World Housing Encyclopedia

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

an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Small concrete block masonry walls with concrete floors and roofs

Report #	53
Report Date	05-06-2002
Country	RUSSIAN FEDERATION
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Concrete block masonry in cement mortar
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Summary

This is a typical residential construction found both in urban and rural areas. It represents a construction practice followed in the former Soviet Union. Buildings of this type constitute 15 to 30% of the housing stock in seismically prone areas of Russia (Far East, Siberia, Baikal

Lake Region, North Caucasus) and in CIS states (Central Asia, Armenia, Georgia, etc.). The main load-bearing system for lateral and gravity loads consists of concrete block masonry walls and concrete floor slabs. Seismic resistance is relatively good, provided that the welded block wall connections are present and well constructed.

1. General Information

Buildings of this construction type can be found in seismically prone areas of Russia (Far East, Siberia, Baikal Lake Region, North Caucasus) and CIS states (Central Asia, Armenia, Georgia, etc.) where it accounts for 10 to 15% of the housing stock. This type of housing construction is commonly found in both rural and 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 Soviet Union construction practice followed during the last 50-60 years (after the Second World War).

Figure 1: Typical Building

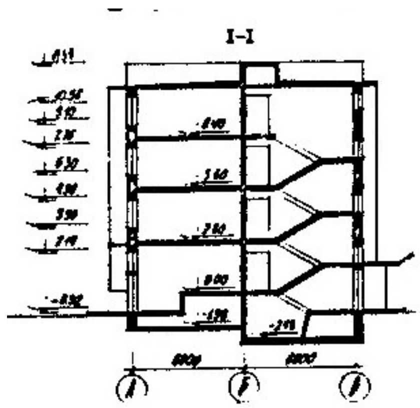

Figure 2A: Key Load-Bearing Elements

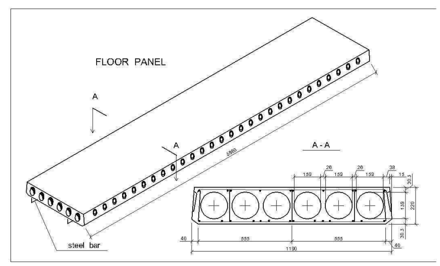

Figure 2B: Precast Hollow-Core Reinforced Concrete Floor Slab (Source: U. Begaliev and S. Uranova)

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%; on the flat terrain approximately 85% When separated from adjacent buildings, the typical distance from a neighboring building is 5 meters.

2.2 Building Configuration

In general all building plans are of rectangular shape. 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 1-2 fire-protected exit staircases. Usually there is one exit stair with one main entry in one section of a building. An average section includes 12 housing units in total (i.e. 3 units per floor).

2.4 Modification to Building

Typical modification patterns include the demolition of interior walls and perforation of walls with door openings.

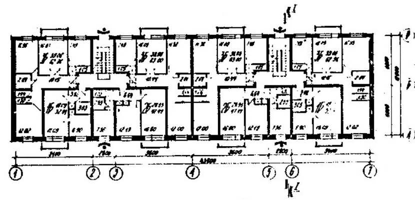

Figure 3: Plan of a Typical Building

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
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	☐
		24	Moment frame	☐
			Prestressed moment frame	

	Precast concrete	25	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). Same as lateral load-resisting system.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Lateral load-resisting system consists of concrete block masonry walls and precast reinforced floor structure. In most cases floor structure consists of the precast reinforced concrete hollow core panels, which are combined in horizontal diaphragm by means of cast-in-situ reinforced concrete bond beams (belt) constructed at the building perimeter.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 43 and 43 meters, and widths between 12 and 12 meters. The building has 2 to 4 storey(s). The typical span of the roofing/flooring system is 6 meters. The typical storey height in such buildings is 2.7 meters. The typical structural wall density is more than 20 %. 20-25%.

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	☐

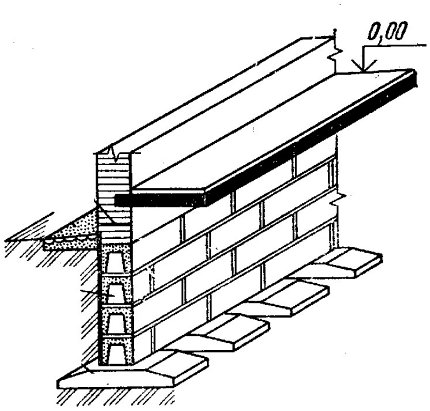

Figure 4: Critical Structural Details: Wall section and the foundations

Figure 5A: A Photograph Illustrating Typical Earthquake Damage (Spitak, Armenia earthquake 1988)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). 36 units in each building. Usually there are 12 - 36 units in each building. The number of inhabitants in a building during the day or business hours is 11-20. The number of inhabitants during the evening and night is more than 20.

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 common).

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	- Absence of lime and plastifier; - Low cohesion of masonry (<120 kPa); (cohesion is equal to tension strength of masonry when shear stress=0). - Low-strength masonry and cement mortar.		
Frame (columns, beams)			
Roof and floors	-Floor slabs cannot be considered as rigid diaphragms due to poor quality of joints and connections.		
Other			

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., poor 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 *C: MEDIUM VULNERABILITY (i.e., moderate 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
1959	Kamchatka, Russia	7.8	VIII (MSK)
1971	Kamchatka, Russia	7.2	VII (MSK)
1988	Spitak, Armenia	6.9	IX (MSK)

Some buildings of this type were damaged in the 1959 and 1971 Kamchatka earthquakes and 1988 Spitak earthquake.

Figure 5B: Typical Earthquake Damage

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Masonry Steel Concrete	50 kg/m² (compressive strength) 295 MPa (Steel yield strength) 20-30 MPa (cube compressive strength)		
Foundation	Concrete	10-15 MPa (cube compressive strength) 295 MPa (Steel yield strength)		
Frames (beams & columns)				
Roof and floor(s)	Slabs - reinforced concrete	30 MPa (cube compressive strength) 295 MPa (Steel yield strength)		

6.2 Builder

Buildings of this type were built by government-owned construction companies.

6.3 Construction Process, Problems and Phasing

All precast structure members and concrete blocks are manufactured in special construction plants. Masonry mortar is usually produced in the factory, too. Lifting crane is used for the erection of the building. 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. Design performed by Professional Engineers and Architects.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Building Catalog of Typical Project for housing seria of 1-306c, 1-307c, 1957y. The year the first code/standard addressing this type of construction issued was 1951. Construction in the Seismic Regions. SNiP II-7-81*. The most recent code/standard addressing this construction type issued was 1981. Afterward numerous amendments were introduced. Title of the code or standard: Building Catalog of Typical Project for housing seria of 1-306c, 1-307c, 1957y. Year the first code/standard addressing this type of construction issued: 1951 National building code, material codes and seismic codes/standards: Construction in the Seismic Regions. SNiP II-7-81* When was the most recent code/standard addressing this construction type issued? 1981. Afterward numerous amendments were introduced.

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

250-350 \$US/m² (per the official rate). It takes about 30 man-months to build a 4-story building with plan dimensions 12m X 42m.

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 typically covers about 3-5% of the 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**
Inadequate seismic resistance of masonry walls	The method of exterior frame - see Additional Comments
Inadequate seismic resistance of masonry walls	Vertical post-tensioning; see Additional Comments and Figures 6A, 6B, and 6C
Inadequate seismic resistance of masonry walls	The method of added stiffness (reinforced concrete overlay); see Additional Comments and Figures 6D and 6E
Inadequate seismic resistance of masonry walls	Strengthening using the "Upper Damping Story" method

The recommended methods for seismic strengthening of buildings of this construction type are: METHOD OF EXTERIOR FRAME (MEF) - Goal: To increase lateral seismic stability of buildings with load-bearing masonry or large-block concrete walls. - Concept: The system of precast or "cast-in-situ" concrete buttresses (counterforts) (1) tied to the longitudinal exterior wall. - Application: This method has been used successfully for seismic strengthening of buildings with longitudinal bearing walls and deficient lateral earthquake resistance both as self-contained strengthening system and as a combination with PTS (for stringer walls) or with SIS (for extended masonry buildings with widely spaced lateral inner walls) - Description: The MEF is performed by constructing special concrete buttresses (counterforts) tied to the longitudinal load-bearing walls at the building ends and other locations as required. In order to ensure a uniform seismic performance of the existing structure strengthened with the buttresses, the buttresses are tied to the existing walls by means of the dowels and anchors. This solution does not require the pairs of buttresses (counterforts) to be tied at each floor level; it is considered to be adequate to install a prestressed tie to connect the buttresses (counterforts) at the roof level. STRENGTHENING OF BUILDINGS USING THE POST - TENSIONING SYSTEM (PTS) - Goal: To increase seismic resistance of existing buildings. - Concept: The reduction in principal tensile stresses induced by seismic loads to allowable levels. - Description and sequence of operations: * Drilling of the vertical holes is carried out by means of special equipment; the amount of opening (10) is not less than one for each partition. * The wire cables (2) are pulled through each opening (10) * Cables are anchored at the basement level and then post-tensioned up to 1600 KN. * A special cement-based grout (1) is injected into the holes and the cables are subsequently anchored at the roof level. The post-tensioning of walls prevents the formation of cracks in an earthquake and results in the increased seismic resistance of the individual walls and the building as a whole. - Equipment: For drilling: "GEARMEC" (Sweden); for post-tensioning: IMS system (Yugoslavia). THE METHOD OF ADDED STIFFNESS (SIS) - Goal: Seismic strengthening of masonry buildings to achieve increased seismic reliability and safety. - Concept: The stiffness increase is achieved by means of a new reinforced concrete wall (overlay) attached to the existing wall. In this way, the coupled perforated shear walls are formed, and lateral seismic loads are redistributed: the seismic loads remove on the spine walls from principal one. - Description: The SIS method consists of constructing new cast-in-situ concrete walls (1) of 10-15 cm thickness reinforced with steel wire mesh. The new walls are attached to the existing ones using dowels (3) and anchors (4). The new walls may be constructed with additional pilasters (2) if required. - Equipment: Sheathing "MEVA" (Germany), instruments: "Bosch" and "Hilti" (Germany). THE METHOD OF UPPER DAMPING STOREY (UDS) - Goal: To develop a big mass damper for the self-damping of buildings under seismic impact. - Concept: To achieve a flexible structure with stiffness and mass capable of reducing the seismic demand in an existing building to a permissible level. - Application: Masonry or block buildings with deficient seismic resistance D=2.0 (MSK scale). A very effective application for 4- to 5-story residential masonry and large-block houses with D=1.0-1.5. The superstructure can be constructed as a "cold" garret or as additional floor (duplex apartment).

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. A number of buildings of this type have been strengthened using the above described methodology.

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

In most cases repair was executed after earthquake damage.

8.3 Construction and Performance of Seismic Strengthening

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

Yes.

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

Strengthening of buildings is accomplished by contractor. All processes are controlled by engineers.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

N/A.

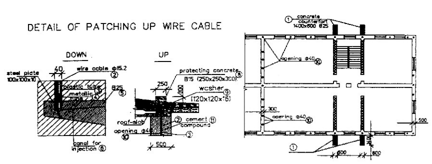

Figure 6A: Illustration of Seismic Strengthening Techniques


Figure 6B: Seismic Strengthening: Application of Post-Tensioning System

Figure 6C: A building Strengthened using Post-Tensioning System

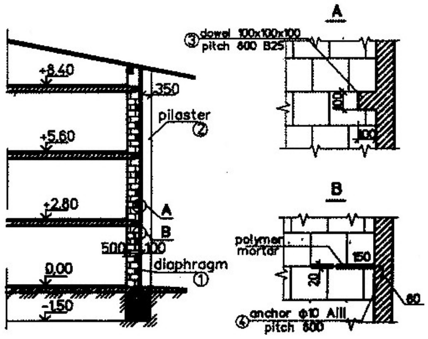

Figure 6D: Seismic Strenthening - The Method of Added Stiffness


Figure 6E: A Building Stengthening Using the Method of Added Stiffness

Reference(s)

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

2. Recommendations for Preventive Seismic Strengthening of Buildings
   CENDR, Russia 1993

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