Historical knowledge in the preservation of heritage timber structures

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In the analysis and rehabilitation of ancient timber structures, the knowledge on the mechanical properties of wood that was available at construction time and the dimensioning rules adopted are an important element for understanding the structure in its original conceptual design and its subsequent history. This information is particularly significant when considering historic timber structures dating back to the XVIII – XIX centuries, because major developments and formalization of the theory of structures and of the strength of materials were taking place at those times and the relevant body of knowledge as known nowadays was only in part available to constructors. In order to investigate the level of information on the behavior of timber structures which was accessible during the design and building phases, a precious source is in the treatises and handbooks which were in use in the geographic area at the time when the structure was built.

The knowledge on the behavior of timber as structural material at the end of the XVIII century was based on precise and extended experimental campaigns developed on timber elements, as it appears from contemporary manuals and treatises; design criteria were derived by researchers on the basis of such experimentation and were made available to professional practice.

Considering central Europe and the contribution of French researchers in particular, during the 18th century much experimental work was due to George Leclerc Comte de Buffon, who investigated timber elements in bending and published in 1741 tables of results that were intended also for use in professional practice. He utilized oak and spruce specimens, the two species mostly used in construction. In his work, concepts as ultimate strength, safety factor, life of the structure are also present.

The work of Charles Augustin Coulomb published in 1773 supplies information of theoretical type as, for instance, the position of the neutral axis for a cross section in bending, the value of the section modulus and, in terms of failure modes, the differences of behavior between timber and stone at failure. The most significant contribution of Coulomb's work in this area is in the development of the beam theory. For what concerns the experimental part, Coulomb strongly relies on available experimental data and on a more limited experimental activity, that will bring him to recognize the existence of tangential stresses.

Extended experimentation on timber in compression was performed by Pierre Simon Girard, who attained a very good knowledge of the material, describing in detail the effect of loading on the specimens including the increase of dimensions in the cross section as a consequence of the separation of fibers, different effects of environmental conditions as temperature variation (effect of heat and cold on the opening or closing of pores), the humidity, the influence of load duration on the deflection, and

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the non homogeneous structure of fibers. He recognized and regretted as well the inadequacy of the instrumentation of that time in detecting small property variations.
The design criteria for timber bridges are reported in treatises by various authors. Jean-Baptiste Rondelet in 1840 deals with the topic of timber structures. For timber bridges he presents a synthetic review of the most important ones. He supplies some pratical indications for design, suggesting for instance the insertion of a vertical strut at midspan or two or more inclined struts under the deck in order to reduce slenderness, based on the experience of various timber bridges built in Switzerland in the second half of the 18th century where the deck undergoes a considerable bending moment. The formulas suggested are very close to those that can be used nowadays.
Claude Louis Navier in his text of 1826 also deals with the design of timber bridges and, in particular, the sizing of timber members. This topic is subdivided in the text in three parts, each devoted to a typical structural typology. Bridges with the deck supported by beams and struts, for instance, are treated in the first part. On the basis of equilibrium equations it is possible to determine the internal forces in the struts. Accurate formulas to define their dimensions follow. Additional, simplified formulas permitting to size the cross-sections with reasonably approximated calculations are then given for practical application. Detailed treatment of arch bridges is also developed, with interesting considerations and detailing rules for the joints of composed elements.
As a general conclusion, interesting considerations stem out when analyzing treatises and manuals on strength of materials and on timber construction of the 18th and early 19th century. The reports on experimental testing performed to investigate the mechanical behavior of wood as structural material are well documented and endowed with detailed comments and considerations. Tests were performed with precision and the data well organized into tables intended for public use and application purposes. A recognized limit was in the accuracy of instrumentation, yet a good knowledge of the mechanical behavior of the material in its various aspects stands out clear from this documentation. The authors, and texts, that develop innovation from the theoretical point of view make reference for their findings to the data and observations presented in such experimental reports. Simple indications and formulas developed for the practical design of timber elements are given in the texts as final result of both the experimentation and the theoretical development.