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Restoration of Wood Structures at Federal University of Rio de Janeiro

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ABSTRACT: The University Palace of the Federal University of Rio de Janeiro, a renowned neoclassic style building, was erected between 1842 and 1852 as a tribute to the Emperor Dom Pedro II adulthood. The need to repair the wooden floor structures of the Palace, attacked by a overwhelming termite infestation, required hiring a multidisciplinary technical group including structural engineers, building companies acting in historical buildings restoration and biologists specialized in urban insect infestations. Since this building is protected by the National Institute of Historical and Artistic Landmarks, every stage of the project, as well as, the works for the floor restoration were controlled by the landmark institute.

The project elaboration details and building work development are described in this paper.

1 INTRODUCTION

The University Palace of the Federal University of Rio de Janeiro, located in the “Praia Vermelha” Campus, extends to 11000 m² of constructed area, see Fig. 1.

Outstanding XIX century architects designed it to be the former Pedro II Asylum, a pioneer initiative of an oriented hospital for mental diseased treatment, as well as, to honour the monarch majority.

Occupied ever since 1952 by teaching units and scientific and cultural centers, it had its artistic and historical value acknowledges, when the National Institute of Historical and Artistic Landmarks has endorsed it in 1972. Preservation of architectonic landmarks requires a scientific care and needs a variety of techniques concerning its implementation. This article deals with the actions taken to control a xylophagous infestation, as well as, to renovate the floor structures of one of the most important architectonic monuments of Rio de Janeiro.

Figure 1 : University Palace façade, 2002.

2 ARCHITECTONIC ASPECTS

The University Palace façades retain its original architectonic typology. Its installations are intended to educational and administrative activities, congresses, solemnities and even religious ceremonies.

Door and window frames, in original state, are in *Cedrela* sp, *Nectandra* sp, *Tabebuia* sp and *Plathymenia foliolosa* Benth woods. (Mainieri and Chimelo 1989)

The exterior walls are 1,00 m thick whilst the interior ones are 0,70 m. Both walls are structural; in other words, they present structural resistance along their lengths. They are made of stone with lime and sand mortar.

In the building there exist lath-and-plaster walls, even brickwork, as well as reinforced concrete slabs which are suitable for structural floors; however, they result from light modifications or additions aiming to adapt the building to its new use.

The wood floor is supported by wooden beams which transfer its reactions to the walls, forming an integrated structure: the wooden beams are inserted in the walls and they could not be removed, for fear the wall resistance would decrease. This matter was taken into account in choosing the construction plan, which is described below.

3 STRUCTURAL STRENGTHENING

3.1 Floor investigation

The UFRJ Rector has entrusted the author in 1995 to direct the conservation works of the University Palace.

The assignment included the building adaptation to its usage needs.

Moreover, the physical integrity of the historical building should also be checked.

Under this work, a routine inspection in 1996 revealed the existence of loose floor wood boards.

To identify the problem causes, forge nails were pulled away and the floor wood boards removed to allow the investigation of the supporting wooden beams.

Visual analysis pointed out the degradation of some of these wooden beams. Some rooms of the Education Faculty had to be interdicted right away, specifically those of the post graduation courses.

A multidisciplinary team was assembled, formed by prominent structural engineers coordinated by a renowned professor of this institution to assess what had been left of the floor resistant capacity.

Furthermore, biologists specialized in urban pests were summoned upon. During this evaluation, these technicians came to the conclusion that a meaningful part of the woodwork was destroyed due to the termite action.

3.2 Biological characterization

3.2.1 Infesting species

The determination of infesting species of the woodwork of the Palace was essential to characterize its biological features, as well as the most effective method to fight them.

The wood destruction characteristics caused by an attack of a certain biological agent can define a termite species. After a careful evaluation, was possible to identify two different termite species, which were responsible for the infestation of the Palace floors. They are:

a-Cryptotermes brevis (Walter 1853). This species usually is not found in natural environments. It is cosmopolitan, so to speak, attacking primarily industrialized wood employed in human constructions, named, for that reason, by dry wood termites. They dig burrows interconnected by canalicula in the alburnum, and even within the wood core, consuming it entirely without destroying the exterior layers of the wood piece, in which they open just tiny holes, to outlet excreta. The termite colonies are small, but a wood piece is generally infected by hundreds of them. Its destruction power is significant. Its usual designation is based on the fact that these woods display relatively low moisture content.

b- *Coptotermes havilandi* (Holmgren 1911).This termite species is found either in rural or in urban areas. Their social layers are rather complex, presenting following castes: queen, king, soldiers, workers and winged-breeders. The soldiers are asexual and their role is to coordinate worker activities, protecting the colonies from natural enemies. They are commonly called ground termites, but they should be more accurately named according to the substrate upon which the colony settles, such as, structure termite, masonry termite, tree termite and so on. They need a high humidity level to survive. Its colonies may shelter thousands of individuals and remain active for more than twenty years. The colony size varies from few centimetres to several meters.

3.2.2 Infestation dissemination

The factors that attract Criptotermes brevis counteract those impelling the action of Coptotermis havilandi, inasmuch as the former feed on dry wood, whilst the latter feed on humid wood.

In the University Palace, however, these species coexist in a rather uncommon harmony. They are found in same room and oftentimes in the same wood piece.

The infestation takes place by flock due to some architectonic features of the construction, in addition to its unsatisfactory conservation over the years.

The cellars, created to allow a transverse ventilation system underneath the building, filled with construction debris, became one of the main access channels to the termites.

The disaggregated plaster from the façades and the existence of six inner garden courtyards caused rainwater and humid seawater infiltration in the beams and supporting walls, rendering them humid and friendly to termite colonies.

A stimulus to colony growing took place due to alternating dry and wet conditions, triggered by roof flaws, cracked and displaced tiles, gutter debris, unprotected construction joints and water pipe clogging. Furthermore, the replacement of copper water troughs by those in asbestos-cement, about 20 cm higher than the original ones, led to a drastic reduction of the slope of the two last tile rows, turning them flat and inducing water return to the inner section of the building, see Fig. 2.

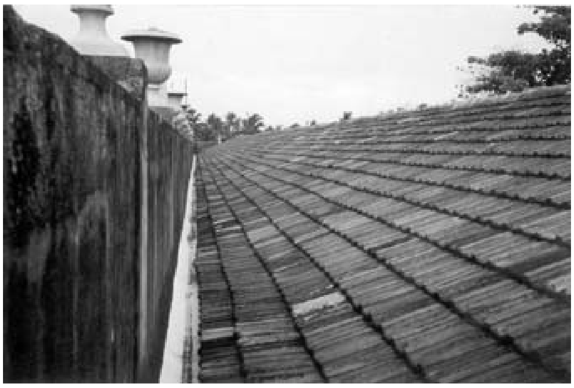

Figure 2 : Two last tile rows flat at University Palace's roof.

3.2.3 Termite control in University Palace

Due to the impossibility to interrupt activities in the building, with its unremitting flow of students, teachers, workers and visitors, the action against termites required two strict criteria: the insecticide efficiency and its low toxicity to human beings.

The utilized method has succeeded previously in other historical buildings. It consisted in combining 4th generation techniques, applied by means of baits, made of cellulose, as well as, using 2nd generation method, using insecticide sprinkling.

The 4^{th} generation technique employs growth hormones, exterminating termite colonies by interfering in its metabolism and their physiological balance. The 2^{nd} generation technique aims at preventing new woodwork infestations.

3.3 *Structural assessment*

3.3.1 *Floor mapping*

After mapping the distribution of the wooden boards, investigation was expanded to evaluate the structural damage.

The removed boards were located mainly near the windows, rather vulnerable areas due to humidity and termite attack.

In addition to the representation of the wooden beam distributions, each individual board was marked with removable ink and mapped in the floor plan drawings together with their wood species, ornate and mortises.

3.3.2 *Structural assessment*

Any wood in unfavorable moisture conditions is prone to deterioration by xylophaga.

The passage of water from stone-and-plaster masonry to floor wood was due, in this case, to the descending water originating from the roof infiltrations and due the salt content in the mortar, frequently found in marine regions, as in this construction.

In the University Palace, occurred various kinds of sensibility to biological agents attack: for single termite specie and for concomitant attacks, even in the same wooden beam. The inspection of wooden beams revealed a superficial attack in some of them and a reduction of a wood section in others advancing till the core. Percussion was utilized with the help of hammers, comparing the sound generated for the rather hollow wood mass in comparison to the no destroyed ones (Mateus, 2002). Perforations were carried out with drilling machines for the analysis of extent of the *canaliculus* depths excavated by *xylophaga*.

Floors boards covered by ink layers were also examined and often their degradation degree required compulsory replacement. The removal of board nails, to treat the wooden board structures, was carefully done to prevent irreversible damages to the pieces.

3.3.3 *Beam analysis*

Each wooden beam was evaluated after removal of its damaged parts.

The operation was achieved using adequate instruments pertinent to a meticulous handiwork, essential to determine the final piece conditions. After eliminating the damaged materials, part of the wood sets was reutilised. During beam analysis two conditions emerged:

a. The flawless pieces. They were treated using the aforementioned techniques. A large variety of woods was found in the construction, among which: *Tabebuia* sp, *Astronium macrocalyx* Engl., *Manilkara longifolia* and *Peltogyne recifensis* Ducke. The resistance of the latter was noteworthy, since it was the least affected by the xilophagous attacks (Mainieri, Chimelo, 1989)

b. The affected pieces

b.1 The useless ones. The destroyed wooden beams were discarded, since they could not act as a structural member.

b.2 The still usable ones. After undergoing entire or partial treatment they could still be used. These wooden beams were rigorously inspected. The wood pieces, most of them showing a 25cm x 25 cm cross-section, were oversizely designed. Even after material removal, some of them were still capable of undertaking their structural role, as verified by a structural engineer after deformation and resistance calculations.

4 FLOOR RESTORATION

The floor restoration in the historical building was accomplished according to particular architectonic and constructive techniques of each room.

Each one presented its own features as shown below.

4.1 *Restoration of post-graduation coordination room of the Education Faculty*

The room measures 5.65m x 7.20m and its floor is supported by 10” x 10” wooden beams with 45 cm spacing. (Hoirisch, Hermes, 2005). The construction procedure is described below:

- The boards of the floor and inferior ceiling were removed, see Fig. 3a.
- They were further reutilized after termite treatment.
- Masonry cavity removal in both wall sides to allow the support of new strengthening wooden beams (in this room the affected beams attacked by termites were not removed)
- Termite treatment in the remaining viable beams.
- Supplying and installation of two strengthening beams made of *Manilkara longifolia*. wood with a cross section of 3” x 9” placed on both sides along the partially destructed wood piece, after previous infestation control, see Fig. 3b.
- Filling of the masonry opening with grout, making sure that each bearing wall would maintain its structural resistance.
- Reinstallation of floor and ceiling skirting boards using a new replacement screw fixation.

Figure 3a: The boards of the inferior ceiling were removed, 1996

Figure 3b: Installation of two strengthening beams.

4.2 Restoration of the Rector Room in the Science and Culture Forum unit

The room measures 6.45m x 9.10m and the floor structure consists in 10” x 10” wooden beams. It is disconnected from the lower ceiling structure of the lower deck and it is formed by 6” x 6” beams. The construction stages were as follows:

- The removal of the floorboards and the ceiling boards of lower deck for further reutilization. Preservation of the both board systems, see Fig. 4a.
- Shoring the of the floor structure from the lower floor.
- Cavity opening in the masonry wall adjacent to the supports of the damaged beams, for a posterior installation of the strengthening beams.
- Temporary distribution of some of the damaged beams loads without support in the walls, to the adjacent beams, with the help of adequate temporary connection.

Figure 4a : Degradation of wooden beams, Rector room, 1996.

Figure 4b : Installation of floor 10” x 10” *Tabebuia* sp wood beams, 1996.

- Removal of the damaged beams, which previously supported the floor and the ceiling lining, see Fig.4a. Termite treatment of the beams to be kept.
- Supplying and transportation of the new beams to the work site employing wheeled carts and cranes. Installation of 6” x 6” *Tabebuia* sp wood beams from the ceiling lining in the place of the damaged ones.
- Supplying and installation of floor 10” x 10” *Tabebuia* sp wood beams, replacing damaged ones, see Fig. 4b.
- Filling of the masonry opening with grout, making sure that each bearing wall would maintain its structural resistance.
- Installation of new transversal wooden pieces replacing the previous damaged ones to guarantee the floor leveling and the structural stiffness.
- Termite treatment of the floor and its supporting structure.
- Reinstallation of wooden boards with tongue and groove connections of the previous floor, obeying exactly the previous arrangement.
- Grating, joint filling and waxing of the newly installed floor.

4.3 The Golden Room restoration

The room measures 9.10m x 18.14m and its floor is supported by 10” x 10”wooden beams presenting a 64cm approximate spacing, see Fig. 5a.

Figure 5a: The Golden Room restoration process, 1996.

Figure 5b: The Golden room after completion of restoration work, 2002.

- The 9.10m length is subdivided in two 6.04m and 2.36m beam spans supported by a 70cm thick intermediate wall, which separates, in the lower floor at ground level, a room and a gallery. The last one runs along the building inner garden.
- Similar procedures to the ones described for the other rooms have been adopted for the Golden Room, except for the wooden beams, which had been replaced in an alternate way, to avoid removal of the floor lining, since it remained supported by the remaining beams.
- The Golden Room after completion of restoration, see Fig. 5b.

3.4. Wood selection and drying process

Wood selection was based on its resistance capacity and structural stiffness, for in this present case the beam length may attain 10m, causing, occasionally, excessive and uncomfortable floor flexibility.

To avoid the risk of future wood shortening strains, a rigorous drying process was required, prior to the installation of the wood beams and floorboards. (Ponce, Watai, 1985).

5 CONCLUSIONS

A long period without appropriate conservation leads to a severe degradation of historical and artistic landmark buildings. Precautionary maintenance works are recommended.

As termite infestation takes place surreptitiously, the restoration turns out to be costly, since the infestation has already spread to a critical level when the damage is perceived.

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The rotting of wooden pieces occurs at the beam wall supports, due to the consequences of the humid walls. It can lead to a complete loss of its resistance capacity. (Aguiar, 2005).

For wooden floors and roof structures, the commonest anomalies are due to the rotting and to the destruction caused by fungi and insects, which induce excessive deformations at long-term. Additionally the biological attack is stimulated by the wood moisture, if no protection has been provided to the wood (Aguiar, 2005.)

Critical points should be periodically inspected since no long-lasting chemical products are available against termites. It is strongly recommended to replace forge nails, utilized in the connections of the wood boards to the beams, by screws, to allow possible periodical board removal to control infestation, to assess the humidity levels and to evaluate the conservation state of the wooden beams.

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