ANTIQUE WOODEN FLOOR REUSE POSSIBILITIES IN VIEW OF THEIR USAGE PROPERTIES PRESERVATION

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Palace of Versailles, the Hall of Mirrors, 1679
Jules Hardoiun-Mansart and Charles Le Brun (1647-1708)
2. AIM and SCOPE of RESEARCH

• The aim of this research consists in proposing criteria to assess antique, decorative wooden floors and decide on the possibility of their further usage and conservation methods.

• The research of antique floors covered 76 rooms in 21 castles, hunting lodges and manor houses in South-Eastern Poland, dated from the 19th century.

• We paid particular attention to the stage of diagnostics.

• It was paramount to closely follow the currently standards and guidelines.

• The conservation and restoration activities had to be: necessary, minimum and reversible, and the efficiency of the used techniques had to be proven.

• The plan of conservation interventions in wooden structures was preceded by a scientific study and moreover, mathematical tests and models were indispensable.
3. METHODOLOGY

• The production of parquet materials is regulated by CPR (EU) 305/2011 that requires the application of European harmonised standards.

• The tests of wood resistance properties were carried out in line with the binding standards: bending strength and elasticity modulus tests in line with EN 408, hardness - EN 1534, resistance to abrasion with the Taber method - EN ISO 5470-1, resistance to scratching on the basis of EN 438-2:2005.

• The capacity to transfer the structure’s own, static loads and live loads was assessed through numerical calculations in Autodesk Inventor Professional software.

• The function of each structural layer of the floor was determined by comparing the elasticity (transfer of dynamic loads by shock absorption-force reduction in accordance with the EN 14808 and 14809 standards), while the floor’s resistance to dynamic loads caused by a soft body impact was tested in line with the EN 1195 standard.

• The role of parquet panel designs in the stability of their dimensions and the distribution of stresses were analysed by modeling the swelling process in the SolidWorks Simulation 2011 software.

• Longitudinal curvature was determined in accordance and right angles in line with EN 13647.

• The analysis of the influence of woodwork joints between panel elements on the character of their work and the loading degree were carried out with the use of a series of numerical analyses performed in the Autodesk Inventor Professional.

• Moreover, we tested the moisture equivalent and wetting curves through mass measurements, ergosterol with the use of the Seitz method (1979), and carried out quantitative and qualitative chemical tests (the degree of cellulose polymerization with the help of SEC - Size Exclusion Chromatography analysis).
4. TEST RESULTS
4.1 Construction Solutions in Antique Floors

Chapel in the Łańcut Castle
(a: A- panel, B- sand, C- concrete)

Ball Room in the Łańcut Castle
(b: A – panel, B – boarding, C - ceiling beams, D – sand)

Przewrotne Manor House
(c: A – panel, B – boarding, C - ceiling beams, D – bricked post)

Falejówka Manor House
(d: A – panel, B – boarding, C - ceiling beams, D – binding joist, E -bricked post)
4. TEST RESULTS
4.1 Construction Solutions in Antique Floors

Uneven bottom surface of the panel and signs of mechanical and manual processing (with an axe or a plane) of the parquet’s bottom side.

Differences in thickness between the frame and the elements inside it may reach up to 20mm and serve the purpose of economising the material.

The internal elements are suspended on the frame, on joints and collapse.

Panel elements are connected with one another with the tongue in groove joint, dowel pins and lap joint; and the connections between panels use the spline joint.
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.1 Factors influencing the state of preservation of antique floors

- oak (Quercus sp.)
- fossil oak (Quercus sp.)
- birch (Betula L.)
- sycomore maple (Acer pseudoplatanus L.)
- hornbeam (Carpinus L.)
- yew (Taxus baccata L.)
- ash (Fraxinus excelsior L.)
- elm (Ulmus L.)
- beech (Fagus sylvatica L.)
- walnut (Juglans regia L.)
- cherry (Cerasus Mill.)
- mahogany (Swietenia sp.)
- pine (Pinus silvestris L.)
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests

4.2.1 Factors influencing the state of preservation of antique floors

Differences in the level of antique parquets in the Łańcut Castle, resulting from a different resistance to abrasion of oak, ash and fossil oak.
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.1 Factors influencing the state of preservation of antique floors

- The influence of panel design on the stability of panel dimensions

<table>
<thead>
<tr>
<th>Panel Design</th>
<th>White (MIN)</th>
<th>Black (MAX)</th>
<th>White (MIN)</th>
<th>Black (MAX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>oak (Quercus sp.)</td>
<td>16 MPa</td>
<td>27 MPa</td>
<td>0,00mm</td>
<td>0,13mm</td>
</tr>
<tr>
<td>oak + pine (Quercus sp., Pinus sp.)</td>
<td>17 MPa</td>
<td>30 MPa</td>
<td>0,00mm</td>
<td>0,24mm</td>
</tr>
<tr>
<td>oak + beech (Quercus sp., Fagus sp.)</td>
<td>18 MPa</td>
<td>46 MPa</td>
<td>0,00mm</td>
<td>1,08mm</td>
</tr>
<tr>
<td>oak + elm (Quercus sp., Ulmus sp.)</td>
<td>16 MPa</td>
<td>27 MPa</td>
<td>0,00mm</td>
<td>0,10mm</td>
</tr>
</tbody>
</table>

Panel of the Tarnowiec manor house, room 5 (765x765mm)
4. TEST RESULTS

4.2 Selected Results of Antique Floor Usage Tests

4.2.1 Factors influencing the state of preservation of antique floors
- The influence of panel design on the stability of panel dimensions

Panel of the Tarnowiec manor house, room 5 (765x765mm)

White (MIN): 16 MPa  
Black (MAX): 27 MPa

White (MIN): 0,00mm  
Black (MAX): 0,13mm

White (MIN): 17 MPa  
Black (MAX): 30 MPa

White (MIN): 0,00mm  
Black (MAX): 0,24mm

White (MIN): 18 MPa  
Black (MAX): 46 MPa

White (MIN): 0,00mm  
Black (MAX): 1,08mm

White (MIN): 16 MPa  
Black (MAX): 27 MPa

White (MIN): 0,00mm  
Black (MAX): 0,10mm

oak (Quercus sp.)
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White (MIN): 16 MPa
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White (MIN): 0,00mm
Black (MAX): 0,13mm

White (MIN): 17 MPa
Black (MAX): 30 MPa
White (MIN): 0,00mm
Black (MAX): 0,24mm

White (MIN): 18 MPa
Black (MAX): 46 MPa
White (MIN): 0,00mm
Black (MAX): 1,08mm

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Black (MAX): 27 MPa
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4.2.1 Factors influencing the state of preservation of antique floors

- The influence of panel design on the stability of panel dimensions

Panel of the Tarnowiec manor house, room 5 (765x765mm)

- Wood species applied
- Panel complexity
- Number and proportions of elements
- Minor modifications of the design of panel
- Direction of fibre layout
- Panel size

White (MIN): 16 MPa
Black (MAX): 27 MPa

White (MIN): 0,00mm
Black (MAX): 0,13mm

White (MIN): 17 MPa
Black (MAX): 30 MPa

White (MIN): 0,00mm
Black (MAX): 0,24mm

White (MIN): 18 MPa
Black (MAX): 46 MPa

White (MIN): 0,00mm
Black (MAX): 1,08mm

White (MIN): 16 MPa
Black (MAX): 27 MPa

White (MIN): 0,00mm
Black (MAX): 0,10mm

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4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.2 Resistance parameters of antique woods

- Results of strength tests of oak wood

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Falejówka</td>
<td>Average value</td>
<td>1448.35</td>
<td>77.55</td>
<td>11869.93</td>
<td>10.2</td>
<td>620</td>
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<tr>
<td></td>
<td>Standard deviation</td>
<td>398.20</td>
<td>19.02</td>
<td>1601.13</td>
<td>2.87</td>
<td>33.29</td>
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<td></td>
<td>Coefficient of variation</td>
<td>27.49</td>
<td>24.50</td>
<td>13.49</td>
<td>28.00</td>
<td>5</td>
</tr>
<tr>
<td>Tarnowiec</td>
<td>Average value</td>
<td>1956.42</td>
<td>94.48</td>
<td>13029.73</td>
<td>11.87</td>
<td>720</td>
</tr>
<tr>
<td>Room 1</td>
<td>Standard deviation</td>
<td>434.99</td>
<td>18.87</td>
<td>1337.52</td>
<td>2.72</td>
<td>49.89</td>
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<tr>
<td></td>
<td>Coefficient of variation</td>
<td>22.23</td>
<td>19.98</td>
<td>10.27</td>
<td>22.91</td>
<td>7</td>
</tr>
<tr>
<td>Tarnowiec</td>
<td>Average value</td>
<td>2024.69</td>
<td>76.00</td>
<td>11322.39</td>
<td>14.77</td>
<td>650</td>
</tr>
<tr>
<td>Room 4</td>
<td>Standard deviation</td>
<td>714.33</td>
<td>28.86</td>
<td>3029.09</td>
<td>2.19</td>
<td>37.42</td>
</tr>
<tr>
<td></td>
<td>Coefficient of variation</td>
<td>35.28</td>
<td>37.97</td>
<td>37.97</td>
<td>26.73</td>
<td>6</td>
</tr>
</tbody>
</table>
4. TEST RESULTS

4.2 Selected Results of Antique Floor Usage Tests

4.2.2 Resistance parameters of antique woods

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**HB [N/mm²]**

- Characteristic value

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**Background**

**Methods**

**Results**

**Conclusion**
4. TEST RESULTS

4.2 Selected Results of Antique Floor Usage Tests

4.2.2 Resistance parameters of antique woods

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**Background**

**Methods**

**Results**

**Conclusion**

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4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests

4.2.2 Resistance parameters of antique woods
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4. TEST RESULTS

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4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.3 Static and dynamic load bearing capacity of antique floors

Diagram of dead and live (imposed) structural loads (0.1 MPa) of parquet from Room no. 4 in Tamowiec (a) together with the grid (b) using the finite element method.

The load was applied in two most critical points of the parquet: in the middle of the panel: F2; and at the limit between two adjacent panels: F1 in two parquet variants: contemporary and antique.
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.3 Static and dynamic load bearing capacity of antique floors

The load was applied in two most critical points of the parquet: in the middle of the panel: F2; and at the limit between two adjacent panels: F1 in two parquet variants: contemporary and antique.

Diagram of dead and live (imposed) structural loads (0.1 MPa) of parquet from Room no. 4 in Tarnowiec (a) together with the grid (b) using the finite element method.

<table>
<thead>
<tr>
<th>Simulation results</th>
<th>Floor structure of Tarnowiec Room 1</th>
<th>Floor structure of Tarnowiec Room 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contemporary wood</td>
<td>Antique wood</td>
</tr>
<tr>
<td>F1</td>
<td>F2</td>
<td>F1</td>
</tr>
<tr>
<td>Maximum von Mises stress [MPa]</td>
<td>0.17</td>
<td>0.49</td>
</tr>
<tr>
<td>Maximum deflection [mm]</td>
<td>0.0013</td>
<td>0.023</td>
</tr>
</tbody>
</table>

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4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.3 Static and dynamic load bearing capacity of antique floors

Panel parquets are similar to area elastic sports floors
PN-EN 14904:2000

parquet
top transversal joists
bottom longitudinal joists
elastic pads
concrete base
The function of joints in the structure of antique wooden tile parquets on the example of parquet from Przewrotne manor house - diagram of dead and live (imposed) structural loads (0.15 MPa) together with the grid (a) and the deformations (b) with the use of the finite element method.
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.3 Static and dynamic load bearing capacity of antique floors

The function of joints in the structure of antique wooden tile parquets on the example of parquet from Przewrotne manor house - diagram of dead and live (imposed)

<table>
<thead>
<tr>
<th>Simulation results</th>
<th>Maximum von Misses stress [MPa]</th>
<th>Maximum deflection [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel with profiled joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>0.166</td>
<td>0.0008</td>
</tr>
<tr>
<td>F2</td>
<td>0.179</td>
<td>0.0034</td>
</tr>
<tr>
<td>Panel without profiled joints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>0.168</td>
<td>0.0005</td>
</tr>
<tr>
<td>F2</td>
<td>0.178</td>
<td>0.0032</td>
</tr>
</tbody>
</table>

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Deviations from flatness of an antique panel from Room no. 4 in Tarnowiec Manor House (a) and its contemporary copy (b).

The curvature was measured on the front side of the panels in points marked by the virtual mesh, size 50 x 50 mm. As a result of the measurements, we obtained an “altitude map” that shows the degree of deviation from flatness in relation with the surface of the entire panel.
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.4 Flatness and shape deformations
4. TEST RESULTS
4.2 Selected Results of Antique Floor Usage Tests
4.2.5 Chemical composition and fungi infestation

Wettability curves of the heartwood of antique wood and of contemporary oak, ash and elm
4. TEST RESULTS
4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements
4. TEST RESULTS
4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements

the state of the floor’s support structure (joists, binding joists and/or subfloor under the sand)
4. TEST RESULTS

4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements

- the state of the floor’s support structure (joists, binding joists and/or subfloor under the sand)

- the condition of the surface layer
  - the most important from the point of view of history and visual aesthetics

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4. TEST RESULTS
4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements

- the state of the floor’s support structure (joists, binding joists and/or subfloor under the sand)
- the condition of the surface layer
  - the most important from the point of view of history and visual aesthetics

layer of hydrothermal and acoustic insulation

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4. TEST RESULTS

4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements

- Impregnation with a bioprotective substance
- Air circulation below the floor surface
- Layer of hydrothermal and acoustic insulation
- The state of the floor’s support structure (joists, binding joists and/or subfloor under the sand)
- The condition of the surface layer - the most important from the point of view of history and visual aesthetics
4. TEST RESULTS
4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements

The dimensions of the cross-section of load bearing elements that transfer loads from the floor, such as joists, binding joists or bricked posts, have to be designed in accordance with the requirements of the designing standards specified in Eurocode EC 5.

Structural elements can be made only of wood approved for construction applications, that is coniferous wood (spruce, pine, fir or larch) that has been strength graded and has a defined strength class C.

The wood has to be marked with a CE mark and should fulfil the requirements of the EN 14081 standard.

The blind floors should be made of strength sorted pine wood planks with joists (dowel type fasteners that fulfill the requirements of the EN 14592 standard) or of engineered wood panels, under the condition that they meet the requirements of EN 13986.

The thickness of planks as well as the amount and type of joints have to be specified on the basis of resistance calculations in line with EN 1995-1-1 or tests carried out in accordance with EN 1195 and EN 12871.
4. TEST RESULTS
4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.1 Design and material requirements

The mineral subfloors are made of crushed stone and a binding agent (cement/anhydrite), in the proportion that is in line with the recipe indicated for a given compressive strength, or a ready mix whose properties are declared by the manufacturer, in accordance with the EN 13813 and EN 13318 standards.

The loads can also be transferred through another structural element - a solid base, usually (in case of contemporary floors) made of concrete or screed.

Floor elements made of solid wood and of multiple layers of broadleaf or coniferous wood, in accordance with EN 14342 and with one of the product standards mentioned below: EN13226, EN13227; EN13228; EN13488; EN13489, EN 13629, EN 13990; EN 14761 shall be used to manufacture parquets glued to a mineral base or glued (and/or also nailed) to a subfloor made of planks (the so called blind floor).

Fasteners - nails, staples, screws should meet the requirements of the EN 14592.

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4. TEST RESULTS
4.3 Usage Requirements for Antique Wooden Floors and the Programme of Conservation Works

4.3.2 Usage conditions of wooden panel parquets

Proper insulation against humidity, always between the brick base and the wooden element.

All the “wet” works in the building must already be finished, internal woodwork installed, and heating must be turned on. In accordance with the recommendations from reference literature, the panels should be kept in microclimate conditions typical for interiors for several weeks in advance, and the works should be carried out in about 20° C and relative air humidity 50-65%.

Instead of the layer of sand or wooden wedges that were used under the panels for levelling in antique parquets, decking can be covered with a vapour insulating foil with foam that is used under floating floors.

In conservation works, it is recommended to use traditional wood surface finishes - oil or wax.

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5. CONCLUSIONS - antique floors

- The fact that elements of wooden parquets have been preserved for almost 200 years shows that the wood quality was high; at the same time, the technical condition of the assessed floors was diverse and resulted from individual factors, most of all usage intensity and assembly technique.

- The decision on whether to renovate or replace antique parquet should be made on the basis of resistance tests carried out on the antique parquet, which allows for a correct assessment of the possibility of its further usage.

- The following wood properties are considered important: density, bending strength, hardness, resistance to abrasion, resistance to scratches, the level of fungi infestation assessed visually and with the help of ergosterol determination, wettability curves, moisture equivalent, as well as the quantitative and qualitative chemical composition.

- The test results of antique floor usage properties can provide a basis for numerical simulations specifying the capability of antique floors to transfer static and dynamic loads.

- Fungi infestation of antique wooden floors does not always entail the need of replacement.

- In case of antique parquet conservation, we are not able to achieve the “perfectly flat” surface that is preferred in contemporary parquets.
5. CONCLUSIONS – reconstructed floors

- Parquets based on conservators’ patterns and assembled with traditional methods should meet both the aesthetic (the way they look and the general impression) and technical requirements binding nowadays, such as flatness, slope (where necessary), dimensional stability, resistance to abrasion of the coating, hardness, scratches, gloss, and in ball rooms, additionally, the capability to absorb energy in the required force reduction range.

- It is recommended to use oak wood or ash wood (beech is not recommended because of its moisture exchange time).

- The structural and filling elements of the reconstructed parquet should have the same thickness.

- Due to the fact that the parquet must be placed on decking, its thickness might be smaller than the thickness of antique parquets supported only by joists, and adjusted to the universally available wood assortment.

- For aesthetic and structural reasons, the reconstructed panels should include profiled woodwork joints.

- The conservation work should be recommended to contemporary standards - for materials, designs and workmanship, wherever this is possible, with respect for the past and tradition.
Thank you for your attention!

*Łancut Castle parquet

annamaria.rozanska@gmail.com
<table>
<thead>
<tr>
<th>Manor House</th>
<th>Date back</th>
<th>Basement</th>
<th>Floor structure</th>
<th>Wood species</th>
<th>Sampling point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarnowiec Room no. 1</td>
<td>ca.1930</td>
<td>+</td>
<td>sand+ joists+ boarding</td>
<td>Oak <em>Quercus</em> sp.</td>
<td>External corner of the room</td>
</tr>
<tr>
<td>Tarnowiec Room no. 1</td>
<td>ca.1930</td>
<td>+</td>
<td>sand+ joists+ boarding</td>
<td>Oak <em>Quercus</em> sp.</td>
<td>Communication</td>
</tr>
<tr>
<td>Tarnowiec Room no. 1</td>
<td>ca.1930</td>
<td>+</td>
<td>sand+ joists+ boarding</td>
<td>Oak <em>Quercus</em> sp.</td>
<td>Internal corner of the room</td>
</tr>
<tr>
<td>Tarnowiec Room no. 4</td>
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<td>Tarnowiec Room no. 4</td>
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<td>sand+ joists</td>
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<td>sand+ joists</td>
<td>Elm <em>Ulmus minor</em> Mill.</td>
<td>Communication</td>
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<td>Tarnowiec Room no. 5</td>
<td>ca.1930</td>
<td>-</td>
<td>sand+ joists</td>
<td>Elm <em>Ulmus minor</em> Mill.</td>
<td>Internal corner of the room</td>
</tr>
<tr>
<td>Falejówka</td>
<td>2nd half 19th c.</td>
<td>-</td>
<td>empty sp.+ beams+ boarding</td>
<td><em>Quercus</em> sp.</td>
<td>Whole room</td>
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<tr>
<td>pine</td>
<td>contemp.</td>
<td>-</td>
<td>-</td>
<td><em>Pinus sylvestris</em> L.</td>
<td>-</td>
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<tr>
<td>ash</td>
<td>contemp.</td>
<td>-</td>
<td>-</td>
<td><em>Fraxinus excelsior</em> L.</td>
<td>-</td>
</tr>
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<td>contemp.</td>
<td>-</td>
<td>-</td>
<td>Oak <em>Quercus robur</em> L.</td>
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<tr>
<td>elm</td>
<td>contemp.</td>
<td>-</td>
<td>-</td>
<td>Elm <em>Ulmus minor</em> Mill.</td>
<td>-</td>
</tr>
</tbody>
</table>