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ADOBE IN ART-NOUVEAU CONSTRUCTIONS IN AVEIRO

Abstract

Nowadays, Aveiro is one of the Portuguese cities where magnificent examples of Art Nouveau movement can be found. Due to construction techniques traditionally used in the area and time period in which the Art Nouveau emerged, most buildings of this style and region were built using adobe blocks, a singularity worldwide. This type of construction has many advantages but also requires particular care to be taken into account in its proper maintenance and preservation. In this paper, the common structural problems and pathologies of this type of buildings will be presented and discussed with the example of the characterization works developed at Major Pessoa house in support to its conservation.

Introduction

The industrial revolution brought, along with major technological developments, a change of mind-set that allowed the development of culture and flourishing of new artistic currents. The Art Nouveau movement flourishes in Europe in the end of the nineteenth century with the development of the industrial age and is described as artistic expression through curved shapes representing natural elements. This style emerged suddenly and lasted for a short period, manifesting in different European countries [Sembach, K.J. (1993)], adopting different names: Art Nouveau in France and Belgium, Judendstill in Germany, Nieuwe Kunst in Holland, Sezessionsstill in Austria, Stile Florale in Italy, Art Nouveau in Catalonia [Sembach, KJ (1993)]. In each country, this artistic movement assumed a distinct character, incorporating aesthetic elements of each nation, adapted to the reality of each country's traditional construction and materials available.

Aveiro, located in the centre of Portugal, is one of the cities where magnificent examples of this architectural style can be observed. Unfortunately, today, a significant number of these buildings present a heightened state of degradation, sometimes with severe problems. However, recently, there has been an effort to preserve and rehabilitate the existing historic heritage with successful interventions already conducted. Nevertheless, in order to conduct adequate rehabilitation works, it is necessary to understand correctly the structural behaviour of adobe building, its fragilities and vulnerabilities, which will be discussed in this paper.

Art Nouveau in Aveiro

The city of Aveiro, located about 10km from the sea, is surrounded by Ria de Aveiro, a vast lagoon area, where rivers flow from Vouga River basin, and connect to the sea. However, long ago there was no link to the sea. Before the reopening of the connection to the sea, in the mid-eighteenth century, the estuary has suffered more than a century of commercial and economic isolation, with vast consequences for the surrounding region. By removing the embankments towards the sea, the revival of the city of Aveiro occurred, with the flourishing of the economy and cultural and artistic expressions. The Art Nouveau in Portugal came a little late in time, about 1906, mainly through the work of architect Francisco Silva Rocha, with works all over the country but with a higher incidence in the Aveiro region. This movement was then adopted as the new architectural language of this

prosperous period [C. M. Aveiro (2004)]. Due to the profusion of magnificent architectural examples of Art Nouveau in Aveiro, this city is regarded as a benchmark in Portugal for this artistic movement. The expression of the Art Nouveau movement in Portugal assumed a primarily decorative nature, with their representative elements rarely transposing the façade. However, there are Art Nouveau buildings in Portugal that attempt to introduce curved shapes, either outside or inside. The facades have windows with undulating balconies and verandas with details of the natural world that reflect the spirit of Art Nouveau. The proliferation of the Portuguese tile with typical floral decoration is considered the most emblematic Art Nouveau [Fernandes, MJ (2009)].

In Aveiro region it is possible to observe several Art Nouveau buildings. Some examples are shown in Figure 1: the City Museum (Figure 1 - a)), Pharmacy Ala (Figure 1 - b)), Four Stations House (Figure 1 - c)) and Major Pessoa House (Figure 1 - d)) [Rota da Luz (2005)].

1.The Major Pessoa House

The Major Pessoa House is an iconic example of Art Nouveau in Aveiro due to the richness of its decoration façade. The stone is distinctly carved, being in harmony with the wrought iron railings, representing the Art Nouveau's superbly undulating line. This building was built around 1907-1909 by Francisco da Silva Rocha and Ernesto Korrodi, facing one of the main canals. It is a multifaceted building, with atrium railings and containing tiled panels, curved spans and furniture. The façade is densely decorated and the rear possesses rich spatiality with a porch, wrought irons and a private little garden. Property of Mário Belmonte Pessoa, a wealthy businessman of Aveiro, the building was used as a family residence until 1995, being at that time in a very advanced state of degradation. It was then purchased and restored by the Town Hall, with the objective of preserving the original design of both the interior and exterior architecture, which resulted in a lengthy and delicate work [Sarabando Dias, M. (2006)].

One of the details common to these buildings, and most of the remaining buildings of Art Nouveau in the Aveiro region, is the type of construction. These buildings were built using adobe blocks, providing a worldwide unique, singular and exclusive case. Indeed, Art Nouveau buildings in Europe were built in steel or wooden structure using stone. However, in Aveiro, in the period in which the Art Nouveau emerged, the construction techniques used traditionally involved adobe masonry. The same construction techniques were used in this new architectural style, leading to some inevitable adaptations due to adobe specific mechanical behaviour.

Adobe construction

In Portugal, adobe has been, until recently, a common construction material. Particularly in Beira Litoral region, in the center of Portugal and where Aveiro is located, it is possible to observe adobe constructions in every type of building either in rural or urban areas, many of which are still in use, such as walls for property delimitation, water wells, churches or warehouses. In the city of Aveiro, about 25% of the buildings were constructed with adobe, while the district of Aveiro, it is estimated that 40% of the buildings are made of adobe. This is due to traditional and economic reasons ([Silva et al.; 2010], [Silveira et al.; 2010]).

It is recognized that adobe constructions have various appealing features and properties. These constructions have associated low cost solutions with local availability and recyclability of materials. Additionally, they possess good thermal and acoustic insulation properties, and are associated with simple construction processes that require small quantities of energy.

Although this type of construction has many advantages, it also requires particular care to be taken into account in its proper maintenance and preservation. Due to particularities of the material, these buildings require special attention regarding repair and maintenance. Moreover, these constructions can have important structural problems that need to be accounted for. This type of material presents low tensile strength and fragile behaviour. When subjected to horizontal loads, such as those induced by earthquakes, structures made of adobe may have a poor performance, leading to serious structural problems or even to its collapse. The rehabilitation of buildings of this type needs a special attention on the aspects related to materials and traditional solutions.

The University of Aveiro has developed several studies concerning adobe construction, with research developed in the subject of mechanical characterization of materials, experimental studies of the structural behaviour of masonry arches and adobe walls. Cylindrical adobe specimens were subjected to compressive and "splitting" tests, and prismatic mortar specimens were subjected to compressive tests. Small wallets, constructed with materials representative of those found in existing adobe constructions, were subjected to compression tests, perpendicularly and diagonally to the bed joints. The structural non-linear response of adobe walls has also been investigated in a series of full-scale tests, in the laboratory and in situ, with imposed horizontal cyclic displacements. ([Varum et al, 2011], [Arêde et al.; 2007], [Silveira et al.; 2007], [Varum et al.; 2008b], [Varum et al.; 2005a]).

In Aveiro, adobe bricks were made with coarse sand, generally with a moderate or low silt–clay fraction, and with air-lime mortar with variable hydraulicity, usually in a proportion of 25%–40% [Silveira, D. et al, 2013]. The natural earth mixtures were corrected by the addition of clay or sand and it was also common the addition of fibers (straw or sisal, for example) to control cracking while adobes were drying in the sun. The techniques adopted in the construction of adobe buildings in Aveiro district were based in the accumulated empirical knowledge [Silveira, D. et al, 2012].

Several studies have been conducted focused on the mechanical behaviour in compression and tension by experimental testing of adobe specimens, which were made accordingly with the tradition or removed from old constructions. Due to the lack of standardization or production control, the composition of adobes and manufacturing procedures could vary significantly, even for the same adobe construction. Differences on the mortars used to bond bricks one to each other, either in their composition or thickness, also conduct to differences on the structural behaviour of the construction.

Hence, adobe testing generally leads to a high variability of results. Nevertheless, a mean behaviour can be concluded. Using the results obtained in the research conducted in [Silveira, D. et al, 2013], similar to those developed in other studies, either for Aveiro adobes or others, it is possible to observe values for compressive strength varying between 0.23 and 1.21 MPa, 0.20 to 1.03 MPa for flexural tensile strength, 0.03 to 0.28MPa for splitting tensile strength, 0.24 to 1.27‰ for strain at peak stress, 7609 to 25000MPa for the modulus of elasticity and 0.10 for Poisson's ratio. High values of flexural tensile strength exist which indicates that flexural testing of adobe bricks can overestimate tensile strength [Silveira, D. et al, 2013]. Regarding the mortar used to bond adobes, the unconfined average strength of the mortar samples varies from 0.45 to 1.68 MPa ([Fernandes, M.; Varum, H.; 2011], [Varum et al; 2007]).

As seen, adobe construction has several advantages in terms of comfort, workability, or cost of construction, but also has limitations in its resistance which may have restricted the desired architectural manifestation in the Art Nouveau style. The introduction of curved shapes in the structure is complicated by the characteristics of masonry adobe and this may also be a reason for the restricted development of architectural expression of Art Nouveau.

Currently, the vast majority of these buildings presents important pathologies, some severe, with implications for its structural integrity and safety. For its architectural value, historical and cultural is urgent that rehabilitate and preserve these buildings properly, it is necessary to first understand the typical problems and common pathologies that arise in these buildings.

Structural problems and common problems in adobe buildings

Adobe construction continues to be widely used in developing countries with few economic resources. However, in many countries, before the introduction of concrete and steel construction, raw earth was

the most common material used in construction, under different construction techniques. Nowadays, with the increased awareness of societies to the problems of sustainability in construction, many are experiencing building with earth.

In the relatively recent past, the earth was a very common building material in Portugal. The adobe and rammed earth was used for many years in virtually all types of construction, and its use decreased dramatically with the emergence of the cement industry and concrete. It is observed that in Beira Litoral these two construction methods have been widely applied to the Mondego River to establish the boundary line between the two regions where the two methods were applied: the adobe construction prevails to the north and rammed earth to the south [Silveira, D. et al (2007)].

Featuring several indisputable qualities, the adobe construction has yet important weaknesses. This type of construction is particularly vulnerable to natural phenomena such as rain, floods or earthquakes. Due to the already advanced age, the great majority of adobe buildings in Aveiro is not properly preserved or adapted to the current functional demands and comfort. Its limited mechanical strength, high weight and brittle behaviour of buildings associated with the lack of maintenance of structures, can lead to structural abnormalities and significant non-structural problems.

An important area of the Aveiro region is characterized by a high groundwater level and consequent high levels of moisture in the walls of buildings. Furthermore, the degree of salinity of the water is high. Some of the most frequent pathologies in this type of construction are moisture infiltrations due to a poor drainage of rainwater or lack of adequate insulation. It is common to observe moisture on the walls of the adobe structures by capillary rise of water from the soil foundation. These situations cause various problems as efflorescence and detachments of coatings.

Due to moisture and infiltration, it is usual to find a strong degradation in wood elements, common in floors and roofs beams of these structures (Figure 2). The presence of water causes the swelling of the wood elements by installing a tension state giving rise to bending, distortion and cracking [Arriaga, F. et al (2002)]. In addition, the water makes the environment favourable to the development of biological agents whose action causes the degradation of wood. High degrees of degradation may also affect the binding of the floor and roof joists to the walls structures, placing at risk building safety.

Due to the high weight of this type of masonry and limited resistance of the adobe material itself, tensile and shear cracks may appear along with excessive deformation inside and outside of the buildings structure. The arches, characteristic of Art Nouveau buildings in Aveiro, if not properly reinforced and stabilized in its support, are conducive to the formation of cracks that could jeopardize the stability of the structure of the buildings, in part or in whole. The most common damages arise associated with deformations of the facades out of plane, with detachment and rotation with respect to the initial frame of the facades of the building.

The facades of some of these constructions used stone, which may bring specific pathologies. Depending on the type of stone used, it may present different levels of degradation (Figure 3). Porous and permeable rock such as limestone, to provide circulation of water therein, is functioning as transport vehicle for damaging chemical agents for stone itself and to other construction elements.

The rehabilitation of buildings of this type needs a special attention on the aspects related to materials and traditional solutions. Unfortunately, there are also frequent rehabilitation interventions that introduce harmful actions damaging the performance and durability of the original construction. Some of the buildings of Art Nouveau in Aveiro have suffered interventions of that particular level, that, through ignorance or lack of information, eventually hinder the construction, both structurally and architecturally. Art Nouveau arches have been modified to solve the problem of cracking and warping, thus causing a radical change of the original architectural expression.

The recovery of structures made of adobe, generally requires special care so that new materials are compatible with the materials and techniques unique. But interventions in Art Nouveau buildings should be even more cautious, especially in the recovery of structural elements that are characteristic of this movement, with decisions always considering all the implications that any intervention might have on the safety of the structure.

Solutions for conservation and maintenance of adobe structures

As mentioned above, the rehabilitation and recovery of adobe structures should be carefully studied and implemented so as not to introduce harmful materials, agents or actions. The traditional techniques and materials must be respected.

With proper maintenance, such structures can preserve their characteristics for structural safety and comfort. Being the infiltration and moisture common problems in such structures, it is necessary to properly insulate the building from aggressive agents, namely ensuring tightness of the cover and window frames as well as insulating the structure from the actions resulting from high groundwater level. This can be done either by introducing solutions or devices able to prevent the rise of capillary moisture, either by the introduction of efficient drainage systems, or eventually pumping the water and thus locally controlling the height of the water level. Furthermore, it should be ensured good ventilation inside the buildings to prevent the development of mold and damp patches.

In the delivery zone of the floor wooden beams and respective support structures, adequate ventilation must be ensured to prevent the development of biological agents which could cause deterioration of the timber frame.

In buildings with an advanced state of decay, monitoring of cracks and openings should be performed in conjunction to understand their evolution. The information collected by this monitoring can provide essential data for the appropriate design, development and application of the rehabilitation and/or strengthening solution. In extreme situations it is advisable to retrain adequately the facades in order to avoid its collapse and detachment, as well as bracing floors and roofs where appropriate.

Regarding horizontal loads, the more problematic action is the earthquake motion. Structures made of adobe have a limited capacity to resist seismic actions, mainly because of their low ability to withstand tensile and shear stresses. Possible techniques are enhanced by the use of steel rods in the walls corners, or by coating the faces of the walls with solutions able to withstand tensile stresses, such as wire mesh, polymeric materials, or composites screens.

The University of Aveiro has developed several studies regarding the repair and retrofit of adobe buildings in the region. Experimental tests were conducted on a real-scale wall of adobe, wherein the solution applied was a simple and, economical reinforcement, compatible with the original materials. The repair solution applied consisted of sealing the cracks with hydraulic lime mortar, and reinforcement by applying a synthetic mesh surrounding wall and covered with plaster. The results from the strengthening solution studied were very satisfactory, with recovery in the improvement of the structural behaviour of the wall ([Oliveira, C. et al. (2010)], [Figueiredo A. et al, 2012]). Figure 4 shows the results in terms of force versus displacement obtained for the original wall and for the strengthened reinforced wall. The tests on the retrofitted wall demonstrated that the wall was able to recover its initial stiffness. Moreover, the lateral strength increased slightly, and the ductility and the energy dissipation capacity improved significantly ([Oliveira, C. et al. (2010)], [Figueiredo A. et al, 2012]).
Several rehabilitation and repairing solutions for adobe construction are available, with proven results of their efficiency. It is thus possible to adequately intervene in such buildings, respecting materials behaviour, traditional construction techniques and architectural designs.

Major Pessoa house

As referred, Major Pessoa House is an iconic example of Art Nouveau building in Aveiro. Before rehabilitation, this house presented a high degree of degradation with important structural and non-structural problems. Due to its historical, patrimonial and architectural value, Aveiro City Hall decided to purchase the building with the objective of its rehabilitation.

At the time, the numerous pathologies present were due mainly to lack of maintenance. Infiltration, deterioration of the wooden structure, local crushing on the resistant walls, deformations of the façades, were, among others, some of the problems observed, which were questioning the durability of the building and even its overall stability (Figure 5).

The complete lack of maintenance of Major Pessoa House in just a few years originated the appearance of a number of pathologies with serious consequences for the building. The most frequent

are essentially cracking and excessive deformations of the façades, endangering their stability. In consequence of these problems, infiltration and moisture appeared with consequent saturation of resistant walls and rotting of wood elements in pavements.

There were serious infiltrations in the ceilings and exterior walls. In these walls, the moisture caused spots, blisters and efflorescence. The state of degradation in this area was very advanced, with detachments of ceiling coatings. The rooftop presented several problems and clearly had a deficient insulation performance. The deficient runoff of rainwater led to saturation of one of the supporting walls.

In the wood elements, the major cause of deterioration is the variation in moisture content, due to infiltration of rainwater. This water is rapidly absorbed by the outer layer of the timber. The humidity difference between the inside and the surface layer promotes the swelling of the wood elements by installing a tension state giving rise to bending, lateral instability and cracks.

The infiltration of rainwater and consequent saturation of the walls, together with the difficulty of ventilation at the delivery zone of wooden beams, led to the development of biological agents whose action caused the rotting of the wood. At some points, the decay affects the entire section.

Initially with two floors, a third floor was added to the building creating a lounge for the illumination of its interior spaces. Structural interventions had occurred in order to accommodate the introduction of a new floor. Steel profiles supported on master walls were placed to work together with the wooden beams of the floor. The significant decrease of the strength of the wooden beams of third floor due to the deterioration of its supports caused a higher concentration of loads on the steel beams. This additional load induced an increase in tension on the resistant walls. In some locations, there was also the aggravation caused by leakage due to poor water drainage from the lobby.

Both façades had structural deficiencies due to the significant detachment occurred. Important cracks and open joints between elements of limestone were observed, proving the occurrence of relative movements between façades, its stone blocks and master walls. It was also detected the degradation of stone in the columns at the level of the second floor, with a significant reduction in their section and significant displacements in stone structural elements. The arc in the first floor of the rear façade was fractured. This arc was formed by limestone blocks on the outer face, while the inner face bow was made with brickwork. Research proved that a repair had been previously made by placing two reinforced concrete columns that although contributing to their stability, harmed the building from aesthetically point of view [Varum et al, 2005b].

The intervention conducted in the rehabilitation of this building included several parts. The advanced state of degradation and the associated repairing costs conditioned the rehabilitation solution. A monitoring system was placed in order to detect possible displacements and movements. A temporary shoring was applied on the structure to assist in the construction works and confinement of the structure.

The posterior and rear façades were preserved as well as the lateral wall. In order to ensure the global stability of the building, a steel frame was built for the interior, preserving its interior architecture [C.M. Aveiro; 2005]. A new wood frame for supporting the rooftop was built. Given the geological and geotechnical conditions of the foundation soil, and the high loads that the new structure would induce in the foundation elements, micropiles were installed. The drilling was performed using fluid direct circulation in order to reduce vibrations for the masonry structure.

New wooden floors were installed, supported on the steel frame and the stone elements were adequately restored along with the paintings and the original carpentry. Conservation and restoration measures were performed on the tiles, metalwork, stairs and decorative sidewalk.
The Major Pessoa House presently accommodates a tea house and the Art Nouveau Museum of Aveiro.

7. Final remarks

Despite the significant historical value and architectural heritage for the Aveiro region, some heritage buildings with more or less relevant influence of the Art Nouveau movement are not properly maintained, even manifesting an advanced state of degradation in some situations.

In the region and at the time when the Art Nouveau developed in Aveiro, the construction methods were dominated by the use of adobe as a building material for the vertical structural elements, constituting a unique example in the world. Currently, most Art Nouveau buildings in Aveiro present a high state of degradation. Many of these buildings are located in the vicinity of Ria and its canals where the groundwater level is very high, being from several years subjected to frequent flooding during periods of high tides. The presence of water is harmful to these constructions, and may cause various problems as a consequence.

These constructions, as cultural and historical heritage, nationally and internationally, are essential to be properly recovered, in order to preserve the artistic expression and unique materials. In the rehabilitation of structures of this type the existing materials and traditional building techniques should always be taken into account, so as not to introduce harmful materials, agents or actions. In this paper, the problems and pathologies of these constructions are listed and some of the possible solutions for rehabilitation and maintenance of these buildings are focused. These aspects should be considered in the development and implementation of rehabilitation strategies directed at this heritage.

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a) b) c) d)

Figure 1 - Examples of Art Nouveau Buildings in Aveiro region: a) City Museum; b) Pharmacy Ala; c) Four Stations House; d) Major Pessoa House [Rota da Luz (2005)]

Figure 2 – Deteriorating wooden beams floor ([Varum, H. et al (2005b)])

Figure 3 – Advanced state of degradation of a limestone façade ([Varum, H. et al (2008a)])

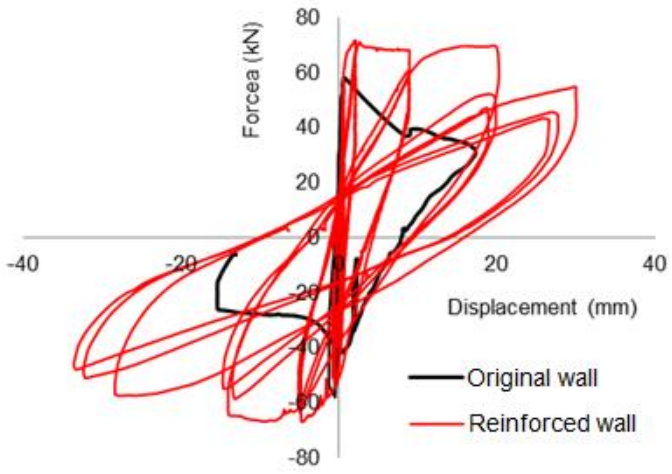

Figure 4 – Force/displacement graph for real scale adobe wall tests ([Oliveira, C. et al. (2010)])

a) b)

Figure 5 – Major Pessoa House: a) before the intervention [Varum, H. et al (2008b)], b) after the intervention (photo: C. Oliveira)