

ECOLOGY AND SAFETY IN THE PRACTICE: MANAGEMENT OF SIGNIFICANT TREES IN URBAN ENVIRONMENT

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Abstract

This paper deals with applying of acoustic tomograph as support tool to ecological assessment of veteran trees in urban environment. Very large old trees provide many ecosystem services in urban parks, historical gardens, and green urban areas. But, sometimes, very large old trees can be considered as a threat for safety of people, visiting green areas. This is because of very large trees can be destroyed in the tree trunk without visible signs of wood destruction inside the tree body. So, acoustic tomography can be used as very effective support tool for ecological assessment of stability and health of veteran trees in urban environment. This paper presents basic methodological approaches to acoustic tomography of veteran trees under some examples from environmental practice in the Czech Republic.

Keywords: *acoustic tomograph, ecological assessment of living trees, safety of visitors, veteran trees, urban green areas*

1. INTRODUCTION

Very large old trees (veteran trees) provided many important ecosystem services in urban environment. Providing of some ecosystem services of old trees is connected with rich presence of tree-holes and similar destructions of wood. But, many trees-holes as well as old dead parts tree body (e.g. very large branches) can influence the tree stability and threat visitors of urban parks and other green urban areas with large old trees. This important issue because of both local people and tourists prefer green areas dominated by charismatic veteran trees with high aesthetic value.

As stated above, significant trees are an important part of historical buildings and protected areas. It is rather surprising that no substantial research attention has been paid till now to the issue of the protection of the trees' health and the safety of visitors to such areas in relation to the significant trees, although there is a genuine risk that visitors might be endangered by the condition of these trees. This important topic is a challenge to be faced as today we already have at our disposal modern non-invasive methods for evaluating the safety and health conditions of old trees, such as e.g. the method of acoustic tomography frequently used in medicine [1]. The team members of the submitted project published their practical experience with applying acoustic tomography in research on significant old trees in forest protected areas and in urban environment of cities [2]. This particular experience from the previous applied research was utilized in the Significant Trees project, especially when testing methods of acoustic tomography and evaluating the condition of the trees in the model territory of the submitted project. The results of this modern non-invasive evaluation of the health and safety condition of trees may be applied immediately and directly in the care of significant trees, which might thus be tailor-made for particular individual trees. This solution, elaborated in a comprehensive way, is offered in the Significant Trees project as a second methodology focused on specialized issues concerning the care of memorable trees. The design of a particular method of care for an individual significant tree is complicated by, among other things, the great age of the tree at issue (and the corresponding condition of the tree) and its often irreplaceable significance in the composition of the landscape design, which also relates to its age. The methodology of the care of significant trees is thus oriented towards interdisciplinary knowledge in order to incorporate, if possible, solutions of all the main conflicts between subjects that are still outstanding (nature preservation, protection of monuments, legislation). The methodology contains structured processes: for the specification of silvicultural treatment proposals

for significant trees (cutting, safety binding, remediation of cavities, tree supports, lightning conductors, etc.); for improving the conditions in their location, and for selecting a suitable period for the execution of the proposed silvicultural measures.

This paper deals with applying of acoustic tomograph as support tool to ecological assessment of veteran trees in urban environment. acoustic tomography can be used as very effective support tool for ecological assessment of stability and health of veteran trees in urban environment. This paper presents basic methodological approaches to acoustic tomography of veteran trees under some examples from environmental practice in the Czech Republic.

2. MATERIALS AND METHODS

2.1. Basic principles of acoustic tomograph

Acoustic tomography is a method for the detection of tree hollows and internal damage to trees which is based on measuring the speed of the transmission of an acoustic signal through a tree trunk or another part of a tree. The method is described in the professional literature, e.g. Bucur (2010). The fundamental principle is an estimate of the damage to the part of the tree as a result of the deceleration of the acoustic signal passing through the trunk of a tree with a hollow or decay. The acoustic velocity is directly proportional to the toughness of the material and indirectly proportional to the density. An internal discontinuity (hollow or crack) or damaged timber causes a change in the track of the signal spread and thus its deceleration. In this way, the internal defect can be localized and its areal range can be estimated. What are termed reference velocities are usually calculated for the determination of the damaged timber. Commonly, they are established on the grounds of the analysis of the velocity of the signal in the cross-section that is measured; the particular algorithms are, habitually, protected property of the producer. As a rule, the surface layers of the tree trunks, undisturbed by decay, which can also be verified visually, are used to determine the degree of the damage.

2.2. Applying of the acoustic tomograph to veteran trees stability and health assessment

The primary purpose of this method is to detect the extent of healthy undamaged timber which is capable of transmitting mechanical stress. Other applications, i.e. the determination of the size of the hollow or of the probability of failure, are secondary and thus might be burdened with a possible misinterpretation.

When determining the size of a hollow, it is impossible to distinguish with sufficient precision between a hollow and badly damaged timber, so we cannot always expect to establish the precise extent of a hollow and disturbed timber. Nevertheless, the remaining timber layer, i.e. the mechanically important tissue of the trunk, undisturbed by decay, can be determined with a high degree of reliability.

The probability of failure is determined by comparing the calculated stress in bending strain to the trunk, associated with cross-section geometry, which is, however, complemented with other constants and parameters necessary for the calculation, such as the solidity of the timber and the load applied (bending moment, stress, etc.). It is thus in the interpretation of the primary result that an error might enter the calculation.

It then follows from the principle of the method that there are situations when its application is not suitable or can even be misleading. These situations include the following:

1. measuring at low temperatures
2. measuring of hollows with a filling
3. measuring of hollows with a small longitudinal extent

Concerning the first of these, when the temperature of the tree trunk sinks, in the long term, below 0 °C, the water in the tree tissues freezes. Ice has different acoustic properties from timber and this may cause a faulty measurement. When the surface layers of the trunk freeze, the reference velocity calculation is disturbed, which might result in faulty establishment of the extent of the decay or even in detecting

decay in a healthy tree trunk (reference velocities are set with reference to a significantly harder material). Measuring should not be carried out at all under such conditions.

Concerning the second point, fillings can change the measured extent of the damage. The necessary condition is that the filling fits tightly to the residual wall of the trunk. Fillings of hollows with water seem to be risky. The velocity of the acoustic signal in water is very similar to the radial and tangential speed of sound in timber and the size of the hollow might be distorted; it might seem significantly smaller. Other fillings which have been found to be risky are fresh or old concrete, which might completely cover up the hollows. Prior to the application of the method, it is thus necessary to rule out these cases. Measuring can be conducted after the removal of the filling. Other types of fillings, such as bricks and other construction materials, sand, expanding foam, and others which do not stick sufficiently well to the wall of the hollow, do not cause this distortion and thus do not obstruct measuring.

Concerning the third point, hollows with a small longitudinal extent may be detected wrongly. The reason for that is that there is a difference in the spread of sound in timber in the longitudinal and transverse directions. In the longitudinal direction, the speed of sound travels approximately five times faster. If measuring is then carried out close to the end of a hollow, the signal may pass through the timber above or below the hollow without its speed being significantly reduced and thus without the defect being detected. In order to guarantee the correct detection of a hollow, it is required for the measured layer to be located 20 cm from the end of the hollow. A situation in which the decay is monitored by measurements in several layers is an exception.

The location of measuring instruments is difficult to define schematically as every single tree is unique. In principle, there are two basic cases: i) a situation in which there is an apparent defect in the tree (including evaluating the tree trunk by patting it), i.e. it is obvious or highly probable that decomposition of the wood or a hollow has occurred inside an undamaged trunk, or ii) a situation in which there is no apparent defect in the tree, or rather, there are no external signs of internal damage.

3. RESULTS

The primary outcome of the measuring by means of acoustic tomography is a matrix of the speed-of-sound values between individual sensors (see Table 1). This outcome should always be presented in a test protocol. As the interpretation of results based on this matrix is, however, rather complicated, the principal outcome of the tomography, from the point of view of the evaluation, is a tomogram, i.e. a graphic illustration of the speed of the signal on the shape of the cross-section (Fig.1). A suitable variant is a web of speed values, again depicted on an outline of the cross-section (Fig.2). These visually easily understandable results are the main outcomes of the measurements. By analysing these values, it is possible to define the extent of a hollow and the width of the remaining healthy wall, which are determining parameters for establishing the probability of failure for the measured site as a result of a tree breakage. It is not essential to name other outcomes, such as a table of times. What is, however, always obligatory in a test report is the date of measuring, height of the measured layer, and orientation of sensor 1, provided it is not located in a northerly position.

	1996	1992	2008	1593	1130	719	757	672	900	1482	1841	1976	1982
1996		1792	2085	1921	1283	797	751	603	761	766	1315	1586	2025
1992	1792		2246	2095	1810	1329	1073	824	752	665	924	1329	1794
2008	2085	2246		1888	1946	1897	1430	925	866	921	770	944	1422
1593	1921	2095	1888		1786	2159	1912	1677	1225	1003	898	839	1172
1130	1283	1810	1946	1786		2396	2149	2230	1906	1318	906	868	860
719	797	1329	1897	2159	2396		1669	2239	1971	1816	981	1028	626

757	751	1073	1430	1912	2149	1669		2284	1951	1996	1805	1596	1014
672	603	824	925	1677	2230	2239	2284		1433	1843	1819	1682	1106
900	761	752	866	1225	1906	1971	1951	1433		1695	1960	1922	1805
1482	766	665	921	1003	1318	1816	1996	1843	1695		1929	2040	2128
1841	1315	924	770	898	906	981	1805	1819	1960	1929		1646	2055
1976	1586	1329	944	839	868	1028	1596	1682	1922	2040	1646		1956
1982	2025	1794	1422	1172	860	626	1014	1106	1805	2128	2055	1956	

Table 1. Matrix of measured speed values, primary result of measuring.

Source: Original of Authors.

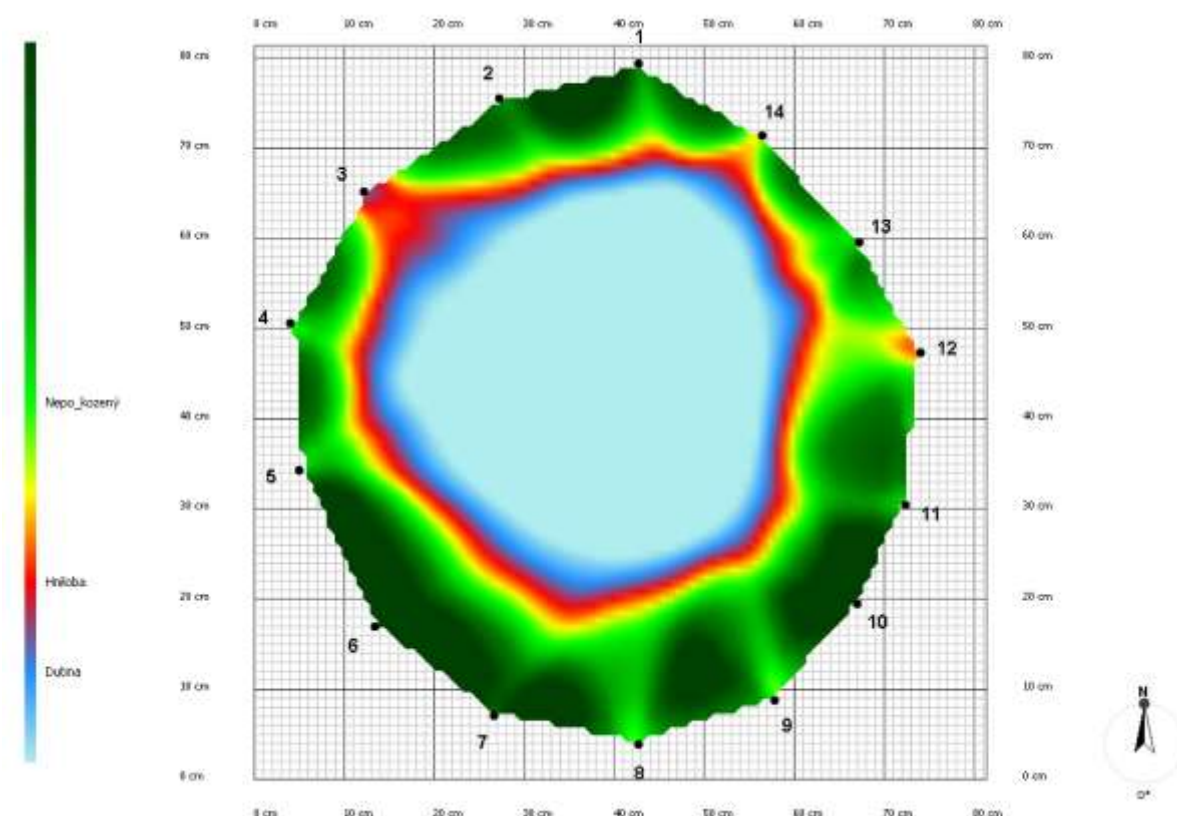


Figure 1. Tomogram of internal damages in veteran tree. Source: Original of Authors.

The interpretation of the results depends on the requirement of the submitter. If what is required is detection of the extent of internal damage then a tomogram, and possibly also a diagram of measuring, is a sufficient outcome (Fig. 1.). For further analysis, however, it is recommended to read the minimum thickness of the residual wall of the given cross-section and determine its orientation towards the prevailing wind direction and the percentage of the extent of the decay compared with the entire area of the cross-section.

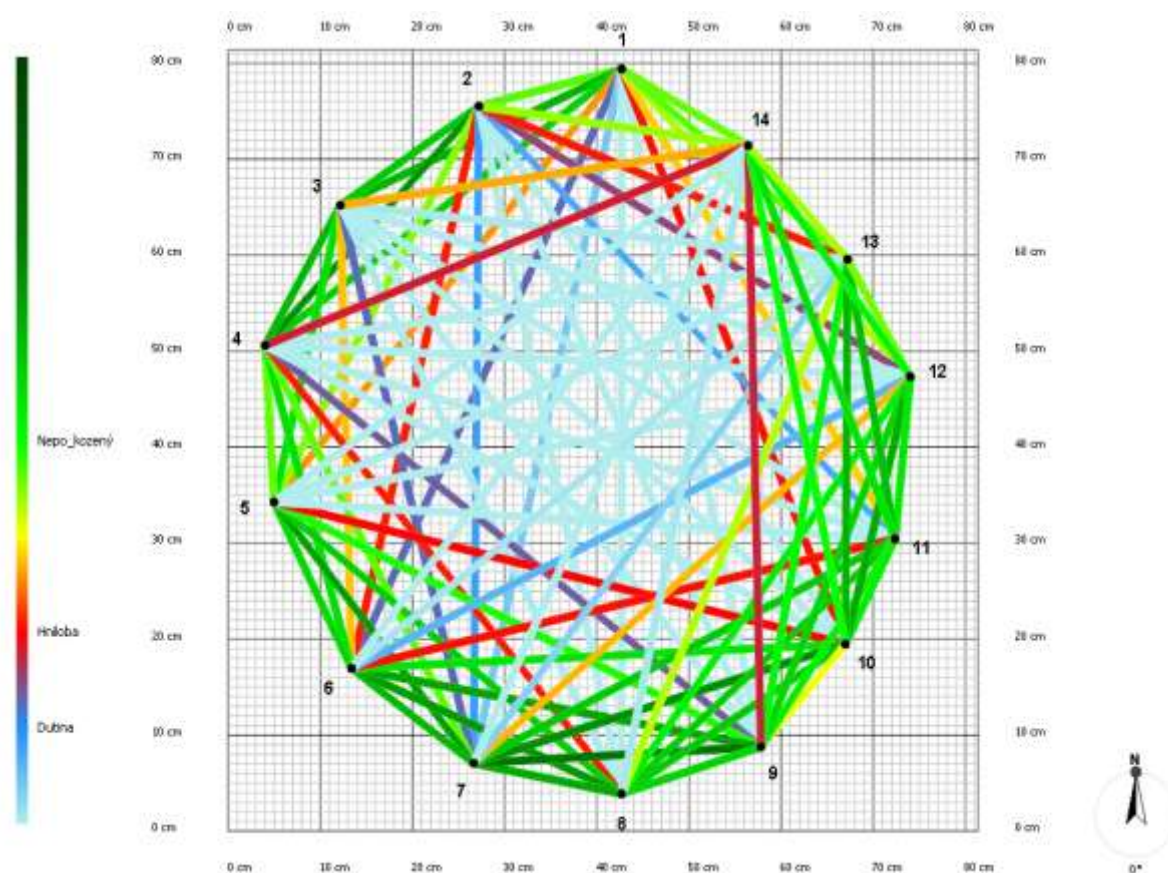


Figure 2. Failure probability analysis of a tree. Source: Original of Authors.

If the required outcome is a failure probability analysis (Fig. 2) of a tree, the measured data is used to calculate a potentially emergent stress, which is then compared with the solidity of the timber of a given taxon.

4. DISCUSSION

Veteran and other very large trees form an integral part of our natural, cultural, and historical heritage. The trees that are regarded as significant are woody species associated with an important cultural or historical event or bearing a message concerning a certain historical fact about the place where they grow. Significant trees put the finishing touches to the local genius loci; they can even be a dominant feature of a cultural landscape [3]. Ancient and monumental trees adorn the character of landscape and highlight valuable historical parks and gardens. Very large old trees often have the character of living monuments and witnesses of long-gone events. With their appearance and uniqueness, they contribute to the broader public being better able to perceive and understand the values of the natural heritage of the cultural landscape [4].

Acoustic methods have recently also been applied in non-destructive analyses of the quality of the wooden material [5]. In the field of tree surgery, this method of acoustic tomography might be applied more often in future in non-invasive examination of the mechanical stability and internal structure of living trees [6]. The potential application of acoustic tomography in trees is based on the finding that sound carries faster in undamaged wood than in a damaged wood structure. Acoustic tomography measures the time that a mechanical impulse (shock wave) needs to cover the distance between the sensors located in the tree trunk [7]. The evaluation of the trunk measurement in the two-dimensional tomogram then depicts and quantifies fissures and hollows in the cross-section of the trunk [8].

By definition, the results of the tomography measurement provide a basis for recommending mere stabilization interventions (the method determines the possibility of failure), practically only circumferential and local reductions, or possibly the installation of bindings [9]. A specific result may be a decision on the possibility of installing drilled static bindings, which can be carried out only on an intact trunk or branch without the presence of decay. When management intervention is prescribed, it is necessary to take into account a safety or sanitary incision.

A stabilization incision can be considered if the value of a safety factor is 1.5 or less [10]. If the safety value is below 0.5, the possibility of stabilization through an incision is significantly reduced as the intervention would usually have to be deeper than the permitted 30%. The decision on the intervention must be carried out individually, after also considering other aspects, such as the historical or biological value of the tree.

In the case of infection of ramification, the installation of binding might be considered in place of circumferential or local reduction. The installation of binding does not have to be combined with reduction incision but it is possible to do so, especially if it is desired to achieve stabilization of a more extensive defect. The installation of a dynamic binding ensures safety for the defective part of the tree (in the event of failure, this part of the tree is held by means of the system that has been installed). This method, however, does not prevent the tree from failure. Enforcement of the defected area can be carried out with a static binding. The designs of various binding styles are described in the relevant standard.

The principle of the method limits, to a certain degree, the use of acoustic tomography in various defects. These are conditions and defects in which the results might be distorted (Fig. 3). The method is based on measuring the speed of an acoustic signal. Parameters of the environment which have the capacity to change this speed might significantly affect the test results. The fundamental one of these is the temperature of the tree trunk. This is the reason why it is necessary to rule out any possibility of measuring under thermal conditions of a tree trunk below 2 °C, i.e. if the air temperature sinks below -10 °C in the long term.

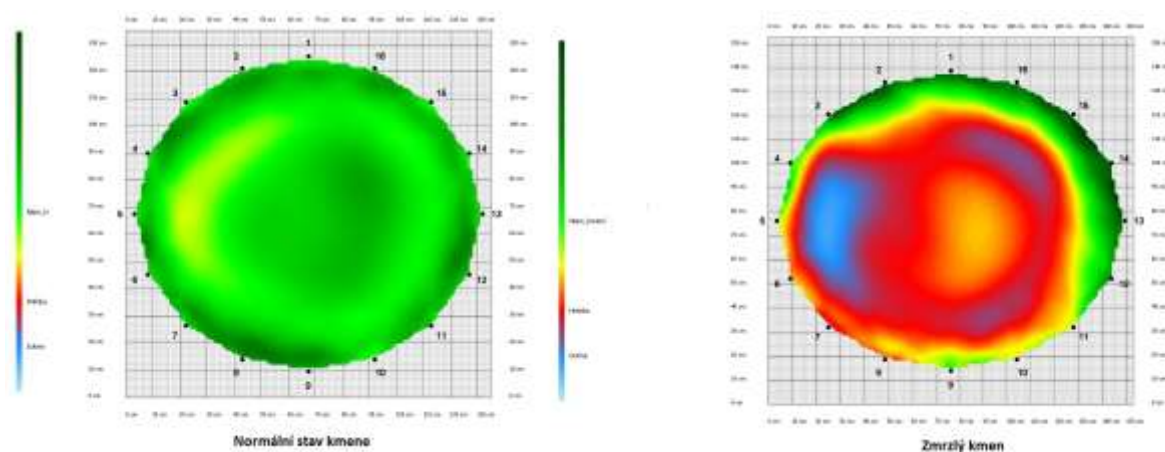


Figure 3. Comparing tomography of the same tree trunk under normal temperatures (left) and under freezing conditions (right). Source: Original of Authors.

Example from our original measurements is shown at Figure 3: Frozen surface layers cause a faulty calculation of reference speed values and, as a result, the tree trunk is wrongly assessed. Measurement with tomography determined the reference speed as 1031-1348 m/s under normal conditions and 1411-1845 m/s in a frozen trunk.

5. CONCLUSIONS

This paper presents acoustic tomography as a perspective support decision tool for management and conservation of very large trees in urban environment regarding to safety of people visiting green urban areas. We believe that in certain significant tree (especially veteran tree) it is not obligatory to follow schematically the restrictions on interventions which are stated in professional standards. Instead, if need be, it is recommended to modify the interventions in significant trees in a suitable way, taking into consideration the current condition of the tree, especially its vitality.

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