Prefabrication and Modular Construction Dwellings in Albania

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Abstract— More than half of the buildings in Albania, today, have been built over the years from 1945 to 1990 and present significant problems, especially in relation to energy performance and wellness conditions of their inhabitants. In this framework, the research in order to understand the heritage in its complexity is focused on the cognitive investigation of the dwellings composed of precast concrete panels, given the particularity of the subject and being the type that reports more problems in relation to energy performance. With a look through the history of the prefabricated buildings of postwar and the design approach during socialism, and technological solutions – at that time innovative, research aims to understand and study these buildings, their original construction and distribution aspects, highlighting the material, performance and functional degradation, with the main objective of identifying design strategies for their energy, functional and social requalification. As the initial part of an extensive research, the following study focuses on exploring the reasons of building in national context, in relation to the historical framework, oriented essentially to the collection and analysis of archival data, bibliography, photographic surveys and identification of significant examples and case studies. The research is developed in the following points: identification and evaluation of the different building types; identification of the basic typological matrix; identification of aggregation systems between building types; evaluation of functional flexibility; evaluation of the distinctive elements of the types; analysis of the materials usage in relation to technological evolution.

Index Terms— Aggregation systems, building type, dwellings, planimetric modules, precast concrete panels, prefabricated buildings, socialist architecture, typological matrix.

1 Introduction

THE response to the growing demand for new houses, to the excessive mastery required at construction sites and the longtime of construction with traditional techniques was the industrialization and massive prefabrication of residential construction. It was the People's Republic of China which gave Albania the factory that later on will be called "The 2000 apartment factory", as well as 300 other industrial and economic structures throughout Albania built thanks to their financing.

Fig. 1. (a) During the design of prefabricated buildings in the 1970s, (b) phase of production of silicate bricks in the Josif Pashko factory [1].

At the end of the 1970s in Albania for the first time the factory "Josif Pashko" started operating. This typology was based on construction technologies from China, on the other hand based on the Russian model, which provided a continuous structure with load-bearing panels, aimed at building large residential complexes in a short time, through precast reinforced concrete elements.

In the early years after the war, several studies were carried out in order to develop useful and especially cheap type projects to host single families. The Institute of Design Studies no. 1 (I.D.S. no. 1) was the body responsible for the development and design of the housing type module, approved in 1972 by the Ministry of Construction. Based on this module, the measurements of the concrete panels and the respective spaces were obtained, in relation to which the metal crates were produced for the production of the panels and the respective production units for the production plant of the 2000 apartments a year [2]. Initially, the production process was assisted by Chinese specialists.

The prefabricated buildings were essentially composed of four different planimetric modules with bilateral exposure and two blind side walls, which were used to bring together linear schemes and create urban complexes [2]. To allow greater flexibility and various urban planning solutions and to avoid the production of continuous special elements in the factory, for angular units between two different buildings were used with concrete frame structure and terracotta brick walls (Fig. 1b).

Among the first prefabricated buildings there is the district "Porcelani" in the city of Tirana, which became a kind of case study and where the new principles of prefabricated building were tested. During the first years the problems of the production and construction process, the installation duration were analyzed, and as well as the architectural solutions were improved.

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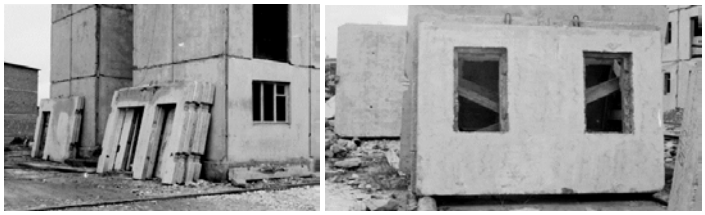

Fig 2. Construction site in the Lapraka district in the city of Tirana [AQTN][1]

On their base in cities and rural areas, large residential neighborhoods with concrete buildings were designed and built [2]. The model dwelling houses have been developed in buildings of five to six floors. Most of these buildings were grouped into neighborhoods with green spaces, children playgrounds, and necessary services such as shops, school buildings, clinics etc.

Fig 3. Urban studio - Residential district with prefabricated panels in Lushnja city [3]

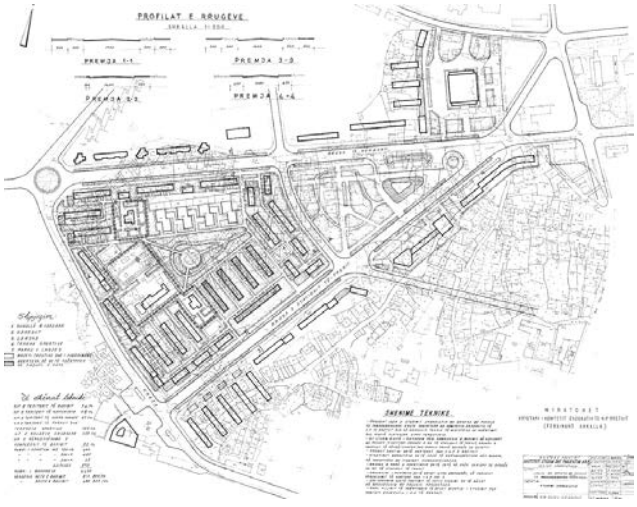

Fig. 4. Urban studio - Residential district with prefabricated panels in Elbasan city I.S.P. no. 1, 1979 [4]

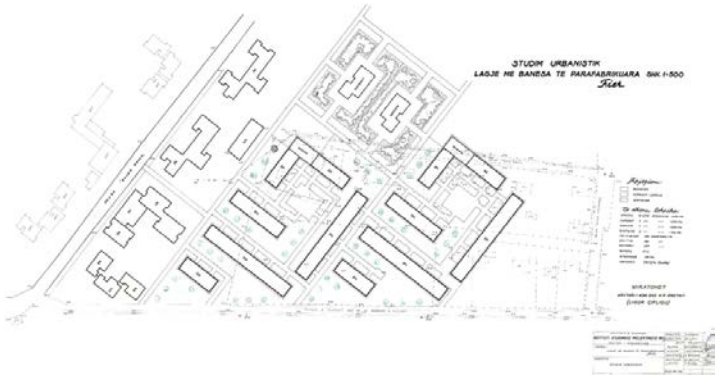

Fig 5. Urban studio - Residential district with prefabricated panels in Fier city I.S.P. no. 1, 1979 [5]

Thanks to the new railway, these buildings have spread throughout the country, such as Shkodër, Tirana, Durrës, Lushnje, Burrel, Elbasan, Berat, Pogradec, Laç, Lezhë, Korçë, Tepelenë, Gjirokastër etc. Prefabricated neighborhoods began to appear everywhere, becoming the main type of construction of that period.

Initially, the panels were transported unprocessed to the construction site, and after having gathered them, they were left exposed. Only after some years it was decided to plaster them in a simple way by reflecting the underlying panels.

The typology of the construction elements, the mass production and the continuous repetition of the modules has generated monotonous and featureless buildings. In fact, during the early years, simple and continuous facades were the cause of discussions and criticism by various architects and important personalities of the time, some of whom dedicated their jobs and some of whom were commissioned to work in the factory to find better solutions. Thus, we can mention the engineer and modernist architect Petraq Kolevica, who together with two other colleagues, were the first to express their concern in this regard. The article published in 1972 "Buildings that we embellish, or beauties we build" talked about the new risk of the monotony that was seen in the horizon of Albanian architecture, has been interpreted as offensive to the People's Republic of China. Later, he was publicly discredited and sent to work in the factory and only after a short time was forbidden to work in the profession [6].

Subsequently, new housing modules were developed with discontinuous facades, with various colors and with worked details of the construction components, with the aim of creating expressiveness and allowing the different districts to stand out for their architecture.

During the first five years, the housing model was improved along with the quality of construction, facades and completion. However, the raw materials and construction techniques remained the same.

[1] Technical Central Archive of Construction

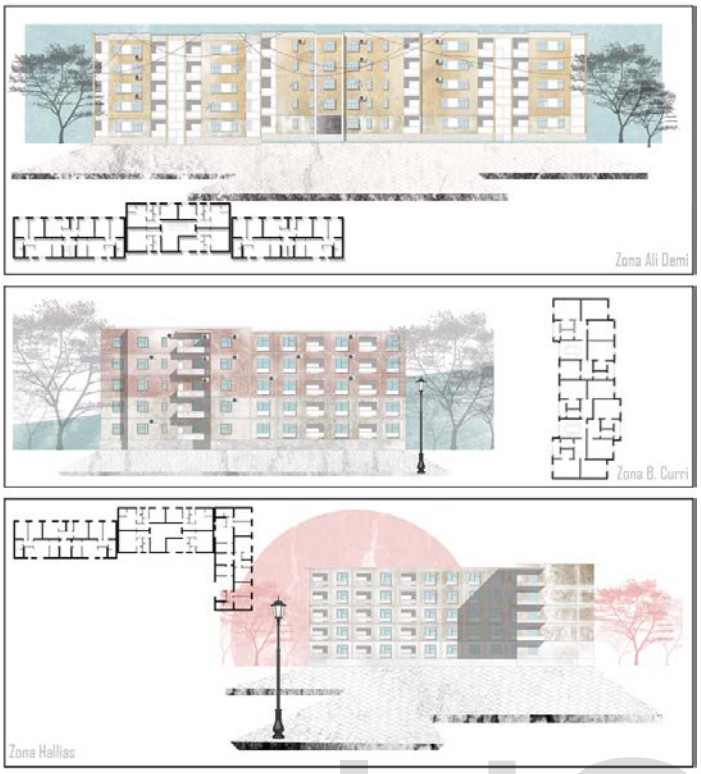

Fig 6. Presentation of the plants and facades of some prefabricated buildings composed of different planimetric modules, in the city of Tirana © B. Tataveshi.

After the rupture of relations with China and the isolation of the country, the building quality underwent a significant decrease. With the main objective of reaching the government's plans, construction times were reduced, neglecting the execution of the works. The poor quality of production, the lack of competitions, the sealing of the joints between the external panels and the treatments for corrosion of the metal elements have led to the construction of buildings with low thermal performance and living comfort.
The "Josif Pashko" factory was located in the city of Tirana and had the capacity to produce 2000 apartments a year and for this reason it was also called "The 2000 apartment factory". The panels, through vehicles with special trailers, were easily transported to Tirana, while in other cities the transport was carried out through the railway network (Fig. 7) with special wagons that were adapted to allow the loading of the panels without incurring damage [7].

With the experience gained in the first five years, using the prefabrication technique could significantly reduce costs and shorten the construction period from nine to three months and, at the same time, decreasing the workforce to a group of five people. The team of five people, that were enough to build the entire building, could produce two whole apartments a day [1]. Unlike traditional techniques, prefabricated buildings could also be mounted during the winter. The new industrialized system, from a technical and construction point of view, reduced the construction costs by 40% and required 35% less working hours.

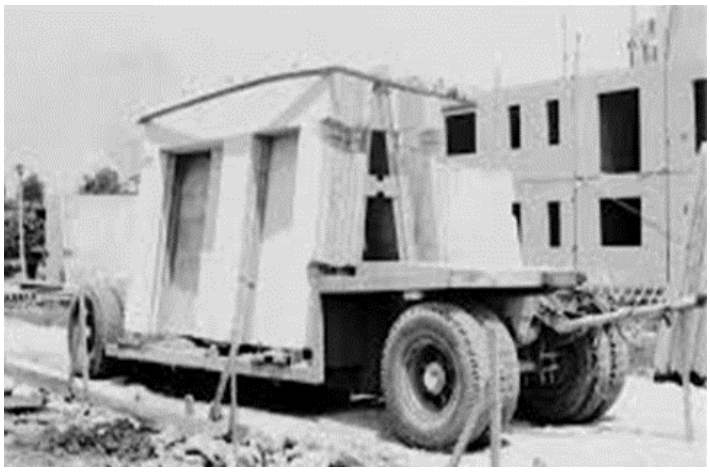

Fig. 7. Vehicles with trailers suitable for transporting precast panels to the construction site © AQTN

2 Architectural and Functional Solutions

The typical housing projects with precast panels were developed by the Institute of Design Studies no. 1 in Tirana and then were approved by the Ministry of Construction. As for the distribution schemes and architectural solutions made of precast panels, there were developed four main planimetric modules, which could be combined into linear schemes to create different floor plans in buildings from two to six floors.

- Module 1
- Module 1a
- Module 2
- Module 2a

The four modules consist of a central staircase consisting of two ramps and two landings, one that allows access to two or three apartments for floor, while the intermediate landing is open in the shape of a lodge. In most cases the buildings are of five or six floors and composed of different modules, the number of which depended on the urban project. The articulation of the different modules allowed a compositional adaptability of the distribution of the volumes according to the needs of the context.

2.1 Module 1

The construction project of Module 1 was developed based on the standard housing module approved in 1972 and designed by the State Design Institute. On the basis of the module, were obtained the measurements of the concrete panels and the respective spaces in relation to which the metal houses for the production of the panels and the respective production units for the "Josif Pashko" factory were produced. During the design of Module 1, the measurements and the number of precast panels of the approved Type Module were maintained.
This module has a simple rectangular plan with two blind walls that allow the other modules to be placed side by side.

According to the standard module, on each staircase there are two apartments, a 54 m² one-bedroom apartment and a 72 m² two-bedroom apartment with a kitchenette, a storage room and a bathroom with a window and direct lighting [8]. Both apartments have a North-South and East-West bilateral orientation and allow good cross ventilation.

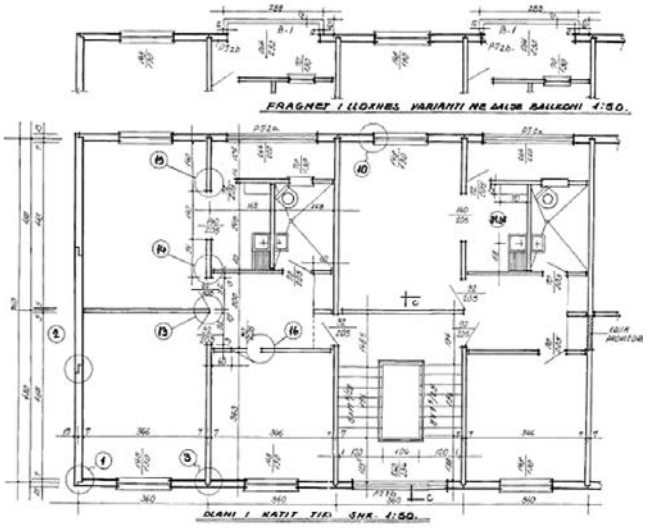

Fig 8. Plan of Module 1 with lodge and balcony © AQTN

As for the facade, module 1 could be built with a balcony or lodge. Furthermore, it was possible to choose, depending on the case, among the different solutions provided in the ten variants of the facades of the standard module. In addition, the Committee (office) of the designers of the factory "Josif Pashko" and of the regional districts, according to their studies, could propose different solutions for the facades [8].

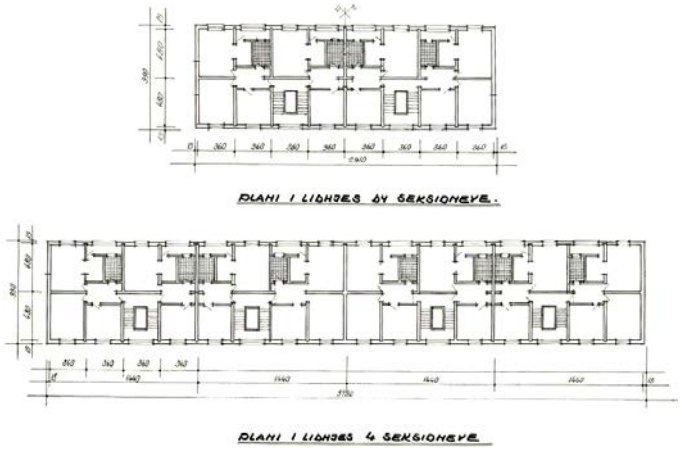

Fig 9. Connection plan of two and four Modules 1 © AQTN

The design of the Type Module did not include the basement bunker project.
The project of the anti-collision bunkers was provided by the planning bodies dedicated to the fortification structures, which was the Institute of Studies and Design of Protective Works (Defenses) (I.S.P.V.M.).

2.2 Module 1a

Like the housing module 1, Module 1a has also the same organizational structure made up of two apartments, a 54 m² one-bedroom apartment and a 72 m² two-bedroom apartment with kitchenette, utility room and bathroom, with bilateral orientation and two blind walls. Unlike module 1, this typology shows a discontinuous and more articulated facade.

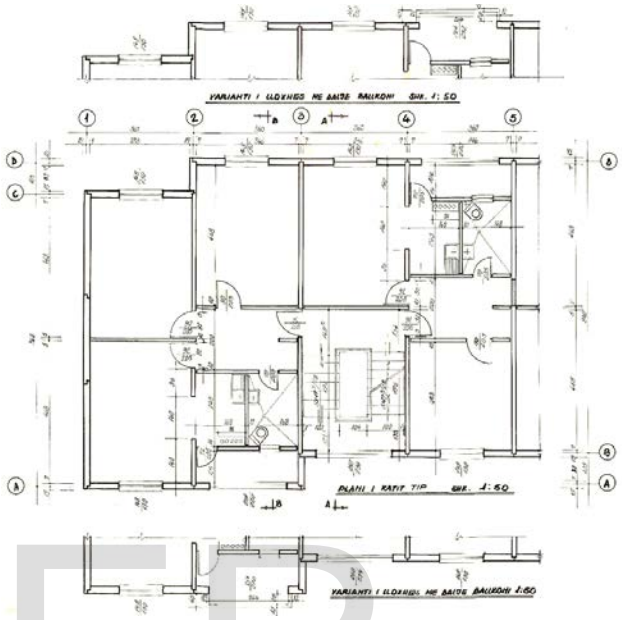

Fig 10. Plan of Module 1a, variation with lodge and balcony © AQTN

2.3 Housing module 2

The housing module 2 was developed based on the standard project approved by the Technical Council of the Ministry of Construction on 30 October 1979. This module consists of three housing units per scale, two side apartments with double exposure and one positioned in the center with one-sided orientation. The three apartments consist of a living room with kitchenette, a bedroom, bathroom and storage room with an area of 58 m² [9].

Module 2 can be built separately or combined with other modules depending on the urban planning solution; furthermore, depending on the case, the side walls can be with external or internal panels. Like module 1 and 1a, modules 2 and 2a are also built with the balcony or the lodge.

Existing panels and slabs were used for this module, except for some new external and internal and frame elements.

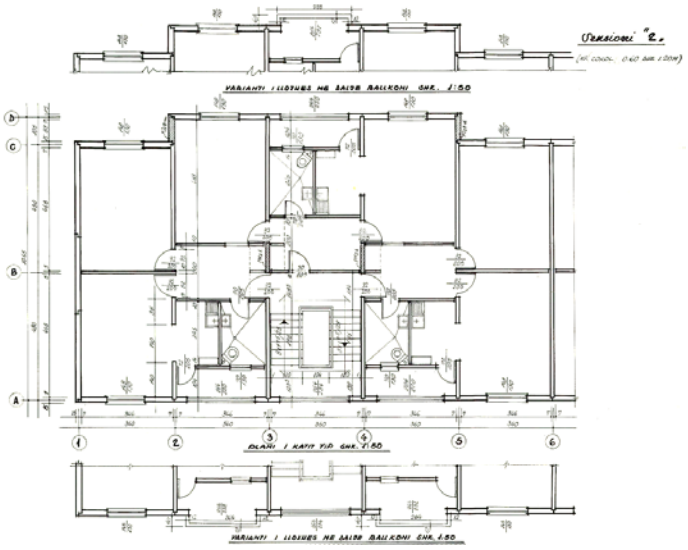

Fig 11. Plan of Module 2, variation with lodge and balcony © AQTN

2.4 Module 2

Like the Housing Module 2, Module 2a has the same organizational structure with the only difference of the discontinuity and the change of volumes in the facade, which allow greater architectural expressiveness.

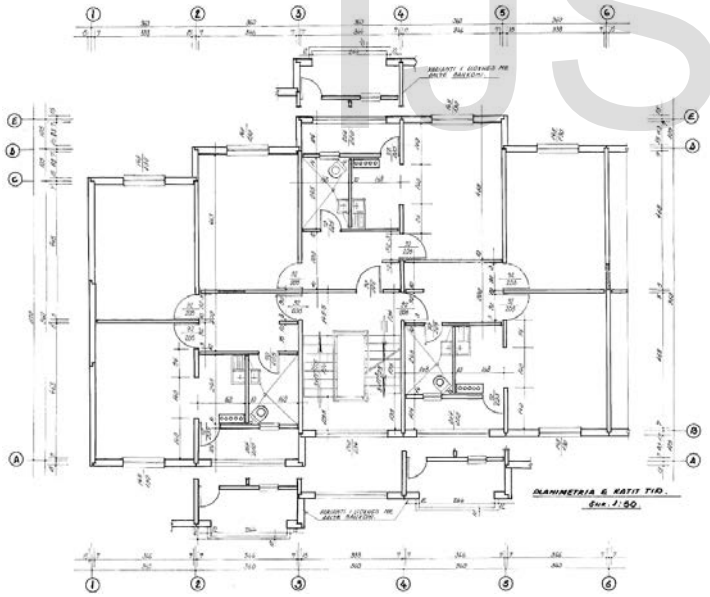

Fig 12. Plan of Module 2a, variation with lodge and balcony © AQTN

The planimetric module 1 and 1a with the bilateral apartments offer better ventilation and for this reason we find them mostly applied in the southern areas of the country.

After the development of the individual housing modules and the composition of the buildings, the architects had to develop the architectural and urban composition and find the most rational distribution of buildings in the neighborhood. The most economical and rational choice, obviously provided buildings as high as possible. In fact, most of the prefabricated buildings have five or six floors, each with a height of 280 cm. In Albania, prefabricated buildings of more than six floors were not built, which would have required the installation of the elevators. The economic crisis and the backward technology made their production impossible. Apart from the rational use of urban spaces, these neighborhoods have always been designed considering the best solution from a hygienic-sanitary point of view, allowing good lighting, ventilation, recreational public spaces and green spaces in relation to the number of inhabitants.

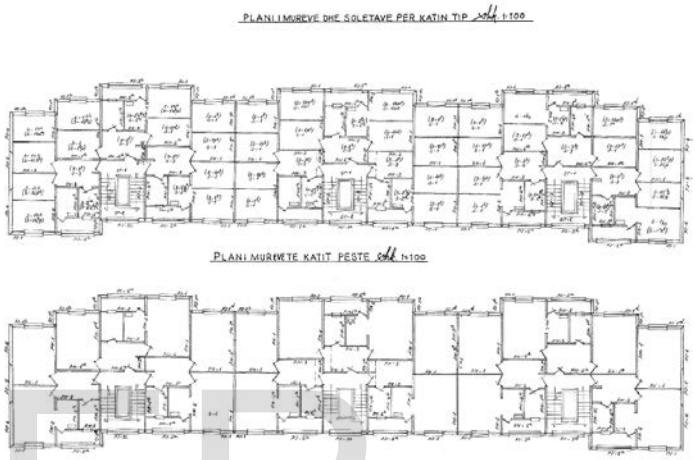

Fig 13. Connection plan of three Modules 2a, (a) Plan of the walls and slabs of the standard floor, (b) plan of the panels of the walls of the fifth floor © AQTN

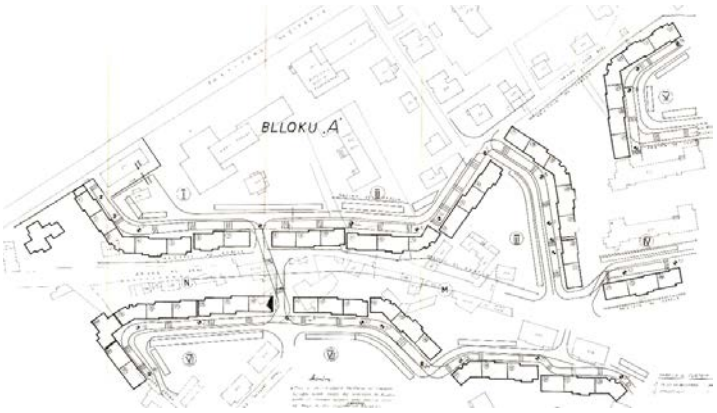

Fig 14. Example of the application of the different modules (1, 1a, 2, 2a) in Ali Demi district in Tirana © AQTN

3 Construction Diagram and Composition of Prefabricated Elements

During the period of prefabrication, research was mainly focused on architectural creativity and only a little on new construction schemes. In fact, in all prefabricated constructions a single construction scheme has been applied, namely that of a

"continuous structure", with external and internal load-bearing panels. These structures have no pillars and are composed of different categories of panels: horizontal (S) and vertical (PJ, PM, PN), load-bearing and non-load-bearing. The vertical external and internal (supporting) panels connected to each other and to the panels of the floors transmit the loads of each floor directly to the ground.

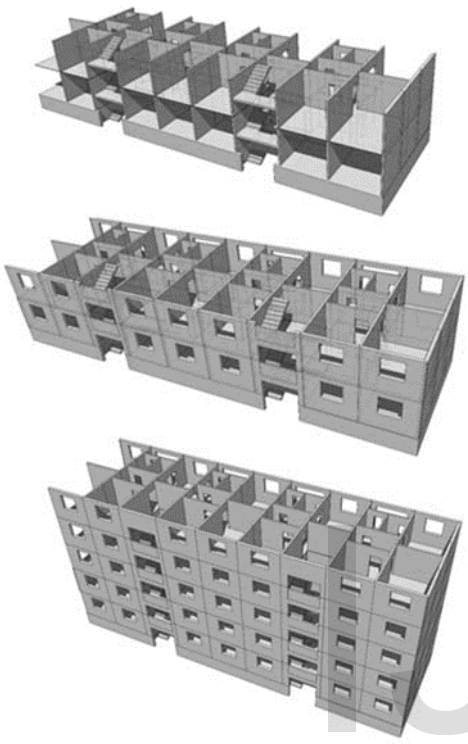

Fig 15. Construction diagram of buildings with continuous structure and load-bearing panels [10]

According to the technical drawings of the Institute of Design Studies no.1[8] in the various modules of the housing types 1, 1a, 2 and 2a results that each building compositional module is generally composed of about 45-46 types of panels, grouped according to their function in:

- External panels - PJ
- Load-bearing panels - PM
- Dividing panels - PN
- Inter-floor slab panels - S
- Cover slabs panels - St
- Other constructive elements such as the panels forming the chimneys, the elements that compose the staircases such as the ramps and slabs of the staircases, the parapets of the balconies and lodges, the corners of the terraces etc.

Based on the changes of the housing modules, the types of the composite panels were also updated [8].

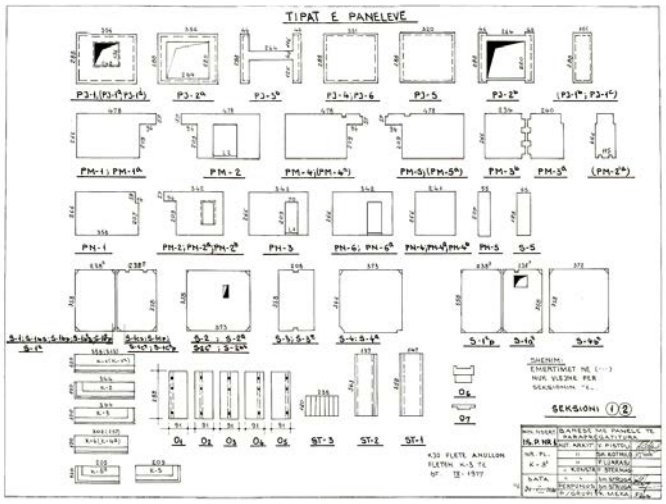

Fig 16. Types of panels © AQTN

The disadvantage of the construction scheme with load-bearing panels lies in the fact that the internal load-bearing transverse walls (PM) make it difficult, if not impossible, to modify the interior spaces.

Fig 17. Installation of the panels © AQTN

4 Technological and Construction Aspects

The production of the panels took place in metal workings prepared to produce panels of excellent quality, precise dimensions, excellent completion etc. Before casting, it was necessary to make sure that the armature was positioned correctly and to make sure that the metal elements did not corrode. Particular attention also required the process of checking the quality of the completion that was prepared at the factory. The panels were taken to the construction site in a vertical position by vehicles with trailers with special structures to avoid damage during transport and installation. The installation was done by crane (Fig. 17), following a precise order defined already in the design phase (Fig. 18). After the installation, the elements were welded with each other.

The structure of the prefabricated buildings was designed to withstand seismic activities with reference to the danger of the various areas of the territory. Prefabricated buildings can withstand up to a magnitude 9 for areas of high seismicity. In these cases, the irons of the connections of the panels and the

reinforcement of the columns change with respect to those of the zones with seismicity calculated with a magnitude of 6-7.
According to the information of the I.S.P. no.1, the concrete slabs were reinforced with a wire mesh. Two types of steel were used for the reinforcement: steel with a diameter greater than 6.5 mm with a (minimum) resistance of 2100 kg / cm² and processed, cold, drawn steel, with a diameter of 4 and 5 mm.
It is envisaged that the steel reinforcement 3 with a diameter greater than 6.5 mm, that is added in addition to the slabs of the walls and slabs would relate to wire in the reticulated grid. The slabs in the panels are fixed by welding with the bars of the net.
The air-entrained concrete called "peno-beton", used for the thermal installation of external panels, had a thickness of 14 cm and a compressive strength of not less than 4 kg/cm². Cellular concrete panels had to be laid dry and placed attached to each other with an empty space of no more than 2-3 mm.

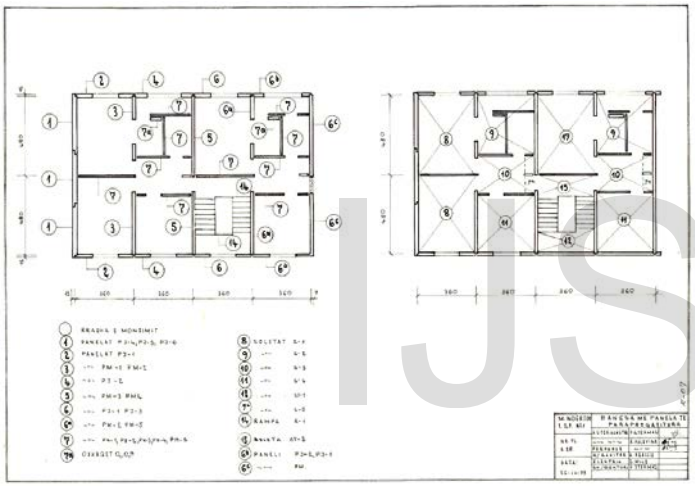

Fig 18. The order of installation of the various panels - Housing module 1a © AQTN

As far as the structural aspect is concerned, the planimetric configuration is defined by supporting perimeter elements intersected by an internal partition system that acts as bracing of the structure. The foundations of the buildings are about 1.3 m deep compared to the ground level and were made by concrete, with a compressive strength of 100 kg/cm2. The foundations are calculated for a ground with a good bearing capacity of 2 kg/cm². For a seismicity of the ground different from the expected one, the respective calculations had to be done for their correction [9].
The buildings could be built without joints up to a length of 60m. For longer lengths it had to be built with double-wall joints.
When laying the panels of the floors on the walls or the walls one above the other, it was necessary to lay a cement mixture of 1:2 composition with a thickness of 2 cm. This mortar was laid parallel to the positioning of the panels and should not have been laid less than 15 minutes from the panel position.
The concrete filling of the columns that is created in the connection nodes of the panels was done after the insulation.
The filling of the vertical nodes with waterproofing bituminous paste was done from the top, instead the filling of the vertical and horizontal nodes with paste was done from outside. To guarantee the flow of humidity it was necessary for the two metal sheets in the vertical node to fall on the inclined sheet coming out of the panel. The metal sheet (groove) was placed at the beginning after laying the panels from inside the building. The insulation from the outside of the nodes with paste both in the horizontal and vertical nodes had to be well laid, without interruption, in the intersection of the nodes. [9].

5 The Design of the Facades and the External and Interior Completions

In prefabricated buildings architectural design was closely linked to the production process. The mass production of construction elements and the typing of details limited the architectural creativity. Recognizing the importance, the architects of the Institute of Design Studies no. 1 focused on the study and development of the various planimetric modules, which, although with the same distribution of the internal environments, allowed different volumetric solutions and greater expressiveness and architectural individuality. Along with the change of volumes, other elements have also been studied to improve the appearance of the facades (such as the use of different colors, the balcony parapets, the frames of the terraces parapets, etc.), trying to improve the variety, obviously using as much as possible the available prefabricated elements.
Few alterations have been made to the elements of the facade to adapt to the climatic characteristics of the place. In the southern areas we find mainly to be applied modules 1 and 1a with bilateral exposure and better ventilation; however, we also find them in cold climatic zones used for their compact shape and smaller external surfaces, even if the measurements of the openings on the facade have always remained the same.

According to the technical notes of Modules 1 and 2 [9] the preparation of the plaster of the panels, the inter-floor slabs and the floors of the roof were already prepared in the factory. Instead the joining of the corners of the panels was carried out on site with the same applied completions in the prefabricated panels. The joints between the different panels were initially occurred with a layer of cement-based mortar prepared on site, which was applied in the horizontal and vertical nodes [8]. In recent years, however, during the period of isolation and the economic crisis, the nodes of the facades have been left uncovered.

When it comes to the completion of the panel, color has played an important role in the composition of the facades; just have a look at the image below where the same building is shown, consisting of the simplest standard form (M.1), differentiating the facade elements using the play of colors. Color was the simplest and cheapest method to improve the appearance of facades without referring to the production of new elements. For each module, ten different variants of façades were availa-

ble. The colored plaster, with a thickness of 2-3 cm, was applied to the entire or partial surface of the panels according to the variations of the facades.

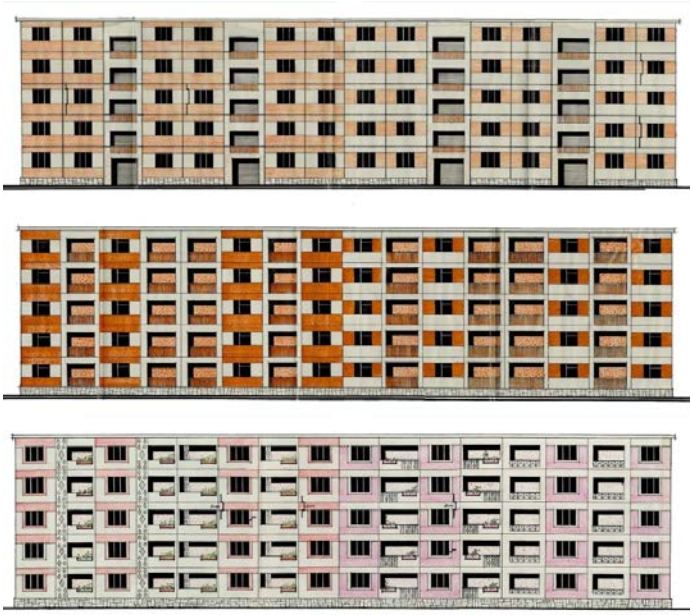

Fig 19. Variants of facade treatment [7]

Together with the color, the treatment of the balcony, lodges and staircase parapet was another element adopted to create individual and lively solutions in the facades. According to the technical notes of Module 1 and 2 [9], based on the Decision of the Technical Council of the Ministry on October 30, 1979, further elaborations were made, and the external panels of the lodges and stairs were reviewed in terms of functionality (enlargement of their spaces) and aesthetics. Different types were used for the treatment of the lodges and balconies parapets, among which two variants prevail:
- The variant with corrugated concrete and iron parapet
- The variant of decorative bricks and iron parapet that were also used for the staircase panel.
Instead of bricks we often find the ceramic coating and concrete slabs with various shapes and completion. The frame is composed of a prefabricated concrete slab. In some cases, part of the handrail is placed in concrete planters (Fig. 20).

The lodge, in addition to having the function of enlarging the spaces, served as another element, used to rhythm the facades, mainly applied in the facades of the South.

After having mounted the structure at the same time in the external part, the interior works were carried out, such as the electrical and hydraulic systems, the installation of the doors and windows, the laying of the parquet and the tiles, the plastering and the painting of the panels on the inner surface, installing the handrail in the stairs, etc.

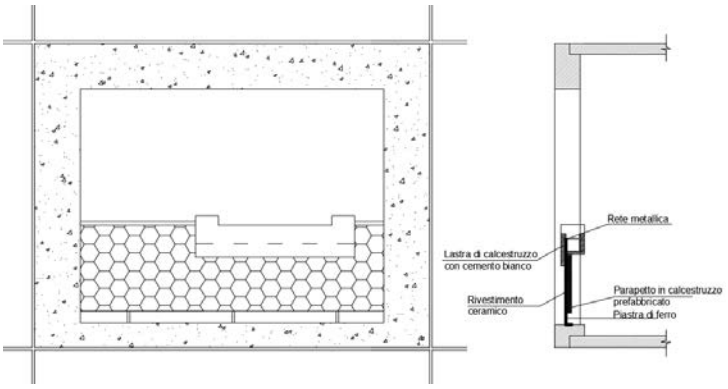

Fig 20. The detail of the balcony parapet with planter

The interior walls were colored with lime. The floor of the bedrooms was covered with parquet, while the living room, the kitchen and the service areas were covered with granulated stone tiles. The water insulation of the floors of the lodges, balconies and bathrooms consisted of bitumen waterproofing membranes. In the bathrooms, the insulation rises 10 cm in the side walls.

In most cases, the staircase parapets are made of iron with a tubular section and a wooden handrail. The metal railing was prepared according to the measures taken on site.

In relation to the functional aspect and the surfaces of the volumes, the housing units of the prefabricated buildings, even if they offer better living conditions in relation to the accommodations built up until the mid-1970s [7], they consist of apartments with small spaces and with partition walls in reinforced concrete which makes modifications difficult. The composition of the interior rooms was predefined and could not be changed. For this reason, it was important to study in depth the furniture and their unification for the different housing modules. Subsequently, a choice of custom-made furniture was proposed which used the available spaces in a rational way and satisfied the needs of the inhabitants.

Fig 21. (a) Example of the furnishing of the living area, (b) furnishing the kitchen / dining area corner

According to the estimates prepared by the Institute of Design Studies no.1 (1987), the construction costs of the housing units

in Tirana for the period 1986-90 are around 400 Lek/m² (3.2 Euro), excluding transport costs, for a total of:
Module 1 - 285.155 Lek (about 2281 Euro)
Module 1a - 292.724 Lek (about 2342 Euro)
Module 2a - 386306 Lek (about 3090 Euro)

6 State of Fact

Currently, there are no reliable data regarding the number of buildings constructed with prefabricated panels. During the obtaining of the information of Census 2011, no recordings were made regarding the construction type of the buildings. Based on Census 2001 data, we note that 5% of nationally constructed buildings consist of buildings with prefabricated concrete panels. Some twenty thousand apartments are thought to have been installed in more than twenty urban centers [10]. In the city of Tirana, the highest number of prefabricated housing units was built with around 1015 apartments distributed in 9 residential districts, initially in suburban areas, but today, with the development of the city, are found in central areas of the city.

7 Conclusion

Today, in Eastern Europe around 100 million people live in buildings made of prefabricated concrete panels [12]. These buildings show the same problems, namely: degradation of components, thermal loss, presence of thermal bridges, presence of humidity, low comfort in living spaces and high energy expenses.
Consequently, in recent years, the debate on the future of prefabricated buildings has been at the center of attention for European countries, particularly in Eastern Europe, where the number of these buildings is considerable. The energy retrofitting of this building heritage offers a good opportunity for reducing energy consumption and for improving indoor spaces, people's health and wellbeing.
The considerations made during the cognitive phase of the prefabricated typology, represent the base from which to start to face the planning of targeted interventions according to the needs, in order to improve the building performance.
In the next phase, the research activity will focus on the analysis of some examples, to create a general overview of the different ways in which this topic has been addressed. Evaluating strengths and weaknesses helps to understand the main common problems and the best retrofitting interventions. Considering their similarity, positive results can be applied to the vast heritage of buildings with prefabricated panels as in other residential buildings built during the period of socialism in Albania.
Furthermore, the research activity will focus on the analysis of the current condition of the built heritage in order to identify the technical, economic and social criticalities that will serve to identify guidelines for the sustainable redevelopment of this heritage.

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