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
Block of flats with 11 floors out of cast-in-situ concrete, gliding frameworks

Report #	87
Report Date	30-11-2002
Country	ROMANIA
Housing Type	RC Structural Wall Building
Housing Sub-Type	RC Structural Wall Building : Moment frame with in-situ shear walls
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Summary

This is an urban high-rise, built in Romanian cities, especially in Bucharest, during the Communist era. Romania is known as a seismically prone area. The epicenter of damaging earthquakes is near Vrancea and can affect half of the country at one time. Earthquakes higher

than magnitude 7.0 on the Richter scale occur once in 30 years. Bucharest, the capital, is located on the banks of the Dâmbovita and Colentina rivers, on non-homogeneous alluvial soil deposits, around 150 km south of the epicenter in the main direction of the seismic wave propagation. This construction type is another example of a building with reinforced concrete shear walls. Unlike the OD type, described in report #78, this construction has more than just a single load-bearing wall in the longitudinal direction, and thus the behavior of the building under seismic loads is significantly improved. These exclusively residential buildings are found in large green-belt areas, in peripheral neighborhoods, either as an isolated building or in groups. Having uniform height and rectangular form, they generally contain four units on a floor. Characteristically, there is a ground floor with either 4 or 10 upper floors. This example is the Y-type, with 10 upper floors. The structural type is the "Fagure" (honeycomb) one, commonly used in Romanian construction practice. Although the perimeter walls are load-bearing, there are wide openings in them. During the earthquake of 4 March 1977 (Richter magnitude 7.2), over 30 buildings collapsed in Bucharest and killed 1,424 people. This type of building behaved rather well, with only superficial damage observed. Seismic strengthening was thus limited to repairs, where necessary.

1. General Information

Buildings of this construction type can be found in the peripheral areas of bigger towns, especially Bucharest. An example of distribution of different structural types in new building in the city of Jassy (Iasi in Romanian), north of the epicentre is: 36% RC shear walls (this type), 36% large panels, 15% load bearing masonry, 13% current and lamellar frames. This type of housing construction is commonly found in urban areas.

in the periphery, on previously agricultural lands.

This construction type has been in practice for less than 50 years.

Currently, this type of construction is not being built. It was practiced during 1960-1990.

Figure 1: Assembly view with neighbouring buildings of another type

Figure 2: Assembly of buildings of this type

Figure 3: View of the main south facade of a typical building.

Figure 4: View of the corner of a typical building

Figure 5: Ascendent view of the corner of a typical building (after Bostenaru, 2004)

Figure 6: Part of the side view of a typical building.

Figure 7: View of the entrance in a typical block.

Figure 8: Partial view of the main south facade.

Figure 9: Facade detail

Figure 10: View of a building with increased length, due to the presence of two staircase. Figure 10: The layout of the individual flats except a single room flat in the middle, and the typical structure are the same.

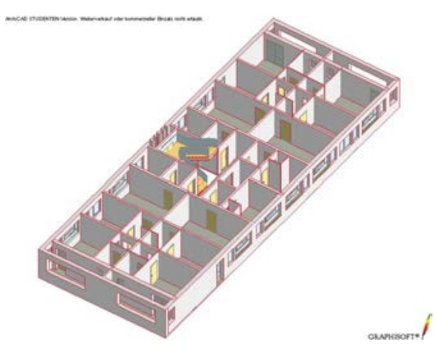

Figure 11: Axonometric view of current floor

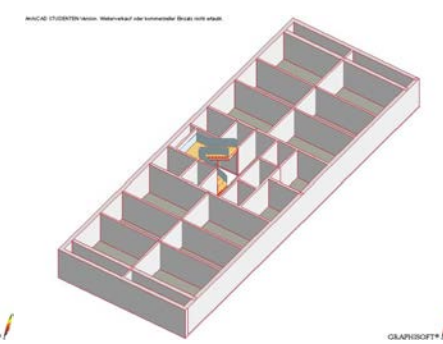

Figure 12: Axonometric view of reinforced concrete shear walls of a floor

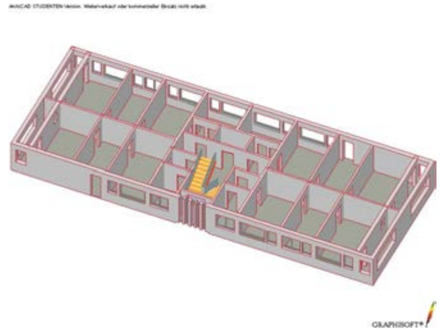

Figure 13: Axonometric view of load bearing walls and openings (from Bostenaru, 2004)

Figure 14: Longitudinal 3D section. Note that in the first and second upper floors the non structural walls respectivelly the openings have been omited.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. It is 1/2 height (15m) at short side, and 2 times height (60m) at long side When separated from adjacent buildings, the typical distance from a neighboring building is 30 meters.

2.2 Building Configuration

rectangular. 32 windows and 23 doors in load bearing walls. This means two door openings in each transversal load bearing wall which is continuous along the building depth (12,5% door area) and none in the shorter ones or in the the longitudinal middle wall. In the longitudinal perimeter wall there are about 13 windows (25%). On a characteristic floor the size of openings is as follows: The interior doors are usually 90cm/210cm in size, with the exception of two secondary doors situated next in the middle short longitudinal walls and which are 80cm/210cm. In the exterior walls the "french windows" (glazen doors not opening into another room) are 90cm/230cm, while two balcony doors are of same size and two other balcony doors are 160cm/230cm. Most of the windows are composed from a big one, 220cm/140cm associated to a thin separated 80cm/140cm. There are small openings to the sanitary room of 60cm/90cm.

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. One staircase, 1.20 m wide flights and a lift for 4 persons. Only one exit door, 1.20 m wide.

2.4 Modification to Building

No modifications.

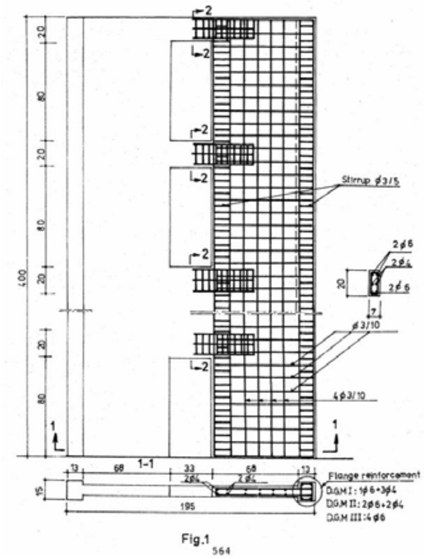

Figure 15: Model of a typical wall for a building of this type but 4 floors high (after Ciuhandu and Mihaescu in Aroni and Constantinescu, P. 564)

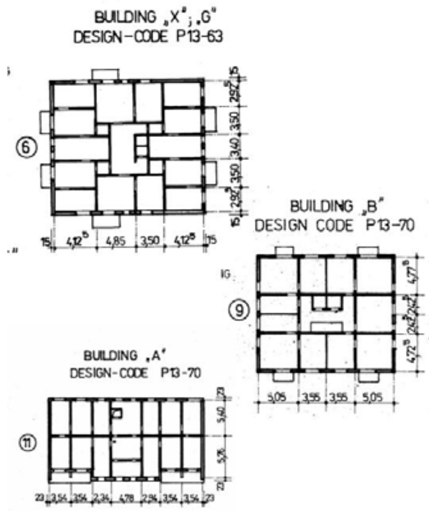

Figure 16: TOP: Plan of a building of related type: cast-in-place, gliding formworsk walls, cast-in-place slabs, foundation raft; MIDDLE: Plan of another building of this type: cast-in-place shear walls with gliding formworks, cast-in-place slabs, foundation raft (after Mihalache in Aroni and Constantinescu, P. 136); BOTTOM: Plan of a building of related type: Cast-in-place, glinding formworks shear walls, cast-in-place slabs; foundation raft (after Mihalache in Aroni and Constantinescu, P. 137).

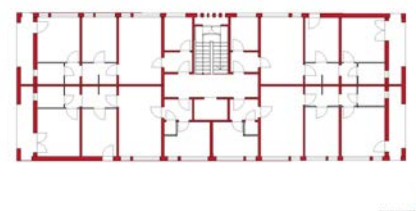

Figure 17: Architectural plan of current floor (from Bostenaru, 2004)

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 reinforced concrete structural walls (with frame). This building type is characterised by the "honeycomb" ("fagure" in Romanian) layout, so often met in Romanian housing design. This means that rooms are all box-type units, connected only by means of doors. In such a building configuration walls are well connected and carry loads in uniform manner. Cast-in-situ RC slabs are supported directly by the structural walls on the contour of the "honeycomb" units, including on the facade.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete structural walls (with frame). The main lateral load-resisting structure consists of reinforced concrete shear walls in both longitudinal and transversal direction. Additional rigidity is provided by cast-in-situ RC slabs. The 12 transversal and 3 longitudinal walls are continuous through the whole building height, including the ground floor. From the longitudinal walls two are on the contour and present huge openings, especially in the middle. The central longitudinal wall in discontinued in the middle but does not present other openings. From the transversal walls the two close to the middle are discontinued, but the other ones only present two narrow openings each, to provide access from one room to the other. Generally if can be said that the rigidities are uniformly and optimally distributed and that the wall density is rather high. Wall thickness varies from 150 to 200mm for inner walls to 320/330 mm for the exterior ones, which contain also a layer of thermoisolation in the middle. The way of reinforcement is unknown. There are light concrete partition walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 31 and 45 meters, and widths between 11 and 11.5 meters. The building is 11 storey high. The typical span of the roofing/flooring system is 3.4 meters. Typical Plan Dimensions: The length varies according to the number of staircases. Typical Span: The spans in longitudinal direction are: 3.4, 2.8, 3.4 and 3.7m, then mirrored the same. The spans in transversal direction are each 5.3m. The typical storey height in such buildings is 2.86 meters. The typical structural wall density is none. 6.66% - 7.18% For the whole building 7.5%.

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	☐

Typically mat foundations.

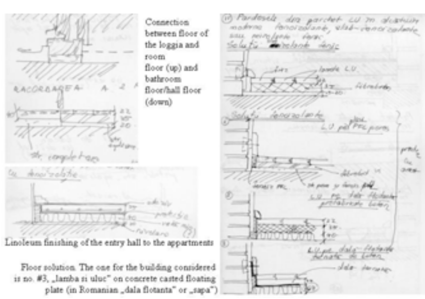

Figure 18: Finishing details of floors

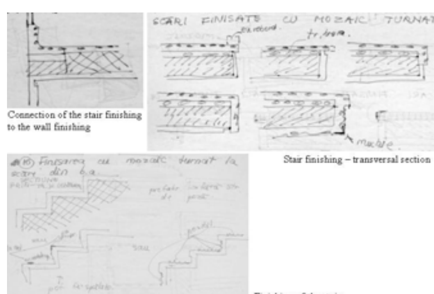

Figure 19: Stair finishing details

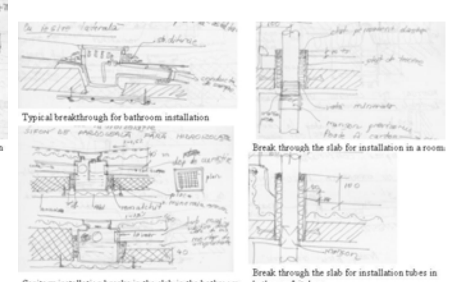

Figure 20: Details of bathroom installations

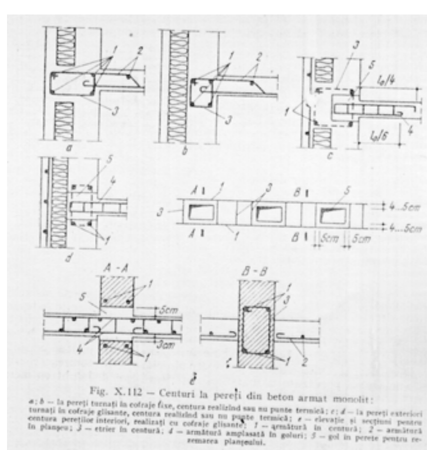

Figure 22: Ringbeams at cast-in-place RC walls (after the additional notes to finishings course, source unknown): a,b: - walls cast in fixed

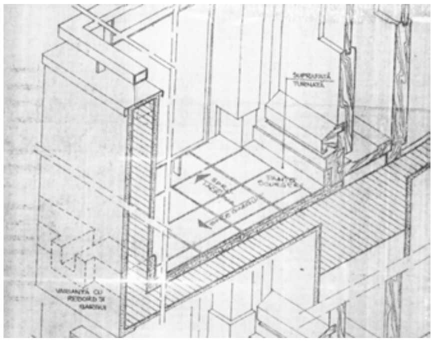

Figure 21: Axonometric view of balcony finishing (from Stan)

formwork, the ringbeam constitutes or not thermal bridge; c, d - walls casted in gliding formwork, the ringbeam constitutes or not thermal bridge; e - verticalv iew and sections through the ringbeam of interior walls, realised with gliding framework; 1- reinforcement in the ringbeam; 2 - reinforcement in the slab; 3 - stirrup in the ringbeam; 4 - reinforcement in the holes; 5 - hole in the wall for supporting the slab.

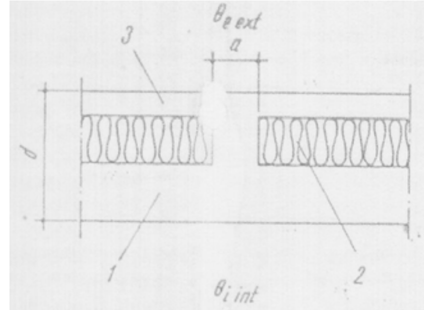

Figure 23: Horizontal section through a facade wall (from additional notes to finishings course): 1 - layer with big mass; 2 - thermoisolating layer; 3 - protection layer.

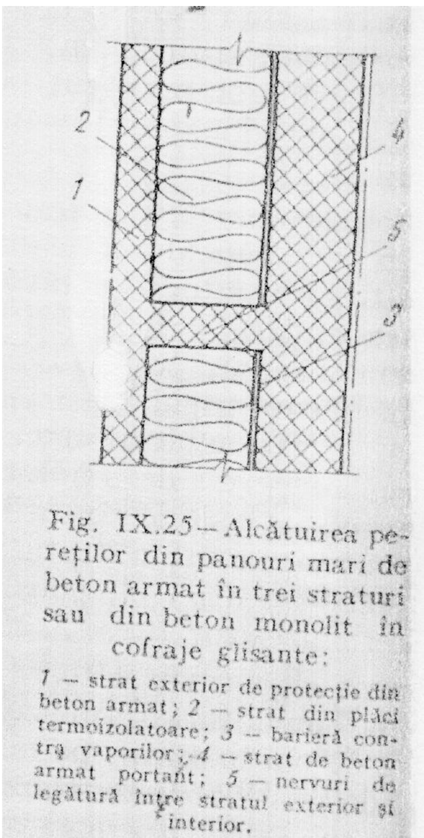

Figure 24: Composition of big panels or cast-in-place with gliding formwork RC walls: 1 - external protection layer out of RC; 2 - layer out of thermoisolating plates; 3 - barrier against vapors; 4 - layer out of load bearing concrete; 5 - connecting ribs between the external and internal layer.

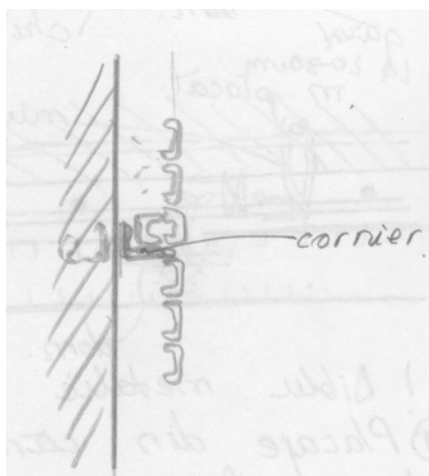

Figure 25: Detail of the facade wall finishing with brick plates, 60mm wide on cement mortar.

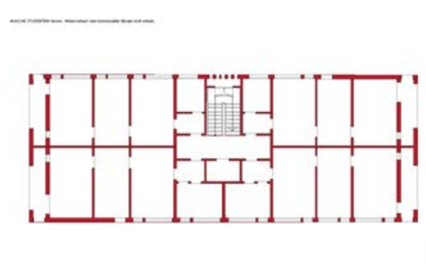

Figure 26: Layout of load bearing walls and their openings in a current floor

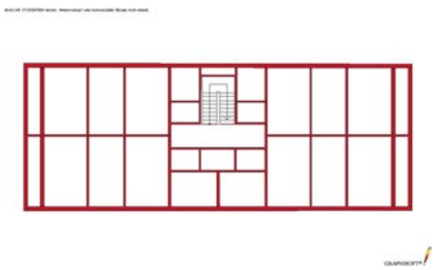

Figure 27: Reinforced concrete shear walls - plan layout (from Bostenaru, 2004)

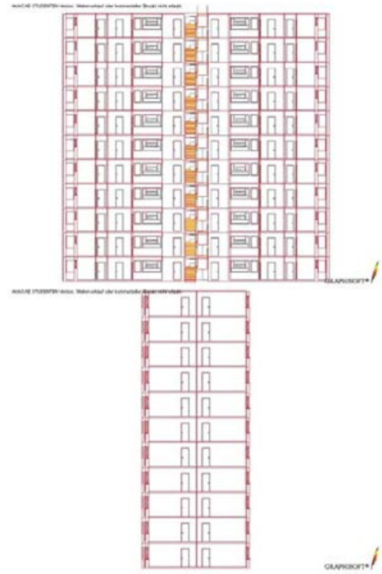

Figure 28: Longitudinal section (top) and transversal section through the living room (bottom)

Figure 29: Drawing of the south facade (top) and of north facade (bottom)

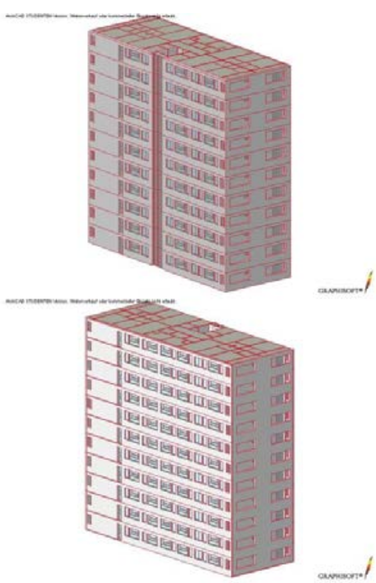

Figure 30: Axonometric view of the N and W side (top) and of S and E side (bottom)

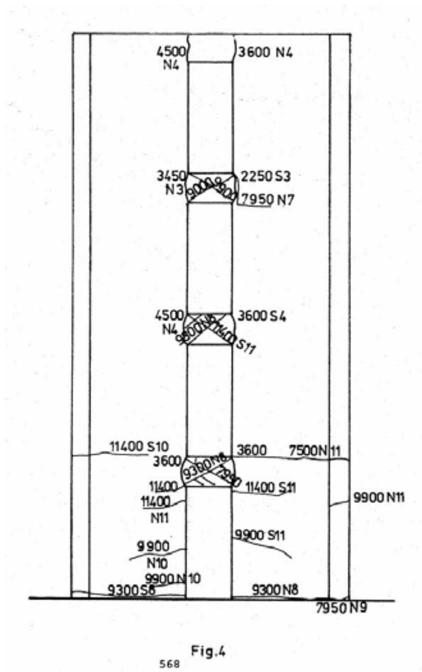

Figure 31: Damages on the model of a typical wall for a building of this type but 4 floors high (after Ciuhandu and Mihaescu in Aroni and Constantinescu, P. 568)

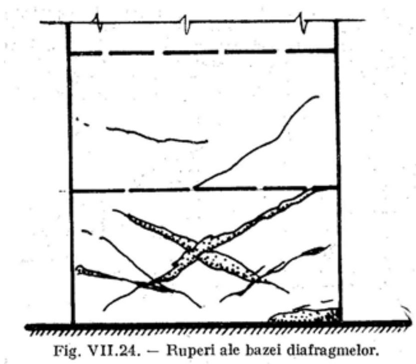

Figure 32: Typical damages at the basis of shear walls (after Balan)

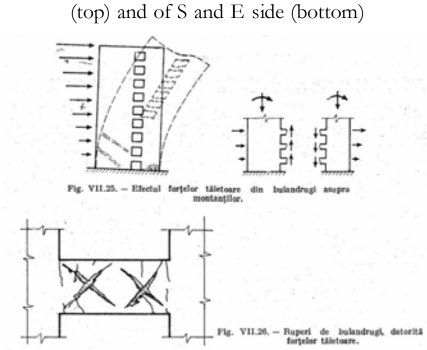

Figure 34: Typical damages in lintels (after Balan)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). 44 units in each building. Typically 4 flats each floor. There is a variation with two staircases with 9 flats each 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. During business hours there are about 20 people, in the evening/night up to 160.

4.2 Patterns of Occupancy

One family of 1 (typically retired person) to 4 members (ex. parents, child and grandparent or parents with two children) occupies a 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)	☐

Between 10/1 and 6/1 depending on inhabitant. Economic Level: For Middle Class the ratio of Housing Price Unit to their Annual Income is 10:1.

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)	☐

Recently the "credit ipotecar" has been introduced, which allows taking credits, provided the buyer has an initial capital and a constant safe income, to purchase a flat. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is 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)	☐

Renting flats from owners to others (eg. students) is rare in this type of building, given the size of the flats (3 rooms usually). Flatsharing is not a usual rent form in Romania. Some (few) blocks might be still owned by the state and long-time-rented.

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	☑	☐	☐
	The total width of door and window openings in a wall is:			

Wall openings	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
Structural walls	- inadequate (too small) wall thickness for some walls; - too small depth of the lintels (around 600mm) due to reduced floor height; - absence of continuous reinforcement vertically.	- good wall density; - good layout and distribution of rigidities, regarding uniformity and respect to the centre of mass and rotation.	Rifts in the lintels. The rifts in plastering shown in the attached images have the same shape as the profound rifts in the 1977 earthquake. In 1977 there were horizontal rifts as well. Typical damages at buildings of this kind were: - brittle failure at the basis of the shaer wall, from combined bending, axial compression and shear failure (see figure); - brittle failure of the lintels in shear, as first postelastic adaptation possibility (see figure); - multiple rifts in vertical, diagonal and horizontal direction * diagonal or X rifts, from bending, are not characteristic for the "honeycomb" type (they are to be found in "cellular" type) * vertical rifts appear at all levels, at the connection between transversal and longitudinal shear walls * diagonal rifts appear in the zones weakened by the gliding formwork.
Non-structural elements	Very stiff building.		At upper floors the kitchen plates, glasses etc. broke.
Roof and floors	none	- stiffness; - good anchorage of the facade; - openings reduced to the minimum necessary.	none
foundation	The foundation for this particular building had the "trafor" (strom change unit) at one of the ends, which leaded to a kind of desequilibrum.		It is considered that this contributed to the fact that the building was damaged at all.

At the time of the 1977 earthquake one of the neighbouring blocks was being built and the foundation grave was open, thus causing more sever damages than usual for this building type. Detailed description of damages in buildings of the same structural type can be found in Mihalache in ARCC, P. 129-139.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is E: LOW VULNERABILITY (i.e., very good seismic performance), the lower bound (i.e., the worst possible) is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), and the upper bound (i.e., the best possible) is F: VERY LOW VULNERABILITY (i.e., excellent 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
1977	Vrancea	7.2	VIII (MMI)
1986	Vrancea	7	VIII (MMI)
1990	Vrancea	6.7	VII (MMI)

None to light damages. However, during the earthquake of 4 March 1977 over 30 buildings collapsed in Bucharest killing 1,424 people. Only two buildings in structural wall type collapsed, one of them having soft ground floor and the other one being of the type described in report #78.

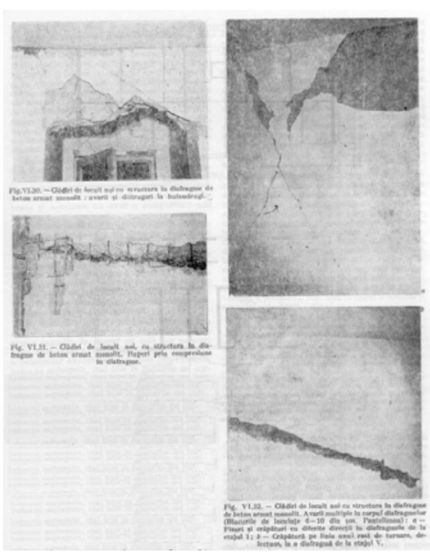

Figure 34: Typical damages in another buildings of this kind: VI.30: Damages and destructions in lintels; VI.31: compression breaks; VI.32: multipled damages: a. cracks and rifts in different directions at first floor; b. rift along a wrong casting joint. (from Balan)

Figure 35: Vertical rift in shear wall going out from door opening corner

Figure 36: Vertical rift near door.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
	Structural walls: reinforced	Structural walls: between 1962-1975 the characteristic strength of concrete has	Structural walls:	

Walls	concrete Partition walls: lightweight concrete	been (according to Balan P. 390) between 1960 and 1965 it was 260-360 daN/cm^2 (concrete of mark B200) or between 3 and 4 N/mm^2 at a density of 2200-2300 kg/m^3 and porosity between 3 and 7%(see Balan p. 380) Reinforcement of PC52, PC60, OB37	reinforcement distributed after Navier section principles	Partition walls: non-load bearing
Foundation	reinforced concrete	between 1962-1975 the characteristic strength of concrete has been (according to Balan P. 390) between 1960 and 1965 it was 260-360 daN/cm^2 (concrete of mark B200) or between 3 and 4 N/mm^2 at a density of 2200-2300 kg/m^3 and porosity between 3 and 7%(see Balan p. 380) Reinforcement of PC52, PC60, OB37		
Frames (beams & columns)				
Roof and floor(s)	reinforced concrete	between 1962-1975 the characteristic strength of concrete has been (according to Balan P. 390) between 1960 and 1965 it was 260-360 daN/cm^2 (concrete of mark B200) or between 3 and 4 N/mm^2 at a density of 2200-2300 kg/m^3 and porosity between 3 and 7%(see Balan p. 380) Reinforcement of PC52, PC60, OB37		

6.2 Builder

Sold by OCLPP ("Oficiul de Constructii si Locuinte Pentu Populatie" = [The Office for Constructions and Residences for the Population]). After signing the contract ("subscribing") the payment was made in rates. The builder were government-owned companies.

6.3 Construction Process, Problems and Phasing

During the construction work, in order to assure the continuity of the cast-in-situ structural walls gliding formwork ("cofraje glisante" in Romanian) were used. Gliding formworks was the most spread method for casting in place in the city of Jassy, more than plywood panels formworks and plain steel forms (see Mihalache in ARCC). Between 1960-1990 all construction work was performed by government-owned companies. They involved technical professionals in the construction process. 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

No data available. Design professionals, both engineers and architects, were involved in the process, from design to construction.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. P13-1970, STAS 800-67. The year the first code/standard addressing this type of construction issued was 1963 (year of Skopje EQ). The code refers explicitly to seismic design of buildings. P13 was issued in 1963 and revised in 1970. The latest Code, which is applied currently is P100-1992. The most recent code/standard addressing this construction type issued was 1992 (A most recent version is ready, but not yet published.). Title of the code or standard: P13-1970, STAS 800-67 Year the first code/standard addressing this type of construction issued: 1963 (year of Skopje EQ) National building code, material codes and seismic codes/standards: The code reffers explicitely to seismic design of buildings. P13 was issued in 1963 and revised in 1970. The latest Code, which is applied currently is P100-1992. When was the most recent code/standard addressing this construction type issued? 1992 (A most recent version is ready, but not yet published.).

Evolution of the global seismic coefficients for this type of building: - provisional instructions of the MLP in 1942 * seismic degree A - not considered * seismic degree B - not considered - Time between 1950-1963 * seismic degree 7 - 2.5 * seismic degree 8 - 5.0 - P13-63 * seismic degree 7 - 3.7 * seismic degree 8 - 7.4 * seismic degree 9 - 14.8 - P13-70 * seismic degree 7 - 4.9 * seismic degree 8 - 8.1 * seismic degree 9 - 13.0 - P100-78 * seismic degree 7 - 4.6 * seismic degree 8 - 7.6 * seismic degree 9 - 12.2 - P100-81 * seismic degree 7 - 4.6 * seismic degree 8 - 7.6 * seismic degree 9 - 12.2 - P100-92 * seismic degree 7 - 6.0 * seismic degree 8 - 10.0 * seismic degree 9 - 16.0.

6.6 Building Permits and Development Control Rules

This type of construction is an 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). The Owners' Association.

6.8 Construction Economics

The price of a new apartment (40.18 main function space) was 70000 lei in 1974. At that time 1 $ ~ 12-14 lei.

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. From 2004 on, assurance against disasters (esp. because flooding) will be compulsory. Right now there is no compulsory assurance against earthquakes. The negotiation space for assurance premium is small. For an apartment of 15000$ value (like these ones) the assurance is 50$/year. The value estimates are made by the owners. For a higher value estimate the assurance may be 70$ and so on.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Small cracks in structural walls and lintels	Epoxy resins injections and plating with Rooving layers ("Folie") 1. Dismantling the plastering; 2. Mechanical execution of 2cm wide holes (4 in a square metre); 3. injections of the cracks with epoxy resin; 4. Plating of the elements with Rooving-type weaving; 5. Plastering with M50-T mortar. More details can be seen at INCERC.

According to tests done at the Aristotle University of Thessaloniki (as quoted by G. Bourlotos in his study work; original source Dritsos P. 190) epoxy resin injections fully establish the properties the structural wall had before the measure.

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?
Epoxy resins injections were performed in the door lintels, but probably after the method described at report #78. The method described in the above table is the one in use now (year 2000) for pre-damaged buildings in order to mitigate.

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

It was performed following an earthquake damage. Efforts are done now for mitigation on pre-damaged buildings.

8.3 Construction and Performance of Seismic Strengthening

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

The inspection was made by an engineer from the owner's association.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
The retrofitting was made by the organs which were in charge for this after the 1977 earthquake. After an application from the inhabitants these were coming, inspecting, and approving a retrofit action or not. More precise they were looking if the damage really affected structural elements or just the plastering. In this particular case the implied civil engineer was one specialised in road construction.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
It has performed very well, but the 1986 and 1990 were by far not so strong as the 1977 earthquake, in order to be able to fully evaluate the performance.

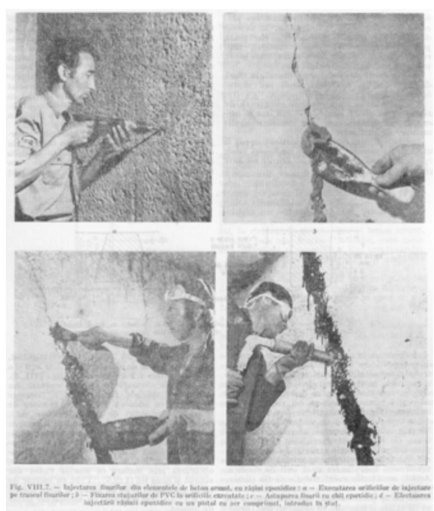

Figure 37: Epoxy resin injections (after Balan, P. 416)

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