AN EARLIER EXAMPLE OF PORTUGUESE CONCRETE PREFABRICATION, THE "TORRE DA BOAVISTA" CONDOMINIUM IN PORTO

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Abstract *Prefabrication is a paradigm of the Modernity with a late and minor implementation in Portugal. The first large scale concrete prefabrication in Oporto takes place only in the 70's. Nuno Tasso de Sousa, a Portuguese architect influenced by the work of José Lluís Sert and by other international references designed a set of two buildings that apply a precast concrete slabs system on the facades' cladding.*

The absence of knowledge and technological skills leads to the use of the two buildings as a testing laboratory of design solutions, execution and assembly of panels, refined throughout the building phases. The designer company was a subsidiary of the building owner, a construction firm, fact that helped the relation between project and construction.

The experience gained in these works ultimately lead to the creation of new company devoted to prefabrication that still exists today, and has work done in several countries.

The objective of the study was to analyse the construction processes of these two building, its constructive characterization, mainly related to the facade elements and connections system, identifying differences between phases. Both the architect and the general contractor are still alive and in work practice so they were valuable sources of information along with the building and its building permit process.

This Portuguese pioneering example, developed with "craftwork" solutions that still are in good conditions after 40 years, is an example of a durable mixed high-low-tech solution, with low cost and good long-term behaviour.

1. INTRODUCTION

Construction industrialization and Prefabrication were seen, in mid 20th century, as a modernity paradigm and a motor of change. Le Corbusier expression *'Une maison est une machine à habiter'* wasn't only a functionalist approach to design, related to the adaptability of spaces to the functions that they host, but extended itself to the construction activities, in a rationality of resources and execution forms.

In a certain way, it was envisioned for construction activities the application of what had been the contributions of industrialization for global progress, namely standardized mass production.

The heavy prefabrication had moments of special use, essentially related to reconstruction efforts of large devastated areas, or suppression of endogenous shortages after major policy changes. In the first example, an extensive use of building prefabrication enabled the reconversion / refurbishment of the arms industry after war conflicts, as happened in Europe and the United States after World War II; the second aspect, associated with policy changes, can be seen in Eastern Europe and some Latin American countries such as Cuba and Chile.

The economic and social gap between Portugal and the rest of Europe (and world), that occur during most of the 20th century, mainly for reasons of political regime, determined that international references reached our country with a considerable lag.

If transposition of what was going on abroad was easier when we consider architectural images and styles, it was much harder when it was related to the implementation of technological systems, or use of building materials, that didn't exist in Portugal.

Although the respect for a specific architectonic image - of 'national' roots - was the main question posed to architects by the central state, technological aspects of construction were also important, as there were several political implications of its use, mainly one that would mean a bet on a standardized building system, and standardized large building.

Portugal stayed apart from this late 40s and 50s European implementation of prefabrication, despite our previous, in certain ways pioneering, standardized building experiences of Lisbon's reconstruction after the earthquake and Oporto Improvement Plan promoted by Board of Public Works (corresponding to different time – 18th and 19th centuries - with other materials - stone, steel and wood - and smaller scale - only building components).

However, if we evaluate the situation objectively, in the mid 20th century Portugal did not fulfil the necessary requirements for the implementation of a heavy prefabrication system. But some Portuguese professionals, architects and engineers, longed for the rationality - in terms of architectonic language, execution processes, but also final quality - that the implementation of such a system would bring to the construction activities.

If we examine bibliographic sources from that time, we can find several references to prefabrication, mainly as a manifesto trying to promote its use.

In the 1st National Congress of Architecture, in 1948, Arménio Losa presents a paper entitled *"Industry and Construction"* which advocates the use of rational / modern construction methods including prefabrication - in his opinion it should be extended to large housing components as entire walls or toilet modules [1].

More important in this pathway was a 1952 publication, by the National Laboratory of Civil Engineering [LNEC] - recently created in 1946 - on *"Prospects of prefabrication in housing construction"* [2] signed by Ruy José Gomes.

The increase in construction, either in volume and in size of urban developments - which was happening in the capital and also will begin to be visible in Oporto, mainly after the publication of the Horizontal Property Regime in 1955 [3] - were certainly determinants factor in this bet on prefabrication, that ceases to be an individual manifesto, and began to have the institutional backing of LNEC.

Aiming at dissemination to a wider/extended public, on 58 Gomes published in *Revista Binário* - a magazine dedicated to architecture and construction - an article about prefabrication, contextualizing it historically and geographically, then explaining the reasons for the significance of its implementation in Portugal [4]. Still in the same journal in 1964, a new article will enhance dissemination of this technique among architects and engineers [5].

2. "TORRE DA BOAVISTA" CONDOMINIUM

It's in this particular circumstance, a growing desire for a rationality of processes expressed by technicians, but also a strong link between design and construction, that the development located in the street corner between Avenida da Boavista and Rua Beato Inácio de Azevedo begins in the 70s. Architect Nuno Tasso de Sousa and engineer Arménio Ribeiro Ferreira, while technical staff of Vértice design office, design a *"a set of two independent buildings, with distinct volumetries and originally of different owners"* [6], but with common architectural image and built in sequence - with a time lag of about two years.

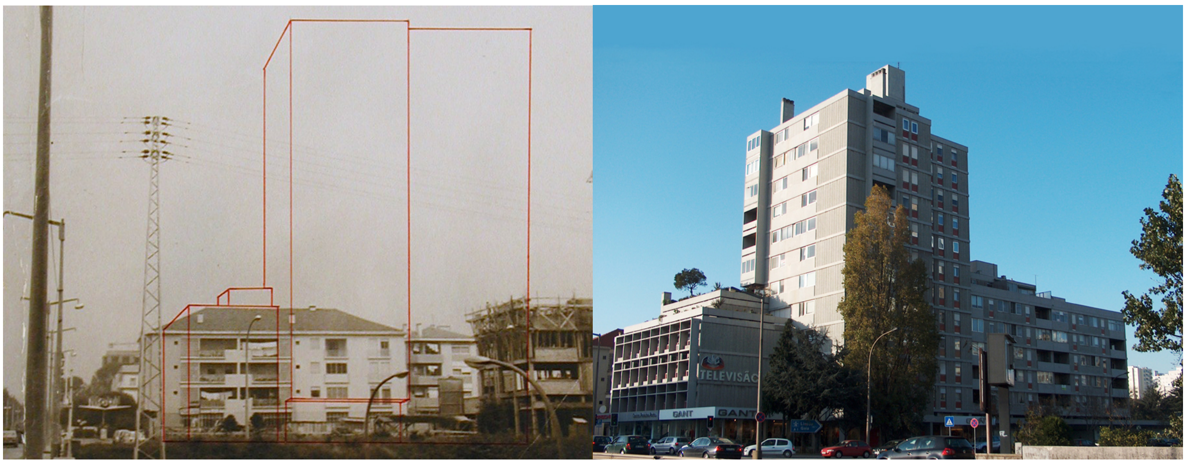

Figure 1. "Torre da Boavista" Condominium – Before construction and nowadays.

Taking advantage of the favourable circumstances that the design office was part of a construction company, Soares da Costa, the first building design was thought, right from the earliest times, to use precast concrete slab in facades' cladding, in a comprehensive manner. Tasso de Sousa specifically mentioned the influence of Josep Lluis Sert work [7], but it is possible to draw parallels with a kind of architectural image that began to deploy in some European cities, mainly in the urban extension areas.

In these buildings the prefabrication should be used in the coating of facades but also in some other architectural elements, such as chimneys and balcony guards.

From this initial decision resulted a design direction in terms of modulation, proportion, ratio of opaque zones and openings, but also a search for implementation solutions, to address issues raised by the connection between the several precast slabs and the concrete structure.

In Oporto there was not the technical knowledge nor the technological skills to respond to this request and the two buildings, slightly staggered in time, become a testing laboratory of design solutions, execution and assembly of panels, refined throughout building stages.

This becomes, in Oporto, the first experience of heavy concrete precast slabs covering the entire facade of a building - the process of finding solutions, learning between phases of execution, and implementation of handmade solutions is very clear.

This set consists of two buildings with distinct heights. The first to be built - usually called lower block - corresponded to a seven-storey block, with housing programs on the floors, shops on the ground floor and underground parking.

The second building, the tower, has a smaller area in plan. It is divided into two parts of different height. A lower one, near Avenida da Boavista, which makes continuity with the neighbouring buildings, and, retreated from this alignment, a thirteen-storey tower - with a mixed program of housing on the higher floors, offices on the middle floors, commerce on the ground floor and parking in the basement.

2.1. Description of the constructive system

The constructive system definition is very close in the two buildings, including those relating to prefabricated facades' cladding. There is however some differences in the resolution of the vertical supporting structure determined by the different volumes.

Both buildings use a reinforced concrete structure consisting of pillars, beams and pre-stressed lightened slabs, recurring to concrete piling foundations. The tower block has the insertion of some additional reinforced concrete walls, to ensure bracing.

The lower block, the first to be designed and built, also corresponds to the first definition of the building system preconized for exterior walls - defining *"a double exterior wall, with interior 11cm hollow brick wall, 5cm cavity, and prefabricated slabs with stone aggregate finish on the outside "*[8].

Should be noted the different description between processes, the first referred to as "prefabricated slabs" and the second calling "prefabricated panels". Also noted that in the first process there are no definition of thickness for the panels, and in the second it's mentioned a 10cm thickness.

2.2. Panels design and execution process

Regarding the prefabricated panels, more enlightening than the descriptions made, are the drawn elements of architectural and structural projects - despite their scale, they represent correctly the solution adopted, not only in terms of form and stereotomy, but also in technical-constructive solution for fixing and support.

The panels, working between structural slabs, are one storey high, about 40 cm wide (50 cm in design stage) and a varying thickness between 10 cm in the contour and 6 cm in the centre [9]. This allows both reducing weight while maintaining resistance and ensure enough thickness to conform the connections between panels and between panels and slabs. The horizontal and vertical tops of the panels have grooves - for connection with slabs and for the application of a sealing joint between panels.

The panels stereotomy in the facade' representation is perfectly defined either in the lower block either in the tower. However, its representation in plan only appears in the first of the buildings, in which is clear perceived the panel's width and its thickness variation.

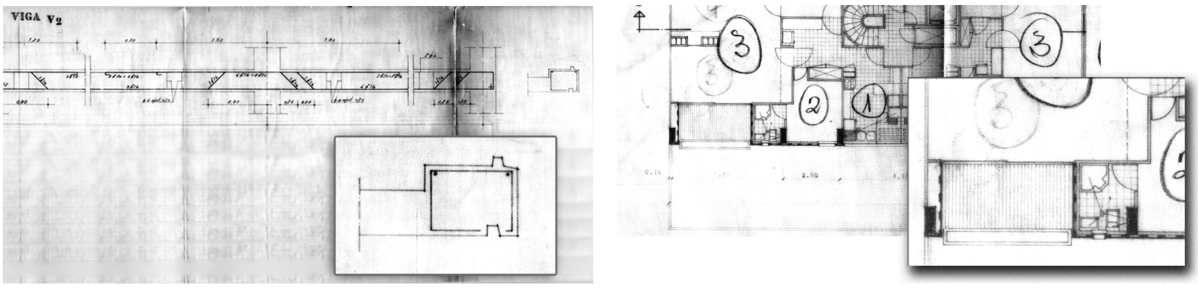

Figure 2. Design elements from the lower block.

According to the foreman of prefabrication, António Baltazar [10], were initially considered two ways of implementing the panels, one that was done in two concreting stages and another in just a phase. The second was the one used - it would require greater control of the quality of manpower but also gave greater assurance of final appearance and durability.

The panel was made with its entire thickness, the stone aggregate was put on the panel surface, tight, to achieve a close connection between layers. Then the panel was placed vertically and washed with water and a brush, to remove the accumulation of gum on the surface, ensuring washed appearance.

At the time, they didn't have the current vibrating tables, so they used makeshift tables and the concrete compacting was obtained by continuous beating of a hammer handle, or similar instrument, in the structure that served as the base mould.

The entire process of panels manufacturing was very handcrafted, made on the construction site and not at the factory, and based on subsequent experiences, whether in defining the panels shape, design and 'ideal' dimensions as its form of execution. With rigor of execution, the artisanal methods can equally guaranteed which later mechanization brought.

Indeed, this 40 years old building still maintains an image close to its initial time, and with reduced maintenance - an intervention of joints correction and some concrete repairs, in the lower block, and a façade washing to remove dust and dirt on the tower, which will soon be the target of a heavier intervention.

The choice of aggregate stone, *Viana* green marble, also aimed to help a good aging process of the building [11]. The colour, nor too light, nor too dark, allows runoff water lines that carries dust to be imperceptible in the façade.

2.3. Fixing and support system

The fixing system of prefabricated exterior panels fits directly in the horizontal concrete structure, without using mechanical fastening. For this, the design of structural elements is adapted - and represented in the first building design, albeit in a somewhat simplistic form.

In the concrete slabs, or perimetral beams, are left during concreting some connections for the mounting of the panels - the slab upper surface has a small protrusion for engagement with the panel groove; the slab underside has a groove for mounting handily, being gravity the only responsible for keeping the panel in place.

This system of execution and assembly implies an increased rigor on the structure work, not only a perfect sizing of the grooves, as the exact alignment of all floors to ensure the perfect verticality of the final coating.

2.4. Assembly and sealing between panels

The assembly of prefabricated panels was also subject of experimentation to get the best results with fewer resources - from defining the best design of the panels that facilitate assembly, guarantee the sealing, up to resizing its stereotomy, as seems to have been the passage from 50 to 40 cm between design stage and construction stage.

With panels that occupy the space between two slabs the only forms of mounting them would be or the lack of protrusions in some areas (which act as panels entry points), or ensuring clearances to allow putting the slanted panel, bringing it to the correct position, but with implications at the level of air tightness.

In the first building the option was the non existence of fittings in some areas - areas that correspond to the locations of windows and are marked by the red panels - serving either as panels entry points, either as horizontal clearance to allow panels movement needed for application of the sealing system: A very interesting solution, for its ingenious idea using ordinary inexpensive materials. So, for the sealing between panels it was used a hose - same type that is used for irrigation - heated in big cans and placed compressed between the grooves of the prefabricated panels. The hose simultaneously acts as a seal and an inner joint, allowing the subsequent application of mastic sealing as reinforcement. This implied that the panel was not placed in its final location, but slightly to the side, to allow the placement of the hoses, hence the need for clearances assembly, guaranteed by the spaces without fittings.

Figure 3. Lower block - Panels entry points

2.5. Differences between the two buildings

There are some important differences between the facade cladding system of the two buildings, and, if in general appearance they are not noticeable, at a constructive solution level they are effectively distinct.

The structural design of the second building is much more complete and detailed than the first, partly because of the complexity of the building, and an increase of quality of licensing elements, but also because of a better understanding of the work circumstances, directly resulting from construction of the first building - a lag of about two years allowed that the first work experience could be integrated in the second building permit.

The first work served as a dress rehearsal of the recommended solution, enabling to learn from the ‘mistakes’. An example of this was the difficulty in sealing the connection between panels and structure found in the first building that determined a change of detail.

In the first building the waterproofing barrier in the connection between panel and bottom slab - the worst area, because of the permanence of water - was almost entirely dependent on the use of sealants, mastics or other, placed outside and for that too subject to degradation, poor durability as well as deficient application. Despite the male-female connection between the slab and the panel, the joint was easily subject to capillarity phenomena.

In the second project some changes in the design were done in the fittings that were left in the structural elements, and that were defining with greater detail in the licensing process. Thus, between projects, the relative coordinates between panels and interior structural slabs were changed as well as its exact detail.

In the first building, the fit of the panels is made at same level with the interior floors. In the tower project was chosen to make this fitting below the inner slab level, ensuring that there was always a gravitational barrier to moisture penetration. This difference of 9 cm is a constant throughout the project, whether it's a 24cm thick slab or a 99cm high beam. Are also constant throughout the building, and independent of the structural element, the shapes and dimensions of fittings that are left on the slabs, that guarantee the same slab thickness in elevation, and the same ledge, necessary to panels support and also for guards of balconies.

The type of cut made in the structure to receive the panels, and the lower sealing system also changes between phases. The docking profile has two different designs - as in the first stage - one for the lower support and the other one as operating space and the upper fitting. There are elements with both details, and other elements with just one, depending on its location on the facade. But, while in the initial solution the upper face of the support slab had a protruding element, in the second building is made a groove in the concrete, equivalent to the panel groove, which allows to use the same sealing system that was used between panels - the heated hose. So, the hose was placed over the slab groove, and when the panels were putted in place, they 'squeeze' the hose, thus ensuring the sealing system.

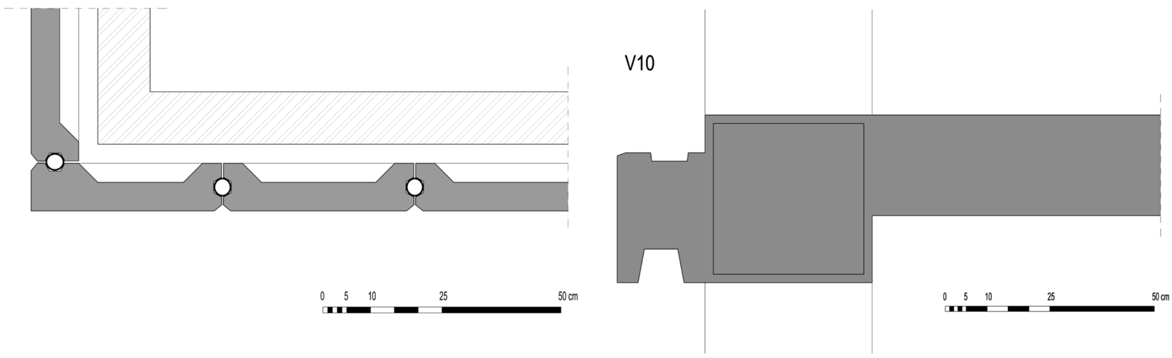

Figure 4. Sealing between panels with the heated hose, and details from the second building.

The mounting conditions were also resolved in different ways in the two stages - another way in which the experience of a work has been transposed to the next. In the second building as the docking, at the bottom, was not made by a protrusion but by a groove, there was no need for areas without fitting elements. This alteration of detail also allowed that the building corners would be use as clearance spaces.

3. CONCLUSIONS

What can be observed in these two buildings, after this analysis, is that there is a very strong connection between architectonic vocabulary and constructive definition, and we can perceive that the design process - while formal definition of the building - was parallel to the research and tests of the constructive system solutions. In the way the licensing process designs was made we can assume that the constructive solution was already defined and probably experienced in a small scale - the marks of the panels different thickness, the slab detail, and also the fact that the image proposed in licensing had not changed substantially during the construction phase, as is customary in many projects, all show the perfect harmony that existed between the development of the architectural solution and construction system. The fact that the office responsible for the project includes architects and engineers, while being integrated in a construction company, was also an important factor because it enabled the parallel development of a constructive solution and architectural design, adapting each other to the same idea.

However, initially the prefabrication was more strongly bound to the building image then to the execution process. For instance, the balcony guards of the lower block are concreted in situ, but wish the appearance of prefabricated elements.

Both processes started before April 25, with the construction of the first building fully completed before the revolution, serving this experience as a dress rehearsal to be replicated after 74. The significant increase in volume of construction, and the need to a quickly response to a requests for new buildings, triggered by political and social changes that came out of the revolutionary process, were determinant to the growth of precast industry in Portugal.

The experience gained in these works ultimately lead to the creation of Prégaia, a company devoted to prefabrication that still exists today, and has work done in several countries.

This pioneering example in Portugal, developed with "craftwork" solutions that were also used in some later works with success, and that are still in good conditions after 40 years, can serve as a reference for new buildings, regarding low-tech solutions with low cost and good long term behaviour, durable and therefore sustainable once viewed in the building's life cycle.

REFERENCES

[1] A. Losa, A. (1948), "Indústria e Construção", in 1º Congresso Nacional de Arquitectura, Lisboa.

[2] R.J. Gomes (1952) Perspectivas da pré-fabricação na construção de habitações, publicação nº29, LNEC, Lisboa.

[3] C. P. Vale, V.A. Almeida, "Urban Dynamics and Horizontal Property: Case Study of the Boavista Axis, Porto, Portugal", in Nuts & Bolts of Construction History, Paris, France, July 3-7 2012.

[4] R.J. Gomes, "Pré-fabricação na construção de edificios" *Binário*, Nº1, pp.15-19, 1958.

[5] M.L. Antunes, "Considerações sobre a pré-fabricação em Portugal" *Binário*, Nº 73, pp.244-249, 1964.

[6] C. P. Vale (2012). Um alinhamento urbano na construção edificada do Porto. O eixo da Boavista (1927-1999). Contributo para a História da Construção em Portugal no século XX. PhD Thesis, FAUP, Porto.

[7] Interview in 27/09/2007.

[8] A.R.Ferreira. N.J. Tasso de Sousa (1970) Memória Descritiva, Rua Beato Inácio de Azevedo nº 75, Licença nº 433/1971. Porto: CMPORTO-AG.

[9] According to N.J. Tasso de Sousa and António Baltazar.

[10] Interview in October, 2007.

[11] Interview in 27/09/2007.