World Housing Encyclopedia Report

Country: Romania

Housing Type: Precast concrete panel apartment buildings

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Created on: 10/21/2002
Last Modified: 7/2/2003

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1 General Information

1.1 Country

Romania

FIGURE 1: A typical building

1.3 Housing Type

Precast concrete panel apartment buildings

1.4 Summary

This multi-family urban housing construction was practiced in Romania between the 1960s and 1990s. The load-bearing system is a precast reinforced concrete large panel construction. Buildings of this type are typically highrises (10 or 11 stories high), although there are also low- to medium-rise buildings (4 to 8 stories high) of this construction type (with different structural details). In general, buildings of this type are of rectangular plan, with honeycomb ("fagure") layout, housing typically four apartments per floor. Wall panels are laid in both the longitudinal and the transverse direction. The panels are mechanically coupled at the base, with continuous vertical reinforcement bars.
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 on average every 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 rivers, on nonhomogenous alluvial soil deposits. During the earthquake of 4 March 1977 (Richter magnitude 7.2), over 30 buildings collapsed in Bucharest, killing 1,424 people. There was no significant damage reported to the buildings of this construction type in the 1977 earthquake. Consequently, this construction technique has continued to be practiced since the earthquake. The building described in this report was built after the 1977 earthquake, and has not been exposed to damaging earthquakes so far.

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	X
< 50 years	
< 75 years	
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
		X

Additional Comments: This construction was practiced between 1960 and 1990. In the Bucharest area, buildings of this type were initially built in 1959-1960; those were 5-storey buildings. In the period 1961-1963 some 8-storey buildings of this type were built. Between 1963 and 1973, 4-storey buildings were built. After 1973, 9-storey buildings were built. The building described in this report is an 11-storey tall building (ground floor + 10 floors). This construction practice has not been followed in the post-communist period (after 1990).

1.6 Region(s) Where Used

All major urban areas in the country.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	X
In rural areas	
In suburban areas	
Both in rural and urban areas	

2 Architectural Features

2.1 Openings

There are between 20 and 30 windows per floor. Each room has one window and one door, except for the corridors (larger number of doors). Windows constitute around 25% of the exterior wall area, whereas doors constitute less than 15% of the interior wall area.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		X
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 2.5 meters

2.3 Building Configuration

Rectangular

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	
Multiple housing units	X
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

2.5 Means of Escape

Elevator for 4 persons, staircase, main entrance door (1.60m width x 2.30m height), secondary entrance door (0.80m width x 2.20m height).

2.6 Modification of Buildings

Modifications in buildings of this type are not common.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

One family per housing unit.

3.2 Number of Housing Units in a Building

150 units in each building.

Additional Comments: In general, there are 48 to 54 housing units per building block. Each building block is centered around a staircase. There are usually between one and five building blocks in a typical building complex.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5		
5 to 10		
10-20		
> 20	X	X
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 0

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor		/
Middle Class	X	/
Rich		/

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	
Personal Savings	
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	
Other	X

Additional Comments: Before 1990, the construction was financed by funds from the central government. After 1990 (post-communist period), individual apartments are owned by the inhabitants.

3.7 Ownership

Type of Ownership/Occupancy	
Rent	
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

4 Structural Features

4.1 Lateral Load-Resisting System

The load-bearing walls are laid in two principal directions, as illustrated in Figure 9. In general, there are two interior walls in the longitudinal direction and nine walls in the transverse direction; it should be noted that four transverse walls are continuous over the building width, whereas the other five walls are shorter. In addition, there are lightweight concrete partition walls, some of which have been removed in building renovations carried out by owners.

The main lateral load-resisting structure consists of 200 mm precast reinforced concrete wall panels supported by RC slabs (walls in pre-1977 buildings are typically 140 mm thick). The wall panels form a box of room size ("panouri mari"). The lateral stability is provided by the columns tied to the wall panels, as illustrated in an example of corner panels, see Figure 12. Boundary elements are used instead of the columns as "stiffening" elements at the exterior (as shown in Figure 10). According to NBS (1977), the mechanical union of wall panels in the joints is achieved by means of splice bars welded to the transverse reinforcement of adjacent panels. Longitudinal bars, used singly in vertical joints and in pairs in horizontal joints, provide an added bearing area for the transfer of tension across the connections. The coupling of the floor panels is somewhat different, as illustrated in Figure 15a. The top bars are splice welded while the bottom bars are bent up 90 degrees and lapped. This particular scheme gives greater continuity to the floors at the supports than the lapped loop arrangement used in the high-rise building system. The wall panels are mechanically coupled at their base, as illustrated in Figure 15b, so that all vertical bars are continuous across the horizontal joints (it should be noted that in the case of the high-rise building panel connections only the longitudinal bars of vertical joints are coupled).

4.2 Gravity Load-Bearing Structure

This building type is characterized by a so-called "honeycomb" ("fagure" in Romanian) building plan characteristic for Romanian housing design - the same system is described for the "OD" housing type (World Housing Encyclopedia Report 78). It consists of box-type units creating rooms. Due to such a building configuration, the walls are well connected and are able to carry the loads in a uniform manner. Floor structures are 120 mm thick reinforced concrete solid slabs supported by the loadbearing walls. Typical wall-floor connection is illustrated in Figure 13. These buildings are supported by mat foundations. The basement walls are cast-in-place.

The special feature of the building described in this report is that the facade walls are non-loadbearing structures of lightweight block masonry construction. In some buildings of this construction type, precast concrete wall panels are used as façade elements. The interior wall panels are of solid concrete construction - in this case, there is no need for a 3-layered panel section with thermal insulation in the middle (typical for the façade wall panels).

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	X
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

4.4 Type of Foundation

Type	Description	
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	X
	No foundation	
Deep Foundation	Reinforced concrete bearing piles	
	Reinforced concrete skin friction piles	
	Steel bearing piles	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

Additional Comments: In general, these buildings are supported by mat foundations. There are cast in-situ basement walls.

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)	X	X
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
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 single roof		
	Wood planks or beams that support clay tiles		
	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			

4.6 Typical Plan Dimensions

Length: 25 - 125 meters
Width: 25 - 125 meters

4.7 Typical Number of Stories

4 - 11

4.8 Typical Story Height

2.6 meters

4.9 Typical Span

4 meters

Additional Comments: The span ranges from 2.5-5.5 m

4.10 Typical Wall Density

5% - 7%
Wall density is larger in the transverse direction.

4.11 General Applicability of Answers to Questions in Section 4

This report has been prepared based on a case study of an apartment in a residential building of this type. Low- and mid-rise buildings present structurally different details. Also, structures with load-bearing or at least pre-cast facade walls are more typical.

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	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 form the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
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.	X		
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.	X		
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.	X		
Wall and frame structures- redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.			X
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	X		
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).	X		
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	X		
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	X		
Other				

Additional Comments: The buildings described in this report were designed in accordance with the P100-81 norm (the 1981 edition of the Romanian seismic standard).

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall		- Large panel stiffness; redundancy provided by several wall panels in both directions with frequent cross walls; regular and symmetric plan; good quality of concrete construction.	According to the reports on the 1977 earthquake (Balan et al. 1982), some buildings of this type experienced cracking in the wall panel connection area, especially at the wall corner joints and intersections, and wall-floor connections. In some cases, those were existing cracks that were widenend in the 1977 earthquake. However, in the city of Iasi (north of the epicentre), 45° cracks developed in the walls especially above the openings and around the staircases in some 8-storey buildings built around 1960.
Frame (Columns, beams)			
Roof and floors		- Rigid floor and roof structures;	
Other			

Additional Comments: Inofrmation on earthquake damage patterns is based on other buildings of similar construction that experienced the 1977 earthquake. The building described in this report was built after the 1977 earthquake.

5.3 Seismic Vulnerability Rating

Vulnerability						
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class			<	0	>	

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1986	Vrancea	7	8 (MMI)
1990	Vrancea	6.7	7 (MMI)

Additional Comments: No damage to buildings of this type was observed in the 1986 and 1990 earthquakes. In the 1977 earthquake (M 7.2), no significant damage was observed to other buildings of similar construction (as discussed in Section 5.2).

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	reinforced concrete: steel	Steel PC 52 - steel yield strength 350 MPa; Concrete: around 1970s, typical concrete strength was in the range of 25 MPa (cube strength)		Information on concrete and steel properties is in agreement with the reports after the 1977 earthquake (e.g. NBS 1977)

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

Buildings of this type were financed by government housing funds and were built by construction companies.

7.3 Construction Process

The construction was performed using specialized equipment for prefabricated construction.

7.4 Design/Construction Expertise

The building design was developed by "Design Institutes", which employ trained technical specialists, including engineers and architects. The construction was made by technical specialists employed by the construction companies using the specialized equipment. The construction was additionally supervised by a special unit called "State Inspection for Buildings".

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

Title of the code or standard: P-100-81
Year the first code/standard addressing this type of construction issued: 1981
When was the most recent code/standard addressing this construction type issued? 1992

7.6 Role of Engineers and Architects

The building design was done by engineers and architects employed by the "Design Institutes". The construction was also performed by technical specialists employed by the construction companies.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required	X	
Informal construction		X
Construction authorized per development control rules	X	

Additional Comments: Building permits were required in the period when this construction was practiced. Building inspection was performed by the construction company staff and also through a special government department called "State Construction Inspection".

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)		X
Building originally designed for its final constructed size	X	

Additional Comments: In some cases, new building blocks were built at the same location (see comments in the Section 1.5), however these new blocks were built as completely new buildings, with their own walls and foundations.

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	
No one	
Other	

7.10 Process for Building Code Enforcement

Information not available.

7.11 Typical Problems Associated with this Type of Construction

Information not available.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

The 1991 price was 2590 lei/m.sq. of the built area (176 USD/m/sq/.). Note that this is a real estate price (reflecting the value of an existing building) and not the cost of new construction (which is not available).

8.2 Labor Requirements (estimate)

Information not available, as the construction company no longer exists.

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available	X	
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

Additional Comments: There is "Voluntary Complex Insurance of the Households of Physical Persons" through "S.C. ASIGURAREA ROMÂNEASCA - ASIROM S.A." (public company)

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

Based on the good performance of buildings of similar construction in the 1977 earthquake, it is considered that retrofit is not required.

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

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

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

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

11 References

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Smighielschi, S. (1990). Course notes on Building Construction, Architectural Institute "Ion Mincu", Bucharest, Romania.

NBS (1977). Observations on the Behavior of Buildings in the Romania Earthquake of March 4, 1977. U.S. Department of Commerce/National Bureau of Standards, NBS Special Publication 490, Washington, D.C., USA.

12 Contributors

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13 Figures

FIGURE 1: A typical building

FIGURE 2: A corner view

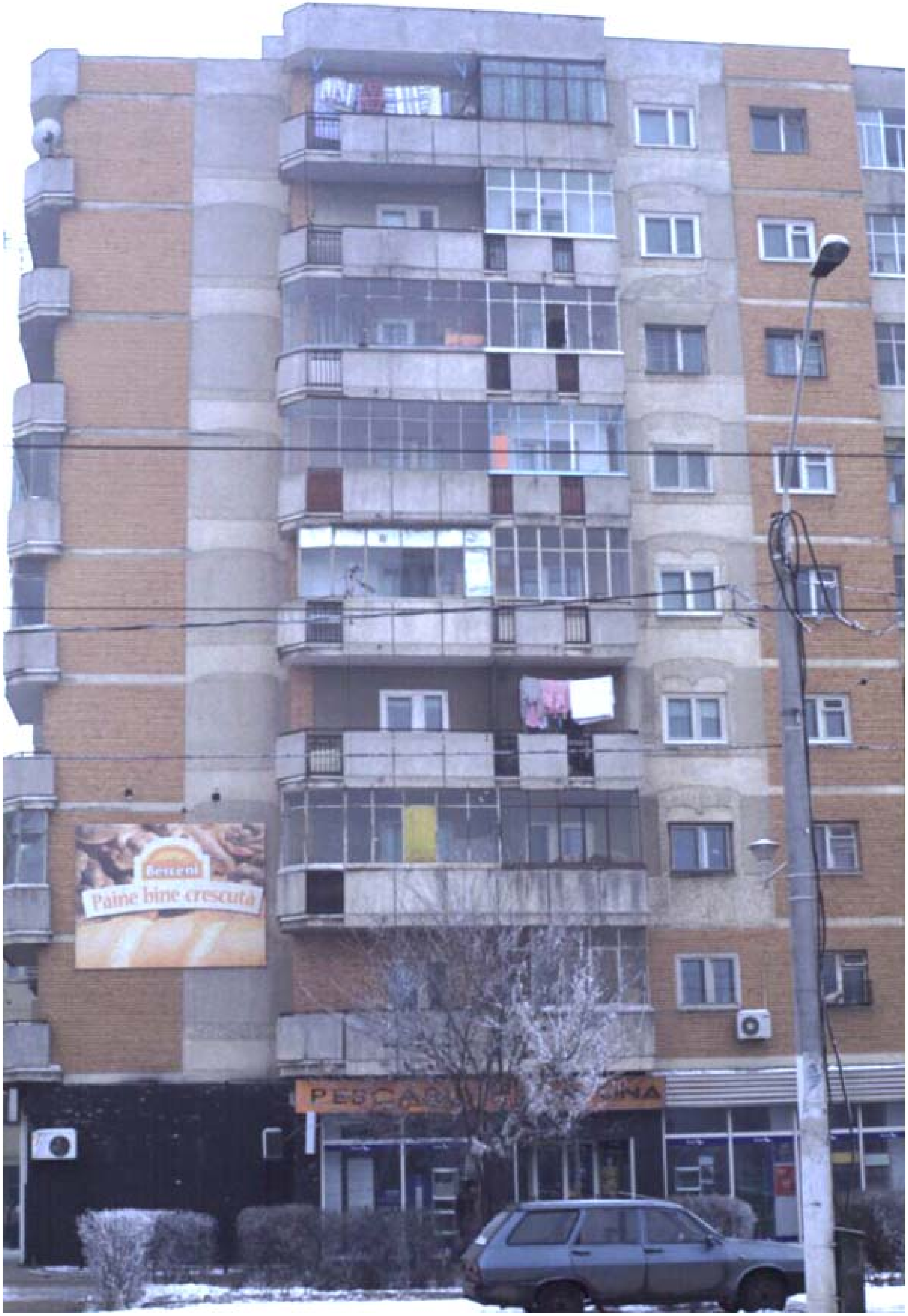

Berceni
Paine bine crescuta

FIGURE 3: A facade view

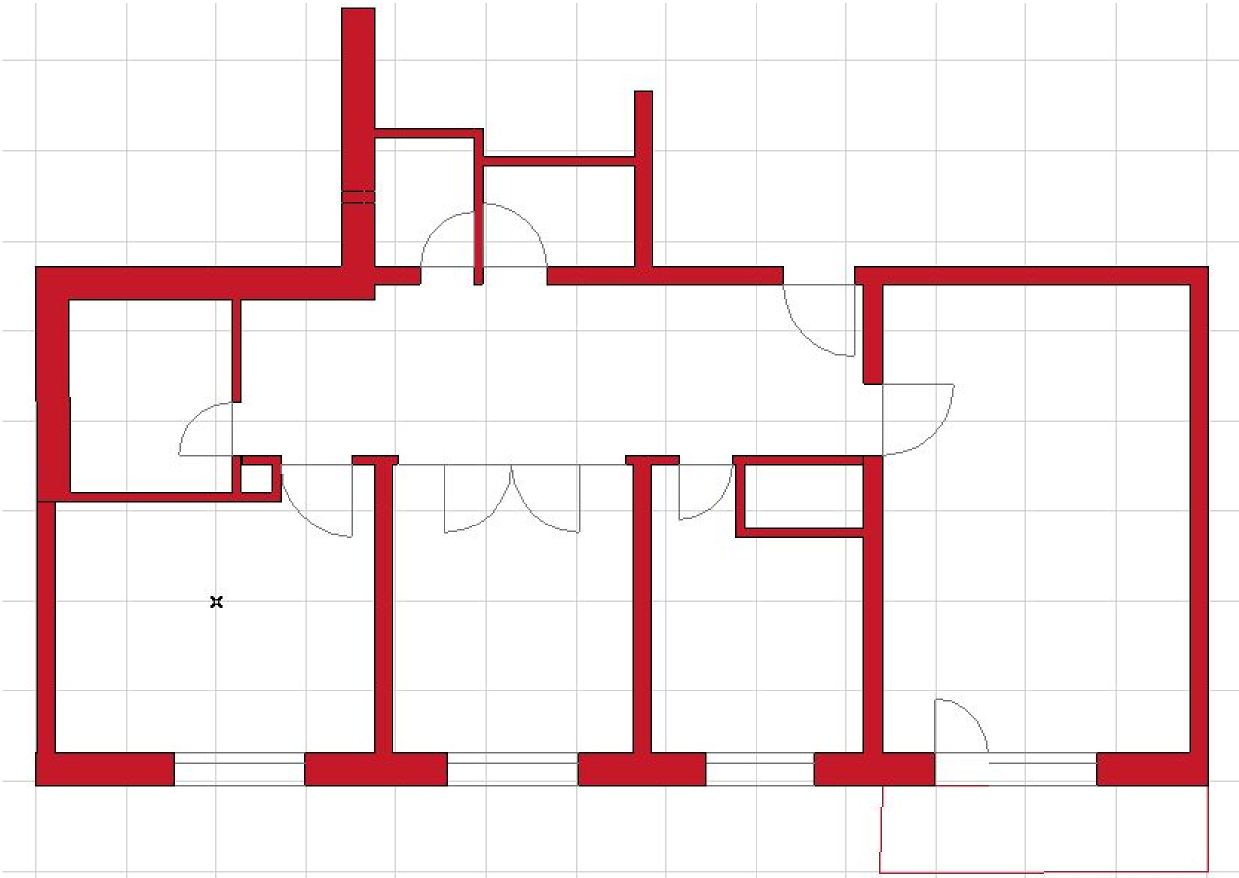


FIGURE 4: Plan of an apartment

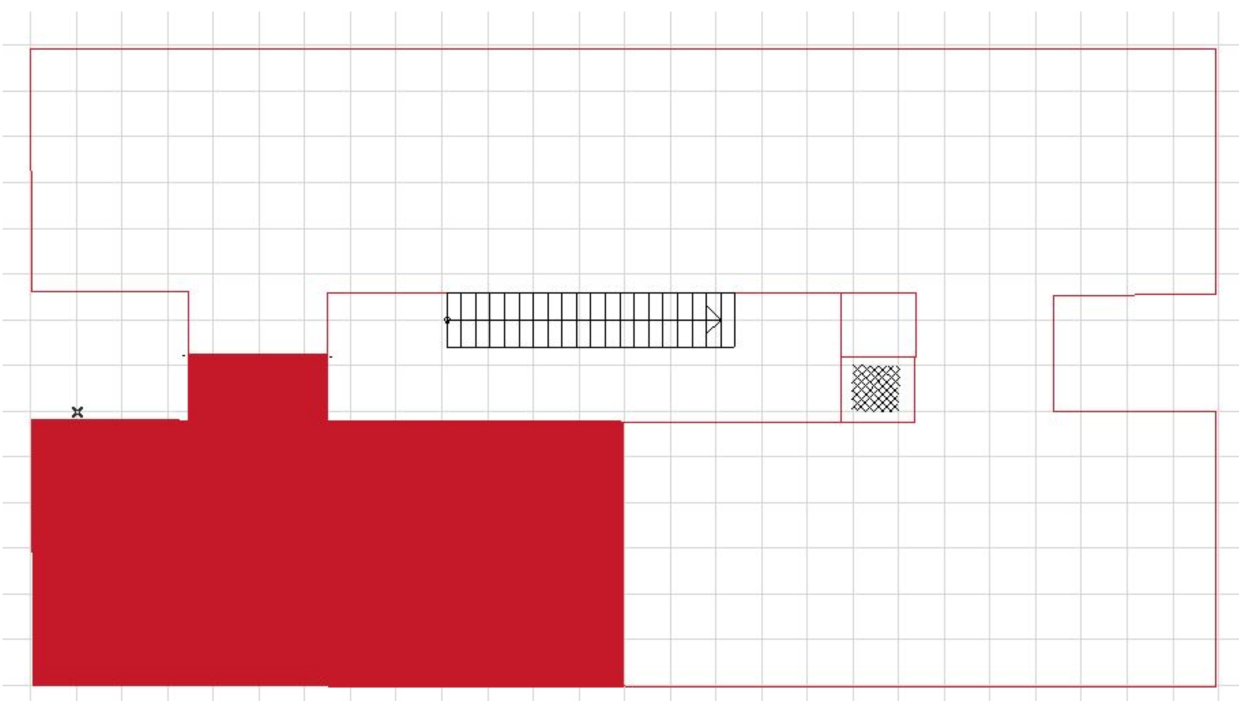


FIGURE 5: Position of the apartment on the floor plan

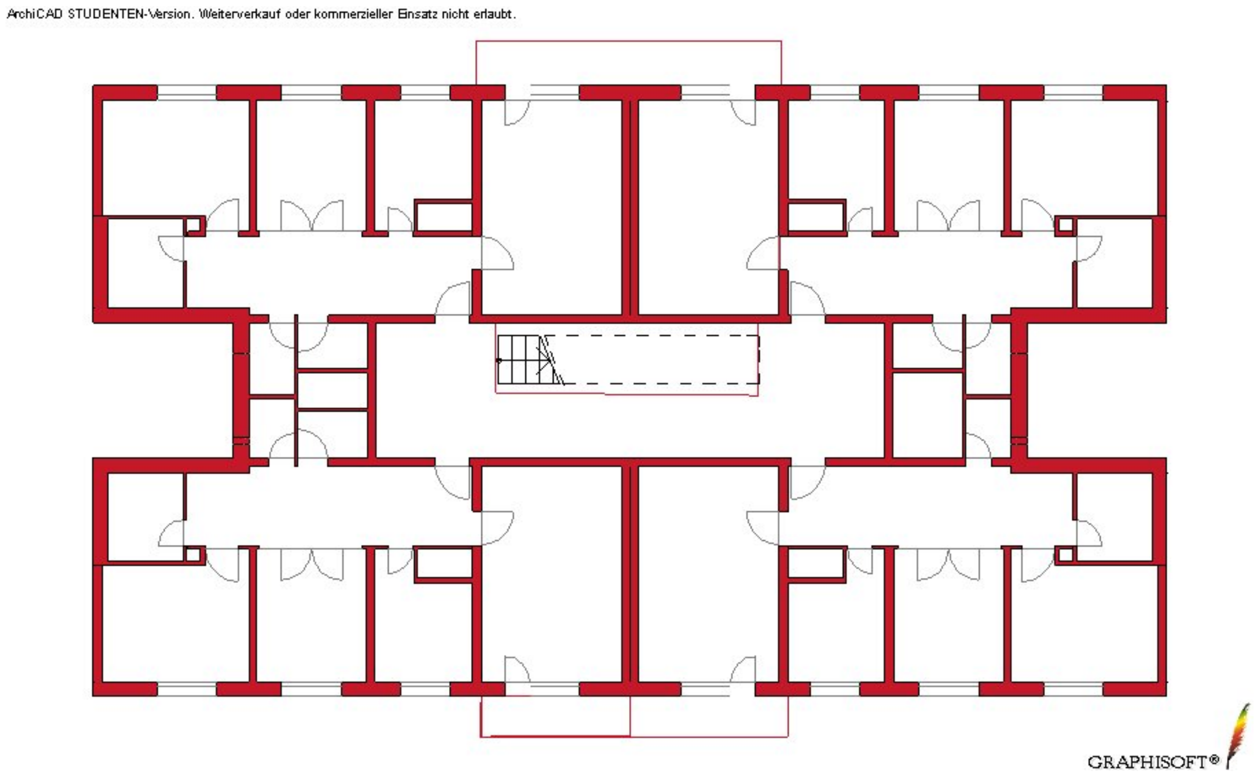


FIGURE 6: A typical floor plan

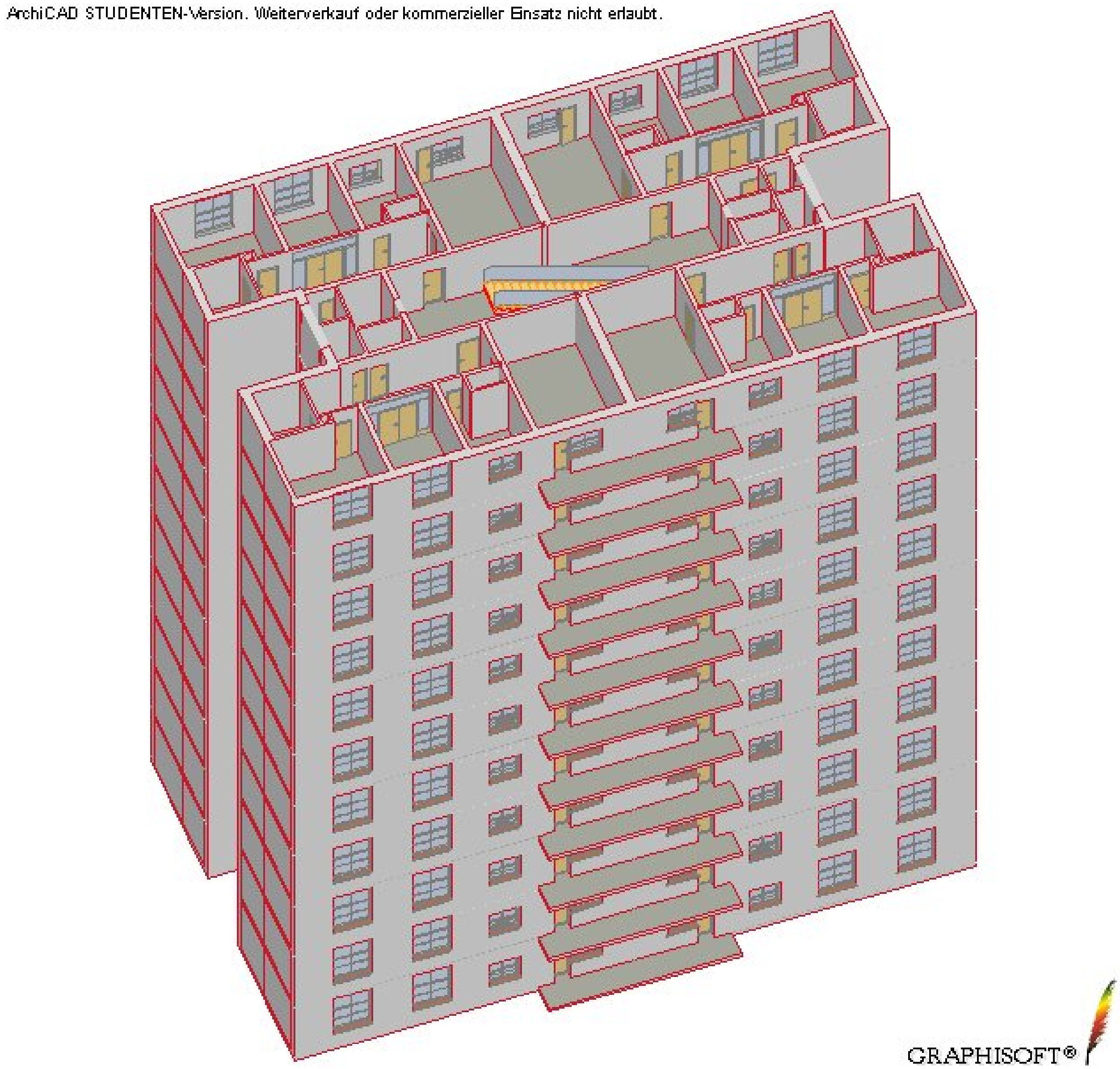


FIGURE 7: Axonometric building view

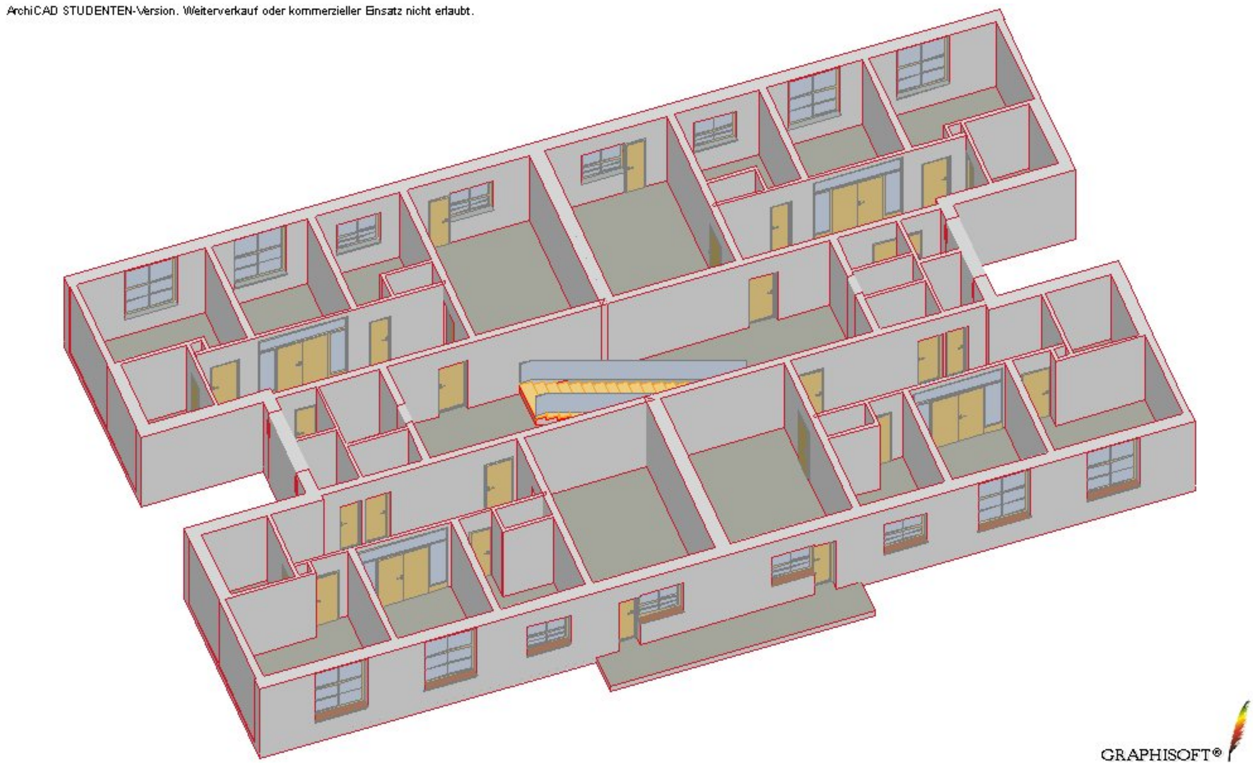


FIGURE 8: Axonometric floor view

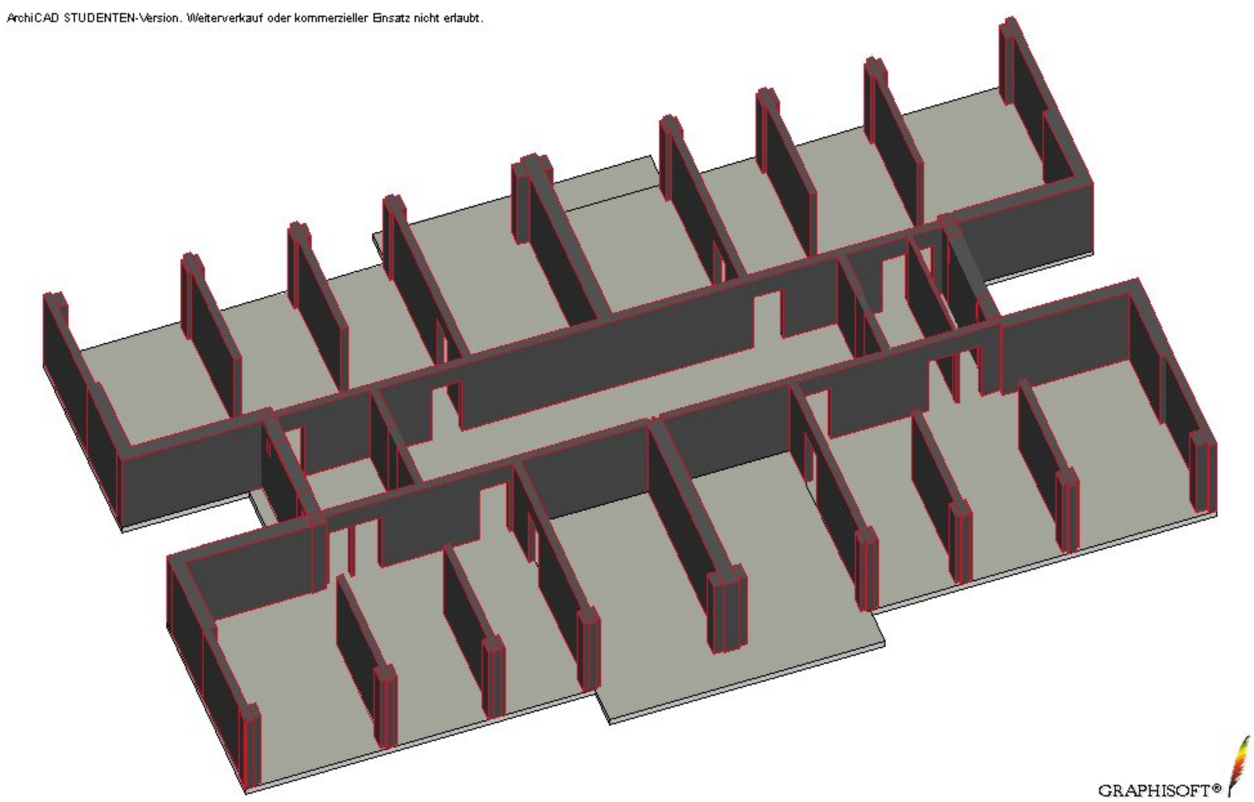


FIGURE 9: An axonometric view showing loadbearing walls and boundary elements

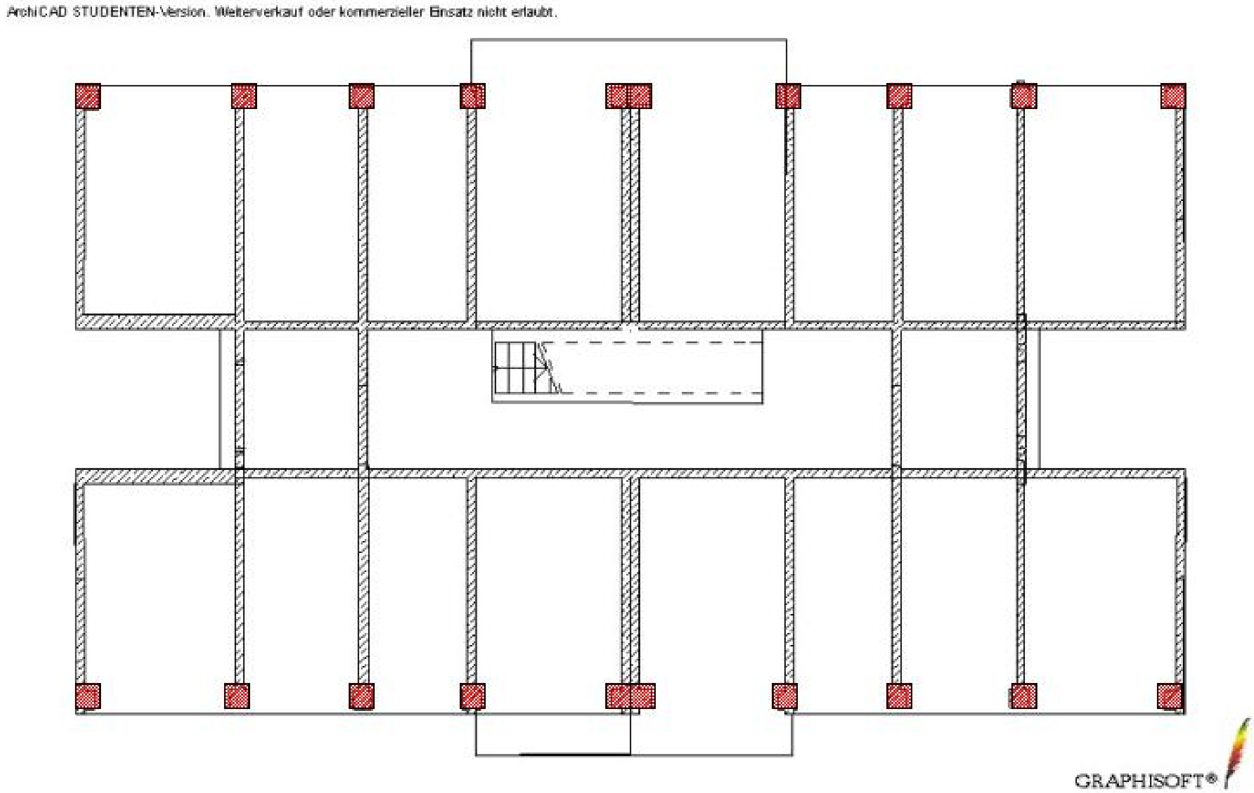


FIGURE 10: Floor plan showing the wall panels and the stiffening boundary elements

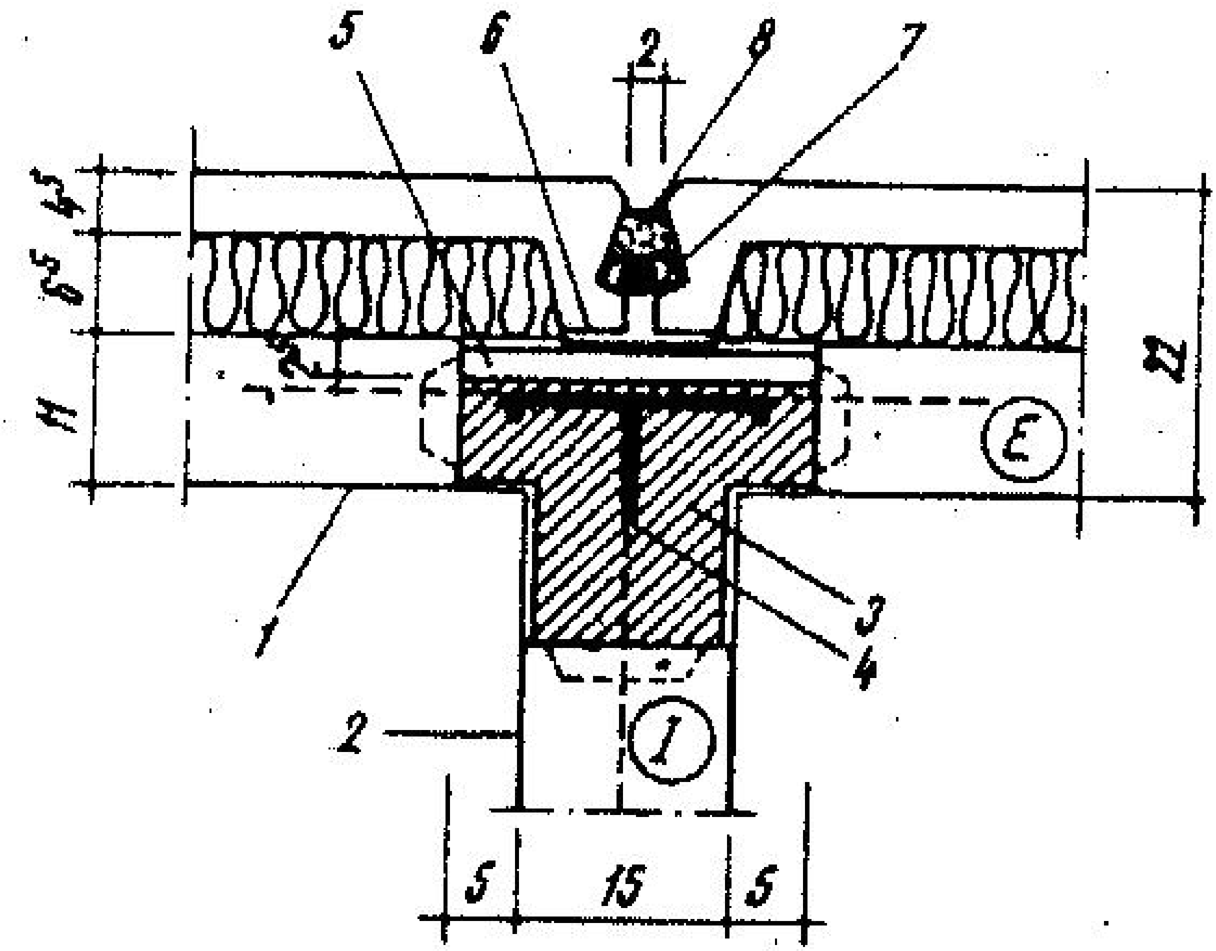


Fig. IX.29 — Corecția termică la îmbinarea verticală a panourilor de pereți:

1 — panou exterior; *2* — panou interior; *3* — beton de monolitizare; *4* — armătura îmbinării; *5* — izolație termică suplimentară; *6* — carton bitumat; *7* — strat etanș la aer (semițeavă P.V.C.); *8* — mortar decorativ.

FIGURE 11: A horizontal section through a precast wall panel connection showing boundary elements (note the precast exterior panels)

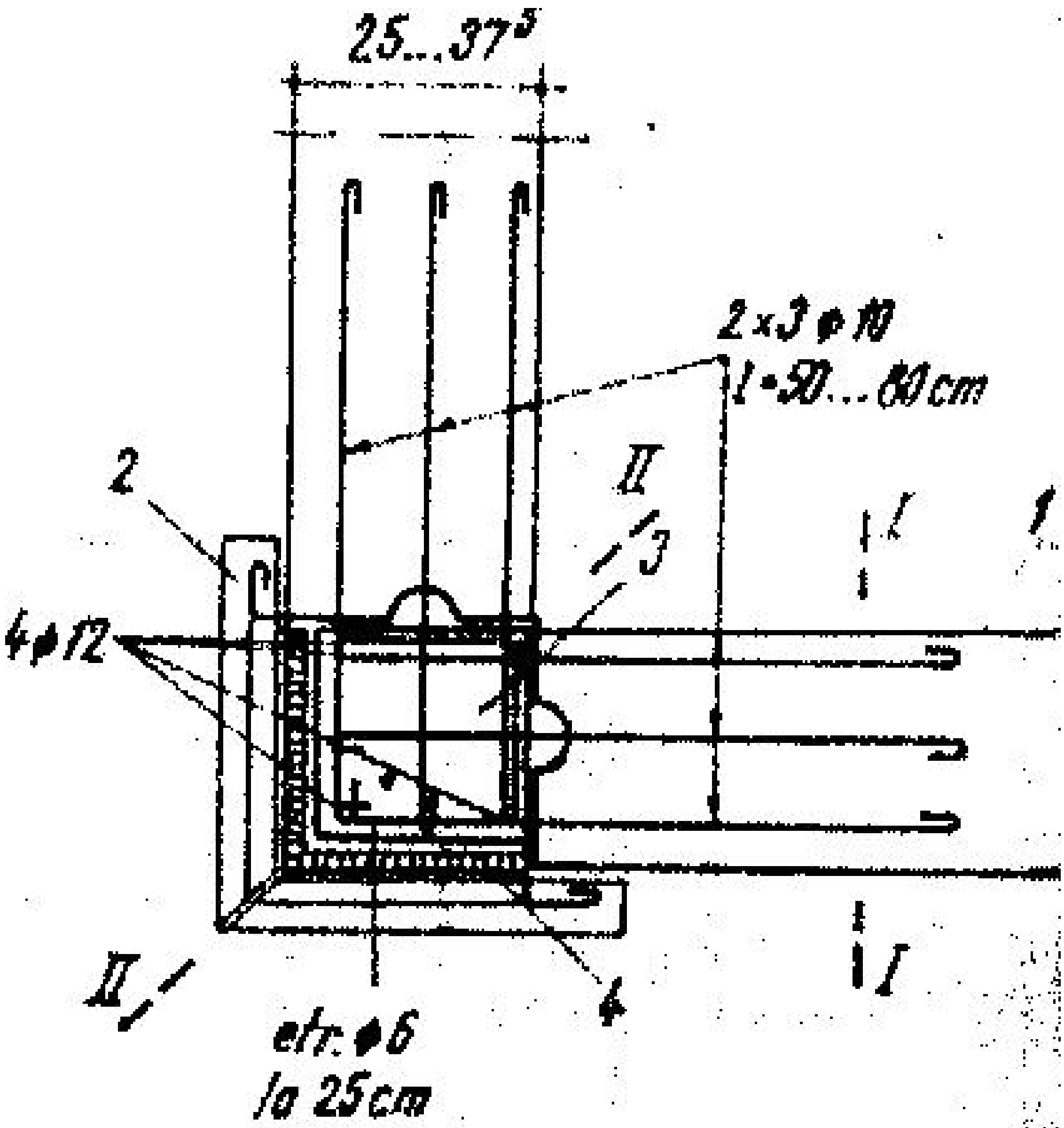


Fig. IX.30 — Corecţia termică la colţ perete:

1 — perete de colţ; 2 — element prefabricat colţ; 3 — stîlp monolit; 4 — izolaţie termică colţ.

FIGURE 12: A corner precast wall panel connection (note different facade panels)

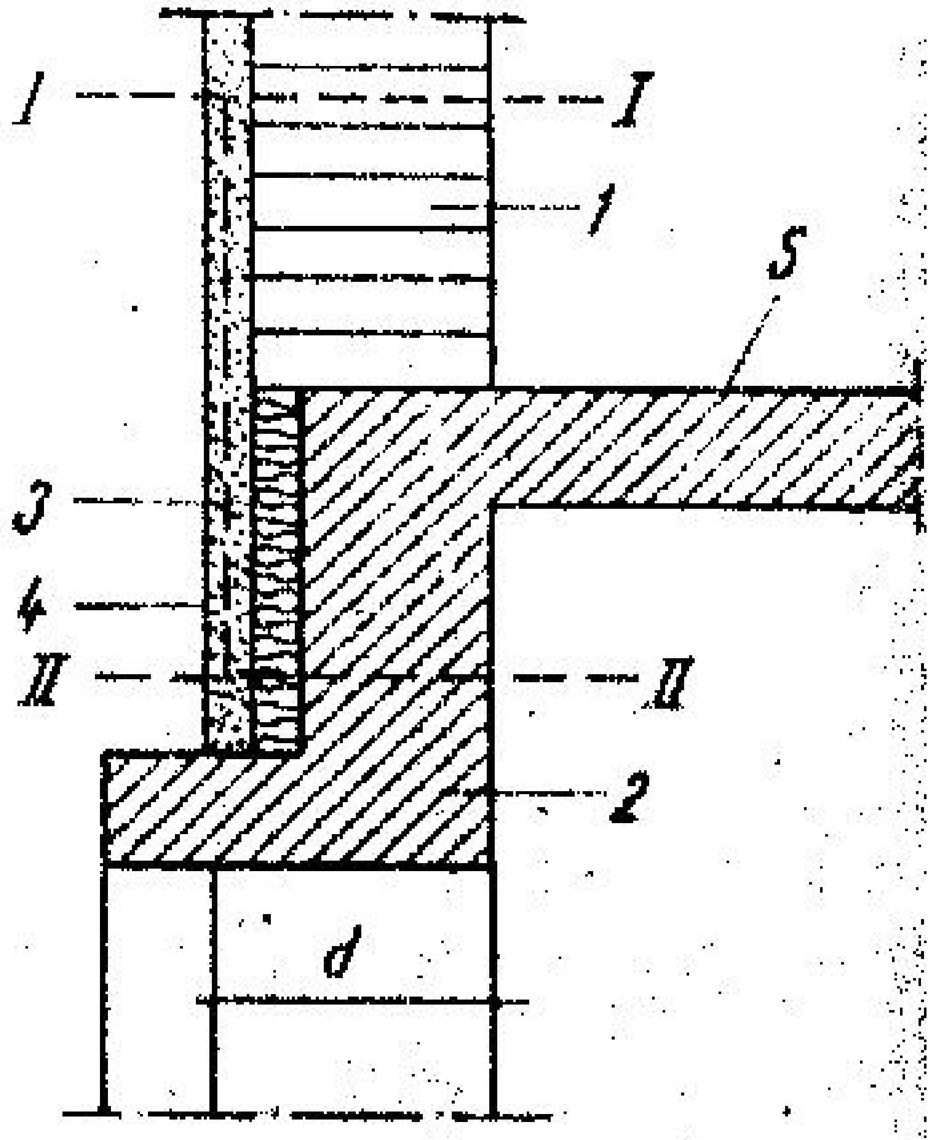
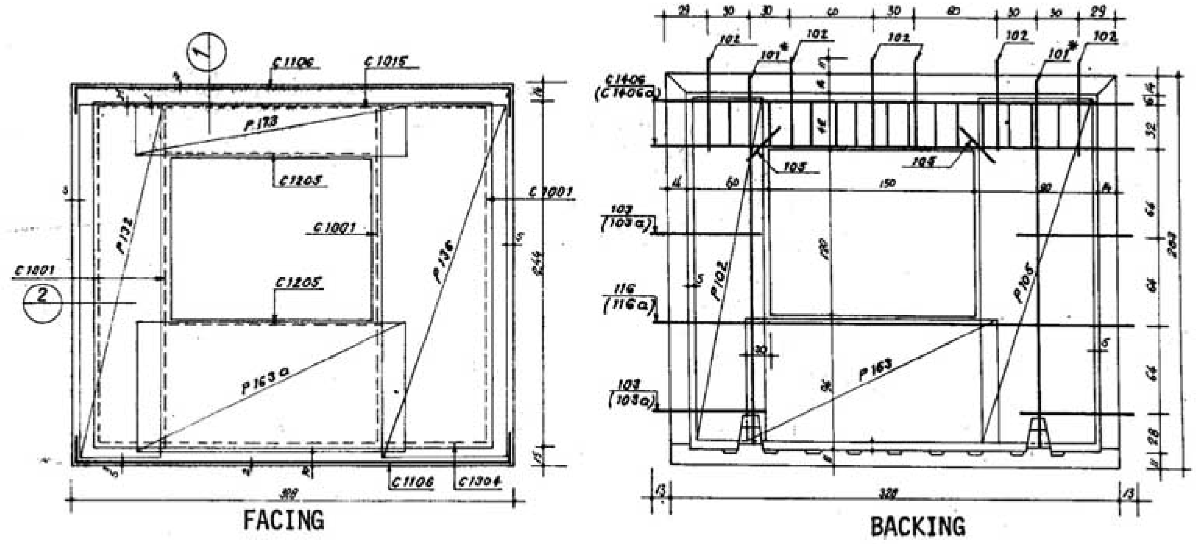


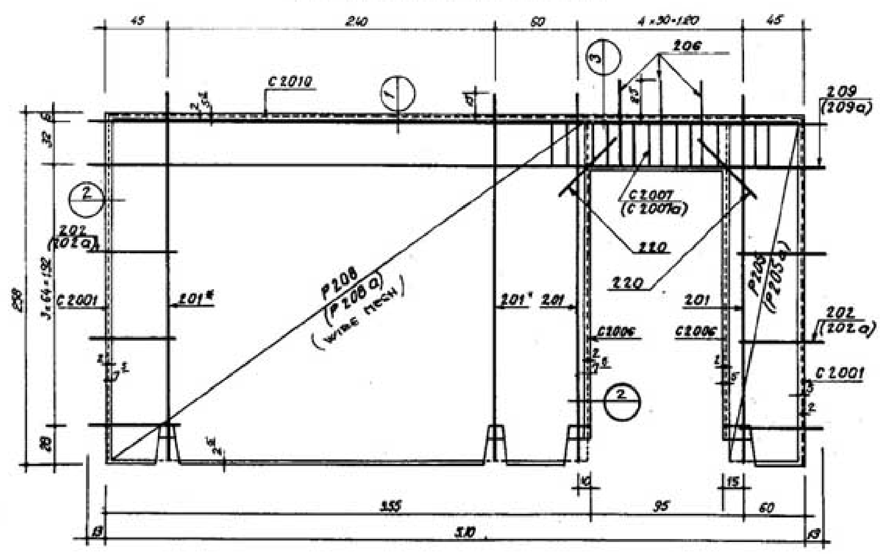
Fig. IX.32 — Corecţia termică a centurilor buiandrug:

1 — perete; 2 — centură buiandrug; 3 — izolaţie termică, rigidă; 4 — strat de tencuială pe carton bitumat şi rabiţ; 5 — planşeu.

FIGURE 13: A typical floor-to-facade panel connection

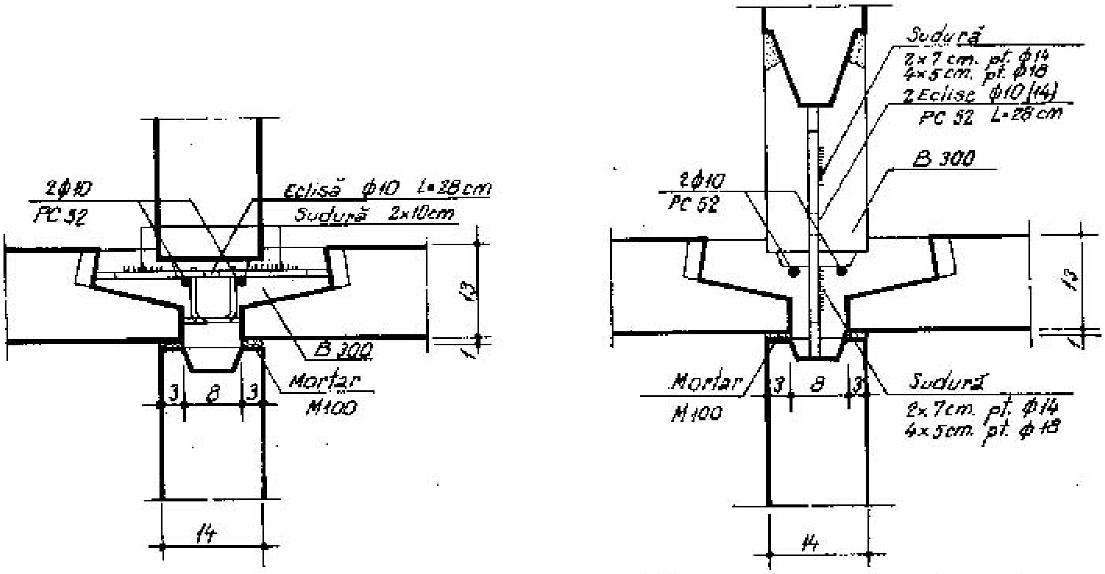


(a) Interior Wall Panel



(b) Interior Wall Panel

FIGURE 14: Typical interior wall panel details (NBS 1977)



(a) connection of floor panels

(b) connection of wall panels

HORIZONTAL JOINT CONNECTION DETAILS

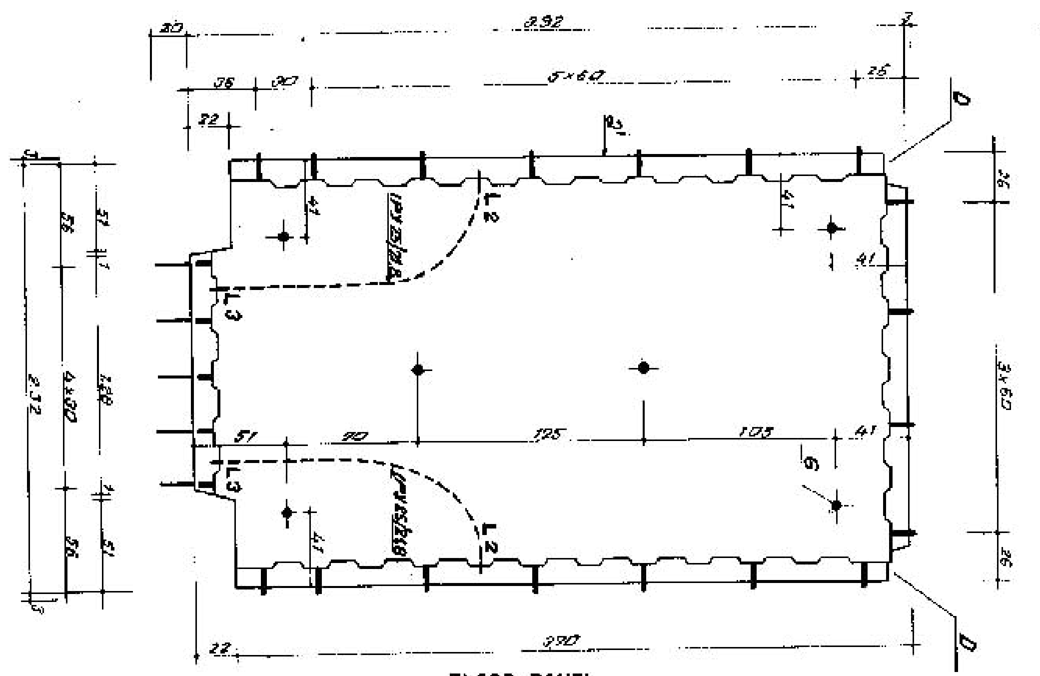


FIGURE 15: Floor panel and horizontal joint details (NBS 1977)

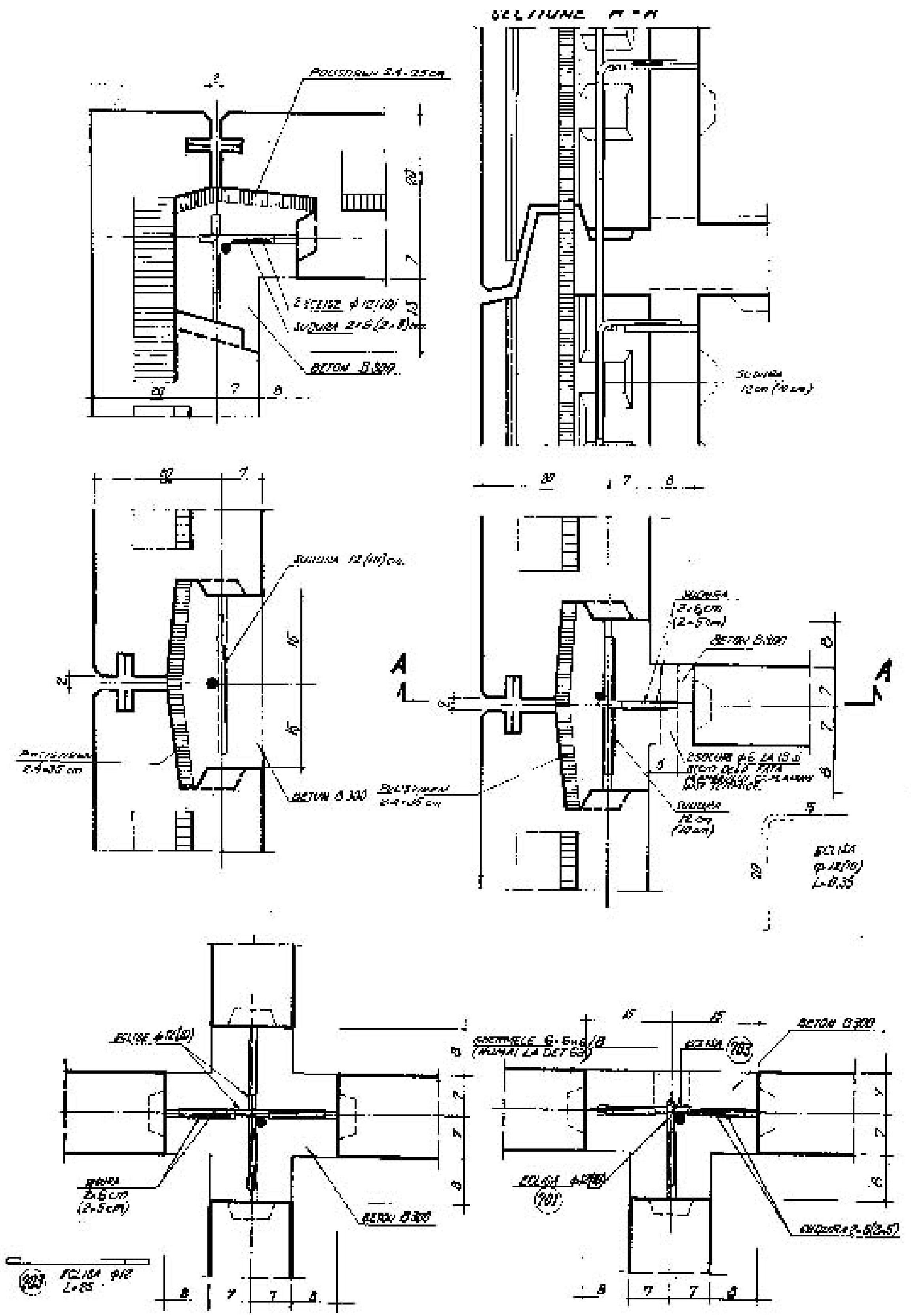


FIGURE 16: Vertical panel joint details (NBS 1977)