10.2478/tvsb-2013-0010

Transactions of the VŠB – Technical University of Ostrava

No. 2, 2013, Vol. XIII, Civil Engineering Series

paper #10

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DIAGNOSTICS OF THE TECHNICAL CONDITION OF TIMBER ROOF FRAMES USING FAKOPP 3D SONIC TOMOGRAPH

Abstract

The Fakopp 3D Sonic Tomograph is used in practice for making the diagnosis of latent, i.e. internal, damage to living trees. We experimented with the possibility of using this device for decay detection in timber elements of a roof frame. It was tested in the laboratory (in labo) as well as in the roof space of a historical truss (in situ). We examined the timber elements of historical wooden trusses that had relatively a small diameter.

Keywords

Sonic tomograph, timber element, wood damage.

1 INTRODUCTION

The many valuable historic timber structures are located in Slovakia. There are already trusses of the Middle Ages [1]. In the field of sustainability of historic roofs is necessary to use non-destructive diagnostic methods [2, 3, 4]. The aim of our work was to find out whether this tool would be suitable for diagnosing the technical condition of timber components in historical trusses. Since it is a semi-destructive method, there are minimal interventions in wood [5]. In fact it is the measuring of time taken for sonic stress waves to pass through the wood of a tree. A series of nails are installed around the tree at the measuring plane as the measuring points and are used to send or receive sound waves that are generated by hammer tapping on one of them. Longer time indicates internal biotic damage, possibly a cavity in a tree trunk or inside a timber element. The velocity of sonic waves in sound wood depends on its species, moisture content, and the direction of measurement [6]. The paper presents results of the study investigating 6 timber elements - 4 were tested under laboratory conditions, and 2 in a roof space.

Employed equipment: the Fakopp 3D Sonic Tomograph, the Greisinger Hygrometer for specifying absolute wood moisture, a tape, a calliper.

The evaluation of spatial distribution of the speed of sound in timber elements was compared with the outcome of their visual inspection. The average velocity of ultrasonic waves in timber component, depending on wood species, is shown in Table 1.[7]. This evaluation was processed graphically, and has the following shading (see Fig. 1):

- dark green - sound wood,
- yellow to red - the stage of wood decay,
- blue - the presence of cavities.

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Tab. 1: The average velocity of a ultrasonic wave according to the tree species [7]

The average velocity perpendicular to grains (m/s)			
The stage of damage	tree species		
	spruce, fir	pine	oak
1	1260 - 1800	1160 – 1750	1640 – 2100
2	920 - 1260	840 – 1160	1180 – 1640
3	750 - 920	680 – 840	850 – 1180
4	500 - 750	500 - 680	600 - 850

2 CASE MEASUREMENTS IN SITU

2.1 The village of Turzovka – a Roman Catholic church, the truss over the sanctuary

The church has an original timber roof frame over the nave dated from 1759 [8]. It is made of spruce with hewn elements. A part of the truss over the sanctuary is colonised by bats, there are obvious leavings of their excrements on timber. Measurements were made in a collar beam nearby the central trestle. The lower speed of sound indicated the higher moisture content in wood. It is because its capillaries that were filled up with the air are now filled up with water [6]. In consequence of this the environmental resistance to spreading ultrasonic waves rises. The collar beam is 190/140 mm horizontally. It is clearly broken-down by ligniperdous insects, but it is weak, non-active damage. There are visible cracks close to the surface on its bottom, maximally 5 mm wide.

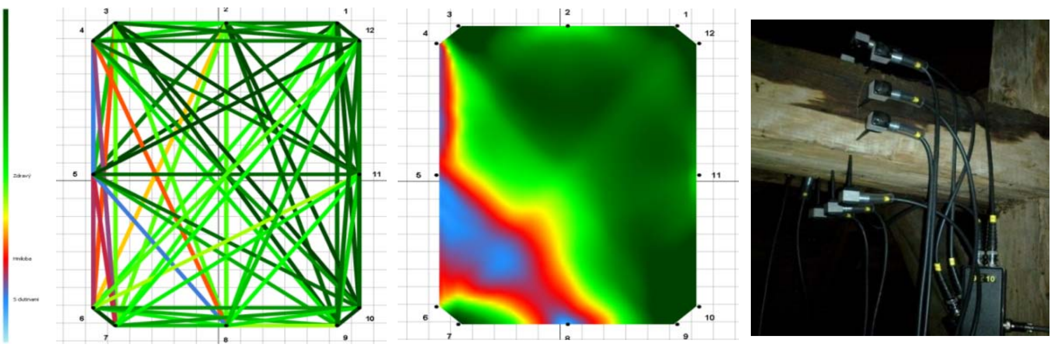

Fig. 1: The collar beam - the roof frame of the Turzovka´s church. The linear and 2D tomogram, right - the photo from measuring

The tomograms prove that there are cavities, or some larger crannies in the lower corner of its cross-section, which is not evident from the visual inspection. Measurements may be affected by bats´ droppings.

2.2 The village of Turzovka – a Roman Catholic church,the truss over the main nave

The church has an original timber roof frame over the sanctuary dated from 1759 [8]. This truss is quite well-preserved; there is some local significant damage, especially on its foot. A foot strut of a king post, with dimensions 180/215 mm, on the southern side was tested. The visual examination refers to perceptible surface damage. It is the consequence of ageing and an attack of ligniperdous insects - woodworm that is not active. There are also splits nearby the surface, their width is max. 5 mm, their depth is unequivocal. The tomogram demonstrates only surface damage of a timber element which is sound at its depth.

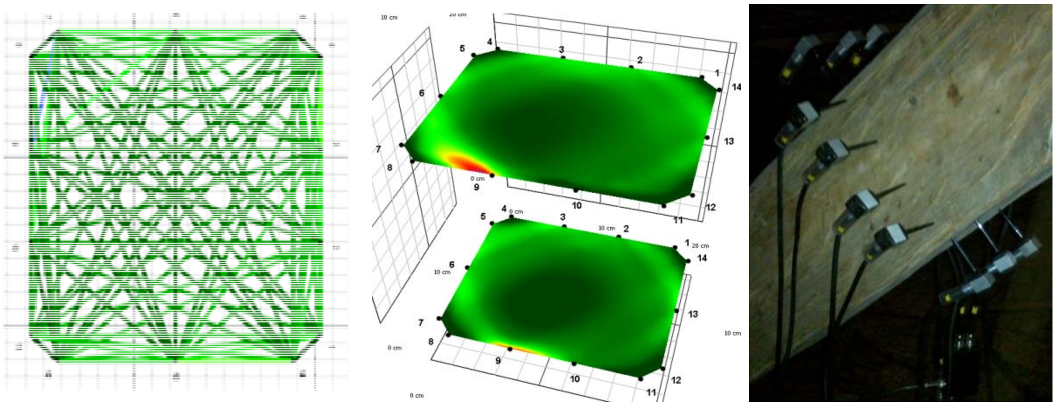

Fig. 2: The foot strut - the roof frame over the nave in the Turzovka´s church. The two-level tomogram with 300 mm spacing, right - the photo from measuring

3 CASE MEASUREMENTS IN LABO

3.1 The village of Čierny Váh - a part of a strut of the church truss.

The roof frame of the church in Čierny Váh is of 1803 (d) [9]. Measured timber part is spruce, and has 190/170 mm. The moisture content of wood is 10 %. The ocular inspection confirms distinctive breaches, and surface degradation caused by ligniperdous insects and ageing.

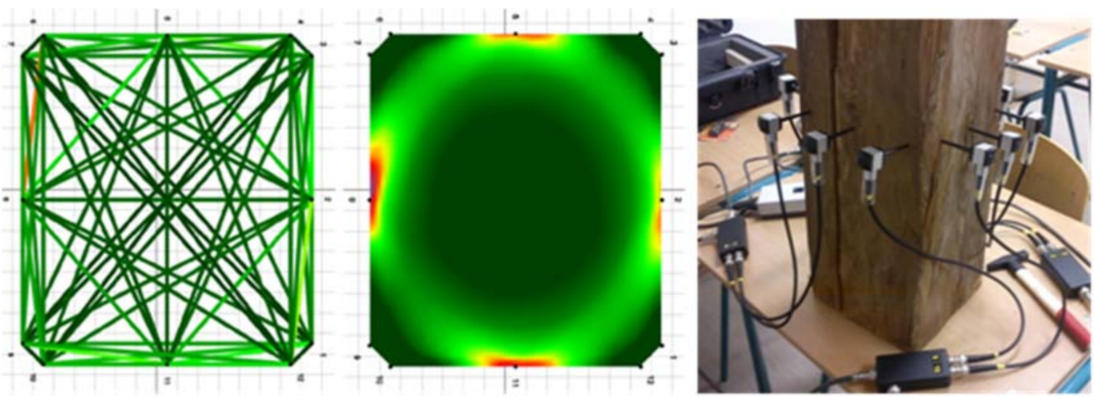

Fig. 3: The part of a strut - the roof frame of the church in Čierny Váh. The 2D tomogram, right - photo from measuring

One evident crack is 70 mm deep, and reaches almost the diameter centre. Its width is 12 mm on the surface with gradual tapering towards the centre. It was not clearly caught by scanning. The linear tomogram indicates a defect between sensors 6 and 8, unlike the 2D one.

3.2 The village of Kamenná Poruba - a part of a post of the church truss

The truss construction, made of spruce, arose in 1870. The moisture content of wood is 10%. We studied a timber element with dimensions 230/190 mm. The visual examination reveals some damage on its surface as a result of an activity of ligniperdous insects. It has a fissure extending to 100 mm, running towards the centre where it has the width of around 1 mm. Despite it is rather deep, it is not visible neither in the 2D tomogram, nor in the linear one.

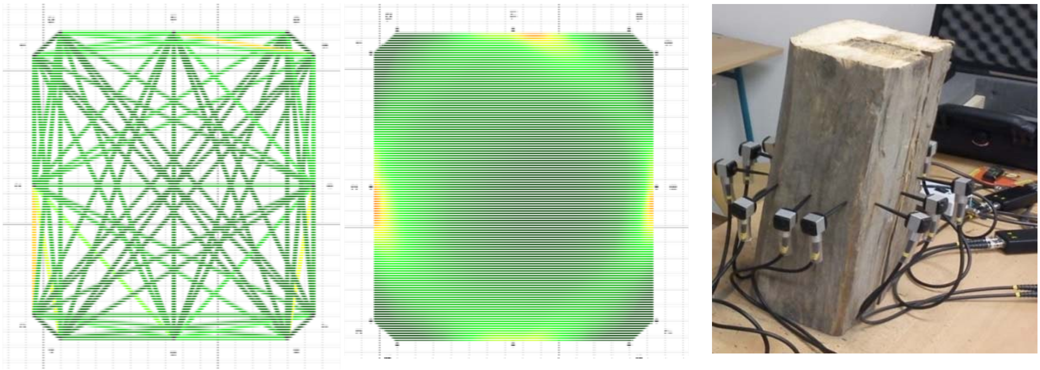

Fig. 4: The part of a post - the roof frame of the church in Kamenná Poruba.
The 2D tomogram, right - photo from measuring.

3.3 The village of Socovce - a part of a strut of the church truss

The roof frame of the church in Socovce is of 1775 (d) [10]. The timber strut is spruce with the cross-section of 190/150 mm. The moisture content of wood is 10%. There are discernible marks of damage from ligniperdous insects, and more surface cracks max. 3 mm wide. One of them is 10 mm wide and 50 mm deep, but it is not found in the 2D tomogram. The linear one shows a defect between sensors 2 and 3. There is obvious surface damage in the middle part of the cross-section.

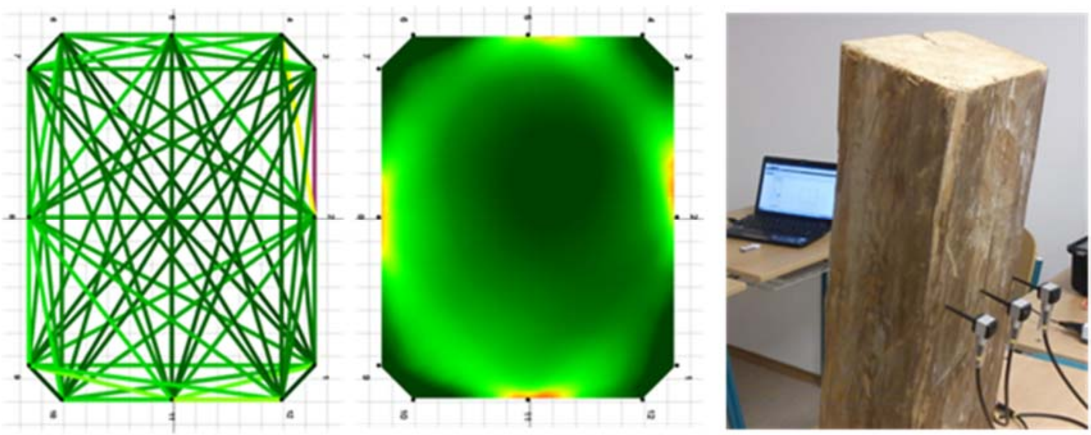

Fig. 5: The strut - the roof frame of the Socovce´s church. The linear and 2D tomogram, right - photo from measuring

3.4 The village of Čimhová - a part of a wall plate of the church truss

The roof frame of the church in Čimhová is of 1775 (d) [8]. This part of a wall plate in the church truss made of fir was chosen as an example of an irregular cross-section of a timber element. It is approximately 200/190 mm. The visual study unveils the higher age of an element as well as its decay in a large measure. The leaking water caused considerable damage

The tomogram refers to its surface damage with one rotted small channel, and points out the difficulty of achieving an exact scan of such a section. Therefore, the precision of this measurement is debatable.

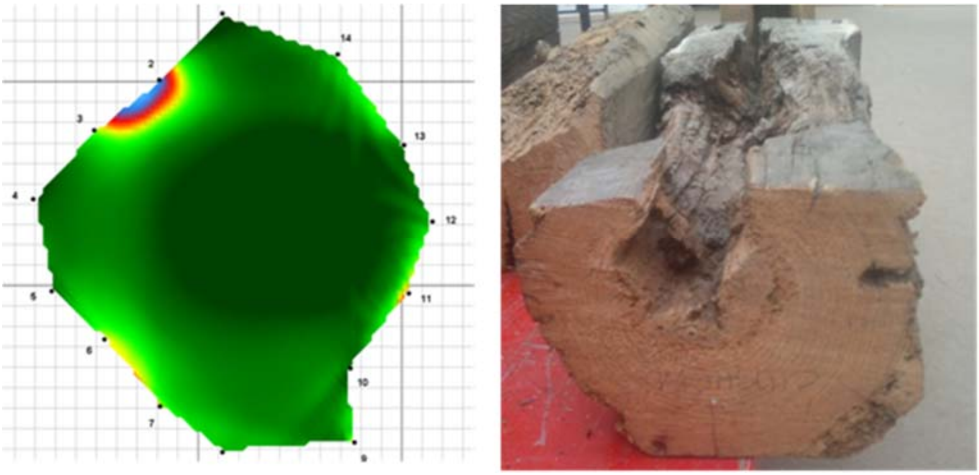

Fig. 6: The involved part of a wall plate - the roof frame of the Čimhová´s church.
The tomogram, left - photo of measured element

4 CONCLUSION

The Fakopp 3D Sonic Tomograph is used for making the diagnosis of latent, i.e. internal, damage to living trees. Due to the conservation as well as the historical value of investigated timber elements it is necessary to prefer non-invasive detection techniques to prevent the loss of valuable information. That is why sensory perception (visual, tactual, auditory) is required to be used in determining the technical condition of historical trusses. However, such a method is not always sufficient, and therefore it is recommended to employ the devices that can provide non-destructive examination [11].

The paper was aimed to highlight the differences between the results gathered by visual inspection, and those that were obtained in making the diagnosis using the Fakopp 3D Sonic Tomograph. Six timber components were studied and assessed. Introduced outcomes prove that the visual assessment is in contrast with that which was made with the equipment. The evident cracks on timber elements, tested in the laboratory, did not occur in tomograms.

It can be claimed that this measuring manner was not successful in the case of the timber component damaged by breach running almost into its centre. It means that such a procedure may not fit for crack detection in timber with small dimensions. The fissure was not found and scanned as supposed. It is needful to take into consideration certain disadvantages of measuring, particularly the fact that only one cross-section, i.e. the area of one element, is investigated. Regardless this, it would be advisable to continue in testing this tool as a helpful instrument to settle the technical condition of historically valuable timber, and to try to specify what may affect the quality and accuracy of measurements made with this device.

ACKNOWLEDGEMENT

This contribution is the result of the project implementation: "Support of Research and Development for Centre of Excellence in Transport Engineering" (ITMS: 26220120031) supported by the Research & Development Operational Programme funded by the ERDF.

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