World Housing Encyclopedia

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

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HOUSING REPORT
Confined brick masonry house

Report #	88
Report Date	12-12-2002
Country	SLOVENIA
Housing Type	Confined Masonry Building
Housing Sub-Type	Confined Masonry Building : Clay brick masonry, with concrete tie-columns and beams
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Summary

This is a very common single-family residential construction practice found throughout Slovenia, both in urban and rural areas. It is estimated that this construction accounts for approximately 40% of the entire housing stock in the country. Confined masonry has been practiced since the wide use of perforated clay blocks has started in the 1970s. The walls are

constructed using perforated clay blocks in lime/cement or cement mortar. The main confining elements include horizontal reinforced concrete bond beams constructed atop the structural walls at each floor level, and vertical reinforced concrete tie-columns at the wall intersections. Floors are either of composite construction, consisting of concrete joists and hollow masonry tiles, or cast in-situ reinforced concrete slabs. Timber roofs are typically used in this type of construction. Since the first national seismic code was issued in 1964, the use of vertical reinforced concrete tie-columns is typically prescribed by the structural design. However, many existing houses were constructed without these critical structural elements. An additional deficiency characteristic for this construction practice is the absence of the top bond-beams along the gable walls (crown beams). This construction is expected to show good seismic performance. Buildings of this type were generally not affected by the past earthquakes in Slovenia.

1. General Information

Buildings of this construction type can be found in most parts of Slovenia and it is estimated that it accounts for 40 % of the entire housing stock in Slovenia. 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. .


Figure 1: Typical House


Figure 2A: Key Load-Bearing Elements

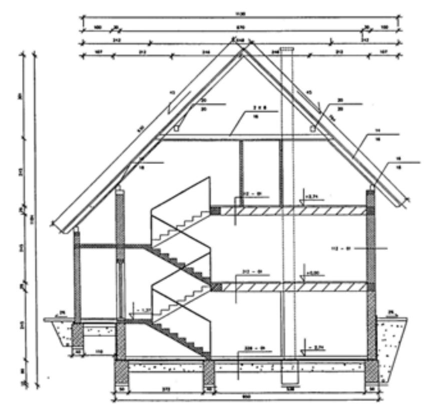
Figure 2B: Typical Elevation Showing Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

Typical shape of a house plan is rectangular. The average area of a window opening in the front exterior wall is 1.4 m.sq. The door opening area in exterior and interior bearing walls is on the order of 1.8 m.sq. The overall opening area in the exterior walls, expressed as a fraction of the overall wall surface area, is approximately equal to 25% on the sunny side of the house and 10% on the shaded side of the house.

2.3 Functional Planning

Single and Multiple Housing Units. By and large, houses of this construction type have maximum two housing units. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Houses for one or two families usually have a rear door leading to the backyard, however there is no additional stair besides the main staircase.

2.4 Modification to Building

Since this construction type has been used for the last 30 years, no significant structural modifications have been observed. In some cases, the extensions to the original houses have been made, often without the adequate structural connections between the original and the extended part.

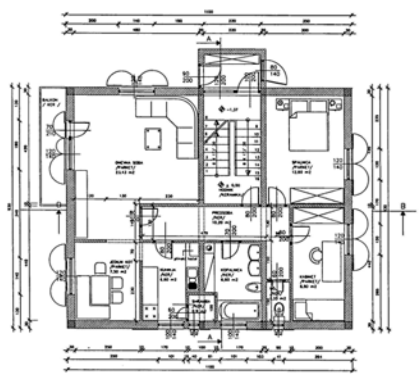

Figure 3: Plan of a Typical House

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)	☐

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. Typically, this construction is characterized with pitched roofs made out of wood. In case of the older, pre-1975 houses, the floor structures are one-way bearing r.c. floor structures, made of hollow clay tile blocks and reinforced concrete joists. In the case of newer houses, the floor structures are simple cast in-situ r.c. slabs. In both cases, the floor structures are cast in-situ, together with r.c. bond-beams atop all structural walls.

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 block masonry walls, uniformly distributed both in the transverse and longitudinal direction. The wall thickness varies from 190 mm (interior walls) to 290 mm (exterior and some interior walls). The walls are constructed using perforated clay blocks in lime/cement or cement mortar. According to Tomazevic (1999), a perforated block has vertical perforations accounting for 25-50% of the total block volume. In order to improve structural integrity, masonry walls are confined with vertical and horizontal confining elements. Horizontal bond beams are the main horizontal confining elements. These beams, mainly of reinforced concrete construction, have been cast atop all structural walls at the floor level together with floor structures. The reinforcement of horizontal bond beams consists of minimum 4 steel bars of 12 mm diameter. In addition to this, the walls are confined vertically with tie columns located at all wall corners and intersections. The tie columns are constructed either as reinforced concrete columns, cast in-situ using regular shuttering after the masonry has been constructed , or by using special blocks with vertical holes, in which the vertical reinforcement is placed and filled with infill or grout. The tie columns are reinforced with minimum 4 steel bars of 14 mm diameter. These columns should be also constructed at all free ends of the walls and around larger openings, however these elements are often omitted. The walls are typically supported by reinforced concrete strip foundations.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 14 meters, and widths between 8 and 12 meters. The building has 1 to 2 storey(s). The typical span of the roofing/flooring system is 5 meters. Typical Number of Stories: Due to the pitched roof construction, buildings of these type have an attic which could be used as a residential area as well. Typical Story Height: Story height ranges from 2.60 m to 2.90 m. Typical Span: It is a typical distance between the two adjacent walls ranging from 2 to 10 m. Typical span of floor structures ranges from 2 to 5 m. The typical storey height in such buildings is 2.75 meters. The typical structural wall density is none. 5% - 8% The wall density at the first floor level ranges from 5 to 8 % in each direction.

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)	☐	☐
	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	☐	☐

Timber	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 choice of the roof covering material depends on the roof slope and the architectural design style typical for a particular area. Typically, the roof is covered with concrete or clay tiles, or metal, asbestos-cement or plastic corrugated sheets.

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 4A: Critical Structural Details - Masonry Wall Construction

Figure 4B: Critical Structural Details - Reinforced Concrete Tie Columns at the First Floor Level

Figure 4C: Critical Structural Details- Reinforced Concrete Tie Columns at the Second Floor Level (note that the columns have been constructed using special blocks with vertical holes)

Figure 4D: Critical Structural Details - Rebars Extended from the Walls for Fixing the Roof Purlins to the Bond Beam (roof level)

Figure 4E: Critical Structural Details - A Typical Timber Roof and the Bond Beam (crown beam)

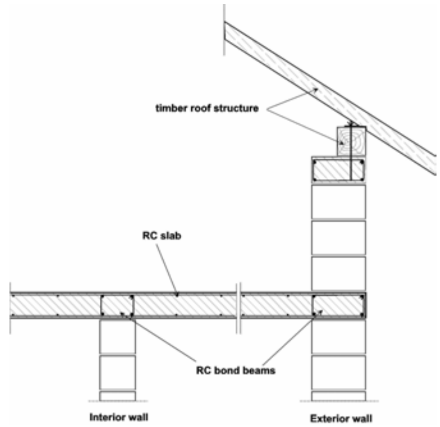

Figure 4F: Critical Structural Details - Wall-Floor and Wall-Roof Connections

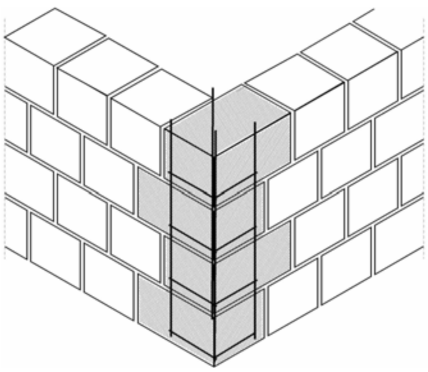

Figure 4G: Critical Structural Details: Masonry Confined with Corner RC column

Figure 5A: Key Structural Deficiencies - Masonry Units Absorb the Moisture from the Mortar

Figure 5B: Key Structural Deficiencies - Head Joints Partially Filled on Both Faces of the Wall

Figure 5C: Key Structural Deficiencies - Missing Bond Beams at the Roof Level and Some Vertical Tie-Columns

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 2 housing unit(s). 1-2 units in each building. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5. also 5-10 possible.

4.2 Patterns of Occupancy

This type of house is typically occupied by a single family or sometimes by two families (two generations of the same family).

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$. It has been assumed that middle-class families live in smaller houses (plan area of approx. 100 m.sq.). Rich people live in larger houses (plan area of approx. 200 m.sq.). Economic Level: For Middle Class the Housing Price Unit is 100000 and the Annual Income is 8000. For Rich Class the Housing Price Unit is 200000 and the Annual Income is 17000.

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), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

One or sometimes two bathrooms and one latrine per housing unit. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership and ownership with debt (mortgage or other).

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.	☑	☐	☐
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	Generally, it can be found that the width of door and window openings in one out of 10-15 walls exceeds ½ of the wall length (i.e. the distance between the two adjacent cross walls).			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	This structural type, usually used for 2-story houses, does not have major structural deficiencies, however some common construction faults that could influence the seismic performance are as follows: i) masonry units should be soaked in water before the construction in order to prevent burning of the mortar; in some cases, this rule is not respected and consequently the units absorb the moisture from mortar; ii) head joints (vertical joints) should be completely filled with mortar in order to provide adequate seismic resistance of masonry; in construction practice, head joints are sometimes filled only partially on both wall faces.		In the case of an earthquake with high intensity, shear ("X") cracks might develop in the walls.
Frame (columns, beams)			
Roof and floors	In case of one-way roof and floor structures (i.e. carry load in one direction only), the walls in the longitudinal and transverse direction are not equally loaded.	If floor structures are r.c. floor slabs equally reinforced in two directions, a good distribution of gravity load onto the bearing walls is achieved; consequently, similar seismic resistance is developed in both orthogonal directions.	In the case of one-way systems horizontal cracks might develop along the wall-floor joints in the walls that do not carry gravity load.
Building and structural layout	The distance between the adjacent structural walls is sometimes too large. Vertical tie-columns that should be placed at all vertical wall intersections and at both sides of larger openings are often missing. In addition to the above, gable walls are typically not confined by means of top bond beams (crown beams).	The building layout is usually regular, wall densities for both orthogonal directions are very similar, and bearing walls are distributed uniformly in case r.c. floor slabs are used.	

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), the lower bound (i.e., the worst possible) is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), and the upper bound (i.e., the best possible) is E: LOW VULNERABILITY (i.e., very 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
1976	Friuli, Italy*	6.5	IX-X (EMS)
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 located 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 were beyond repair). The effectiveness of strengthening methods applied after the 1976 earthquake was studied. The majority of damaged buildings were of rubble-stone masonry construction. Buildings of confined masonry construction either remained undamaged or experienced a minor damage (a few cracks developed). Most of the observed damage was due to the mistakes made by the building owners, who have built their houses by themselves. In some cases, masonry units and/or mortar of poor quality were used in the construction. Also, the spacing between the cross walls was too large in some cases; the floor slabs were found to be too slender in some cases. Often, the houses were built without vertical tie-columns at the wall corners and intersections, and without the bond beams along the gable walls (crown beams), see Fig.6.

Figure 6: Typical Earthquake Damage: A House without Vertical Tie-Columns and without Top Bond-Beams in Attics (1988 Bovec earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Perforated clay blocks, Mortar, Masonry	Compressive strength: 10-15 MPa (perforated clay blocks), 2.5-5.0 MPa (mortar), 3.0-6.0 MPa (masonry); Tensile strength: 0.18-0.30 MPa (masonry)	Block dimensions: b/w/h=290/190/190 mm, Mortar-Cement:lime:sand= 1:3:9 to 1:2:6	
Foundation	Concrete, steel reinforcement	C15 (cube compressive strength 15 MPa), fy/fu = 400/500 MPa (steel)	4 fractions of gravel and sand and 200 kg/m3 of cement	
Frames (beams & columns)	Concrete, steel reinforcement	C20 (cube compressive strength 20 MPa), fy/fu = 400/500 MPa (steel)	4-5 fractions of gravel and sand and 250 kg/m3 of cement	
Roof and floor(s)	Concrete, steel reinforcement	C30 (cube compressive strength 30 MPa), fy/fu = 400/500 MPa (steel)	4-5 fractions of gravel and sand and 300 kg/m3 of cement	

6.2 Builder

Houses of this type are generally built by construction companies. Smaller houses (plan area less than 250 m.sq.) may be alternatively built by the owner himself/herself with the help of semi-skilled workers.

6.3 Construction Process, Problems and Phasing

The construction process begins with the excavation, forming and stabilization of the ground. Subsequently, the strip foundations are constructed, by placing the shuttering and reinforcement and pouring the concrete. The basement walls are usually built using perforated concrete blocks. However, the walls at the upper stories are built using perforated clay blocks. The construction of r.c. tie columns consists of reinforcement placed in vertical holes, enclosed either by shuttering or special clay blocks. The concrete of r.c. tie columns for each story is poured once the wall construction is complete in order to achieve good bond between the walls and the tie-columns. Subsequently, the shuttering and the reinforcement for the floor structure, bond beams and lintel beams is placed and the concrete is poured. Mortar for masonry construction is prepared at the site by using the ready dry mix; water is added at the site, and the mortar is mixed using machine mixers. Concrete for r.c. elements is plant-mixed concrete, taken to the site by the truck mixer and poured by mobile concrete pump. 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

Architects and structural engineers design houses of this type. It is a very common type of residential construction. It there are no significant irregularities in structural design, its design and construction expertise is usually good. The supervision has to be carried out by a structural 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 1963 earthquake in Skopje, Macedonia (in the former Yugoslavia), 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 1963 earthquake in Skopje, Macedonia (in the former Yugoslavia), 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.

In order to get the building permit, the design of a building has to be approved by the state authorities. Structural engineers have to and usually do consider the requirements of National Seismic Code for Buildings, but for these individual residential houses it is usually not verified. The supervision during the construction also has to be provided. However, the technical inspection after the construction is completed is usually not carried out (although this should be performed in order to get the building use and occupancy permit).

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not 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).

6.8 Construction Economics

The unit construction cost (per m.sq.) for this housing type is approx. 500-750 $US/m.sq., whereas the market unit cost for the completed house is approx. 750-1200 $US/m.sq. (including the price of the lot and complete infrastructure). The design of a house takes about 3 months. These houses are usually built individually. The construction requires approx. 5 skilled workers and it takes up to 1 year.

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 entire 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.
Inadequate lateral load resistance	Additional structural walls can be constructed, replacing the nonbearing partition walls, or existing structural walls can be strengthened by means of reinforced-cement coating, placed on both wall surfaces.
The walls at the attics level are built without top bond beams (crown beams)	The roof structure is temporary lifted and r.c. bond beams are constructed atop all walls at the attics level (Fig.7)

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?
Since this construction practice has been followed only in the last 30 years and no significant earthquake damage has been reported so far, only a few repair or retrofit interventions have been carried out so far.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
The work was done as a repair following the 1998 earthquake, however a very few houses of this type that have been damaged in recent earthquakes have been repaired and strengthened.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
Yes. The construction inspected in same manner as the new construction.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
An architect and a structural engineer is involved in the retrofit design. The construction is carried out by a contractor. After the 1998 Bovec earthquake, all contractors who were performing repair and strengthening were additionally trained.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
Information is not available, as damaging earthquakes were not reported since 1998.

Figure 7: Illustration of Seismic Strengthening Techniques: Construction of the Top Bond Beam (crown beam)in Attics in an existing house

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