Timber “Science” in Herculaneum during the 1st Century A.D.

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Abstract. The paper deals with the state of the knowledge on wood material used for constructions during the 1st century in Herculaneum, focusing in particular on the analysis of durability measures and for limiting the effects of timber shrinkage. The study founds on the historical literature and on the finds exceptionally conserved in the archaeological site “thanks” to the Vesuvius’ eruption.

1 Introduction

The theme of the conservation of ancient constructions belonging to the historical and architectural heritage and in particular ruins in archaeological sites [1-4] is more and more generating interest in researchers to develop investigation methodologies [5-11] and innovative technologies for strengthening them [12-15]. In this field the paper presents the results, relate to the material characterization, regarding the analysis carried out on timbers discovered in the archaeological site of Herculaneum. The terrible Vesuvius’ eruption of the 79 A.D. that buried Pompeii, Herculaneum and Stabia was characterized by a Plinian eruptive dynamics, with different effects on the hit towns relate to the orientation, the buildings disposition and the distance from the volcano. Specific studies on the deposits stratigraphy discovered in Herculaneum reveals a sequence that was dominated by pyroclastic flows alternated to surges. The high temperatures reached by the volcano’s winds, till approximately to 400 °C, provoked the wood combustion. Immediately after the deposit of eruptive materials, the consequent generation of an environment lacking of oxygen [16] entailed the transformation of the wood in a chemically stable material devoid of organic components, therefore not degradable by biotic agents. Others archaeological finds, as those of the *Casa del Rilievo di Telefo* (fig. 1), seem to have been inundated by mud flows (lahar), constituted by pyroclastic debris and water [17] which, covering the wooden material still not charred, generated a preserving environment from biotic decay, allowing its conservation until the discovery at the end of the 20th century.

It is an exceptional condition that, with the opportune aid of the historical sources, has permitted to study the material features and the installation modalities of the carpentries in Herculaneum during the 1st century, from which to deduce the knowledge advancement on timber material.

Figure 1. Herculaneum, *Casa del Rilievo di Telefo*.

2 Material characterization

2.1 Defects

The strength parameters have an extreme variability in dependence of the material features relatively, in particular, to the grain inclination and the position and dimension of the knots, besides the timber specie. The palynological analyses carried out in Campania (Italy) reveal the presence of a forestation surface on Mount Vesuvius with more trees species than in the current situation [18]. The forest of the Lattari’s mounts and the Vesuvius were predominantly characterized by arboreal species classifiable as *Quercus pubescens*, *Pinus pinea* and, at altitudes above 200 meters quotes, birch (*Betula sp.*) and silver fir (*Abies alba*) [19]. Furthermore the presence of the hornbeam (*Carpinus betulus*), chestnut (*Castanea sativa*), and trees belonging to the *Populus*

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Figure 2. Herculaneum, *Casa del Rilievo di Telefo*’s roof. The find n. 9 (photo property of HerculaneumConservation Project: Parco Archeologico di Ercolano, Packard Humanities Institute, Istituto Packard per i Beni Culturali).

genus [20] is attested. Therefore, it is a considerable forestry heritage, which arboreal species is coherent with the wooden finds discovered in the Vesuvius’ area, that testify an use of poplars, chestnut and oak as well as of silver fir in the construction for the load bearing structures. The latter is very common and represents the wood specie used for the *Casa del Rilievo di Telefo*’s roof [21] discovered during the excavation conducted in the Eighties and expanded between 2009 and 2010. The dendrochronological analysis, based on the master curves made from buildings of the Central Germany that finds correspondence also for the South Italy, dates the wooden elements back to the early years of the 1st century A.D. [22]. Such members, approximately 500, vary both with regard to the conservation state and the original function as well as the dimension and the geometry; some ones, that are no longer intact, are subdivided into two or more elements. The majority of the timbers are characterized by an approximately circular section still with the bark or just un-barked, for which the use as purlins can be hypothesized. The members, considering the conservation situation, water mixed to pyroclastic materials, although most of them are not charred, present an extended and intense cellular degradation with a high percentage of water (MWC). That condition does not permit to detect extended data on the material features and, in particular, on the presence of possible defects that influence the timbers structural behaviour. However, from a visual analysis, the presence of checks due to the shrinkage can be observed, that are useful to provide information on the grain orientation that seems to be regular and almost straight (i.e. finds 9 and 11) (fig. 2).

Figure 3. Herculaneum, The *Collegio degli Augustali*. The “recreation” of the beam, applying erratic carbonized wood parts on a metallic core.

The knots are, in general, not recurrent, with a limited diameter and placed approximately in the middle of the

member (for example find 11). Only in few cases the knots are at the lower edge of the beam where, in general, fibers are stretched and (find 8) could entail a fragile rupture. The squared members with a prevalent rectangular geometry, some with bevels, are characterized, most likely, by a saw manufacturing. The thickest elements contain the heartwood almost entirely, a condition that inhibits the timber twisting due to the shrinkage and, concurrently, reduces the cut of the fibres. A more difficult interpretation is that referred to the carbonized wood of Herculaneum, in many cases still in the original position. This analysis gets complicated due to some inadequate intervention of restoration carried out in the 20th c, even if this circumstance is limited only to few finds. In fact, some *anastylosis* interventions have included the “recreation” of the beam, applying erratic carbonized wood parts on a metallic core, generating an alteration of the original position of the wood, hence an anomalous morphology of the material (fig. 3).

2.2 Measures for a proper seasoning and shrinkage control

Timber tends, immediately after the tree knocking down, to lose the water present in the liquid state and as component of cell walls aimed at reaching the equilibrium with the hygrometric conditions of the environment in which it is used. A material moisture variation that causes dimensional modification and different deformations according to the radial, tangential and longitudinal direction due to a strongly anisotropic behaviour of the wood. Several Latin authors [23] provide indications on how to conduct a correct seasoning for controlling and reducing such deformations. Pliny (*Naturalis Historia*, 77 A.D.) suggests to put the timber under the wheat in order to trigger a slow process of equilibrium between the wood moisture and the external humidity (NH, XIII, 99). Cato (*De Agri Cultura*, c.a. 160 B.C.) recommends, as a proper methodology, to immerse the beams in a mix of water and manure (cat. Agr. Cult. 31). The method proposed by Columella (*De Re Rustica*, ca. 60–65 A.D.) is particularly advanced, precursor of the modern exsiccation system; in fact, it suggests to adopt a *fumarium* for the timber seasoning, in which to flow in the heat deriving from the heating of the villa’s baths [23]. Therefore, it is an expedient for improving the strength and durability but mostly aimed at inhibiting a scarce dimensional stability that could entail negative interactions with the other materials and, in general, with the construction itself. An use of the continuous boards that cross the entire masonry section, with the aim of obstructing dimensional variations due to the shrinkage, is attested in several floors of Herculaneum. An arrangement that clearly echoes Vitruvius’ entry in the *liber VII*, I, “... no wall has to raise

up to the top of the house ... but rather has the board ... In fact if a wall is erected without interruption, when the beams start to dry out and to twist, it, remaining unmovable due to its robust structure, inevitably provokes cracks in the paving on the right and left part ..." ("... ne qui paries, qui non exeat ad summum ... habeat coactionem ... Cum enim solidus exit, contignationibus are scentibus aut pandationes identibus, permanens structurae soliditatem extra ac sinistra secundum se facit in pavimentis necessario rimas ..."). Similar precept was applied in the *Collegio degli Augustali's* atrium, in which the discontinuity of the masonry has represented a preferential rupture way triggered by the horizontal action determined by the eruption winds, with the

deriving from unequal foundation settlements. That beam is constituted by two overlapping and outdistanced elements. An organization that finds possible references in Vitruvius and, in particular, in his provision regarding the *trabes compactiles* of the Etruscan temples (Liber IV, 7, 4) "... the gap (between the two elements) has to be two inches because if the beams touch each other and are not ventilated, they immediately heat up and quickly rot..." ("... ut compactura duorum digitorum habeant laxationem. Cum enim inter se tangunt et non spiramentum et perflatum venti recipiunt, concallescunt et celeriter putrescunt ..."). A passage that emphasizes an extraordinary intuition of the Architect of Augustus, even though he makes the mistake of

Figure 4. a) Herculaneum. The *Collegio degli Augustali's* atrium; b) Herculaneum. The shop belonging to the *Casa del Colonnato Tuscanico*.

consequent generation of a horizontal hinge exactly in correspondence to the wall interruption (fig. 4a).

2.3 Measures for the durability

The inter-storey floors are, analogously to the Pompeii [24] ones, characterized by unique order of beams arranged with a small spacing, approximately 45 centimetres, with an evident will of obtaining resistant and in horizontal plane stiffen floors. Bricks are present close to the support and they frame the beam socket (fig. 4b). The probable purpose of such an arrangement is to isolate the carpentry from the masonry, possible water carrier, namely to avoid favourable condition for the decay due to biotic factors. However, those fictile elements, most likely also with the function of squaring, in a fast and economical manner, the hole in the chaotic masonry, represent a measure of doubtful effectiveness. In fact the highly porous bricks, rather than to provide isolation, can transfer humidity from the masonry to the timber members, due to capillarity phenomena. Conversely, the roughness generated by a hole execution with not planar surfaces would have achieved limited contact points between the wall and the timber and a consequent beam socket airing.

The carbonized beam of the porch in front of the *Bottega ad cucumas* is peculiar. It is a unique continuous member on three supports, with a static scheme that reduces the bending moment and adequately responds to failures

attributing to the heating the cause of the rottenness. In fact, the presence of a ventilation layer between the two overlapping members permits to prevent the condense generation that could imply possible fungi and insects infestation.

3 Conclusions

The devices adopted in the timber carpentries of the ancient Herculaneum testify a deep knowledge of the *materia*. An empirical approach and the precepts contained in the Latin treatises, on which *De Architectura* stands out, constitute the basis of the progress of the timber science during the 1st century in Herculaneum. A particularly advanced knowledge that allowed choosing constructive solutions capable of ensuring the durability and mitigating the effect of the dilatation and contractions caused by the moisture variations and, contemporaneously, capable of permitting to use very strong wood. However, the latter property is, most likely, to be ascribed only to the carpentry of wealthy families dwellings and public buildings.

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