Della Rovere Castle: from the diagnosis of structural performance to the upgrading system design of several wooden-floors dating from XVI Century in Torino, Italy.

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ABSTRACT

This paper aims at describing the restoration project of several wooden floors, dating from XVI century, within Della Rovere Castle, located in Vinovo, Torino (Italy) (Fig. 1). Several wooden-floors typology, particularly valuable from the historical heritage point of view were found here, and, in this paper three rehabilitation projects, which represent the record of cases of the upgrading interventions performed on the wooden floors, will be analyzed in details.

The restoration project for the preservation of Della Rovere Castle, foresee the re-use of it as a multifunctional building, several activities will be performed in there, such as conferences, lectures series, professional courses, etc, but it will be also possible to locate in there cafés and restaurants.

The restoration interventions were framed, at the global scale, within the principles expressed by the ICOMOS doctrine (Venice Charter, 1964), (Nara Document on Authenticity, 1994), and, in particular regarding the timber structures the reference point is the International Charter for the Preservation of Historic Timber Structures (ICOMOS, 1995). At the local scale, the methodological approach to diagnostic study of timber structures is framed within European literature (Ceccotti, Uzielli, 1989), (Bonamini, 1995).

One of the goals of the restoration project 2, and the focus of this paper, is the preservation of the historical heritage of the antique timber carpentry found in this castle. This heritage is expressed by the use of traditional typological and structural systems, and by the decorative apparatus particularly accurate and valuable. The preservation of their integrity and authenticity is therefore to be considered mandatory.

The work shows the significant link intercrossing between diagnostic studies and upgrading systems design. Diagnosis of structural performance has been accomplished by means of Visual inspections and Non Destructive Testing (ND). Diagnosis was nevertheless fundamental in order to define minimum interventions (ICOMOS 1995), those allow for preserving, as far as possible, both the load bearing capacity of these structures, and their appearance. Each case discussed in this paper represents a unique situation, regarding Conservation State and upgrading system solutions adopted in relation to it.

A description of structural typologies and of diagnostic study results will be provided for the three cases described in this paper. Nevertheless upgrading systems will be discussed in order to underline the successful definition of minimum intervention based on the Conservation State of structures.

GENERAL RESTORATION PRINCIPLES

Oftentimes a compromise has to be reached between what could be conserved and what needs to be sacrificed, in order for the monument to be preserved (Buti, 1994). The re-use of the Della Rovere castle as a multi functional space prescribed to upgrade the wooden floor structures in order to comply with the safety criteria and requirements that arose from the new use.

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2 Restoration project: Arch. Mauro Ricchetti, Arch. Simonetta Barozzi. Upgrading systems design: Ing. Luigi Lembo, Arch. Mauro Maspero. The author of the paper performed the diagnostic study on the wooden floors.
The re-use of the building happens at a point in its history where restoration is urgently needed to guarantee the preservation of a monument whose decay increased exponentially in the last decades of no use. The restoration project is currently being in process; it foresees the restoration of the entire building and it regards the preservation of all of its structural and decorative systems. In fact, not just the timber structures but several other important structural and decorative systems, which are of fundamental importance for the maintenance of the historical heritage expressed by this antique mansion, could have been lost if the restoration project did/does not promote an action to stop decay.

The occupancy of the building is therefore the only guarantee for its survival, therefore the reuse of the building for a different purpose then the one for which it was originally conceived is an acceptable solution needed for its maintenance (Amsterdam Charter, 1975); therefore the conservation issues have to be integrated with the users needs. For this reason a compromise is often needed and accepted between the need of the monument to be preserved in its authenticity and integrity (The Nara Document on Authenticity, 1994) and the needs of the new users whose presence is the only guarantee for future maintenance.

Fig. 1. Caste Della Rovere, XVI century.

The need to satisfy the required safety criteria and conservation issues, guided the choices made regarding the restoration solutions that were adopted. The ideal situation being that no intervention was needed. This case, however, occurred infrequently, and appropriate interventions were needed in most cases to upgrade the structures. Ideally, regarding wooden floors, the preservation of integrity and authenticity demands that both appearance and load bearing capacity be preserved without significant alterations (ICOMOS, 1995). In some cases this was possible even though by integrating the structure with the addition of new structural elements (reinforced concrete slab) with which the original wooden elements collaborates, in order to comply with the requirements of the new service conditions. In other cases the load-bearing capacity of the original members has been partly lost; in these cases in fact original wood elements carry only themselves and part of the dead loads of the structure; this means that major load bearing capacity (dead + live loads) is taken by the new structures introduced (e.g. steel beams), in these cases only a minimum restoration objective was reached, which is defined as maintenance of the appearance of the structures.

3 We refer to the concept of Integrated Conservation expressed for the first time in this charter.
In the first stage of analysis not all the wooden floors were entirely accessible, therefore the preliminary study conducted should be defined as pre-diagnostic. Risky situations were evaluated before to continue with the inspections; some structures were provided with provisional elements to reinforce them; those in fact showed consistent deflections, or other major problems such as wood rot at beam hedges, fractures, etc.

Pre-diagnostic analysis was helpful in order to obtain general information regarding wood species utilized and original quality of material. Regarding decay observation, the information obtained in this phase were non complete. Only later, during the preparation for the restoration works, when the structures became entirely accessible, it was possible to inspect the elements completely and to make final decisions regarding the possible solutions and the restoration techniques to be adopted. Oftentimes the situation revealed by the complete assessment of the timber elements entirely changed the restoration project, which needed therefore to be flexible and open to new solutions when final results were available.

Diagnostic study was conducted via Visual observation and by means of few Non Destructive techniques, for the determination of moisture content (M.C.) (Hydromette HTR 300) and decay extension (Pylodin 6J). Diagnostic study results were essential in providing the data for the assessment of structural performance. Diagnostic study and assessment of structural performance were strictly interrelated, and leaded to the definition of specific interventions in each case analyzed.

Several traditional wooden floor typologies were found within Della Rovere Castle. Attention will be pointed to three case studies chosen for this paper, which correspond to three different restorations techniques adopted. The record of cases chosen for this paper, in fact, represents the main types of interventions performed on the wooden floors. The philosophy of each intervention is the preservation of the antique wooden carpentry. The focus of preservation was not only pointed on maintenance of the appearance of the wooden floors, which was considered the minimum objective of interventions, but also on maintenance of the original structural conception and therefore on preservation of the load bearing capacity of elements. The goal has been reached partly or totally, depending essentially from both the Conservation State of the structures and the new needs arising from the re-use of the building.

The first wooden floor analyzed in this paper is representative of reaching the goal of conservation of both load bearing capacity and appearance of the original structures. The wooden floor analyzed belongs to the traditional typology called “Solaio a cassettoni” or wooden floor with paneled ceiling (Fig. 2, 3). The particularity of this wooden floor is that the paneled ceiling presents plaster moldings and decorations at the intrados side.

Fig. 2, 3. On the left wooden floor with paneled ceiling. On the right an image from Breymann, 1884 illustrating the wooden floor typology.
The paneled ceiling is constituted by the perpendicular intersection of two main beams and two secondary beams, which subdivide the ceiling in 9 square panels of approximately equal dimensions. The main beams of Chestnut are uninterrupted simply supported elements, spanning 7.2 m from wall to wall. Perpendicular to the main beams are positioned the two series of secondary beams, called horse beams. Oak has been used also for secondary beams.

The depth of the paneled ceiling (40 cm) is higher than that of the beams, since it comprehends also the depth of the plaster moldings at the intrados. Breymann describes the process of realization of this particular typology advising to use light and well-seasoned material so that wood will not move or crack once it has been put in place; this is particularly important for the durability of the plaster decorations on the intrados. To improve the adherence between plaster and wood short oblique lines have been carved in the beams. Main beams are fixed by iron-connections to the outside masonry walls; therefore they can act as chain-beams (Goffi F., Giannico F., 1999).

The particular care shown in the preparation of wood beams and connections suggests that this structure was originally meant to be seen; therefore the plaster ceiling had to be realized at a later time. This hypothesis is also supported from the presence of several wooden floors of the same typology, which have not been covered with plaster moldings.

Third grade Oak has been used for the realization of this wooden floor. Moisture content measured was approximately 18%, which can be considered normal in relationship to the thermo hygrometry conditions registered in the castle. Still with this M.C. wood does not perform in best conditions; however no fungus or wood boring insects attacks have been observed on these elements, which showed instead to be preserved in good condition (Tab. 1).

<table>
<thead>
<tr>
<th>Element</th>
<th>Dimensions b x h (cm)</th>
<th>Wood species</th>
<th>Grade</th>
<th>M.C. %</th>
<th>Section Area (cm²)</th>
<th>Decay depth (cm)</th>
<th>Section area Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main beams</td>
<td>28 x 35</td>
<td>Chestnut <em>Castanea sativa Mill.</em></td>
<td>2nd, 3rd</td>
<td>17,5</td>
<td>980</td>
<td>0,00</td>
<td>0%</td>
</tr>
<tr>
<td>Small beams</td>
<td>8 x 15</td>
<td>Oak <em>Quercus sp.</em></td>
<td>1st</td>
<td>17,7</td>
<td>120</td>
<td>0,00</td>
<td>0%</td>
</tr>
</tbody>
</table>

The re-use of this building as multi functional space determines a live load of 300 Kgp/m². Structural analysis proved that the structure needed to be upgraded and the good Conservation State of the wood beams allows for the realization of a mixed structure constituted by the original wood elements and a concrete reinforced beam and slab (Fig. 4, 5).

![Fig. 4, 5. On the left scheme of the mixed structure (wood + concrete) realized.](image)

![On the right disposition of the shear connectors.](image)

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4 Each of them is constituted by 3 shorter pieces; those elements actually carry only the plaster moldings and serve mainly to create the characteristic pattern of the paneled ceiling.

5 Inter axis between small beams is equal to 50 cm.

6 The total dead load derived by the addition of both original and new structure is 300 Kgp/m².
The new reinforced concrete beams are located in correspondence of the original wood beams, just above them. A concrete slab is finally realized on top of the mixed concrete-wood beam. Shear connectors create the conjunction between the three structural layers represented by the superimposition of the reinforced concrete slab, reinforced concrete beam, original wood beams. Wood beams had to be supported with provisional elements until the concrete structure realized on top did not start cooperating with them. Only subsequently it was possible to dismantle the provisional elements. The upgrading technique chosen allows for maintaining not just the appearance of the structure, but also the load bearing capacity of the original wood beams, which were still in good Conservation State. Plaster moldings needed to be restored, guaranteeing better adherence between the plaster and the wood supporting it.

The second case study belongs to the same floor typology as the first one examined, a wooden floor with paneled ceiling (Tab.2). The plaster moldings and decorations at the intrados side are in this case much more elaborated (Fig. 7). Conservation of appearance and load bearing capacity was considered fundamental also in this case.

Unluckily decay conditions of main beams did not allow in this case for the preservation of load bearing capacity of wood members; in order for the structures to carry safely the loads arising from plaster moldings and from the new loads due to the new function, it was necessary to introduce a new structure that takes over all the structural dead and live loads. Therefore intervention consists in the anchoring of the original structure to a series of new steel beams oriented perpendicular to the original ones (Fig. 6, 8, 9). Dead and live loads are taken over by the new steel beams introduced. In this case only the minimum objective of conservation of the appearance of the structure has been reached due to the severe decay suffered by main beams in correspondence of beam hedges.

![Fig. 6. Second case study: floor plan.](image)

Five steel beams support the original wood structure.

**TABLE 2. Summary of diagnostic study results regarding the second wooden floor analyzed.**

<table>
<thead>
<tr>
<th>Element</th>
<th>Dimensions b x h (cm)</th>
<th>Wood species</th>
<th>Grade</th>
<th>M.C. %</th>
<th>Section Area (cm²)</th>
<th>Decay depth (cm)</th>
<th>Section area Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main beams</td>
<td>28 x 35</td>
<td>Chestnut <em>Castanea sativa</em> Mill.</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;, 3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>19,8</td>
<td>980</td>
<td>0,00</td>
<td>0%</td>
</tr>
<tr>
<td>Small beams</td>
<td>8 x 14</td>
<td>Black poplar <em>Populus nigra.</em></td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>19,1</td>
<td>112</td>
<td>1,50</td>
<td>51%</td>
</tr>
</tbody>
</table>

The third case study regards a wooden floor belonging to the traditional typology called *Solaio a cassettoni*, Lacunars wooden floor. A wooden bas-relief ceiling is hanging from a series of Oak beams; secondary elements are made of Chestnut. For the realization of the wooden bas-relief Spruce has been used. It is possible to appreciate the careful realization of the bas-relief where the repetition of the wagon wheel image represents the fundamental decorative motif.

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7 Each reinforced concrete beam has a base of 15 cm and a height of 19 cm.
8 The concrete slab is 5 cm high and it is reinforced with a welded wire fabric 15x15 cm, Ø 0,5 cm.
9 Two shear connectors were located every 12,5 cm, and have a diameter of 2 cm. Steel FeB44K was used.
10 These elements span 6,8 m from wall to wall, and can be schematized like simply supported beams.
11 Five HEB 220B (Fe 360) have been placed at equal distance. Two of them are located near to perimeter walls. On the top it has been realized a reinforced concrete slab (welded wire fabric 15 x 15 cm, diameter 0,5 cm).
12 Severe decay damage was concentrated on beam hedges.
13 Distance between small beams is equal to 50cm.
Resistant sections of main beams were reduced in average 60%, due to severe decay (Tab. 3). Original members could no longer perform structural functions. The restoration intervention foresees in this case the complete replacement of original wood beams with new steel beams. In this particular case original structural elements have been completely lost; it has been possible to preserve only the appearance of the wooden ceiling (Fig. 10).
TABLE 3. Summary of diagnostic study results regarding the third wooden floor analyzed.

<table>
<thead>
<tr>
<th>Element</th>
<th>Dimensions b x h (cm)</th>
<th>Wood species</th>
<th>Grade</th>
<th>M.C. %</th>
<th>Section Area (cm²)</th>
<th>Decay depth (cm)</th>
<th>Section area Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main beams</td>
<td>26 x 32</td>
<td>Oak Quercus sp.</td>
<td>1st</td>
<td>17,0</td>
<td>832</td>
<td>5,00</td>
<td>60%</td>
</tr>
<tr>
<td>Small beams</td>
<td>8 x 13,5</td>
<td>Chestnut Castanea sativa Mill.</td>
<td>1st</td>
<td>17,0</td>
<td>108</td>
<td>1,50</td>
<td>51%</td>
</tr>
</tbody>
</table>

Fig. 10. Third case study: lacunars wooden floor with wooden bas-relief ceiling representing wagon wheals.

FINAL WORDS

Restoration often occurs when maintenance has been neglected for long periods of time, therefore interventions may alter more or less significantly original structures, and, it is not always possible to preserve integrity and authenticity of appearance and structural conception of timber structures, as it is desired.

For all the case study reported in this paper it has been possible to preserve integrally the appearance of the plaster and timber molding and decorations visible at the intrados of the floors structures; this was considered the minimum objective of the restoration project.

Regarding the maintenance of the structural systems and of the load bearing capacity of the elements, the goal has been reached only in the first case examined, by integrating the original wood structure with a new reinforced concrete structure. In the second case examined, in fact, it was possible to preserve only the appearance of the plaster moldings and of the structural elements, which in this case did not maintain the load-carrying capacity. Original wood members have not been removed however; they will be preserved for any future study and memory, even though they cannot provide a structural contribution. The steel beams introduced above the original timber ones have been designed to take all the dead

14 Distance between small beams is equal to 50cm.
and live loads. In the third and last case it has been possible to preserve only the appearance of the wooden decorated ceiling, and, original structural elements had to be removed because of the severe damage suffered in service. New steel beams replaced the original elements, and support all the structural loads. The original wood ceiling, which constitutes the precious, decorated skin of the original structure, is hanging from the new steel beams. Even though the goal of conservation is to preserve not just the appearance but also the entire structural system as a working system, recognizing it as a witness of a specific way to master material and technology at a specific time, oftentimes, and in this last one too this is not possible.

Decay conditions surveyed within Della Rovere Castle are the result of neglecting maintenance and of the non-use of the monument for several decades. Therefore maintenance and reuse both appears to be fundamental tools in preserving historical heritage and in preventing major restoration interventions, that may lead to the final result of altering in some cases the original structures which is in converse desired to preserve in their authenticity and integrity.

Decisions regarding restoration actions arise from considering all the issues involved in defining the problem, such as cultural heritage issues, safety issues, new users needs, economical issues, etc, and a compromise has to be reached between what can be conserved and what needs to be replaced or transformed. Usually one aspect should not prevail over the other, even though the conservation of the cultural heritage is our main goal, in practice a compromise has to be reached in order to define a solution that takes into consideration all the issues involved in defining the problem, trying to minimize the loss of aesthetic and cultural values by operating minimum interventions in relationship to the conservation state acknowledged.

AKNOWLEDGEMENTS

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BIBLIOGRAPHY


