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Case study

Comparative analysis of the reinforcement of a traditional wood floor in collective housing. In depth development with cross laminated timber and concrete

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ABSTRACT

The restoration of heritage buildings deserves innovative and sustainable solutions that prioritize reinforcement versus substitution. When considering materials to undertake the actions, wood and its derivatives such as cross-laminated timber (CLT) are an interesting option. The aim of this study is to conduct a comparative analysis of two constructive systems from a structural point of view. Both are mixed systems: concrete-wood and CLT-wood. The reference floor structure proposed to simulate a real situation is searched among the typology of existing floors described in different treaties from XVIII and XIX Centuries.

After comparing the samples in terms of deformation, in fire situation, and considering the influence by load increases on the building foundations, the lightness of the mixed solution wood-CLT offers advantages as it makes the state of permanent loads very similar to the original state of loads of the building.

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1. Introduction

The growing development that problems related to rehabilitation of wooden floor structures, presents actions with various constructive solutions, and while the choice frequently responds to purely economic reasons, nowadays the possible historical and artistic value of the building on which the action is undertaken, should be considered. This can justify, despite being more expensive, opting for reinforcement versus substitution. Furthermore, there is an increasing sensibility towards the problem of reversible and less invasive techniques of restoration [1].

When such situations are faced, among causes which usually require to choose the type of measures to be adopted, they are wood degradation (loss of resistant section), change of use of the building (increase in service loads), functional reasons (deformations, vibrations), or the need to adapt to recent regulations (fire protection, soundproofing, etc.)

In any case, the generalized criterion of the designer during the 20th century when choosing the material to be used has been to prefer using concrete and steel rather than wood itself, usually considered as a more archaic and less practical or reliable material.

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In this type of construction it is increasingly common that changes in use are proposed, so the need to strengthen their wood slabs is faced, even being in good condition, to increase its loading capacity, and in turn increase their rigidity, as is frequently exceeded the allowable maximum deformation for certain loads.

The increasing demands on security make that these floor structures should also perform functions that were not considered priority at their time of construction, like the ability to function as a rigid diaphragm in its plane, the vertical elements linked to it, in solidarity, so that they have a box behavior, allowing to absorb horizontal actions, and the ability to redistribute the gravitational loads between the different linear elements that compose it, so if one of them is overloaded, it can work together with the adjacent.

One of the most frequent reinforcement solutions applied to date has been the placement of a slab of lightly reinforced concrete on the existing slab previously cleared. But new lines of research are providing innovative and sustainable solutions that make wood and its derivatives currently an option to take into account when deciding the material to be used in such situations, as in the case of cross laminated timber.

In order to assist the process of decision-making in the design phase, a comparative analysis will be carried out from a structural point of view, for both building systems, to thus be able to assess which, with equality of benefits, presents more advantages and better qualities.

A case study is proposed to use it as a parameter of comparison, in a framework very close to what could be a real situation, although understanding that it is not a generalization.

2. Bases for the selection of the reference floor structure. The case study

The framework in which the analysis is located is the need for a reinforcement by change of use from housing to office, in a reference slab in good condition, located in the first floor of a building type of collective housing between party walls, with development in depth of the Madrid of the XIX Century.

The variety of existing slabs complicates the choice of what might be called a reference slab. It is a complex situation that has taken place in other practical research seeking a type, with the object of achieving practicality and application in decision making, both economic and design [2].

The documents found to date are not accurate, and in this typology lumber and parts form demolition used to be reused, so the dimensions of the elements are not very homogeneous. For this study, in order to simplify calculations, sections are made to the same sample. To be able to narrow the typology of existing floors, the base has been the following documents:

- The “Treaty on urban ordinances in Madrid”, from Teodoro de Árdemans in 1791 [3], since in it there are references to the scantlings used in the floor structures of the XVIII and XIX Centuries and, though the dimensions are based in anthropomorphic measures, in the “Law of Equalization of weights and measures” throughout the Kingdom, enacted by Carlos IV in 1801, there are already established equivalencies between the old measures and the new metric.
- Treaties and Construction Manuals, managed by architects and site managers for centuries, that collect guidelines of the constructive system with timber framework that has governed for centuries, allowing us to understand the principles used by those in their design and dimensioning. While in Spain there is little documentation of timber construction prior to the XVII Century, it’s known that the wooden structures that were made at the time were calculated mostly applying rules from French technical texts. In Benito de Blais Treaty, “Elements of mathematics” of 1783 [4], the teachings of the major Gallic texts of the time are gathered.
- The “Treaty of masonry” of 1827 of Villanueva [5], that describes the types and construction processes of the beam filling that are often found, doing a very descriptive review of system and process.

2.1. Determination of span, squareness and beam fill

- In his treaty Árdemans contemplates a series of rules that relate the length of the floor structure with the scantlings to be used and that is summarized in the following:
- For small spans, of up to 3.60 m, a wood of a ten (8.70×12.18 cm), either a “sexma” and eighth beam (10.44×13.93 cm).
- In medium spans of up to 4.10 a wood of an eight (12.18×15.67 cm) was used, and up to 4.50 m were solved with a wood of six (20×13.93 cm).

Table 1
Joists dimensioning following Bails.

Span (Feet/m)	Squareness(Inches/cm)
15/4.5	$5 \times 7/13 \times 18$
15–18/4.5–5.4	$6 \times 8/15 \times 20$
18–21/5.4–6.3	$7 \times 9/18 \times 23$
21–28/6.3–8.4	$8 \times 11/20 \times 28$

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