DIAGNOSIS AND PROPOSAL FOR THE RESTORATION OF A TIMBER-FRAMED BUILDING AND ITS RESULTS APPLYING STATIC AND DYNAMIC TESTS

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ABSTRACT

This communication presents the results of the tests carried out on a newly assessed and subsequently restored timber structure of a residential building in the city of Valladolid (Spain).
Initially, a diagnosis of the structural timber condition, applying non-destructive testing techniques and visual recognition was performed. Also, a dynamic test was carried out, monitoring the slab with a self-developed measurement chain (AMEMOME) and exciting the structure with a shaker.
Based on the previous results, constructive actions were planned based on specific local interventions and on the general reinforcement of the floor slabs with a mixed solution, wood and concrete with mechanical connections.
After the works carried out, the suitability of the works performed was checked by means of static load tests.

INTRODUCTION

The building, which is approximately 100 years old, is located between party walls, in the historic center of the city of Valladolid. It has been used for residential purpose, but for several years it was abandoned and in a state of serious decay until it was finally acquired in 2019 by a real estate company with the aim of refurbishing it and putting it back on sale. (Figure 1:).

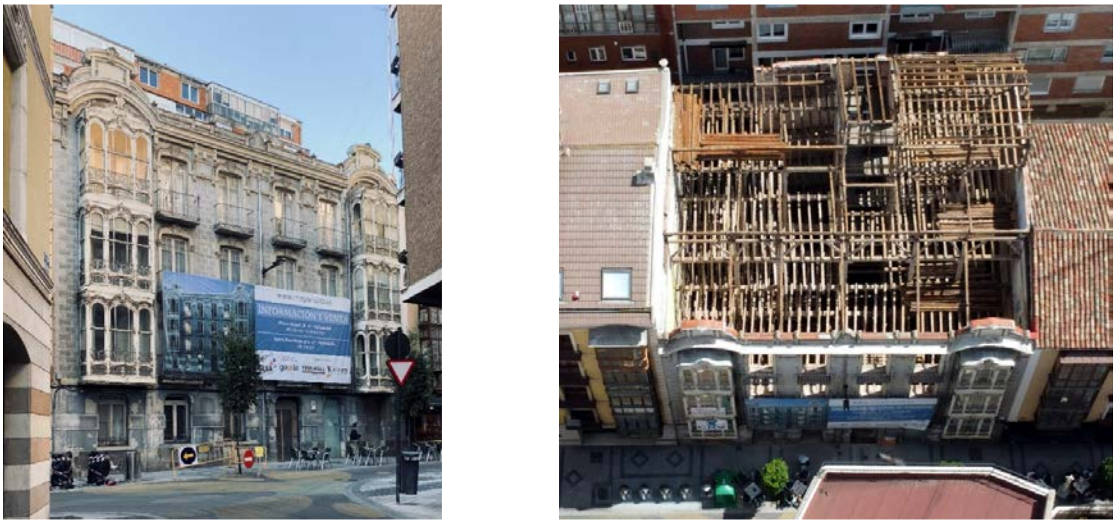

Figure 1: Previous state of the buiding (2019).

The building has a ground floor plus three complete floors, one more under the roof -with a smaller surface area- and a partial underground area- located at the back. Each floor has an approximate surface area of 250 m^2. The vertical and horizontal structure is entirely made of wood and, initially, the owner company was asked to demolish all the supported construction systems, keeping only the wooden load-bearing structure, in order to study it. (Figure 2:).

Figure 2: Timber structure (initial state).

METHODOLOGY

Macroscopically, it was determined that the wood corresponds to a conifer, most probably a pine. Previous studies of buildings in this region show that the species most commonly used for their construction have been Scots pine and, to a lesser extent, *Pinus pinaster*. Given the great inter-species similarity, it was not considered necessary for the purposes of this work to investigate further.
As a preliminary assessment, a visual classification of the wood was carried out, based on the European standard UNE EN 56.544 for conifers [1], which specifies the methodology to measure the different defects and singularities in the wood of these species and to be able to assign a specific quality based on them.

The following non-destructive tests were carried out on a selection of pieces:

- Determination of the humidity with a resistance xylohygrometer, mod. GANN-Hydromette BL A plus.
- Density estimation by means of a test specimen piece, extracting samples on site.
- Ultrasonic wave propagation tests (9 tests) with a FAKOPP Microsecond Timer© model.
- Tests with a resistograph, model RINN-TECH RESISTOGRAPH® SC-650.

Secondly, a dynamic test was carried out on one of the floor slabs, applying vibrations by means of a long stroke shaker with ball bearing SPA-APS 113. The data was collected by means of a series of digital MEMS accelerometers. forming part of an original measurement chain (AMEMOME) developed and fine-tuned by our research team as an alternative to the usual vibration monitoring systems in the industry, which are much more expensive [7].
Regarding the state of the structure and the technical and economic feasibility of its rehabilitation, it was recommended to carry out local repair operations of the parts with damages and constructive problems, and a generalized reinforcement of the floors with a concrete slab, lightly steel reinforced and mechanically connected to the timber structure (Figure 3: and Figure 4:).

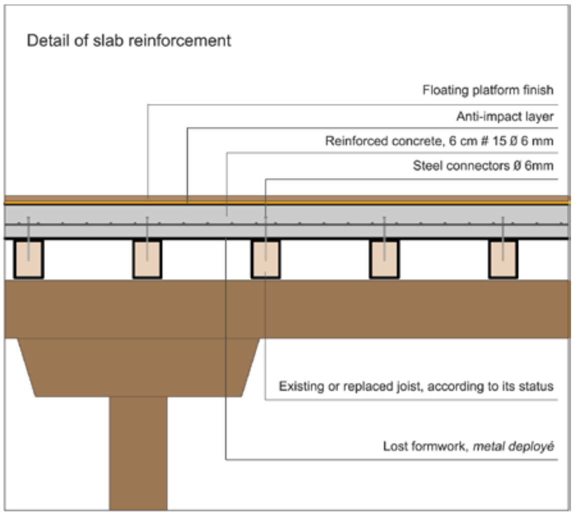

Figure 3: Detail of the reinforcement of the floors.

Figure 4: Laying of the mixed floor slab.

Finally, once the repair and reinforcement work on the timber structure was completed, EPTISA carried out a static load test on two specific zones of the floors, in order to verify that the strain under load was within the expected range [5]. For the loading, pools of water were used, up to a maximum depth of 55 cm, equivalent to 100% of the total load expected in the project, which was applied in 5 steps. And for strain measurement, 5 MITUTOYO analog micrometers with a precision of 0.01 mm were used.

RESULTS

The results of visual inspection and non-destructive testing were included in a complete report and were plotted on the drawings provided by the client, following the Spanish UNE 41808 standard [4]. As an example, one of the floors of the building is shown below. (Figure 5:):

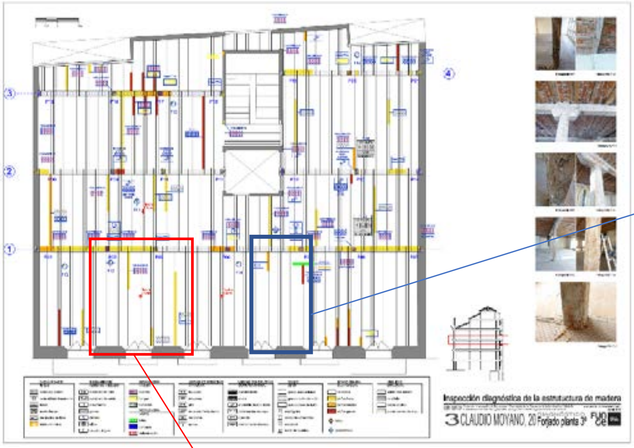

Figure 5: Diagnosis of pathology and test areas.

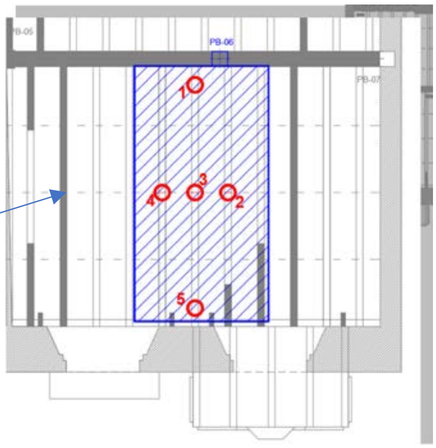

Figure 6: Static load test area.

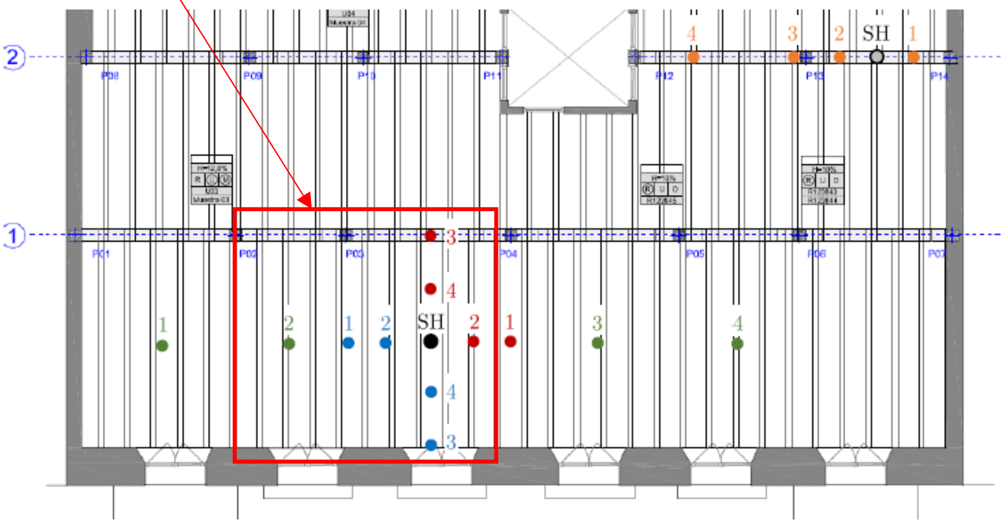

Figure 7: Dynamic test area.

The area shown in Figure 7: was instrumented with accelerometers distributed in 12 points throughout the span in 3 set-ups, adding 2 more common accelerometers located in the fixed and mobile part of the shaker. After an upward sweep from 1 Hz to 20 Hz, lasting 120 s, and the corresponding downward sweep, all recorded at 400 S/s, the frequency response functions were calculated and the modal parameters (including modal shapes, eigenfrequencies and modal damping) were extracted. As a result, after the modal identification, it was estimated that the liveliest and most relevant mode of the timber floor was the bending vertical one, at 8.97 Hz, with a damping ratio of 4.6%. This is valuable information from which derive an updated computational model.

The results of the static load test were summarized as follows:

Table 1: Absolute strain at each instrumented point.

STRAIN (mm)						
Stage	Date/time	Micrometers				
		1	2	3	4	5
Unloaded	11/01/2022 – 09:40h	0.00	0.00	0.00	0.00	0.00
1º load step (1kPa)	11/01/2022 – 10:05h	0.04	0.19	0.19	0.15	0.05
2º load step (2kPa)	11/01/2022 – 10:25h	0.14	0.42	0.42	0.34	0.06
3º load step (3kPa)	11/01/2022 – 10:50h	0.25	0.66	0.68	0.57	0.11
4 º load step (4.5kPa)	11/01/2022 – 11:30h	0.49	0.98	1.11	0.96	0.25
5 º load step - full load (5.5kPa)	11/01/2022 – 11:55h	0.58	1.32	1.35	1.16	0.36
5 º load step - full load (5.3kPa)	12/01/2022 – 12:00h	0.50	0.78	0.90	0.86	0.36
1º load step (2.7kPa)	12/01/2022 – 12:35	0.24	0.18	0.30	0.32	0.11
Unloaded	12/01/2022 – 12:55h	-0.07	-0.49	-0.35	-0.24	-0.22
Unloaded	12/01/2022 – 13:10h	-0.07	-0.59	-0.40	-0.24	-0.26

DISCUSSION

The combined study of the wood species, visual grading and nondestructive testing results led to the following timber grading proposal:

Table 2: Resistant class proposal for solid wood.

RESISTANCE CLASS	MOR f_m (N/mm²)	MOE $E_{0,med}$ (N/mm²)	Mean density (Kg/m³)
Scots pine (*Pinus sylvestris* L.)	18 (C18)	9.000 (C18)	460 (C30)

The density is the value determined in the tests carried out with real samples, higher than the one stated in the UNE EN 338 [2] for C-18, since it is on the safety side as it is part of the permanent loads of the structure.

The maximum strain values (between 1.16 and 1.35 mm) obtained in the load test are below the limit value prescribed by the Spanish Structural Code [6] for this type of structures. In addition, the maximum strain value obtained in the test is lower than the theoretical one, which can be estimated according to the mechanical characteristics of the materials that make up the floor slab and the general theory of structures. Finally, when the structure was unloaded, recoveries above the initial situation (negative) were obtained at some points

CONCLUSION

The visual inspection, in accordance with the visual grading standards, allows to determine the quality of the structural timber of old buildings and, with it and the wood species, to assign a resistance class.

Logically, it is advisable to carry out complementary non-destructive tests, which in this case have shown values different from those specified in the standards for some properties, which must be used on the safety side.

The proposed rehabilitation of this timber structure by means of a mixed timber-concrete solution has demonstrated. In the final load tests to which it has been subjected, a structural safety and stiffness superior to those obtained by the calculation methods of the general theory of structures, complying with the limitations of the applicable regulations.

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