World Housing Encyclopedia

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

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Earthquake Engineering Research Institute (EERI) and
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HOUSING REPORT
Large reinforced concrete panel buildings (Series 122, 135 and 1-464c)

Report #	55
Report Date	05-06-2002
Country	RUSSIAN FEDERATION
Housing Type	Precast Concrete Building
Housing Sub-Type	Precast Concrete Building : Large Panel Precast Walls
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Summary

Large panel buildings represent one of the most common multifamily housing construction types (apartment buildings) in the former Soviet Union. Buildings of this type range from 4 to 9 stories high. This construction practice started in the 1960s and has been followed ever

since. This contribution describes three different types (series) of large panel construction, known as seria 122, seria 135, and seria 1-464c. These three types (seria) are characterized by welded panel connections. The main vertical load-bearing elements, designed to carry both gravity and lateral loads, are precast reinforced concrete panels. Typically, buildings are of a regular plan and are characterized with only one interior load-bearing wall in the longitudinal direction and several walls in the transverse direction. Floor and roof structures are also made of precast reinforced concrete panels. Both wall and floor panels are of room dimensions, and the assembly of these structures consists of setting the panels in their final position and joining them in a box-type structure by means of welded joints. The methodology of achieving panel connections in large panel construction practice has significantly improved in the last 50 years. Seria 1-464c is among the first seria of large panel construction. Initially, panel joints in seria 1-464c were achieved by welding the steel elements projecting from the panels. Later on, welded joints were replaced with the monolithic joints. Seria 1-464c is characterized by a plan typical for large panel buildings with continuous walls and a typical span (2.7 m or 3.6 m) of cross walls (Figures 3C and 3D). Seria 122 is characterized by discontinuous façade walls in the longitudinal direction (Figure 3A). Seria 135 is characterized by a larger span of cross walls (6m) as compared to the other types (see figure 3B). Due to the large wall density, these buildings are rather rigid. Seismic resistance in this construction type is generally good, as these buildings have been exposed to several strong earthquakes in the former Soviet Union.

1. General Information

Buildings of this construction type can be found in Russia and Central Asia. It constitutes between 20 and 100 % of the housing stock in seismic zones of Russia and Central Asia. Large panel construction of Seria 122 is common for the areas with extremely severe climate (East Siberia and North Far East), Seria 135 can be found in Russia (Siberia, Baikal Lake Region, North Caucasus) and CIS countries (Caucasus), whereas the Seria 1-464c is found in seismic prone areas of Russia (Far East-Kamchatka) and CIS (Central Asia). 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. This is the former Soviet Union construction practice that was followed in the last 50 years.

Figure 1A: Typial Building

Figure 1B: Typical Building on Seria 135

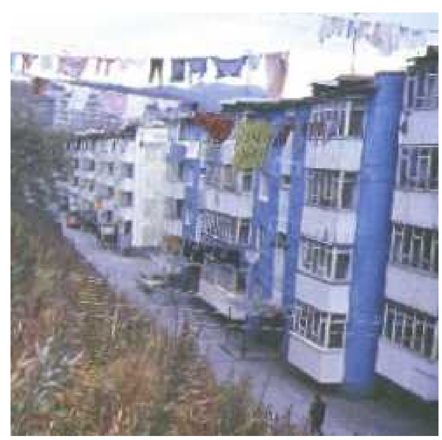

Figure 1C: Typical Building of Seria 122

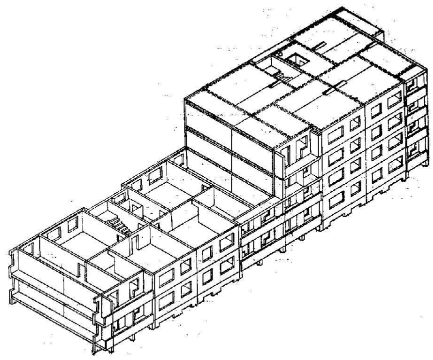

Figure 2A: Key Load-Bearing Elements

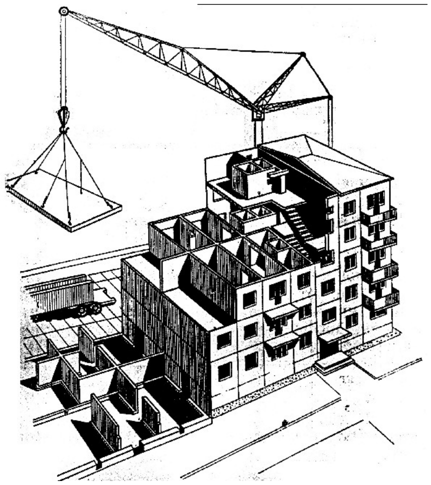

Figure 2B: Large Panel Buidings of Seria 135 - Assembly in Progress

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. In hilly areas, from <1.5% to ~15% When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

In general, all buildings of this type are of rectangular plan. Windows: 10-15%; Doors: 5-8%.

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 3-4 fire-protected exit staircases. One staircase for each section (3-4 housing units per floor) and, in some cases, two entrances at the ground floor level.

2.4 Modification to Building

In general, all buildings of this type are of rectangular plan.

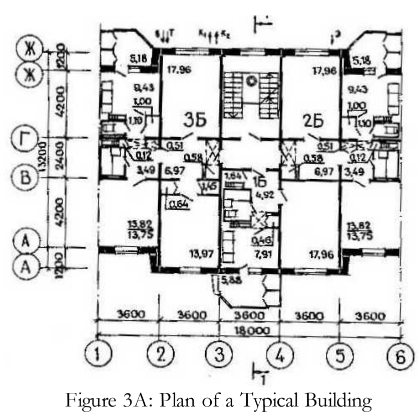

Figure 3A: Plan of a Typical Building

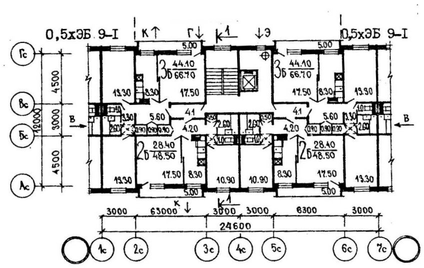

Figure 3B: Building Plan of 135 seria

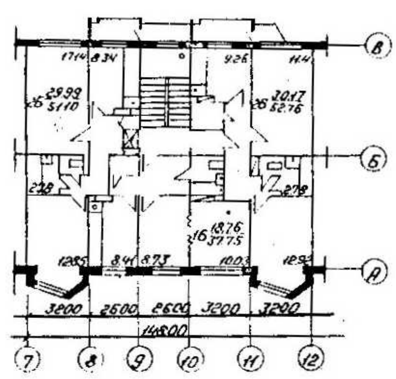

Figure 3C: Building Plan of Seria 1-464

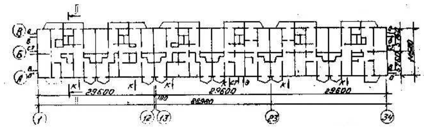

Figure 3D: Building Plan of Seria 1-464

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 others (described below). Longitudinal and cross walls and floor slabs.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Lateral-load system is a rigid 3-D box-type structure, which consists of precast reinforced concrete wall and floor panels. Panels are joined together by means of special joints (either welded or monolithic). In the initial stage of large panel construction, the panels were joined together by means of welding. Wall panels have steel plate elements at the top and bottom end which are welded with similar elements of other panels (Figure 4C). The connection between the floor panels (Figure 4B) and the wall panels is achieved by welding the steel elements (see Figure 4D). In case of monolithic joints, vertical wall panel joints comprise of vertical steel bars projected from the panels, horizontal lapping steel and grooved panel surface. After the panel erection is complete and the steel bars are welded to the lapping steel, the gap is filled with concrete.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 60 and 60 meters, and widths between 12 and 12 meters. The building has 4 to 9 storey(s). The typical span of the roofing/flooring system is 3.6 meters. Typical Plan Dimensions: Seria 122: (for 5-story buildings) length: 36-54 m; width: 12 or 13.8 m Seria 135: (for 5-story buildings) length: 20-30 m; width: 12 or 13.8 m Seria 1-464c: (for 5-story buildings) length: 89 m; width: 11.5 m Typical Story Height: 3.0 m (Seria 122); 2.8 - 3.2 m. (Seria 135); 2.7 m (Seria 1-464c) Typical Span: 3.0 - 3.6 m (Seria 122); 3 - 6.6 m. (Seria 135); 2.7 - 3.6 m (Seria 1-464c). The typical storey height in such buildings is 3 meters. The typical structural wall density is none. 8-10 % (Seria 1-464c) 12-15% (Seria 122 and 135).

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	☑	☑

Solid precast slabs of room dimensions. Solid precast slabs of room dimensions.

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	☐
	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐

Deep foundation	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

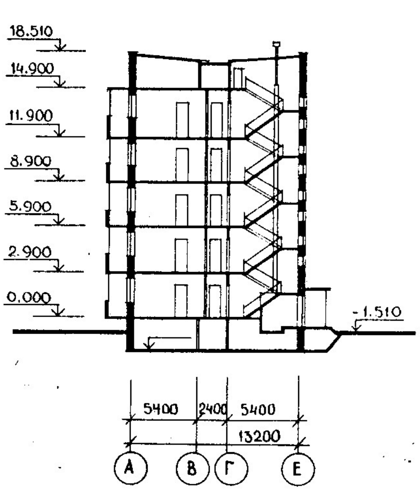

Figure 4A: Critical Structural Details- Elevation of a Typical Large Panel Building

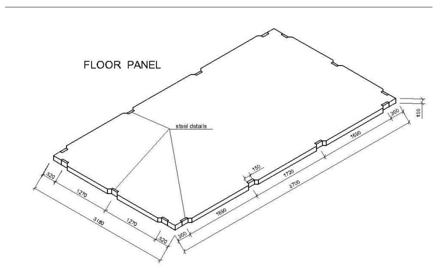

Figure 4B: Floor Panel Details

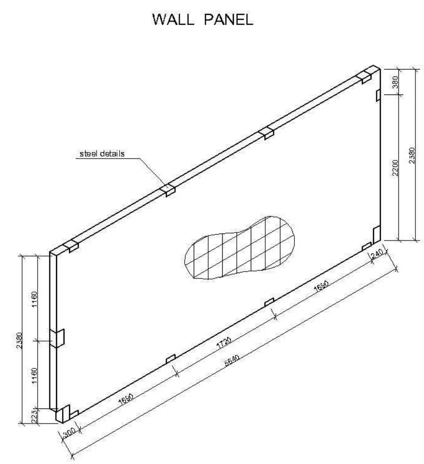

Figure 4C: Wall Panel Details

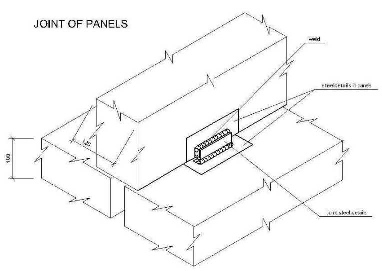

Figure 4D: Panel Joint Details

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 51-100 housing unit(s). 80 units in each building. Approximately 80 units per a 5-storey high 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 others (as described below). > 200.

4.2 Patterns of Occupancy

One family per unit (apartment).

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)	☐

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).

Usually one bathroom per one family (unit). .

4.4 Ownership

The type of ownership or occupancy is outright ownership and long-term lease.

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)	☐

Own outright (for unit). Long-term lease (most often).

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	-Welded connections are poor or absent; - The corrosion of the steel joints	- Rigid box-type system; - 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.	
Frame (columns, beams)			
Roof and floors	Corrosion of the steel joints		
Other: beams around the openings			

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance)*, the lower bound (i.e., the worst possible) is C: MEDIUM VULNERABILITY (i.e., moderate 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
1976	Gazly, Uzbekistan	7.3	IX (MSK)
1976	Gazly, Uzbekistan	7	VII (MSK)
1984	Gazly, Uzbekistan	7.2	IX (MSK)
1988	Spitak, Armenia	6.9	IX (MSK)

1971 Petropavlovsk, Kamchatka earthquake (Richter magnitude 7.2) - panel buildings were not damaged in this earthquake. Also, panel buildings were not damaged in the 1966 Tashkent (Uzbekistan) earthquake (I=8). However, it should be noted that large panel buildings were not located in the epicentral zone of the Tashkent earthquake; they were located in the area with intensity of less than VII on MSK scale. Many large panel buildings were damaged in the second Gazly earthquake of 1976; this can be explained by seismic impact on the buildings already damaged in the previous Gazly earthquake that occurred in the same year (1976). Before the 1976 earthquake, the Gazly area was considered as zone of moderate seismic risk (intensity VI per MSK scale). Consequently, buildings were not characterized with any seismic provisions. Panel joints were not adequate for seismic conditions, however in spite of that, these buildings suffered much less damage as compared to other building types. Damages to large panel buildings in the Gazly earthquake are not typical for the performance of large buildings in seismic zones. It was observed that some exterior wall panels toppled and fell off the buildings. Damage to large panel buildings in the 1976 Gazly earthquake is shown on Figure 5. Panel buildings suffered only a minor damage in the 1988 Spitak, Armenia earthquake. However, these panel buildings were of different type (Seria A1-451 KP-16/1), which is similar to the construction described in another contribution by Itskov, Ashimbayev and Chernov (Kazakhstan) on large panel construction with two longitudinal walls.

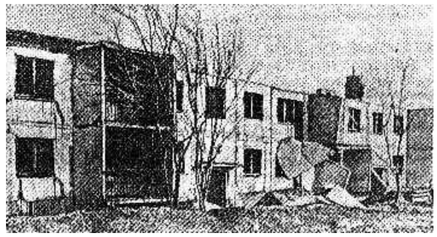

Figure 5: A Photograph Illustrating Gazly Earthquake Damage

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Reinforced Concrete	30-35 MPa (concrete cube compressive strength) 390 MPa (Steel yield stress)		
Foundation	Reinforced Concrete	20 MPa (cube compressive strength) 295 MPa (Steel yield stress)		
Frames (beams & columns)				
Roof and floor(s)	Reinforced Concrete	30-35 MPa (concrete cube compressive strength) 390 MPa (Steel yield stress)		

6.2 Builder

It is typical for this type of housing to be built by developers.

6.3 Construction Process, Problems and Phasing

Construction of this type is carried out by special industrial complexes, including plants for panel production and the construction assembly. These complexes are specialized for this type of construction. The construction equipment includes special trucks for the transportation of panels, lifting crane, welding equipment, and concrete mixer. 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 for design of buildings of this type was available, including the construction quality procedure developed by the author of this contribution. The design was performed 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. - SN-321-65 "Recommendations for the Design of Large-Panel Residential Buildings",1965. - GOST 11-309-65 "Residential Large-Panel Buildings. Technical

Requirements", 1965. - SN-328-65 "Requirements for the design of Large-panel Residential Buildings in Seismic Areas", 1965. - BSN-32-65 "Instructions for the Design of Large Panel Residential Buildings", 1965. The year the first code/standard addressing this type of construction issued was 1961. SNIP II-7-81 "Construction in Seismic Regions. Design Standards", Moscow, 1982. The most recent code/standard addressing this construction type issued was 1981. Title of the code or standard: - SN-321-65 "Recommendations for the Design of Large-Panel Residential Buildings",1965. - GOST 11-309-65 "Residential Large-Panel Buildings. Technical Requirements", 1965. - SN-328-65 "Requirements for the design of Large-panel Residential Buildings in Seismic Areas", 1965. - BSN-32-65 "Instructions for the Design of Large Panel Residential Buildings", 1965. Year the first code/standard addressing this type of construction issued: 1961 National building code, material codes and seismic codes/standards: SNIP II-7-81 "Construction in Seismic Regions. Design Standards", Moscow, 1982. When was the most recent code/standard addressing this construction type issued? 1981.

The process consists of issuing permits for the design and construction, including the architectural permits and urban planning/municipal permits. Designers need to have license to practice and are responsible to follow the building codes. Building inspection is performed and the permit is issued.

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). The maintenance is performed either by the owner (city) or (periodically) by a contractor - a maintenance firm.

6.8 Construction Economics

200-300 $US/m² (per the official rate). It takes 380 man-months to build a 4-story building with plan dimensions of 59.2 m X 10.8 m.

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. The insurance is available as a part of the usual property insurance. Insurance covers about 3-5% of thew total estimated property value.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used

Deficient panel joints	- Installation of reinforced concrete bushing keys, - Application of reinforced ganite overlay on panel surface, - Crack injection with polymer-cement grout.

The seismic strengthening methods outlined in the table above are considered to be effective in improving seismic resistance of large panel buildings.

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. Seismic strengthening of this construction type had not been used in practice on a regular basis. Some strengthening was done after the Gazly earthquake.

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.

Reference(s)

1. Manual on Certification of Buildings and Structures in the Seismic-Prone Areas, Second Edition
   CENDR, Petropavlovsk, Kamchatka, Russia 1990

2. Earthquakes and Us
   Klyachko,M.A.
   Intergraf, Saint Peterburg, Russia (in Russian) 1999

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