Contemporary On Rehabilitation of Popular Architecture

To cite this article: Ines Daniel de Campos and Luis Filipe Almeida Bernardo 2019 IOP Conf. Ser.: Mater. Sci. Eng. 471 072023

View the article online for updates and enhancements.
Contemporary On Rehabilitation of Popular Architecture

Ines Daniel de Campos 1, Luis Filipe Almeida Bernardo 2

1 CIAUD, Lisbon School of Architecture. Rua Sá Nogueira, Polo Universitário, Alto da Ajuda, 1349-055, Lisboa, Portugal. & Department of Civil Engineering and Architecture, University of Beira Interior, Calçada Fonte do Lameiro, 6200-001 Covilhã, Portugal
2 Department of Civil Engineering and Architecture, University of Beira Interior, Centre of Materials and Building Technologies - C-MADE, Calçada Fonte do Lameiro, 6200-001 Covilhã Portugal

idc@ubi.pt

Abstract. As architects, we must respect and protect the identity and the Genius Loci of the place we intervene. Popular Portuguese architecture, as one of the references chosen for this investigation, consists of housing clusters whose need arose from population growth. This type of construction uses local materials that lose their identity when removed from this context. Ruins of shale or granite, only with its imposing walls, located in strategic places due to subsistence reasons, with a subtle history and culture, maintain intact its essence and character to inhabit. It is increasingly important, necessary and urgent to protect this heritage, where there are precious lessons to be learnt from coherent and harmonious villages, with a functional simplicity, framed in the landscapes that surround them. Recovering the heritage, being in many cases in the phase of ruin, allows architects to conjugate new concepts with the existing ones. Starting from the analysis of all these premises and of the need to rehabilitate these places, a modular system composed of metallic structures with an L-shaped profile was developed. This conceptual and building system consists of loose elements, for a better adaptation to each place, client and topography, gaining an identity in each composition. The choice of steel profiles allows the architectural project to acquire aspects such as the lightness of the conceptual language, resistance to internal efforts and minimisation of the selectable area, together with easy transport and handling in the assembly during construction. These are some of the characteristics that justify the use of these steel profiles in the rehabilitation of ruins, creating a repetitive modular system, as if it was a "living organism" that interrelates to the existing one.

1. Introduction
The popular architecture contains precious sources for the knowledge of the architectural genesis. The simple functioning of rural buildings and their close correlation with geographical factors, climate, economic and social conditions, or their strong intuition, highlight certain basic concepts of Architecture [1]. The popular Portuguese architecture, as the reference chosen for this research, has no urban origin. It consists of housing clusters that arise from the need and growth of the population and use local materials which when removed from this context lose their identity.

The importance of protecting this heritage lays in the preservation of the precious knowledge of the simple, coherent and harmonious settlements and buildings that respond to a functional simplicity, framed in the landscape that surrounds them. Most of these buildings are being refurbished without
any criteria and appreciation. Many villages have lost their main characteristics due to the influences of other cultures brought by emigrants, which makes it difficult to find buildings in which their architecture remains intact. A surgical intervention is necessary to recover the existing ones [2].

The re-conquest of this heritage, in a phase of ruin, allows architects to create new concepts and the conjugation of these with the existing ones, thus being reinterpreted in order to adapt themselves to the current reality that is full of stories and experiences that are unique in each place.

In the recovery of an existing building, some important questions that lead to the analysis of each case individually are raised in order to decide whether we should rebuild it (which is difficult due to the evolution of techniques so that they are not built in the same way), or whether to introduce something new (new languages and materials).

Starting from the analysis of these premises and of the need to rehabilitate these abandoned places, a modular system, in which the metallic structure, in view, was part of the creative and conceptual process, was developed. This system consists of loose parts for a better adaptation to each place, client and topography, thus gaining a new identity in each conjugation.

The prototype, which aimed at implementing industrialised processes for the construction of modular houses, uses a standard metallic profile with equal 'L' angle bars that allows economising the building process. The choice of these steel profiles allows architectural design aspects such as the lightness of a contemporary language, the necessary resistance to the internal stresses through convenient composite sections and a minimisation of the area of the profile to be sectioned [3].

It also allows us to, aesthetically, take advantage of the structures, as they are very elegant elements and are easy to transport and handle during the assembly at the construction site. These are some of the characteristics that justify the use of these steel profiles in the rehabilitation of ruins, a modular system that repeats itself, as if it was a "living organism" that interrelates with the existing one, thus articulating the interior and exterior spaces of new living spaces.

2. Contemporary in the Rehabilitation of Popular Portuguese Architecture

Designing houses requires understanding the society, culture and, above all, the importance of functionality for the client. It is necessary to pay close attention to the transformations of lifestyles, to the reinterpretation of the spaces, to the difference between "intermediate spaces", "semi-public spaces", and "semi-private spaces", to the interior/exterior dichotomy and to sustainability systems, which bring greater efficiency into the architecture of the metallic construction and lowers the costs to be borne by the client. The same thing happens when you intervene in pre-existences that have already responded to the same functions in another period, and although they are considered outdated and do not respond to current needs, they may currently have had characteristics that are very similar to what we need nowadays [4].

The concept of 'Living Machine' was developed by Le Corbusier to create a standard model for the new houses of modern society, facilitating their functions and responding to the needs of those who would inhabit them. In this sense, an abstract model was created for a 'standard' person that encompasses generalised characteristics.

While developing a project, it is important to define spaces well, but when it comes to creating houses with minimal dimensions it is important to design them systematically so that they have good solar orientation and receive ventilation and natural light. Houses become pleasant if the interior spaces are designed with certain proportions and offer harmony to those who inhabit them.

To Le Corbusier, the 'living machine' would facilitate all functions for the modern Man as he considered him as being mechanical in his daily activity and in this sense he generalised his needs, his functions and his aesthetic taste. For him, when the modern Man acts in his space, he needs order, harmony and it is essential that the dwellings are arranged in a precise way and that the proportions are adequate to all the activities. Therefore, Le Corbusier had taken for granted that, in general, all men function in the same way and have the same practical needs [4].

The Portuguese architect Eduardo Souto de Moura has worked in rehabilitation with the reintegration of ruins in the space of living. Another conceptual solution involves the recovery of the
ruin of the ruin, with the main element to consider being the way in which the project camouflages itself into the natural environment. The spaces are designed to become comfortable and welcoming, enclosed, thus giving high importance to the experience of its interior, but at the same time embracing nature from large panoramic glass planes. The project of the house Baião influenced by the modernism of Mies Van der Rohe allowed the use of a ruin-house and walls-and the architect decided to recover the house, leaving it as an empty space of living/garden. He also integrated it in the terraces during the creation of its project by taking advantage of the existing walls. The simple shape and typology of the house, between the blind walls embedded in the ground with a main glazed facade, allowed the house to blend naturally into the landscape.

The house is one of the most researched themes by Souto de Moura, for whom the relationship with the culture and spirit of each place, the Genius Loci, is one of the main points of his projects. The idea of building for a place, together with the popular architecture, allows and requires the understanding of the essence of each location, projecting the best and respecting the circumstances that surround it, thus valuing the existing and the proposed.

2.1. Conceptualization in Rehabilitation of these ways of living

During the process of building of a conceptual model, oriented towards the architectural design, it is important to have a complete approach to its creation that goes through some stages, such as:

- the analysis of the programmatic needs of who will use the space and whether it is temporary or permanent;
- the analysis of the place to be intervened based on history, culture, experiential and sensorial references;
- the type of topography and its surroundings to obtain a better relationship with the place;
- solar orientation and climate;
- the pre-existing elements (built or natural) that can in a sense influence, help or condition the project;
- the choice of materials to reduce costs.

This type of conceptual and design organisation, based on the compilation of all the knowledge analysed and structured in a cyclical system as defined in the previous schemes, contributes to a better creation, production and assembly of the entire evolutionary process of the architectural object. It is especially important if the object/module functions as a repetitive, serial-producing unit. This is because it becomes necessary to transform this industrial process into a well-defined product like any other architectural project and may have a good criticism of the construction in architecture.

The characterisation and definition, so that an architectural object is only construction or is defined as architecture, becomes possible when the modular object of study is based on the specific historical and scientific evolution of inhabiting and can be adapted to different places with personal characteristics.

In this process, there are some important theoretical concepts that define architectural design and that help us to understand the language of architecture. During the creative process - the concept of design - architects use concepts such as 'type' and 'model', 'typology' and 'order', 'geometry' and 'scale', for the definition and characterisation of their work.

The methodology used to create the 'conceptual model'/structural system' applied in a modular architectural project to be implemented in a place, is summarised in the schemes represented in the form of the "Tripod of Life" (figure 1), which emphasises three major themes: "Culture," Inhabit "and" Structure", [5].

When you move into the creative process of a modular object, designed as an element that can work by itself or in conjunction with its repetitions and applied to a specific place, it is fundamental to interpret the process under analysis as a whole.
Figure 1 – I. CAMPOS, Methodological scheme of the construction of the Modular Conceptual Model - “Tripod of Life”.

2.1.1. The "Greek cross" in the structural and architectural design.
Starting from the conceptual idea of habitable cells and the need to interconnect the structure that will unite them as a web and think about this interconnection as being part of the conceptual process, it justifies the interdisciplinary of the two areas under study (architecture and engineering) giving that both reinforce this research.

The type of metal structure and the type of standard steel profile were chosen and designed according to the concept that originated Greek cross pillars (four equal-sided angle bars - L100x100x8). These easily allow the connection of each room, in the corners, and they can be added or changed depending on the area and shape desired, always keeping the same ratio.

Figure 2 – I. CAMPOS, Connection of pillars and beams in the shape of a Greek cross

One type of standard profiles - equal-sided angle bars – was chosen to create a light pillar and beams structure in the composition of the conceptual module. This type of profile by being often used
in roofing and in systems of bracing of metallic structures and by not being widely used as a building solution for structural lattices (pillars and beams – figure 2), emerged in this investigation as a response/solution to the conceptual and creative studies [5].

The design of structures and the architecture project will evolve side by side and, by defining the type of structure to be used based on the design ideas, it is necessary to move to the structuring of the modules to inhabit.

The idea of the pillar in the shape of a Greek cross arose from the concept that allowed connectivity between the cells, the living spaces, in the corners, thus making the pillar the connecting link of all the areas. In a sense, the pillar became the delimiter of each room and allowed responding to the conjugation of the form with the function.

This type of pillar, used by the architect Mies Van der Rohe in his designs, was designed in order to obtain a subtle pillar without volume and aesthetically demonstrates the idea of his famous quote "less is more".

With this type of system, it was possible to use angle bars throughout the construction of the main structure or in the structure of the ladder. It was also possible to use it for the application as a support of wall panels and to fix the window frames of the glass planes. In this way, the diversification of steel profiles to be used is minimised, thus obtaining repetitive profitability.

As a result, a building system for houses up to two floors was developed based on the definition of spaces with specific functions to inhabit and in function of the client and of the project, by using repetitions of these pillars that, placed horizontally, have the same function of a master or main beams.

The basic principle of this building system consists in the articulation of several three-dimensional modules defined by the habitable spatial category that functions as cells and that allow the composition of several types of housing without losing respect for the entire architectural process and the client's program.

In an industrialised process, the possibility of resorting to the phenomenology of architecture helps in the organic composition of the web that is composed of modular cells that, in turn, adapt to the existing space and in which the type of structure designed offers a great variety of alternatives of connections so that the final object is unique [6].

The main idea is the possibility of production of a dwelling by resorting to series production in order to standardise the construction system and to extend the offer so that it corresponds to the individualised needs of each client.

3. The Structural Calculation of the prototype

The structural solution [7] adopted was strongly conditioned by diverse factors, namely:

i) - impositions of architectural nature (dictated by the Architecture Project and which integrate the drawings - plan and cuts);
ii) - economic factors.

The conjugation of all the factors mentioned led to a solution based essentially on a three-dimensional structure composed of a regular system of a metallic portal, being the pillars and beams created by the association of 4 angles of interconnected equal-sized angle bars (4xL-100-8) and tightly connected with bolts. The floors and roof were structurally created by using a grid solution with a binding joist built by joining 2 interconnected angle bars (2xL-100-8), which indirectly support the floor beams and roof by means of rigid bolted connections. The diagonals were also made by joining 2 interconnected angle bars with the same size (2xL-100-8).

The loads from the superstructure are transferred to the foundation ground by means of direct foundations consisting of insulated reinforced concrete shoes for the pillars.

Considerations on the seismic behaviour of the structure:
Although the building is lightweight and small, the effects associated with seismic action in a structural analysis were not completely neglected and were taken into account.

**Combinations of actions:**

The security verification criteria laid down by law, in particular in the Safety and Actions Regulation for Buildings and Bridges Structures (SAR), are based on the quantification of values calculation, in which the effects of the various actions that are requested by the structure are simultaneously recorded. The combination of actions contemplated in article 9 of the SAR provide for the establishment of a basic variable action, with the remaining affected corrective coefficients determined according to the actions which they refer to; in turn, the basic variable actions and the permanent actions are usually increased with the use of security coefficients.

The combination of actions considered throughout this project account for the effect of gravity actions (permanent loads, overload and snow) and the dynamic actions of earthquakes, which are as follows:

(i) Basic variable action: use overload
\[ S_d = \gamma_G \times S_G + \gamma_Q \times (S_Q + \psi_{on} \times S_N) \]

(ii) Basic variable action: earthquake
\[ S_d = S_G \pm \gamma_E \times S_E + \psi_{2q} \times S_Q \]

**Structural elements:**

The metal profiles that make up the building superstructure shall not be hot-rolled. The characterising parameters of the steel that makes up so many profiles, as well as the connecting and reinforcing plates, which are the basis for the design phase, are quantifiable according to EC3 and are listed below.

**Steel S355 (Fe510) (properties):**

- Calculation value of the tensile strength at single traction: \( f_u = 510 \text{ MPa} \)
- Calculation value of the tensile yield stress: \( f_y = 355 \text{ MPa} \)
- Modulus of elasticity value: \( E_s = 210 \text{ GPa} \)
- The damping coefficient corresponding to the metal structure takes the value of 2%.

**Structural analysis:**

The structural analysis through which it was possible to determine the efforts involved in the sizing process was based on the study of a three-dimensional reticular model, having assumed dynamic and gravitational actions. It should be noted that, as a starting point, the elastic characteristics of the bars associated with the geometric definition resulting from the pre-dimensioning phase were considered. The analysis of the three-dimensional portal and the dimensioning of its structural elements were processed by using the TRICALC Program to automatically make calculations.

**Security Check:**

In the present study, the safety assessment was carried out in accordance with the general requirements (independently of the materials used in construction) set out in the SAR, while respecting the particular conditions laid down in EC2 (foundations) and EC3 (metal structure and connections). In this way, the safety check was generally guaranteed by comparing the robust calculation efforts with the actuating calculation efforts (\( S_d \leq R_d \)), and based on the concept of the limit state. In addition, the SAR classifies the limit states in ultimate limit states and serviceability
limit states (deformation in the case of metal structure). In this study, the verification of the serviceability limit states was carried out automatically by the calculation program used and being limited to the long-term arrow at 1/500 of the span.

4. Conclusions
The main conclusions are:

1. In order to verify that the proposed modular system was valid, a pre-existence site was chosen to implement the prototype and it was necessary to make a historical analysis of the existing construction: Popular Portuguese Architecture in an area where the most used material is shale. As a result, we analysed the Portuguese architectural culture and the ways of inhabiting in this period: the inhabiting space of the buildings considered as popular architecture characterised by minimal spaces and few habitable conditions. A spatial, formal, typological and scale analysis was also made. It evidenced the experiential and cultural characteristics of this type of architecture, through the dwelling and the relationship with the place, with the interior/exterior space, delimitation surfaces of the space, the building system and the applied structure.

2. The construction of the theoretical and applied model has as the main objective, in this investigation, the justification of the conceptual process of the architectural object. Thus, the model was defined with a scheme, starting from the representation of the 'Tripod of Life' that evolved to create the 'Flower of Life' in the Sacred Geometry. This whole concept helped to understand the creative process developed in this study. Each circle that is added creates nuclei with sub-themes that help to clarify and characterise the object under study.

3. This prototype was designed with very precise objectives that go through the implementation of the industrialised processes for the construction of modular dwellings, in which a standard metallic profile is used to economise the building process. The reduction of construction costs and its profitability, the promotion of a high diversity and customisation of the offer and the flexibility of the projected solutions are evident in the quality of the final product.

4. It is concluded that a theoretical model, applied to a conceptual model connected to a modular system in metallic structures, responds to the current needs. It can go from prejudice to tradition without replacing other architectural languages and building solutions. It becomes a solution used on a reduced scale as it is found in single-family housing, and especially for the recovery of abandoned areas of the countryside, where the interior and exterior relationship between spaces are quite different. Therefore, it is a solution allows the architect to create unique, contemporary, simple projects that are visible in the finished project.

Acknowledgment(s)
This research has the financial support from the Research Center of Architecture, Urbanism and Design (CIAUD) from the Lisbon School of Architecture and the FCT, Foundation for Science and Technology through national funds.

References
[1] A.A.V.V., Associação dos Arquitectos Portugueses, *Arquitectura Popular em Portugal*, 2ª edição, Lisboa, p.XXII, 1980.
[2] H. Engel, Sistemas de Estruturas, Editorial Gustavo Gili, SA, Barcelona, 2001.
[3] I. D. D. Campos, and L.F.A. Bernardo, “*Do Xisto ao Aço. Reabilitar no Interior Esquecido*”. X Congresso de Construção Metálica e Mista, organized by CMM at: Coimbra, Iparque, Volume: 1, 2015
[4] J. M. Redrigues, and A.A.V.V., *Teoria e Critica de Aquitectura século XX*, Ed. Ordem Arquitectos – Secção Regional Sul, Lisboa, 2010

[5] I. D. D. Campos, “*Concepção Arquitectónica e Estruturas Metálicas em Habitação – Sistema Modular Aplicado*”, Tese de Doutoramento, Universidade da Beira Interior, 2015.

[6] A.A.V.V., *Houses of Steel: Living steel’s international architecture*, Ed. The Images Publishing Group Pty Ltd, Australia, 2009.

[7] I. D. D. Campos, “*Concepção Arquitectónica e Estruturas Metálicas em Habitação – Sistema Modular Aplicado*”, Tese de Doutoramento, Universidade da Beira Interior, 2015. Executed by the coorientador Prof. Doutor Luís Filipe Almeida Bernardo, Engenheiro, Centre of Materials and Building Technologies - C-MADE.