World Housing Encyclopedia

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

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HOUSING REPORT
Reinforced concrete cast-in situ shear wall buildings ("OD"-type, with "fagure" plan)

Report #	78
Report Date	05-06-2002
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 typical urban multi-family housing practiced throughout Romania in the period from 1965 to 1989. There are many existing buildings of this type at the present time, with about 8,000 apartments in Bucharest alone. Concrete shear wall construction is commonly used for

the residential construction and it accounts for over 60% of new housing. Buildings of this type are typically 10 or 11 stories high. The main load-bearing structure is a cast in-situ concrete shear wall structure supported by RC solid slabs. Each building block consists of several (5-6) identical building units ("tronsons" in Romanian) separated by means of seismic joints. The walls are continuous throughout the building height and orientated in two directions, with only one centrally located wall in the longitudinal direction and eight walls in the transverse direction. In addition, there are some lightweight concrete partition walls. This building plan is known as the honeycomb ("fagure") plan. The buildings are often supported by mat foundations due to soft (alluvial) soil conditions. Many buildings of this type were designed according to the 1963 Romanian Building Code (P13-1963) which was updated in 1970 (P13-1970). The 1963 Code considered a magnitude 7 design earthquake for the Bucharest area. This region is well known as a seismically prone area, with the epicentre of damaging earthquakes close to Vrancea. Earthquakes with the Richter magnitude of over 7.0 occur once in 30 years. Bucharest, the capital, is located around 150 km south of the epicentre and lies in the main direction of the propagation of seismic waves. The Bucharest area is located on the banks of the Dâmbovita and Colentina river, on non-homogeneous alluvial soil deposits. During the earthquake of 4 March 1977 (Richter magnitude 7.2), over 30 buildings collapsed in Bucharest, killing 1,424 people. The buildings of "OD" type suffered damages of various extent in the 1977 earthquake, and one building unit ("tronson") totally collapsed (that was the only shear wall building that collapsed in the FIGURE 1A: Typical Building Page 1 earthquake). Buildings with their longitudinal direction aligned parallel with the direction of seismic waves were most affected. The earthquake action in 1977 was mainly in NNE-SSV direction. Out of 167 building units ("tronson"s) of the "OD" type existing in Bucharest at the time of the 1977 earthquake, only 7 were lightly damaged; the remaining building units suffered a partial collapse (7 units) or damages (19 were significantly damaged, 72 were moderately damaged, and 61 were lightly damaged). According to the reports, damages to this construction type were due to inadequate wall density in the longitudinal direction, inadequate amount and detailing of wall reinforcement, lack of lateral confinement in the walls and in the boundary elements ("bulbs") causing brittle concrete failure and buckling of reinforcement. In addition, the quality of concrete construction was found to be rather poor.

1. General Information

Buildings of this construction type can be found in all parts of Romania, and is particularly common in the capital Bucharest. This construction can be found in six quarters (districts) of Bucharest: Militari, Colentina, Drumul Taberii, Pantelimon, Berceni, Iancului, with the total of 8,000 apartment units. Except Iancului, other quarters are located in the suburban area of the city and consist mainly of newer settlements (built after the World War II). Concrete shear wall construction is commonly used for the urban residential construction and it accounts for over 60% of the new buildings. There are four different types of shear wall construction which were affected by the 1977 earthquake - type "OD" described in this contribution is one of them. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 50 years.

Currently, this type of construction is not being built. This construction was practiced in the period from 1965 to 1989.


Figure 1A: Typical Building


Figure 1B: Typical Building


Figure 1C: Typical Building

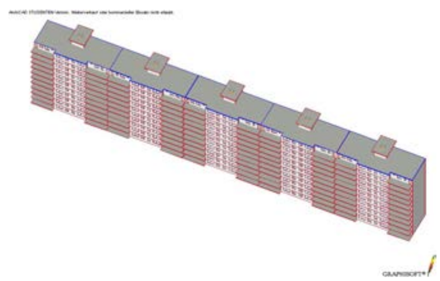
Figure 1D: Typical Building

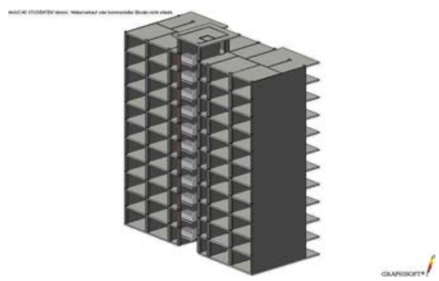
Figure 2A: Key Load-Bearing Elements

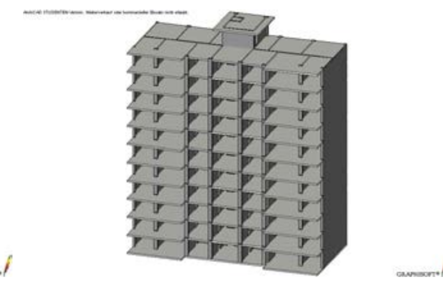
Figure 2B: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 0.07 meters.

2.2 Building Configuration

Buildings of this type are of rectangular shape, with a very large length/width aspect ratio (of over 10). Each building consists of several (5-6) identical building units (tronsons in Romanian) of rectangular shape separated by means of seismic joints. "OD" in Romanian stands for Double Orientation ("Orientare Dubla") - meaning that the larger apartments have light from two sides (i.e. in the morning and in the afternoon) in different rooms. This building type is characterized with a so-called "honeycomb" ("fagure" in Romanian) building plan typical for the Romanian housing design. It consists of smaller box-type units creating rooms. In this system, there are no corridors, and the rooms are connected only by means of openings (doors and windows). This construction is characterized with large cantilevered balconies. One window and door opening per room, in some cases with a door leading to balcony/loggia. The total window area is about 25% of the overall wall area, and the total door area is even smaller. The walls with windows are generally not load-bearing structures.

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. Each building unit (tronson) contains four apartments per floor, with a 1.2 m wide staircase, a 4-person elevator, the main entrance with a double door, and the secondary entrance with single door. For a typical 10-11 storey building, 44 flats or about 110 persons use the above described means of escape for evacuation (note that each building typically consists of 5 to 6 building units).

2.4 Modification to Building

No modifications were observed.

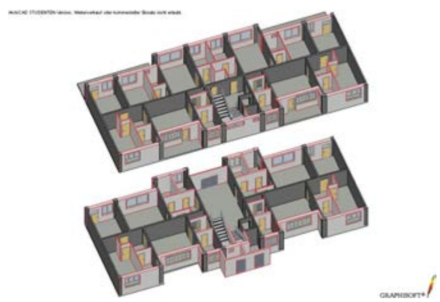

Figure 2C: Key Load-Bearing Elements- a typical building unit (tronson)

Figure 2D: Key Load-Bearing Elements - a typical building unit (tronson)

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	☐
		17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐

Structural concrete	Moment resisting frame	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 others (described below). This building type is characterized with a so-called "honeycomb" ("fagure" in Romanian) building plan characteristic for the Romanian housing design. It consists of box-type units creating rooms. Due to such building configuration, the walls are well connected and are able to carry the loads in a uniform manner. The walls are supported by 120 mm reinforced concrete solid slabs clamped in the walls and elastically supported by the facade beams. These buildings are typically supported by mat foundations.

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 supported by RC slabs. The walls are continuous throughout the building height and laid in two directions, with only one centrally located wall in the longitudinal direction and eight walls in the transverse direction (four are continuous over the building width, and other four are of smaller length). The transverse shear walls end on facade with "bulbs"- boundary elements. Wall thickness is on the order of 140 mm. Walls are rather lightly reinforced, with one layer of 12 mm diameter vertical bars and 8 mm horizontal bars. The reinforcement spacing varies from 150 mm (longitudinal direction) to 250 mm (transverse direction) on centre. There are light concrete partition walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 137.5 and 137.5 meters, and widths between 11.5 and 11.5 meters. The building has 10 to 11 storey(s). The typical span of the roofing/flooring system is 4.5 meters. Typical Plan Dimensions: Length of a building unit (tronson) = 27.5 m; length of entire building (with 5 tronsons) = 137.5 m Typical Span: Spans are variable in the range from 2.2 m to 4.6 m (based on the available information). The typical storey height in such buildings is 2.6 meters. The typical structural wall density is up to 5 %. 1.4% - 4.8% 1.4% in the longitudinal direction and 4.8% in the transverse 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	☐

The Bucharest area is located on non-homogeneous alluvial soil deposits. The buildings usually rest on mat foundations.

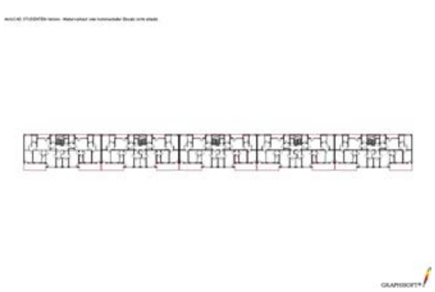

Figure 3: Plan of a Typical Building

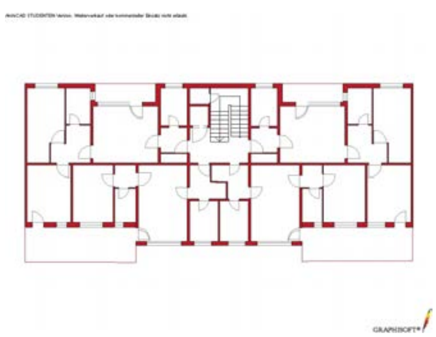

Figure 3B: Plan of a Typical Building Unit (tronson)

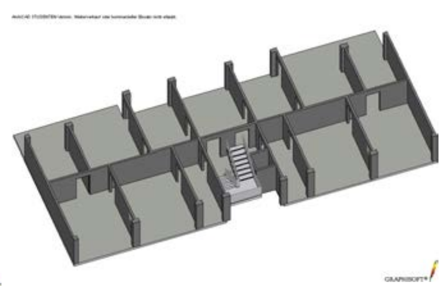

Figure 4A: Key Seismic Features - Shear Wall Layout (note only one shear wall in the longitudinal direction)

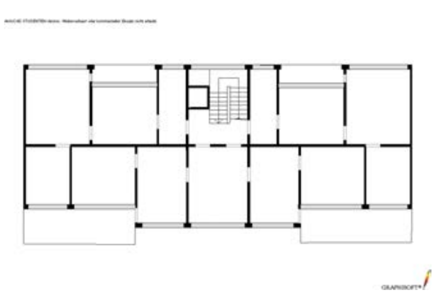

Figure 4B: Key Seismic Deficiencies - Significantly Smaller Wall Density in the Longitudinal Direction

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). The number of inhabitants in a building during the day or business hours is others (as described below). The number of inhabitants during the evening and night is others (as described below). About 120 people inhabit each building unit ("tronson"); there are typically 5 tronsons per building.

4.2 Patterns of Occupancy

One family per housing unit (apartment).

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 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 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 (based on visual inspection of			

Quality of workmanship	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
Shear Walls	- Inadequate (too small) wall thickness of 140 mm; - Inadequate wall density in the longitudinal direction (one shear wall only); - Significantly different wall density in the two principal directions (i.e. larger wall density in the transverse direction); - Lack of ductility and inadequate amount of reinforcement (especially in the transverse direction);	- Large stiffness, resulting in small displacements and minimized damage to nonstructural elements;	- Damage was more pronounced in the longitudinal wall (vertical and inclined cracks); - Cracking in the transverse walls was more pronounced at the lower levels where extensive "X" cracks developed in the piers between the door openings); - Brittle failure of wall end zones with spalling and bursting of the concrete at the base and buckling of reinforcement bars; - see Figures 5C and 5D
'"Bulbs"-Boundary Elements'-boundary elements	- Inadequate cross-sectional dimensions (too small); - Inadequate reinforcement (10-12 mm dia longitudinal bars, very scarce ties (300 mm spacing on centre)	- Bulbs can be considered as a provision against the brittle failure; these boundary elements carry large compressive forces induced by overturning moments acting on the walls.	- Brittle failure with concrete spalling and crushing at the base and buckling of the reinforcement (OD16 building) - Crushing of concrete and reinforcement buckling at the first floor level (OD1 example) - see Figure 5E
Lintels	- Too small depth (around 500 mm) due to the reduced floor height (2.60 - 2.70 m)	- Energy dissipation	- Extensive cracking
Other	- Actual gravity loads were larger as compared to the design loads due to finishing works and some flower pots at the balconies. - construction deficiencies: variation in concrete strength, honeycombing of concrete (especially in boundary elements); - inadequate construction of seismic joints (Figure 5D)		

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)

This region is well known as a seismically prone area, with the epicenter of damaging earthquakes dose to Vrancea. Earthquakes with the Richter magnitude of over 7.0 occur once in 30 years. Bucharest, the capital, is located around 150 km south of the epicenter and lies in the main direction of the propagation of seismic waves. The Bucharest area is located on the banks of the Dâmbovita and Colentina river, on non-homogeneous alluvial soil deposits. During the earthquake of 4 March 1977 (Richter magnitude 7.2), over 30 buildings collapsed in Bucharest, killing 1,424 people. It should be noted that the buildings of "OD" type suffered damages of various extent in the 1977 earthquake, and one building unit ("tronson") totally collapsed (that was the only shear wall building that collapsed in the earthquake). Buildings with their longitudinal direction aligned parallel with the direction of seismic waves (mainly in Berceni and Drumul Taberii areas of Bucharest) were most affected. The damage patterns were the strongest on the OD16 site. The earthquake action in 1977 was mainly in NNE-SSV direction. Out of 167 building units ("tronsons") of the "OD" type existing in Bucharest at the time of the 1977 earthquake, only 7 were lightly damaged; the remaining building units suffered a partial collapse (7 units) or were damaged (19 significantly damaged, 72 moderately damaged, 61 lightly damaged) Balan (1982), Argent (1998). According to the reports, damages to this construction type were due to inadequate wall density in the longitudinal direction, inadequate amount and detailing of wall reinforcement, lack of lateral confinement in the walls and in the boundary elements ("bulbs") causing brittle concrete failure and buckling of reinforcement. In addition, quality of concrete construction was found to be rather poor. No damages to the buildings of this type were observed in the 1986 and 1990 earthquakes. In the 1977 earthquake (M 7.2), no significant damages were observed on other buildings of similar construction (as discussed in Section 5.2).

Figure 5A: Collapse of OD16 Building in the 1977 Vrancea Earthquake

Figure 5B: Building Collapse in the 1977 Vrancea Earthquake (OD16 Building)

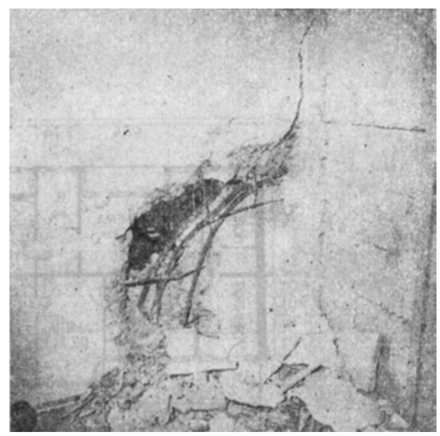

Figure 5C: Typical Earthquake Damage in RC Shear Walls (1977 Vrancea Earthquake)

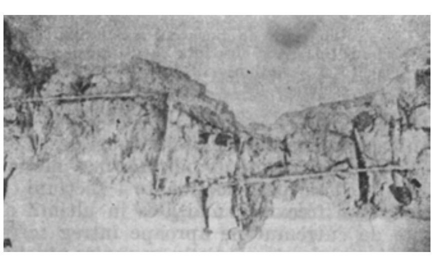

Figure 5D: Typical Earthquake Damage in RC

Figure 5E: Typical Earthquake Damage to a

Shear walls; note cracking in the construction joint (1977 Vrancea Earthquake)

Boundary Element (bulb) (1977 Vrancea Earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Reinforced Concrete	Concrete:cube compressive strength 25 MPa Reinforcement: tensile strength 370 or 520 MPa		
Foundation	Reinforced Concrete	Concrete:cube compressive strength 25 MPa Reinforcement: tensile strength 370 or 520 MPa		
Frames (beams & columns)	Reinforced Concrete	Concrete:cube compressive strength 25 MPa Reinforcement: tensile strength 370 or 520 MPa		
Roof and floor(s)	Reinforced Concrete	Concrete:cube compressive strength 25 MPa Reinforcement: tensile strength 370 or 520 MPa		

6.2 Builder

These buildings were built as residential construction by the government-owned companies.

6.3 Construction Process, Problems and Phasing

Between 1960-1990 all construction was performed by government-owned companies. Technical professionals were involved in the construction. 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

The quality of design and construction was ensured by "The State Inspection for Construction". Design professionals (engineers and architects) were involved in the design and construction of this type.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. P13-1970, STAS 8000-67. The year the first code/standard addressing this type of construction issued was 1963. The code reffers explicitly to seismic design of buildings (issued in 1963 and revised in 1970) P13-1963, P13-1970; the latest Code is P100-1992. The most recent code/standard addressing this construction type issued was 1996. Title of the code or standard: P13-1970, STAS 8000-67 Year the first code/standard addressing this type of construction issued: 1963 National building code, material codes and seismic codes/standards: The code reffers explicitly to seismic design of buildings (issued in 1963 and revised in 1970) P13-1963, P13-1970; the latest Code is P100-1992 When was the most recent code/standard addressing this construction type issued? 1996.

Many buildings of this type were designed according to the P.13-1963 Romanian Code, although the Code was changed in 1970 (P13-1970). The P13-1963 Code considered a magnitude 7 earthquake for the Bucharest area.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and 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) and Tenant(s).

6.8 Construction Economics

At the time of the original construction (1974) the unit cost was 1170 lei/m². The information is not available as the construction company ceased to exist in 1990.

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. There is "The Voluntary Complex Insurance of the Households and Physical Persons" through ASIROM.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Shear walls: inadequate wall thickness and reinforcement	- Cast in-situ RC jacketing of the boundary elements-bulbs (see Figure 6). A special care is taken to ensure the adequate bond between the new and existing concrete. - Jacketing with glass fibre woven fabric and epoxy resins in the severely damaged areas.
Cracks in shear walls and lintels	Small cracks - injecting the cracks with epoxy grout; Large cracks - filling the cracks with epoxy mortar (paste);
Small cracks in shear walls and lintels	Crack injections with epoxy resins. This was the most widely used method to repair the damages after the 1977 earthquake. The domestic resin DINOX 10L was used per the INCERC technology (C. 183-77). The injection is applied by cleaning the surface, making the injection holes and applying the resin.

The above described methods are used for seismic retrofit of RC structures in Romania. These methods were used for retrofitting the buildings OD16 and OD1 damaged in the 1977 earthquake.

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?
Seismic strengthening was performed in the design practice after the 1977 earthquake. Many buildings in Bucharest were damaged in the 1977 earthquake, however the strengthening was not performed in most cases. For that reason, in 1999-2000 the Ministry for Public Works (MLPA) established a special committee to evaluate seismic resistance and possible retrofit requirements for this construction type according to the P100-1992 Code (latest edition issued in 1996). The scale of work and financial resources required for the retrofit are quite significant. As a result, the progress is rather slow and in case of an earthquake a significant life and property loss could be expected.

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 earthquake damage.

8.3 Construction and Performance of Seismic Strengthening

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

Yes, the construction was inspected through "The State Inspection for Construction Works".

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

The construction was performed by a specialized state agency.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
The strengthening was performed after the 1977 earthquake. The 1986 and 1990 earthquakes were not very strong and did not cause damages to the strengthened buildings.

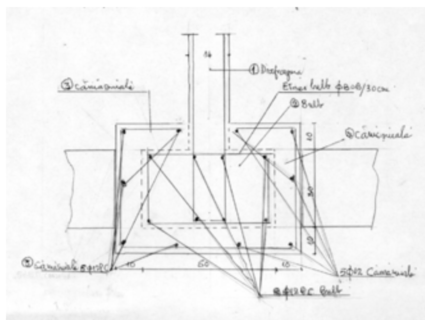

Figure 6: Illustration of Seismic Strengthening Techniques-Retrofit of Boundary Elements (bulbs)

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