World Housing Encyclopedia

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

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HOUSING REPORT
Precast reinforced concrete frame building with cruciform and linear-beam elements (Series 106)

Report #	33
Report Date	06-05-2002
Country	KYRGYZSTAN
Housing Type	Precast Concrete Building
Housing Sub-Type	Precast Concrete Building : Moment frame
Author(s)	Ulugbek T. Begaliev, Svetlana Uranova, V. Manukovskiy
Reviewer(s)	Vanja Alendar

Summary

Precast reinforced concrete frame buildings (series 106) were introduced in Kyrgyzstan around 1975. These apartment buildings are usually 9 stories high; less frequently they may be 12 stories. The fundamental period of vibrations is typically in the range of 0.65-0.85 sec. Series

106 was developed by the Kyrgyz Design Institute for construction in earthquake-prone areas. Several buildings of this type (about 15 in total) were built in the capital city Bishkek (design seismicity 8 on the MSK scale). The load-bearing structure consists of a precast reinforced concrete space frame and precast floor slabs. Partition walls are constructed using clay-brick masonry units or small concrete blocks. Buildings of this type have not yet been subjected to major earthquakes. These buildings are not considered to be highly vulnerable to earthquake effects, provided that the construction quality, particularly with reference to the joints, is satisfactory. It should be noted that precast frame buildings of a different type (Series 111) performed very poorly in the 1988 Spitak (Armenia) earthquake.

1. General Information

Buildings of this construction type can be found in Bishkek (the capital of Kyrgyzstan). 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 1A: Typical Building


Figure 1B: Typical Building


Figure 2A: Key Load-Bearing Elements

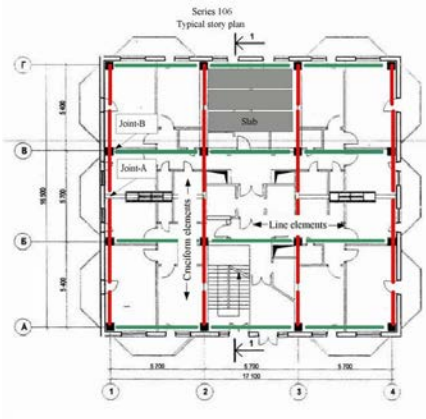

Figure 2B: Key Load-Bearing Elements Shown on a Building Plan

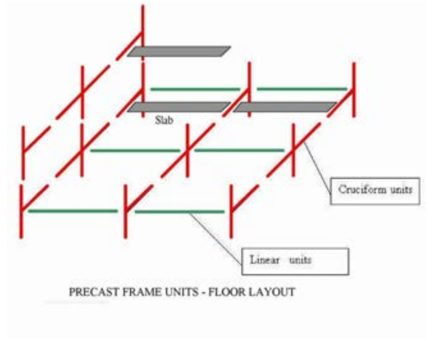

Figure 2C: Key Load-Bearing Elements- A Perspective

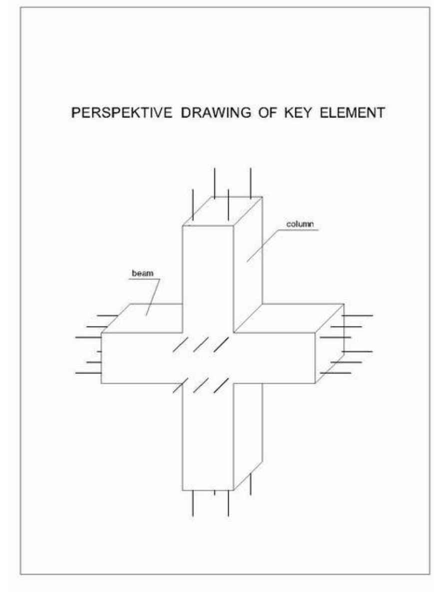

Figure 2D: A Cruciform Element

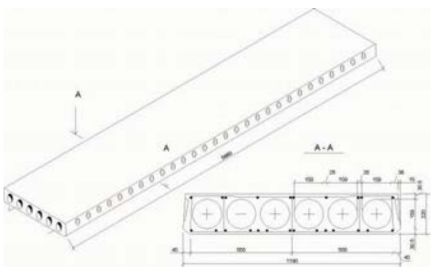

Figure 2E: Floor slab element

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 distance between buildings can be more than 10 meters 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 form with some modifications at the perimeter. Walls do not constitute a part of load-bearing structure in moment-resisting space frame buildings. Typical size of windows is: 1.2 m (height) X 1.5-2 m (width), doors : 2 m (height) X 0.9-1 m (width). The overall area of window openings accounts for 30 to 40% of facade walls, while doors account for less than 10% of partition wall 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 stair in one building unit. Building unit has 2-6 apartments (housing units) on each floor. Building has 1-4 building units.

2.4 Modification to Building

Usually, the modifications are made in non-structural (exterior and interior) walls.

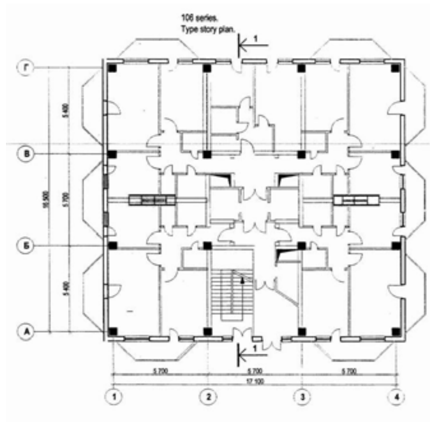

Figure 3: Plan of a Typical Building

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	☐
	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	☐

Structural concrete		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 moment resisting frame. The gravity load-bearing structure is moment resisting concrete frame.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete moment resisting frame. The lateral load-resisting system is moment-resisting concrete frame. The load-bearing structure consists of a precast reinforced concrete space frame and precast floor slabs. The space frame (with column spans of 6 m) is constructed using two main modular elements: cruciform element and linear-beam element. The cruciform element consists of the transverse frame joint with half of the adjacent beam and column lengths. The longitudinal frames are constructed by installing the precast beam elements in-between the transverse frame joints. The precast elements are joined by welding of the projected reinforcement bars (dowels) and casting the concrete in-situ. Joints between the cruciform elements are located at the mid-span of beams and columns, whereas the longitudinal precast beam-column connections are located dose to the columns. The floor structure consists of precast reinforced concrete hollow-core slabs; reinforcement bars are projected from the slabs for achieving the anchorage to the beams.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 48 and 48 meters, and widths between 12 and 12 meters. The building has 9 to 12 storey(s). The typical span of the roofing/flooring system is 6 meters. Typical Plan Dimensions: Usually variation of length is 48-60 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is none. Not applicable-walls are not a part of load-bearing structure.

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	☐

Buildings of this type have the basement floor. Frames at the basement are infilled with concrete block walls. The isolated footings are tied with the reinforced concrete foundation beams, which are acting as the foundation for basement walls.

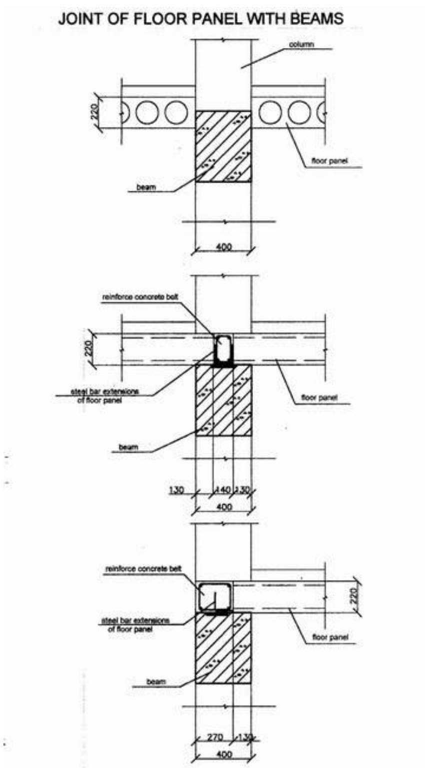

Figure 4A: Wall Panel Details

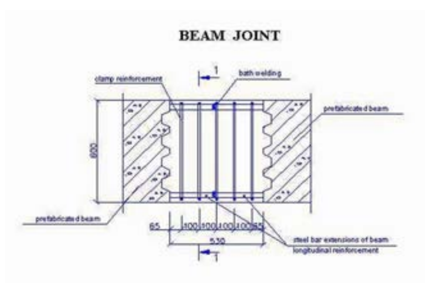

Figure 4B: Beam Joint Details

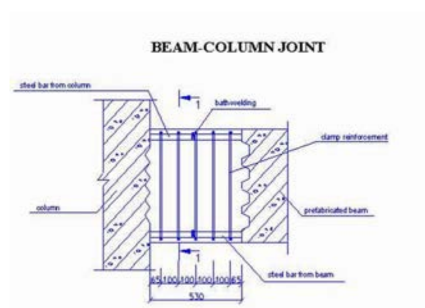

Figure 4C: Beam-Column Joint


Figure 5: Cruciform Element- as Constructed

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 51-100 housing unit(s). 60 units in each building. Ordinary building has 36-120 units. 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 of building unit has 2-4 housing units. One family occupies one housing unit. In general, 36 to 120 families occupy one building (depending on the number of building units and stories in a 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)	☐

40% poor and 50% 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)	☐

This is the present situation. Before 1990 the source of financing was by Government. Now all new and existing apartment buildings are private. In each housing unit, there are 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

Very often bathroom and latrine are combined in the one housing unit. .

4.4 Ownership

The type of ownership or occupancy is renting, 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 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	☑	☐	☐
	The total width of door and window openings in a wall is:			

Wall openings	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
Partition Walls	Walls are not lateral load-resisting structures. Poor quality of walls and wall-column and wall-floor joints.		
Frame (columns, beams)	Poor quality of joints between the precast frame elements.	Joints of columns are located at the column mid-height (where seismic bending moment=0). Joints for gravity load-bearing beams are located at the mid-span (where seismic bending moment=0).	Damage to joints expected.
Roof and floors			

This is a moment-resisting frame structure. The fundamental vibration period is relatively low, on the order of 0.65-0.85 sec (considering that there are no shear walls in buildings of this type). Structures of this type are designed for earthquake effects according to the 1981 Building Code, and therefore they are not expected to be very vulnerable to earthquake effects. This structure is characterized with special construction details for precast frames; such details are not present in other precast frame systems found in the Post Soviet Union, like precast frame of Series 111 that had performed very poorly in the 1988 Spitak, Armenia earthquake. Important construction details characteristic for this construction type are: 1. A larger size of cast in-situ joint (approximately 50 cm long). In this way, installation of the reinforcement bars, welding, and casting of concrete is largely facilitated as compared with other similar systems (characterized with smaller joint sizes). This is particularly important if non-plastic (i.e. less workable) concrete mixture is used (which is a common case). However, the quality of in-situ construction is considered to be generally poor. 2. Cruciform member joints are located in the low-stressed portions of the beams and columns (away from the beam-column joints) - at the beam mid-span and at the column mid-height. Beams spanning in the longitudinal direction are loaded only due to lateral load actions, e.g. winds or earthquakes; joints in these beams are located near the columns, in the highly stressed beam zones.

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

Buildings of this type have not been subjected to the effects of damaging earthquakes. Precast frame buildings that were affected by strong earthquakes in the former Soviet Union (e.g. 1988 Spitak, Armenia earthquake) had linear precast elements (i.e. no cruciform members), and the joints were located in zones of maximum seismic moment. It should be noted that the precast frame buildings affected by the 1988 Spitak earthquake (Series 111) are different from precast frame buildings (series 106) described in this contribution. The main difference is in the cruciform elements, larger joint areas, and location of critical joints away from the highly stressed areas of beams and columns-these are all positive features of the Series 106 described in this contribution (see also Table 5.2).

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Brick and gasconcrete masonry.	Non load-bearing structure.		
Foundation	Reinforced concrete.	10-15 MPa (cube compressive strength) Steel yield limit 295 MPa.	Different, depends on mix materials.	
Frames (beams & columns)	Reinforced concrete.	40-45 MPa (cube compressive strength) Steel yield limit 390 MPa.	Different, depends on mix materials.	
Roof and floor(s)	Reinforced concrete.	30-35 MPa (cube compressive strength) Steel yield limit 390 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

The construction is performed by builders. The Design Institute develops the design documentation. The construction company makes the precast elements and performs the assembly. Precast elements can be made in the factory (plant). The main equipment used for construction is: 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 design and construction of this type according to the legal system of Kyrgyz Republic was available. Designs for buildings of this type were prepared by specialized design institutes with expertise in this type of construction. Design for this construction type was done completely by engineers and architects. Engineers played 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. SNiP II-7-81. Building in Seismic Regions. Design code. The year the first code/standard addressing this type of construction issued was 1961. 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: 1961 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 with the building by- low, building cannot be inhabited without the formal approval by a special committee. The committee gives the approval 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, Owner(s) and Tenant(s).

6.8 Construction Economics

For load-bearing structures only about 180 US$/m². For load-bearing structures only would take from 9 to 12 month for a team of 10 workers.

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 joint of precast frame elements	Usual methods for concrete frames. Reinforced concrete and steel jackets.

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?

N/A.

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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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

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

Reviewer(s)

1. Vanja Alendar
   Research Associate

Dept. of Civil Engineering, University of Belgrade
Belgrade 11001, SERBIA
Email:vanja@imk.grf.bg.ac.yu FAX: (381-11) 33-70-253