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

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HOUSING REPORT
Unreinforced Brick Masonry Apartment Building

Report #	73
Report Date	05-06-2002
Country	SLOVENIA
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in lime/cement mortar
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Summary

This construction was commonly used for residential buildings in all Slovenian towns, and it constitutes up to 30% of the entire housing stock in Slovenia. The majority of these buildings were built between 1920 and 1965. They are generally medium-rise, usually 4 to 6 stories high. The walls are unreinforced brick masonry construction laid in lime/cement mortar. In some cases, the wall density in the longitudinal direction is significantly smaller than in the

transverse direction. In pre-1950 construction, there are mainly wooden floor structures without RC tie-beams. In post-1950s construction, there are concrete floors with RC bond-beams provided in the structural walls. Roof structures are either made of wood (pitched roofs) or reinforced concrete (flat roofs). Since this construction was widely practiced prior to the development of the seismic code (the first such code was issued in 1964), many buildings of this type exceed the allowable number of stories permitted by the current seismic code (maximum 2 or 3 stories for unreinforced masonry construction). Buildings of this type have been exposed to earthquake effects in Slovenia. However, this construction type experienced the most significant damage in the 1963 Skopje, Macedonia, earthquake, which severely damaged or caused the collapse of many buildings.

1. General Information

Buildings of this construction type can be found in all Slovenian towns, and it constitutes up to 30 % of the entire housing stock in Slovenia. This construction type was also practiced in other countries in the region, in particular Montenegro and Macedonia, which were part of the former Yugoslavia. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 100 years.

Currently, this type of construction is not being built. This housing construction was practiced in the period between 1920 and 1965.

Figure 1A: Typical Building

Figure 1B: Typical Building

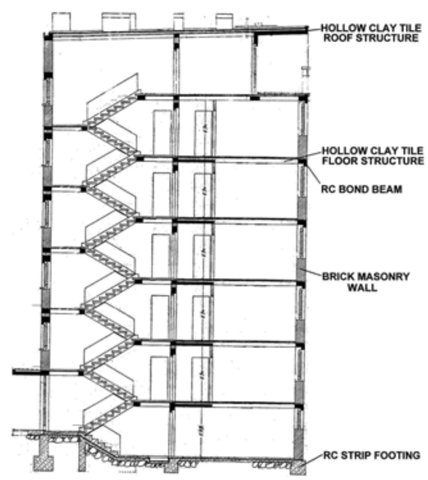


Figure 2: Vertical Elevation Showing Key Load-Bearing Elements

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

Typical shape of building plan is rectangular with length/width ratio ranging from 2.0 to 8.0. In the longitudinal direction, the building is usually divided into 2 to 5 segments. Each segment has its own entrance, staircase and elevator. The buildings of this type are characterized by two longitudinal exterior walls with the majority of openings located in these walls, and two exterior walls in the transverse direction with a few smaller window openings or no openings at all. The average area of a window opening is 1.8 m^2 in longitudinal exterior bearing walls. The exterior walls in the transverse direction are characterized with smaller kitchen or toilet window openings of typical area less than 0.5 m². The area of balcony door and window openings is approx. 4.0 m². The door area in the exterior and interior load bearing walls is approximately 2.0 m². The total area of openings is approximately equal to 30 % of the longitudinal exterior wall surface area.

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 are no additional exit doors besides the main entrance. There is also no additional exit staircase besides the main staircase. The main entry and the main staircase of each segment of the building represent the only means of escape from the building.

2.4 Modification to Building

A few modifications have been carried out in these buildings. Since the majority of interior walls have been constructed as load bearing walls, no significant changes are observed. In some cases, an additional floor has been built atop the flat roof; the additional floor typically has a pitched roof.

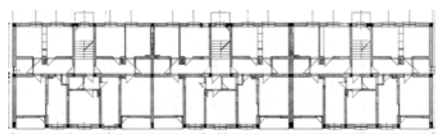


Figure 3: Plan of a Typical Building

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	☐
	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)	☐

The mortar is made of lime or composite lime and cement mix.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is un-reinforced masonry walls. The gravity-load bearing structure consists of roof and floor structures and structural walls. In the case of an additional top floor built atop the original flat RC roof structure, there is a new timber pitched roof.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. The lateral load-resisting system consists of exterior and interior brick masonry walls. Wall thickness varies from 380 mm (exterior and some interior walls) to 250 mm (the majority of interior walls). The mortar mix varies through the building height: pure cement mortar is used at the lowest two floors, composite lime/cement mortar is used for the middle portion and pure lime mortar for the upper floors. Due to large openings and longitudinal exterior walls, the lateral resistance in longitudinal direction is often significantly inferior as compared to the lateral resistance in the transverse direction. The lateral load transfer to load-bearing walls is accomplished through roof and floor structures. In the case of older buildings of pre-1950 construction characterized with wooden floor structures, the walls were not joined together by means of wooden or iron ties. In the case of newer buildings, all structural walls are tied together with RC edge beams of RC floors. The walls are supported by concrete strip foundations. The weakest link in this construction are usually wall-floor and wall-roof connections in case of timber floor construction.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 25 and 90 meters, and widths between 10 and 13 meters. The building has 4 to 6 storey(s). The typical span of the roofing/flooring system is 5 meters. Typical Story Height:Story height ranges from 2.7 to 3 m. Typical Span: It is the typical distance between two adjacent walls and it ranges from 2.2 to 9 m. The bearing direction of floor structures, that carry load in one direction only, is usually the direction of the shorter distance between two adjacent longitudinal or transversal walls. Typical span of floor structures ranges from 2.2 to 6 m. The typical storey height in such buildings is 2.85 meters. The typical structural wall density is up to 10 %. 2.2-6% in longitudinal direction (typical distance between two adjacent walls ranges from 5.4-11.6 m), and 5.5-6.6% in transverse direction (typical distance between two adjacent walls ranges from 2.2-8.7 m).

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	☑	☑

The floor and roof structures are made of timber in pre-1950 construction.

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	☐

Foundations are often made of unreinforced concrete.

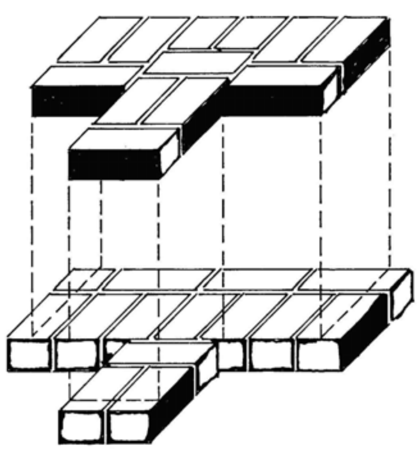


Figure 4A: Critical Details-Bonding arrangements of masonry units

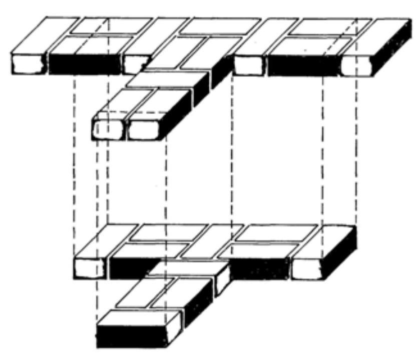


Figure 4B: Critical Details -Bonding arrangement of masonry units

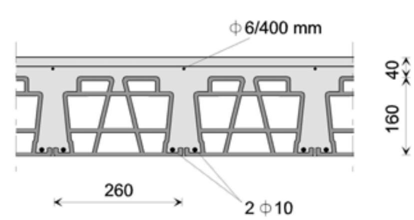
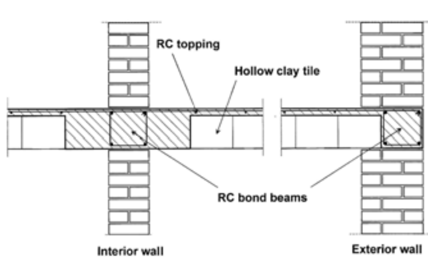


Figure 4C: Critical Details - Hollow-Clay Tile Floor Structure



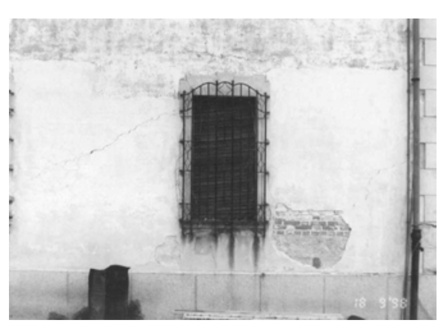


Figure 4D: Critical Details - Wall to Hollow-Clay Tile Floor Connection

Figure 5: Seismic Deficiencies - Typical diagonal cracks developed in wall piers

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). 12 - 60 units in each building. Number of housing units depends on the size of the building; it varies from 12-60 units in each building. There are typically 4 - 10 housing units per floor. 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

One family occupies one housing unit.

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)	☐

The prices are expressed in US$. Smaller apartments (50 m²) may cost US$ 30.000, and the annual income for a person may be US$ 5.000. Larger apartments (70 m²) may cost US$ 45.000, and the annual income for a person may be US$ 8.000. Economic Level: For Poor Class the Housing Unit price is 30000 and the Annual Income is 5000. For Middle Class the Housing Unit price is 45000 and the Annual Income is 8000.

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)	☑

Government-owned housing foundation. In each housing unit, there are no bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) induding toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting and individual 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)	☐

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.	☑	☐	☐
	Exterior walls are anchored for out-of-plane seismic			

Wall-roof connections	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	Roof and floor construction: If floor and roof structures are made of timber, they are not considered to be rigid, unless they are stiffened by means of additional diagonal ties. Wall openings: The width of window and door openings in external longitudinal walls are sometimes more than 1/2 of the distance between adjacent cross walls. Sometimes large balcony door and window are placed not in an opening in external longitudinal wall, but just between two adjacent cross walls.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Masonry shear strength is not adequate to sustain larger seismic effects. The normal stresses due to gravity loads are often high and brittle wall failure can be expected.	The mortar mix is variable through the building height: pure cement mortar used at the lowest two floor levels, composite lime/cement mortar used in the middle portion, and pure lime mortar for the upper floors.	Damage ranges from diagonal (X) cracks to severe damage of structural walls.
Roof and floors	If the roof and floor structures are one-way systems (i.e. carry load in one direction only), the walls in longitudinal and transverse directions are not equally loaded.		Horizontal cracks along the wall-to-floor joints in the walls that do not carry gravity load.
Building layout	In some cases, wall density in the longitudinal direction is significantly smaller as compared to the transverse direction; as a result, lateral load resistance in the longitudinal direction is often not adequate.		Many buildings of similar construction were severely damaged or collapsed in the 1963 Skopje, Macedonia earthquake due to the predominant ground motion occurring in the weak direction of the building.
Other			

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
1963	Skopje, Macedonia***	6	IX (MSK)
1976	Friuli, Italy*	6.5	IX-X (EMS)
1979	Montenegro, Yugoslavia***	7.2	IX (MCS)
1998	Bovec, Slovenia**	5.5	VII-VIII (EMS)

* The epicenters of the main shock on May 6, 1976 (M= 6.5, focal depth 20-30 km) and the strongest aftershock on September 15, 1976 (M=5.9) were in Friuli, Italy, 20.5 km from the border between Italy and Slovenia. In Italy, 965 people died and an enormous damage was caused. In Slovenia, the maximum intensity was VIII EMS. Out of 6,175 damaged buildings, 1,709 had to be demolished and 4,467 were retrofitted. ** The strongest earthquake with the epicenter in Slovenia in the 20th century occurred on April 12, 1998. The epicenter was approx. 6.3 km South-East from the town of Bovec, and the focal depth was between 15 and 18 km. No building collapses were reported; however, out of 952 inspected buildings, 337 were found to be unsafe, out of which 123 buildings were beyond repair. The majority of damaged buildings were rubble-stone masonry houses. Brick masonry buildings of this construction type remained undamaged or just a few cracks (mostly diagonal shear) were developed (Plain masonry building in Bovec: Fig.5). *** This construction was also practiced in Montenegro and Macedonia, which used to be, like Slovenia, part of the former Yugoslavia. Many buildings of this type were seriously damaged in the 1979 Montenegro earthquake (typical shear cracks in wall piers of a building in Budva, see Fig.6A), and the 1963 Skopje earthquake (severely damaged building with inadequate wall density in predominant earthquake direction: Fig.6B). Over 1,500 people died in the 1963 Skopje earthquake.

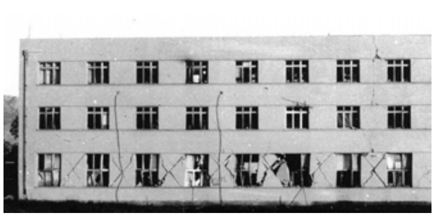


Figure 6A: A Photograph Illustrating Typical Earthquake Damage-Diagonal "X"-type shear cracks in wall piers

Figure 6B: Typical Earthquake Damage-Severly Damaged Building with Inadequate Wall Density in Predominant Earthquake Direction (1963 Skopje earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Solid clay bricks units are used with cement mortar in the masonry.	Compressive strength 10 - 15 MPa Compressive strength 0.5 - 5 MPa Compressive strength 2.0 - 4.0 MPa Tensile strength 0.12 - 0.25 MPa	Solid brick size is l/w/h=250/120/65 mm. The mortars used are (a) 1: 3 (lime:sand), (b) 1 : 3 : 9 (cement:lime:sand), and (c) 1 : 4 (cement:sand).	
Foundation	Plain concrete	C10 - C15 (cube compressive strength 10-15 MPa)		

Frames (beams & columns)				
Roof and floor(s)	Hollow clay tile masonry blocks Concrete Steel reinforcement	C25 grade concrete is used with cube compressive strength of 25 MPa. The steel used has properties fy and fu of 240 MPa and 360 MPa, respectively.		

6.2 Builder

The buildings of this type were built by builders. Sometimes they also live in buildings of this type.

6.3 Construction Process, Problems and Phasing

The construction was usually carried out by a government-owned construction company. After the stabilization of the ground floor, the foundations and the basement walls are constructed of cast-in-situ concrete. The brick walls are built manually atop the floor structure. Hollow clay tile floor is usually constructed spanning in the transverse direction of the building. Hollow clay tiles are first placed on the shuttering. Subsequently, the longitudinal steel bars in the ribs, transverse steel bars for the RC topping, and the bond beam reinforcement are placed. Finally, the concrete topping is poured atop the masonry. Concrete and mortar is prepared using machine 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. The buildings were originally designed for a certain height. If the owners decide to build an additional floor atop the existing building, the load-bearing capacity of the upper floor structure needs to be verified. Building permits are required for any structural expansion and renovation.

6.4 Design and Construction Expertise

Architects and engineers designed buildings of this type. It used to be a very common type of residential construction. As a result, design and construction expertise was good. The construction foreman was usually a technician; however the supervision was carried out by an engineer. Architects are in charge of the architectural design, and structural engineers are in charge of the structural design, construction process and supervision.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. National Seismic Code for Buildings (1981). The year the first code/standard addressing this type of construction issued was 1964. The first code including design vertical load, wind and seismic load was the Preliminary National Building Code (1948). After the catastrophic earthquake in Skopje (in former Yugoslavia) in 1963, the first Seismic Code addressing this type of construction was issued (1964). In addition to the National Seismic Code for Buildings, Eurocode 8 is being used at the present time. The most recent code/standard addressing this construction type issued was 1981. Title of the code or standard: National Seismic Code for Buildings (1981) Year the first code/standard addressing this type of construction issued: 1964 National building code, material codes and seismic codes/standards: The first code including design vertical load, wind and seismic load was the Preliminary National Building Code (1948). After the catastrophic earthquake in Skopje (in former Yugoslavia) in 1963, the first Seismic Code addressing this type of construction was issued (1964). In addition to the National Seismic Code for Buildings, Eurocode 8 is being used at the present time. When was the most recent code/standard addressing this construction type issued? 1981.

Since the buildings were built as public residential buildings, the building codes have been enforced. The design, construction and supervision were carried out with consideration of the National Building Code. The design of a building was approved by the state authorities. After the construction, building had to pass technical verification in order to get the use and occupancy permit.

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 owners need to retain a house management company to coordinate and organize the building maintenance.

6.8 Construction Economics

Total value per m² of an apartment area estimated in 1966 was 80 $US/m². The current market value of apartments in these buildings is much higher (500 - 1000 $US/m²), depending on the building location. The design of a building took about 3 - 4 months. Typically, several buildings of the same type were built at the same site, and the construction took 1 - 2 years for a team of about 50 skilled workers.

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. Refer to Section 9.2. The whole area of Slovenia has been divided into the two "seismic insurance zones". The residential buildings are divided into two categories depending on the age of construction: older buildings, built before or in 1965, and the newer buildings, built in 1966 or later. For the higher seismic zone, the annual insurance rate is 0.105 % of the building value for older buildings and 0.07 % for the newer buildings. For the lower seismic zone, the annual insurance rate is 0.07 % and 0.045 % of the building value for older and newer buildings respectively.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Cracks caused by the differential foundation settlement	Repair of cracks: Cracks are injected with cement grout which contains anti-shrinkage admixtures. After cleaning the wall surface, the grout is injected into the cracks through injection tubes and nozzles, which are drilled into the wall along the crack at 300 to 600 mm spacing. The grout is injected under low pressure. Epoxy grout is recommended instead of the cement grout in the case of fine cracks.
Poor mortar quality	Repointing (Fig.7A): In the case of poor mortar quality and good quality brick masonry units, the existing mortar can be partially replaced with a cement or lime/cement mortar of significantly better quality. The existing mortar is removed from the joints up to 1/3rd of the wall thickness on each wall surface. After cleaning the surface and the joints, the joints are repointed using cement or lime/cement mortar. In addition, steel reinforcement can be placed in the bed joints to improve the wall ductility characteristics.
Inadequate lateral load resistance of the walls	Reinforced-cement coating (Fig. 7B): After removing the old plaster and cleaning the wall surface, new reinforced coating (two-layer cement coating with steel mesh) is placed on both wall surfaces. The reinforcing meshes at both wall surfaces are joined together by means of steel anchors.

Some of the above described provisions are included in the National Seismic Code related to the post-earthquake repair and strengthening.

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?
Not on a large scale. Buildings of this type have not been exposed to a major damaging earthquake in Slovenia, which might cause severe cracking and damage to the walls, no repair interventions have been carried out so far. However, some buildings of this type have been strengthened using the above described provisions.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
Some of undamaged buildings have been strengthened as part of the renovation work.

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?
An architect and an engineer were involved in the retrofit design. The construction is carried out by a contractor.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
Information is not available. The effectiveness of the above described provisions has been verified only by laboratory tests so far.

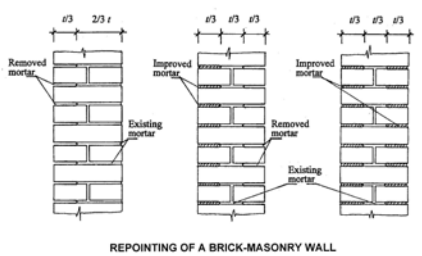


Figure 7A: Illustration of Seismic Strengthening Techniques-Repointing

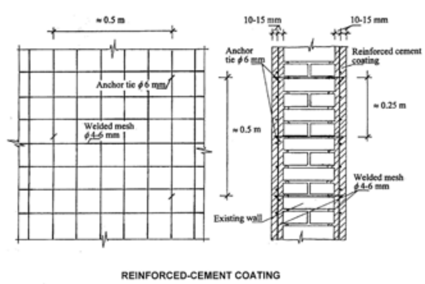


Figure 7B: Seismic Strengthening Techniques-Reinforced cement coating

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