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THE DISCOVERY OF "MAROUFLAGE" ON DECORATED STRUCTURAL TIMBER IN A VILLA OF THE XV CENTURY

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Abstract

A restoration project on the ancient Villa Rucellai in Quaracchi, Florence (XV century, project attributed to Leon Battista Alberti), kicked off the on-site inspection of the wooden structures, as basic way for the assessment of historical timber buildings. During the inspection of the two-trusses timber roof, some significant remains of pictorial decorations were found and, on many surfaces of the timber elements, some fragments of fabric were discovered. In front of these facts, by means of a multidisciplinary approach, the trusses were deeply investigated according to the following examinations: image analysis to recognise all the surfaces covered by textile materials; ^{14}C dating on fabric and wood, in particular applying wiggle-matching for the latter material; microscopic analysis to identify the textile fibers and the wooden species. The results of the analyses, combined with the relevant information obtained by the on-site technological inspection, confirmed historical information on the Villa and proved the use of mercerised flax fibers, derived from pre-existing fabric artefacts, far older than decoration; in addition, it showed the widespread application of fabrics made of linen, to smooth the wood surfaces for painting, allowing us to establish the first case of "marouflage" ("incamottatura") applied on structural timber elements.

Keywords*: Abies alba; Fabric; Flax fibers; Incamottatura; King-post truss; Populus sp.; Structural timber; Wiggle-matching.*

Introduction

The ancient Giovanni Rucellai's Villa in Quaracchi, Florence (Italy), also called Villa lo Specchio, dated back XV century and attributed to the project of the Italian architect Leon Battista Alberti [1], was about to undergo restoration works. Among the different parts of the Villa, some wooden structural components inside two floors and roofs of the west wing of the building were of particular interest, due to the presence of old beams. As basic way for the assessment of historical timber buildings, the on-site inspection [2, 3] was carried out to evaluate the original quality of timber members, their conservation conditions, the actual effective residual section [4] and their mechanical properties [5, 6]. Particularly the *in-situ* analysis was applied to the structure of the roof, made by a two simple king-post trusses, with the king-post connected with the tie-beam, to cover a span of about 7m. Historical information about the Villa [1] attested the presence of some decoration, reproducing some plants into geometric frames, on the timber elements of the roof, wanted by Mr Rucellai in 1450-1456, to decorate the large room for residential use on the first floor. We can suppose that the same

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drawn plants were really present in the Renaissance garden, realised in that period in front of Villa Rucellai and accurately described in ‘Il Zibaldone Quaresimale’[7], written by Giovanni Rucellai starting from 1457. Actually, during the on-site inspection, some significant remains of pictorial decorations were found and, on many surfaces of the timber elements, some fragments of fabric glued to wood were discovered.

The course fabric also known as the canvas had historically been used as a component of the supports for paintings on flat surfaces (e.g. panel paintings, painting on canvas) and also on 3D surfaces (e.g. wooden sculptures) [8]. In particular the marouflage, also called "incamottatura", is the well-known technique of fastening a canvas onto a solid support, such as a wooden board [9]. The course fabric was generally present as a layer to cover and join the wood panels of the support, to prepare the board to be painted, according to the typical order which was studied and appositely reproduced in a recent research [10]: wood surface, the *‘incamottatura’* layer (a layer of fabric and hide glue), the *‘ammannitura’* layer (layers of gesso mixing rabbit-skin glue), the *‘imprimitura’* layer (a layer of rabbit-skin glue), the paint layer. Layers sometimes were of different thicknesses [11], particularly to smooth and plane the joining adjacent edges of timber boards [12] and also as a sort of reinforcement of the panel paintings [13]. Unfortunately, there have not been any publications nor written evidences, describing the use of such a technique on structural timber beams until today, although the decorations on wooden structure have been common for centuries [14].

By means of a multidisciplinary approach, the timber members of the two trusses in the roof have been deeply investigated according to different methodologies with the broad scope to clarify the particularity of the findings, to achieve the following objectives: investigating on the wooden elements to identify species, restoration history and other relevant characteristics; quantifying, identifying and qualifying the fabric; dating timber and textile material.

Material and methods

Technological inspection

The *in-situ* inspection is the basic approach for the analysis and the assessment of historical timber structures [2]. The two trusses of the roof underwent a detailed inspection, leading to the assessment of each timber element. In addition to the information about the state of conservation of wood, the modification of the whole structure was estimated, identifying historical restoration works and all the changes that the timber components have suffered over the time. The technological inspection has been conducted with the help of simple tools, such as screwdrivers, hammer, borers, etc., taking into consideration every feature or sign susceptible to affect the structural behaviour of each timber member or to give information on some historical events and paying attention not to damage decorations.

Wood identification

Microscopic wood identification is the only infallible and completely trustworthy method for the analysis of wood, as it supplies with all the anatomic features, useful for the complete identification procedure [15, 16]. Traditionally it is performed through the removal of small wood samples from timber elements thanks to the use of tweezers or blades. This method allows the preparation of slides consisting of thin sections of wood cut in transverse, radial and tangential direction. The slides are then examined with a transmitted light microscope with a wide range of possible magnifications and also polarized light filters to reveal the presence of crystals in wood. On the studied timber structure, one small piece of wood was extracted by each wooden member. In particular: close to some original defects, on the edges, or on some natural shrinkage fissures, not to damage the mechanical properties of beams, nor the remaining decoration. Totally 16 specimens were examined.

Image analysis

Fabric was applied in many points of the trusses. Unfortunately the largest part of textile material had been lost during the centuries, leaving under it the raw wood without any kind of pictorial layer. To recognise, quantify and expound the reason because of the position of fabric covering initially the timber elements, an image approach was decided. The image analysis of all the wood surfaces has been applied to recognise decorations and to identify the level of chiaroscuro. In fact all the surfaces of wooden members with the coloured decoration, or with the remaining preparation, resulted lighter, whereas, under the missing fabric or under the metal connectors, the natural colour of ancient wood was darker; furthermore the border line of each lost strip of fabric was well characterized, precisely reading the chiaroscuro. By means of a digital camera (Nikon D3300) and of a tripod, the images of all the trusses components were collected in pictures which had to be composed like a mosaic to achieve a complete overview of the structure. The optical aberration produced by the lens of the camera was removed and the pictures were straighten out before the composition. Some pictures under raking light were also captured, to reveal features such as texture and details and to identify the fabric shreds still in place.

Fabric identification

The fabric was sampled to be studied and identified through the morphological characterisation of textile fibers [17]. Three little shreds of fabric were collected, in different points, directly on the truss surfaces from which they were hanging on, as they were partially detached from the wood, thus avoiding any further damage. Each sample underwent stereomicroscopic observation before cleaning.

The cleaning process was due to remove incrustations (glues, residual painting, gesso, etc.). Specimens were soaked for 10 minutes in a hot saline solution (10% of Na_2CO_3 at 80°C) and then rinsed into deionised water several times. If needed, the process was repeated to achieve pure textile material. Some of the constituent fibers were observed through the optical microscope under transmitted and partially polarized light, to identify the weaving pattern and highlight the content of cellulose.

Chronology–radiocarbon dating

The procedures for dating the artefact were fulfilled for both fabric and wood. Different samples were collected: one fabric fragment taken away from one truss and some wood samples, extracted from a structural member, to proceed according to the well-known "wiggle-matching" technique. Wiggle-matching is a method for dating a sequence of related samples of known relative calendar years, although their absolute calendar dates are unknown, using the high precision radiocarbon calibration curve [18]. Wooden samples were collected from one timber element of coniferous. We chose one decorated top-chord of the truss 2, due to the large amount of annual rings that were visible on the surface of the beam. Samples were extracted from four different rings on a strip of dark raw wood, without any surface decoration or preparation layer. The collected annual rings were signed with a numbering related to the year: 2, 23, 37 and 52, starting from the inner part, so that the temporal distances between two chosen consecutive rings were respectively 20, 13 and 14 years. Unfortunately, the last growing ring of the original tree (close to the bark) was not present. The piece of fabric was cut off from the head of the beam (a cantilever) from which it was hanging, detached.

Radiocarbon concentration in collected samples was measured by Accelerator Mass Spectrometry (AMS) at the LABEC [19], Florence, according to procedures set-up for wood and fabric. Before the AMS measurement, each sample was pre-treated in order to remove any possible contaminant, following the ABA (acid – base – acid) procedure [20, 21]: it was first put to soak into a hot acid solution (HCl 1M at 80°C) to remove all natural carbonates, then in a basic solution (NaOH 0.1M, at room temperature), to remove traces of humic acids, finally again in the hot acid solution, to eliminate any traces of atmospheric carbon dioxide that might have been absorbed by the samples during the base washing. Thereafter, samples were dried at

80°C for about 12 hours. After this pre-treatment, purified carbon dioxide was collected from samples by combustion in an elemental analyser (Thermo Flash EA1112); finally, the recovered gaseous CO_2 was converted to elemental C (graphite) by chemical reaction with hydrogen, in the presence of iron as catalyst. Two graphite samples were independently prepared from each of the pre-treated material. During the AMS measurements, both $^{14}C/^{12}C$ and $^{13}C/^{12}C$ isotopic ratios were measured; normalized radiocarbon concentrations were determined by subtracting background counts, correcting for isotopic fractionation and by normalizing to isotopic ratios measured in some reference samples (NIST Oxalic Acid II).

Radiocarbon ages were converted to calendar ages on the basis of the IntCal13 calibration curve [22], using the OxCal software, version 4.3.1 [23]. As mentioned, wiggle matching modelling was applied to calibrate wooden samples.

Results and discussion

Wood identification.

The identification of timber showed that three different species were used to build the trusses. In particular 8 members, including the longest tie-beams (cross section 30x24cm), were made with white fir (*Abies alba*); the king-posts of the two trusses (cross section 18x15cm) and two of the struts were made with European elm (*Ulmus* sp.); 4 members were made of poplar (*Populus* sp.). The identified species are shown in Table 1.

Table 1. Species identification according to the truss

	top-chords	**tie-beam**	**king post**	**struts**	**cantilevers**
Truss 1	*Populus* sp.	*Abies alba*	*Ulmus* sp.	*Ulmus* sp.	*Abies alba*
Truss 2	*Abies alba*	*Abies alba*	*Ulmus* sp.	*Abies alba*	*Populus* sp.

Elm wood for king-posts was chosen because of its density, much higher than the other two species, so to better withstand the compression stress perpendicular to the grain, on the structural connection with the top-chords and the struts.

The fir members had a good structural quality: straight, no slope of the grain, small defects, very narrow annual rings. In the Tuscany region, for the structures of important ancient buildings, fir wood were typically used.

Poplar top-chords had not the same quality level of fir members, because of the species and its own characteristics; probably they were been used in the lack of long fir beams, thanks to the wide availability and the diffuse presence of this tree on the wet alluvial plain of the Arno river, which was very close to the Villa. Due to its wide availability, poplar was cheaper, but in contrast to the quality of the structure which, in the Florentine constructive tradition, had to be made with fir.

Health of the structure

Technological inspection revealed some interesting information, thanks to the residual pictorial decoration too: in unknown historical period, the tie-beams of the two trusses (cross sections 28x18cm), were disassembled, shortened and reused to substitute two top-chords, one on each truss. Probably some wood decay due to bio-deterioration on the heel joint (connection between the top- and the bottom-chord) forced the heavy restoration of the roof, with the shortening of bottom-chord to cut away the decayed portion. Signs of the symmetric paintings and the decoration gap, with raw and dark wood (under the central stirrup in the original truss, Fig. 1), revealed the preceding use of the timber members. The two original tie-beams were replaced with more recent fir beams, which evidently had not any sign of decoration nor any piece of fabric glued on. The two replaced original top-chords, their textile materials and decorations, have been definitely lost.

The conservation condition of the roof were good, thanks to the ancient covering system which did not seal the roof and allowed a good ventilation all the time life, so that also the species with low and no durability (i.e. fir and poplar, respectively in durability class n. 4 and 5, according to the standard EN 350 [24]), after the historical restauration, were well maintained. Many signs of water were present on top-chords, for rain percolating by the roof in historical period, so that most part of decorations and of the fabrics has been heavily damaged.

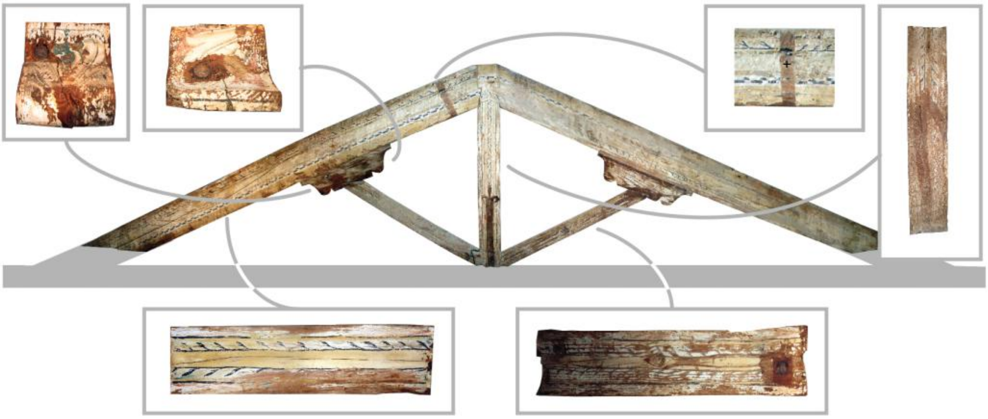

Fig. 1. Decorated truss n. 1. Picture rearranged by mosaic composition. The sign of king-post stirrup (+) in its original position, rotated and centred onto the tie-beam (nowadays under the floor)

Fabric of the marouflage

After the investigation we found that the fabric was originally present with 37 strips on the remaining part of the two trusses, 16 in the first truss and 21 in the second one (Fig. 2).

Fig. 2. Example of fabric on structural timber. Left: strip of fabric, residual on earlywood, to cover two nails. Right: end-grain of a cantilever with fabric (still present, with gaps) to upholster nails and a shrinkage fissure

Totally the sum of the strips surfaces adds up to 1.40m². On the second truss we found both the smallest strip, 23cm² on a cantilever, which covered the head of a nail, and the largest one (2685cm²), to cover the contact areas between the top-chord and the king-post, a shrinkage fissure, along the right top chord, and some knots. We can imagine that these numerous strips had been used by the artist to achieve a very smoothed and uniform surfaces, to limit the discontinuity of timber (the rough edges of the contact line between different timber elements), defects, mechanical connectors (nails) and to obtain a high-quality decoration, richly painting the wooden trusses with geometric figures and plants.

All the fabric strips were catalogued according to the condition in which they were found, their position and the possible reason of their presence. As for latter criterion, schematically they can be allocated into four different groups: ‘connections’, to give the needed continuity to the surfaces to be decorated, particularly on the connection line between timber members; ‘defect/s’, to cover some defects which could give problems to the decoration quality (e.g. knots, shrinkage fissures, etc.); ‘end-grain’, to cover end-grains of some timber elements, which were visible (to be decorated) and could give different response to the colours appearance; ‘nails’, to cover the head of big nails. Results are reported in Table 2. Some strips of fabric have had more than one function, so they were counted twice (the sum of percentage, is more than 100%).

Table 2. Fabric found on the trusses, distributed according to the covering functions

Groups	Connection	Defect/s	End-grain	Nails	Whole truss
Truss n.1					
Strip (n.)	3	6	4	7	16
Surfaces sum (cm²)	1903	1546	1080	2074	5523
	34%	28%	20%	38%	
Truss n.2					
Strip (n.)	9	10	4	10	21
Surfaces sum (cm²)	5913	4819	1080	3474	8481
	70%	57%	13%	41%	
Sum of trusses					
Strip (n.)	12	16	8	17	37
Surfaces sum (cm²)	7816	6366	2160	5548	14004
	56%	46%	15%	40%	

From the point of view of the fabric conservation state, four classes have been established: class ‘lost’, where no traces of fabric are present nowadays; class ‘earlywood’, if fabric was present only partially, like thin shreds glued only on the earlywood of annual rings; class **‘**gaps**’**, if the strip is even now on place, but there are one or more gaps inside, with fabric partially lost; class **‘**present**’**, where the entire original fabric strip is complete and still in its place. The results have been collected in the Table 3.

Table 3. Fabric found on trusses, catalogued according to its state of conservation.

Classes	Lost	Earlywood	Gaps	Present	Whole truss
Truss n.1					
Strip (n.)	7	3	6	0	16
Surfaces sum (cm²)	2430	1903	1191	0	5523
	44%	34%	22%	0%	100%
Truss n.2					
Strip (n.)	14	3	3	1	21
Surfaces sum (cm²)	5954	1447	810	270	8481
	70%	17%	10%	3%	100%
Sum of trusses					
Strip (n.)	21	6	9	1	37
Surfaces sum (cm²)	8383	3350	2001	270	14004
	60%	24%	14%	2%	100%

The strips of fabric which maintain a sort of continuity are around a total of 0,23 m², which correspond to the 16% of original glued fabric. Earlywood is the portion of annual rings, grown during the springtime, less dense and with larger cellular elements, so that the adhesion of the preparation layer and fabric had been more effective and durable in comparison to latewood (particular in Fig. 2).

Fabric identification

The identification of the three shreds of fabric revealed that they were made of mercerised flax fibers. The fabric was characterized by a weaving pattern known as "plain weave" (the simplest weave), made of simple yarns, Z fibers twisted (to be noted that the twist direction of fibers corresponds with the direction of the central portion of the letter S or Z). Looking at the samples at the stereomicroscope, yarns were quite irregular, with evident differences in the dimensions (diameters), from 0.17 to 0.43mm (Fig. 3). Fibers were very fragile, easy to be fragmented. We can guess the artist used some waste fabrics, which originally were used for other functions (e.g. dress, bed sheets, etc.). Otherwise, the flax to be glued onto wood would not have any need for being improved by mercerization process.

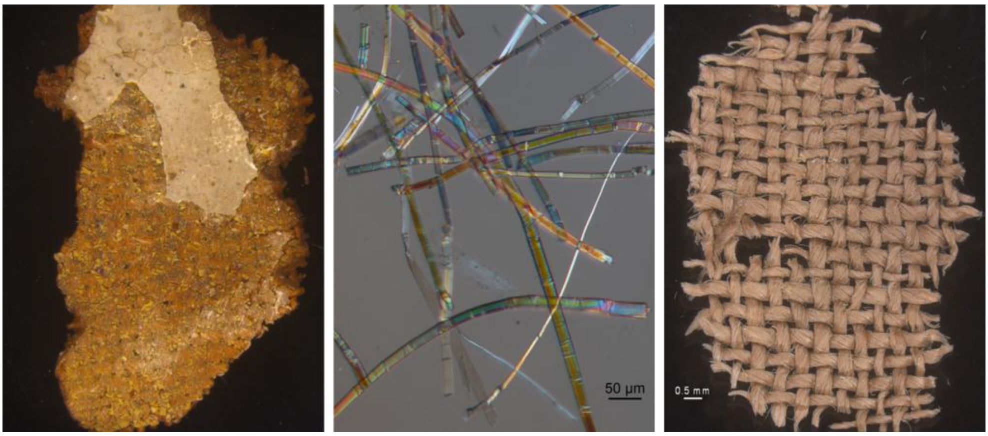

Fig. 3. Sampled fabric. Left: small piece with residual preparation and decoration. Center: flax fibers at microscope (polarized light). Right: clean fabric; the irregular diameters of yarns is well visible

Dating

The dating operation gave remarkable results both for timber and for fabric. Table 4 shows the ^{14}C results.

Table 4. Results of radiocarbon measurements: for each dated sample, the conventional radiocarbon age was determined as the weighted average of the two measured graphite fractions (experimental uncertainties on radiocarbon ages are quoted at 1 sigma)

Sample	Material	Lab. code	tRC (years BP)	Cal date (AD) (95% level of probability)
Punt.2	wood	Fi3399 – Fi3404	835 ± 50	1175 – 1250
Punt.23	wood	Fi3400 – Fi3403	800 ± 55	1195 – 1270
Punt.37	wood	Fi3402 – Fi3407	830 ± 50	1210 – 1280
Punt.52	wood	Fi3408 – Fi3410	710 ± 40	1225 – 1295
TessutoSP	flax	Fi3422 – Fi3424	620 ± 50	1280 – 1410

The timber dating with the wiggle-matching method revealed that the most external annual ring sampled on the top-chord (which was originally positioned as tie-beam), is dated to the period 1225-1295 (at 95% level of probability). This pretty close dating range was possible to be obtained just thanks to the combination of the results for the 4 annual rings (Fig. 4). The dated timber proved to be much older than expected, according to the historical information regarding the roof [1], but three different reasons may be provided: the beam could have been stored in a warehouse for many years after the harvesting operation and before the use; after the date corresponding to most external annual ring, sampled on the beam (without any possibility to identify if was sapwood or heartwood), the original tree lived many more years, before the harvesting; and, lastly, the beam could have been reused from the dismantling of a small building that existed before the Villa [1].

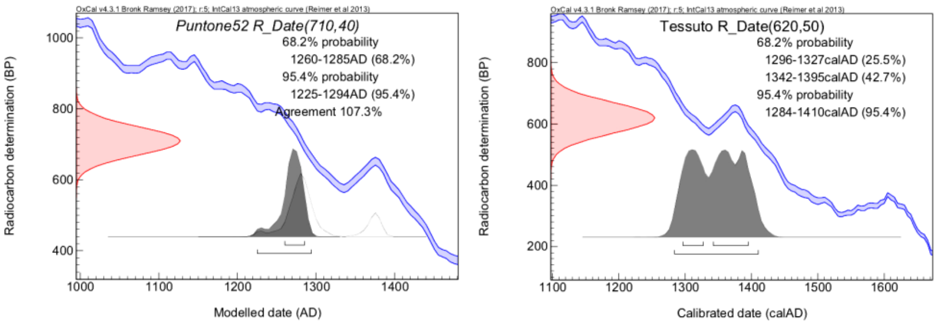

Fig. 4. Dating: results of fabric (right) and wiggle-matching on the annual ring n.52 of the wooden element (left)

The shred of fabric was dated to the period 1285-1410 A.D. (at 95% level of probability) (Fig. 4). In addition to the comments about the fabric identification, this result also suggests that the fabric strips had been probably already available in the artist's laboratory at the time of roof decoration, probably as old waste fabrics, which could have been selected, for example, on the base of their size, compared to the needs for the re-use.

Conclusions

The multidisciplinary approach to the study of two decorated wooden trusses of an ancient roof in Rucellai's Villa, which presented several strips of fabric glued onto the timber surfaces, resulted very effectiveness for the first characterization. Results let us proclaim the first reported case of marouflage (also called incamottatura) applied on structural timber elements. This technique, known and used on panel paintings, had been applied by the artist to improve the final quality of his decoration work, enhancing the level of the pictorial decoration on the Florentine wooden structures in general and reaching in the fifteenth century its pinnacle.

The research methods applied in the study let us reconstruct a part of the historical events that concerned the structural elements, particularly regarding the dismantling of the roof for repairing, and to register the extensive use of fabric, made by mercerised flax fibers, as the basis for the pictorial decoration of ancient wooden beams. The dating of wood and textile material, prior of the historical date of the building construction, gives more value and importance to the discovery. Further studies have been planned, in particular regarding the specific stratification of the marouflage (thickness of the layers, composition of the preparation layer and type of glue used), to deepen its knowledge.

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