World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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
Last Updated	
Country	Russia
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Important

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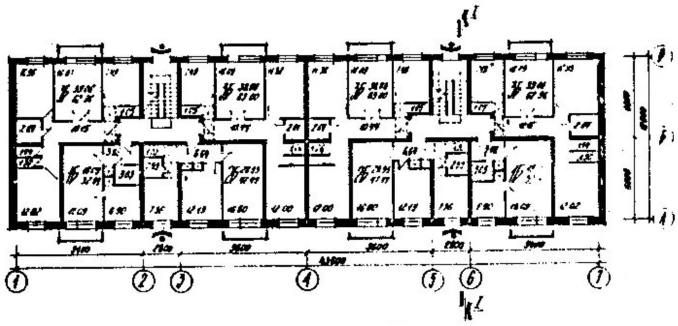
General Information

Building Type:	Small concrete block masonry walls with concrete floors and roofs
Country:	Russia
Author(s):	Mark Klyachko Yuriy Gordeev Freda Kolosova
Last Updated:	
Regions Where Found:	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.
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, BaikalLake 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.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 20-49 units
Typical number of stories:	2-4
Terrain-Flat:	Typically
Terrain-Sloped:	Occasionally
Comments:	This is the Soviet Union construction practice followed during the last 50-60 years (after the Second World War). Building Occu

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	In general all building plans are of rectangular shape.
Typical plan length (meters)	43
Typical plan width (meters)	12
Typical story height (meters)	2.7
Type of Structural System	Masonry: Unreinforced Masonry Walls: Concrete block masonry in cement mortar
Additional comments on structural system	Lateral Load-Resisting System: 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. Gravity Load-Bearing Structure: Same as lateral load-resisting system.
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	The typical structural wall density is more than 20 %. 20-25%.
Wall Openings	Windows: 10-15%; Doors: 5-8%.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Typical modification patterns include the demolition of interior walls and perforation of walls with door openings.

Type of Foundation	Shallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	
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	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.



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	**Building Material (s)**	**Comment (s)**
Wall/Frame	Masonry Steel Concrete	Characteristic Strength Masonry: 50 kg/m.sq. (compressive strength) Steel: 295 MPa (Steel yield strength) Concrete: 20-30 MPa (cube compressive strength)
Foundations	Concrete	Characteristic Strength: 10-15 MPa (cube compressive strength) 295

		MPa (Steel yield strength)
Floors	Slabs # reinforced concrete	Characteristic Strength: 30 MPa (cube compressive strength) 295 MPa (Steel yield strength)
Roof	Slabs # reinforced concrete	Characteristic Strength: 30 MPa (cube compressive strength) 295 MPa (Steel yield strength)
Other		

Design Process

Who is involved with the design process?	EngineerArchitect
Roles of those involved in the design process	Design performed by Professional Engineers and Architects.
Expertise of those involved in the design process	Expertise for design of buildings of this type was available, including the construction quality procedure developed by the author of this contribution.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	Buildings of this type were built by government-owned construction companies.
Expertise of those involved in building process	
Construction process 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.
Construction issues	

Building Codes and Standards

Is this construction type address by	Yes

codes/standards?	
Applicable codes or standards	Code/Standard: Building Catalog of Typical Project for housing seria of 1-306c, 1-307c, 1957y, issued1951 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.
Process for building code enforcement	The process consists of issuing permits for the design & construction, including the architectural permits and urban planning/municipal permits. Designers need to have licence to practice and are responsible to follow the building codes. Building inspection is performed and the permit is issued.

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	

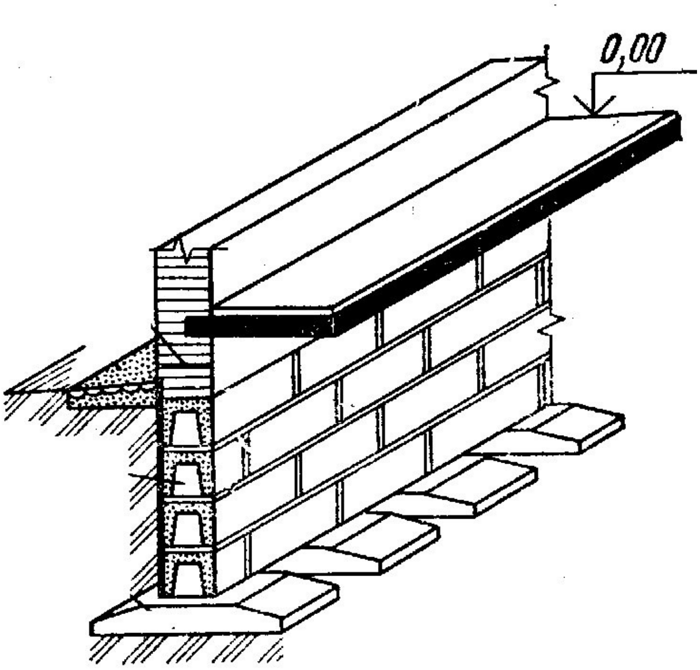
Building Maintenance and Condition

Typical problems associated with this type of construction	Use of rigid mortars in the construction and a low cohesion in the masonry.
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	The maintenance is performed either by the owner (city) or (periodically) by a contractor # a maintenance firm.

Construction Economics

Unit construction cost	250-350 $US/sq m (per the official rate).

Labor requirements	It takes about 30 man-months to build a 4-story building with plan dimensions 12m x 42m.
Additional comments section 3	



Critical Structural Details: Wall section and the foundations

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

Socio-Economic Issues

Patterns of occupancy	One family per unit (apartment). Each building typically has 36 housing unit(s). Usually there are 12 - 36 units in each building.
Number of inhabitants in a typical building of this construction type during the day	10-20
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	Very low-income class (very poor)Low-income class

inhabitants	(poor)Middle-income class
Additional comments on economic level of inhabitants	Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Government-owned housing
Additional comments on financing	
Type of Ownership	Own outrightLong-term lease
Additional comments on ownership	Own outright (for unit); Long-term lease (most common)
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	The insurance is available as a part of the usual property insurance. Insurance typically covers about 3-5% of the total estimated property value.
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	It is not common that owners purchase earthquake insurance.

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1959	Kamchatka, Russia
1971	Kamchatka, Russia
1988	Spitak, Armenia

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Some buildings of this type were damaged in the 1959 and 1971 Kamchatka earthquakes and 1988 Spitak earthquake.
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 any horizontal direction that serves to transfer inertial forces from the building to the foundation.	FALSE
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	TRUE

	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.	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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	TRUE
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		TRUE
Quality of Building Materials	Quality of building materials is considered	FALSE

	to be adequate per the requirements of national codes and standards (an estimate).	
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	-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.
Earthquake-resilient features in walls	
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	#NAME?
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	-|			

Typical Earthquake Damage

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	**Seismic Strengthening**
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 9 and 10.

Inadequate seismic resistance of masonry walls	The method of added stiffness (reinforced concrete overlay); see Additional Comments and Figures 11 and 12.
Inadequate seismic resistance of masonry walls	Strengthening using the "Upper Damping Storey" method

Additional comments on seismic strengthening provisions	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 indivdual 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).
Has seismic strengthening described in the above table been performed?	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 a repair following earthquake damages?	In most cases repair was executed after earthquake damage.
Was the construction inspected in the same manner as new construction?	Yes
Who performed the construction: 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 has been the performance of retrofitted buildings of this type in subsequent earthquakes?	N/A
Additional comments section 6	

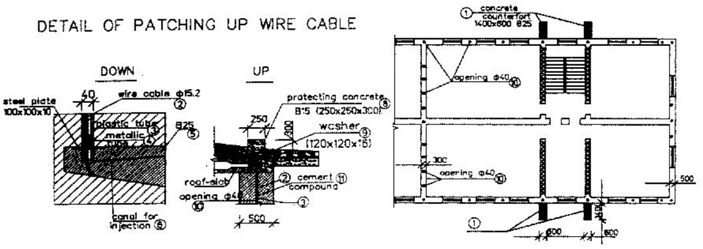
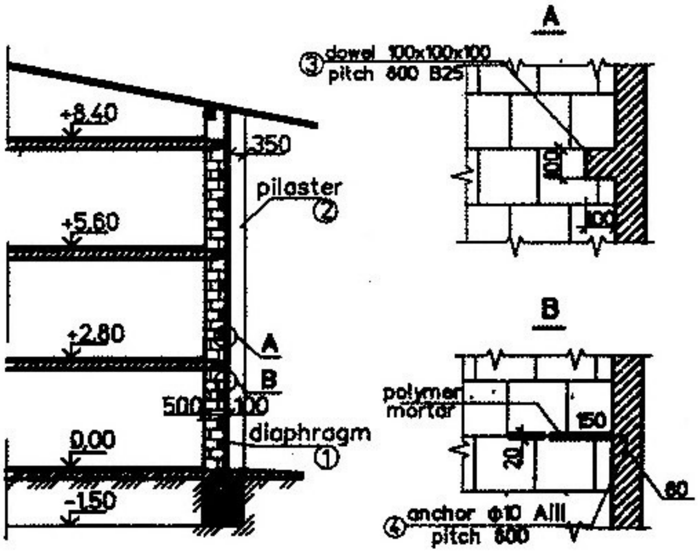


Illustration of Seismic Strengthening Techniques

Seismic Strengthening: Application of Post-Tensioning System

Seismic Strengthening: Application of Post-Tensioning System



Seismic Strengthening - The Method of Added Stiffness

A Building Strengthening Using the Method of Added Stiffness

References

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