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TIMBER INDUSTRIAL HERITAGE

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ABSTRACT: Industrial heritage has recently become a tourist and cultural resource, without forgetting its social aspect. Timber was widely used in the industrial sector during the pre-industrial era and the early stage of the Industrial Revolution. In more recent times, steel and concrete have significantly displaced timber in the industrial sector. However, timber was and is still used in certain industrial applications due to its advantages over other structural materials, such as high strength/density rate, durability, cost-effectiveness, and, more recently, sustainability and aesthetic aspects. Some examples include saltworks and phosphate factories, where the aggressive nature of the product provides timber with a clear durability advantage compared to steel or concrete. Timber species were selected depending on the industrial use (structure, machinery) based on economical and durability reasons. Recent interventions in timber industrial heritage are mainly related to a change of use (museums, offices, libraries, etc.). Protection policies depend on countries and regions, and some elements are protected under inclusion in the World Heritage List. The Timber Construction Research Group from the Technical University of Madrid (Spain) has recently created a research line of "Timber Industrial Heritage" including heritage promotion, technical assistance during interventions and educational activities.

KEYWORDS: Durability, Industrial archaeology, Inventory, Rehabilitation works, Wood

1 INTRODUCTION

Industrial heritage has gained significant importance in recent years, serving not only for tourism and cultural purposes but also as a means to preserve a vital part of history. The process of industrialization profoundly altered both lifestyle and environment, and it exhibits a strong social component in the regions where it is found.

Industrial heritage consists of the remains of industrial culture which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education [1]. These activities arose from the economic system established during the Industrial Revolution (starting in 1760) and extended to the latter part of the 20th century. However, even before this period, in the 16th and 17th centuries, there existed pre-industrial industries (including fulling mills, forges, smithies, trip hammers, windmills, watermills, sawmills) which predominantly used wood as structural material, for infrastructure, for installations, and for machinery [2-4].

The interest in preserving industrial heritage began to rise in the 1950s and 1960s in several European countries. This movement gained international momentum with the establishment of The International Committee for the Conservation of Industrial Heritage (TICCIH) in 1978. Since them, associations were created in many countries around the world. E.g. in Australia, the National Scientific Committee on Industrial Heritage (NSC-IH) was established in February 2018, to be a voice for industrial heritage advocating for the preservation, conservation, investigation, documentation, research and interpretation of Australian industrial heritage [5]. In the case of Spain, the Spanish Association of Industrial Heritage and Public Works (Asociación Española de Patrimonio Industrial y Obra Pública) was created in 1986. Since 2002, there is a Spanish national plan for industrial heritage [6]. These kinds of associations are promoting industrial heritage, organizing conference and pushing authorities to create protection policies.

The Timber Construction Research Group, from the Technical University of Madrid, Spain, created a "Timber Industrial Heritage" research line in mid-2023.

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The three main objectives of this research line are: (1) to collect information and highlight the value of the timber industrial heritage by promoting it, (2) to provide technical advice on intervention works, and (3) to incorporate it into educational curricula in subjects related to timber construction.

2 WOOD APPLICATION IN INDUSTRY

2.1 MATERIALS

In the 19th and 20th centuries, steel and concrete have largely displaced wood in the industrial field, which has led to the misconception that wood is unsuitable for industrial uses. However, there are industrial applications where wood has clear advantages over those materials. Some examples include saltworks and phosphate factories due to the aggressive environment, or areas where the abundance of wood offered an economical advantage over other materials (sawmills and forest extraction cables).

Wooden elements in industrial structures

Although timber is one of the most sustainable construction materials, its use in the current construction industry is very limited. Nowadays, it is mainly restricted to certain cases such as salt storage warehouses and coke quenching towers, both for durability reasons. It is also employed in constructions within the timber processing industry, for economic reasons and product marketing. Historically, it was found multiple uses of wood in the industrial sector in different elements as structure or machinery (Table 1).

Table 1: Wood applications in industrial heritage

Kind	Element		Fig.
Structure	Facade	Structure and cladding	1a
		Half-timbered	1b
	Post-and-beam		1c
	Roof	Truss	1d
		Other kinds	-
Machinery	Machine	Mill, fulling, hammers, loom	1e
	Transmission system	Wheel, sheave, shaft, wind blade	1f
	Transportation	Duct, pipe, trolley, hopper	1g

In some cases, the structure is entirely made of timber with no façade or even roof, such as in the case of forest extraction cables, grading towers for salt production in central and northern Europe, and antennas. However, the most common are timber buildings with facades.

The most commonly used construction type is the post-and-beam method in multi-story industrial facilities, such as flour mills. However, in many cases, the columns on the first floor are made of cast iron instead of timber. For roof structures, trusses are the most common elements due to the industrial need for large and clear spans. Trusses were typically used for spans from 7 up to 16 m. For higher spans, intermediate columns were usually added, or steel trusses were used. Additionally, in the case of timber trusses, at least in Spain, it is more common to find iron ties (inferior chords) in industrial buildings than in other types of construction. This may be due to the fact that most of this industrial heritage dates back to the 19th century as well as proximity to industrial areas with forges, making the use of iron ties more economical than timber ones.

Wood species

Species of wood used for the structure, were mainly the most common ones available in the area. However, in the case of machinery, the most suitable wood for that purpose was used. E.g., ducts in flour mills were made from species that limit the proliferation of insects, teeth of windmill gears were made from harder wood, but the wood for the wheel was more flexible and bendable [7].

2.2 REHABILITATION WORKS

Regarding interventions in timber structures, in 2017, the International Council on Monuments and Sites (ICOMOS) published principles for the conservation of wooden built heritage, including recommendations for proper intervention [8]. E.g., clause 13 is referring to keep as much as possible the original timber elements and when no possible, substitutes them reusing timber from other structures: “As much as possible of the existing members should be retained. Where replacement of a member or part of a member is necessary it should respect the character and significance of the structure. In cultures where the tradition exists, aged building parts from other structures might be used in the intervention”. Most interventions have been associated with a change of use. For instance, these structures have been repurposed as museums, offices, residences, sports centers, event venues, libraries, hotels and restaurants.

2.3 PROTECTION REGULATIONS

The protection of the industrial heritage depends on each country or region legislation; however, some elements have been included by UNESCO in the World Heritage List (WHL). In 2001, there were 28 industrial heritage elements included in the WHL (considering industrial heritage even from Roman times), of which 78 % were in Europe [9]. In 2012, there were 46 elements in the WHR [10]. Currently, the authors of the present work have identified 66 in the WHL, estimating that approximately half of them contain wooden elements either in the structure or in the machinery. Most of the national and local protection figures are not specifically for industrial heritage and are shared with other kind of monuments. E.g., in Australia, there is a National Heritage List and the states heritage register [11]. In Spain, depending on if the element is own by central government or by local governments, different protection figures for heritage are applicable [12].

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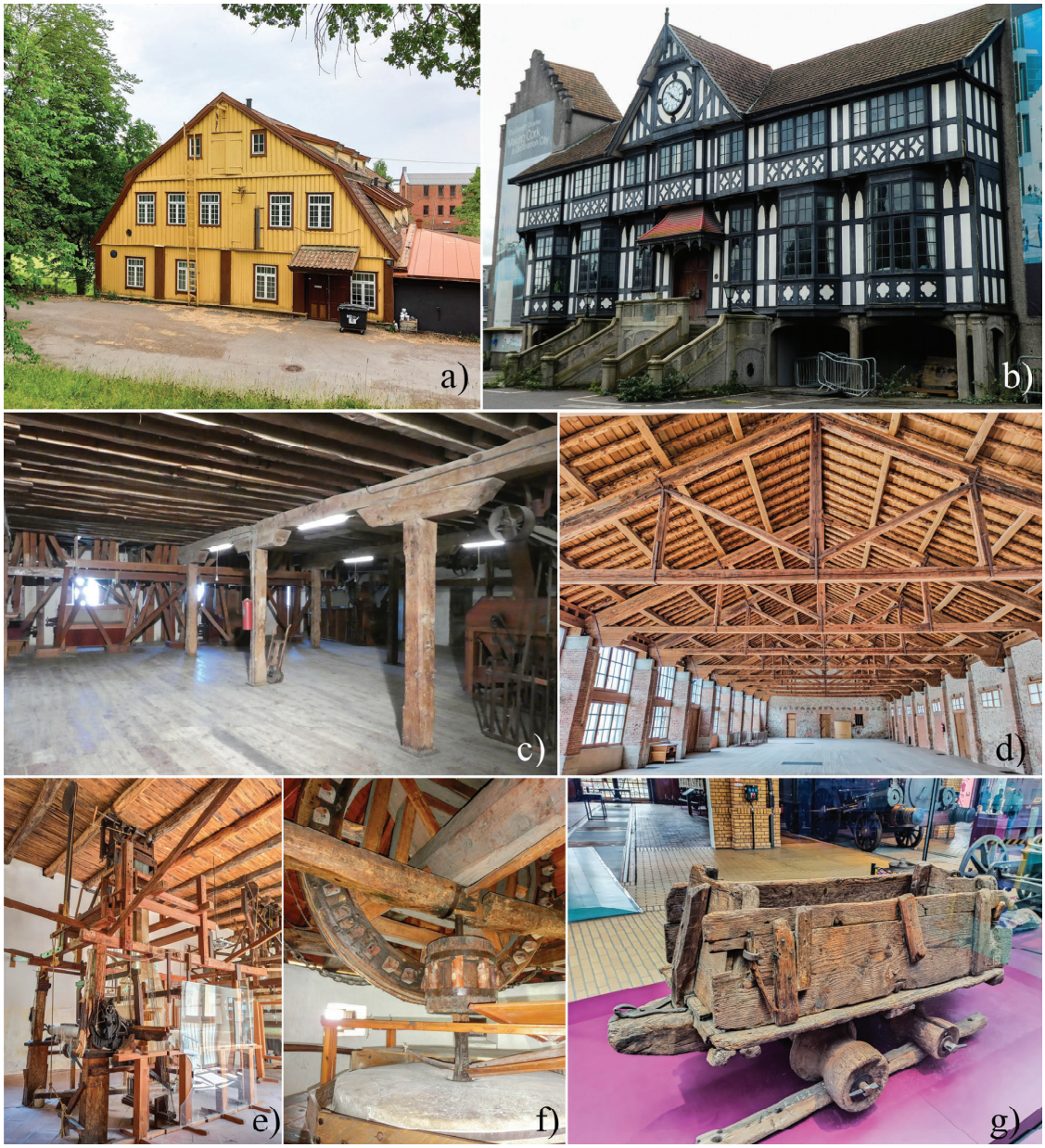

Figure 1. a) Timber structure and cladding facade, Glads Mølle 1736, Norway b) Half-timbered facade, Beamish & Crawford 1919, Ireland c) Post-and-beam, San Antonio flour mill 1852, Spain d) Timber truss, Royal Sawmill of Valsaín 1884, Spain e) Silk loom, Italy f) Windmill cogwheels, Spain g) Trolley from Transylvania 1700, Technikmuseum Germany.

3 TIMBER INDUSTRIAL HERITAGE RESEARCH LINE

Although the Timber Construction Research Group from the Technical University of Madrid had previous experience in works involving the intervention in Timber Industrial Heritage (such as the Rio Tinto ore loader wharf and the Royal Sawmill of Valsaín), it was not until July 2023 that a specific research line focused on Timber Industrial Heritage was created.

3.1 INVENTORY AND PROMOTION

Since then, an interactive map of industrial timber elements, primarily in Spain, has been developed with the aim of identifying them (inventory), studying the interventions carried out on some of them, and promote their recognition. Eighteen information fields can be completed, if information is available for each of the elements included in the map. The map is divided in seven layers by the original use of the building:

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1. Timber industry
2. Food and agriculture industry
3. Wooden machines (pre-industrial)
4. Mining heritage
5. Railway heritage
6. Textile industry
7. Others

This is the link to the map: https://www.google.com/maps/d/embed?mid=1IWjZXE5xA1wzhUpg5EypaFw4Ra-mRFY&ehbc=2E312F

Furthermore, for promotion of Timber Industrial Heritage was also create an Instagram profile: patrimonio_industrial_madera

3.2 TECHNICAL ASSISTANCE

The Timber Construction Research Group participated in two important interventions on Timber Industrial Heritage.

Huelva pier of the Rio Tinto mining company is a loader wharf located int the southwest of Spain. It was inaugurated in 1876 for the export of copper ore extracted from the north of the Huelva province and transported by railway to the wharf, where it was loaded onto ships. The structure is divided into three sections, currently not connected to each other. The first elevated section (93 m long), was built using American pitch pine or southern pine and was recently reinforced with larch pieces. The second section (143 m long), is on a land area and it is a structure combining cast-iron pillars and timber flooring recently replaced by iroko timber. The third section (397 m long), is on the water composed by cast-iron pillars supported by a timber pile foundation at the bottom of the estuary and timber structure. It was renovated using missanda or tali (*Erythrophleum* sp.) timber, circa 380 m^3 of girders and 620 m^3 of secondary elements (Fig. 2a). The Timber Construction Research Group provided technical assistance and timber quality control including the timber strength grading based on non-destructive testing and visual parameters [13]. Wharf industrial activities closed in 1975 and in 2003 it was declared "Bien de Interés Cultural (BIC)" (the highest category of the heritage protection registers in Spain). Nowadays, it is used as a pedestrian seashore promenade.

Technical assistance was also provided in the The "Real Taller de Aserrío de Valsaín" (Royal Sawmill of Valsaín), Segovia, Spain. It was built in 1884 and operated as sawmill for the Valsaín forest until 1952. The building presents longitudinal orientation North-South. It is composed by a central single-story clear area, two symmetric two-story lateral areas and basement. Building dimensions are 80 by 21 m. Construction materials are brick-stone masonry for walls and Scots pine (*Pinus sylvestris* L.) timber for roof structure. The building was refurbished working on load bearing structure and roofs (Fig. 2b). In the North lateral area, floor slab of the second story was removed, a new timber rafter roof structure was built and the wall between steam machine and boilers was substituted by a new wall over steel columns creating a clear space. The central part (sawing area) is a clear space of dimensions 48 by 15.3 m and the roof structure is composed by ten timber trusses supported on brick pillars. Timber trusses presented big bending deformation in ties, shear failure in the principal rafter tie cogging joint and rot at the support points. All timber pieces were visually and non-destructive graded as C22 strength class. Timber trusses were dismantled, repaired and reinforced on the ground using steel and composite bars, epoxy formulations and LVL. After assembling, a proof loading test was carried out on place. Purlins, common rafters and roof boards were substituted by new timber due to rotten condition and new fire resistance regulations [14]. On the 5th of July 2022 it was protected declaring it as BIC. It is expected to be used soon as timber museum

Figure 2. a) Huelva pier of Rio Tinto under reformation b) Royal Sawmill of Valsaín under reformation.

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3.3 EDUCATIONAL ACTIVITIES

Timber Industrial Heritage is taught inside the Master of Timber Construction of the Technical University of Madrid. Teaching is focused on raise awareness of the Timber Industrial Heritage and its importance for the society, heritage protection frameworks, the assessment of industrial timber structures and correct intervention practices.

Furthermore, several timber industrial structures are visited and construction characteristics and renovation work are explained to the students, during the Master's technical study trips celebrated each course. Few of these timber industrial structures are still in operation for their original uses, while most of them were refurbishing for different uses. Some examples visited with students in recent years were: saltworks in operation since 1928 (Cardona, Spain, 2022) (Fig. 3a), old textile factory renovated for expositions (Mataró, Spain, 2022), old gasworks under renovation for offices (Madrid, Spain, 2023), old sawmill renovated for a museum (Valsaín, Spain, 2023), old forge hammer (Navafría, Spain, 2023) [15], old sugar factory under renovation for a different industrial use (Santa Fe, Spain, 2024), old tobacco drying barn abandoned (Granada, Spain, 2024), traditional shipbuilding carpentry in operation since 1961 (Málaga, Spain, 2024), old tobacco factory renovated for business incubator, coworking spaces, and social activities (Rovereto, Italy, 2024), old artillery factory under renovation for an exposition center (Seville, Spain, 2025) (Fig. 3b), old ore loader wharf renovated for a promenade (Huelva, Spain, 2025).

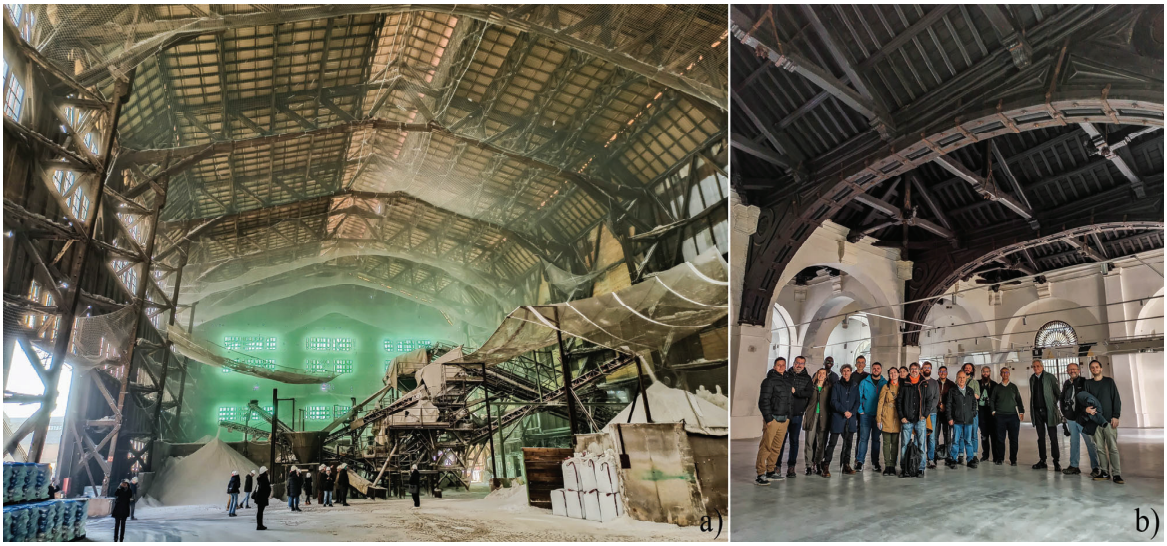

Figure 3. Master of Timber Construction, technical visits with student a) Saltworks in operation, Spain b) Royal Artillery Factory renovated for an exposition center, Spain.

4 CONCLUSIONS

Timber was frequently used in industrial facilities in pre-industrial times and, at the beginning of the Industrial Revolution and afterwards, occasionally by economical and durability reasons. Hence, there is an extensive Timber Industrial Heritage that needs to be inventoried, recognized and preserved.

Most common building typologies were post-and-beam structures and timber roof trusses. Species were usually selected by economic reasons for the structures and by durability reasons for the machinery.

Nowadays, most building interventions in timber industrial heritage are associated with a change of use, typically different from their original industrial purposes. This was also the case for the two interventions presented, with assistance from the Timber Construction Research Group, which involved repurposing the structures for a museum and a promenade.

Industrial heritage protection policies are usually depending on countries or regions and also some heritage was included on the UNESCO World Heritage List. Heritage protection figures are not usually specific to industrial heritage, as they are also applicable to other types of monuments.

It is essential not only to promote and protect Timber Industrial Heritage, but also to incorporate it into educational curricula in subjects related to timber construction, in order to train future professionals in this field.

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