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Characterization of 'Placa' Buildings

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1. INTRODUCTION

This report presents a brief description of the 'Placa' buildings, characteristic of the urban expansion of Lisbon on the decade between 40 and 60 of the twentieth century. This period began after the end of the period of 'gaioleiro' buildings and it is characterized to be the last type of construction in Lisbon using the masonry as a structural element.

Thus, this new type of construction coincides with the transition period between the masonry buildings and reinforced concrete ones. This period is essentially characterized by the gradual introduction of reinforced concrete in construction, first by means of slabs and later as complete reinforced concrete frame.

It is believed that these buildings present a considerable seismic vulnerability, essential because the introduction of reinforced concrete slabs represents a significant increase of mass (and then of inertia forces) without the increase structural resistance of vertical elements. Nevertheless, this typology still represents an important part of the Lisbon building stock, justifying first the assessment of their seismic behavior and afterwards the propose of strengthen solutions.

2. HISTORIC SURVEY

The final period of 'gaioleiro' buildings construction is characterized by the complete abandonment of the wooden structures on the structural walls, the systemic use of brick masonry walls on the interior and by the use of composite floors (steel beams and ceramic bricks) on balconies, kitchens and bathrooms. However, the majority of the buildings were built with masonry exterior walls.

The construction techniques used so far have been changed with the appearance of the concrete in the end of the nineteenth century in France and later in Portugal, and with the first code for the design of reinforced concrete structures in 1918 (Ribeiro, 2007).

First, from the second decade of the twentieth century construction there has been the emergence of certain elements of reinforced concrete in 'gaioleiro' buildings, especially at the façade.

In 1930 the General Regulation of Urban Construction (Original Title: 'Regulamento Geral da Construção Urbana (RGCU)') was published, aiming to improve strength and safety on the buildings construction. This Regulation recommended, for example, the insertion of reinforced concrete beams at the floor level to ensure the locking of the exterior masonry walls, particularly on buildings without a timber interior structure from the 'pombalino' buildings construction (Sousa *et. al*, 2006).

Since the implementation of the 'Estado Novo' in 1933, the Lisbon City Hall was faced with serious problems of homelessness, due to significant population growth (migration from rural areas) and poor housing (Silva, 1994).

So, the early 1930s were marked by the design of social housing neighborhoods promoted by the 'Estado Novo', the known economic homes from 1933. The political principles promoted the protection of the national values, constituting an explanation for the creation of its own architectural movement, known as Portuguese Architecture. This concept with the aforementioned regulation RGCU has improved significantly the buildings construction, and there was the beginning of the disappearance of 'gaioleiro' buildings (Silva, 1994).

Single-family houses recreating the traditional village environment composed the new neighborhoods. This social policy results on the urbanization of Salazar neighbourhood (1937, what is now Alvito neighbourhood), Quinta do Jacinto (1937), Belém (1938), Camarão da Ajuda (1938), Quinta das Furnas (1938), Quinta da Calçada (1939), Alto da Boa Vista (1939- 1940), Alto da Serafina (1940), Encarnação (1940), Madre Deus (1942), Campolide (1943).

In 1938, a new urbanization plan was commissioned by engineer Duarte Pacheco, in the position of Lisbon Mayor and Minister of Public Construction (Original Title: 'Plano Geral de Urbanização e Expansão de Lisboa', only published in 1948). The project was designed by the French architect Étienne de Gröer, involving the main lines of the city development. The program began with an enormous package of

expropriations (Figure 1), allowing the expansion to the north of the city, promoting the construction of new housing areas, the construction of the international airport on the north part of Lisbon and the creation of a green area around the city, including the Monsanto Park with 900 hectares (ha).

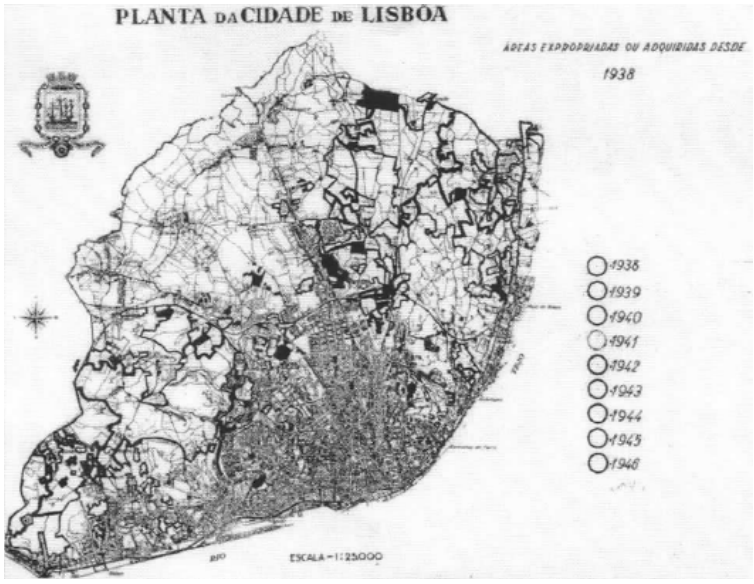
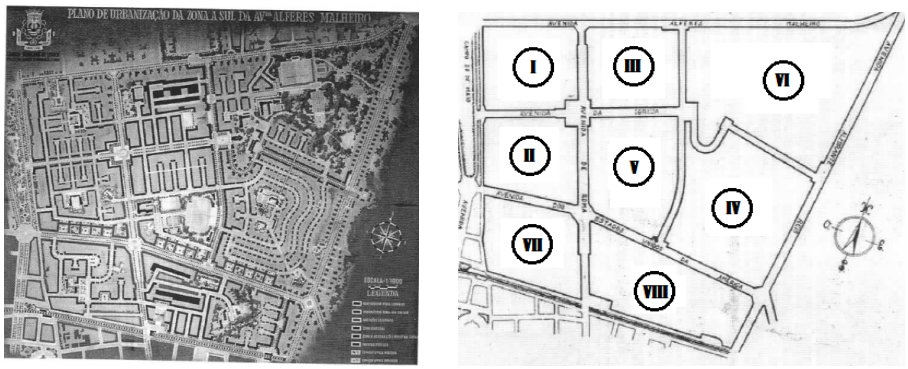


Figure 1 – Lisbon Plant – Lisbon areas expropriated between 1938 and 1946 (Costa, 1997)

Later, the Government recognized that the program based in its policy on social housing, the economic houses, let out a considerable portion of the population. Thus, in 1945 was enacted a new law on 'economic rent houses'. This program was intended mainly to the middle class who was excluded from the 'economic houses' for various reasons (Silva, 1994).

One of the notable urbanizations of this period was Bairro de Alvalade, developed by the architect Faria da Costa and design for 45,000 inhabitants (Figure 2). It provided the integration of different social groups and activities organized in eight central residential compounds (or cells). The area was limited by Alferes Malheiro Avenue (what is now Brasil Avenue) on the north side, Aeroporto Avenue (what is now Gago Coutinho Avenue) on the east, Campo Grande on the west and by the road-rail crossing Roma Avenue on the south, occupying an area of 230 ha (Figure 2).

The study for the urbanization of cells I to VII (Figure 2b) was developed between 1945 and 1957 by the architects Miguel Jacobetty, Fernando Silva, Dário Fernandes and Lima Franco in accordance with the architectural principles of the Estado Novo Regime. The studies for the urbanization of cell VIII on the south of Estados Unidos da América Avenue were developed by the architects Joaquim Ferreira and Orlando Azevedo between 1949 and 1952, approaching the contemporary modern architecture that launched the development of higher buildings built with reinforced concrete framing structures.



a) b)

Figure 2 – Urbanization of Bairro de Alvalade (Costa, 1997): a) Urbanization Plan of the south area of Alferes Malheiro Avenue developed by the architect Faria da Costa in 1945; and b) Division of the compound in Eight Cells.

In 1947 to overcome the inadequacies of the 'economic rent houses', the Government launched another housing program called the 'houses of limited income'. This program initiated the private housing supported by the Government, which allowed controlling the level of rents.

Examples of this new program are almost every buildings on east of the Rome Avenue and Manuel da Maia Avenue, located between D. Afonso Henriques Alley and the railway limit (Figure 3), such as the Bairro de S. João de Deus, Bairro dos Actores, Madrid Avenue, Guerra Junqueiro Avenue, João XXI Avenue, Paris Avenue, Pasteur Square (Silva, 1994).

a) b) c)

Figure 3 – New neighborhoods: a) Bairro dos Actores (Alto do Pina) b) and c) Roma Avenue

So, the emergence of reinforced concrete and the appearance of laws and regulations mentioned before were crucial in the gradual forgetfulness of traditional building techniques used for centuries. When the Engineers and Architects discovered the capacities of reinforced concrete and their significant structural capacity they definitively abandoned the traditional construction techniques and increasingly began to build with reinforced concrete (Nereu, 2001).

Although the use of reinforced concrete in the residential buildings construction arises occasionally in Portugal in the 30s, it is in the next decade that it becomes current in practice. This date states the transition period between the masonry buildings and reinforced concrete.

Thus a new type of buildings arises in the Lisbon city center: the 'placa' building. This type of buildings is also called mixed buildings of reinforced concrete and masonry. This period is essentially characterized by the gradual introduction of reinforced concrete in construction, first on slabs and later as reinforced concrete frame (Sousa, 2008).

The generalization of the concrete and the appearance of the first draft regulation on earthquake-resistant structures (RSCCS, 1958 – Regulamento de Segurança das Construções contra os Sismos) in the late 50s of twenty century marked the end of the 'placa' buildings period (Sousa *et. al*, 2006).

According to the Census of 2001, 10 years ago, in Lisbon there were about 20% of buildings housing with the 'placa' buildings typology (Ravara *et al*., 2001) (Sousa *et. al*, 2006).

3. DESCRIPTION OF BUILDINGS

The social housing neighborhoods promoted by the Estado Novo Regime were mostly composed by single family houses with one to two stories in line with the rural areas. They were designed for unskilled worker with low salaries, and they are characterized by symmetric neighborhoods with the influence of the English Garden City model (Figure 4). They are formed by single or band houses for one family only, very simple, rectangular, with masonry walls and wood flooring. These neighborhoods are located in the outskirts of Lisbon (Silva, 1994; Costa, 1997).

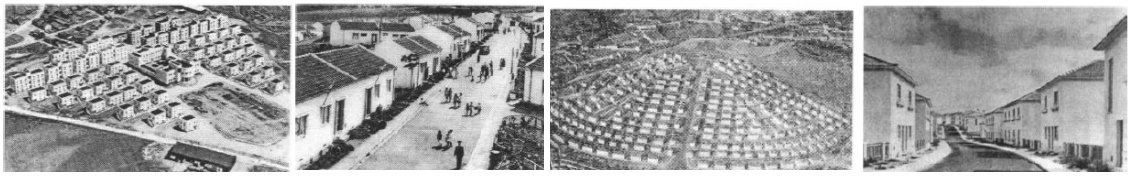


Figure 4 – Program of Economic Houses (AFML): Alvito (1937), Alto da Serafina (1940), Madre Deus (1942) and Campolide (1943)

Contrasting with the collection of *Art Nouveau* details typical of the 'gaioleiro' buildings, the new buildings built to be sold or rented were characterized by the simplicity of the façade walls.

The design of the façade walls was dominated by large smooth surfaces covered in marble and by the complete absence of decorative details. In fact, and in relation to the main façades, occurred a reduction of decorative elements characteristic of the 'gaioleiro' buildings, such as the guards at the windows and balconies and through sculptural elements. Apart from the exterior modification, the buildings structure continues to be made of rubble stone masonry walls and timber floors.

These buildings mark the transition of the two periods of construction. The first is related with the gradual replacement of the wooden structures on the walls for the brick masonry walls and the use of reinforced concrete prefabricated elements started to appear on the façade balconies and interior staircases.

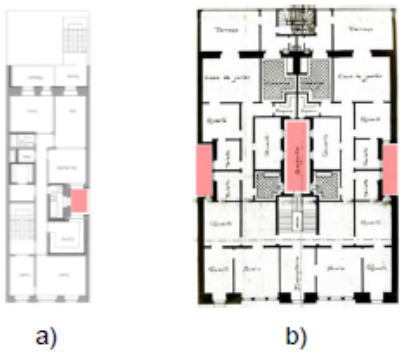
In the beginning of the 40s it was observed the emergence of buildings with reinforced concrete slab replaced the timber floors, which gives the name of 'placa' (plate) to this typology of buildings.

One can say that from the 40s comes a much more simplistic new design. The façades are symmetric and marked by horizontal and vertical lines, resulting from modern architecture (Figure 5). Moreover the story height is also reduced to about three meters (Ferreira, 2001).

a) b)

Figure 5 – The differences between the façade of (Nereu, 2001): a) 'Gaioleiro' Building and b) 'Placa' Buildings.

At this period the plane draw of the buildings tend to be less depth and the light –shafts, characteristic of the 'gaioleiro' buildings (Figure 6), which provide natural light and ventilation to the interior rooms, were no longer introduced regarding the rules imposed by RGCU.



a) b)

Figure 6 – Plant of 'Gaioleiro' buildings (Branco, 2007): a) type 1 b) type 3

In this period two plant types of buildings appear. One of them has a rectangular design with no interior compartments providing natural light to all rooms (Figure 7). This type is associated to economic rent houses which intended to rationalize the space; thus these buildings were designed for a low population class (Alegre *et. al*, 1999).

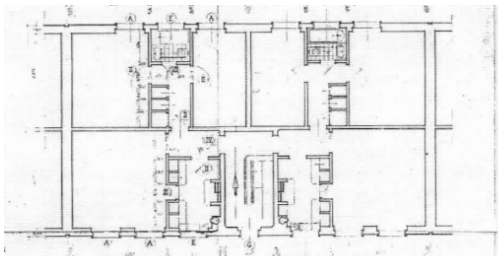


Figure 7 - Plant of 'Placa' buildings – rectangular plant (Costa, 1997).

The Bairro de Alvalade is a great example of this type of buildings. This neighborhood began with the construction of the Economic Rent Houses located on cells I and II financial supported by the 'Federação das Caixas de Previdência' (Figure 8). These cells were limited on the north by Brasil Avenue, on east by Rome Avenue, on the south by Estados Unidos da América Avenue and on the west by Campo Grande. The main idea was to start the urbanization of the district in a dynamic and active way in order to catch the private constructors for the urbanization of the remaining cells located on the south, closer to the urban area and therefore, valuing the land.

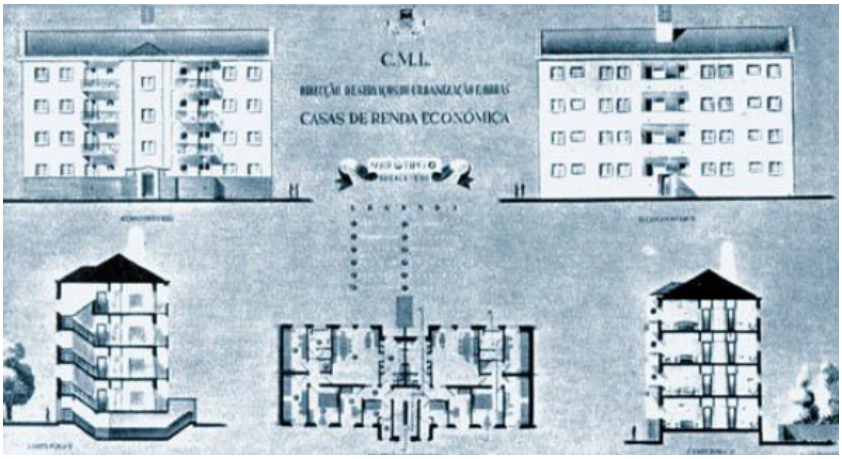


Figure 8 – Design of the Economic Rent Houses (Original Title: 'Casas de Renda Economica') designed by the architect Miguel Jacobetty in 1945 (Costa, 1997).

The construction of cells I and II was developed between 1947 and 1950, and in the same period, began the construction of Houses of Economic Rent on cells V and VI. These buildings, with no more than four floors, were grouped in bands with interior backyards guaranteeing the natural light and ventilation (Figure 9). The exterior design of the buildings has few architectonic details or variations, in accordance with the picture of traditional village. The front façade wall has a symmetric design with balanced balconies aligned along the height of the building. The main entrance is located on the center of the building accessing a two flight staircase separated by a half-landing, guaranteeing two houses per floor. The design of these buildings is mainly associated with the architect Miguel Jacoberty (Costa, 1997).

Figure 9 – View of Bairro de Alvalade (cells I and II) (Google Maps).

The main goal was to obtain an economic solution compatible with the function and the space organization, reducing the presence of spaces not used and making buildings wider than long. For the first time, after the Marquis of Pombal, the construction methods were based on normalization and rationalization principles, producing buildings of great uniformity in architectural and constructional terms. It was common the use of prefabricated elements, concrete balconies and staircases for example, or doors and windows framing, resulting in less expensive constructions.

The second and the most common type of buildings in this period arose from the expansion of the lateral light-shafts characteristic of the 'gaioleiro' buildings into the back yard of the compound of buildings.

This new plant type of building, known as "Rabo de Bacalhau" (Figure 10), presents a rectangular salient shape on the back of the building intended for the service areas (kitchen, bathroom and a waiver), including a secondary staircase to the building, while the living rooms were located in the main block of the building. This salient shape may have different sizes depending on the dimension of the buildings (Figure 10).

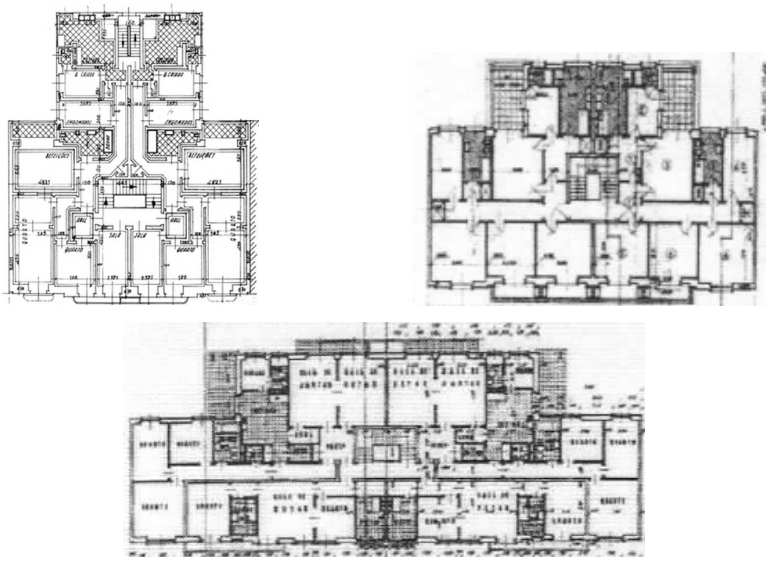
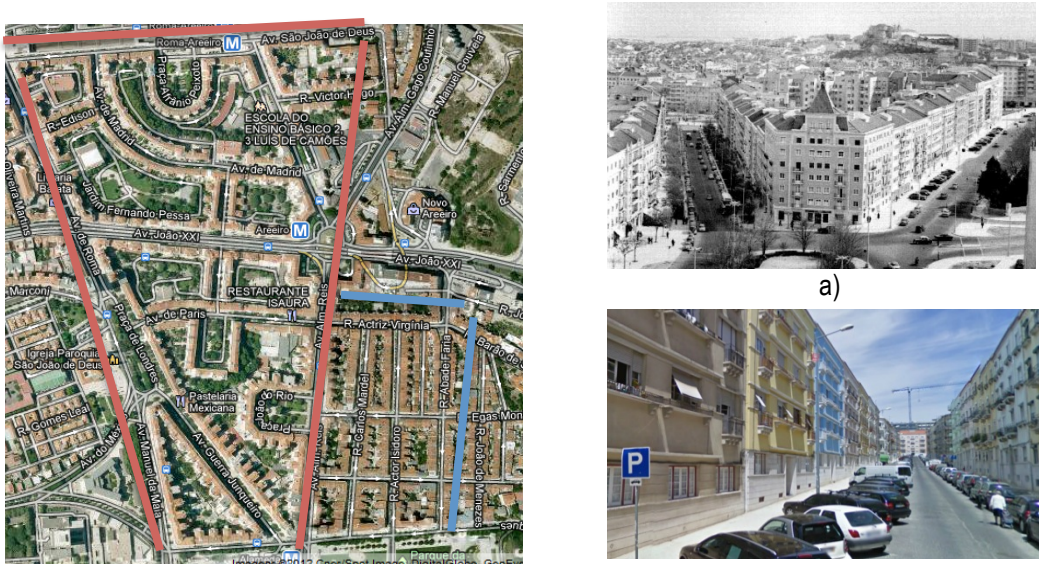


Figure 10 – Different Plants of 'Placa' buildings – type of "Rabo de Bacalhau" (Costa, 1997) (Nereu, 2001)

This typology is clearly visible on the east side of Rome Avenue and Manuel da Maia Avenue (Figure 11) as well as in cell III in Alvalade, which is limited on the north by Brasil Avenue, on east by Rio de Janeiro Avenue, on the south by Igreja Avenue and on the west by Roma Avenue. These buildings were built over the decade of 40 by private owners and were considered as 'houses of limited income' with a rent defined by the government. The design of these buildings is mainly associated with the architect Fernando Silva (Costa, 1997) with a construction much rich and they were mainly intended to a medium/high class.



a) b)

a)

b)

Figure 11 – View of 'Rabo de Bacalhau' typology: a) high class - east side of Rome Avenue and Manuel da Maia Avenue (AFML) b) middle classe – Actores Neighborhood (Google Maps)

In general these structures were composed by mixed buildings, with commercial spaces on the ground floors and housing on the upper floors. Even within this typology, it is possible to check the differences between the houses for the high class and for the middle class (Figure 11). The first group is located in east side of Rome Avenue and Manuel da Maia Avenue which coincides with some important trade areas. The buildings have in average five and six floors. The second group corresponds to the Bairro dos Actores, with poorer quality of the construction and simpler façades with an average of four floors.

After the 1950s, the masonry was no longer used on the construction of buildings in Lisbon, being limited to the construction of single family houses on the rest of the country. This period is also witness of the gradual increase of the buildings' height, which was no longer constrained by the limitations imposed by the masonry structures.

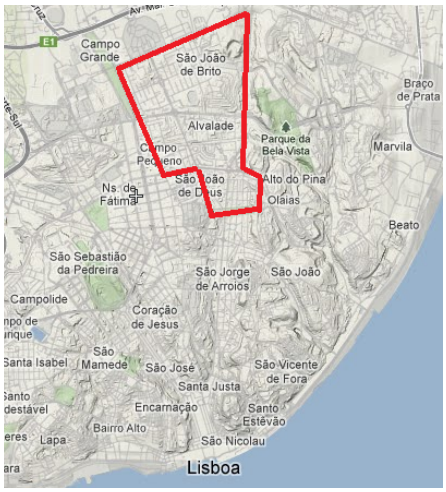
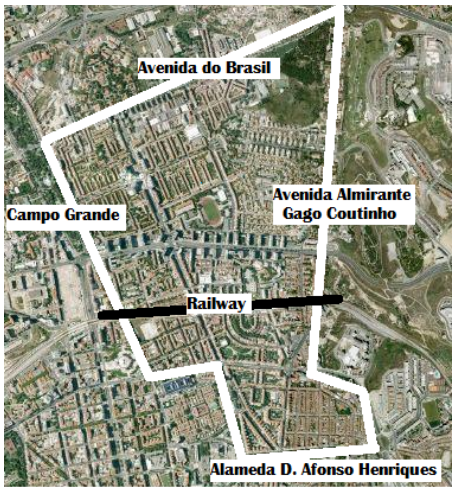
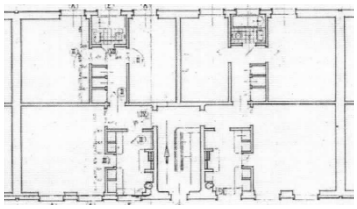
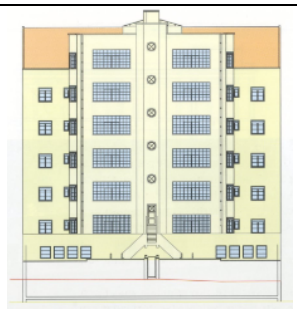
One of the first sets of tall buildings using reinforced concrete were built on the Bairro de Alvalade at the intersection between Estados Unidos da América Avenue and Gago Coutinho Avenue with the construction of two towers with ten stories (Figure 12.a and 12.b). It was the beginning of the reinforced concrete period as the main structural solution, perceptible by the construction of Estacas neighborhood designed by Formosinho Sanchez and Rui d'Athouguia, which received several national and international awards (Figure 12.c).

a) b) c)

Figure 12 – The first buildings in reinforced concrete in the Alvalade district (AFML): a) Tower at the intersection between Estados Unidos da America Avenue and Gago Coutinho Avenue b) Overview of Estados Unidos da America Avenue c) Estacas Neighborhood

The main characteristics of the 'Placa' buildings, aforementioned referred, are schematically presented in Table 1.

Table 1 – Summary table about the description of the buildings of 'Placa' Buildings

Date	1940 – 1960
Location	Bairro de Alvalade and the area between the railway and Alameda D. Afonso Henriques  
Types of construction in plan	Rectangular in Plan  Predominant type in the Bairro de Alvalade ''Rabo de Bacalhau"  Predominant type in the area between the railway and D. Afonso Henriques Alley
The facade	 Front  Back
Number of storeys	4 – 6
Story height	Around 3 meters (constant storey height between; exception the ground floor)

4. DESCRIPTION OF THE STRUCTURE

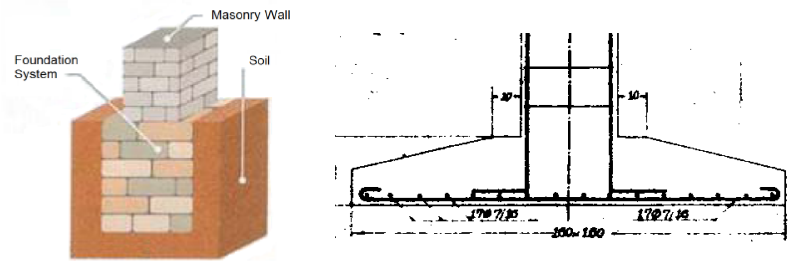
The ‘placa’ buildings sign the period of construction characterized by the abandonment of traditional techniques and materials and the progressive adaptation to effective reinforced concrete structural solutions of construction.

Although the use of reinforced concrete in residential buildings construction in Portugal appeared occasionally in the 30s and was generalized on the following decade. The reinforced concrete begins to be employed at the slabs which discharging directly on masonry stone walls, so the buildings were becoming hybrid systems of masonry and concrete.

In an initial perspective, the buildings from the 40’s become more reliable than the traditional processes used in ‘gaioleiro’ buildings, since the interior wood walls are replaced by brickwork and the timber floors for solid slabs of reinforced concrete. This new material is also integrated in the interior and exterior staircases, flat roofs and balconies.

In addition to the concrete emergence, in 1930 the General Regulation of Urban Construction (Original Title: ‘Regulamento Geral da Construção Urbana (RGCU)’) appears in order to improve the buildings construction for the strength and safety.

Usually the foundation of this typology is made by stone masonry very stiff and with a hydraulic mortar (Figure 13.a). The foundation works as a thick continuous wall which is enlarged in its base with a minimum depth of 0.30m and 0.5m until hard rock. However, in this period, the first reinforced concrete foundations appear in some buildings (Figure 13.b) (RGCU, 1930).



a) b)

Figure 13 – Foundation system: a) Continuous walls in limestone masonry (Appleton, 2003) b) Reinforced concrete foundations (AML)

In this period the façade walls continue in general to be constituted by rubble stone or brick masonry (Figure 14), usually with wall thicknesses between 0.40m to 0.70m and 0.30m to 0.40m, respectively. In some buildings the wall thickness decreases in height (RGCU, 1930).

a) b)

Figure 14 – Examples of the different walls used: a) façade walls with ruble masonry (Alegre, 1999) b) gable walls with brick masonry (Lucchese, nd)

The gabble walls are made with the same materials of the façade walls, but with lower thickness. The interior walls were built by brick masonry or by concrete blocks with 0.15m to 0.25m thicknesses. As in the case of the façade walls, in these walls the thickness can decrease in height (RGCU, 1930).

The 'tabique' walls, which were characteristic to the 'gaioleiro' buildings, continued only to be used as partition walls in the attic and in the collected floors.

It is during this period that significant differences in the floor level of the buildings arise. First the General Regulation of Urban Construction recommended the introduction of reinforced concrete beams at the floor level supported on the exterior masonry walls to ensure the locking of the exterior masonry walls, particularly on buildings with more than two stories (including basements). The bibliography suggests that these concrete beams were reinforced by 4ϕ3/8'' longitudinal flat rods on the corners braced by ϕ3/16'' stirrups generally 0.20 cm spaced (Sousa *et. al*, 2006).

The reinforced concrete solutions, firstly introduced as ring beams at the floor level, were progressively replacing other structural elements. The presence of Portland cement and concrete starts to be noticed on the interior walls made of hollow concrete blocks, on the prefabricated concrete slabs from the balconies and staircases, and on other covering materials. In fact, this regulation signals the end of the 'pombalino' techniques of construction, already degenerated by 'gaioleiro' buildings, and states the transition between the old masonry buildings and the reinforced concrete buildings.

Later, it was observed the introduction of reinforced concrete at the level of upper floors just on the back balconies and the service rooms of the houses (kitchens and bathrooms) which was initially applied due to the inadequate behavior of wood in contact with moisture in those humid zones. After, the solution was extended to the whole floor supporting the name 'placa' (meaning concrete slab) given to this typology of buildings. These concrete slabs were barely reinforced by steel rods, generally with only one layer of reinforcement for positive moments. In the beginning there is also no guarantee on the continuity of the

reinforcement between spans, so the slabs do not work as a continuous floor but as several panels in each room (Alegre, 1999).
Generally the concrete slabs have approximately 0.07m to 0.1m thickness and are simply supported on masonry walls.

In some buildings the floors are still made by a wooden structure which is supported by wooden beams (normally with 0.08m width and 0.18 m height) spaced from 0.4 to 0.4 m. The floor has an overall thickness of about 0.30 m and it is directly supported on the exterior and interior walls.

According to RGCU the buildings with more than three floors should have a ladder preferably constructed in reinforced concrete and with the capacity to install a lift. The buildings with more than four stories should have a service staircase with access from the street (Figure 15) and may be constructed in reinforced concrete or iron (RGCU, 1930).

Figure 15 – Service stairs in reinforced concrete (Nereu, 2001).

In this period, in addition to the traditional solutions of the coverage with sloping wooden structure covered with ceramic tile, appeared the first flat roofs built in reinforced concrete forming the terraces (Nereu, 2001).

In the case of Bairro de Alvalade, the Economic Rent Houses from cells I and II, and later in cells V and VI, were made with exterior rubble stone masonry walls and interior brick masonry walls (solid or hollow). These constructions represent the last examples of the use of timber floors made of pine beams (usually with 0.08 x 0.16 m^2 sections) and covered by pine boards. The roof structure was made of wood and covered by ceramic tile (Alegre, 1999).

Apparently, these buildings are not much different from the last 'gaioleiro' buildings; however the timber floors started to be strengthened by peripheral concrete beams (20 to 40 mm thickness) supported on the exterior masonry walls, as well as the concrete slab (70 to 100 mm thickness) in the damp areas coincident with the kitchen and bathroom (Figure 16) (Alegre, 1999).

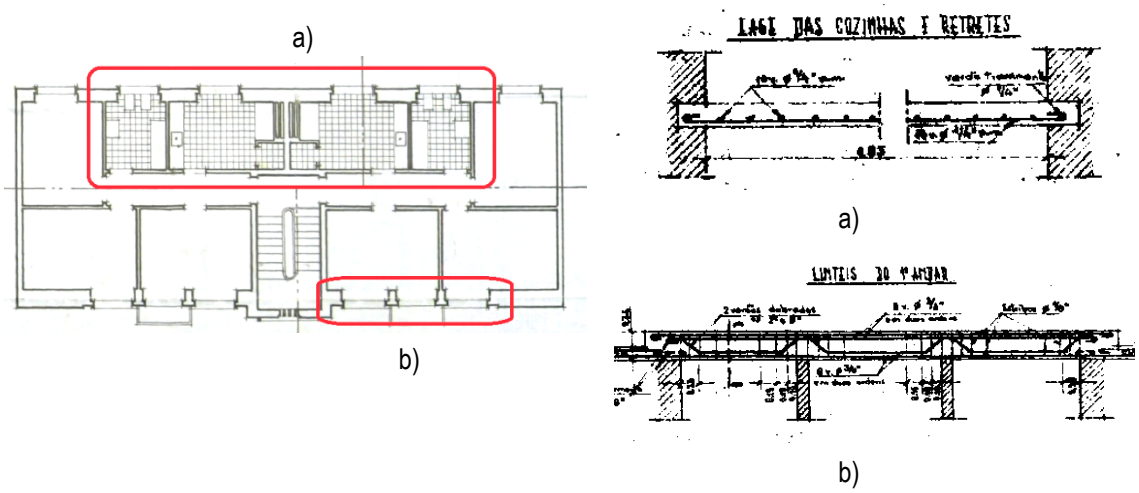


Figure 16 – Example of a house in the Alvalade District: a) with only concrete slab in the services area b) with a brace of reinforced concrete at the floors level in the outer contour of the building (AML).

The construction of the Bairro de Alvalade occurred in parallel with the construction on the east side of Rome Avenue and Manuel da Maia Avenue, where the back balconies and wet areas of the houses started to be built with slender concrete slabs supported on masonry walls.

In these houses of limited income the reinforced concrete slabs usually coincide with the salient area of the plant where the service area is located, one characteristic of 'Rabo de Bacaulhau' buildings (Figure 17). Later the reinforced concrete slabs were also extended to the whole floor.

It is in this type of buildings the first concrete columns appear on the salient corners in the back of the building and only after extended to the front of the building. These concrete columns were reinforced by 4 ϕ5/16'' longitudinal rods on the corners braced by ϕ3/16'' stirrups generally 0.25 cm spaced (Sousa *et. al*, 2006). There are also cases where the side walls were built with unreinforced concrete with or without reinforced concrete beams and columns (Lopes et al., 2008).

The reinforced concrete frame structure started to appear at the ground floor of the buildings meant for commercial use. The need of larger spans on the front wall and open spaces was overcome by the use of reinforced concrete beams supported on reinforced concrete columns.

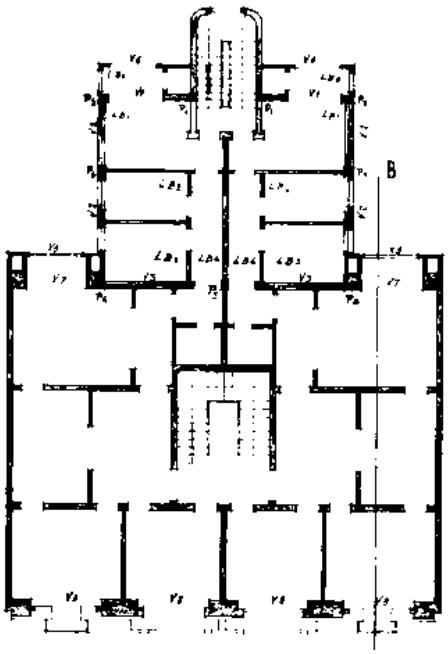


Figure 17 – Example of a 'Rabo de Bacalhau' building with a reinforced concrete structure in the salient body of the building and with the reinforced concrete slab in the same area (AML).

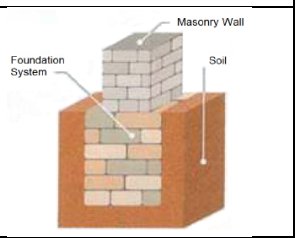
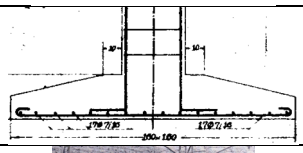
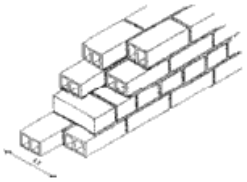
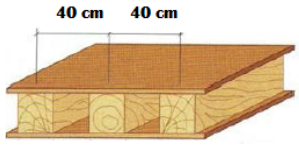
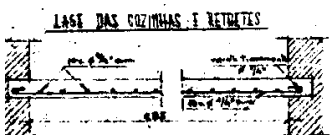
The generalization of reinforced concrete structures has imposed a revolution on the construction habits, on the structural solutions and on the architecture of the buildings. It establishes a clear separation between the buildings characterized by the dominant use of masonry and wood structures and the modern buildings, characterized by the dominant use of concrete as the structural material.

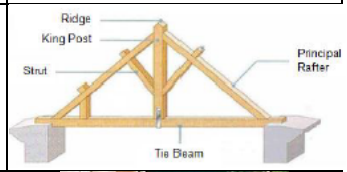
Nevertheless, as stated by Portas (1998) Alvalade neighborhood has proved to be a field of technical innovations as well as an example of the social coexistence establishing itself as a unique case in the recent urban heritage again, that must be preserved. In fact, these transition buildings are not incorporated under the actions of global intervention program (Alegre, 1999).

The creation of a normative instrument for the regulation of the interventions on this neighborhood is urgent in order to ensure the effective rehabilitation of the buildings.

The following table (Table 2) summarizes the main characteristics of the structures of the 'Placa' buildings, previously described in detail.

Table 2 – Summary table about the description of the structure of the 'Placa' Buildings

Structural Elements				
Element	**Material**	**Dimensions**	**Remarks**	**Image**
Foundations	Stone masonry very stiff and with a hydraulic mortar	Minimum depth of 0.30m and 0.5m until hard rock	The foundation works as a continuous wall which is enlarged in its base	
	Reinforced concrete		The first reinforced concrete column bases	
Exterior Walls	Rubble masonry	Wall thicknesses varies from 0.40m to 0.70m	Sometimes it was observed that the wall thickness decreases in height	
	Brick masonry	Wall thicknesses varies from 0.30m to 0.40m		
Interior Walls	Brick masonry or concrete blocks	Wall thicknesses between 0.15m to 0.25m	The brick masonry can be solid or hollow.	
Floors	Wooden structure	Wooden beams (0.08m x 0.18m) spaced from 0.4m to 0.4m. Overall thickness of about 0.30m	The wooden floor is supported directly on the exterior and interior walls	
	Reinforced concrete	Thickness between 0.07m to 0.1m	The slabs are simply supported on masonry walls and have only one layer of reinforcement for positive moments First the introduction of reinforced concrete slabs on the service areas and after extended for the entire floor	

Element	Material	Remarks	Image
Coverage	Wooden structure covered with ceramic tile	The roof structure is composed by a set of parallel trusses connected by purlins (main beams), common rafters and slats that support the roof tiles	
	Reinforced concrete	First flat roofs forming the terraces mainly on the "Rabo de Bacalhau'' buildings	
Main Stairs	Reinforced concrete or Wood structure	Usually in the middle of the building. Should have the capacity to install a lift	
Service Staircase	Reinforced concrete or Iron	On the back of the building	

Other Structural Elements that Appeared Later

Element	Material	Dimensions	Location	Reinforcement
Beams	Reinforced concrete	Thickness between 20 to 40 mm	At the floor level supported on the exterior masonry walls to ensure the locking of these exterior walls	These concrete beams were reinforced by 4ϕ3/8'' longitudinal flat rods on the corners braced by ϕ3/16'' stirrups generally 0.20 cm spaced
Columns	Reinforced concrete	Minimum dimensions for calculation of compression internal forces	Began to appear in the salient corners in the back of the building and only after extended to the front of the building	These concrete columns were reinforced by 4ϕ5/16'' longitudinal rods on the corners braced by ϕ3/16'' stirrups generally 0.25 cm spaced

5. STRUCTURAL BEHAVIOUR

Associated with this transition period between the old masonry buildings and the new reinforced concrete buildings, there is an evident absence of specific design features in terms of the amount and detailing of the reinforcement that ensures the necessary ductility or the verification of structural safety of the system. Moreover, the concrete used in the buildings has a low to moderate resistance (C20/25 on the best cases) and was slightly compact. The reinforced concrete structures are slender and lightly reinforced, revealing, in the case of an earthquake occurred, problems of excessive deformability and structural weaknesses.

Nevertheless, the variation of the structural materials between the ground floor and the upper floors, at the same time between the back and front of the buildings and the interruption of the interior walls on the first floor, results in important stiffness variations on the buildings, leading to significant structural irregularities.

The appearance of the reinforced concrete slabs in the buildings allows the floors behave as rigid in its own plan. However these new reinforced concrete floors significantly increase the mass of the building and affect its earthquake resistance. These buildings do not have any vertical elements with enough capacity to withstand shear and bending. So the structural elements do not have enough capacity to transmit the inertia forces produced during the seismic action without the occurrence of collapse (Sousa *et. al*, 2006).

The main weakness of these buildings is the insufficient number of vertical structural elements. Firstly, vertical reinforced concrete elements were introduced as columns on the corners of the back façade walls (often with 4ϕ5/16'' on the corners and ϕ3/16'' stirrups generally 0.25 cm spaced), and only after extended to the front façade walls.

Moreover, the resistant masonry walls should not have enough resistance capacity of deformation for the actions perpendicular to its plane, so it is possible that occurs the out-of-plane collapse due to the higher values of inertia forces caused by the reinforced concrete rigid floor (Figure 18).

Figure 18 – Representative example of the possible damage of the 'placa' buildings during an earthquake (Ingham, 2012).

So, this type of buildings may eventually behave satisfactorily for a small number of floors as long as the building has a sufficient number of interior walls with some resistance.

On the other hand there is a deficiency in the functioning of the floors as a rigid diaphragm in their plans. This deficiency is caused due the interruption between the floors slabs and masonry walls that support them, because the slab concrete does not work as a continuous slab (Proença et al, 2011).

Anyway is extremely important to ensure an adequate connection between the structural elements (walls-roof, walls-floors and walls-walls) to ensure an overall stability because, in most of the cases, the concrete slabs are simply supported on the masonry walls (Pomba, 2007).

Often, these buildings are integrated in blocks, which slightly improve its behavior by sharing the actions in a global way. So, the analyses should take into account the structural interaction between buildings, because they sharing the side rubble masonry walls. The structural interventions and retrofitting measures should be taken in a global perspective, which would possibly result in a more sustainable rehabilitation of the building stock.

Besides, the assessment of the seismic vulnerability of masonry buildings must be supported on their constructive evolution, including the survey of the structural modifications performed and causes of degradation.

According to the references, the set of measures for correcting the 'placa' buildings weaknesses are in first place to correct the structural modifications that building has been subject, after improve the resistance to bending of the walls, in the plane and out of plane, and introduce walls resistant to shear or for example the introduction of an additional steel structure (Ravara *et al*., 2001).

Finally, it is worth to mention that the cost for the seismic rehabilitation of 'placa' buildings and the first reinforced concrete buildings should be similar, mainly because the later are also not designed for the seismic action (Ravara *et al*., 2001).

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