World Housing Encyclopedia

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

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HOUSING REPORT

Prefabricated concrete panel buildings with monolithic panel joints

Report #	38
Report Date	05-06-2002
Country	KYRGYZSTAN
Housing Type	Precast Concrete Building
Housing Sub-Type	Precast Concrete Building : Large Panel Precast Walls
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Summary

Prefabricated concrete panel building construction with monolithic panel joints has been practiced throughout the former Soviet Union (including Kyrgyzstan) since 1965. This type of prefabricated construction is known as seria 105. Apartment buildings of this type are usually 5-9 stories high. The foundations are made of cast in-situ reinforced concrete. Steel dowels are provided in the

foundations to ensure anchorage of steel rebars located in the panels and in the panel joints. The load-bearing structure in large panel buildings consists of reinforced concrete panels combined to form a box-type rigid system by means of special joints. This building type is considered to be one of the most earthquake-resistant construction types in the former Soviet Union.

1. General Information

Buildings of this construction type can be found in most large cities of Kyrgyzstan and other republics of the former Soviet Union. In Kyrgyzstan, buildings of this construction type can be found in the following cities: Bishkek, Tokmok, Och, Karakol (Kyrgyzstan). Large panel buildings account for up to 35 - 40% of the multi-story residential building stock in the capitol, Bishkek. Buildings of this type are less common in other cities mentioned above. This type of housing construction is commonly found in urban areas.

There are large panel buildings in suburban areas too.

This construction type has been in practice for less than 50 years.

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


Figure 1A: Typical Building


Figure 1B: 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

The typical shape of a building of this housing type is rectangular. Large panel prefabricated construction technology does not allow for a variation in the size of door and window openings. Usually, for a 3.6 m long panel, the window size is 1.82 m (width) X 1.53 m (height); for a 2.7 m long panel - the window size is 1.24 m (width) X 1.53 m (height). The size of a balcony door (together with window) is either 2.25 m or 1.66 m wide and 1.9 m in height. The overall window and door area account for 17% of the overall wall area. There are 16 windows for a building with plan dimensions of 10.8 m X 25.2 m.

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 each building unit (with average plan dimensions 10.8 m X 12.6 m).

2.4 Modification to Building

Buildings of this type are generally standardized and therefore modifications are not very common. Typical modifications include perforation of new door openings.

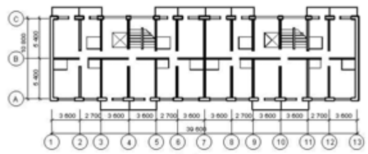

Figure 3: Plan of a Typical Building

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 reinforced concrete precast wall system. The gravity load-bearing structure consists of large reinforced concrete wall panels and concrete floor slabs.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete precast wall system. The lateral load-resisting system consists of large reinforced concrete panels acting as shear walls. All wall and floor panels are combined together, thus creating a rigid structure by means of special joint system. Horizontal and vertical steel dowels are provided in wall and floor panels. Once the panels are erected in their final position, the dowels are welded, and the gaps between the panels are filled with cast in-situ concrete. Shear stress in the joints is resisted by means of shear keys. Vertical steel bars are placed close to the window and door openings in the panels. These bars are located in vertical joints. FIGURE 4A shows a typical precast floor panel with steel dowels and grooves (shear keys) for achieving monolithic concrete panel joints. Details of a typical wall panel without openings are shown in FIGURE 4B, whereas a typical panel with a wall opening is shown in FIGURE 4C. Horizontal and vertical sections of exterior wall panels are shown in FIGURE 4D and FIGURE 4E, respectively. Horizontal and vertical sections of an interior panel are shown in FIGURE 4F and FIGURE 4G, respectively. Wall and floor panel dimensions are of room size. Interior wall panels and floor panels are of normal-weight concrete (density 24 kN/m^3), and the facade (exterior)-wall panels are of light-weight concrete. The thickness of the interior wall panels is typically 120 mm or 160 mm. The size of a typical wall panel is 2.7 m (width) X 3 m (height) or 3.6 m (width) X 3.0 m (height). The thickness of a floor panel is 160 mm.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 39.6 and 39.6 meters, and widths between 10.8 and 10.8 meters. The building has 5 to 9 storey(s). The typical span of the roofing/flooring system is 2.7 meters. Typical Span: For cross walls: 3.6 m or 2.7 m. For longitudinal walls: 5.4 m. The typical storey height in such buildings is 3 meters. The typical structural wall density is more than 20 %. The ratio of total wall area/plan area is about 0.14. Wall density in two principal directions is not equal; in one of the directions wall density is less by 20 to 30% as compared to the other 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	☑	☑

Floors considered to be rigid diaphragms. Roof considered to be a rigid diaphragm.

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	☐

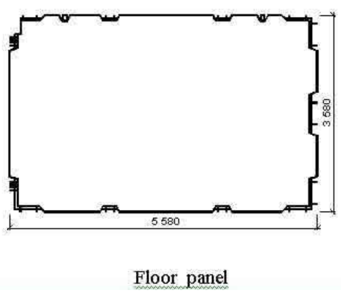

Figure 4A: Critical structural details - typical floor panel construction

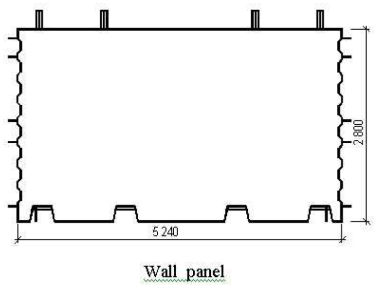

Figure 4B: Precast interior wall panel with steel dowels and grooves

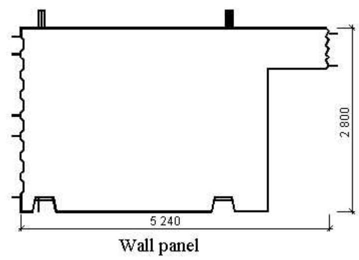

Figure 4C: Precast interior wall panel with a door opening

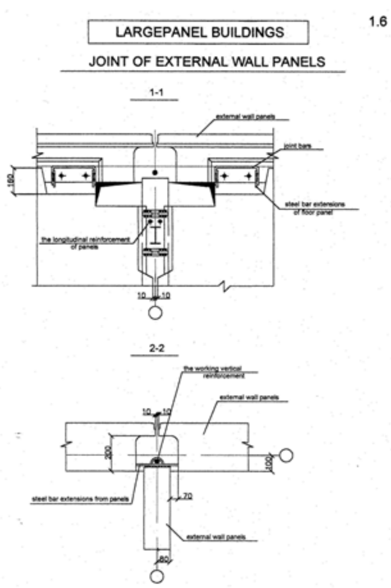

Figure 4D: Horizontal section of an exterior wall panel connection

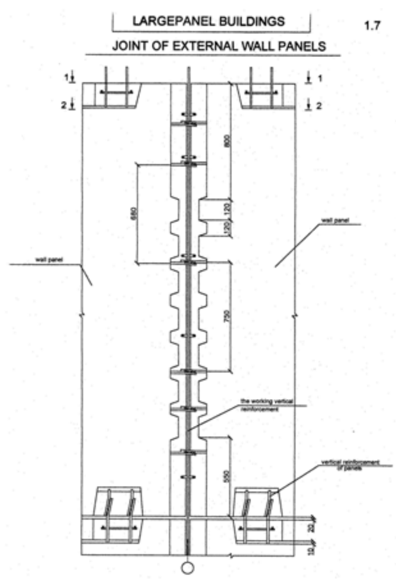

Figure 4E: Vertical section of an exterior wall panel connection

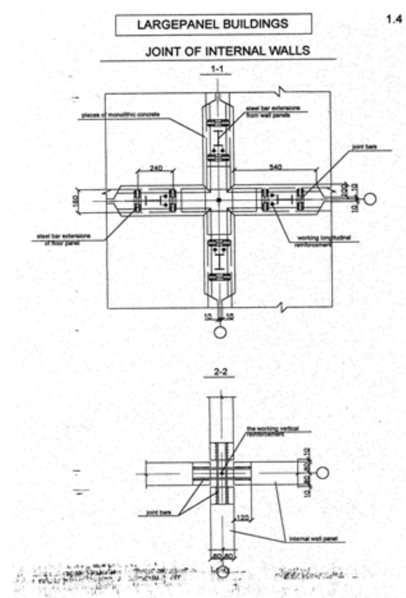

Figure 4F: Horizontal section of an interior wall panel connection

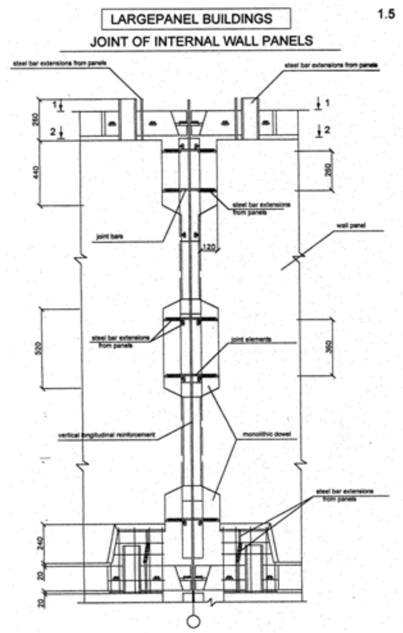

Figure 4G: Vertical section of an interior wall panel connection

Figure 4H: Building Under Construction, Showing Panel Connections (Source: Imanbekov, Uranova and Iwan, 1999)

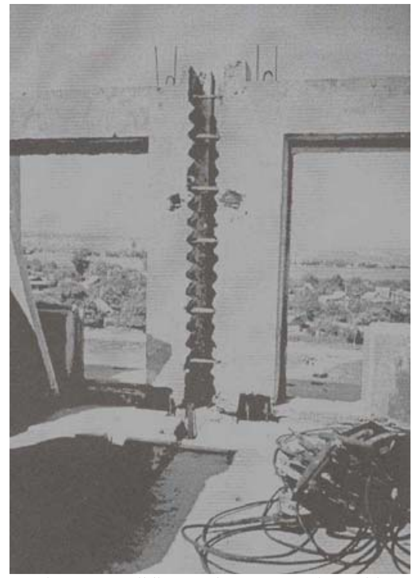

Figure 4I: Building Under Construction With Exposed Vertical Panel Joint (Source: Imanbekov, Uranova and Iwan, 1999)

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. The number of units can vary between 40-80. 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

In general, in a building of this type there are 4-8 housing units per building unit ("Block-Section"). One family occupies one housing unit. Depending on the size of the building (number of stories), there are 20 to 36 families occupying one building unit.

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 60% middle class inhabitants occupy building 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).

Very often bathroom and latrine are combined. .

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 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	The building maintenance level is variable. The majority of buildings in Bishkek are rather well maintained, however maintenance is not equally good in other cities.			

5.2 Seismic Features

Structural Element	**Seismic Deficiency**	**Earthquake Resilient Features**	**Earthquake Damage Patterns**
Wall	Panel joints; quality of construction, especially welding of reinforcing bars from the adjacent panels and filling the gaps between the panels with concrete is not satisfactory in some cases.	Due to a large number and uniform distribution of panel joints existing in one building, deficient construction of some joints does not have a major impact on the overall seismic resistance in the building as a whole.	Cracking in joints and panels.
Roof and Floors	Panel joints; quality of construction, especially welding of reinforcing bars from the adjacent panels and filling the gap between the panels with concrete is not satisfactory in some cases.	Due to large number and uniform distribution of panel joints in a building, deficient construction of some joints does not have a major impact on the overall seismic resistance of the building as a whole.	Cracking in the joints and panels
Roof and floors			
Other			

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
1986	Karakum	6.8	7
1988	Spitak	7.4	9

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Reinforced concrete.	Concrete: 20-30 MPa (cube compressive strength) Steel: 295-390 MPa (yield strength).		
Foundation	Reinforced concrete.	Concrete: 20-30 MPa (cube compressive strength) Steel: 295-390 MPa (yield strength).		
Frames (beams & columns)				
Roof and floor(s)	Reinforced concrete.	Concrete: 20-30 MPa (cube compressive strength) Steel: 295-390 MPa (yield strength).		

6.2 Builder

Anyone can live in buildings of this construction type.

6.3 Construction Process, Problems and Phasing

Typically, buildings of this type are constructed by construction companies specializing in prefabricated construction. Typical equipment used for the erection includes crane, welding equipment, and scaffolding. Panels are cast in the plants using a mechanized process. Steam is used in the panel manufacturing process. Typically, distance from a plant to a site is not more than 100-150 km. The panels are transported from a plant to the construction site by means of special vehicles. 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 Kyrgyzstan 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 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. When was the most recent code/standard addressing this construction type issued? 1981.

A 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, a building cannot be occupied without the formal approval of a special committee. The committee gives the approval if the 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 Owner(s).

6.8 Construction Economics

For load-bearing structure only (without finishes) about 150-200 US$/m². For load-bearing structure only (depending on the number of stories and plan area), the construction would take from 1 to 6 months for a team of 15 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
Cracks in joints and panels	-Installation of reinforced concrete bushing key; - Gunite applied on the panel surface; - Crack injection by means of polymers.

Some recommended methods for seismic strengthening are: installation of reinforced concrete bushing keys, applying reinforced gunite on panel surface, injection of polymers in cracks. It is usually not required to strengthen buildings of this type. Poor quality of construction is uncommon and does not significantly influence the reliability of buildings. There is some experience with strengthening the existing load-bearing structures in Kyrgyzstan. In Uzbekistan, there is experience with strengthening the buildings damaged in the 1978 Gazly earthquake; there, damaged buildings had been constructed without earthquake-resistant features (as the area was thought to be of low seismic risk i.e. seismicity 6 on 12 intensity scale).

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.

8.3 Construction and Performance of Seismic Strengthening

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