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ANALYSIS OF DIAGNOSTIC METHODS FOR DETECTING THE PRESENCE OF *GLOEOPHYLLUM* SPP.

Roman Fojtík
Všb-Technical University of Ostrava, Department of Civil Engineering
Ostrava, Czech Republic

Kateřina Dědková
Všb-Technical University of Ostrava, Centre for Advanced and Innovative Technologies
Ostrava, Czech Republic

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ABSTRACT

The development of wood use as a renewable raw material for construction caused that can be also seen as the construction of bridge structures, which have to withstand the environment. It is a modern construction using LLD or replicas of historical buildings using RD. Many of these constructions, despite impregnation, are struggling with biological pests that greatly reduce their durability. Revealing of the most dangerous ones is complex and usually cost such amount of money. Diagnostic methods and their results are different. The article deals with the comparison of the diagnosis methods of wood decaying fungi from the family of *Gloeophyllaceae* to the real construction.

KEYWORDS: Wood, diagnostics, wood decaying fungi, bridges.

INTRODUCTION

With the use of wooden elements, construction of wood decaying fungi from the family *Gloeophyllaceae* is the so-called acoustic tapping method. Is this method sufficient to determine the extent of the damage? With the use of wooden elements for construction of exterior structures, especially wooden footbridges and bridges can be encountered one of the most dangerous families of wood decaying fungi attacking clay and deciduous wood in Central Europe (Irbe et al. 2012). It is *Gloeophyllum* spp. An example of the attack is a large number of wooden transport structures. Revealing the attack is especially difficult in the first phase. The common diagnostic method used in practice is the so-called acoustic taping method, which has been used for generations. Since it is a very aggressive and rapidly spreading species of wood decaying fungi, the early detection is key to the possibility of remediation or prevention of serious disruptions or accidents. To determine the occurrence of this dangerous wood decaying fungi there are currently many possible diagnostic methods through acoustic, cultivation, and DNA tests (Hervé et al. 2014, Shirouzu et al. 2016). Reliability, as well as the timeliness of detecting an attack using some of these methods, is the subject of this article.

MATERIAL AND METHODS

It is a bridge construction on the river Vltava in Český Krumlov. Since it is a building in a heriage protected area, wood and design have been selected as a replica of the original bridge. This Lazebnický bridge serves as a local road connecting Český Krumlov castle with the historical downtown, see Fig.1

Fig. 1: Lazebnický bridge.

It is a two-pole continuous bridge with an upper bridge deck. Bearings are sliding steel tangential. There are no bridge joints in the construction. The supporting steel core is made of elements of the temporary bridge„ Škoda – Faltus". The batten support is made up of six main welded stiff beams of the shape I. The transverse bracing is provided by U-shaped cross members, which connect the main stiff beams. Horizontal bracing is ensured by L-shaped rolled profiles. On the steel beams there is a wooden bridge deck with raised two-sided sidewalks and a wooden railing. The bridge deck is made of spruce crossbars (prisms) thickness 160 mm and a height of 140 mm and the road elements are oak thickness 0.05 m. Crossbars are made up of three elements of different lengths as shown in Fig. 2. The longest elements by its execution constitute a support for the construction of the railing. Medium-length crossbars also have a static scheme of a continuous beam with overhanging ends. The shortest crossbars are stored as continuous beams. The road elements are placed obliquely across the crossbars as shown in Fig. 2. (Ceсháková et al. 2012, Vavrušová et al 2016, Vašková et al. 2016, Vašková et al. 2017, Rumlová and Fojtík 2014).

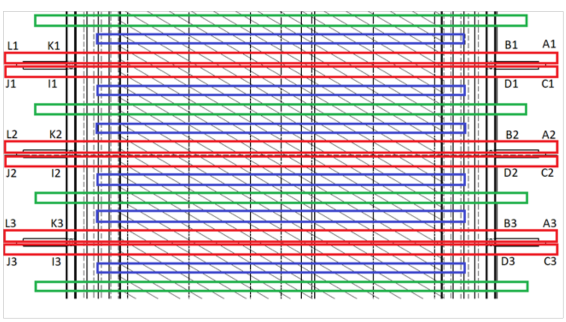

Fig. 2 :Scheme of the layout of wooden elements of cross members and road elements.

The wooden construction was protected by the KORASIT CK impregnating agent. It is a fluid based on chromium and copper compounds. The impregnating agent acts against fungi and wood-destroying insects. Preservatives containing chromium together with copper are then fixable in the treated wood and resistant to water leaching (Reinprecht 2016). The impregnation was applied by vacuum-pressure technology, however technical details about this process are unknown. The labelling of the elements corresponds to the authentic labelling at the measuring point shown in Fig. 6.

Four years after put into service some fructification of *Gloeophyllum* spp. started to appear on some crossbars. These findings suggested an advanced stage of attack on the bridge construction (Lokaj and Klajmanová 2014, Rumlová and Fojtík 2015).

Fig. 3: The attack of wood decaying fungi from family Gloeophyllaceae.

The cause of attack

The occurrence of wood decaying fungi requires especially suitable conditions for growth. Basic parameters include wood, moisture, temperature and wood pH. In particular, impregnation prevents the attachment and attack of wood by, for example, changing the pH. Impregnation perfectly protects the surface, and if it does not break, the wood is protected. Cracks occurring after impregnation can be a way of attacking wood decaying fungi, including *Gloeophyllum* spp. On the construction of the Lazebnický bridge, fructification grew only from cracks in wood. This attack was caused by impregnation of wet wood, due to which the surface of the construction elements was perfectly protected. After the wet wood has been incorporated into the structure, it has been rapidly dried during the summer period, which has caused considerable leakage cracks. This damage originated primarily on the top of the sunny side of the cross members, due to that water and impurities have formed into the core of the cross section, creating the ideal conditions for *Gloeophyllum* spp. (Reinprecht et al. 2001, Reinprecht and Vidholdová 2017).

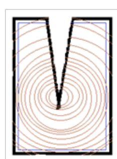

Fig. 4: The manner of disruption.

In case of the attack of the impregnated element by the wood decaying fungi from the family *Gloeophyllaceae*, which after the incorporation contains drain cracks, the unprotected core is affected and the internal mass of the cross-section is destroyed. Due to the impregnation of the element circumference, there are no signs of attack with this fungus until the frustum appears and this is mostly late. Early identification of infection by fungi from thefamily *Gloeophyllaceae* is key to ensure the viability of construction.

Gloeophyllaceae

These wood decaying fungi attack both softwood and deciduous trees. For growth it needs a temperature range of 5 - 46°C and a moisture of 30 - 60%. This is a very dangerous fungi especially for building constructions. The danger is mainly associated with the destruction of wood mass, which usually proceeds from the core of the cross-section to the outside.

Spores of these wood decaying fungi sprout in dry wood cracks. It forms a substrate mycelium orange colour that grows through wood. Daylight, however, stops its growth. *Gloeophyllaceae* have a particularly high resistance to weathering, especially to drying out, both mycelium, frustration and spores. Damage on the surface, unless a fructification appears, is not apparent. The remediation work is complicated by the fact that the fungi acts inside the wood and in these cases often only surface treatment is not sufficient.

Wood decaying caused by fungi is normal process occurring when conditions such as temperature and humidity are optimal for fungi growing. There are three major types of wood decaying by fungi. White rot basidiomycetes degrade both wood polysaccharides and lignin. In certain cases, they delignified wood selectively. Brown rot basidiomycetes degrade wood polysaccharides whereas leave behind an oxidized residue of lignin. The last types are soft rot ascomycetes and deuteromycetes which look like brown rotters in that they degrade wood polysaccharides more readily than lignin. Gloeophyllum sepiarium is very common saphrophytic wood-decaying fungi belonging into the brown rot fungi (Goodell 2003).

Diagnostic methods

The most commonly used are three types of diagnostic methods that differ in effectiveness, proficiency, and purposefulness. Methods are selected primarily according to economic and time requirements.

a) *Acoustic tapping method*
This method is one of the oldest and most commonly used building practises. This is primarily beause of the minimum technical requirements and speed of identification. The method consists in tapping the stick on the monitored element, and human hearing monitors the hollowness of the element. This method can be influenced by many factors, including, for example, the boundary conditions of the element storage, its humidity and the degree of damage. For a bridge construction where there is a large number of the same elements both in terms of storage and moisture, this method can be effective.

b) *Acoustic ultrasonic method*
Acoustic methods include ultrasonic diagnostic methods that are able to detect cavities in wood. These methods cannot be used on some constructions primarily because of access to tracked elements.

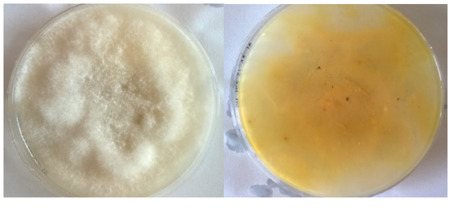

Fig. 5: Cultivation of mycelium on agar plate.

c) *Cultivation method*
Another possible way of identifying wood attack lies in its cultivation, when it is possible to grow mycelium under the given conditions, which subsequently serves to identify the wood decaying fungi. The mycelium of *Gloeophyllaceaei* s orange-rosy, when it is young it is white (Fig. 5). Re-inoculation on a new agar plate and cultivation at 40°C can prove the presence of *Gloeophyllaceae* because other wood decaying fungi do not grow at such high temperatures.

d) *DNA*
The last, but time and economically, most demanding method is DNA isolation from mycelium and its subsequent analysis, where the so-called DNA finger print is obtained. This analysis allows a very precise identification of the wood decaying fungi presented in wood. However, the material and technical equipment necessary to conduct these analysis considerably limited by its extension for routine (Borges et al. 2017, Gabriel and Švec 2017).

RESULTS AND DISCUSSION

Analysis of diagnostics of observed bridge construction

The aim of the diagnosis was to determine the extent of damage of the wooden crossbars of the Lazebnický bridge with a *Gloeophyllum* spp. Two methods were selected for this task. The first method was an acoustic tapping method designed to quickly detect damaged elements. The second method was the cultivation method aimed at confirming the tapping method, as well as the precise determination of the extent of the attack. Both methods were applied to all vertical crossbars that were threatened by leaking water and dirt. On each console, two-beam 4 places were observed. The first field was marked with the section ABCD and the KLIJ section (see Fig. 2). The second field was marked as EFGH and OPMN sections. In total, it was a set of 212 elements.

The acoustic tapping method was applied using a pestle that that created the tracked element. A professional technician evaluated the subsequent acoustic response. Acoustic sound has been always compared to the cross beam response for optimal results. The result was the determination of the affected elements, which is shown in Fig. 6.

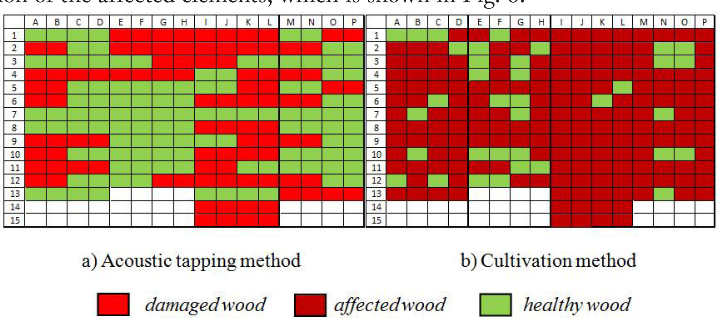

Fig. 6: Graphical representation of results obtained by acoustic tapping method and cultivation method.

From the graphical representation of Fig. 6a is visible that about 46% of the monitored elements were declared as damaged by the acoustic tapping method. The probable cause of the damage was determined *Gloeophyllum* spp.

Cultivation method was selected as the control method. Samples were taken from all the elements studied by a core drill and separated for subsequent laboratory evaluation of the occurrence of *Gloeophyllum* spp .Cultivation of wood samples was performed on Sabouraud agar with gentamycin and chloramphenicol (Trios, spol. s.r.o.) at room temperature with higher moisture and under dark conditions for one week. All samples were cultivated in parallel arrangement. After one week of incubation growth of mycelium of fungi was observed in the case of affected wood sample.

From the graphical representation of Fig. 6b) is visible the cultivation method revealed an infiltration of *Gloeophyllum* spp.at 83% of the monitored elements.

The comparison of methods

Both methods were applied to the same elements, but with different results. Affect to the elements, determined by the acoustic tapping method, included about 46% of the observed elements. The remaining approximately 54% were negative. The control culture method confirmed the wood decaying fungi affect in approximately 41% of the damaged elements identified by the first method. In addition, the extent of the attack on the monitored elements has increased by about 37%. The remaining 17% were declared as healthy wood. These results are indicated in Fig. 7.

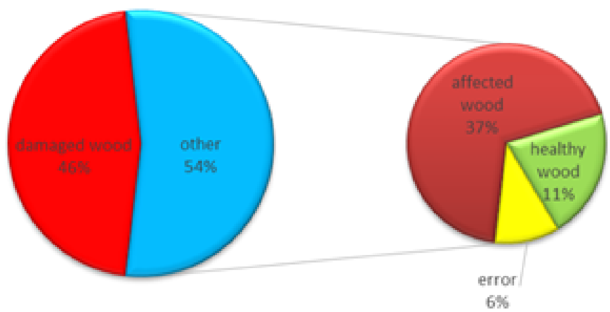

Fig. 7: Graphical representation of extent of damage and wood attack.

Damaged elements diagnosed by the acoustic tapping method revealed about 6% of damaged construction elements, which were not confirmed by the control culture method. This difference can be considered an error that could have been caused by several factors in diagnostics, including the extent and size of the cracks, the structure of the wood mass, the influence of the environment, noise and others. These elements were declared undamaged because they did not show the presence of wood decaying fungi by the cultivation method. This error could also be a mistake in the cultivation method, as an unlikely venue for sampling as the most likely cause. This factor is very unlikely because the sampling was always done to capture potential damage but cannot be excluded.

In terms of economic comparison of both methods, a more favourable method is acoustic tapping method in the ratio of 1: 5. The demand for the cultivation method is mainly in sampling, subsequent sorting and preparation for laboratory diagnostics and cultivation and evaluation itself. The most sophisticated method of detecting wood decaying fungi is the so-called DNA test. However, this method is economically incomparable with the cultivation method.

CONCLUSIONS

Wood decaying fungi from the family *Gloeophyllaceae* are one of the greatest hazards especially for wooden bridges and footbridges. Her hazards are especially difficult to detect with a regular visual inspection. These fungi mainly attack the cross-section core, which is not so protected by impregnation as the envelope of the wooden structural element. After the attack, destruction of the internal structure of the cross-section of the wood core is very often and only an undamaged impregnated envelope remains. The attack of this wood decaying fungi has been monitored on about 10 bridges and foot bridges in the Czech Republic.

At the monitored construction of the historic Lazebnický bridge across the Vltava river in Český Krumlov, 212 pieces of cross-pieces were diagnosed to determine the damage of the wooden elements. For this purpose, the acoustic tapping method was used, which is a common diagnostic method for determining the damage of the elements due to the wood decaying fungi from the family *Gloeophyllaceae*. Laboratory culture was selected as the control method. The results show that the classical acoustic tapping method is very accurate from the viewpoint of wood damage by wood decaying fungi from the family *Gloeophyllaceae*. The range of attack, as demonstrated by the cultivation method, is much larger, mainly due to the different stage of growth of *Gloeophyllum* spp. in individual elements.

The research proved the effectiveness and efficiency of the acoustic tapping method. Recommendations for practical application consist in the diagnosis of damage to the elements by an acoustic method and the recommendation of removing all elements of wood near the exposed damage with the same humidity parameters (Bak et al. 2012).

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Roman Fojtík*
Všb-Technical University of Ostrava
Department of Civil Engineering
Ostrava
Czech Republic
Corresponding author: roman.fojtik@vsb.cz

Kateřina Dědková
Všb-Technical University of Ostrava
Centre for Advanced and Innovative Technologies
17.Listopadu 15/2172
708 33 Ostrava
Czech Republic