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Non-destructive Evaluation of Timber Structures

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Abstract. This paper was made as a preparation for further research of timber and the purpose of this paper is to summarize and describe the currently used non-destructive assessment methods of a timber structures used in modern civil engineering. The principle of each method is shortly introduced and the reader is familiarized with tools needed for the assessment and output parameters provided by the method.

Introduction

This paper is a preparation for further and more complex research of timber beams made of glued laminated timber [4]. Goal is to describe possible methods how to non-destructively evaluate the timber beams, so the basic properties of each beam could be obtained as fast and accurately as possible. It summarizes and describes the currently used non-destructive assessment methods of a timber structures used in modern civil engineering. The principle of each method is shortly introduced and the reader is familiarized with tools necessary for the assessment and output parameters provided by the method [3].

The non-destructive testing of the timber can be effectively used for measurement of mechanical and physical properties such as density, strength, humidity, modulus of elasticity etc. Moreover, even determine location of the defects (knots etc.) can be determined and locate places where the bad part of timber ends and healthy part begins. There are few cheap and fast methods, where the results are available immediately on site, but also ones that are expensive and time consuming where the results needs to be processed by the software. There is a bunch of different methods that can be used; however, the each of them is different in its principle and suitable for a different application.

List of Non-destructive Methods

First and most important method is a *visual method* is a basic way to assess the quality of timber. Kind, approximate age and location of organic or inorganic defects can be relatively easily determined by a naked eye (Fig. 1a). Most importantly the method is used for determination of the following steps for further and more complex assessment. On the other hand there is a need for some basic knowledge of the timber and its properties. This method should be used prior to other methods of the assessment and testing [6].

One of the most common and affordable ways to assess the timber quality is to exploit the *electrical method*. It uses the basic physical phenomenon of electrical conductivity. Using calibrated handheld devices the humidity can be measured and even the presence of the rotting can be detected (Fig. 1b). When the device is attached to the timber, the electrical

resistance between two electrodes is measured, and when the temperature and kind of investigated timber is known, the method can yield quite accurate values. The devices can be purchased for a price in range of tens to hundreds of Euros [2].

Fig. 1. Examples: a – Organic defects (http://uglyhousephotos.com), b – Humidity meter (http://www.elbez.cz).

Most commonly used method for investigation of timber quality in civil engineering is *Method of ultrasonic waves*. It exploits sound sensors to measure the spreading of ultrasonic waves through the material (Fig. 2a). It can be used to determine the timber properties such as density, modulus of elasticity, strength and localize the position of abnormalities (knots, cracks or other damage). The device consists of two sensors and a measuring device that determines the speed of waves spreading between the sensors. With higher humidity of timber the speed decreases, while in case of a crack or any other defect the speed rises. For more detailed investigation the timber specimen must be measured at several locations. The measurement can be accomplished either parallel to fibers or perpendicular to fibers with sensors of different frequencies for different dimensions of the timber. The first way of measurement is good for obtaining approximate properties of the timber and to gain overview of the element. The second way of measurement is good for getting detailed overview of the properties and to localize any defect. The price of the device is in range of hundreds to thousands of Euros. [6]

Radiation method is demanding but suitable for historical timber structures. The method uses ionizing radiation and allows to "look" into the element. It is divided into the radiometry and radiography. The great advantage of this method is its non-destructive nature, but it is very important to take certain safety measures to reduce hazards associated with exposure to radiation. The price of the device is in range of tens to few hundreds of thousands of Euros.
The *radiometry* utilizes the phenomenon of the passage of gamma radiation through a shielding material (Fig. 2b). It leads to the absorption and scattering and these data are then evaluated.

The *radiography* then uses X-rays to create a negative image on the X-ray film or at radioscopy the X-rays passes through the magnetoscope and creates a digital image (Fig. 2c) [6].

Method of spike is not totally non-destructive, but the damage of an investigate specimen is minimal and it doesn't affect its mechanical properties. These are measured using a mechanical device that fires a spike with calibrated strength and measure the depth of penetration into the sample. The most ideal measurement is radial where the measured values should vary up to 10%. If measured tangentially the pin can be fired into hard annual rings and thus the measured values can vary significantly. The maximum penetration depth of the spike is 40 mm. With this measurement the density can be determined as well as the strength and the modulus of elasticity. The most commonly used device for this test is called Pilodyn 6J (Fig. 3a). The price of the device is around a few hundreds of Euros [5].

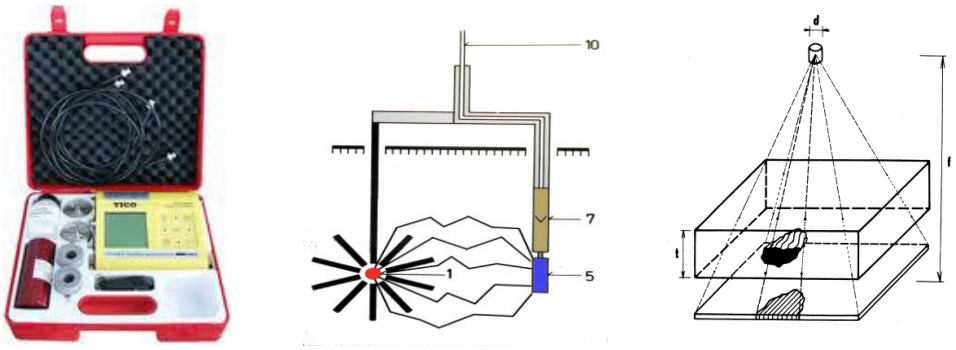

Fig. 2. Examples: a – Ultrasonic device (http://tico.com), b – Principle of radiometry (http://balkanplumbing.com), c – Principle of radiography (http://ndt-ed.org/).

Method of resistive micro drilling allows for the detection of internal defects by using deep drilling resistance micro drill equipped by resistograph (Fig. 3b). The results of the measurement are displayed by a diagram showing the dependence between the resistance of the drill and its penetration. This method is time consuming and is more suitable for a local analysis of properties. The price of the device is around a few hundreds of Euros. [2]

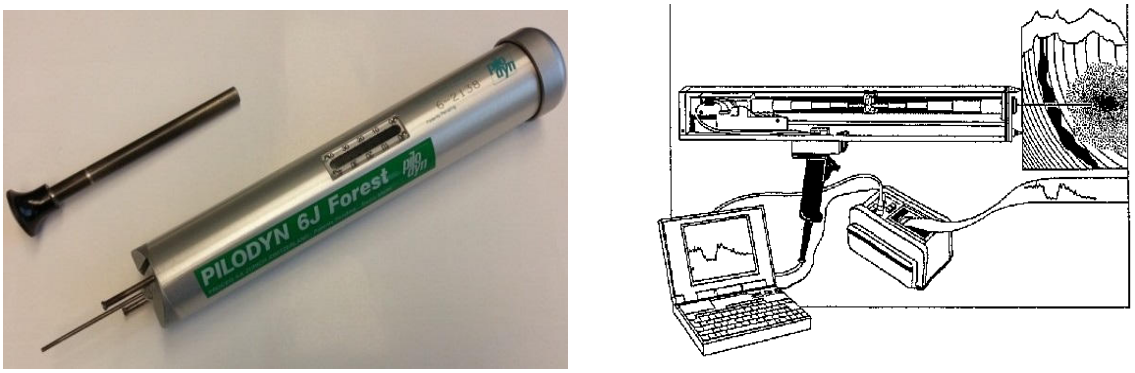

Fig. 3. Examples: a – Pilodyn 6J (http://www.gsxlslks.com), b – Principle of the method (http://www.bam.de/).

Method of resistive micro drilling uses specially adapted drill, the samples with a diameter of 4.8 mm and a minimum length of 20 mm are taken from a specimen (Fig. 4a). Those samples are then tested in the laboratory to determine the mechanical properties (strength, modulus of elasticity, moisture). By the naked eye you can easily determine the presence of a rot, depth of penetration of the impregnation substances and others. The price of the device is around a few hundreds of Euros.

Fig. 4. Examples: a – Specially adapted drill (http://inspectapedia.com/), b – The impact hammer during the measurement.

Pulse method is a dynamic method which is based on measurement of natural frequencies of the element with a set consisting of impact hammer (driver), sensors and computer that records the response of the element (Fig. 4b). Using the impact hammer the specimen is excited and the measurement station subsequently records the excitation force and the response of an element. The result is a response model consisting of frequency response functions (FRF) of the tested specimen. The natural frequencies are then evaluated from FRFs and used to determine the dynamic modulus of elasticity. The price of the set is in range of hundreds to thousands of Euros [1].

Conclusions

There are few cheap and fast methods, where the results are available immediately on site, but also ones that are expensive and time consuming where the results needs to be processed by the software. There are many ways how to non-destructively evaluate the properties of timber and their choice depends on an expert, according to output data needed and available equipment. For our research, the pulse method is appealing to be the ideal method to evaluate timber beams.

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