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
Two-story unreinforced brick masonry building with wooden floors

Report #	41
Report Date	05-06-2002
Country	KYRGYZSTAN
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in mud/lime mortar
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Summary

This is a non-engineered construction practiced in Kyrgyzstan from 1920 to 1957. The load-bearing structure consists of unreinforced brick masonry walls and wooden floor beams. Brick masonry walls are usually constructed of mud mortar. Walls are usually perforated with rather

large door and window openings. The wall length between the adjacent cross walls is on the order of 9-10 m. Wooden floor elements (beams) are not tied together and they do not behave as diaphragms. Based on the performance in past earthquakes, this building type is considered to be highly vulnerable to seismic effects.

1. General Information

Buildings of this construction type can be found in the cities throughout Kyrgyzstan. It is estimated that around 5% of residential buildings in Bischkek and 5-7% of buildings in other cities are of this type. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 100 years.

Currently, this type of construction is not being built. .

Figure 1: Typical Building

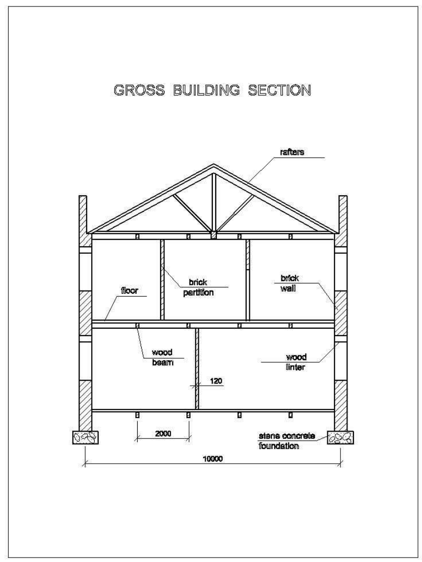

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

Typical shape of a building plan for this housing type is rectangular. Typical size of window openings is 1.2 m - 1.5 m (height) X 1.5 - 2 m (width), and the door openings: 2 m (height) X 1m (width). There are 16-20 windows at each floor level in the building. The overall window and door areas constitute around 15% of the overall wall surface area.

2.3 Functional Planning

Single, Mulitple and Mixed Housing Units. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. There is one stair per building unit. Building unit consists of 2-4 apartments (housing units) located on the same floor. There are typically 2 building units (floors) per building.

2.4 Modification to Building

Modifications in buildings of this type are common e.g. installation of new doors and windows, new walls and partitions, deletion of doors and windows, demolition of existing load-bearing walls and partitions, construction of new balconies, etc.

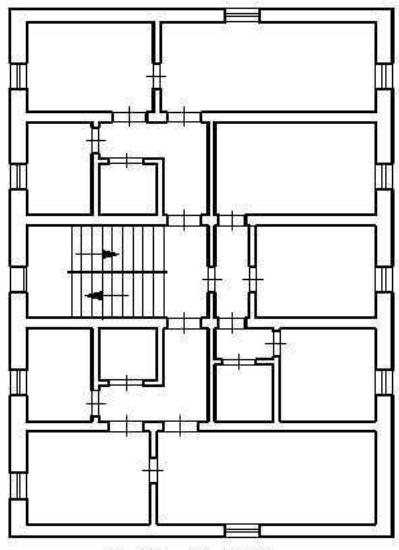

Figure 3: Plan of a Typical Building

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	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	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 un-reinforced masonry walls. Elements of gravity load-resisting system are the same as lateral load-resisting system. Wooden floor beams are also carrying the gravity loads. The beams are supported by the walls, however, without any special anchorage. Typical beam cross-sectional dimensions are: 70-150 mm width and 150-250 mm depth. Wooden floors typically do not have concrete topping. Details of floor structures and wall-floor connections are illustrated in FIGURE 4A.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. Lateral load-resisting system in buildings of this type consists of unreinforced brick masonry walls. Brick masonry walls are usually constructed in mud mortar. Typical wall thickness ranges from 380 mm to 510 mm. Walls are usually perforated with rather large door and window openings. Window and door lintel beams are made of timber board or steel bars embedded in mortar. Typical lintel details are shown in FIGURE 4B. Wooden floors are not acting as diaphragms.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 30 and 30 meters, and widths between 12 and 12 meters. The building is 2 storey high. The typical span of the roofing/flooring system is 6 meters. Typical Story Height: Story height varies from 3 to 3.5 meters. Typical Span: Usually typical span is 5-6 meters. The typical storey height in such buildings is 3.5 meters. The typical structural wall density is up to 20 %. Total wall area/plan area is 15%. The range between the ratios of the area of all the walls in each principal direction divided by the total area of the plan is 7-8%.

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	☑	☑

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	☐

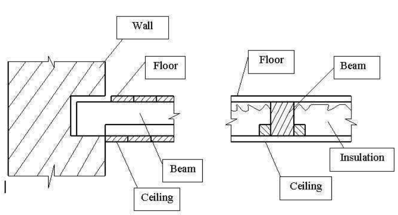

Figure 4A: Critical Structural Details - wall and floor connection details

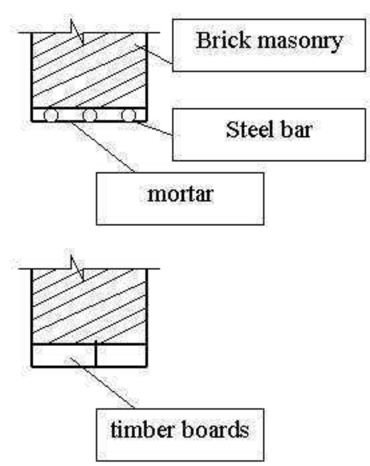

Figure 4B: Cross-section through door lintels

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 10-20 housing unit(s). 16 units in each building. Usually there are 8 - 16 units in buildings.

The number of inhabitants in a building during the day or business hours is 11-20. The number of inhabitants during the evening and night is more than 20.

4.2 Patterns of Occupancy

There are 2-4 housing units in a building unit at each floor level. One family occupies one housing unit. In general, between 8 to 16 families occupy one building of this type.

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)	☐

70% poor and 30% middle class inhabitants occupy buildings of this type.

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 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is outright ownership.

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	- Brick masonry walls have poor shear, tension and compression resistance, and steel reinforcement is generally not provided; - Window and door lintels are made of timber boards or steel bars; - Walls are usually perforated with rather large door and window openings		Damage to the walls or complete collapse of buildings; the extent of damage depends on the direction of seismic waves, earthquake intensity, and pier dimensions. Wall failure occurs due to in-plane or out-of-plane shear, more often as a result of out-of-plane shear.
Frame (columns, beams)			
Roof and floors	Wood beams are not joined in the rigid diaphragm.		

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *C: MEDIUM VULNERABILITY (i.e., moderate 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
1986	Kairakuum, Tadjikistan	6.8	VII
1988	Spitak, Armenia		
1992	Suusamir, Kyrgyzstan	7.4	VII

The epicenter of the Suusamir earthquake was in the hilly area (mountains). Maximum earthquake intensity (based on the 12-point intensity scale) was 9. Buildings of this type affected by the earthquake were away from the epicenter, located in the region with intensity 6-7 on the same 12-point intensity scale. In the Kairakum earthquake, intensity reported in the cities (where this type of construction is found) was 6-7. Most buildings of this type had suffered various extent of damage to masonry walls. Buildings of this type were also damaged in the 1988 Spitak, Armenia earthquake (see FIGURE 5).

Figure 5: A Photograph Illustrating Typical Earthquake Damage (1988 Armenia earthquake, source: EERI Annotated slide collection)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Brick masonry.	Rt < 30 kPa; brick compressive strength is over 750 MPa, and mortar compressive strength of over 50 MPa.		Rt= adhesion between mortar and bricks.
Foundation	Stone			
Frames (beams & columns)				
Roof and floor(s)	Wood		Typically pine or aspen wood	

6.2 Builder

Anyone can live in buildings of this construction type (including the builders).

6.3 Construction Process, Problems and Phasing

Construction of this type was practiced many years ago. Usually an engineer managed the construction, however construction workers did not have any construction-related experience. In some cases, buildings of this type had been constructed without a proper design documentation. 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.

6.4 Design and Construction Expertise

In general, this is a non-engineered construction (constructed without qualified technical expertise). Usually an engineer managed the construction of this type.

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 a non-engineered, and not authorized as per development control rules. Building permits are not 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

Cost of load-bearing structure is on the order of 100 US$/m². 10 persons need to work for 12-24 months in order to build a building of this type.

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

Seismic strengthening is not considered to be feasible for buildings of this type. If strengthening were to be implemented, there would be a need to install new floors, provide jacketing of the walls (on both faces) etc. This is considered to be expensive and therefore the buildings of this type, if severely damaged in an earthquake, are replaced with the new buildings. In case of minor damage (e.g. cracks developed in the walls), these cracks are repaired without strengthening being performed.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

Reference(s)

1. Seismic Hazard and Buildings Vulnerability in Post-Soviet Central Asia Republics
   NATO Series, Netherlands

2. Buildings and Constructions Design in Seismic Regions - Handbook
   Bishkek 1996

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