Inspection of timber construction by measuring drilling resistance using Resistograph F300-S

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Abstract

Preservation of historical and cultural heritage architecture requires information on the condition of building material. In case of construction timber, wood is a natural material and, if not preserved in time, subject to biological and physical decomposition. Timber constructions have to be inspected in order to evaluate stability and safety. To prevent unnecessary wood damages, the Resistograph F300-S was used to evaluate the quality of timber. The Resistograph F300 S is an instrument used for detecting and measuring cracks, voids, and decay in different stages in the invisible inside of a structure. Micro drillings made by a small drilling needle for measuring the drill resistance reveal the relative density distribution of wood. In the present paper, construction timber and joints of different wood species were examined. Micro drills with the Resistograph F300-S were taken from different joints. Additionally, some examples of micro drills in wooden beams under different joints, compared with the corresponding saw-cut, will be given. The results show a good agreement between the recorded data and the condition of the examined timber. Invisible Decay and hollow spaces in structures could be detected. The Resistograph F300-S will provide a good understanding and impression of the current condition of the inspected timber.
1 Introduction

Timber is a simply machinable, versatile usable and regenerating raw material. Due to its favorable material properties it is used for thousands of years as construction and building material. Its high strength linked with less dead weight and its durability were used for establishing wooden supports, stakes, dwellings and working places, bridges and other wood-constructions. Over the course of time great timber constructions were established, which should be conserved for cultural monuments to future generations. Nowadays a restoration of many old timber constructions is necessary. For the restoration of old timber constructions a proof of the transmitting capability of the timber construction is necessary. This can be done by examination of the load-bearing construction units. An important factor is to test those timber structures on decay and rot in order to determine kind and extent of the damage. In addition to a visual control an advanced stability control by taking microdrillings is investigated.

2 Methods and results

2.1 Resistograph F300-S with electronic unit

The IML-Resistograph System is a diagnostic tool used for hazardous tree management and investigation of timber structures and utility poles [1]. It is based on a drilling resistance measuring method. Micro drillings for measuring drill resistance of a small drilling needle will be taken. The drilling needle with a diameter of 1.5 mm to 3.0 mm penetrates into the wooden structure with a regular advance speed, and the drilling resistance is measured. The drilling resistance is transferred to a pointer that is visible at the top of the instrument. The pointer scratches the drilling profile on a waterproof wax paper printout at a scale of 1:1 and optionally the data are stored in an attached electronic unit. A special computer program is available for the instrument. Graph profiles can be downloaded and analyzed.

As the drilling resistance is correlated with mechanical properties, defect zones can be detected and assessed [2]. The advantages of the Resistograph are quite obvious: The wood will only be insignificantly injured, and the drilling hole closes itself due to a special drilling angle that was customized for the drill bit. The shavings remain in the drilling hole. The measuring profiles reveal the relative density distribution of the investigated wood.

The recently developed Resistograph-F-line could be attached to commercially available drilling machines (Figure 1). Their advantageous features are easy operation, compactness, low weight and low cost. The Resistograph F300-S uses a drilling needle of 300 mm length with 1.5 mm shaft diameter and a tip diameter of 3 mm. It was attached to battery-operated drill.
2.2 Drill-resistance profiles of beams with different damages

In wood a set of defects like frost cracks, enclosed bark, tension wood, spiral grain etc. may occur during the growth phase of the tree [3]. Further details on defects and wood mechanics are outlined in [4]. In proper timber constructions such defects, already existing with the building, usually are not incorporated. Defects which occur during the timber construction is assembled, like rot or decay are dangerous for the stability of the construction. Due to the spread of the decay the danger increases. Figure 2 presents a microdrilling through a non decayed beam of softwood. Drilling in radial direction, perpendicular to the annual rings of the tree reveals alternating earlywood and latewood along the penetration path. Because latewood is much denser than earlywood the drill-resistance is alternating too and a typical profile will be recorded.
Figure 2: Drill-resistance of a non decayed timber.

Figure 3 shows drill-resistance profiles of cracks in timber. If the penetration path of the needle is almost perpendicular to the crack (drilling 1) the length of the penetration path of the needle due to the opening of the crack is visible by zero level drill-resistance. If decay spreads out from the crack, the drill-resistance decreases slowly towards the crack. The timber around the crack is not decayed, where the drill-resistance changes immediately. If the needle moves along the crack, the drill-resistance is almost zero (drilling 2). Even if the needle meets the crack at a small angle it could be deviated along the crack. Drilling towards decayed or rotten areas is also addicted to a decrease of the drill-resistance to a lower level (Figure 4). The degree of the decrease of the drill-resistance depends on kind and state of the decomposition. Further information on advanced investigations of the mechanical properties of decayed wood, especially with Fractometer II, is given in [5]. A decrease of the drilling-resistance is given as well as the penetration path of the needle moves along an earlywood zone of an annual ring. Missing the pith scarcely, close to the pith the drilling become more and more tangential to the annual rings. If the needle meets the next latewood zone at a small angle it could be deviated along the earlywood zone. To differ those different reasons for a decrease of the drill-resistance it is useful to make an additional crossover measurement. Two microdrill-measurements, even if possible perpendicular to each other, through the same maybe weak spot will give a good overview of the extend of the damage. Also a visual control if there are enclosed branches and a imagination where the pith could be expected, respectively how the annual rings are arranged could be helpful to interpret the profile. The place where the needle leaves the timber give information if the needle was deviated on its way through. Considering all the information will help to evaluate the hidden damage of the investigated timber [6].
Figure 3: Drill-resistance of timber with cracks.

Figure 4: Drill-resistance of timber with decay.
2.3 Drill-resistance profiles of different mortise and tenon joints

Of special interest in timber constructions are the strength durability of timber joints. For a basic investigation by microdrilling, three different kinds of mortise and tenon joints were produced to have well-defined conditions. In the Figures below the drill-resistance profiles taken with the Resistograph F300-S are illustrated. The drilling was taken through the assembled joint, along the plotted white line.

In Figure 5 the drill-resistance profile through a good looking mortise and tenon joint is illustrated. Both parts of the joint consist of the same material (pine). Reading the profile the tenon could be identified by the missing drill-resistance in the gaps.

![Drill-resistance profile through a good looking mortise and tenon joint](image)

Figure 5: Drill-resistance of a mortise and tenon joint (both pine).

Figure 6 presents the drill-resistance profile through a mortise and tenon joint consisting of two different timber species. The part including the tenon was built of oak, whereas the complement was built of pine. The profile displays beneath a significant higher level through the tenon, because of the higher density of the hardwood. In Figure 7 a part of the tenon was removed to simulate a void or an advanced decay. The mortise and tenon joint was completely built of pine. In the same way than the previous profiles the gaps between tenon and complement are well identifiable. As well the void and its extend is clearly visible. The immediate decrease of the drill-resistance at both sides of the void indicates that no decay spreads out from this void.
Figure 6: Drill-resistance of a mortise and tenon joint (pine / oak).

Figure 7: Drill-resistance of a mortise and tenon joint with a void.
Investigation of timber and timber joints without disassembling by microdrilling needs some experience. If more information is needed further microdrillings are useful. Figure 8 demonstrates a typical drill-resistance profile of an installed mortise and tenon joint. The microdrilling starts nearly tangential to the annual rings. The drill-resistance is moderate without distinct peaks like in radial drillings caused by alternating early- and latewood. While drilling through the tenon, the penetration path is almost perpendicular to the annual rings. After leaving the tenon, the angle between the annual rings and the drilling direction increases, which causes a higher drill resistance.

Figure 8: Drill-resistance of a mortise and tenon joint (1).

Figure 9 shows two perpendicular drillings through an other mortise and tenon joint. Even if drilling 1 seems to be equal to the drilling in Figure 8 the drill-resistance profile differs. The drill-resistance within the tenon is almost zero, because the penetration path moves only through earlywood of a width annual ring. To avoid misinterpretation drilling 2 was done perpendicular to drilling 1. The profile of drilling 2 shows neither a crack nor decay in the tenon but broad annual rings. The distance between two peaks is equal to the width of the annual ring.
3 Conclusion

Microdrillings using the Resistograph F300-S are a good facility to detect internal defects such as cracks and decay in timber constructions. Best results are obtained, if the direction of the drill is perpendicular to the annual rings. Microdrillings in extended earlywood areas i.e. parallel to the annual rings or along cracks show a lower drill-resistance. They are more difficult to interpret. In those cases a second microdrill in cross direction is helpful to determine the mode and extend of a damage.
References


