AN ASSESSMENT OF THE CONDITION OF TIMBER STRUCTURES

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ABSTRACT

Timber is one of the longest-used building materials for various types of structures, and has been used in the construction of both historical and modern structures. The primary reasons for its usage have been its ready availability, as well as its good mechanical properties, low thermal conductivity and aesthetic appeal, among others.

Due to its organic origins, timber is subject to degradation factors, mainly biological but also mechanical. Today we can increase the durability of timber by applying timber preservation treatments, which were not always available over the whole period of timber usage as building material. As a result, timber structures very often show various degrees of deterioration that have been caused both by timber degradation and damage to the structures.

To ensure the further preservation of timber structures or an effective plan for their replacement, repair or reconstruction, it is essential to know their building-technical condition. This can be carried out through building-technical research, which may form part of building-historical research. In appraising the condition of a timber structure, it is necessary to take into account the organic origin of timber. The building-technical research must therefore be aimed towards two areas:

- *an assessment of the state of the timber*
- *an assessment of the building-technical condition of the structures*

Non-destructive testing methods, localized damage methods and laboratory methods are used for determination of the condition of both timber and timber structures. Either the ultrasonic pulse method or the hardness measurement method is used for measurement of the deterioration level of wooden material, while compression strength along fiber alignment can be determined by micro-drillings. The occurrence of fungal hyphae can be informatively detected by a chemical method involving indicators (determination of the hydrogen ion concentration).

The article describes procedures for timber and timber structure assessment, states their monitored parameters, testing methods and procedures for assessment of the building – technical condition.

BASIC PHASES OF TIMBER STRUCTURE ASSESSMENT

This paper aims at assessment of building/technical condition of timber structures i.e. structures of their own as well as condition of built-in materials along with tracing of their basic parameters essential to static analysis, as the case may be.

In general, timber structure assessment can be divided in two basic parts:

- assessment of building/technical condition of timber structures and tracing of their assembly (horizontal structures);
- assessment of timber health.

All defects traced are to be recorded in structure technical record keeper that means designed elements shall be unambiguously marked and covered by individual data as to their health condition e.g. degree of wood material failure, wood defects and so on.

Assessment of Building/Technical Condition of Timber Structures
Condition of timber structure elements is analyzed as to their deformation (floor supporting beams: deflection; roof elements: distortion, shrink cracks, oversized knags) as well as cross-section reduction whether as a result of decay fungi deleterious effect or other mechanical damage. Also we have to trace in-leak spots, size and arrangement of particular elements (roof construction), and floor structure (horizontal load bearing structures).

Assessment of Timber Health
Taking into account that timber is natural building material, it is subject – in case of inadequate protection – to deterioration (namely with old timber structures i.e. also with historical building structures). Among others, the most dangerous are decay fungi and wood-borer.

Presence of decay fungi is subject to increased wood moisture. Most widespread decay fungi under Czech Republic condition are in particular house fungus (Serpula Lacrymans) followed by cellar fungus (Coniophora Puteana) and Gloeophyllum Sepiarium. Decay fungi are most dangerous for timber built in moist brickwork. The decay fungi break down either wood pulp from wood mass (creating progressive browning and cubiform decomposition) or lignin (resulting in wood colour loss and spalling). Typically, fungi are indicated by mycelium fibrillating through wood mass or covering timber surface.

Particularly, wood-borer is harmful to timber in a mechanical manner i.e. it eats worm-holes from wood mass along with creation of surface output openings. Wood-borer presence is proved by evidence of aforementioned surface openings, and also by findings of insect galleries (so called wood flour) being situated under timber elements affected. Most widespread wood-borer in timber structures are roof beetle (Hylotrupes Baiulus) and woodworms (striped beetle – Anobium Punctatum and deathwatch beetle – Anobium Pertinax.

ASSESSMENT OF BUILDING/TECHNICAL CONDITION OF TIMBER STRUCTURES
Assessing timber structures, we have to pay our attention to both assessment of timber structure as a whole and to assessment of particular elements. Presence of failure or defect of one element does not mean that other ones would be affected as well.

We have to check all elements because it is not possible to make sure that some other parts would be free of failure or absence due to various reconstruction or botched-up repairs.

Particular elements are analyzed as to:
- element position: we check position compliance with contract documents and/or general principles covering given roof;
- geometrical shape i.e. height, width (thickness) length (span) through measurement;
- supporting beams spacing and span through measurement or uncovering in case the beams are hidden;
- floor structure through measurement of particular component elements and layers;
- in-leak spots positioning (potential timber failure) – see Figure 1
- element deformation (warping, twisting, deflections) and timber joint quality;
- mechanical damage – see Figure 2;
- element mounting, especially its installation in brickwork;
- cracks (able to reduce bending strength even by 38%) – see Figure 3

- presence of knags (number and size – reducing timber strength) – see Figure 4
- timber health.

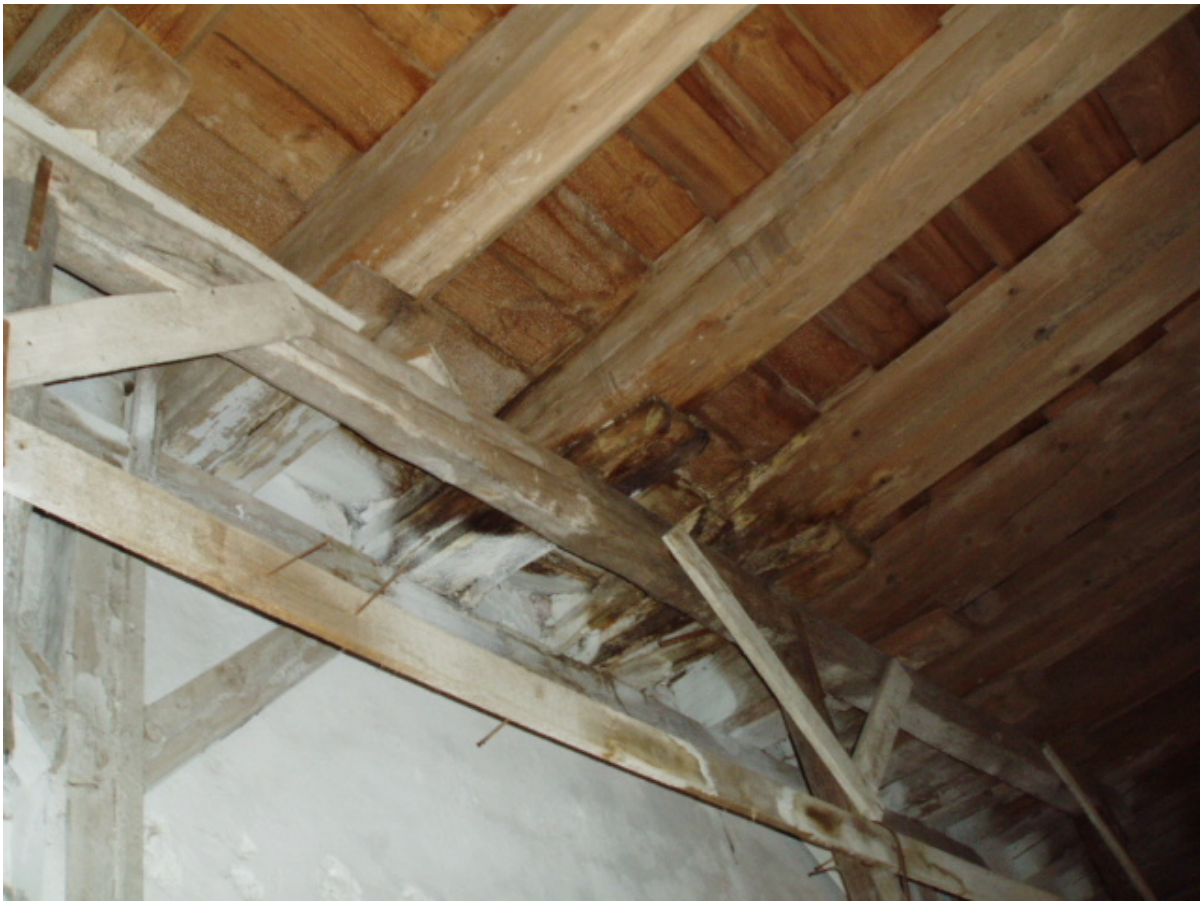

Figure 1. Roof In-Leak

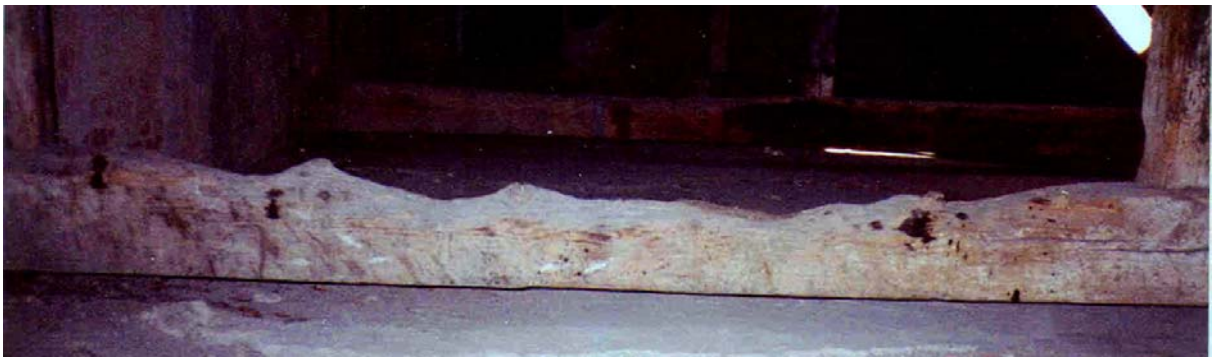

Figure 2. Beam Mechanical Damage (cross-sections reduction due to wood chopping)

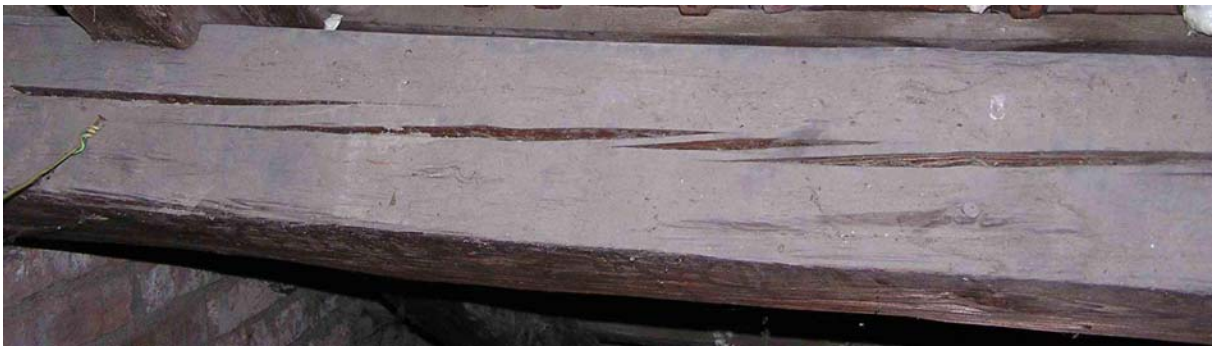

Figure 3. Shrink Crack in a Roof Element

Figure 4. Knags in a Roof Beam

ASSESSMENT OF TIMBER HEALTH AND PARAMETERS

Assessing timber health, we have to focus on rate of its failure due to wood-rotting borer attack (decay fungi and insects) i.e. cross-section reduction and scope of element failure.

Timber health is analyzed as follows:

- visually
- non-destructive testing
- local invasion.

Visual Assessment

On the basis of characteristic features of particular types of wood-rotting borers (change in wood colour and/or structure, fungi fruiting body or mycelium, presence of insect output openings, insect galleries, in-leak spots and so on) – see Figure 5 and Figure 6 for timber failure due to wood-rotting borer attacks.

Figure 5. Roof Failure Due to House Fungus Attack

Figure 6. Beam Head Failure

Non-Destructive Testing

To analyze changes in wood structure under fungi attack in particular, we can use non-destructive testing as follows:

- Ultrasonic pulse method – under constant measuring base, we analyze either difference in velocity of ultrasonic pulse velocity, or – directly – difference in transit time (constant measurement means the one differing up to 2 % from nominal measurement along whole length of the test specimen under examination). Exciter natural frequency: 82 kHz. Test specimens are measured through direct sounding – see Figure 7 – along with wood moisture measurement in test spots. Formula (1) is used to calculate ultrasonic pulse velocity as follows:

$$V = \frac{L}{T} \tag{1}$$

Where:
V ultrasonic pulse velocity (km/s)
L length of measuring base (mm)
T transit time (μs)

As an illustration, see Table 1 for findings as to ultrasonic pulse testing of roof timber elements.

Element	V	Element		V
unit	[km/s]	unit		[km/s]
K1 spar – inattacked	1.432	K4 spar – attacked	0.892	
K2 spar – inattacked	1.328	K5 spar – attacked	1.022	
K3 spar – inattacked	1.528	K6 spar – attacked	N/A	
T1 joining balk – attacked	1.386	T2 joining balk – attacked		

Table 1: Ultrasonic Pulse Testing of Roof Timber Elements Consisting of Wood Mass Varying in Quality

The above Table manifests that the ultrasonic pulse method is applicable to identification of timber element spots featuring changes in wood mass structure due to attack of wood-rotting borers.

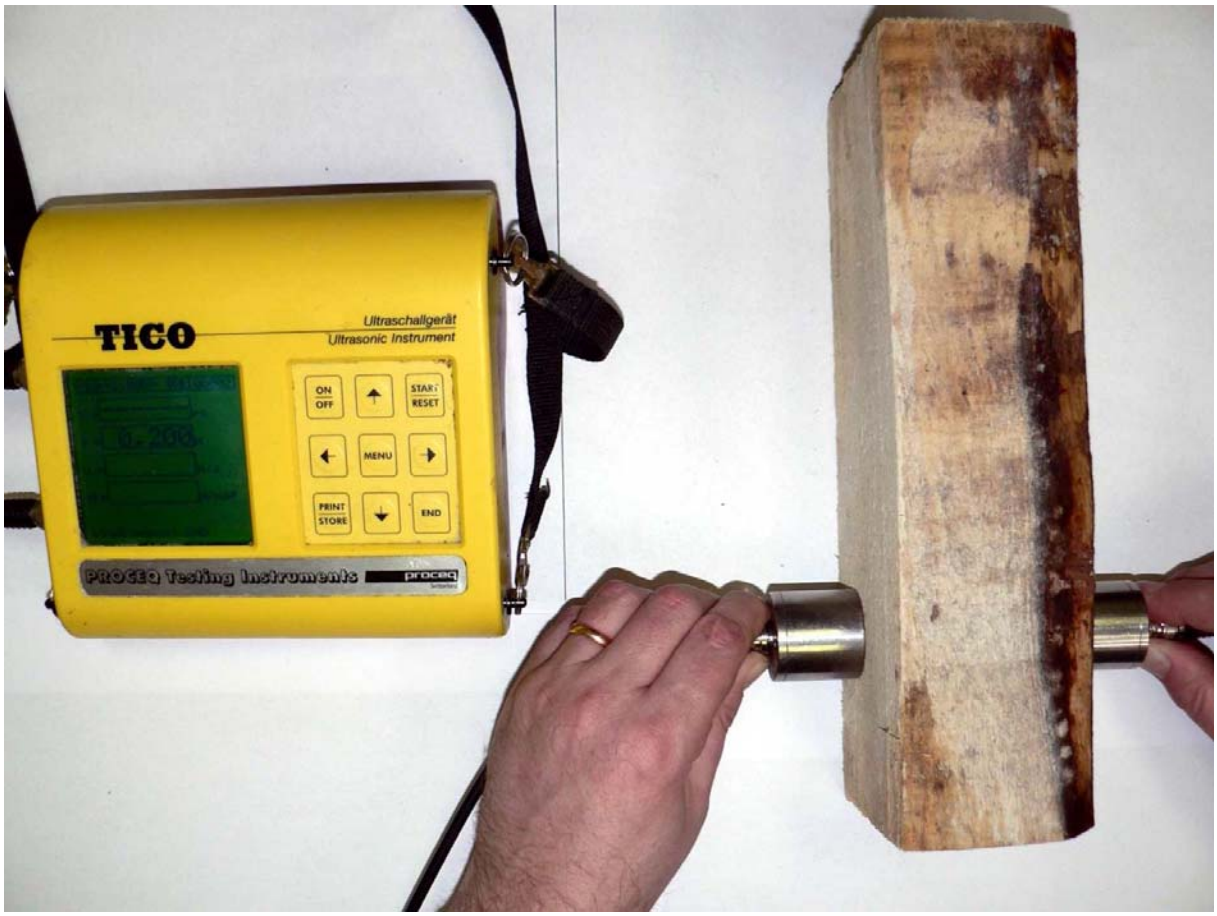

Figure 7. Measurement of Ultrasonic Pulse Transit through a Timber Element – Direct Transmission

- Sclerometric method – to identify faulty timber elements, it is possible to use PILODYN 6J wood tester made by PROCEQ S.A. – see Figure 8. Its principle consists in driving of a steel impact pin into tested timber using defined power (6J). Penetration depth depends

on condition of wood under testing. We monitor penetration of steel impact pin into health wood as compared to the same into affected wood. In case calibration correlations for given kind of wood are at hand, we are able to deduce its strength taking into account appropriate non-destructive testing parameter.

Depth of timber failure i.e. cross-sections reduction is possible to detect by means of either common tools such as chisel, hatchet, and handsaw, or incremental wood drill (lesser disturbance of the element under testing) – see Figure 9.

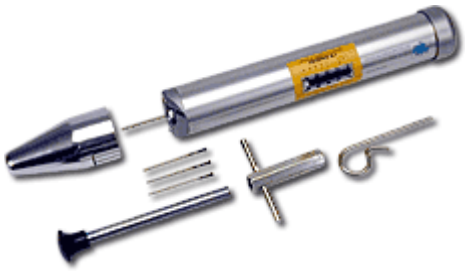

Figure 8. PILODYN Wood Tester

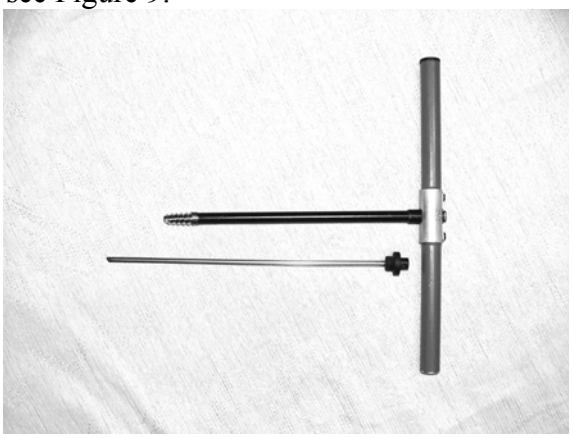

Figure 9. Incremental Wood Drill

- Chemical methods – usable for informative detection of fungal hyphae in timber through testing of its pH value. This method is based on finding that concentration of hydrogen ions in sound wood (pH from 5 to 6) differs from the same of wood affected by wood-rotting fungi (pH from 3 to 5). To detect pH value, we use these indicators: Bromophenol Blue and Bromocresol Green.

  Test procedure:
  Prepare 0.04 % indicator solution in denatured alcohol.
  Apply the indicator (diluted 1:1 by distilled water) on a fresh cut under testing.
  Let the indicator to take effect for a period of c. 3 minutes; watch wood colouring.
  In case of Bromophenol Blue: sound wood turns blue, affected one turns yellow (original indicator colour).
  In case of Bromocresol Green: sound wood turns blue-green, affected one turns yellow (original indicator colour).
  At suspicion of fungal hyphae occurrence, there is necessary to take samples for laboratory tests.

- Electric methods – electric moisture meters are based on various principles (capacitive moisture meters, resistance moisture meters). Increased moisture indicates potential conditions for occurrence of affected wood.

- Local invasion methods – such as compression strength recognition on bores. This tests are based on collection of wood bore samples along their fibres. Sample size: ≥ 38 mm in diameter, ≥ 25 mm in length. Tool used: core drill. Such samples are shaped to standard test specimen 20 × 20 × 30 mm and put to the test of along fibre compression strength in testing machine according to ČSN 490110.

CONDITION OF TIMBER STRUCTURES: EVALUATION OF TEST RESULTS

Assessment of Elements Affected by Wood-Borers

For guidance, failure seriousness can be assessed by number of output openings in relation to 1 m^2 of surface according to criteria mentioned in Table 2 below.

Kind of wood-borers	∅ of surface output opening	number of output openings in relation to 1 m^2 for particular failure type		
	[mm]	mild	medium	hard
sawyer beetle	4 to 9	2 to 4	5 to 16	more than 16
woodworm	1 to 3	6 to 10	11 to 24	more than 24

Table 2: Criteria for Assessment of Elements Affected by Wood-Borers

Assessment of Elements Affected by Cross-Section Reduction

Elements affected by such reduction due to decay fungi and wood-borer action can be categorized as follows:

- mild failure: cross-section reduction < 5 %
- medium failure: cross-section reduction 5 to 15 %
- hard failure: cross-section reduction > 15 %.

Based on outcomes of examination performed, particular timber elements are categorized by scope of attack or – as the case may be – a recommendation is prepared listing reparable elements along with remainders necessary to replace.

CONCLUSION

This paper describes techniques covering assessment of timber structure condition. Obviously, non-destructive testing (ultrasonic pulse test, sclerometric test) increases efficiency of timber element wood material assessment although parameters based on non-destructive testing are usable as comparative one i.e. for confrontation of sound timber values with values found on affected timber elements.

Criteria of timber element assessment, as mentioned above, serve for further decision on eventual repair of damaged elements of timber structures.

ACKNOWLEDGEMENTS

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