World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Precast reinforced concrete frame building with cruciform and linear-beam elements (Series 106)

Report#	33
Last Updated	
Country	Kyrgyzstan
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Important

Engineering, the Engineering Information Foundation, John A, Martin & Associates, Inc. or the participant’s organizations.

General Information

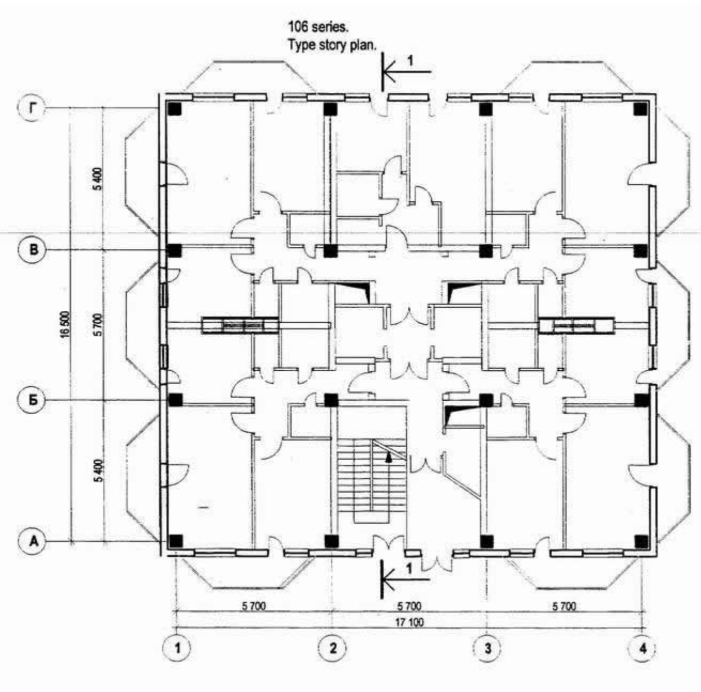
Building Type:	Precast reinforced concrete frame building with cruciform and linear-beam elements (Series 106)
Country:	Kyrgyzstan
Author(s):	Ulugbek T. Begaliev Svetlana Uranova Manukovskiy V.
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Bishkek (the capital of Kyrgyzstan). This type of housing construction is commonly found in urban areas.
Summary:	Precast reinforced concrete frame buildings (series 106) were introduced in Kyrgyzstan around 1975. This type of apartment building is usually 9-stories high; less frequently, they may be 12 stories. The fundamental period of vibrations is typically in the range from 0.65-0.85 sec. Series 106 was developed by the Kyrgyz Design Institute for construction in seismically-prone areas. Several buildings of this type (about 15 in total) were built in the capital city Bishkek (design seismicity 8 on the MSK scale). The load-bearing structure consists of a precast reinforced concrete space frame and precast floor slabs. Partition walls are constructed using clay brick masonry units or small concrete blocks. Buildings of this type have not yet been subjected to major earthquakes. These buildings are not considered to be highly vulnerable to earthquake effects, provided that the construction quality, particularly with reference to the joints, is satisfactory. It should be noted that precast frame buildings of a different type (Series 111) performed very poorly in the 1988 Spitak (Armenia) earthquake.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 50+ units
Typical number of stories:	9-12
Terrain-Flat:	Typically
Terrain-Sloped:	3

Comments:

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	Typical shape of a building plan for this housing type is rectangular form with some modifications at the perimeter.
Typical plan length (meters)	18
Typical plan width (meters)	12
Typical story height (meters)	3
Type of Structural System	Structural Concrete: Precast Concrete: Moment frame
Additional comments on structural system	Lateral load-resisting system: The lateral load-resisting system is moment-resisting concrete frame. The load-bearing structure consists of a precast reinforced concrete space frame and precast floor slabs. The space frame (with column spans of 6 m) is constructed using two main modular elements: cruciform element and linear-beam element. The cruciform element consists of the transverse frame joint with half of the adjacent beam and column lengths. The longitudinal frames are constructed by installing the precast beam elements in-between the transverse frame joints. The precast elements are joined by welding of the projected reinforcement bars (dowels) and casting the concrete in-situ. Joints between the cruciform elements are located at the midspan of beams and columns, whereas the longitudinal precast beam-column connections are located close to the columns. The floor structure consists of precast reinforced concrete hollow-core slabs; reinforcement bars are projected from the slabs for achieving the anchorage to the beams. Gravity load-bearing system: The gravity load-bearing structure is moment resisting concrete frame.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	Not applicable-walls are not a part of load-bearing structure.
	Walls do not constitute a part of the load-bearing structure in moment-resisting space frame buildings. Typical size of windows is: 1.2m (height) X 1.5-2m (width),

Wall Openings	doors : 2m (height) X 0.9-1m (width). The overall area of window openings accounts for 30 to 40% of facade walls, while doors account for less than 10% of partition wall area.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Usually, modifications are made in non-structural (exterior and interior) walls.
Type of Foundation	Shallow Foundation: Reinforced concrete isolated footing
Additional comments on foundation	Buildings of this type have basement floor; frames at the basement are infilled with concrete block walls. The isolated footings are tied with the reinforced concrete foundation beams, which are acting as the foundation for basement walls.
Type of Floor System	Other floor system
Additional comments on floor system	Precast hollow core concrete slabs
Type of Roof System	Roof system, other
Additional comments on roof system	Precast hollow core concrete slabs
Additional comments section 2	Typical separation distance between buildings: 10 meters and more



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	(Partition)Wall: Brick and gasconcrete masonry Frame: Reinforced concrete	Wall: Non load-bearing structure Frame: Characteristic Strength- 40-45 MPa (cube compressive strength) Steel yield limit 390MPa. Mix Proportion/Dimensions- Different, depending on type of mix materials
Foundations	Reinforced concrete	Characteristic Strength: 10-15 MPa (cube compressive strength) Steel yield limit 295MPa Mix Proportion/Dimensions: Different, depending on type of mix materials
Floors	Reinforced concrete	Characteristic Strength: 30-35 MPa (cube compressive strength) Steel yield limit 390MPa. Mix Proportion/Dimensions: 1:1,7:3,2 (different depending on type of mix materials)
Roof	Reinforced concrete	Characteristic Strength: 30-35 MPa (cube compressive strength) Steel yield limit 390MPa. Mix Proportion/Dimensions: 1:1,7:3,2 (different depending on type of mix materials)
Other		

Design Process

Who is involved with the design process?	EngineerArchitectOther
Roles of those involved in the design process	The Design Institute develops the design documentation. Design for this construction type was done completely by engineers and architects.
Expertise of those involved in the design process	Expertise related to design and construction of this type according to the legal sistem of Kyrgyz Republic was available. Designs for buildings of this type were prepared

the design process	by specialized design institutes with experise in this type of construction.

Construction Process

Who typically builds this construction type?	Builder
Roles of those involved in the building process	The construction is performed by builders. Engineers played a leading role in each stage of construction.
Expertise of those involved in building process	
Construction process and phasing	The construction company makes the precast elements and performs the assembly. Precast elements can be made in the factory (plant). The main equipment used for construction is: crane, welding equipment and concrete mixers. This building is not typically constructed incrementally and is designed for its final constructed size.
Construction issues	Poor quality of construction work resulting in inadequate load-bearing capacity of joints.

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	SNiP II-7-81. Building in Seismic Regions.Design code. The first code/standard addressing this type of construction was issued 1961; the most recent code/standard addressing this construction was issued 1981.
Process for building code enforcement	Building permit will be given if the design documents have been approved by the State Experts. State Experts check the compliance of design documents with pertinent Building Codes. According to the building by- law, buildings cannot be inhabited without the formal approval of a special committee. The committee gives the approval if design documents are complete and the construction has been carried out in compliance with Building Codes.

Building Permits and Development Control Rules

Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes
Additional comments on	

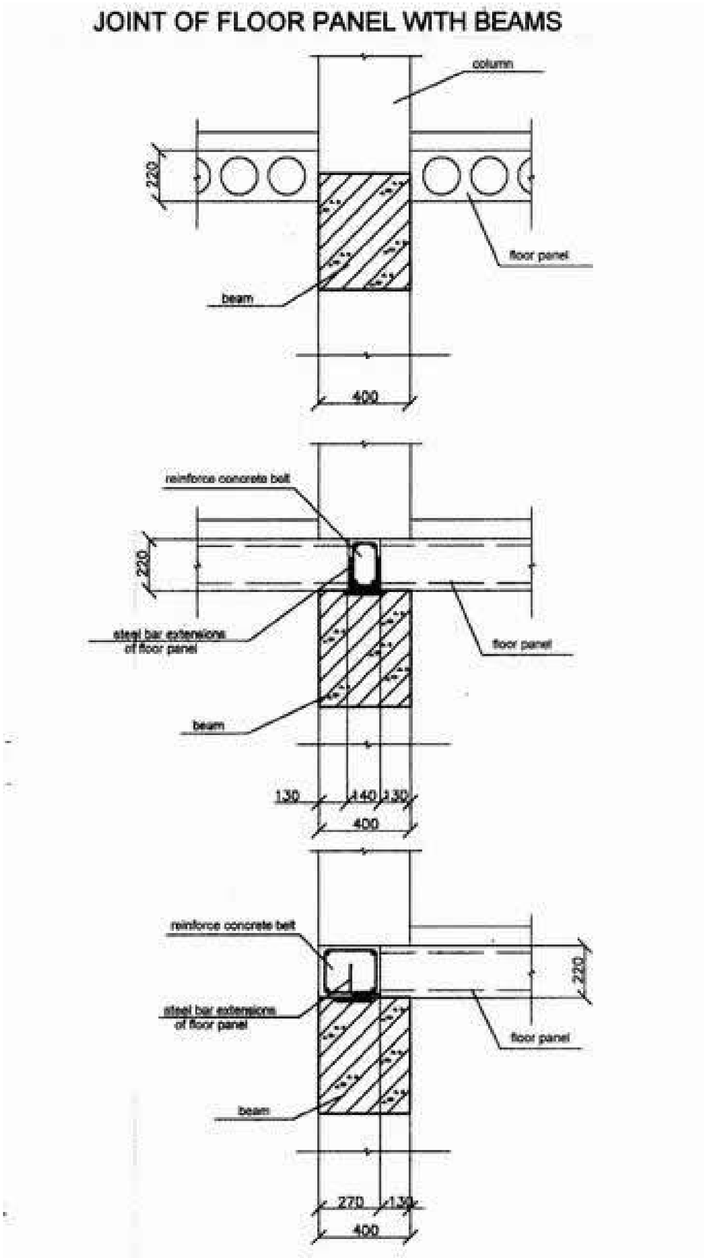
building permits and development control rules	

Building Maintenance and Condition

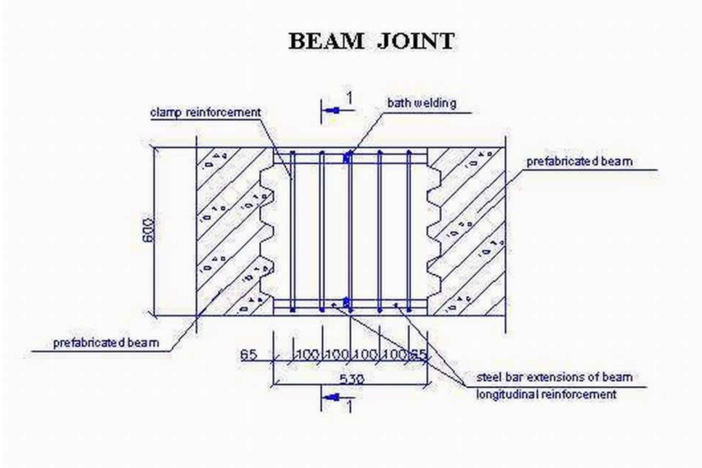
Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	BuilderOwner(s)Renter(s)
Additional comments on maintenance and building condition	

Construction Economics

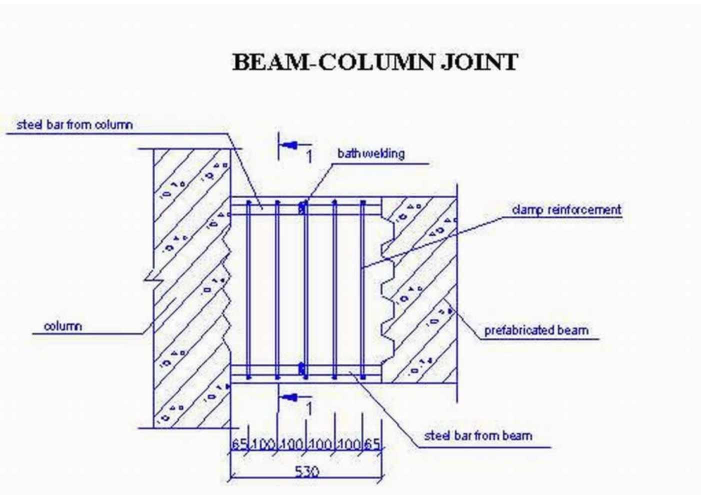
Unit construction cost	For load-bearing structures only about 180$/m2.
Labor requirements	For load-bearing structures, a team of 10 workers would take 9 to 12 months
Additional comments section 3	



Wall Panel Details



Beam Joint Details



Beam-Column Joint

Cruciform Element- as Constructed

Socio-Economic Issues

Patterns of occupancy	Each floor has 2-4 housing units. One family occupies one housing unit. In general, 36 to 120 families occupy one building (depending on the number of building units and stories in a building).
Number of inhabitants in a typical building of this construction type during the day	>20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	40% poor, 50% middle class
Typical Source of Financing	Owner financedPersonal savings
Additional comments on financing	This is the present situation. Before 1990 the source of financing was the government. Now, all new and existing apartment buildings are private.
Type of Ownership	RentOwn outrightUnits owned individually (condominium)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on premium discounts	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Buildings of this type have not been subjected to the effects of damaging earthquakes. Precast frame buildings that were affected by strong earthquakes in the former Soviet Union (e.g. 1988 Spitak, Armenia earthquake) had linear precast elements (i.e. no cruciform members), and the joints were located in zones of maximum seismic moment. It should be noted that the precast frame buildings affected by the 1988 Spitak earthquake (Series 111) are different from precast frame buildings (series 106) described in this contribution. The main difference is in the cruciform elements, larger joint areas, and location of critical joints away from the highly stressed areas of beams and columns-these are all positive features of the Series 106 described in this contribution (see also Table 5.2).
Additional comments on earthquake damage patterns	

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 "Handbook for the Seismic Evaluation of Buildings-A Pre-standard", Federal Emergency Management Agency, Washington, D.C., 1998.

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.

Structural/Architectural Feature	Statement	Seismic Resistance
Lateral load path	The structure contains a complete load path for seismic force effects from	TRUE

	any horizontal direction that serves to transfer inertial forces from the building to the foundation.	
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	TRUE
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.	TRUE
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.	TRUE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
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);	N/A
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are	TRUE

	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.	TRUE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	TRUE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Walls are not lateral load-resisting structures. Poor quality of walls, and wall-column and wall-floor joints.
Earthquake-resilient features in walls	
Seismic deficiency in frames	Poor quality of joints between the precast frame elements; damage to joints expected

Earthquake-resilient features in frame	Joints of columns are located at the column mid-height (where seismic bending moment=0). Joints for gravity load-bearing beams are located at the mid-span (where seismic bending moment=0).
Seismic deficiency in roof and floors	
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the Seismic Vulnerability Guidelines

	High vulnerability		**Medium vulnerability**		**Low vulnerability**	
	A	B	C	D	E	F
Seismic vulnerability class		|-	o	-|		

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	**Seismic Strengthening**
Poor quality of joint of precast frame elements	Usual methods for concrete frames, reinforced concrete and steel jackets.

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	N/A
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake	N/A

damages?	
Was the construction inspected in the same manner as new construction?	N/A
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	N/A
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	N/A
Additional comments section 6	

References

Seismic Hazard and Buildings Vulnerability in Post-Soviet Central Asia Republics. Edited by Stephanie A. King, Vitaly I. Khalturin and Brian E. Tucker. Kluwer Academic Publishers, P.O. Box 17, 3300 AA Dordrecht, The Netherlands. (Proceeding of the NATO Advanced Research Workshop on Earthquake Risk Management Strategies for Post-Soviet Central Asian Republics. Almaty, Kazakhstan, 22-25 October 1996)

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