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The behavior of large panel constructions to seismic actions

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***Abstract* – Large panel structures were used on a large scale between 1975-1987 for block structures, being one of the solutions with high productivity for that period. Considering the appreciable volume of residential buildings with such a structure, the author group proposed to conduct research on the behavior of these structures, both in seismic actions and in other actions as a whole doing research on the way of behavior over time. The results of this research led to the application of appropriate methods and techniques for their rehabilitation, for some intervention works as a result of some identified shortcomings. Mainly the buildings that have facades made of large panels were studied, but buildings that were made with such a structure in their integrity are also presented. The obtained results offer valuable material in the development of knowledge and in the assessment of the degree of risk and vulnerability.**

***Keywords* – earthquake, large panel structures, seismic actions**

1. INTRODUCTION

After 1960, a lot of constructions for collective housing were built in Romania with the structure of large panels. The fully prefabricated buildings were built with P+4E height regime in the country, but in Bucharest there are also P+7-8E. Starting from 1964, they were made with P+4E height regime, but since 1973, this solution has also been applied for P+8E buildings based on the IPCT project, having an adequate structural conformation and with loop joints and monolithic joints with concrete, but also provided with adjustment bolts.

As a whole, these buildings had a bar-type configuration with a honeycomb structure having diaphragms in both directions with appropriate joints and able to realize the transfer of efforts. These constructions generally behaved well, but we conducted a research on types of structures and damage that occurred during operation due to execution deficiencies and operating conditions.

2. DESIGN BASIS OF COMPOSITE STRUCTURES

As is known, large panels are flat elements made in the form of plates with a large surface and relatively low thickness. Depending on the position in the whole structure, the large panels can be made with or without a thermal insulation layer.[1] The dimensions of the large panels have been established in such a way that no additional finishes are needed in the joining joints, but also due to resistance conditions.

Another condition that generates the dimensions of a large panel is related to their mass, so as to allow handling, transport and installation on site. From the point of view of design, buildings made of large panels can be with or without a resistance shell. In general, the structures without the resistance shell were designed so that the vertical loads are taken over by the panels that make up the load-bearing walls, and the horizontal loads are distributed through the floors.

The buildings with resistance shells are either located in seismic zones or correspond to blocks with a height regime higher than four floors. In general, the resistance housings are made from prefabricated frames. Another category of large panel structures from the existing built stock was the prefabricated spatial structures. Their advantage is the possibility to control the joint areas, to eliminate potential shortcomings.

The large panels are made in the form of solid flat panels or with gaps of doors, windows, the upper connections being treated as lintels. Reinforcement of the panels can be done by placing the reinforcement in the median plane or double reinforcement, the latter being mandatory for blocks with a height regime over P+4E.

An important problem in the design of large panel structures was also the functional structuring of the space given the fact that subsequent changes are not possible (demolition of panels, voids created to reconfigure the functionality). But examples of such interventions were identified during exploitation.

The abolition of a panel between the kitchen and the living room generated the deformation on the support line of the upper floor where the boards that were joined in that area became free on the support.[2] In the image below, an apartment in a building in Huedin built between 1964-1966, where the deformation of the floor, of the floor where the modification was carried out, is masked by plasterboard and the floor of the upper floor is clearly deformed.

Fig. 1 Floor 3 of 4 [3]

Fig. 2 Floor 4 of 4 [3]

When the horizontal joints between the panels ensure the continuity of the diaphragms and the vertical joints allow sliding between two adjacent panels, the structure works as an assembly of independent consoles, the floors ensuring the effect of a rigid washer.[5]

If vertical strength joints are made, the behavior is similar to that of complex cantilevers whose cumulative stiffness far exceeds the sum of the stiffnesses of adjacent elementary cantilevers.[6]

The resistance joints are executed either at the floor level or along the length of the contact line of the panels through cells and reinforced and monolithic thresholds. In such structures, the overall stiffnesses of the vertical and horizontal diaphragms must be close.[5]

At the same time, to reduce torsion, it is recommended that the diaphragms be symmetrical. The provision of joints capable of absorbing energy through plastic deformations ensured the constructions a good behavior during earthquakes.

The floor panels can be identified as resting on two, three, four sides, their dimensions coincide in most situations with those of the cellular-functional unit. Their thickness was established from conditions of strength, rigidity and sound insulation.[7] For ordinary openings the thickness of the floor slabs was 10-12 cm. For large openings, precompression was recommended.

With reference to the method of execution of the joints, we must specify the fact that resistance to horizontal forces is ensured by the formation of bracing elements, by assembling the panels vertically, forming simple brackets embedded in the foundation, and if the joints between the elementary brackets allow relative sliding, the rigidity it is calculated as the sum of the stiffnesses of the consoles.

If between the vertical brackets there are links capable of transmitting tangential forces, then complex brackets are formed whose stiffness is equal to the sum of all the stiffnesses of the elementary brackets.[4]

Complex consoles can have discontinuous joints or continuous vertical joints. The continuous joints differ according to the side faces of the panels, respectively its edges can be linear imprinted, alveoli or thresholds.

According to the technical instructions applicable at the time these constructions were made, the joints of the large panel structures were continuously monolithic, appearing in the form of monolithic reinforced concrete pillars, which ensure the horizontal connection between the panels. These joints transmit tangential forces, while the continuous horizontal joints that were made as reinforced concrete belts transmit normal compression forces.

The links were designed in such a way as to prevent horizontal movement. In addition to the belt-type horizontal joints, horizontal joints capable of ensuring the continuity of the slab were also executed between the floor panels. In this area, the reinforcements were anchored through loops, welded whiskers or whiskers anchored in concrete.

The wall panels require some checks in the structure as a whole, such as: the check for compression with buckling and the shear force, as well as the checks related to transport, handling, assembly.

Checking the overall strength of the panel is an eccentric compression check with consideration of buckling, often accentuated by the effect of slow flow.

In the calculation, the panel is considered articulated along the horizontal sides. The buckling coefficient is established depending on the structural eccentricity, the accidental eccentricity, the eccentricity caused by some external loads.[6]

The structural eccentricity is given by:

- Eccentric position of supports, floors and walls;
- Deviation of the axis of the joint compared to the axis of the panel;
- Deviation of the axes of two overlapping panels.

The accidental eccentricity is given by:

- Flatness defects of the panels;
- Deviation caused by the inhomogeneity of the concrete;
- Posing defects of the lower panel compared to the upper one;

The eccentricity caused by external loads can be generated by wind action, seismic action and temperature variations.

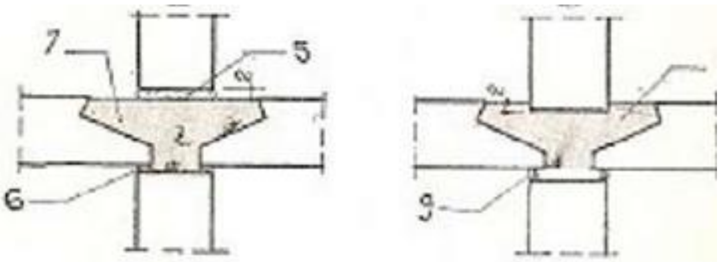

Fig. 3 Types of eccentricity [4]

For stamped vertical joints, the main stress due to lateral loads is the shear force, the value of which is determined according to the thickness of the panel, the height of the panel and the tangential effort in the direction of the vertical joint (normative P100/7/1978 valid at the date of the large-scale execution of this constructive solutions provided that the cutting force in the vertical joint should be increased by 1.5). [4] It is also specified that the horizontal joints can be found as made with overconcreting or with wedges.

The joints with overconcreting are checked for compression at the end of the panel, in the area of contact with the horizontal joint.

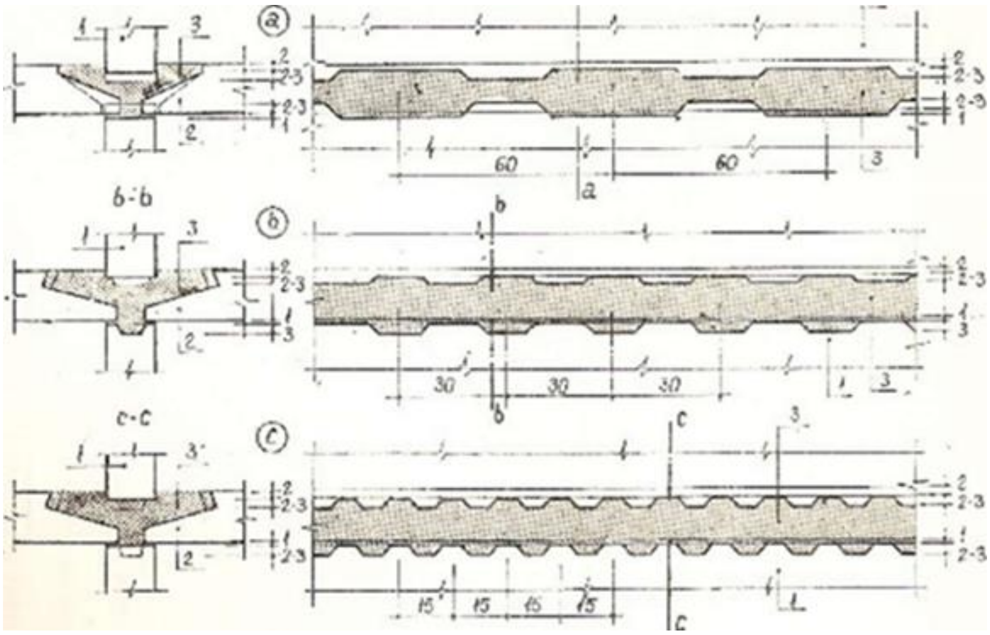

Fig. 4 Types of joints [4]

Another category of constructions is the storied buildings, made by the combined method, respectively of monolithic resistance structures and prefabricated elements. A special problem is the realization of the joints.

For the first time, the connections to the structures made of large panels were recorded in the P100/1/2006 standard, which deals with mandatory checks that need to be carried out.[2] Until that moment, the calculation provisions contained general elements, for example "joints should be compatible with the deformations of the structure under seismic action" or "for the large-scale application of these solutions, the joints should be verified experimentally".

The analysis of the behavior of these constructions during the earthquake revealed a good behavior as a whole, with no damage to the structural elements affecting stability and resistance.

This good behavior is explained by the relatively high rigidity of the buildings made with large panels, rigidity given by the diaphragms distributed along both directions.

The only damages identified are those related to the appearance of cracks in the joint areas, rarely the expulsion of concrete from these areas. Another inadvertence in behavior was the appearance of inclined cracks in the area of the lintels.

The nature of the joints between the large panels with profiles to transmit compressive stress by sliding and reinforcements to absorb tension helped the structure to dissipate energy and ensure structural cooperation.

Fig. 5 and **Fig. 6** Cracks in a block of large panels, Galati [3]

Prefabricated space structures performed well in the 1977 earthquake. [5]

Some deterioration of the concrete in the joints can be observed on the coastal area.

The interventions of the last period with the wrapping brought a favorable factor of protection against corrosive factors but, to the same extent, the impossibility of making visual observations on the joining areas. [8]


Fig. 7 and **Fig. 8** Facade where visual observations of behavior were made before and after wrapping [3]

3. CONCLUSION

The analysis of the behavior of these residential structures, with large panels, highlights a good behavior for the actions considered in the design. P+4E constructions are advantageous for seismic areas compared to taller structures.

Such blocks do not allow manual functional modifications, but only with the taking of special measures by experts to ensure both rigidity and the support system.

In the future, the structural solution with large panels will show interest again due to the high productivity and speed of execution, being able to be used successfully with the current construction quality system.

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