World Housing Encyclopedia

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

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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Precast concrete panel apartment buildings

Report #	83
Report Date	21-10-2002
Country	ROMANIA
Housing Type	Precast Concrete Building
Housing Sub-Type	Precast Concrete Building : Large Panel Precast Walls
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Important
This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John A. Martin & Associates, Inc. or the participants' organizations.

Summary

This multi-family urban housing construction type was built in Romania from the 1960s through the 1990s. The load-bearing system is a precast-reinforced-concrete large-panel construction. Buildings of this type are typically high-rises (10 or 11 stories), although there are also low-to medium-rise buildings (4 to 8 stories) with different structural details. In general, these buildings consist of a rectangular plan, with a honeycomb ("fagure") layout,

typically housing 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 an earthquake-prone area, with the epicenter of damaging earthquakes close to Vrancea. Earthquakes with a Richter magnitude of over 7.0 occur, on average, every 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 rivers, on non-homogenous 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 so far has not been exposed to damaging earthquakes.

1. General Information

Buildings of this construction type can be found in all major urban areas in the country. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 25 years.

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

Figure 1: A typical building

Figure 2: A corner view

Figure 3: A facade view

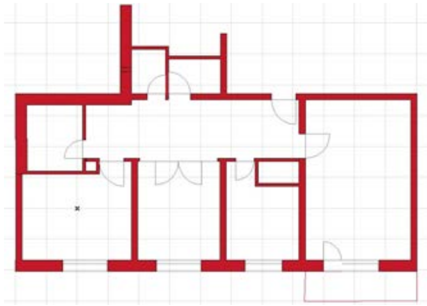

Figure 4: Plan of an apartment

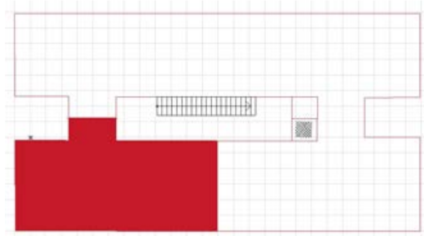

Figure 5: Position of the apartment on the floor plan

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 2.5 meters.

2.2 Building Configuration

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

2.3 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. 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).

2.4 Modification to Building

Modifications in buildings of this type are not common.

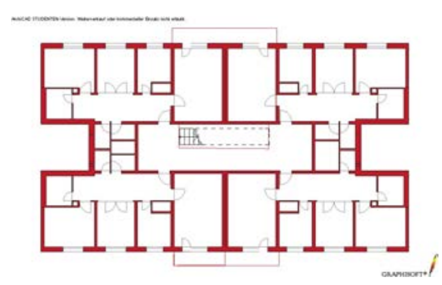

Figure 6: A typical floor plan

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
			Dressed stone masonry (in	

Masonry		2	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	☐
		36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
			Masonry with horizontal	

Timber	Load-bearing timber frame	38	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 by a so-called "honeycomb" ("fagure" in Romanian) building plan characteristic of Romanian housing design -- the same system is described for the "OD" housing type (World Housing Encyclopedia Report 78). It consists of box-type units, which create the rooms. Because of the 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 load-bearing 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 the facade walls, which are non load-bearing 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).

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). 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 the 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 the 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 does 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.).

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 25 and 125 meters, and widths between 12 and 13 meters. The building has 4 to 11 storey(s). The typical span of the roofing/flooring system is 4 meters. Typical Span: The span ranges from 2.5 - 5.5 m. The typical storey height in such buildings is 2.6 meters. The typical structural wall density is none. 5% - 7% Wall density is larger 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	☐

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

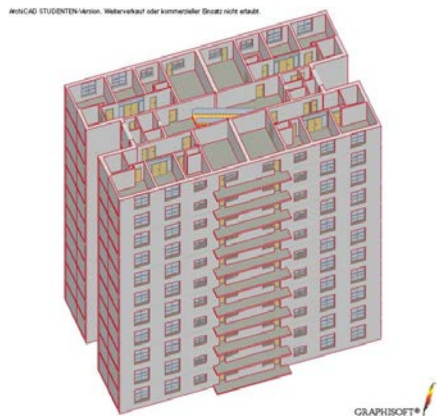

Figure 7: Axonometric building view

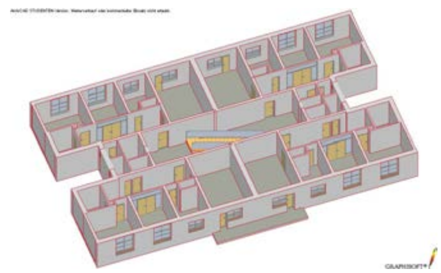

Figure 8: Axonometric floor view

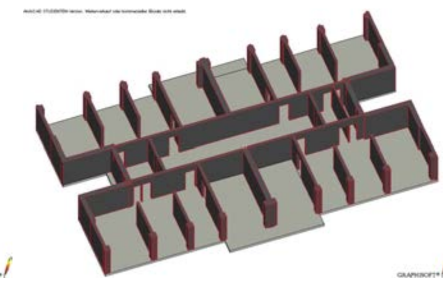

Figure 9: An axonometric view showing loadbearing walls and boundary elements

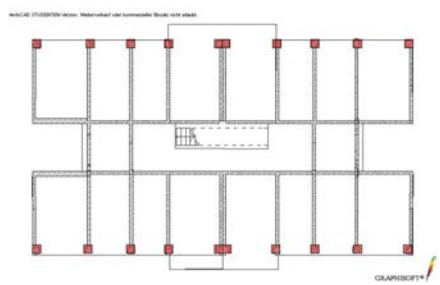

Figure 10: Floor plan showing the wall panels and the stiffening boundary elements

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has more than 100 housing unit(s). 150 units in each building. 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. 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.

4.2 Patterns of Occupancy

One family per 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)	☐

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)	☑

Before 1990 the construction was financed by funds from the central government. After 1990 (the post-communist period), individual apartments have been owned by the inhabitants. 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 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/		Most appropriate type

Architectural Feature	Statement	Yes	No	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	☑	☐	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	☑	☐	☐
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area.	☑	☐	☐
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☑	☐	☐
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	☑	☐	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☑	☐	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☐	☑
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	☑	☐	☐
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☑	☐	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☑	☐	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☑	☐	☐
Additional Comments	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	Seismic	Earthquake Resilient	

Element	Deficiency	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 at the wall-floor connections. In some cases, those were existing cracks, which were widened in the 1977 earthquake. However, in the city of Iasi (north of the epicenter), 45° cracks developed in the walls, especially above the openings and around the staircases in some 8-story buildings built around 1960.
Frame (Columns and beams)			
Roof and floors		Rigid floor and roof structures.	
Other			

Information 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 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), the lower bound (i.e., the worst possible) is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), and the upper bound (i.e., the best possible) is E: LOW VULNERABILITY (i.e., very good seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☐	☑	☐	☑	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1986	Vrancea	7	8 (MMI)
1990	Vrancea	6.7	7 (MMI)

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).

6. Construction

6.1 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)
Foundation				

Frames (beams & columns)				
Roof and floor(s)				

6.2 Builder

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

6.3 Construction Process, Problems and Phasing

The construction was performed using specialized equipment for prefabricated 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. 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.

6.4 Design and Construction Expertise

The building design was developed by "Design Institutes" that employ trained technical specialists, including engineers and architects. The construction was performed 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.". 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.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. P-100-81. The year the first code/standard addressing this type of construction issued was 1981. The most recent code/standard addressing this construction type issued was 1992. 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.

Information not available.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per development control rules.

Building permits were required in the period when this construction was practiced. Building inspections were performed by the construction company staff and also by a special government department called "State Construction Inspection.". Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

The 1991 price was 2590 lei/m.sq. of the built area (176 USD/m/sq/.). Note that this is a real estate price, which reflects the value of an existing building and not the cost of new construction (which is not available). Information not available, because the construction company no longer exists.

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 "Voluntary Complex Insurance of the Households of Physical Persons" through S.C. ASIGURAREA ROMÂNEASCA - ASIROM S.A. (a public company).

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

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?
Based on the good performance of buildings of similar construction in the 1977 earthquake, retrofitting is not required.

8.3 Construction and Performance of Seismic Strengthening

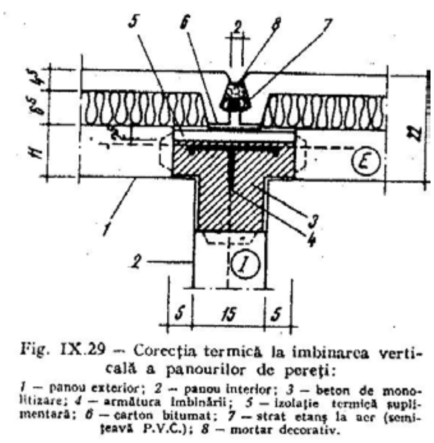

Figure 11: A horizontal section through a precast wall panel connection showing boundary elements (note the precast exterior panels)

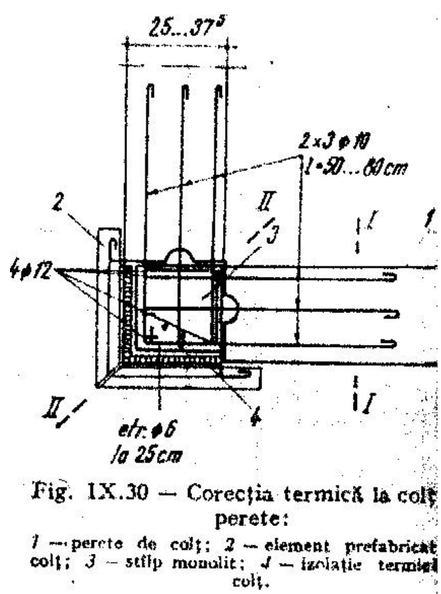

Figure 12: A corner precast wall panel connection (note different facade panels)

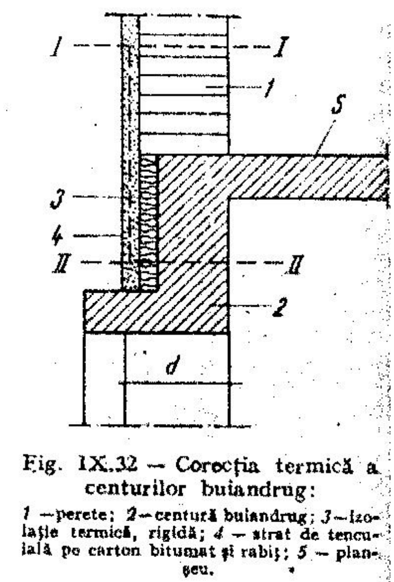

Figure 13: A typical floor-to-facade panel connection

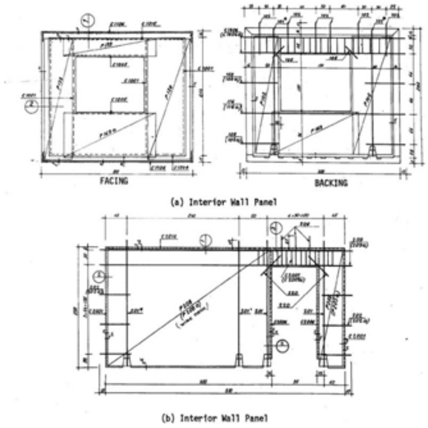

Figure 14: Typical interior wall panel details (NBS 1977)

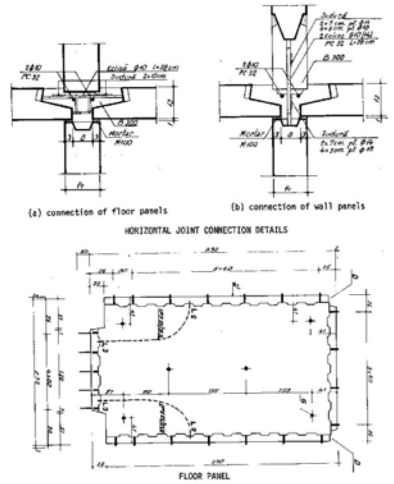

Figure 15: Floor panel and horizontal joint details (NBS 1977)

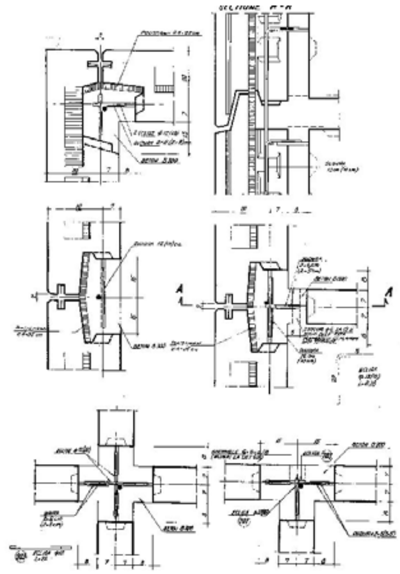

Figure 16: Vertical panel joint details (NBS 1977)

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