Historical timber-framed buildings / characterization and acquaintance

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Abstract This paper is of historical nature, intending to clarify the technique interpretation of timber-framed buildings by different authors of construction treatises, and structural intentions of the carpentry designers and master builders, throughout the centuries, until the period where was assayed a scientific structural theory. It describes the "box-frame" construction appeared in Lisbon, after the earthquake of 1755, characterized by its good seismic resistance. This knowledge is important to determine a strategy of an efficient restore in historical constructions. The paper also includes the most important properties of wood to structure purposes, the defects of structural timbers, the framing and the preliminary survey followed by the structural survey where some difficulties can be overcame in practice.

Keywords structural timbers, survey of traditional timber-frame buildings

1. INTRODUCTION

The knowledge of failures of timber structures and of deformation and breaking processes of timber members, become, since the past, the general analytic method for understand their behavior and causes of failure. This knowledge was the base to the design and dimensioning of the new structures, in the past, and a method found for the conservation of the timber structure. Traditional methods of repair presuppose knowledge of traditional design methods and construction techniques.

2. HISTORICAL TIMBER-FRAMED BUILDINGS AND RESTORATION

The *opus craticium* was the wide spreader mixed structure in the ancient architecture of the Italic Peninsula and of Europe. The ancient builders employed the principle of the truss, tying the feet of the rafters, creating a system of triangulation, to use timbers of lesser length and especially of smaller cross-section to introduce wide spans. In this manner the rafter feet do not spread outward, and the horizontal, overturning force at the wall head was restrained.
The *cruck* frame has been used from 1st century, in Great-Britain, Germany and Netherlands. The early medieval timber-framing in France, Germany, Netherlands and Scandinavia, like the palisade-wall developed to the *stabbau*. After ca. 1300, till 16th century curved or elbowed oaks were used in arched multitier roofs. Metallic-edged blades, used widely in the middle age, contribute to the technical development of hardwood carpentry and of complex joining. The *medieval half-timbered wall* rose on the building façades and in its interior, as partition walls. The voids between the studs or posts and

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rails or plates could be filled with wattle and daub or with stone and mortar covered with plaster, where were executed stuccos or molded fanciful decoration.
Philipert de l' Orme, in 1561, idealized arched spans of 60 meters and large vaults of ogee profile. He proposed new structures, not based on traditional timber framing with triangulated beam members, but with *segmental arches* built up from small timber elements. Modern trusses for long-span application are described by Andrea Palladio in 1570. The good performance of Cismone River Bridge, in Italy, results from its different parts are reciprocally supported by using bolted metal cramps.
The fortification experience and knowledge from military engineers as Vauban (1692) and Belidor (1726), the publication of encyclopedias like that one of Diderot and D'Alembert (1751-1780), were important resources for the Portuguese "gaiola pombalina" creation, the box-frame construction of Marquis of Pombal period. This last one resulted in a structural timber-framing model improved by Manuel da Maia and Carlos Mardel, especially with regard to its seismic behavior.
Paul Planat, in 1887, makes some warnings in relation to connection between timber members of composite structures. The designated *«Coronel Emy System»*, consists in a composed structure which use boards with the greater surface turned to the intrados to create arches of rectangular cross-section.
In **restoration interventions**, the general principle is the one of using the same wooden specie found at the original building. In case of timber-frame constructions, which life is ending, it can be applied the following methods: dismounting and rejoining of timber members with restricted incorporation of new members; periodic reconstruction according the original model; setting the building under a shelter; construction to scale, of a maquette. Repair joints must be well distinguished in the historic structure, facilitating its behavior monitorization.

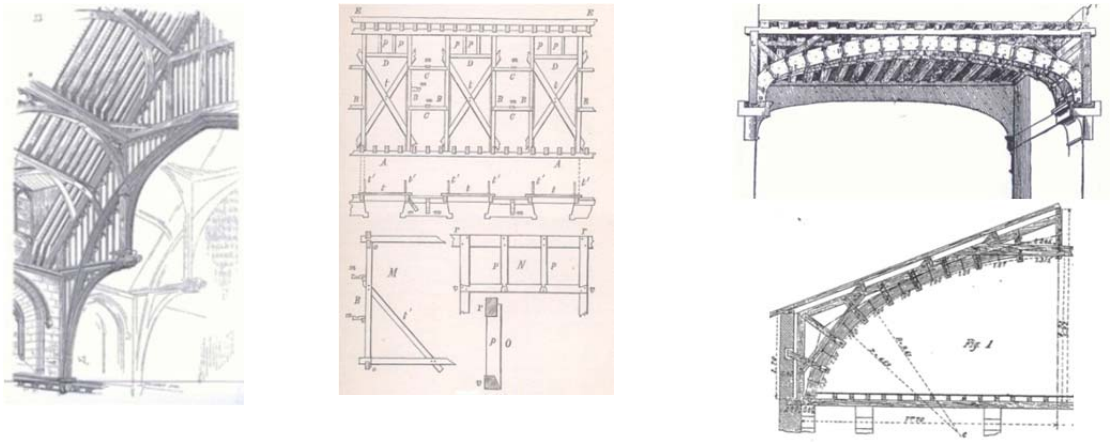

Fig.1 – Westminster Hall, 1397; "Gaiola Pombalina", 1755; de l'Orm, 1561; "Système du Coronel Émy", 1887.

3. DISCUSSION / CONCLUSIONS

Joints are the whole details whereby one timber member is related, attached or linked to another. Is a common rule, to render possible the perfect contact between the joint surfaces to be engaged, to make the force distribution uniform as much as possible at the member joint, avoiding any excessively overloaded surfaces. Another referred prescription is that one the notches made in the joining members must be in such a way that the removal amount of section does not weaken the individual members and joint. The same must be referred for the holes to bore to introduce the keys and bolts. Philipert's arched spans in tens of meters and large vaults would create appreciable lateral thrust on a supporting wall, so this system was not practical for use in tall buildings. The arches of Emy have the inconvenient of, in consequence of the relaxation of tighten metallic pieces which keep the shape of structural members, suffering pronounced deformation, with the time.
Finally, while the original structural joints allow slight movement in the total frame without exerting stress in the members, avoiding their fracture, and keeping the knots in good conditions, the repair joints are rigid. So, glues must be avoided and plating and bolting be introduced.
Those countries whose cultural heritage comprise a significant number of timber frame buildings must adopt certain criterions, taking into account factors like durability, biologic agents, fire, humidity and climatic conditions, to assert the preservation and restoration of those buildings.