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

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HOUSING REPORT
Prefabricated large panel concrete buildings with two interior longitudinal walls.

Report #	32
Report Date	05-06-2002
Country	KAZAKHSTAN
Housing Type	RC Structural Wall Building
Housing Sub-Type	RC Structural Wall Building : Moment frame with precast shear wall
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Summary

This is a typical urban residential construction type commonly found in the southern part of Kazakhstan. Typical buildings of this type are 5- or 9-stories high. This is a prefabricated large panel construction typical for the post-Soviet Union. Large panel buildings with two interior

longitudinal walls (as described in this contribution) were developed in Kazakhstan and were specifically designed for the areas of high seismic hazard (intensity 9 and higher per MSK scale). It is considered that this building type (with two interior longitudinal walls) is superior as compared to other large panel building types (usually characterized with one longitudinal wall only) in terms of seismic resistance. The load-bearing system consists of precast reinforced concrete walls and floor panels. All precast members are joined in a box-type structure by means of panel joints. Facade walls are usually made of 2 exterior layers of low-strength lightweight (ceramsite) concrete with good thermal insulation properties and the interior layer of normal-weight concrete. Large panel buildings are generally well-known for their good seismic resistance, which is mainly due to the large rigidity and high degree of redundancy. The fundamental period of vibration for a 9-story building of this type is approximately 0.35-0.4 sec. Large panel buildings of a similar construction (with one longitudinal interior wall) existed in Armenia at the time of the 1988 Spitak earthquake and they remained undamaged, whereas other precast construction types (mainly concrete frame construction) had suffered significant damage and/or collapse. Although the buildings of this type have not been exposed to major damaging earthquakes in Kazakhstan as yet, their dynamic performance was evaluated by means of harmonic forced vibration tests simulating earthquake effects. The buildings subjected to these tests did not experience any damage.

1. General Information

Buildings of this construction type can be found in Almaty - former capital of Kazakhstan and other cities in Kazakhstan. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 25 years.

Currently, this type of construction is not being built. This construction practice started in Kazakhstan in early 1980s.

Figure 1A: Typical Building

Figure 1B: Typical Building

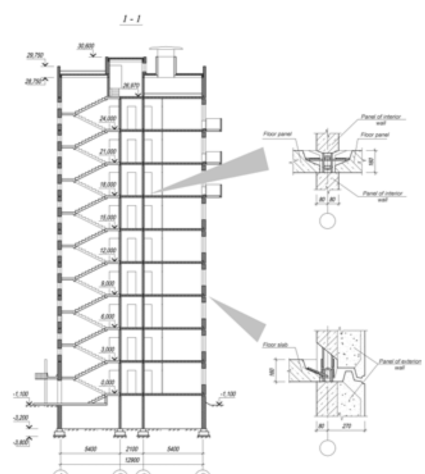

Figure 2: Key Load-Bearing Elements

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

Rectangular shape. Typical window sizes are: 2.1 m X 1.5 m; 1.2 m X 1.5 m; 3.0 m X 1.5 m; 1.0 m X 0.8 m. Average door sizes are: 1 m X 2 m. Total window and door area constitute up to 20% of the overall 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. One staircase for each segment (three housing units at each floor) and two entrances at the ground floor level.

2.4 Modification to Building

In practice there are no significant modifications for this type of construction. Typical modification patterns include the perforation of walls with door openings.

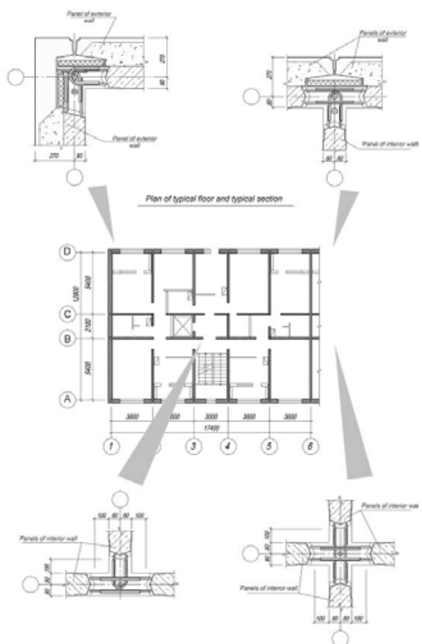

Figure 3: Plan of a Typical Building

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	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	☐
		7	Brick masonry in mud/lime mortar	☐

Masonry	Unreinforced masonry walls	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). Longitudinal and cross walls and floor slabs.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete structural walls (with frame). Large panel buildings with two interior longitudinal walls (as described in this contribution) were developed in Kazakhstan and were specifically designed for the areas of high seismic hazard (intensity 9 and higher per MSK scale). It is considered that this building type (with two interior longitudinal walls) is superior as compared to other large panel building types (usually characterized with one longitudinal wall only) in terms of seismic resistance. In large panel buildings, seismic resistance in the longitudinal direction is generally worse as compared to the resistance in the transverse direction. Therefore, additional interior longitudinal wall in a building contributes to its improved seismic resistance. The lateral load-resisting structure consists of the system of precast elements: slabs and the longitudinal and cross wall panels. The length of wall panels is equal to room dimension (length/width), and the thickness is equal to 160 mm (interior walls) and 300 mm (exterior walls). Rigidity and load resistance in the longitudinal direction is provided by four walls: 2 exterior and 2 interior walls. All the walls are continuous throughout the building height. Joint system is developed such that all structural elements work together as a box-type system. Vertical wall panel connections are accomplished by means of groove joints, which consist of a continuous void between the panels with lapping horizontal steel and vertical tie-bars. Horizontal joint reinforcement consists of dowels (horizontal panel reinforcement) projected from the panels and the hairpin hooks site-welded to the dowels (the welded length of the lapped bars depends on the bar diameter and steel grade). Vertical tie-bars are designed for tension forces developed at the locations of panel intersections. Details of vertical wall panel connections are shown on Figure 3. Vertical wall connections under construction are shown on Figures 4B and 4C (note hairpin hooks). Figure 5 shows the welded horizontal reinforcement and vertical tie-bars. Several sets of hairpin hooks are provided for each wall panel over a floor height. The number is variable (generally ranging from 2 to 5), depending on the seismic demand at a particular location within a building. In general, vertical panel connections are designed to transfer the forces in 3 orthogonal directions. In order to ensure adequate shear transfer, vertical panel edges are serrated (roughened), as illustrated in Figure 4E. Horizontal panel joints are somewhat different from the vertical joints. Either vertical dowels or hairpins are projected from the top and bottom panels at each floor level. The dowels/hairpins are joined by means of welding. Horizontal dowels from the adjacent floor slab panels are also joined together by means of welding. Details of horizontal panel joints are shown on Figure 2. Horizontal wall panel joints under construction are shown on Figures 4A and 4D (note the horizontal dowels projected from the floor panels and hairpins/dowels projected from the wall panels). Both the horizontal and vertical joints are grouted in-situ using concrete (same mix as used in the panel construction). Floor panels are solid 2-way slabs supported by the four wall panels.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 34.8 and 34.8 meters, and widths between 34.8 and 34.8 meters. The building has 5 to 9 storey(s). The typical span of the roofing/flooring system is 3.6 meters. Typical Plan Dimension: 34.8 m is a typical length. Length is equal to 17.4 m X n, where "n" is number of sections. Typical Span: In longitudinal direction the span between cross walls is 3 m and 3.6 m. In cross direction the span between longitudinal walls is 5.4 m and 2.1 m. The typical storey height in such buildings is 3 meters. The typical structural wall density is none. Wall density in longitudinal direction is 0.05 and in the cross direction this value is 0.07.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☑	☑
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☑	☑
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☐
	Wood shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☐
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☐
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☐	☐
Other	Described below	☑	☑

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	Reinforced-concrete isolated footing	☐
	Reinforced-concrete strip footing	☑
	Mat foundation	☐
	No foundation	☐
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐

Other	Described below	☐

Figure 4A: Critical Structural Details # Wall and Floor Panels

Figure 4B: Critical Structural Details- Vertical Wall Panel Joint

Figure 4C: Critical Structural Details- Vertical Wall Panel Joint

Figure 4D: Critical Structural Details - Erection of Floor Panels

Figure 4E: Critical Structural Details- Serrated Wall Surfaces

Figure 5A: Vertical wall Panel Connection Showing Hairpins and Tie-Bars

Figure 5B: Seismic Features- Vertical Wall Connection Showing Groove Joint

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 51-100 housing unit(s). 81 units in each building. Total number of housing units depends on the number of building sections. Typically, for the three-section building, the number of housing units is 3 X 27=81. 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. > 240 occupants.

4.2 Patterns of Occupancy

The pattern of occupancy depends on the number of typical sections in the building. Three apartments are located at each floor of a typical building section. Typically, over 27 families reside in one section of a 9-story building of this type.

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)	☐

The ratio of Housing Unit Price to their Annual Income is 8:1.

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), no toilet(s) only and 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting and 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)	☐

Typically, these buildings were government-owned and later were transferred to private property due to privatization.

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			

Wall openings	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		- Rigid box-type system; - Good panel and joint structural details; - Buildings of regular plan and elevation. All the walls, both in the longitudinal and cross direction, are continuous throughout the building height; - Multiple panel connections in the vertical and horizontal joints over a panel height. Due to the high degree of redundancy, inadequate construction of some connections does not result in the structural failure; - Adequate quality of precast panels due to the controlled mass production in the plant; - Rather moderate wall span.	
Frame (columns, beams)			
Roof and floors			
Other			

The buildings of this construction type are expected to possess high seismic resistance. Although the buildings of this type have not been exposed to damaging earthquakes as yet, their dynamic performance was evaluated by means of harmonic forced vibration tests, using the resonant frequency of the building for the harmonic excitation. These dynamic loads simulated earthquake effects. The tests showed that the buildings did not experience any damage.

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 E: LOW VULNERABILITY (i.e., very good seismic performance), and the upper bound (i.e., the best possible) is E: LOW VULNERABILITY (i.e., very 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
1911	Null	8.2	

There have been no earthquakes with intensity of over 5 in the region since the construction of this type had started in Kazakhstan. Large panel buildings of similar construction existed in Armenia at the time of the 1988 Spitak earthquake (Richter magnitude 7.0) and they remained undamaged, whereas the buildings of precast frame construction had suffered significant damages and/or collapse, as illustrated in Figure 6. These buildings were of Seria A1-451 KP-16/1 and were characterized with very similar panel connections, however they had only one load-bearing interior wall in the longitudinal direction (whereas the construction which is the subject of this contribution is characterized with the two longitudinal walls). None of the sixteen buildings of this type that existed in Leninakan at the time of the 1988 earthquake suffered any significant damage, except for the minor cracks in horizontal and vertical wall joints. In contrast, all 19 buildings of precast frame construction (series 111) that existed in the area collapsed in the earthquake. There were two large panel buildings of this type in Spitak and none of them suffered any significant damage (except for minor cracking). It should be noted that both towns, Leninakan (population 250,000) and Spitak (population 25,000) were completely destroyed.Around 25,000 people died in the earthquake and 12,000 were injured. More than 500,000 people were left homeless in the earthquake. For more details on the 1988 earthquake refer to Rzhevsky (1999), Markarian (1999) and EERI (1989).

Figure 6: Earthquake Damage - Large Panel Buildings Remained Undamaged in the 1988 Spitak (Armenia) Earthquake (Source: EERI Armenia Earthquake Reconnaissance Report)

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) Steel yield stress 390 MPa.		Bearing concrete layer.
Foundation	Reinforced concrete.	20 MPa (cube compressive strength) Steel yield stress 295 MPa.		
Frames (beams & columns)				
Roof and floor(s)	Reinforced concrete.	30-35 MPa (cube compressive strength) Steel yield stress 390 MPa.		

6.2 Builder

It is more typically for this type of housing to be built by a developer.

6.3 Construction Process, Problems and Phasing

Construction of this type was performed by Almaty House-building complex (ADK), and owner was the City administration. 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

The level of control is very high. First of all, in the factory ADK the control of materials and structural elements was performed, then during the construction the control was performed by designer's organization along with special expertise organization so called State Control Committee for Architecture and Construction. Finally, before putting these buildings in operation they had been checked by the City Control Committee. Design for this type of construction 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-A.12-69* "Construction in seismic regions. Standards of design." (issued in 1970 for the first time and revised in 1974). The year the first code/standard addressing this type of construction issued was 1970. SNIP RK B.1.2-4-98 (current Code). The most recent code/standard addressing this construction type issued was 1998. Title of the code or standard: SNIP II-A.12-69* "Construction in seismic regions. Standards of design." (issued in 1970 for the first time and revised in 1974) Year the first code/standard addressing this type of construction issued: 1970 National building code, material codes and seismic codes/standards: SNIP RK B.1.2-4-98 (current Code) When was the most recent code/standard addressing this construction type issued? 1998.

Although the seismic code has been drastically revised three times over the last decade and the seismic requirements have become more stringent, this type of construction still meets the Code requirements without any modifications.

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 Owner(s) and Tenant(s).

6.8 Construction Economics

Construction cost is about 450 US$/m² ; in terms of the national currency of the Republic of Kazakhstan - 67,000 tenge. It takes 6-8 months to build one section of a 9-storey building. Out of that period, 3 months is required for the assembly of structural elements and the remaining time is used for the finishing works.

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

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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