World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

an initiative of
Earthquake Engineering Research Institue (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Medium/high rise moment resisting reinforced concrete frame building

Report#	97
Last Updated	
Country	Romania
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Reviewers	Svetlana N. Brzev,

Important

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General Information

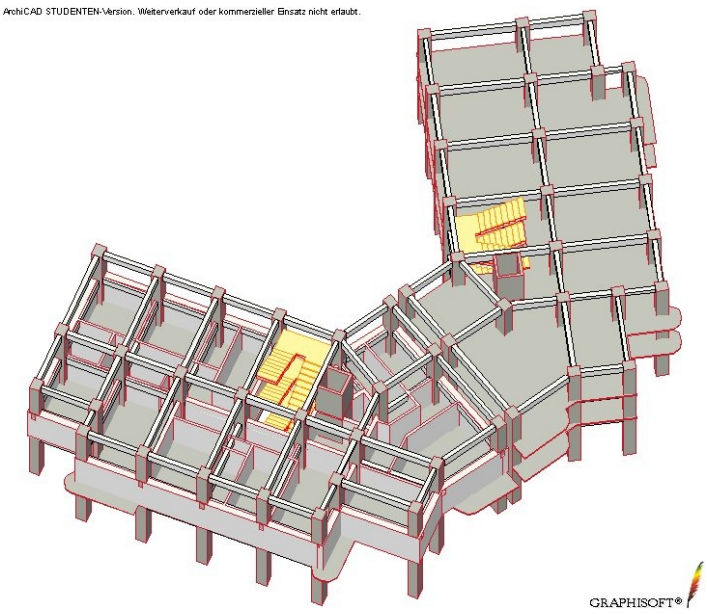
Building Type:	Medium/high rise moment resisting reinforced concrete frame building
Country:	Romania
Author(s):	Maria D. Bostenaru
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Romania. According to Balan (1982), 90% of the building stock inRomania at the time of writing, was built after 1950. In Bucharest itself, between 1950 and the earthquake thatoccurred in 1977, a total of around 400,000 new residential apartment units were constructed, and two thirds of thesewere housed in medium rise constructions. Out of the latter about 4% where built using a reinforced concrete framestructure. This type of housing construction is commonly found in urban areas.
Summary:	Such buildings generally range from 10 to 17 storeys in height with the ground floor being usedfor commercial purposes, whilst the upper floors house residential units. The vertical loadbearing structure consists of moment-resisting reinforced-concrete frames which also generallyserve as the lateral load-resisting system. However, when larger spans are encountered,reinforced-concrete structural walls are included to provide a dual structural system. Masonryinfills built from lightweight concrete masonry units provide architectural space delineation.The seismic performance of such buildings constructed prior to 1977 varies from no damageto complete collapse. To date damage has usually been attributable to conceptual andconstruction mistakes.
Length of time practiced:	Less than 25 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 20-49 unitsMixed residential/commercial

Typical number of stories:	4-18
Terrain-Flat:	Typically
Terrain-Sloped:	3
Comments:	After 1990 new buildings were no longer constructed in thearchitectural socialist post-modern style. Two buildings of this latte

Features

Plan Shape	Square, solidRectangular, solidL-shapeU- or C-shape
Additional comments on plan shape	The plan shape can be any shape, but most typically it is either a rectangular, square, L or U layout.
Typical plan length (meters)	12.7-30
Typical plan width (meters)	12-17
Typical story height (meters)	2.75
Type of Structural System	Structural Concrete: Moment Resisting Frame: Designed for gravity loads only, with URM infill walls
Additional comments on structural system	The vertical load-resisting system is reinforced concrete moment resisting frame. Monolithic cast in-situ reinforcedconcrete slabs transfer the gravity loads to the reinforced concrete beam and column framing down to the foundation.Various architectural requirements give rise to particular cases, such as where window openings result in the beamsbeing cast as up-stands rather than down-stands. Furthermore, in some cases brick masonry infills might actually carry some local vertical load.The lateral load-resisting system is reinforced concrete moment resisting frame. The main lateral load resisting systemis provided by the reinforced concrete moment resisting frames. The infills then, although notaccounted for in design, invariably contribute to the building's stiffness. The use of a higher storey height for the lowerfloor for commercial purposes gives rise to an increased likelihood of a soft storey mechanism.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in	

Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	5-10%
Additional comments on typical wall densities	The typical structural walldensity is up to 10 %. The above values are for the (lightweight concrete) infill walls.
Wall Openings	Openings areformed in the masonry infill (see fig. 2,2B and 2C). Since the masonry infill is usually out of light concrete (betoncelular autoclavizat), the position and size of openings is not generally considered to influence the structuralcharacteristics at the design stage.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	The light partition/infill walls have allowed for numerous modifications to the interior spaces of these buildingswithout directly influencing the geometrical characteristics of the main reinforced concrete structural members. After1990 many facades of these constructions have been modified with balconies being closed off and included in the glassand metal facade structures installed.
Type of Foundation	Shallow Foundation: Mat foundation
Additional comments on foundation	Probably other foundation forms are encountered, such as piles in certain cases.
Type of Floor System	Other floor system
Additional comments on floor system	Solid slabs (cast-in-place); Solid slabs (precast)
Type of Roof System	Roof system, other
Additional comments on roof system	Solid slabs (cast-in-place); Solid slabs (precast)
Additional comments section 2	



Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Interior (partition) infill Walls: first brick masonry thenlight concrete ('beton celular autoclavizat') masonry then light beton strips. Facade infill walls: first brickmasonry then light concrete ('beton celularautoclavizat') masonry then light beton strips orreinforced concrete precast panels in sandwich type.	Interior (partition) infill Walls:1956-1963: 25cm brick masonryFacade infill walls: 1956-1963:37,5cm brick masonryUsed also forjacketing of thecolumns, in order toavoid thermalbridgingand also foraesthetic purposes.
Foundations	reinforced concrete	older constructionused B170 and B200,and later B300. (250daN/cm2)
Floors	reinforced concrete	initially B170 andB200, later (1974-76)B300. (250daN/cm2) ex 8cmover concrete on 5cm"predale"(prefabricated slab)1974-76: precast semi-panels withlarge in-situ zones or with overconcrete 'predale', or, in some cases,15cm thick cast-in-

		place concrete'dale'.In-situ topping on 5cm thickprefabricated"predale" type slabs.
Roof	reinforced concrete	initially B170 andB200, later (1974-76)B300. (250daN/cm2) ex 8cmover concrete on 5cm"predale"(prefabricated slab)1974-76: precast semi-panels withlarge in-situ zones or with overconcrete 'predale', or, in some cases,15cm thick cast-in-place concrete'dale'.In-situ topping on 5cm thickprefabricated"predale" type slabs.
Other	reinforced concrete	initially B170 andB200, later (1974-76)B300. (250daN/cm2)Columns: 1974-76: 60x70-80cm atground floor and first floor, reducedsections at upper floors. Beams:1974-76: constant section at allfloors: 30x65cm in the interior and30x55cm on the perimeter.Columns: cast-insituBeams: cast-insitu andvery rarely precast.

Design Process

Who is involved with the design process?	EngineerArchitect
Roles of those involved in the design process	The architectural plans are developedby architects. Structural design and construction supervision is typically carried out by engineers.
Expertise of those involved in the design process	State enterprises provide all professional architectural and engineering services.

Construction Process

Who typically builds this construction type?	BuilderOther
Roles of those involved in	The builder does not typically live in this

Roles of those involved in the building process	construction type as they were not built by developers but by stateenterprises.
Expertise of those involved in building process	
Construction process and phasing	Little data are available, apart from the obvious steps in constructing an RC framed building. Theconstruction of this type of housing takes place in a single phase. Typically, the building is originally designed for itsfinal constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	This construction type is addressed by the codes/standards of the country. P.13-70. The year the firstcode/standard addressing this type of construction issued was 1970. The most recent code/standard addressing thisconstruction type issued was 1992. March1977: new seismic zonation (decree 66) > new zonation standard in 1978. March 1977: publishing for publicdiscussion the project of the law nr. 8 regarding the durability, the safety in usage, functionality and quality ofconstructions > new anti-seismic design code (normative): P.100-78, later improved in P.100-1981, containing newprescriptions regarding the set-up of cast-in-place and precast reinforced concrete, metal and masonry constructions. Ittook in consideration the new zonation, and accentuated the reduction of construction weight, and the rational shapeof the assembly, computing coefficients were changed, the computing of displacements prescribed in order to avoidpounding damage, ductility was desirable, and also the execution conditions were prescribed (work phases).Documents were made immediately after the earthquake also regarding reparation measures (technical instructions).The document from 1981 did not bring radical modifications, but more precision (regarding the dynamic coefficientdepending on local site conditions, limits of relative displacements and the way to evaluate these, computing methodsfor eccentricity etc). The main completions regard installations and an annex considering spatial oscillations.

Process for building code enforcement	There used to be a quality control organization, CTC (Control Tecnic de Calitate services).

Building Permits and Development Control Rules

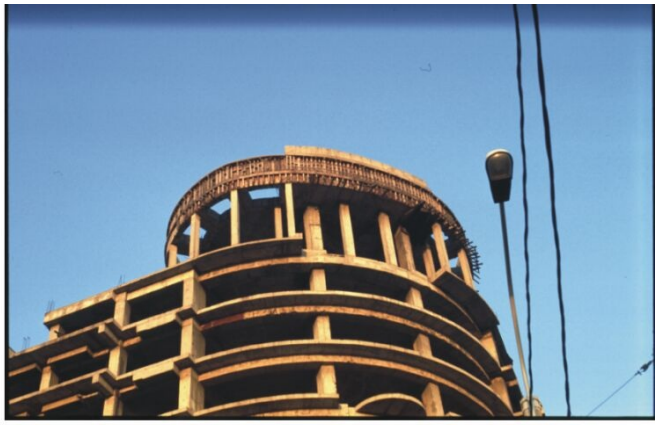
Are building permits required?	Yes
Is this typically informal construction?	No
Is this construction typically authorized as per development control rules?	Yes
Additional comments on building permits and development control rules	

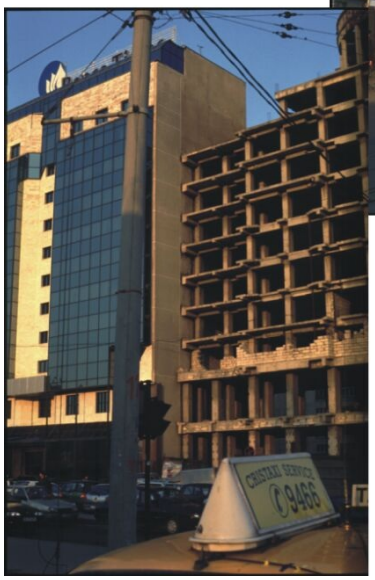
Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	No available data.
Labor requirements	No available data.
Additional comments section 3	





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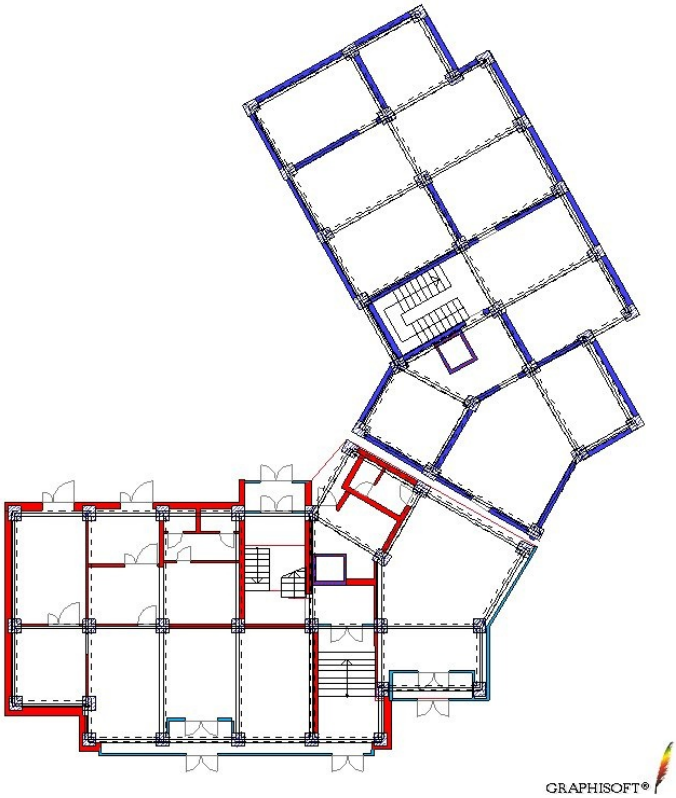

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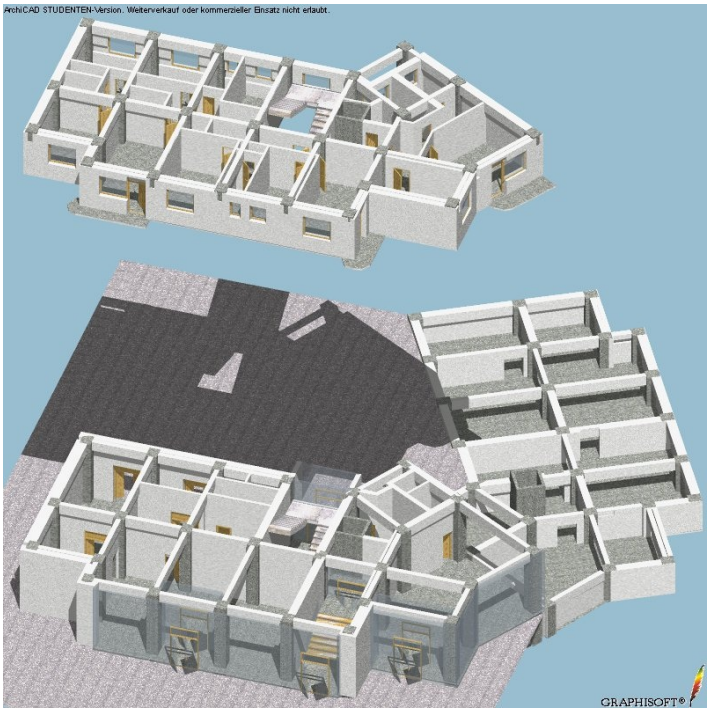

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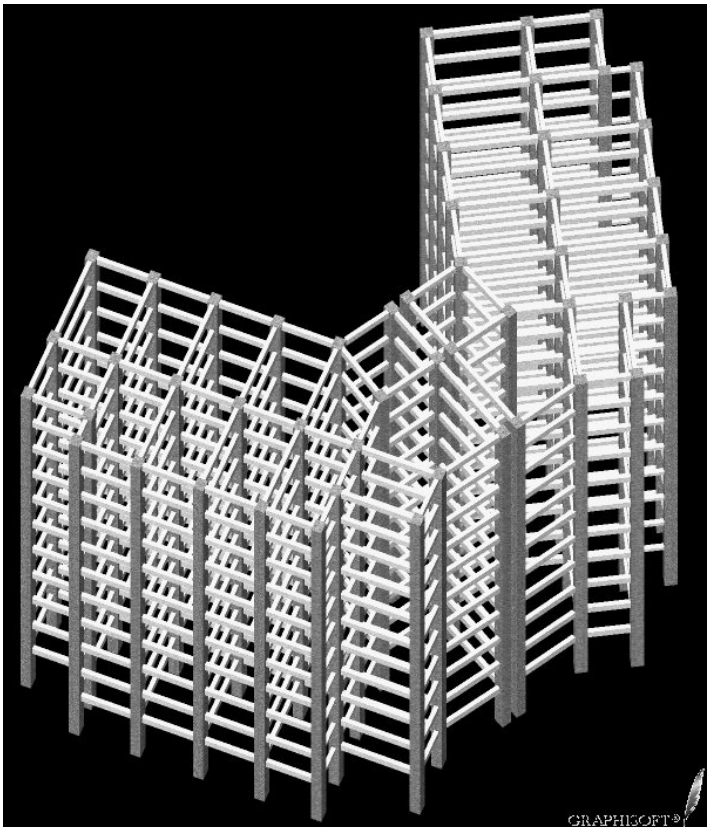
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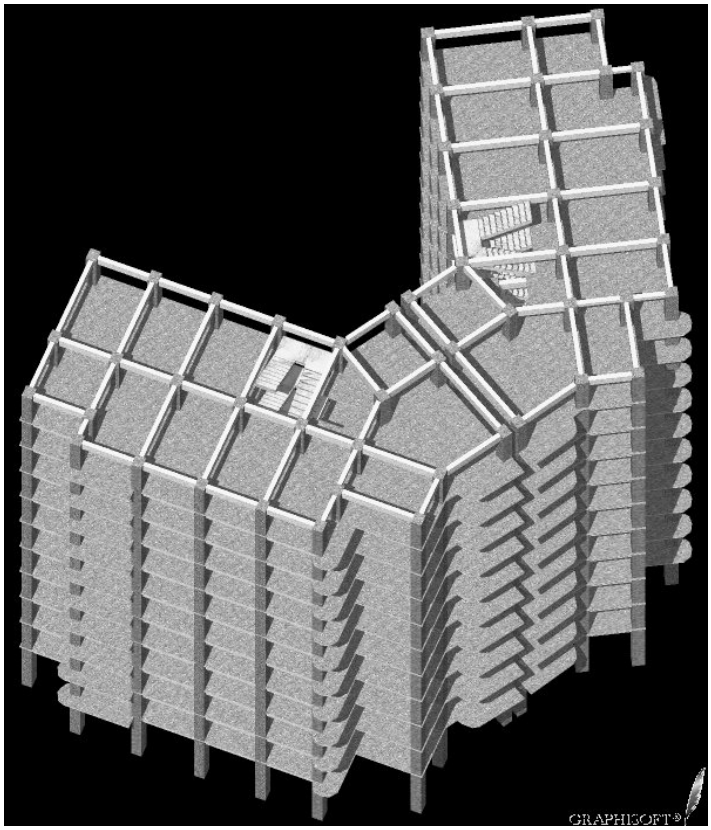
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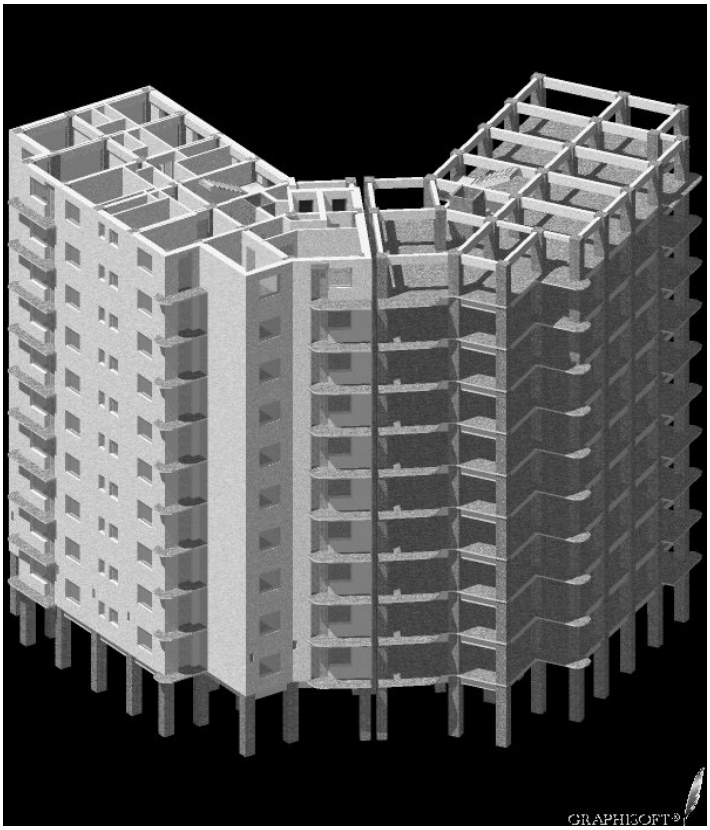
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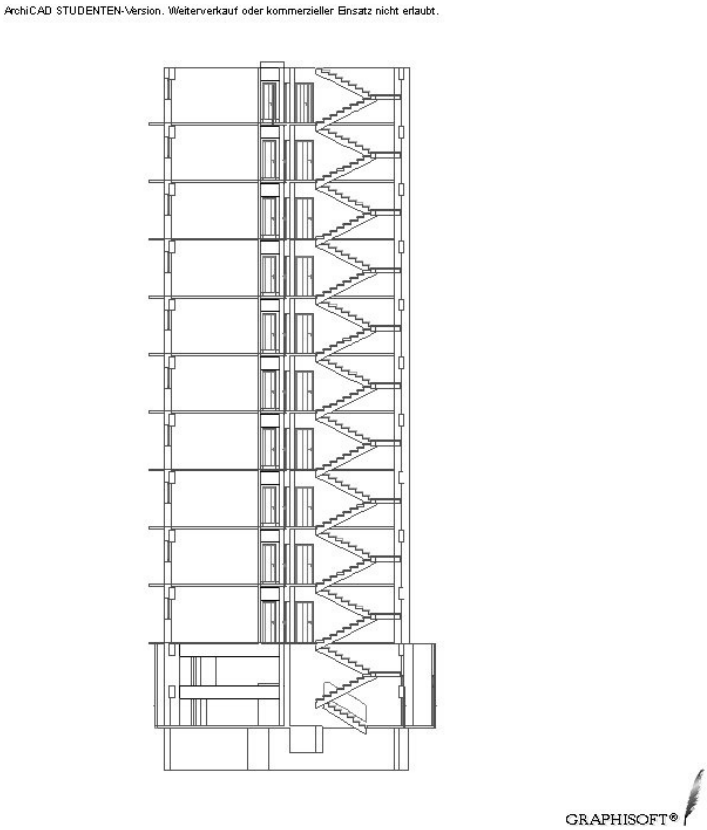
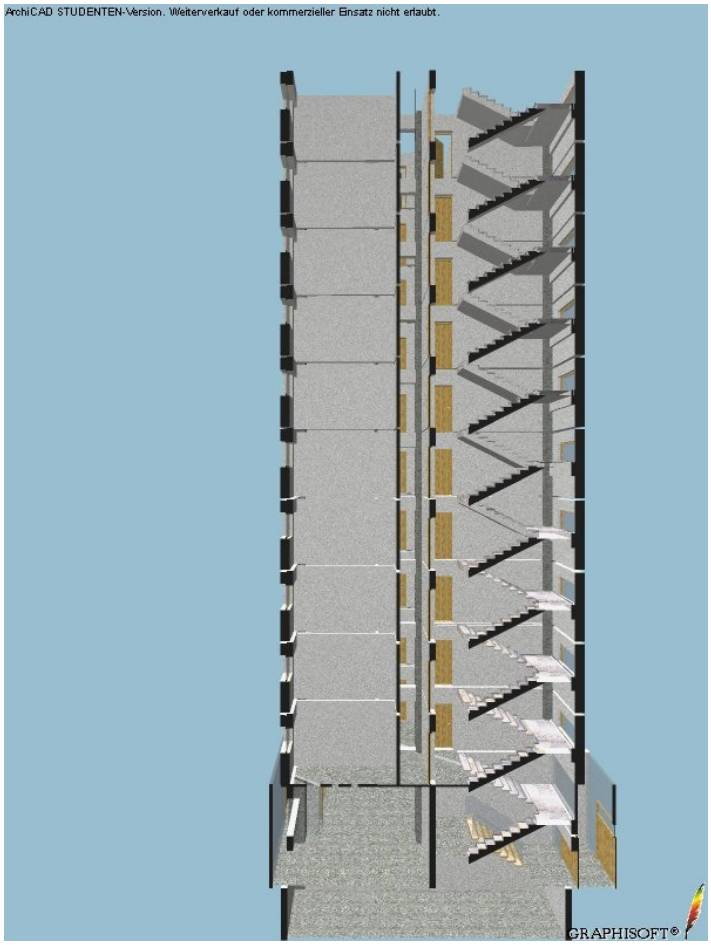




Socio-Economic Issues

Patterns of occupancy	One family occupies a single flat.Each building typically has 30 housing unit(s).
Number of inhabitants in a typical building of this construction type during the day	>20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	
Economic level of inhabitants	Middle-income class
Additional comments on economic level of inhabitants	
Typical Source of Financing	Government-owned housingOther
Additional comments on financing	Originally the buildings were constructed with government financing and then rented out. The tenants later had theopportunity to buy their apartment at a favorable price, given that they had rented them for a certain amount oftime.
Type of Ownership	RentUnits owned individually (condominium)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Yes
Additional comments on premium discounts	

Additional comments section 4	According to "Magazinul Romnesc" 2% of the residences were earthquake assured by the timeof the 2004 earthquake. According to "Magazinul Romnesc" the insurance costs 0,3-0,5% of the value of theresidence.

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1977	Vrancea
1986	Vrancea
1990	Vrancea
2004	Vrancea

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	According to Balan (1982), during the 1977 earthquake, damage was typically concentrated locally in the reinforcedconcrete columns and beams on the ground floor and up to the fourth storey. Furthermore, severedamage to the masonry infill walls was evidenced as well.
Additional comments on earthquake damage patterns	Weak storey: slender columns, concrete spalling, buckling of thereinforcement in plastic hinge locations. Central andshort columns suffer, stirrup rupture, column dislocation, cracks,brittle failures especially at the intersection with staircases which giverise to a captive column effect. Typical storeys: In the columns,horizontal cracks directly under/over the beams, orthogonally to thecolumn axis, concrete spalling, buckling of the reinforcement bars atplastic hinges, inclined X-shaped cracks. In thebeams, larger span beams suffer from concrete spalling in the plastichinge zones. Cracks in the beam-column connections. Inshorter span beams, inclined cracks on the lower half of the beams.Inclined X-shaped cracks, vertical flexural cracks in secondary beams. Superficial cracks in the plastering, separation cracks on the

	perimeter.Inclined X-cracks, sliding failure in the first storey and atconstruction joints, partial or complete failure of the masonry, deformation of the window frames with glass breakages, cracksin the lintels, disintegration of the partition walls especially whereconstruction joints are present. Cracks in the lower storeys, at interaction with central and shortcolumn.

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

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.

Structural/Architectural Feature	Statement	Seismic Resistance
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.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
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.	TRUE
Floor Construction	The floor diaphragm(s) are considered to be rigid and it is expected	TRUE

	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.	N/A
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
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);	N/A
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	N/A
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	TRUE
Quality of Workmanship	Quality of workmanship	TRUE

	(based on visual inspection of a 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).	TRUE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	
Earthquake-resilient features in walls	
Seismic deficiency in frames	Where commercial premises are housed a softstorey mechanism can be prevalent, due to thelarger storey heights and possible larger spans. During the structural design,the influence of the masonry infills is not takeninto account. The amount of reinforcement inthe main structural members is not alwaysexactly prescribed. The detailing of the beam-columnconnections. Poor construction materialquality, mistakes during construction, such asout-of-plumb columns. Where precast structuralmembers are used the connections are a causeof concern.
Earthquake-resilient features in frame	A regular andthree dimensionalcolumn grid givingrise to a robustmoment resistingspatial framesystem. In somebuildingsstructuralreinforcedconcrete walls areincorporated togive rise to a dualsystem.

Seismic deficiency in roof and floors	
Earthquake resilient features in roof and floors	Stiff cast in-situ floors
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines]

	High vulnerability		**Medium vulnerability**		**Low vulnerability**	
	A	B	C	D	E	F
Seismic vulnerability class	o					

Fig. VI.54. — Blocul de locuinţe şi magazine „ALMO-Obor" din Bucureşti. Clădire nouă cu structura în cadre de beton armat monolit (parter şi 10...16 etaje): a — Vedere de ansamblu; b — Avarii la faţada interioară; c — Avarii la capătul superior al unui stîlp (mezanin); d — Fisuri înclinate la o grindă (rost de turnare defectuos).

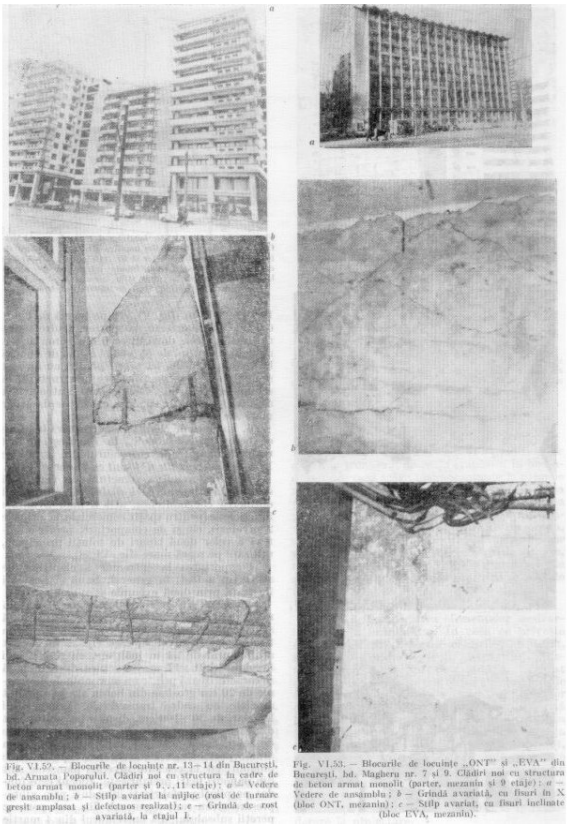


Fig. VI.59. — Blocurile de locuinţe nr. 13–14 din Bucureşti, bd. Armata Poporului. Clădiri noi cu structura în cadre de beton armat monolit (parter şi 9...11 etaje): a — Vedere de ansamblu; b — Stîlp avariat la nădşoc (rost de turnare greşit amplasat şi defectuos realizat); c — Grindă de rost avariată, la etajul I.

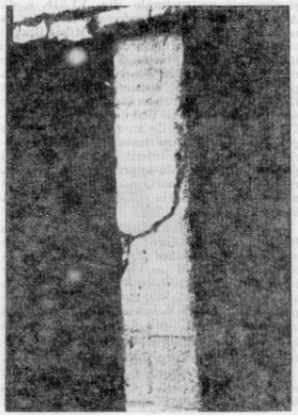
Fig. VI.53. — Blocurile de locuinţe „ONT" şi „EVA" din Bucureşti, bd. Magheru nr. 7 şi 9. Clădiri noi cu structura de beton armat monolit (parter, mezanin şi 9 etaje): a — Vedere de ansamblu; b — Grindă avariată, cu fisuri în X (bloc ONT, mezanin); c — Stîlp avariat, cu fisuri înclinate (bloc EVA, mezanin).

a

b

Fig. VI.51. — Blocuri de locuinţe din Bucureşti, şos. Pan
telimon: Clădiri noi cu cadre de beton armat (parter şi 10...
12 etaje); a — Vedere de ansamblu (bloc 48); b — Stâlp
avariat la bază (bloc 47 parter); c — Stâlp cu rupere inclinată
(bloc 47 parter); d — Stâlp avariat la capătul superior (bloc
B$_2$ etaj I).

c

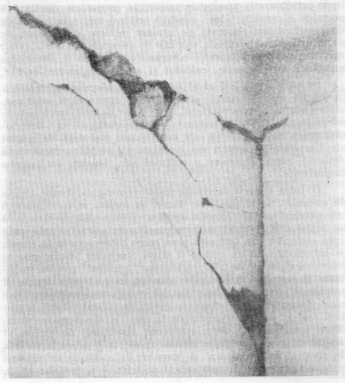


d

a

Fig. VI.47. — Avarii la elementele nestructurale de la clădirile noi de locuit din Bucureşti: a — Avarii la faţade cu pereţi din zidărie de blocuri mici de beton celular autoclavizat (Blocul de locuinţe nr. 48 din şos. Pantelimon); b — Avarii la pereţi interiori (Blocul de locuinţe nr. 9 din Calea Dorobanţi).

b



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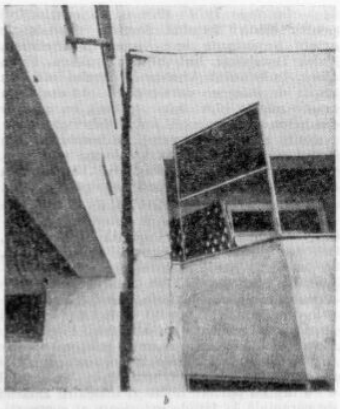
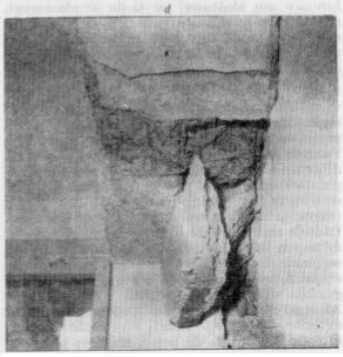


Fig. VI.49. — Blocurile de locuinţe nr. 9 şi 9B din Bucureşti Calea Dorobanţi. Clădiri noi cu structura în cadre de beton armat monolit (parter şi 8...15 etaje): a — Vedere de ansamblu; b — Stâlp de rost între cele două blocuri, la etajul VIII rupt din cauza ciocnirii blocurilor în timpul cutremurului; c — Avarii la un stâlp de la etajul X; d — Avarii la o grindă de rost, de la etajul V.

c

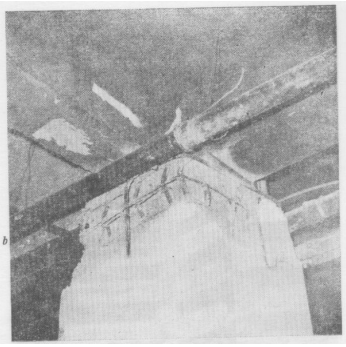
d



a

Fig. VI.50. — Blocul de locuinţe nr. 10 din Bucureşti, Calea Dorobanţi. Clădire nouă cu cadre de beton armat (parter şi 10 etaje); a — Vedere de ansamblu; b — Avarii la un stâlp de la parter (secţiuni slăbite prin trecerea conductelor de instalaţii).

b



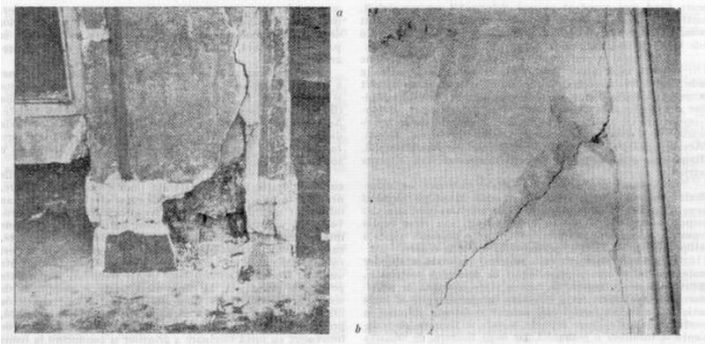


Fig. VI.45. — Stîlpi de beton armat avariaţi de cutremur la structuri în cadre, de la clădiri de locuit noi cu multe niveluri, din Bucureşti : a — Stîlp de colţ la parter, avariat la capătul inferior (Blocul de locuinţe 118 – 128 din şos. Ştefan cel Mare) ; b — Stîlp de la parter, cu rupere înclinată (Blocul de locuinţe nr. 10 din Calea Dorobanţi).

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
superficial rifts in reinforcedconcrete elements	epoxy resin injection
deep rifts, concrete spalling inreinforced concrete elements	recasting of concrete, eventually with local jacketing
break of concrete andreinforcement in reinforcedconcrete elements	Columns: epoxy resin injection, steel/reinforced concrete jacketing; Beams: surface plating; Reinforced concretestructural walls: Jacketing, eventually with shotcrete; Reinforced concrete slabs: overconcrete; stairs: rarely shotcrete,supporting elements are added.

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Yes.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Following the 1977 Vrancea earthquake, various repairs were carried out. Nowadays buildings are being retrofitted as amitigation measure
Was the construction inspected in the same manner as new construction?	No.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Contractors performed the construction and both architecture and engineering institutions were involved.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	The performance was good but the subsequent earthquakes were weaker.

Additional comments section 6	

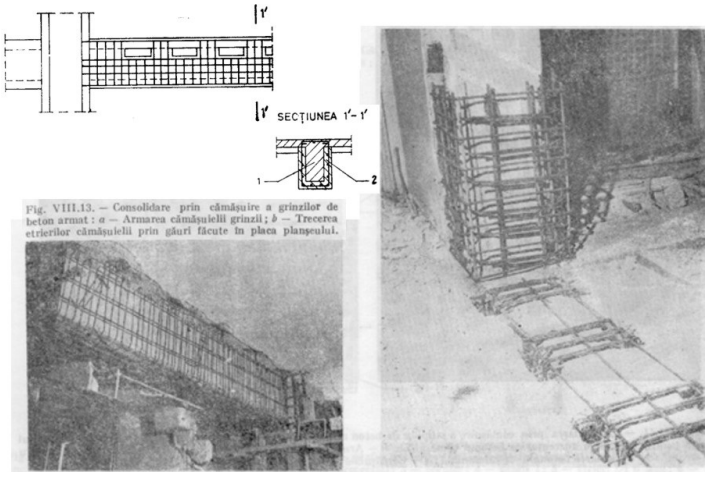
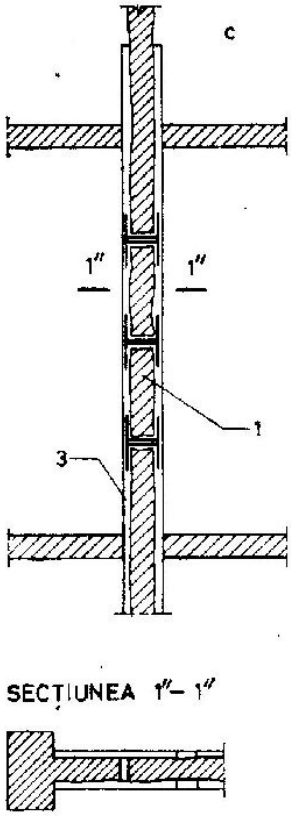


Fig. VIII.13. — Consolidare prin cămăşuire a grinzilor de beton armat : *a* — Armarea cămăşuielii grinzii ; *b* — Trecerea etrierilor cămăşuielii prin găuri făcute în placa planşeului.



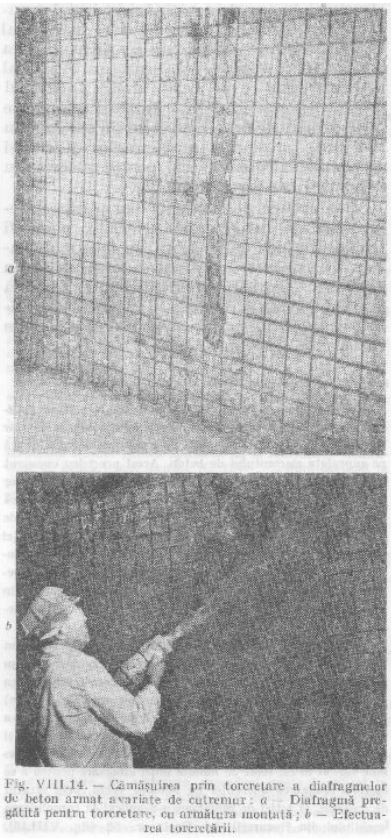


Fig. VIII.14. — Cămăşuirea prin torcretare a diafragmelor de beton armat avariate de cutremur : *a* — Diafragmă pregătită pentru torcretare, cu armătura montată ; *b* — Efectuarea torcretării.

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