World Housing Encyclopedia

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

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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Confined brick masonry building with concrete tie columns and beams

Report #	27
Report Date	06-05-2002
Country	IRAN
Housing Type	Confined Masonry Building
Housing Sub-Type	Confined Masonry Building with Concrete blocks, tie-columns and beams
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Summary

This is a typical confined brick masonry housing construction common in rural areas of Iran. This building type is often used as a single-family house. Brick masonry shear walls confined with concrete tie columns and beams provide earthquake resistance in both directions. This

building type is expected to have good seismic performance.

1. General Information

Buildings of this construction type can be found in rural areas of Iran. The percentage of this housing type in those regions is almost 10%. This type of housing construction is commonly found in rural areas. This construction type has been in practice for less than 50 years.

Currently, this type of construction is being built. .

Figure 1: Typical Building

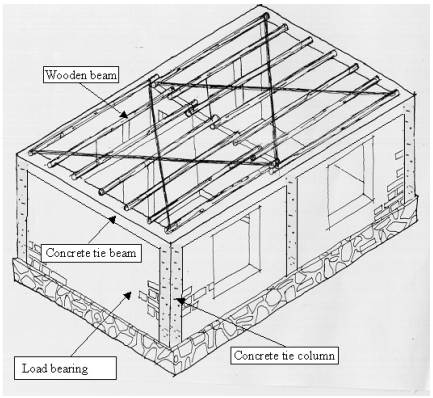


Figure 2A: Key Load-Bearing Elements

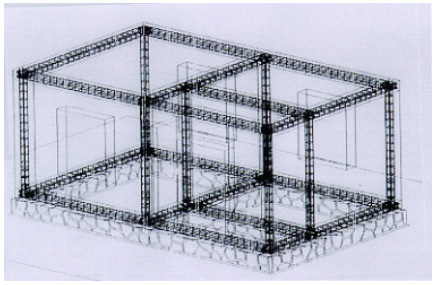


Figure 2B: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They do not share common walls with adjacent buildings. This value of 5 meters is average distance. Buildings of this type in some places are located close together and in other places are scattered When separated from adjacent buildings, the typical distance from a neighboring building is 5 meters.

2.2 Building Configuration

The typical shape of a building plan for this housing type is rectangular. To view outside the building, typically a window opening is built in external walls. These windows almost take 40% of the external walls areas. The other wall has one or two doors. The door sizes are typically 90 X 210 (cm). The overall window and door areas are about 25% of the overall wall surface area.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Building of this type can have as the one main entry so the two doors.

2.4 Modification to Building

This type of construction does not have many modifications.

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☑
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐

Steel	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is confined masonry wall system. Gravity loads sustain by bearing masonry brick walls.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is confined masonry wall system. In both directions of the buildings lateral load-resisting system are provided by masonry brick shear walls which are confined with concrete tie column and beams.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 5 and 5 meters, and widths between 9 and 9 meters. The building has 4 to 6 storey(s). The typical span of the roofing/flooring system is 2.5 meters. Typical Span: Span may be 3.0 m. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 20 %. Total wall area/plan area (for each floor) 0.2.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐

	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☐
	Wood shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	
	Wood planks or beams supporting natural stones slates	☐	☐
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☐
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☐	☐
Other	Described below	☐	☑

The floor/ and roof are considered to be a rigid diaphragm.

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	Reinforced-concrete isolated footing	☐
	Reinforced-concrete strip footing	☑
	Mat foundation	☐
	No foundation	☐
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

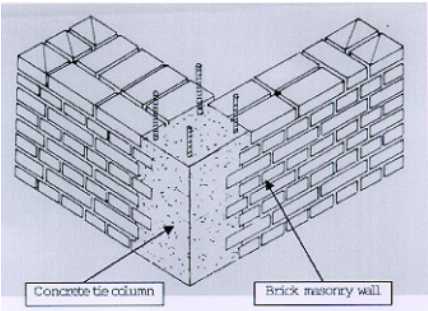


Figure 3: Critical Structural Details: Concrete tie column

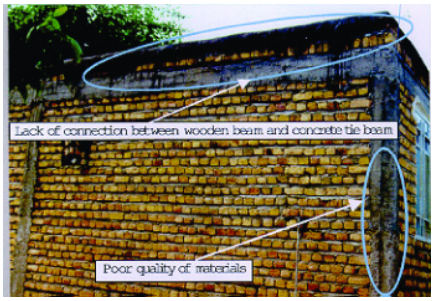


Figure 4A: An Illustration of Key Seismic Deficiencies: lack of Connection Between Wooden Beam and Concrete Tie Beam and Poor Quality of Materials

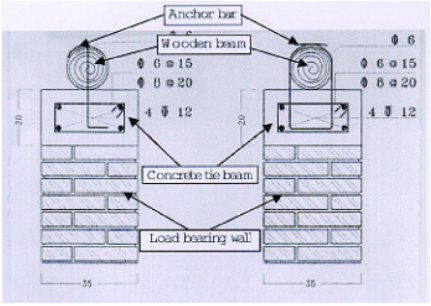


Figure 4B: Wall cross-section showing a concrete tie beam ad roof-to-wall connection

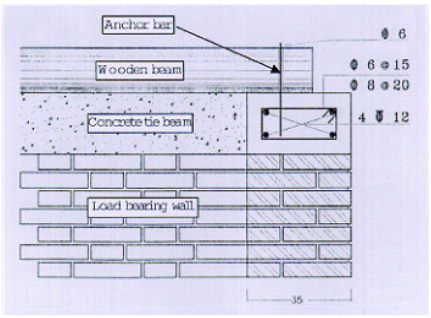


Figure 4C: Wall side view showing a concrete tie beam and roof-to-wall connection

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

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

4.2 Patterns of Occupancy

One family usually occupies each house.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☑
b) low-income class (poor)	☐
c) middle-income class	☐
d) high-income class (rich)	☐

Economic Level: For Poor Class the Housing Price Unit is 5000 and the Annual Income is 1000.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☑
4:1	☐
3:1	☐
1:1 or better	☐

What is a typical source of	

financing for buildings of this type?	Most appropriate type
Owner financed	☑
Personal savings	☑
Informal network: friends and relatives	☐
Small lending institutions / micro-finance institutions	☐
Commercial banks/mortgages	☑
Employers	☐
Investment pools	☐
Government-owned housing	☐
Combination (explain below)	☐
other (explain below)	☐

In each housing unit, there are 1 bathroom(s) without toilet(s), 1 toilet(s) only and no bathroom(s) induding toilet(s).

4.4 Ownership

The type of ownership or occupancy is outright ownership and ownership with debt (mortgage or other).

Type of ownership or occupancy?	Most appropriate type
Renting	☐
outright ownership	☑
Ownership with debt (mortgage or other)	☑
Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	☐	☑	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
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.	☐	☑	☐
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.	☐	☐	☑

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.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☑	☐	☐
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);	☑	☐	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☑	☐	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	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.	☑	☐	☐
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☑	☐	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☐	☑	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☐	☑	☐
Additional Comments				

5.2 Seismic Features

Structural Element	**Seismic Deficiency**	**Earthquake Resilient Features**	**Earthquake Damage Patterns**
Wall	Unequal stiffness distribution.		
Frame (columns, beams)	Poor quality of workmanship and materials.		
Roof and floors	Lack of proper connection between roof and masonry shear walls They are not perfectly rigid diaphragm.		

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *C: MEDIUM VULNERABILITY (i.e., moderate*

seismic performance), the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is *D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance)*.

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☑	☐	☑	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1990	Manjil	7.6	IX

Figure 5: Damage caused by the absence of concrete posts (1990 Manjil earthquake)

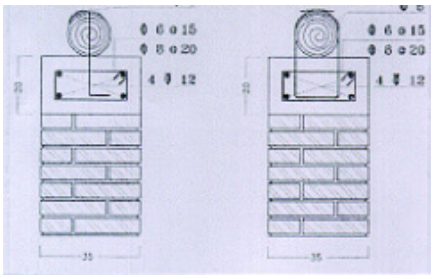


Figure 6A: Illustration of Seismic Strengthening Techniques

Figure 6B: Damage due to large opening, absence of masonry shear wall and short column behavior in concrete post (1990 Manjil earthquake)

Figure 6C: Damage in the wall panel (1990 Manjil earthquake)

Figure 6D: Collapse due to heavy roof (1990 Manjil earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Clay brick masonry.	150 Kg/cm² 10 Kg/cm².	1:6 / 55 X 110 X 220 (mm).	
Foundation	Concrete.	210 kg/cm².	1:2:4	
Frames (beams & columns)	Steel bars.	3000 kg/cm².		
Roof and floor(s)	Wood.			

6.2 Builder

It is typically built by developers and the builders does not necessary live in this building type.

6.3 Construction Process, Problems and Phasing

Typically developers build these types of constructions. Process starts with the foundations and then bearing walls. Process continues by adding the concrete tie columns and then tie beams then placing of wood beams and finally putting the finishing on the hole building. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

As far as the design concern, engineers do their job properly. But the main problem is the construction of this type of buildings in rural areas, due to lack of skilled worker. For design of building, engineers and architectures are both involved. However, during the construction process they do not spend any time to visit the site.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. The first official issue about this type of building was in 1987. The Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800) addressed this type of construction. Iranian Code of Practice for Seismic Resistant Design of Building, 1st Edition-1987 and 2nd Edition-1999 Iranian National Building Code, Part: 8, Reinforced and unreinforced masonry buildings. The year the first code/standard addressing this type of construction issued was 1987. Iranian Code of Practice for Seismic Resistant Design of Building, 1st Edition- 1987 and 2nd Edition-1999. The most recent code/standard addressing this construction type issued was 1999. The first official issue about this type of building was in 1987. The Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800) addressed this type of construction. Iranian Code of Practice for Seismic Resistant Design of Building, 1st Edition- 1987 and 2nd Edition-1999 Iranian National Building Code, Part: 8, Reinforced and unreinforced masonry buildings Year the first code/standard addressing this type of construction issued: 1987 National building code, material codes and seismic codes/standards: Iranian Code of Practice for Seismic Resistant Design of Building, 1st Edition- 1987 and 2nd Edition-1999 When was the most recent code/standard addressing this construction type issued? 1999.

The building department of municipalities approves the design and holds the designer responsible for the projects. For those constructions, which are supported by government's fund, there is a proper control during construction. But for the others, there is not any control.

6.6 Building Permits and Development Control Rules

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

6.8 Construction Economics

A unit construction may cost 500,000 Rials/m^2 (250 \$US/m^2). For a typical one story building needs about 30 to 40 days to complete the load bearing structure.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing

buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Shear wall	Add new shear wall
Tie beams	Increasing the size of the existing tie beams and adding new tie beams for added new walls
Roof	Proper connections of the wood beams to the tie beams

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Shear wall	
Tie beams	
Roof	Proper connections of the wood beams to the tie beams.

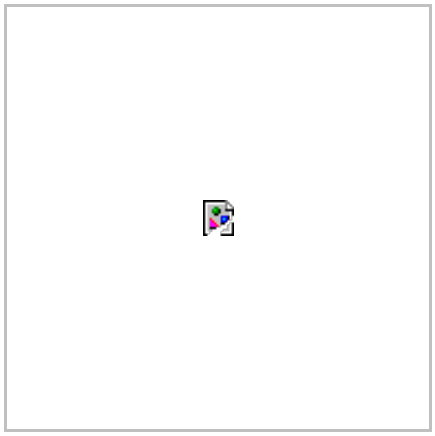
Seismic strengthening techniques are illustrated in Figures 7A, 7B, and 7C.

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?

No.

8.3 Construction and Performance of Seismic Strengthening



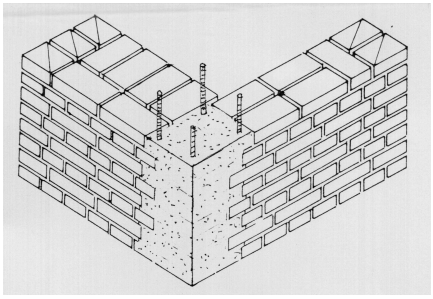


Figure 7A: Seismic Strengthening: Tying the wooden beam to the concrete

tie beam using an anchor bar

Figure 7B: Seismic Strengthening: Addition of a new concrete post

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