World Housing Encyclopedia

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

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HOUSING REPORT
Single-family brick masonry house

Report #	36
Report Date	05-06-2002
Country	KYRGYZSTAN
Housing Type	Confined Masonry Building
Housing Sub-Type	Confined Masonry Building with Concrete blocks, tie-columns and beams
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Summary

This housing type represents a very popular single-family housing construction practice followed in Kyrgyzstan in the recent past. Approximately 80% buildings of this type, mostly those constructed after 1990, do not comply with the Building Code requirements. These are low-rise (1- to 2-story high) buildings with a complex plan and wall layout. The main load-bearing system consists of brick masonry walls in cement mortar partially confined with

reinforced concrete posts and beams; columns are provided only at some wall corners and intersections. Rigid brick masonry walls have low load-carrying capacity. Wall thickness is either 380 mm or 510 mm. SNiP (Building Code) includes provisions for the horizontal wall reinforcement (welded wire mesh at the wall corners) and the provision of reinforced concrete columns at the wall corners. The floor system consists of precast reinforced concrete hollow-core slabs with typical slab panel dimensions of 5.86 m length X 1.2 m width. Reinforced concrete bond beam (belt) is constructed at the building perimeter at the floor level to provide the confinement and diaphragm action for seismic load effects. Complex building geometry and irregular wall distribution results in the significant torsional effects during earthquakes due to the eccentricity between the centre of mass and centre of stiffness. These buildings are located in the regions of high seismic hazard, which had experienced earthquakes of intensity VIII, IX or higher (per the MSK scale) in the past. This type of construction is expected to demonstrate poor seismic performance, due to the poor quality of masonry walls and complex layout resulting in torsional effects.

1. General Information

Buildings of this construction type can be found in all parts of Kyrgyzstan. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 25 years.

Currently, this type of construction is being built. .

Figure 1: Typical Building

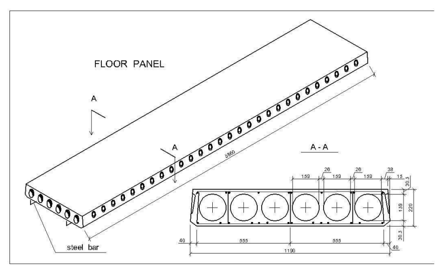

Figure 2: Key Load-Bearing Elements

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

Building plan for this housing type usually has complex plan and geometry. It is impossible to indicate the typical size of openings since it depends on the architectural requirements. Size of windows is around 1.2 m X 1.5 m and doors size is approximately 0.9 m X 1.9 m. Window and door areas constitute 10 to 15% 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. The building has only a single means of escape.

2.4 Modification to Building

Usually buildings of this type are of recent construction, and no modifications have been observed so far. However, some buildings have been modified by providing additional doors and windows, by expanding the building size (by adding new rooms) or by moving the walls.

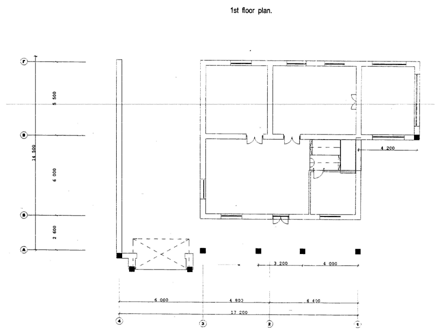

Figure 3A: Plan of a Typical Building

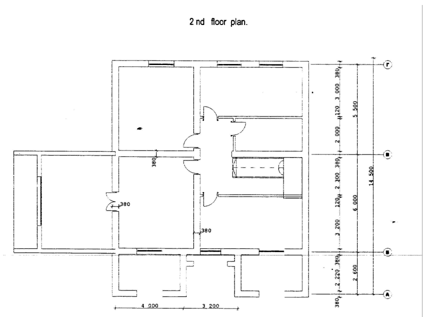

Figure 3B: Plan of the Second Floor for a Typical Building shown in Figure 3

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	☐
		17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐

Structural concrete	Moment resisting frame	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 reinforced masonry walls. Gravity load-bearing structure consists of brick masonry walls, few reinforced concrete columns and beams, and floor concrete panels.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is confined masonry wall system. The main lateral load-resisting system generally consists of brick masonry walls in cement mortar and reinforced concrete posts and beams provided at some locations. According to SNiP Building Code) it is required to provide columns at the wall ends; column reinforcement is illustrated in Figure 4B. SNiP requirements also include the provision of horizontal reinforcement (wire mesh) in mortar bedding joints at each 7th layer (see Figure 4C). Rigid brick masonry walls have low load-carrying capacity. Poor quality of brick masonry results in low earthquake resistance of the walls even when reinforced with welded wire mesh and steel reinforcement bars. Wall thickness is either 380 mm or 510 mm. The floor system consists of precast reinforced concrete hollow-core slabs with typical slab panel dimensions of 5.86m length X 1.2m width (see Figure 2). Reinforced concrete bond beam (belt) is constructed at the building perimeter at the floor level to provide the confinement and diaphragm action for seismic load effects; belt reinforcement details are presented in Figure 4A. Roof structures are made of wood or steel.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 15 and 15 meters, and widths between 15 and 15 meters. The building is 2 storey high. The typical span of the roofing/flooring system is 6 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 20 %. Total wall density is 10% - 15% in each direction.

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
	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone	

Shallow foundation	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	☐

Many buildings have precast concrete strip footing made up of concrete blocks.

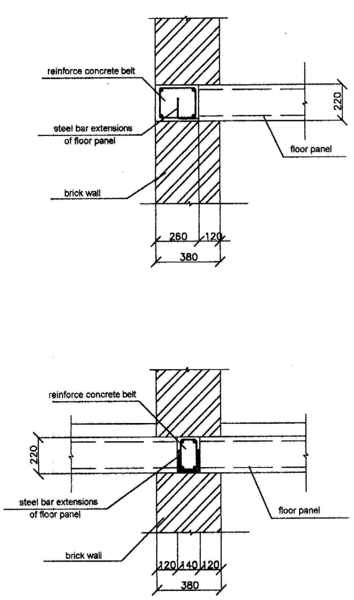

Figure 4A: Critical Structural Details - Wall-Floor Connection Showing Reinforced Concrete Bond Beam (belt) Reinforcement

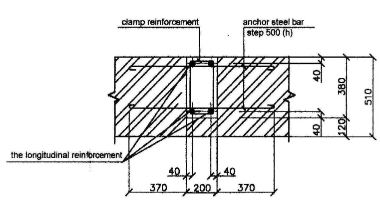

Figure 4B: Horizontal Wall Section Showing Reinforced Concrete Column Reinforcement

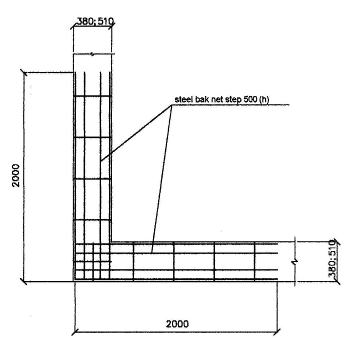

Figure 4C: Horizontal Wall Section Showing Corner Reinforcement

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 5-10.

4.2 Patterns of Occupancy

One family typically occupies one 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)	☑

House ratio to annual income is not available.

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).

In some cases a building has 2 bathrooms. .

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 (based on visual inspection of			

Quality of workmanship	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	- Poor quality of brick masonry; - Different wall rigidity; - The complex building geometry, including the non-symmetrical wall layout, results in significant torsional effects during earthquakes due to the eccentricity between the centre of mass and centre of stiffness.		Diagonal shear cracks in the wall, cracks at the wall corners, partial/complete destruction of the wall.
Frame (columns, beams)			
Roof and floors			

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
1992	Suusamir	7.4	VII

Maximum intensity of the Suusamir earthquake was IX, however buildings of this type were located in the regions with intensity 6-7 on the MSK scale. Buildings of this type had experienced the following wall damage patterns: diagonal "X" cracks in the piers, cracks at the wall corners, and partial destruction of the walls.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Brick masonry.	Tension resistance of mortar less 6.0 MPa.	Variable, from 1:8 to 1:20 cement/sand ratio.	Brick masonry units - dimensions 250 X 120 X 70 mm.
Foundation	Concrete	5 MPa (cube compressive strength)	various	
Frames (beams & columns)	Concrete	20 MPa (cube compressive strength) 390 MPa (steel yield stress).	variable	Steel - Elasticity Modulus (200,000 MPa)
Roof and floor(s)	Concrete	30-35 MPa (cube compressive strength) 390 MPa (steel yield stress)	variable	Steel - Elasticity Modulus (200,000 MPa).

6.2 Builder

These constructions are built by developers and sold in the market.

6.3 Construction Process, Problems and Phasing

This building type may be erected by builders or by owners. Usually only mobile crane is used for the erection and construction process. 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

This building type is not designed or constructed with the required expertise. Usually manager of construction works as the engineer. Engineers play a very limited role in the construction of buildings of this type.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Some of buildings correspond to SNiP II-7-81 Design Code: Building in Seismic Regions. The year the first code/standard addressing this type of construction issued was 1981. 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: Some of buildings correspond to SNiP II-7-81 Design Code: Building in Seismic Regions. Year the first code/standard addressing this type of construction issued: 1981 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.

N/A.

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

For load-bearing structures about 150 US$/m². The construction of a single-family house can be completed in a period of 10-12 months.

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
- Poor seismic resistance of walls; - Nonsymmetrical location of walls with different rigidity	- Installation of new reinforced concrete overlays tied to the existing walls - Installation of new shear walls

Seismic strengthening provisions presented in the above table are recommendations of the authors of this contribution.

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?

N/A.

8.3 Construction and Performance of Seismic Strengthening

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

N/A.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

N/A.

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

N/A.

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