World Housing Encyclopedia

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

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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Precast reinforced concrete frame panel system of seria IIS-04

Report #	66
Report Date	05-06-2002
Country	UZBEKISTAN
Housing Type	Precast Concrete Building
Housing Sub-Type	Precast Concrete Building : Moment frame
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Summary

This housing type is used in the construction of residential and public buildings in many cities throughout Uzbekistan (including the capital city Tashkent) that are located in zones with intensities between 7-9. Residential buildings of this type are generally 9 to 12 stories high,

whereas public buildings of the same construction are 1 to 4 stories high. All seismic load-resisting (and also nonstructural) components, e.g., foundations, columns, girders, slabs, staircases, wall panels, etc., are manufactured in specialized plants. The materials are subsequently transported to the building site. The positive features of this construction type are (1) the ability to manufacture all building materials in an industrialized setting, and (2) the gain in efficiency inasmuch as the same building components may be used both for residential and public buildings. The key drawback is that the welded joints cause seismic vulnerability when the building is located in zones of extremely high seismic loads. These joints have shown extremely brittle behavior during earthquakes. Earthquake damage is mainly concentrated in the column joints, or in the column-to-girder joints. In some cases non-bearing walls and exterior wall panels have collapsed.

1. General Information

Buildings of this construction type can be found in Tashkent and other cities of Uzbekistan and Central Asia. In Tashkent, this housing type accounts for over 18% of the residential building stock and for over 25% of the public building stock. 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 traditional construction practice has been followed for over 35 years. The frame panel seria IIS-04 was first used in 1973.

Figure 1: Typical Building

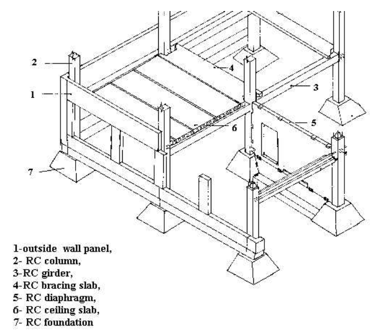

Figure 2: Key Load-Bearing Elements

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 30 meters.

2.2 Building Configuration

Usually a rectangular plan. In this housing type, the main load-bearing elements are the columns, beams and joints (a frame structure). Therefore, seismic vulnerability does not depend on the number and size of the openings. The size of the windows and doors ranges from 2.25 m to 4.5 m.

2.3 Functional Planning

The main function of this building typology is mixed use (both commercial and residential use). In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. The means of escape depends upon the number of apartments on the floor. If a building has "point block" planning (2-4 apartments without a corridor at each floor level), there is typically one staircase and one exit.

2.4 Modification to Building

Minor modifications of interior partition walls may be done by the owners.

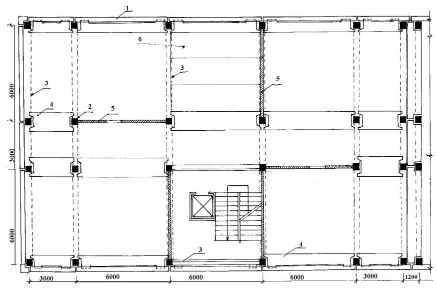

Figure 3: Plan of a Typical Building

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
			Designed for seismic effects,	

Structural concrete		20	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 moment resisting frame. The gravity load-bearing structure consists of reinforced concrete frame, including precast columns and beams and precast floor panels.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete moment resisting frame. The lateral load-resisting system is reinforced concrete frame, which consists of precast columns and beams and cast in-situ or precast concrete shear walls. Precast frame elements are joined together in the space frame structure. Shear walls may be made of precast panels or cast in-situ elevator cores in the taller buildings of this type (e.g., 12-story buildings). In medium-rise buildings of this type (e.g., 4-5 stories), the entire lateral load-resisting system consists of a RC frame only (i.e., shear walls are not present). Precast floor panels are joined in a rigid diaphragm for the distribution of lateral forces.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 24 and 24 meters, and widths between 15 and 15 meters. The building has 9 to 12 storey(s). The typical span of the roofing/flooring system is 6 meters. Typical Plan Dimensions: Typical plan dimensions: 18x18m, 12x36m, 15x24m Typical Span: The typical span may be either 6 or 3 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 5 %. .

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	☐

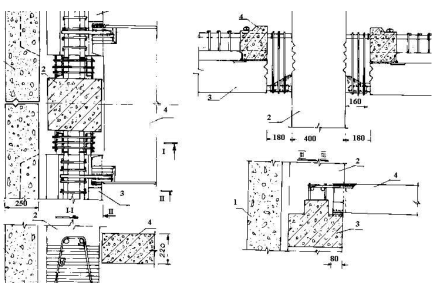

Figure 4: Critical Structural Details

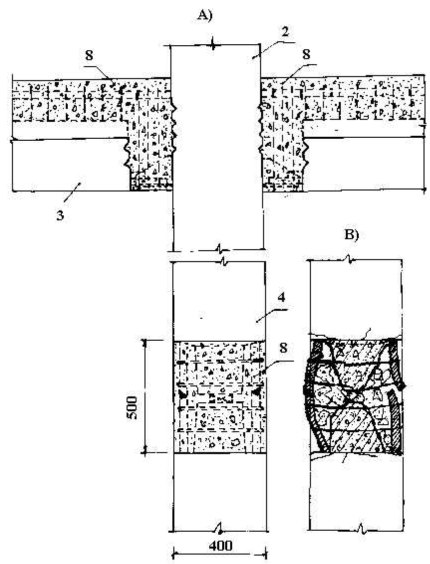

Figure 5: An Illustration of Key Seismic Features and/or Deficiencies

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 51-100 housing unit(s). Usually there are more than 60 units in a 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 more than 20.

4.2 Patterns of Occupancy

It depends on the size of the multi-story building. Typically, over 60 families live in a 12-story building.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☐
b) low-income class (poor)	☑
c) middle-income class	☑

d) high-income class (rich)	☐

Economic Level: For Middle Class the Housing Price Unit is 5000 and the Annual Income is 720.

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)	☐

Almost 90% of the buildings are privately owned and 10% are rented from the local government.

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	Precast floor panels are constructed with special grooves and steel dowels projected on all four sides for achieving the cast in-situ joint. This type of floor structure subjected to lateral loads was tested in the lab. The roof diaphragm is considered to be rigid provided that the quality of construction is adequate.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Partition walls (cladding)	Exterior and interior partition walls are non-load-bearing (i.e., they carry their own weight only).		Due to poor quality of wall-column and wall-beam joints, the walls may experience serious damage in an earthquake.
Frame (columns, beams)	The most vulnerable parts of a frame are beam-column joints; these welded joints are located in the area of extremely high loads. As a result of the welding, steel reinforcement bars may have loose ductility. Also, the concrete poured in these joints is often poorly vibrated.		Damage to beam-column joints
Roof and floors	The joints between the precast slabs (grouted in-situ) are sometimes not properly filled with grout and may lose their strength in an earthquake.		Damage of horizontal panel joints and the subsequent loss of rigid diaphragm behavior
Wall panels, (vertical diaphragms)	The assembled reinforced concrete diaphragms are inadequately welded to the columns. Vertical bars discontinued during the site installation. Due to poor quality of construction, the diaphragm strength may be reduced by 50%.		Failure of precast diaphragm-to-frame connections.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *C: MEDIUM VULNERABILITY (i.e., moderate seismic performance)*, the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is *D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance)*.

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☑	☐	☑	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1984	Gazli	7.2	IX (MSK
1988	Spitak (Armenia)	7.5	IX-X (MSK)

Buildings of this type were damaged during the 1988 Spitak earthquake, as illustrated in Figures 6A and 6B.

Figure 6A: Building Damage in Leninakan (1988

Spitak, Armenia Earthquake)

Figure 6B: Building Damage in Leninakan (1988 Spitak, Armenia Earthquake)

Figure 6C: Building Damage (1988 Spitak, Armenia Earthquake)

Figure 6D: Building Damage (1988 Spitak, Armenia Earthquake) Source: Klyachko 1999

Figure 6E: Building Damage (1994 Shikotansk, Russia Earthquake) Source: Klyachko 1999

Figure 6F: Building Damage (1994 Shikotansk, Russia Earthquake) Source: Klyachko 1999

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Partition Walls: Reinforced concrete Wall panels (vertical diaphragms): Reinforced concrete	Wall panels (vertical diaphragms): 30 MPa (cube compressive strength)	Partition Walls: These walls are not lateral load-resisting elements Mix - 1: 1.5: 2.4: 0.45 Dimensions 6000 X 1500 X 250 (mm) Wall panels (vertical diaphragms): Mix- 1: 1.75: 3.21: 0.51 Dimensions 5600 X 140 X 3280 (mm)	
Foundation	Reinforced concrete	10-15 MPa (cube compressive strength)	Mix- 1: 1,4: 2: 0,49 Dimensions: 1400 X 1400 X 900 (mm)	
Frames (beams & columns)	Column: Reinforced concrete Girder: Reinforced concrete	Column: 40 MPa (cube compressive strength) Girder: 40 MPa (cube compressive strength)	Column: 1: 2: 3: 0.5 Cross sectional dimensions: 400 X 400 (mm) X height (3300 -13500 mm) Girder: Mix- 1: 1.4: 2.8: 0.49 Cross-sectional dimensions: 420 X 480 (mm)	
Roof and floor(s)	Reinforced concrete	30 MPa (cube compressive strength)	Mix- 1: 1.75: 3.24: 0.44 Dimensions : 6000 X 220 X 1600 (mm)	

6.2 Builder

A builder may live in this construction type, and his children may attend the schools housed in buildings of this type.

Typically, frame panel buildings are constructed by order of the municipality.

6.3 Construction Process, Problems and Phasing

Based on the order of the government, a design agency develops a series of industrialized construction elements. Based on the information provided by the design agency, a concrete plant prepares a set of metal forms for the columns, girders, diaphragms, slabs, wall panels, staircases, etc., corresponding to the requirements of a series. Based on the order of a municipality or other clients, design firms develop designs of individual buildings or typical (standardized) building designs. A concrete plant manufactures and delivers all required building elements to the construction site. A construction company erects the building at the construction site. The main pieces of equipment used for the construction are a tower crane, welding equipment, and concrete mixers. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

All designs are reviewed by the State Expert Bureau of the State Committee on Architecture and Construction (SCAC); the revisions are incorporated in the final design (if required). Once the review is completed, the designs are forwarded to the concrete plants and the construction company. The concrete strength is evaluated in the laboratory in the concrete plant, and the reinforcement schedule is checked and compared with the design documents. Periodically (once in six months), the laboratory data are examined by a representative of the State Architecture Construction Control Department (SACC) of SCAC. SCAC also monitors the construction quality at the site. In addition to this, a representative of the design agency or firm also performs a site inspection. The builders should take into account the designer's comments made during the site inspection. Once the construction is complete, a special state expert committee needs to approve the building and to issue the building permit. Use and selection of the typical, standard production of series IIS-04 depend upon load conditions. Engineers and architects cannot change any construction details (joints, connections) in the existing series, which is approved by the government. Only the agency that has developed the series is able to change the details.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. The construction is carried out based upon the catalogs of frame panel seria IIS-04 (developed in 1973), and upon the National Building Code of Uzbekistan: "Construction in Earthquake-prone Areas" (KMK.2.01.03-96). National Building Code, Material Codes and Seismic Codes/Standards; National Building Code of Uzbekistan: Construction in Earthquake-prone Areas (KMK.2.01.03-96). The most recent code/standard addressing this construction type issued was 1996. Title of the code or standard: The construction is carried out based upon the catalogs of frame panel seria IIS-04 (developed in 1973), and upon the National Building Code of Uzbekistan: "Construction in Earthquake-prone Areas" (KMK.2.01.03-96). National building code, material codes and seismic codes/standards: National Building Code, Material Codes and Seismic Codes/Standards; National Building Code of Uzbekistan: onstruction in Earthquake-prone Areas (KMK.2.01.03-96). When was the most recent code/standard addressing this construction type issued? 1996.

Design of buildings using the seria IIS-04 is carried out in accordance with the National Building Code of Uzbekistan: Construction in Earthquake-prone Areas.

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

33000 sum/m² (110 US$/m²). A 12-story residential building with 48 housing units and with plan dimensions

18x18 m may be erected by 10 workers in 10 months.

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 available. The insurance covers approximately 30% of the construction cost.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Beam-column joints	Reinforcing of joints with steel plates
Frame (column)	Installation of additional (external) steel ties (straps)

Seismic strengthening of a building in Tashkent is illustrated in Figures 7A and 7B.

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?

Yes. Seismic strengthening was performed on some buildings in Tashkent.

8.3 Construction and Performance of Seismic Strengthening

Figure 7A: Illustration of Seismic Strengthening Techniques

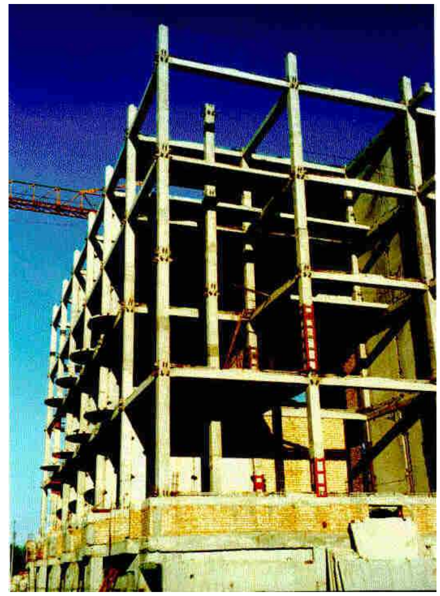

Figure 7B: Illustration of Seismic Strengthening Techniques

Reference(s)

1. Construction in Earthquake-prone Areas
   National Building Code of Uzbekistan, KMK 2.01.03-96 1996

2. Concrete and Reinforced Concrete - Design Codes and Standards

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