World Housing Encyclopedia

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

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HOUSING REPORT
Buildings with cast in-situ load-bearing reinforced concrete walls

Report #	40
Report Date	05-06-2002
Country	KYRGYZSTAN
Housing Type	Precast Concrete Building
Housing Sub-Type	Precast Concrete Building : Shear Wall Structure with Walls Cast In-situ
Author(s)	Svetlana Uranova, Ulugbek T. Begaliev, V. Manukovskiy
Reviewer(s)	Svetlana N. Brzev

Important

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Summary

Buildings with cast-in-situ load-bearing reinforced concrete walls are widespread in many republics of the former Soviet Union. There are many such buildings in Kyrgyzstan in areas with a design seismicity of 8 and 9 on the MSK scale. The buildings with cast-in-situ walls are typically medium- to high-rise buildings (4-18 stories high; often 12-stories high). High-rise buildings of this type (9-18

stories high) have basements. The load-bearing structure consists of cast-in-situ reinforced concrete walls and precast reinforced concrete floor slabs. Floor slabs are either two-way solid slab structures, or, less often, hollow-core slabs. These buildings do not have any frame elements (columns and beams). Facade walls are usually made of lightweight (ceramsite) concrete. The buildings are supported by concrete strip or mat foundations. This building type is considered to be earthquake-resistant. Problems are mainly related to the quality of construction.

1. General Information

Buildings of this construction type can be found in Bishkek (Kyrgyzstan) and the other Republics of the former Soviet Union. Many buildings with cast in-situ load-bearing reinforced concrete walls can be found in Moldova. This type of housing construction is commonly found in urban 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

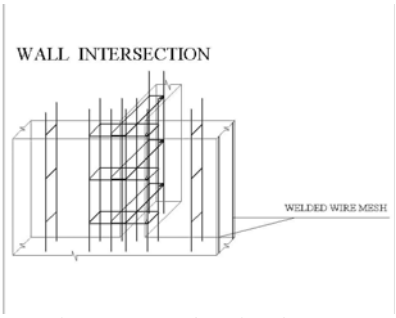

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. The typical separation between buildings can be more than 20 meters When separated from adjacent buildings, the typical distance from a neighboring building is 20 meters.

2.2 Building Configuration

Typical shape of a building plan for this housing type is rectangular or square; in some cases, the plan consists of two rectangles or squares. Typical window opening size is 1.3 m (height) X 1.8m (width), door openings: 2m (height) X 1 m (width). Overall window and door areas constitute up to 20% of the overall wall area. There are 20 to 25 windows in a building with plan dimensions of 28 X 26m.

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 stair per building unit. Typically, one building unit consists of 4 to 8 housing units per floor.

2.4 Modification to Building

Typical patterns of modification include the perforation of walls with door openings. This has been a very serious problem in Kyrgyzstan since 1992. There has been a trend for the people to purchase apartments at low cost and use them as shops. As a result of these modifications, the number of door openings in exterior load-bearing walls has been increased, the fragments of the walls have been removed, and the apertures in the lower stories have been made. Modifications of this type have resulted in the increased seismic vulnerability of buildings of this type. In an attempt to regulate this process in Kyrgyzstan, an annex to the Building Code has been developed, under the title "Change of the building function of some space of the existing apartment buildings" (SNiP 31-01-95). It is interesting to note that in Uzbekistan, modifications in the apartment buildings of this type are prohibited at the ground floor level.

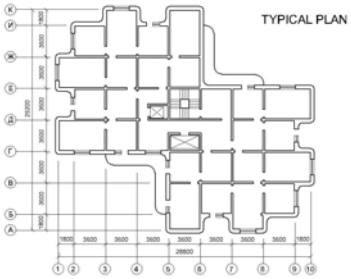

Figure 3A: Plan of a Typical Building

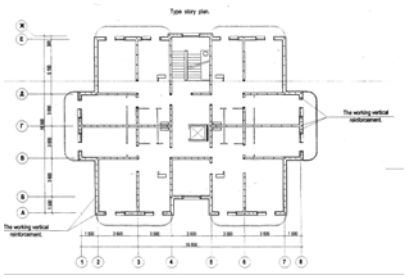
Figure 3B: Plan of Typical Building

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 reinforced concrete structural walls (with frame). Gravity load-bearing structure consists of reinforced concrete walls and slabs.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete structural walls (with frame). Lateral load-resisting system consists

of reinforced concrete walls and reinforced concrete slabs. Walls and slabs are joined together in a rigid space (3-D) system. This system works as a uniform (box-type) construction. Floor slabs are either flat slab structures, or, less often, hollow-core slabs. Buildings of this type do not have any frame elements (columns and beams). Thickness of exterior (façade) walls is usually 300-400 mm, and the thickness of interior walls is 160-200 mm. Thickness of flat slabs and hollow-core slabs is 160 mm and 220 mm respectively. Facade walls are usually made of lightweight (ceramsite) concrete; thickness is variable depending on the thermal insulation requirements. Buildings of this type are supported by concrete strip or mat foundations. Wall reinforcement is designed based on the Building Code requirements. Vertical reinforcement bars are located close to the door and window openings, as well as at the wall end zones and at the wall intersections. Distributed vertical reinforcement is typically installed throughout the wall length, typically in two layers. In addition, two layers of welded-wire mesh are typically installed close to the exterior wall surfaces. If the walls are perforated with openings, coupling beams (spandrel beams) are designed for bending and shear effects. The reinforcement bars are joined together by welding or lap splices.

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 has 4 to 18 storey(s). The typical span of the roofing/flooring system is 3.6 meters. Typical Plan Dimensions: Variation of length: 26-30meters. Variation of width: 12-14 meters. Typical Span: Distance between cross walls is 3.6 m and between longitudinal walls is 5.4m. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 20 %. The total wall density in both directions is on the order of 15%. Wall density in one direction amounts to approx. 70-80% of the wall density in the other direction i.e. walls are rather uniformly distributed in the two principal directions.

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	☑	☑

Floor and roof slabs are of precast construction (either hollow core slabs or solid slabs).

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	☐

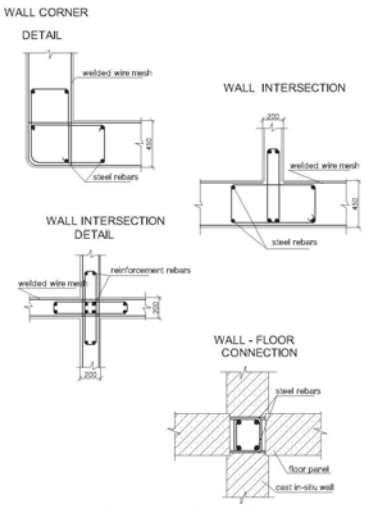

Figure 4: Wall Details

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 51-100 housing unit(s). 54 units in each building. Usually 20-90 units there are in 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 a building has 4-8 housing units. One family occupies one housing unit. Depending on the number of stories, 20 to 90 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)	☐

60% poor and 40% 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)	☐

Until 1990 (the breakdown of the Soviet Union), the main source of financing for buildings of this type had been provided by the Government. At the present time, all new and existing apartment buildings are privately owned. 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 renting, outright ownership and individual ownership.

Type of ownership or	Most appropriate type

occupancy?	
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	Poor quality of concrete, especially at the locations of construction joints; the "as constructed" reinforcement locations do not match with the designed locations, inadequate length of lap splices in steel rebars; inadequate confinement in the highly stressed areas.	The load-bearing structure (consisting of walls and slabs) represents a rigid box system favorable for resisting lateral load effects.	The most common type of damage includes concrete crushing and spalling at the locations of construction joints, as well as the inclined diagonal cracks in the wall piers (due to the shear failure). Severe damage and collapse is not expected.
Frame (columns, beams)			
Roof and floors			

The most serious problem with the buildings of this type is poor quality of concrete.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *E: LOW VULNERABILITY (i.e., very good seismic performance)*, the lower bound (i.e., the worst possible) is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), and the upper bound (i.e., the best possible) is *F: VERY LOW VULNERABILITY (i.e., excellent 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

Buildings of this type have not been subjected to the effects of damaging earthquakes in Kyrgyzstan as yet. However, many existing buildings of this type in Kichinev, Moldova, were exposed to an earthquake of intensity 8 on the MSK scale. Many of these 12-story buildings suffered damage in piers at the lower stories due to the poor quality of concrete construction.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Reinforced concrete.	30-35 MPa (cube compressive strength) 390 MPa (steel yield strength).	variable, depending on the type of ingredients in the mix	
Foundation	Reinforced concrete.	10-15 MPa (cube compressive strength) 295 MPa (Steel yield strength).	variable, depending on the type of ingredients in the mix	
Frames (beams & columns)				
Roof and floor(s)	Reinforced concrete.	30-35 MPa (cube compressive strength) 390 MPa (steel yield strength).	variable, depending on the type of ingredients in the mix	

6.2 Builder

Anyone can live in buildings of this construction type.

6.3 Construction Process, Problems and Phasing

Construction is performed by builders. Design (construction) documents are developed in the design institutes. Specialized construction companies fabricate precast concrete elements and perform casting of concrete in-situ. Precast elements are made at the factory. The main construction equipment includes crane, welding equipment and concrete mixers. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

Expertise related to the design and construction of this building type according to the building regulations of Kyrgyzstan was available. Designs were prepared by specialized design institutes with expertise in this construction practice. Design for this construction type was done completely by engineers and architects. Engineers played a leading role at each stage of construction.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. SNiP II-7-81. Building in Seismic Regions. Design code. The year the first code/standard addressing this type of construction issued was 1981. The most recent code/standard addressing this construction type issued was 1981. Title of the code or standard: SNiP II-7-81. Building in Seismic Regions. Design code. Year the first code/standard addressing this type of construction issued: 1981 When was the most recent code/standard addressing this construction type issued? 1981.

Building permit is issued if the design documents have been approved by the State Experts. The State Experts check the compliance of design documents with the pertinent Building Codes. According to the building bylaw, a building cannot be used without the formal approval.

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, Owner(s) and Tenant(s).

6.8 Construction Economics

For load-bearing structure only: about 150 US$/m². It would take from 10 to 18 month for a team of 15 workers to construct a load-bearing structure for 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

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Poor quality of concrete (especially at the lower part of the building); poor quality of construction joints	Reinforced concrete jacketing, shotcreting

Poor quality of concrete (especially at the lower part of the building); poor quality of construction joints Reinforced concrete jacketing, shotcreting.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

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Author(s)

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

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

3. V. Manukovskiy
   Chairman
   Chui Prospect 164A, Bishkek 720001, KYRGYZSTAN FAX: 996-3312-224355

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

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