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METHODOLOGY OF REHABILITATION OF TIMBER STRUCTURES IN HISTORIC BUILDINGS

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ABSTRACT: The objective of this paper is to present a methodology of the design process for the rehabilitation of Timber structures in Historic buildings. The methodology is based on the author's experience and on recognized standard knowledge, available on heritage documents and standards and expert's Principles of Intervention such as those defined in the 1964 Venice Charter. A real case study related with a roof Timber structure existing in the University of Coimbra, and originally built in the 16th century is used to illustrate the methodology. It is concluded that this type of interventions, on existing structures with a very high patrimonial interest, highly benefits from mixing full restoration principles with innovative tools and in situ modern construction processes and methodologies.

KEYWORDS: Design methodology; Rehabilitation of timber structures; Historic Constructions; Case study

1 INTRODUCTION

Rehabilitating heritage buildings for new uses, or modernizing an existing building with heritage value, introducing modern features, improving its habitability and healthiness and also functional performance in thermal and acoustic terms, is a very difficult task, in many cases, and requires a careful approach in the design phase in order to be able to meet the objectives of the program in terms of the quality of the intervention, respecting the historical memory of the buildings.

This article is mainly based on the experience of the author as a design engineer of wooden structures, and as Consultant of Site Supervision teams of rehabilitation works of ancient buildings with patrimonial value, developed on end-of-life buildings and/or with obsolete construction systems and/or very significant constructive anomalies.

It also benefits from the author's teaching experience in the rehabilitation of timber structures, exercised mainly in the last 20 years at the Faculty of Engineering but also in the Faculty of Architecture in Porto in several postgraduate courses attended by Architects and Engineers with experience in this activity.

In terms of bibliography, it is mainly based on books in which the author collaborated [6] and [7] and reference bibliography that the author regularly uses such as [1] and [2], as well as several articles previously published by the author on similar subjects, such us, [10].

Part of the inspiration of the methodology can also be attributed to Italian standard, UNI 11119, identified in bibliographic references as [3], and other more recent standards and recommendations such as [4] and [5], as well as in the fundamental updated documents of principles of restoration and rehabilitation published by ICOMOS, [8] and [9].

This paper aims to point out that historic buildings need to be used so that they last and are appreciated by the community and that this means that they should be updated technologically on a permanent basis.

Therefore, historic timber structures must be restored but, at the same time, the building needs to be updated and this implies a rehabilitation methodology done in parallel with the restoration process of the historic structures.

The proposed approach is multidisciplinary and integrated, although it gives special emphasis to architecture in all its components but especially in the 'construction' aspect and to foundations and structures, while still considering the issues associated with infrastructure (water supply, sanitation, rainwater, electrical installations, mechanical installations and Data networks), fire safety, thermal and acoustic comfort and general Health and Habitability, mainly measured by sustainability indicators of the projected intervention.

In the context of this Conference, the case presented concerns only the issues relating to wooden structures and refers to a case that is relatively unintrusive and almost totally 'non-destructive', on preexistence and considering the enormous size of the case used as an example, only addressing the rehabilitation of a small part of the current roof area and the existing space between the ceiling of the last floor and the roof in which the space is intended to be occupied with new uses.

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2 GENERAL DESIGN PROCESSES IN PATRIMONIAL BUILDINGS - MAIN PHASES

2.1 MAIN SPECIFICITIES OF A REHABILITATION PROJECT

The existing building (or built set) design processes are quite different from the processes adopted for new construction, since, in existing buildings and especially when the interventions to be carried out are not intrusive, the project is carried out on an existing object and at least this one must be previously well characterized and analyzed in all its components.

In this context, there are steps prior to the development of the project that must be carried out with great care and adequate development.

Thus, the main phases of a rehabilitation project are presented below, highlighting in parallel the specificities associated with the need to design on something existing, hereinafter referred to in this article as "pre-existence" as is usual in the specific language of restoration and rehabilitation of buildings.

2.2 MAIN PHASES OF THE REHABILITATION DESIGN PROCESS - A BRIEF DESCRIPTION

2.2.1 Preliminary survey

This initial phase includes:

- architectural, structural and geometric survey;

- survey of existing building systems (evaluation and complete characterization including foundations, structure, non-structural interior partitions, walls, roofing, facades, coatings and finishes, water, sanitation, electrical and other installations);

- survey of links to service providers in terms of water, sanitation, electricity, gas, rainwater and others, that may exist;

- geotechnical characterization of foundation and surrounding soils, including assessment of groundwater levels and their variation throughout the year.

2.2.2 Inspection and diagnosis

The inspection and diagnosis phase represents an essential preliminary work of the rehabilitation project process. It includes, inter alia, the performance of the following tasks:

- assessment of existing anomalies in existing construction and of their causes;

- characterization of the most relevant materials and components, namely the composition of masonry, physical and mechanical characteristics of stones and woods, characterization of the main coatings and finishes to be maintained, among others;

- definition of generic intervention suggestions to eliminate the causes of anomalies.

2.2.3 Propose an adequate program

This is one of the fundamental phases of the rehabilitation project process, since, often, it is incomplete or sometimes completely misadjusted to the pre-existence which may lead to completely failed rehabilitation works in terms of objectives.

In the restoration processes with maintenance of previous uses this is a less important problem, since it treats the existing building as a "museological object" of itself which facilitates the initial phase of project necessarily more creative and potentially intrusive compared to the existing one (this is the case of the example presented in this article).

In any case, it should be emphasized at the outset that doing a restoration with maintenance of previous use is often a strategic mistake, because it can miss "an opportunity" to rejuvenate and reorient the building to new uses compatible with pre-existence, more or less intrusive according to the needs and /or options of the designers in charge of the project and then with very positive implications in terms of cost-benefit of the future operation and maintenance of the building.

Generally speaking, this phase includes:

- the definition of a future use compatible with the existing object;

- the definition of a methodology of restoration or rehabilitation, more or less intrusive and appropriate to the future use, previously defined, and that allows to find a good cost-benefit ratio for the intervention.

2.2.4 Execution Design phase (D)

This article omits all project previous phases, prior to the “final execution design project” phase, for reasons of simplification of the approach.

Once the fundamental licensing issues associated with the need not to comply with the Regulations applicable for new works have been resolved, the design team starts the implementation project phase working on all documents and studies previously produced in the previous phases, as well as the knowledge of the pre-existence to be rehabilitated/restored, resulting from site visits and all preliminary studies.

This is the main specificity of any rehabilitation project. To detail, without respecting pre-existence, is to perform useless work. Designing new work on an existing building, without solving existing problems, leads to the new work being born with defects that will later be much more difficult to solve.

3 EXECUTION DESIGN PHASE – A METHODOLOGICAL PROPOSAL

3.1 INTRODUCTION

The methodology presented in this article is based mainly on this reality: to build a new work from scratch is mainly based on a well-thought-out and detailed project that can translate what the designer team

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imagined and conceived; rehabilitating or restoring an existing building set presupposes "knowing" well the existing object and conceiving "on" something that already exists and that has already been designed and built by others and that has already been used, has undergone changes in construction systems and spaces, volumetric additions, changes in use, among others, i.e. a whole panoply of events that "strongly condition" the process of the restoration/rehabilitation project to prepare for the site.

Table 1 illustrates in a schematic way the methodological proposal presented in this article. In general terms, this proposal is based on the definition of ordered steps, defining the action of the Architects and Engineers and also on their interaction, aiming to produce the best job possible.

This methodology has a fundamental action at the beginning of the process (steps D1, D2, D3 and D4) and also it cannot fail to solve all the challenges in steps D5 and D6 with all the rigor, see Table 1.

Steps D5 to D8 are similar to common projects to be built on new “clean” plots, without pre-existences to be saved.

Table 1: *Design methodology*

Phase of design	Description
D1 (Arch., Fire Safety engineer)	Definition access building; Definition of vertical and horizontal communications
D2 (Architect ,Networks engineers)	Define complete paths of infrastructure networks
D3 (Architect)	Base design: Geometric tuning; Indoor/outdoor connection;
D4 (Structural engineer)	Resolve ventilation issues; Eliminate moisture problems ; Identify and solve existing problems 1 by 1;
D5 (Networks engineers)	Detailing; respect paths defined in phases D1, D2, D3
D6 (Structural engineer)	Detailing – Finish execution design; respect what has been previously established
D7 (Architect)	Detailing – Finish execution design; Finishes/Partitions
D8 (Other engineers)	Detailing – work close to architects to specify in complete match with them

3.2 VERTICAL AND HORIZONTAL ACCESS AND COMMUNICATIONS (D1)

In a process of rehabilitation of buildings with patrimonial value, with structure formed by exterior walls in stone or wood masonry and walls, floors, stairs and roofs in wooden structure, for new modern uses and fulfilling as much as possible current performance requirements, the first fundamental action of the project is associated with the complete and in-depth study of all the logic of access and movement of people in the areas of collective use, as well as in the areas of private use.

Nothing should advance in the execution project before solving the puzzle that often this issue represents, considering the need to be as intrusive as possible in pre-existence. Often this process is very conditioned and aggravated by the need to maintain larger value zones within the spaces, which can often greatly condition the new solutions to be designed, such as an existing chapel, although small, in the case study (problem not presented and discussed in detail in the article).

It will not often be possible to comply with the applicable regulations for new work and decisions will have to be made! Also often, with regard to the aspects of thermal and acoustic comfort and the general use of the building, difficult decisions should be made, especially with regard to the slope of stairs, the possibility or not of installing an elevator for vertical communications and the possible incompatibility between the maintenance of walls, doors and other building elements and the "will" to improve the thermal and acoustic performance of the building, among others.

In this first stage of the process, fire safety is of particular importance, since in general it is impossible to comply with regulatory requirements for new work and it will be necessary to agree with the licensing authorities the mitigating measures to be taken to improve existing behaviour, situations that often strongly condition the architectural options to be taken.

3.3 SCHEMATIC PATHS OF NETWORKS (D2)

Today, modern buildings include water supply infrastructure networks, other networks, such as sanitation, data, electricity and gas, mechanical and natural ventilation and air conditioning, that occupy large areas and volumes of the construction, and strongly condition the freedom of architectural design.

This problem is substantially aggravated in an existing building set, due to its complete absence in the original construction. It will therefore be necessary to integrate into existing buildings all the new networks needed for their operation in a modern context, using "paths" perhaps already existing or to be created, in a way compatible with the new use to be given to spaces and their own new configuration, trying to affect as little as possible the non-technical uses to be given to the sites and, at the same time, minimizing the occupation of areas and paths of technical infrastructure.

It is generally a very difficult exercise to solve, this should therefore be dealt with, as a priority, before moving forward with everything else.

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3.4 GEOMETRICAL TUNING (D3)

The existing old buildings with heritage value, because of having been built using techniques and equipment less sophisticated than those currently available, have many "defects" of origin that translate into very inclined stairs, uncomfortable steps, narrow corridors, non-orthogonal walls to each other, walls "out of plumb", among others. It will therefore be necessary to consider all these problems in the Architecture design, thinking about "places of closing the spaces / volumes" and solutions of eventual disguise of existing defects such as false ceilings, steps, fillers or simply, assume these imperfections by conceiving spaces and solutions where they are properly "integrated" or assuming, quite simply, their geometric specificities i.e. their original geometric imperfections that occurred throughout the use of the building.

3.5 FUNDAMENTALS OF STRUCTURAL DESIGN (D4)

After stabilizing the geometry of the internal and external spaces, it is time for the structural engineer to assume the main role, evaluating and resolving all the situations resulting from the previous steps, namely:

- eliminating existing structural anomalies;
- introducing new structural systems compatible with the new uses, downgrading the service levels of existing structures, when they can not fulfill the new performances needed, always respecting the architectural design (done in cooperation);
- improving the "habitability" of environments with regard to the health of structures, in particular wooden ones (naturally ventilate spaces and eliminate all causes of moisture);
- solving problems caused by new infrastructure network paths;
- reinforcing/rehabilitating structures for possible new uses;
- solving problems of previous malfunction (vibrations, deformations, defects of original design, defects resulting from previous works poorly conceived or executed.).

The project design process should not move forward without, at least at design level, all structural problems being identified and generally addressed at the level of the principles and methodologies of resolution and the dimensions and location of existing and new structural elements.

3.6 CLOSURE OF THE DESIGN PROCESS (D5 TO D8)

Now, all designers can advance in parallel in the implementation project, respecting everything that was previously agreed.

In the border areas between engineering specialties and these with architecture everything should be properly detailed and compatible.

It should be noted that, at this stage of the process, the project methodology is totally analogous to the design of a new work done in a plot without pre-existence...

4 SPECIFIC RECOMMENDATIONS FOR TIMBER STRUCTURES

4.1 GENERAL RULES

Timber structures have their own specificities that justify the consideration of an autonomous subgroup in terms of rehabilitation. These specificities are essentially the result of the fact that the raw material of which they are made is of trees origin, which gives them a degradation process very different from that foreseen for structures executed based on materials of mineral origin. The main causes of wood degradation in structures are as follows:

- firstly, biological degradation by the effect of fungi, insects, mollusks and crustaceans (the latter in a marine environment);
- secondly, aging by effect of the hygrometric term action (wood is a material with anisotropic mechanical behavior and varies its dimensions and physical, chemical and mechanical properties depending on its water content, in turn variable with the absolute humidity of the environment that surrounds it);
- inadequate structural use due to inadequate design of the elements/components of each substructure, and also of their supports and connections.

It should be noted that humidity is not in itself a fact of degradation of wooden structures. The careless permanence of the structure in humid environments and in poor ventilation provides ideal living conditions to biological agents of wood degradation, which are a direct cause of wood degradation in these contexts. The following are a set of general concrete rules to be applied in the restoration of wooden structures:

- always check other structural systems (foundations, walls, bracings, ...) - stability and level of degradation;
- avoid disassembling the structural elements in wood: the future assembly will place these elements in different states of tension as a result of the new connections to be made;
- use strong solutions: use higher safety coefficients than in current "new" projects;
- make periodic inspections of structures (control the following factors: temperature, humidity, air renewal rate, wood water content, deformations and defects of structural elements, ...);
- improve the service conditions of wood parts: avoid connections with steel or glass if they do not allow the wood to be ventilated or to favor condensations;
- improve the general and localized ventilation of the spaces (air renewal is essential for wood);
- carry out periodic cleaning of the structure;

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- eliminate all external causes of degradation (especially those arising from the surroundings of the building - walls and roofs);
- whenever possible, leave after the restoration intervention, the possibility of all structures being examined from the nearby physical and/or visual point of view;
- always place the wooden elements in the same class of service in environmental terms;
- ensure proper ventilation of the supports by avoiding direct contact of wood in these places, as far as possible, with other materials which may retain moisture or prevent wood from "breathing";
- avoid hiding the structural elements in wood with finishing materials mainly ceilings and false ceilings – the degradation will not be detectable;
- restore the building from the roof to the foundation, if it has not foundation problems– in this case, first solve the foundation problems;
- always ensure the stability and low deformability of the supporting elements before intervening in the wooden structures supported by them;
- always initially restore the most important elements – more robust and/or more degraded.

5 THE CASE OF TIMBER ROOFS

In a concrete case of rehabilitation of a wooden roof of a Historic Building four specific situations can occur:

- repair and point replacement of degraded elements using old techniques;
- repair and point replacement of degraded elements using old techniques and modern connecting solutions;
- integral replacement of the structure using old woods, modern materials and connecting techniques and architectural designs similar to the old ones;
- integral replacement of the structure by modern design solutions, wood elements, materials and connecting techniques to be used.

For historic buildings the ideal solution will be that which corresponds to situations a) or b). It is the author's opinion, however, that the ideal solution will preferably be a hybrid of approaches b) and d) as it ensures improved performance, higher economic value and a much higher durability of the rehabilitation intervention. Materials that ensure higher durability should be used as far as possible.

This can be justified by the following. In many cases, the existing timber structures cannot fulfill the "new design demands" without highly intrusive and expensive reinforcements, and it is very common to consider that it is not convenient to reinforce the existing systems and, therefore, solution b) coexists with "new structures" that occupy the same volumes and liberate architects for an eventually more intrusive program, which we may consider as a hybrid situation of approach b) and d). This is the situation presented in this case study, see section 6.

5.1 SUBSTITUTION AND PUNCTUAL REPAIRS USING TRADITIONAL CONNECTIONS

It's the most current situation in historic buildings in a restoration process, when the architectural program does not change significantly the performance demands of the structures. It assumes that the various elements in wood are generally in good condition, allowing the structure of the roof to remain in place with the existing form, before the intervention. The connections between partially replaced parts will be made using traditional solutions, similar to the original ones.

The most serious mistakes made in the past with wooden structures concern the poor ventilation of the structure, especially in the supports, which implies the biological degradation that is also transmitted rapidly to the support of the parts/connection with the masonry walls. In a specific intervention, adequate ventilation and protection against insects, namely termites, of the new elements/systems should be ensured.

5.2 SUBSTITUTION AND PUNCTUAL REPAIRS USING MODERN CONNECTIONS

It is a situation analogous to the one described above, but in which we seek to solve problems of connections using modern methods and techniques. The author thinks this is the most appropriate solution in general. It makes no sense to use nowadays handmade nails, with a relatively high corrosion speed, when it is possible to resort to stainless steel connecting systems, for example, that are much more durable and equally resistant and that also allow the reversibility of the assemblies by unscrewing.

With regard to support prostheses, the solution to be adopted will be influenced by the extension and strength of the eventually existing xylophagous attacks. If there are no major aesthetic limitations, the use of metal prostheses in situations of exclusive degradation of the elements near the supports will generally be more economical in the case of more extensive degradations. There are no universal rules indicating the best solution for each case. All operations involve the removal of roof tiles, and all other secondary elements of the roof, in order to access the structure both below and above, so that the reinforcements and substitutions may be done.

5.3 SUBSTITUTION OF TIMBER ELEMENTS AND SOLUTIONS USING "USED WOODS" AND MODERN CONNECTIONS

In some cases, for architectural or constructive reasons, it is not possible to carry out the restoration work

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without dismantling the structure. In these cases, the pieces are carefully dismantled and put back on site following modern connecting techniques and using, when it is possible, used woods of equal or similar species, quality and eventually age.

Elements with degraded parts at the ends can be used to obtain smaller elements that can be used in other works or in other places in this same work. It should be noted that an old wood structural part of a durable species is a structural material of high value and should always be carefully assembled and stored for future use.

For example, a beam of 7 m long with 0.5 m of degraded parts on each side allows to realize a beam of 6m in length in optimal conditions, cutting the degraded tops from both sides. The geometry of the new structure is not necessarily coincident with the original structure and, as far as possible, follow the original design models so that one can maintain the memory of the building.

5.4 INTRODUCTION OF A NEW STRUCTURE MAINTAINING OR NOT THE EXISTING ONE

In many cases, the existing structures are not able to withstand the new performance demands. Still, they have historic value and in general should be kept in place as a memory, without structural function, or eventually fulfilling less demanding structural tasks such as supporting the ceilings of the last floor below (in many cases with very high patrimonial value, with "frescos" or decorated carved timber ceilings).

6 CASE STUDY

6.1 GENERAL DESCRIPTION OF THE BUILDING

The College of Arts is part of the University of Coimbra, founded in 1290. Currently, it is used as Faculty of Architecture. The construction of the College of Arts began in 1568, see Figure 1.

Figure 1: General view of the building

The building has undergone successive changes over time in terms of volumetry and use, highlighting a major reform on the early twentieth century, with the expansion of the construction in height and the use of new materials, such as cast iron columns on the raised floor, for the installation of the University Hospital of Coimbra, operating at this site until 1986.

The building belongs to the designated first University Pole of the University of Coimbra and currently presents a deployment area of about 6600m2.

The College of Arts belongs to the architectural ensemble of the University of Coimbra, which since 2013 has been classified as a World Heritage Site by UNESCO.

6.2 ARCHITECTURAL PROGRAM

The architectural program provides for the rehabilitation, restoration and refurbishment of the building of the College of Arts, of high heritage value and that today is naturally aged and weakened, with many conservation problems of various types.

In addition to the spatial and constructive aspects, the infrastructure sits outdated in view of the multipurpose functions it currently has, namely museum and higher education equipment (faculty of architecture).

In addition to the rehabilitation and conservation work of the existing construction systems to be maintained, the Architecture project provides for the demolition of some additions and annexes that were carried out on the northern outskirts of the building, during the operation as a university hospital.

Figure 2 shows a 3D image of the building after completion of the works that are today still in the design phase and beginning of the demolition works.

Figure 2: *3D view of the designed building at the end of the works*

6.3 FLOORS UNDER THE ROOF

The architectural design foresees that this space will become accessible, with offices, study and meeting rooms, along the east, south and west parts of the building.

The floor under the roof on the north side is lower than the rest, so it will not be accessible. In this area, it is expected the complete demolition of the plastered ceilings of the floors below, so that the rooms and spaces of those lower floors obtain a double ceiling with the roof structure in sight. This part of the roof will essentially be restored, although improved in performance.

6.4 DESCRIPTION OF THE CURRENT CONSTRUCTIVE SITUATION

The roof analyzed in this article is of the traditional inclined type, with accessible floors under the roof, which are not used, today. The main current structure consists of wooden trusses that support girders and ceramic tiles. The trusses and the external walls support the floor structures that also support the stucco works of the ceiling of the floors below.

Figure 3 presents a roof plan, divided by zones with different constructive constitution.

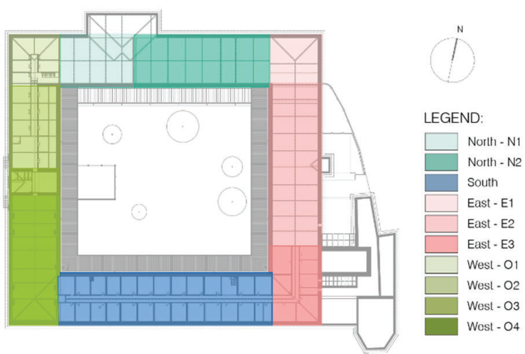

Figure 3: *Roof schematic plan*

This article refers only to the East, West, and South zones, that are all like each other.

6.5 EXISTING WOODEN STRUCTURES AND COATINGS

6.5.1 Exterior coatings

The coating of the roof in the different wings consist of ceramic tiles placed on wooden slats 45x30mm//0.35m and supported on wooden beams 70x110mm//0.50m.

6.5.2 Girders

The coatings of the roof are supported by wooden girders in solid wood, two by slope and one on the ridge, separated from each other around 1.9m to 2.3m approximately, see **Error! Reference source not found.**.

Figure 4: *General view of the roof*

On the top of the external walls in masonry, there are timber components of 100x100mm to 130x150mm in very bad condition, in many cases substituted by mortars or covered by mortars.

6.5.3 Trusses

The trusses are composed of elements in solid wood, overcome spans of approximately 11m and are separated from each other, about 3.5m and 4.3m.

The current truss presents a constitution as shown in figure 5 below. This design is not very common in Portugal and, also for this, has high patrimonial and historic values, although almost all the wooden elements are no longer original, having in general, the oldest, between 100 and 150 years.

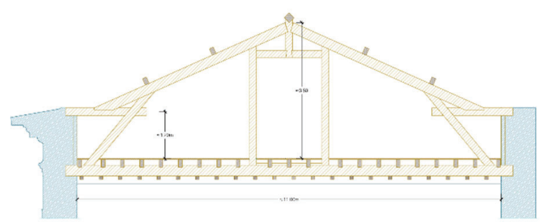

Figure 5: *Current truss*

Occasionally, some of these trusses received reinforcements, the most usual being the additional two timber elements that help to support the legs, see Figure 6.

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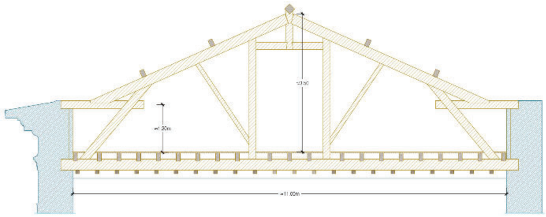

Figure 6: *Casual reinforcements on trusses*

6.5.4 Connections and supports

The connections between the different parts of the trusses are traditional, materialized by carpentry joints and with some metal connectors, see figures 4 and 7.

6.5.5 Floors under the roofs

The current floor is made of solid wood and has approximately 1560m2 along the east, south and west wings of the building, see Figures 4 and 7.

Figure 7: *Floor structure under the roof*

6.6 ANOMALIES IN EXISTING STRUCTURES

6.6.1 General anomalies

At the level of the roof, the coatings are partially fulfilling their function, but there are problems of water tightness, with traces of water and moisture entering the stone masonry walls, especially near the top of the roof.

The floors under the roof have no conditions to be used for any purpose, as they are today.

6.6.2 Structural anomalies

Regarding the trusses, despite the good general condition of most wooden parts, there are several indications of structural problems.

Some trusses have torsions, high deformations, excessive cracking, weakened and inadequate connections, and rot-damaged supports. There are also some reinforcements, carried out in previous apparently loose interventions, which aimed to correct some of those problems, but which were sometimes inadequate.

The girders and the wooden structures that support the floors are in a good state of conservation and have an adequate structural behavior, with malfunction problems in some places.

Most wooden parts do not appear to respect the levels of stress resistance and deformation in service, in accordance with the actual regulations, and it is also stressed that there are some critical situations, with a risk of local collapse, which must be corrected quickly, particularly in the trusses.

6.7 SOLUTION – APPLICATION OF THE INTEGRATED METHODOLOGY

The fundamental principle to follow is to restore the existing structure, applying the principles of restoration and start using it only as a support of ceilings on the lower floor.

Simultaneously, introduce a new wooden structure and coatings and finishes with current modern design fully suited to the new uses, involving the coatings of the roof and the new floors to be executed.

The architectural design is thus completely free to comply with the current, more demanding construction regulations, at the level of walls and infrastructure networks and above all to introduce solutions that allow to meet fire safety requirements and improve thermal and acoustic performance and water and air tightness and natural and artificial ventilation and lighting.

The solutions to be adopted include:

- Maintain the exterior image in ceramic tile and use a sub tile, lining in wood derivatives and waterproofing system with steam-permeable screens; Incorporate zenithal lighting, using skylights and windows in new mansards to be integrated following a geometrical pass compatible with the existing facades view;

-Integrate all new infrastructures (electricity, water, data, ventilation, air conditioning) in the new roof space. Ensure natural ventilation;

- Solve the problem of sanitation (the most difficult), using localized shafts and false ceilings to disguise the corresponding tubes networks.

On the floor below the roof, it is possible to take advantage of a large part of the existing floor structure, which is in good condition, and some current stuccoes (on the lower floor) should be repaired considering the cracking they present.

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6.8 SOLUTION – STRUCTURAL INTERVENTION

The option of keeping the current trusses as the main structural element is not feasible because it involves very significant reinforcements that would completely change existing structures and make them loose their current historic authenticity.

The option to introduce new structures, more modern and efficient, keeping existing ones with lighter functions, allows greater protection of the heritage and allows to design a floor with the carrying capacity, comfort, vibration levels and deformation compatible with the new intended use, also avoiding at the same time to transmit the vibrations from the use of the floor to the current trusses, floors and stuccoes and thereby increasing the longevity of these existing structures and construction systems.

7 CONCLUSION

Historic buildings need to be used to increase their durability and economic interest.

The principles of the restoration of existing buildings with patrimonial value must be respected.

It is possible to respect "difficult" and demanding architectural programs following a methodology in which the introduction of modern construction systems and solutions walks in parallel with the restoration processes of the existing construction systems to preserve, occupying the same volumetric space without the two types of solutions imposing themselves on each other.

This is the solution that was chosen for the case presented in this paper in section 6, which means that the approach followed in the case study is a mix of systems b), restoration using modern connections and eventually materials, and system d), introducing completely new structures and materials, using a modern and highly performative design and approach, see section 5 for a more detailed explanation of the two design approaches.

The case under study represents an excellent example where this methodology is being successfully applied.

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