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
A single-family, two-storey house with brick walls and timber floors

Report #	84
Report Date	21-10-2002
Country	ROMANIA
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in mud/lime mortar
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Summary

This type of urban housing was constructed in Romania in the 1930s as single-family housing for the middle class. Typical buildings described in this report are one- or two-story buildings with load-bearing masonry walls. These buildings called "vila" in Romania are characterized

by a rectangular plan and are usually semidetached; they share a common wall with the adjacent building. A great variety of buildings exist of this structural type. The building type described in this report has load-bearing brick masonry walls constructed of mud mortar. The floor structure consists of timber planks and joists. These buildings are located in an area well-known to be earthquake-prone. The epicenter is located close to Vrancea and earthquakes exceeding magnitude 7.0 on the Richter scale recur every 30 to 35 years. The latest earthquake of this severity was the March 1977 Vrancea earthquake (M 7.2). However, the building type described in this report is located in the Bucharest area and although affected by the November 1940 Naruja (Vrancea) earthquake (M 7.4), it usually performed well during the 1940 and 1977 earthquakes. The most common type of damage was in the form of cracks and falling chimneys. Some of the older buildings of this type have been affected by other past earthquakes. Because this construction is common for many Romanian buildings of the "Brâncovenesc" architectural style, new retrofit techniques have been developed in recent years (in addition to the techniques used after the 1977 earthquake).

1. General Information

Buildings of this construction type can be found in major urban areas of the country: in the cities of Zimnicea, Craiova, Ploiesti, Buzau, Iasi and, of course, Bucharest, also in smaller townships in these counties, and in the Prahova county. After the 1977 earthquake, single-family housing accounted for only about one-third of the new housing units. Information related to the total number of load-bearing masonry buildings is not available; however, statistics related to the multi-storey buildings indicate that only 13% of all buildings have load-bearing masonry walls. This type of housing construction is commonly found in both rural and urban areas.

Buildings of this type are typical for urban areas; only very old buildings of this type exist in rural areas.

This construction type has been in practice for less than 75 years.

Currently, this type of construction is not being built. Buildings of this type built before the 1940 are still in use. Typical buildings described in this report are one- or two-storey buildings with load-bearing masonry walls (called "vila" in Romania), built in the first half of the 20th century. There are also very old buildings of this type with load-bearing brick or stone masonry walls and timber floors. These buildings can be found in rural areas and in older suburbs. This construction practice was discontinued in the 1940s.

Figure 1: Typical building

Figure 2: A typical building block

Figure 3: Facade view

Figure 4: A building complex

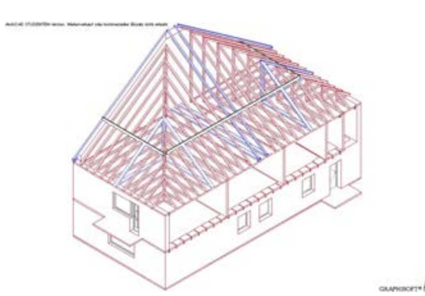

Figure 5: Axonometric view of the load bearing structure

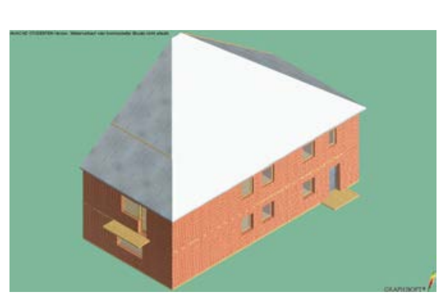

Figure 6: Axonometric view of the facade

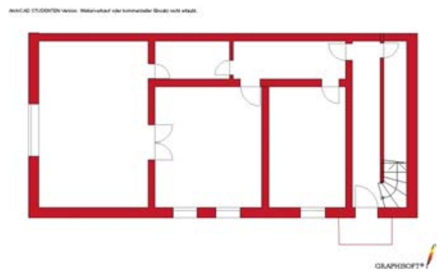

Figure 7: Ground floor plan

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. A typical separation distance between the adjacent buildings ranges from 1.9 m to 3.0 m (there is usually a 1.9 m distance to the lot limit). Usually, these houses were designed as semidetached, although in some cases the adjacent unit was not built at the same time. "Semidetached" in this instance indicates that there is a wall without any windows---referred to in this report as a "party wall"--- separating the buildings. Semidetached houses divided by a party wall may have different heights. To the author's knowledge, party walls were introduced as a mandatory measure to protect adjacent buildings after the big fire, which devastated the capital city of Bucharest some 200 years ago When separated from adjacent buildings, the typical distance from a neighboring building is 1.9 meters.

2.2 Building Configuration

This building type is rectangular. This building type is characterised also by the "honeycomb" ("fagure" in Romanian) building plan characteristic for Romanian housing design. The system has been described in reports #78 and #83 for reinforced concrete structures. This system has been applied for masonry structures as well. It consists of box-type units creating rooms of up to 30-35 meters square. There are about five windows per floor, usually one for each room. Window dimensions (width x depth) are 0.60 m x 1.20 m or 1.40 m x 1.20 m. There are between 5 and 10 doors per building, with dimensions (width x depth) of either 0.60 m x 2.10 m or 0.80 m x 2.10 m. In some cases, these are double doors; in other cases these are balcony doors, etc. The total door and window area is equal to one third of the total wall area.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Internal stairs are 1.10 m wide with a 1.1 m wide escape door at the ground floor.

2.4 Modification to Building

No structural modifications have been reported to the author's knowledge.

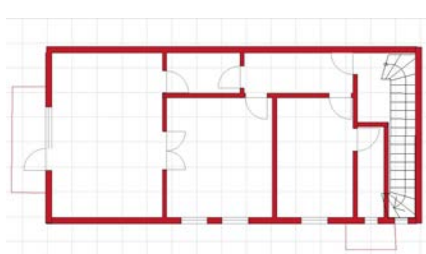

Figure 8: First floor plan

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	☐
	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐

Steel	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)	☐

There are variations of this structural type. In some cases, there is a 3- storey hybrid system, in which the top storey is built in timber and the intermediate storey is built in reinforced brickwork or even reinforced concrete; the bottom storey is of original unreinforced brick masonry construction.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is un-reinforced masonry walls. The gravity load-bearing system is the same as the lateral load-resisting system in this case. Due to the "honeycomb" ("fagure" in Romanian) building configuration (described in Section 2.3), the walls are well connected and carry the loads uniformly. Typically, all walls in a building are load-bearing walls (there are very few partitions).

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. The lateral load-resisting system consists of unreinforced brick masonry walls in mud mortar. The wall thickness varies between floors. In the building described in this report, wall thickness ranges from 420 mm at ground floor to 280 mm at the first floor. The brick headers used to connect orthogonal walls are of full-size bricks, and the same mortar is used in the rest of the wall. The thickness of mortar bed joints is about 12 mm, while vertical joint thickness is on the order of 10 mm and the joints are well-filled. Walls are rather stiff and the stiffness is evenly distributed between the walls. Due to the regular building plan ("fagure" plan described in Section 2.3), there is no chance for torsional effects. The horizontal structure is made of timber joists spaced at a distance of 600 mm and overlaid by timber planks and a suspended ceiling made out of mud mortar on slat and cane. The girders are supported by the longitudinal walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 15 meters, and widths between 5 and 7 meters. The building has 2 to 3 storey(s). The typical span of the roofing/flooring system is 3.6 meters. Typical Number of Stories: Typically 2 storeys, rarely 3 storeys. Typical Span: The typical span ranges from 3.6 to 5.4 m. The typical storey height in such buildings is 2.6 meters. The typical structural wall density is none. 8% - 15% The above figures refer to the upper storey wall density in the transverse and longitudinal direction respectively. Wall density at the lower storey is more uniform: it varies between 14% in the transverse direction and 13% in the longitudinal 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)	☐	☐
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	☐

unreinforced concrete strip footing.

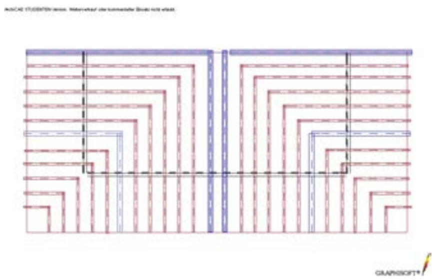

Figure 9: Roof plan

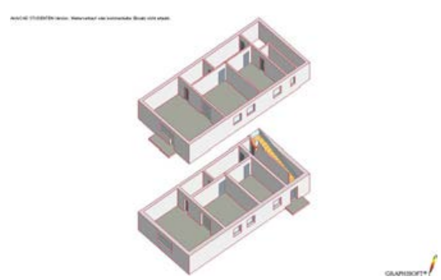

Figure 10: Axonometric view - ground floor and first floor

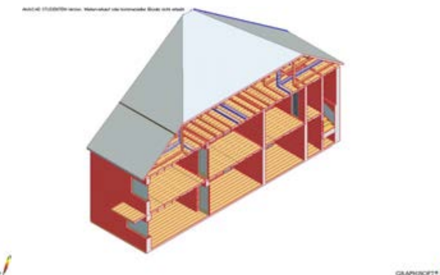

Figure 11: A 3D longitudinal section through the building

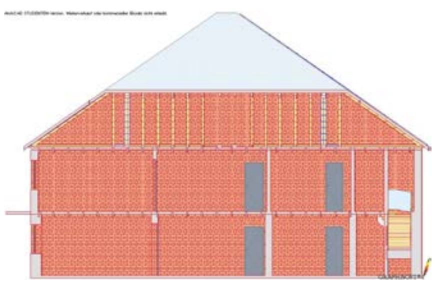

Figure 11: A 3D longitudinal section through the building

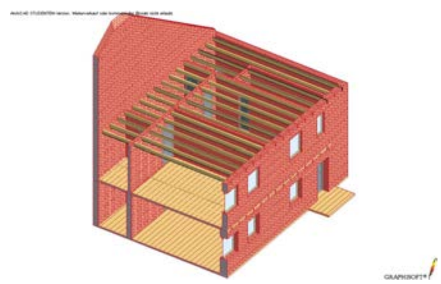

Figure 13: Axonometric view showing walls and floor structure

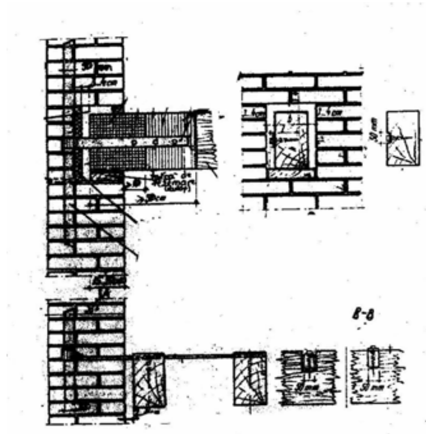

Figure 14: Wooden floor - sections and details

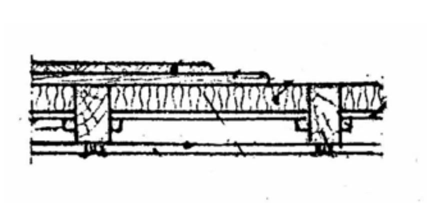

Figure 15: Wooden floor with finishing

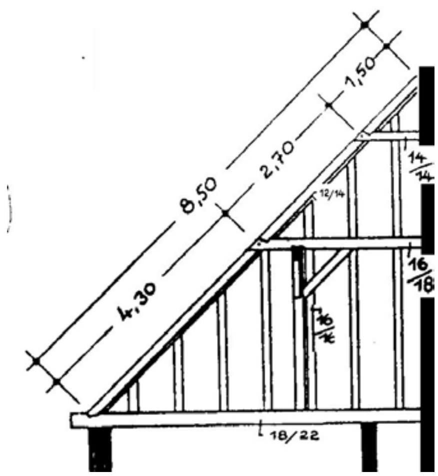

Figure 16: Roof dimensions in the transverse direction - cross-sectional dimensions in cm and spans in m (source unknown, addendum to "Constructions" course, in German)

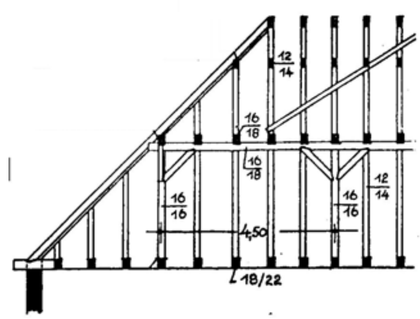

Figure 17: Roof dimensions in the longitudinal direction - cross-sectional dimensions in cm and spans in m (source unknown, addendum to "Constructions" course, in German)

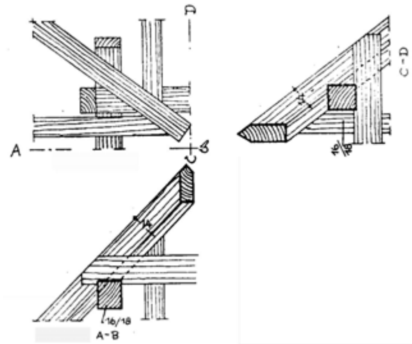

Figure 18: Roof connection details (source unknown, addendum to "Constructions" course, in German)

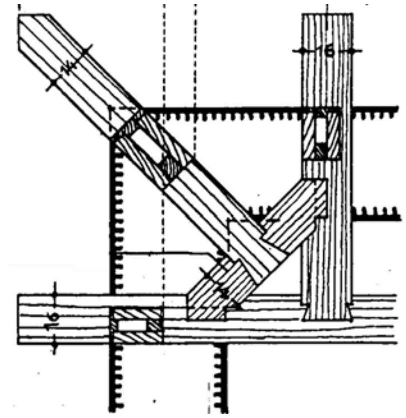

Figure 19: Plan detail of the roof at the corner (source unknown, addendum to "Constructions" course, in German)

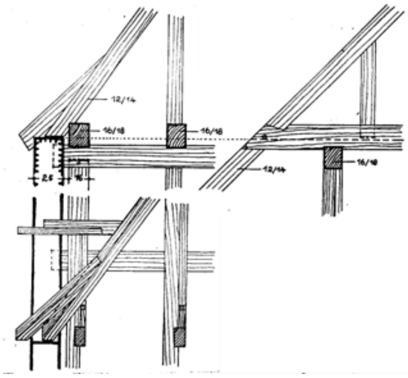

Figure 20: Roof-wall connection, longitudinal direction (source unknown, addendum to "Constructions" course, in German)

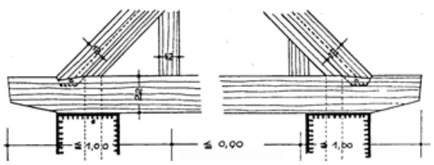

Figure 21: Roof-wall connection, transverse direction (source unknown, addendum to "Constructions" course, in German)

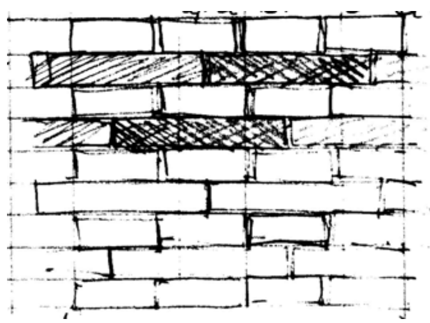

Figure 22: Detail of a brick masonry wall showing "crossed" bond ("tesatura incrucisata" in Romanian)

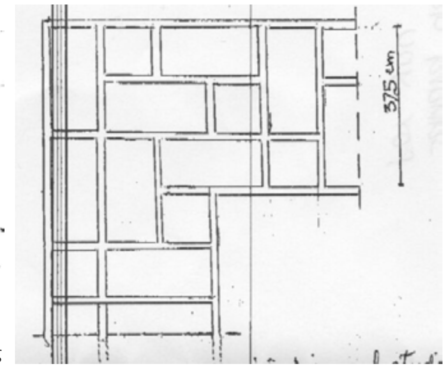

Figure 23: Detail of a wall intersection (brick masonry wall, thickness 375 mm)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 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.

4.2 Patterns of Occupancy

Typically, a family of 4 occupies one building. However, patterns of occupancy changed after World War II during the communist (Ceausescu) regime as compared to the earlier, pre-war situation. During the process of nationalizing privately owned residences, many buildings of this kind were appropriated by the government, demolished, and replaced by blocks of apartments. In some cases, several families lived in a single house; for example, a one-room apartment was created for a student on the upper floor or for an older person on the lower floor.

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 2 bathroom(s) without toilet(s), 1 toilet(s) only and no bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is outright 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.	☐	☐	☑
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	None	Good quality and strength of mortar (past earthquakes have confirmed that the structural integrity and stability of masonry walls depend on the quality of both the bricks and the mortar); evenly distributed stiffness; wall thickness decreases with height (except for the party wall common with the adjacent building): adequate connection between the orthogonal walls.	Some plaster cracks.

Frame (Columns, beams)			
Roof and floors	-Chimneys insufficiently anchored; - Absence of transverse connections at the perimeter of the floors with timber or metal joists (such connections transfer loads in one direction)	Timber floors ensure uniform load distribution (floors are simply supported by the walls inasmuch as these are thick enough); timber floors with joists each measuring 600 mm ensure the uniform distribution of the in-plane rigidities such that torsional effects are avoided. Timber joists are supported by longitudinal walls (the main direction in the building). Support of the floor with joists which are orthogonal on the longitudinal walls is considered by the authors to have had a certain damping effect during the 1977 earthquake.	Collapse of chimneys; envelope got damaged
Other coupling with building of same type	More regular shape	The different height of adjacent buildings can increase the susceptibility to damage.	

Because of the great variety found in this structural type, the damage patterns also vary. The above description refers to the building described in this report.

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
1940	Naruja, Vrancea	7.4	7 (MMI)
1977	Vrancea	7.2	8 (MMI)
1986	Vrancea	7	8 (MMI)
1990	Vrancea	6.7	7 (MMI)

The most common earthquake damage was in the form of cracks and fallen chimneys. The following general damage patterns were observed after the 1977 earthquake: 1) heavily damaged buildings typically had inclined (45° or X-shaped) cracks; such cracks (even if they did not lead to immediate collapse) reduced the strength and stiffness of the walls so that there was imminent danger of collapse from aftershocks; 2) partial collapse if wooden floors were insufficiently anchored into the masonry, and the bricks were of poor quality, affecting mainly buildings from XIXth century; 3) collapse of chimneys (more severe in the case of tiled roofs).

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Bricks 6.25cmx12.5cmx25cm			Quality of brick, mortar, and workmanship very different but very strongly influencing the seismic behaviour
Foundation	Unreinforced concrete			N/A (build in 1930)
Frames (beams & columns)				N/A
Roof and floor(s)	ROOF: wood framework cladding: zinc plated sheet FLOORS: timber joists spaced at 600 mm overlaid by timber boards and a suspended ceiling of mud mortar on slat and cane.			N/A

6.2 Builder

These buildings were built by artisans (small contractors) and the construction was funded by the owners.

6.3 Construction Process, Problems and Phasing

Information not available. 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

Information not available. In general, these buildings were built by artisans (contractors) without involvement of engineers and architects. Some buildings of this type were designed by architects.

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and not authorized as per development control rules.

This construction practice is no longer followed. 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

Information not available. Information not available.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. Information is not available.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Diagonal "X" cracks in the walls	Strengthening using the TENSAR system (Fig. 24), which consists of the following steps: 1. cleaning up plaster 2. cleaning up between bricks 3. making holes for nails 4. fixing nails 5. fixing distancing units 6. rolling out the net 7. bordering windows 8. plastering on both faces of the net
Miscellaneous wall cracks	Crack injection with cement paste (Fig. 25 and 26). The crack injection procedure is as follows: 1. The cracks are cleaned with air and water jet. 2. The cracks are closed with plastering with 1:3 cement mortar on both sides of the masonry, letting injecting holes of 13 mm diametre each 30 to 60 cm along the cracks. 3. Before injecting, the plastering is wetted and the continuity of the injection paths is verified with water. 4. Bottom-top injecting, successively closing the openings and control holes. This method cannot be used if bricks have moved or fallen out.
Rebuilding of collapsed walls	Replace collapsed portions of old walls with new masonry walls built in cement mortar. Ensure the connections with the remaining masonry walls. Epoxy resins may be used.
Large diagonal cracks in the walls or wall dislocations	Use of shotcrete ("torcretare" in Romanian) method (Fig. 27, 28, and 29) as follows: 1. Attach the wire net to the masonry wall. 2. Apply a 30 mm thick torcrete overlay (only on the damaged zones). The remaining portion of the wall is plastered to obtain an even surface. Jacketing is an alternative to the "torcrete" method. The jacketing method consists of applying a 50 mm thick reinforced concrete overlay cast on both sides of the surface of a masonry wall. The reinforcement consists of "sudat" wire nets anchored with clasps into the masonry.
Correction of conceptual design errors	Replace heavy walls with light walls or connect them to the rigid walls of the load-bearing system (this can be also used in construction of new buildings).

All the above-listed provisions are repair methods (except for the TENSAR strengthening). The TENSAR strengthening method is a rather new method which can be used for the repair of damaged buildings or for the strengthening of undamaged buildings at risk of future earthquakes. The method has been recommended for the retrofit of historic buildings in Romania according to article 7.3.4.4. (GOR 1998-2000). GOR does not recommend the use of "TENSAR," because it is a specific commercial product, but rather recommends the use of generic polymer grids. GOR (1998-2000) suggested performing repair with the polymer grids compatible with the mud mortar used in the existing construction; however, mud mortar it is no longer made. Therefore, the application of TENSAR system implies mixing the new cement mortar with the mud mortar and clay bricks in the existing construction. This is a drawback to the TENSAR method (and other similar methods), as it leads to the deterioration of the original material over time and a loss in the effectiveness of the structural strengthening in the event of an earthquake (reviewer's addition). The authors' opinion is that the long-term and short-term time effects of the TENSAR system are not adequately researched at this time. For example, Romanian cities are exposed to significant annual temperature variations (which may range from -30° to +40° in Iasi and other cities). Such significant temperature variations deteriorate the bond between materials with different characteristics. Therefore, systems like TENSAR should be used with caution. The authors believe that the GOR decision to propose this type of system in the above-mentioned document might have been influenced by the limited choices. Reinforced concrete jacketing is an alternative to the use of the TENSAR (or similar alternative) system; however, the jacketing might affect the shape of monuments in a more negative way as compared to the TENSAR 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?
Strengthening was not required for the building described in this report. In past earthquakes, buildings of this type suffered only minor damages, such as the collapse of chimneys which damaged the roof cladding, and some superficial

wall (plaster) cracks. These damages were repaired by qualified workers and the repair was managed by the owner. All above-mentioned strengthening techniques (except the TENSAR strengthening) were used after the 1977 earthquake. Out of these, crack injection was most widely used. After the 1977 earthquake, a crack injection methodology developed by INCERC was used (manual pump was used for minor repairs and mechanised procedures have been developed for larger efforts). There are no reported examples of housing applications for this method; however, several public buildings, including the Architecture Institute, were repaired using this method. The torcrete method was used for repairing diagonal large cracks or dislocations.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
The work was done as repair after the 1977 earthquake. However, some methods, like TENSAR strengthening, can be used for the retrofit of undamaged buildings to protect them against future earthquakes.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
Information not available.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
In general, engineers are involved in the design of the repair and strengthening provisions. Also, architects are involved in aproving the use of certain repair methods for a particular building.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
After the 1977 earthquake, there were no earthquakes of similar intensity. The building described in this report, which required only minor repairs (mainly crack injection) in 1940, was not significantly damaged in the 1977 earthquake.

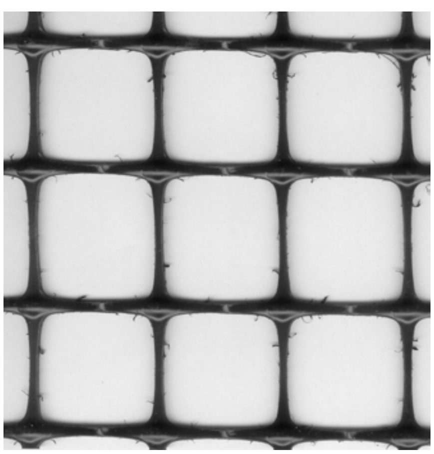

Figure 24: Polymer grid with integrated nodes used for retrofit (similar to the TENSAR system)

Figure 25: Wall repar by injecting cement paste

Figure 26: Wall repair by injecting cement paste with compressed air

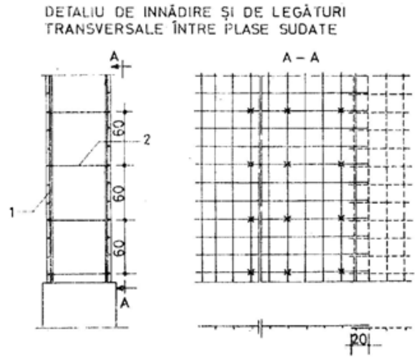

Fig. VIII.22. — Consolidarea prin cămăşuire a zidăriei : 1 — plase sudate ; 2 — agrafe de legătură.

Figure 27: "Torcrete" retrofit method

Figure 28: Torcrete method - step 1: cleaning of the wall surface with compressed air

Figuer 29: "Torcrete" retrofit : application of torcrete overlay on the steel net attached to the wall

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