World Housing Encyclopedia

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

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

HOUSING REPORT

Buildings with hollow clay tile load-bearing walls and precast concrete floor slabs

Report #	34
Report Date	05-06-2002
Country	KYRGYZSTAN
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in lime/cement mortar
Author(s)	Ulugbek T. Begaliev, Svetlana Uranova
Reviewer(s)	Svetlana N. Brzev

Summary

Buildings of this type are characterized with load-bearing masonry walls and precast concrete floors. Typical buildings of this type are 3 to 4 stories high and they are characterized with two longitudinal walls and several cross walls. There are many existing buildings of this type in

Kyrgyzstan, and most of them were constructed in the 1960s. This construction practice was banned after 1966, due to the code provisions that required restriction of the size of the cores in hollow clay tiles (blocks). The exterior walls are made of hollow clay masonry tiles (blocks). In some cases there are two wall wythes: the exterior wythe made of hollow clay tiles and the interior wythe made of solid clay bricks. The floor system consists of precast reinforced concrete hollow core slabs. Buildings of this type were built in the areas with high seismic design intensity (8, 9 and higher on the MSK scale). This building type is considered to be rather vulnerable to seismic effects.

1. General Information

Buildings of this construction type can be found in large parts of Kyrgyzstan: Most of them are located in urban areas. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 75 years.

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

Figure 1: Typical Building

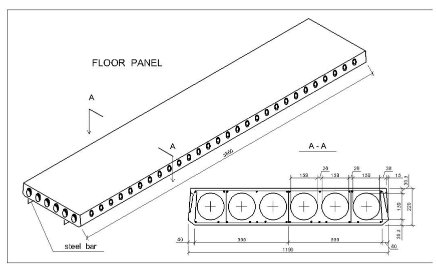

Figure 2A: Key Load-Bearing Elements

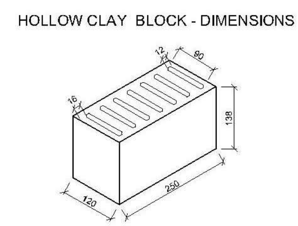

Figure 2B: A typical hollow clay tile (block) dimensions

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 window size is 1.2 m X 1.2 m. Typical door size is 0.9 m (width) X 1.9 m (height). The overall window and door area accounts for 10 to 12% of the overall wall surface area.

2.3 Functional Planning

The main function of this building typology is multi-family housing. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. There is one staircase in each building unit. Building unit consists of 4 apartments (housing units) on each floor. Each building consists of 2 to 4 building units.

2.4 Modification to Building

There are lot of modifications at the ground floor level in buildings of this type. Typical modifications include installation of new door and windows openings, complete/partial removal of existing walls, and horizontal extension (addition of rooms).

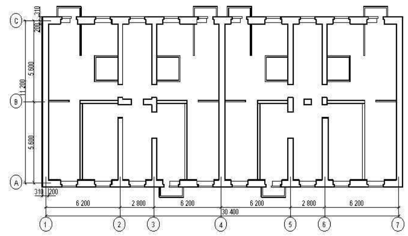

Figure 3: Plan of a Typical Building

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)	☐

Masonry walls are made of hollow clay tiles.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Gravity load-bearing structure consists of load-bearing masonry walls and concrete floor slabs.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Lateral load-resisting system consists of the exterior walls of small-size clay block masonry and the interior brick masonry walls. The exterior walls are made of hollow clay masonry tiles (blocks). The block dimensions are: 138 mm (height) X 120 mm X 250 mm. The blocks have oval hollow cores (90 mm X 16 mm). The area of the cores accounts for 25-33 % of the block area. Due to the large area of hollow cores, masonry is characterized with rather low tensile resistance. Usually mortar is of a poor quality. In some cases, exterior walls consist of two wythes; the exterior wythe is made of hollow clay tiles, whereas the interior wythe is made of solid bricks (dimensions 250 mm thickness X 120 mm X 70 mm). Floor system consists of precast reinforced concrete hollow core slabs. Dimensions of slab panels are 5.86 m length X 1.2 m width. The panels are combined in the uniform diaphragm by means of reinforced concrete belt (cast in-situ reinforced concrete beam). Windows and door lintels are of precast concrete construction.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 60 and 60 meters, and widths between 12 and 12 meters. The building is 4 storey high. The typical span of the roofing/flooring system is 6 meters. Typical Span: Typical distance between the cross walls ranges from 2.8 m to 6 m, whereas the distance between longitudinal walls is 12 m. The typical storey height in such buildings is 2.7 meters. The typical structural wall density is up to 10 %. 7 to 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	☐

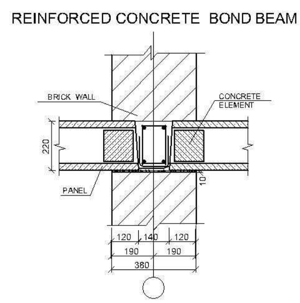

Figure 4: Critical Structural Details: wall section showing concrete bond beam

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 51-100 housing unit(s). 64 units in each building. Usually there are 32-64 units in each building. The number of inhabitants in a building during the day or business hours is more than 20. The number of inhabitants during the evening and night is more than 20.

4.2 Patterns of Occupancy

Each floor in the building consists of 2 to 4 housing units. One family occupies one housing unit. Depending on the number of building units and stories, 32 to 64 families occupy one building.

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)	☐

80% poor and 20% 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)	☐

Before 1990 all kind construction has typical Government source of financing. Now all existing apartment buildings are private. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is outright ownership and individual 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	The building is regular with regards to both the plan	☑		

Configuration	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	- Exterior walls (hollow clay tiles) have poor shear and tensile resistance. - Large unsupported length of the cross walls. - Poor quality of masonry mortar. - Absence of wall reinforcement.		Diagonal cracks in wall, cracks at the wall corners, out-of-plane collapse walls, partial or complete collapse of buildings.

Frame (columns, beams)			
Roof and floors			

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	Kairakum (Kyrgyzstan, Tadjikistan)	6.8	7 (MSK)
1988	Spitak (Armenia)	7	10 (MSK)
1992	Suusamir (Kyrgyzstan)	7.4	7 (MSK)

Damage to walls: inclined and diagonal cracks in the piers, destruction of building corners, partial collapse of walls.

Figure 5A: A Photograph Illustrating Typical Earthquake Damage 1988 Spitak, Armenia earthquake Source: EERI

Figure 5B: Building Collapse in the 1988 Spitak, Armenia Earthquake (Source: Klyachko, 1999)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Masonry.	Tension resistance of mortar less 60 MPa.	mortar mix 1:12 (cement/sand) and less.	(different, depend on mix materials).
Foundation	Concrete.	5-7 MPa (cube compressive strength).	1:3:6	(different, depend on mix materials).
Frames (beams & columns)				
Roof and floor(s)		30-35 MPa (cube compressive strength) Steel: flow limit 390 MPa Elasticity Modulus 200,000 MPa).	1:1,7:3,2 (different depend on type of mix materials).	

6.2 Builder

Anyone can live in buildings of this construction type.

6.3 Construction Process, Problems and Phasing

These buildings are constructed by contractors. Design institutes develop design documentation. Special construction companies perform construction. Precast elements and bricks are made at the plant. Main equipment for construction is: crane, welding equipment and concrete mixers. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size.

6.4 Design and Construction Expertise

Expertise is necessary for the design and the different stages of construction according to the laws of the Kyrgyz Republic. Engineers play a leading role in each stage of construction.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. 1957. The year the first code/standard addressing this type of construction issued was SN-8-57.Building norm and guiding principles in seismic regions, SNiP II-A.12-62 Building in seismic regions:Design codes. SNiP II-7-81. Building in Seismic Regions - Design code. The most recent code/standard addressing this construction type issued was 1981. Title of the code or standard: 1957 Year the first code/standard addressing this type of construction issued: SN-8-57.Building norm and guiding principles in seismic regions, SNiP II-A.12-62 Building in seismic regions:Design codes. National building code, material codes and seismic codes/standards: SNiP II-7-81. Building in Seismic Regions - Design code When was the most recent code/standard addressing this construction type issued? 1981.

Building permit will be given if the design documents have been approved by the State Experts. State Experts check the compliance of design documents with the pertinent Building Codes. According to the building bylaws, the building cannot be used without the formal appoval of a special committee.The committee grants the approval (permit) if design documents are complete and the construction has been carried out in compliance with the Building Codes.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and 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 Builder and Tenant(s).

6.8 Construction Economics

For load-bearing structure only: about 150 US$/m². It would take from 12 to 24 months for a team of 15 workers to build the structure only (without finishes).

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 available.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Poor shear and tensile resistance of hollow clay tile walls	Installation of reinforced concrete overlay (FIGURES 6A and 6B)

Seismic strengthening provisions are included in the official design guidelines, however it is rarely practiced in Kyrgyzstan.

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.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
Very few buildings of this type were strengthened in Kygyzstan. Buildings in Bishkek have been strengthened as a part of building expansion project.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
Yes.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
The construction was performed by contractor. Usually engineers participate in the design and supervise construction process.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

Strengthened buildings were not subjected to the effects of strong earthquakes as yet.

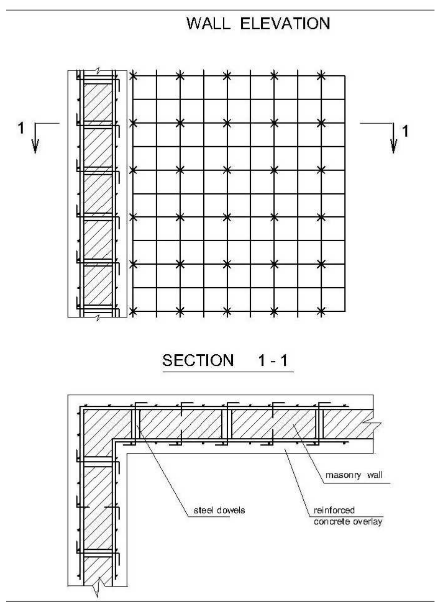

Figure 6A: Illustration of Seismic Strengthening Techniques

Figure 6B: Seismic strengthening under construction

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Author(s)

1. Ulugbek T. Begaliev
   Head of Department, KNIIPC
   Vost Prom Zone Cholponatisky 2, Bishkek 720571, KYRGYZSTAN
   Email:utbegaliev@yahoo.com

2. Svetlana Uranova
   Head of the Laboratory, KRSU
   Kievskai 44, Bishkek 720000, KYRGYZSTAN
   Email:uransv@yahoo.com FAX: 996-3312-282859

Reviewer(s)

1. Svetlana N. Brzev
   Instructor
   Civil and Structural Engineering Technology, British Columbia Institute of Technology
   Burnaby BC V5G 3H2, CANADA
   Email:sbrzev@bcit.ca FAX: (604) 432-8973