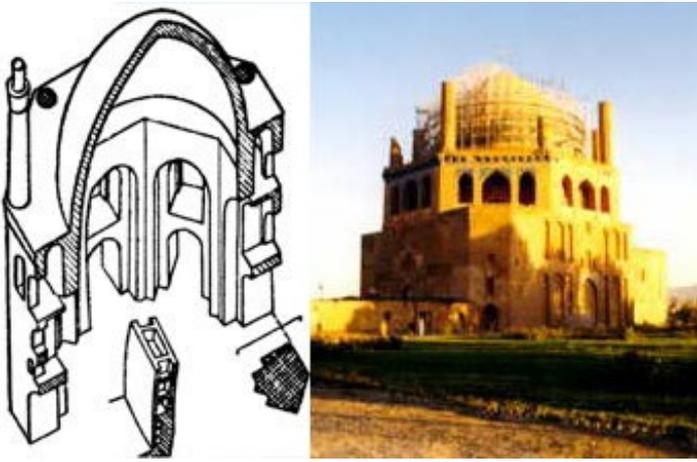


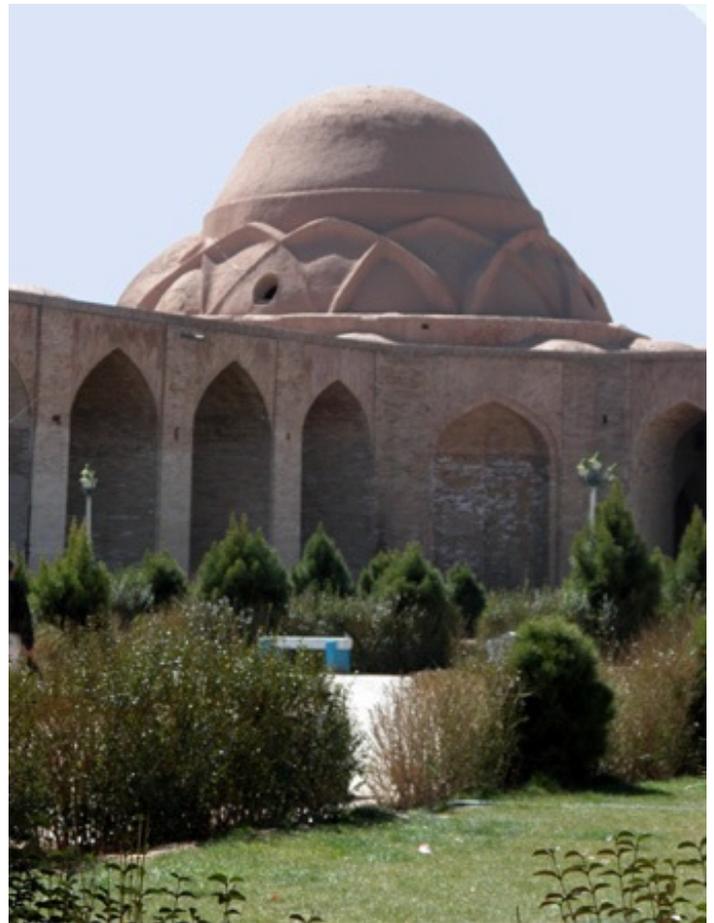
Illustration of seismic strengthening technique



Inside view of the earring



***Soltanieh dome, Zanjan, IRAN
(this dome was built without
earring)***



***Earring over polygonal section
(Kerman, IRAN)***

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Authors

Name	Title	Affiliation	Location	Email
Nima T. Bekloo	Mr.	CPEng, MIEAust	Melbourne/ Australia	poosad@gmail.com

Reviewers

Name	Title	Affiliation	Location	Email