World Housing Encyclopedia Report

Country: Kazakhstan

Housing Type: Prefabricated large panel concrete buildings with two interior longitudinal walls.

Contributors:
Igor Efroimovich Itskov
Ashimbayev Marat Umarbayevich
Nikolai Borisovich Chernov

Primary Reviewer:
Vanja Alendar

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1 General Information

1.1 Country

Kazakhstan

1.3 Housing Type

Prefabricated large panel concrete buildings with two interior longitudinal walls.

1.4 Summary

This is a typical urban residential construction 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 redundance. 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.

FIGURE 1A: Typical Building

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	X
< 50 years	
< 75 years	
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
		X

Additional Comments: This construction practice started in Kazakhstan in early 1980s.

1.6 Region(s) Where Used

Almaty - former capital of Kazakhstan and other cities in Kazakhstan.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	X
In rural areas	
In suburban areas	
Both in rural and urban areas	

2 Architectural Features

2.1 Openings
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.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 10 meters

2.3 Building Configuration
Rectangular shape.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	
Multiple housing units	X
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

2.5 Means of Escape
One staircase for each segment (three housing units at each floor) and two entrances at the ground floor level.

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

3 Socio-Economic Issues

3.1 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.

3.2 Number of Housing Units in a Building

81 units in each building.

Additional Comments: 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.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5		
5 to 10		
10-20		
> 20	X	
Other		X

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 0

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor		/
Middle Class	X	8/1
Rich		/

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	
Personal Savings	
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	X
Other	

3.7 Ownership

Type of Ownership/Occupancy	
Rent	X
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

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

4 Structural Features

4.1 Lateral Load-Resisting System

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.

4.2 Gravity Load-Bearing Structure

Longitudinal and cross walls and floor slabs.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	X
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

4.4 Type of Foundation

Type	Description	
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	X
	Mat foundation	
	No foundation	
Deep Foundation	Reinforced concrete bearing piles	
	Reinforced concrete skin friction piles	
	Steel bearing piles	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)	X	X
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
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 single roof		
	Wood planks or beams that support clay tiles		
	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			

Additional Comments: Precast solid slab.

4.6 Typical Plan Dimensions

Length: 34.8 - 34.8 meters
Width: 34.8 - 34.8 meters
Additional Comments: 34.8 m is a typical length. Length is equal to 17.4 m X n, where "n" is number of sections.

4.7 Typical Number of Stories

5 - 9

4.8 Typical Story Height

3 meters

4.9 Typical Span

3.6 meters

Additional Comments: 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.

4.10 Typical Wall Density

Wall density in longitudinal direction is 0.05 and in the cross direction this value is 0.07.

4.11 General Applicability of Answers to Questions in Section 4

This contribution describes a standardized (prefabricated) construction technology.

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	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 form the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
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.	X		
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.	X		
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.	X		
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	X		
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	X		
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).	X		
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	X		
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	X		
Other				

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			

Additional Comments: 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 Seismic Vulnerability Rating

Vulnerability						
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class					0	

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1911	Null	8.2	

Additional Comments: 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).

7 Building Materials and Construction Process

7.1 Description of 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
Foundations	Reinforced concrete	20 MPa (cube compressive strength) Steel yield stress 295 MPa		
Roof and floors	Reinforced concrete	30-35 MPa (cube compressive strength) Steel yield stress 390 MPa		

Notes:
1.
2. For the exterior walls (2 layers); one layer is made using regular concrete and the other one is made of lightweight concrete (for the purpose of heat insulation). The interior walls are made of regular concrete.

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

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

7.3 Construction Process

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

7.4 Design/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.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

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

7.6 Role of Engineers and Architects

Design for this type of construction was done completely by engineers and architects. Engineers played a leading role in each stage of construction.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required	X	
Informal construction		X
Construction authorized per development control rules	X	

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)		X
Building originally designed for its final constructed size	X	

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	X
No one	
Other	

7.10 Process for Building Code Enforcement

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.

7.11 Typical Problems Associated with this Type of Construction

Quality of construction.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

Construction cost is about 450 US$/m² ; in terms of the national currency of the Republic of Kazakhstan - 67,000 tenge.

8.2 Labor Requirements (estimate)

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.

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available		X
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

No.

10.3 Was the work done as a mitigation effort on an undamaged building, or as repair following earthquake damage?

N/A

10.4 Was the construction inspected in the same manner as new construction?

N/A

10.5 Who performed the construction: a contractor, or owner/user? Was an architect or engineer involved?

N/A

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

N/A

11 References

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12 Contributors

Name	Igor Efroimovich Itskov	Ashimbayev Marat Umarbayevich	Nikolai Borisovich Chernov
Title	Head of Laboratory of Large Panel Buildings	Director	Head of sector of the Laboratory of Large Panel Buildings
Affiliation	KazNIISSA	KazNIISSA	KazNIISSA
Address	53, Mynbayeva str # 305	53, Mynbayeva Str. # 305	53, Mynbayeva str, Almaty, Republic of Kazakhstanoff. # 305
City	Almaty	Almaty	Almaty
Zipcode	480053	480053	480053
Country	Kazakhstan	Kazakhstan	Kazakhstan
Phone		7-3272-436217	
Fax			
Email	laskoz@nursat.kz		
Webpage			

13 Figures

FIGURE 1A: Typical Building

FIGURE 1B: Typical Building

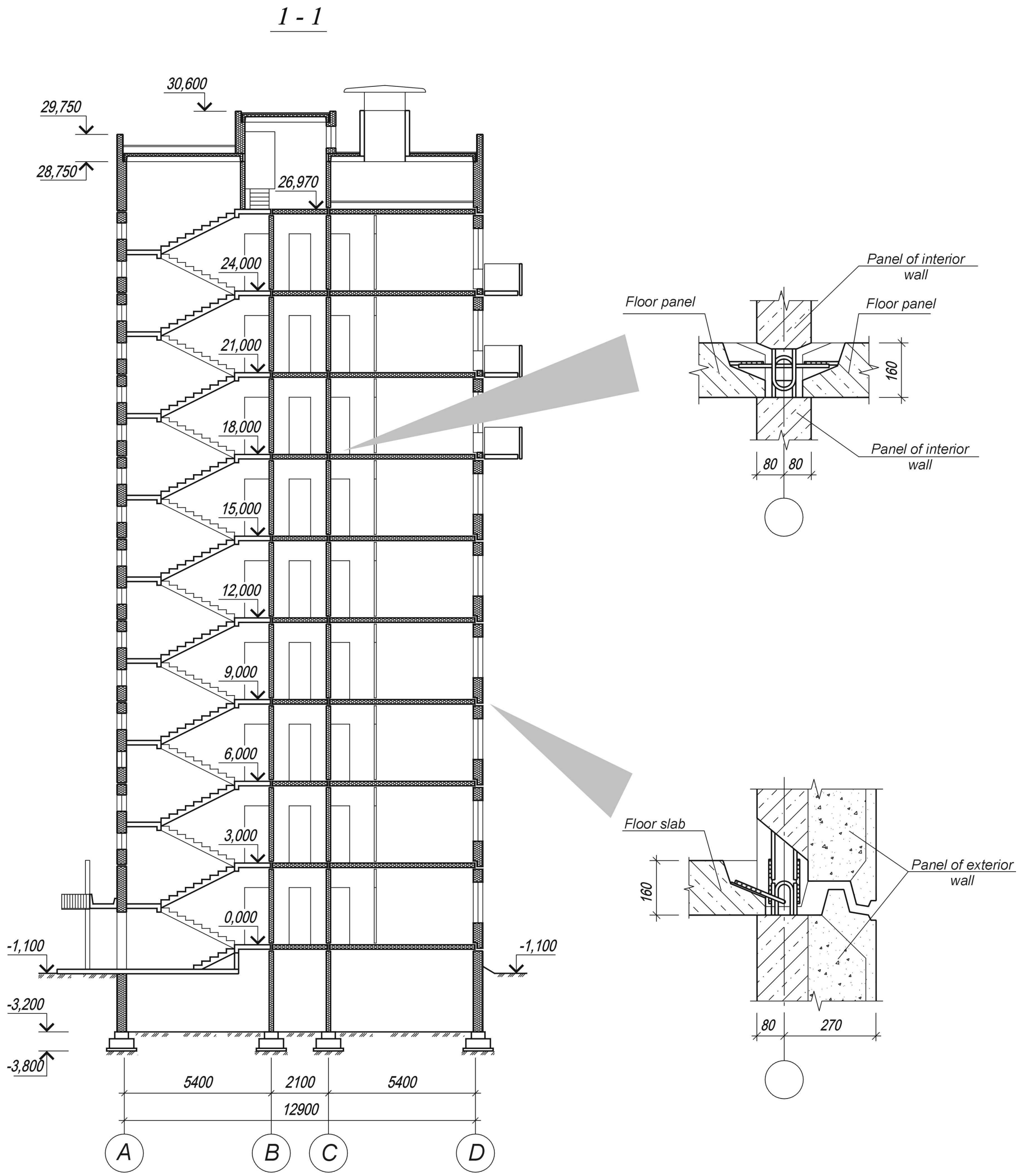
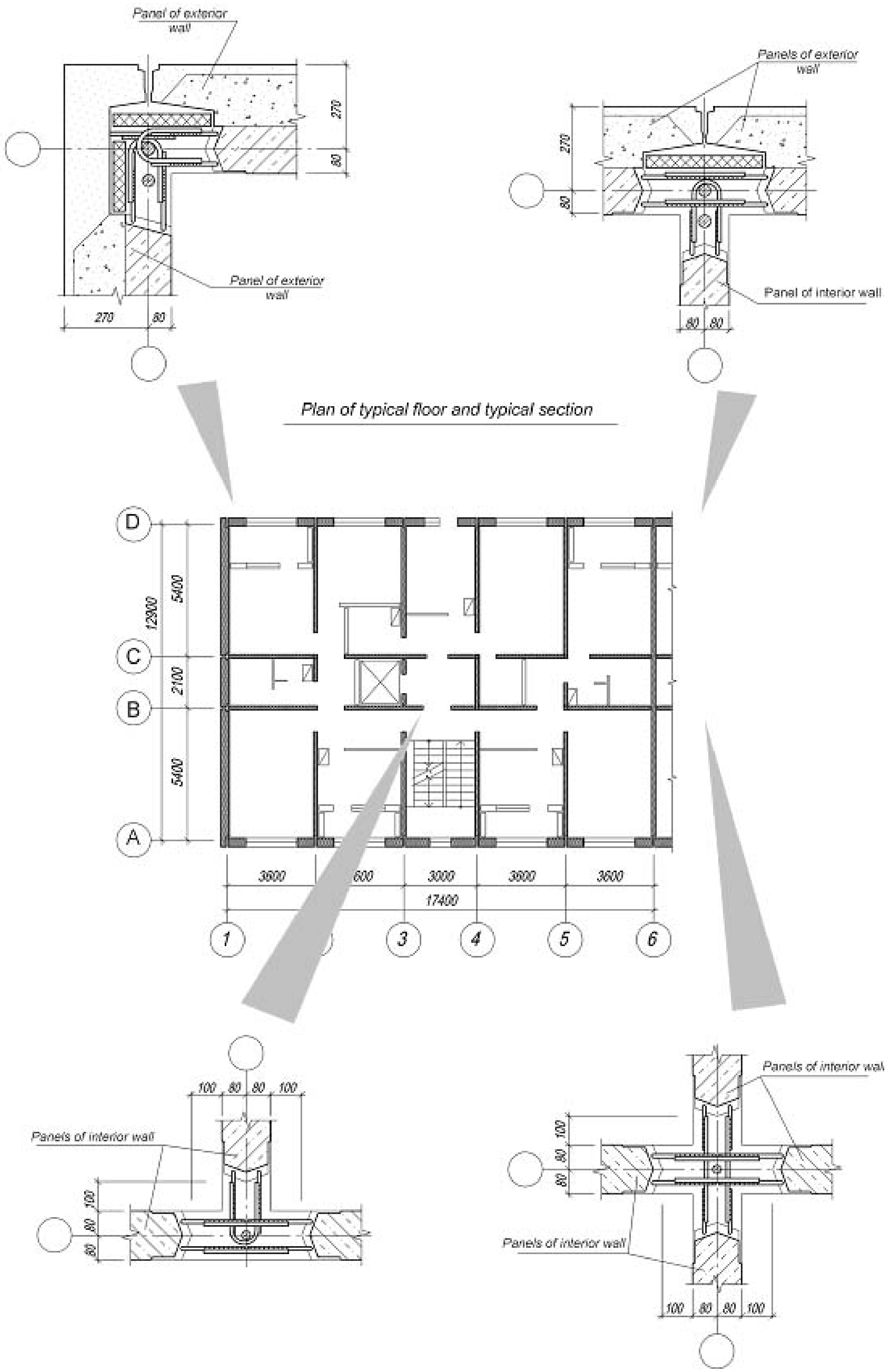


FIGURE 2: Key Load-Bearing Elements



Plan of typical floor and typical section

FIGURE 3: Plan of a Typical Building

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

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