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Sound absorption by tree bark

Mengmeng LI[1]; Timothy Van Renterghem[2]; Jian KANG[1,3]; Dick Botteldooren[2]

[1] School of Architecture, Harbin Institute of Technology; Heilongjiang Cold Region Architectural Science Key Laboratory, China

[2] Ghent University, Faculty of Engineering and Architecture, Department of Information Technology, WAVES research group, Belgium

[3] UCL Institute for Environmental Design and Engineering, The Bartlett, University College London, UK

ABSTRACT

Scattering of sound waves by trunks is part of the noise reducing potential of tree belts, and it has been shown before that the absorbing properties of the trunks are relevant in this respect. Detailed information on bark absorption is currently very limited. Therefore, laboratory experiments were conducted with an impedance tube to measure the bark sound absorption of various species, including variations in bark thickness, tree age, density, and trunk diameter. Preliminary measurements were made to define the relevant part of the trunk for its acoustic absorption and to come to a reproducible sample handling procedure. The measurements show that the absorption (at normal incidence) is generally below 0.1 for the deciduous species considered, and that there is a small variation in between them.

Keywords: Sound absorption, Tree bark, Impedance tube

1. INTRODUCTION

Scattering of sound waves by trunks contributes largely to the noise reduction of tree belts, and it has been shown before that also the absorbing properties of the trunks are relevant in this respect. While absorption by plants did receive quite some attention before (1, 2, 7), research on bark absorption is very limited.

In his pioneering work, Reethof (3) measured the absorption coefficient of a few tree bark samples in the impedance tube. His main conclusions were that the absorption is rather frequency independent in the range of frequencies covered. Some species gave significant higher absorption values.

However, these were only exploratory measurements, and no further analysis was made to reveal what parameters could potentially predict tree stem absorption. Since this study dates already from the 70's, and no further attention has been paid to acoustically characterize tree bark, more extensive and systematic work is needed as will be initiated in this paper.

Although the absorption of bark might be rather low, full-wave numerical simulations reported in Van Renterghem's research (4) shows that even small variations can be relevant e.g. when looking at sound propagation through tree belts. Knowledge of the variation in bark absorption between species and their influencing parameters are therefore of interest to optimize sound attenuation by tree belt.

There are two main methods for measuring the sound absorption coefficient of a material : one is the reverberation chamber method, and the other one is the impedance tube method. Both have been used before to acoustically characterize plant material. Horoshenkov (1) used an impedance tube to test the sound absorption coefficient of five different types of low growing plants with and without soil. It was found that the absorption coefficient of plants is mainly influenced by the density of the leaf area and the leaf main orientation angle. He also showed that there is an interaction between plants and the soil: for heavy-density clay base soil, the absorption in combination with plants significantly increased compared to bare soil. For low-density substratum soil, this interaction is much less pronounced. Yang (2) carried out measurements in a reverberation chamber to test random

[1] limmeng@stu.hit.edu.cn

[2] timothy.vanrenterghem@ugent.be

incidence absorption of plants. In the mid frequencies, the absorption coefficient of top soil increased approximately with 0.2 in case of plant cover. Near 2000 Hz, there was no obvious relationship between absorption and plant cover, and the absorption decreased by about 0.1 when the vegetation cover increased at higher frequency.

In the current work, the impedance tube technique has been used to measure the absorption of bark samples, similar to Reethof. In contrast to the reverberation chamber method, the absorption at normal incidence is then measured.

2. METHODOLOGY

2.1 Experimental Setting

The diameter of the impedance tube was 100 mm, yielding a maximum frequency of 1.5 kHz at which absorption can be measured. A two microphone technique was used, and phase errors were minimized by microphone swapping. The benefits of this specific procedure were shown before in Chung's research (5, 6).

The effect of the necessary thickness of the sample was first tested. We started off with a thickness of the wood sample of about 5 cm, while the bark itself is about 1cm. The wood behind the bark has been cut from 4 cm to 2 cm in different steps. Above 2cm there was no statistically significant effect on the absorption.

To prevent the circumferential gap problem, it has been ensured that each sample was well sealed by the use of plasticine. Each sample was put several times in place (and re-sealed) to check the reproducibility of this rather uncommon sample handling (see Fig.1). Variance analysis shows that the repetitions are not significantly different. Before and after each measurement, the absorption of the empty tube was measured to ensure correct measurements in this low absorption range.

In this study, from each trunk cross section, four cylindrical samples from different orientation along its circumference were made including about 2cm of wood behind the bark.

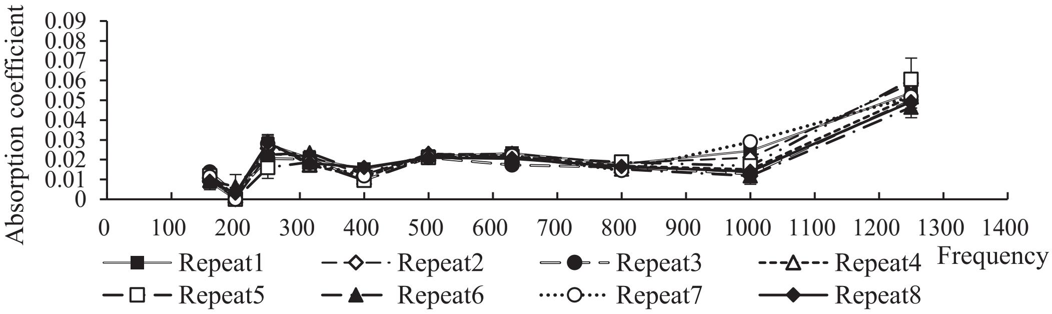
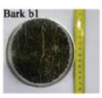
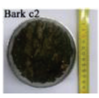
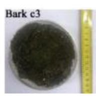


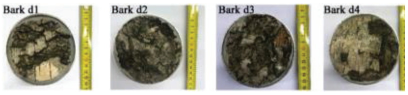
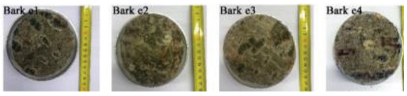
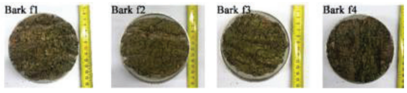
Fig.1 The results for repeat measurements

2.2 Plant Selection

In this study, six species were selected. Table 1 shows the basic characteristics of these species. For the bark classification, Bertrand's (7) research shows a method used to recognize species based on visual bark texture criteria. The tree bark samples can be divided into seven types namely "smooth", "lenticels", "furrows", "ridges", "cracks", "scales" and "strips".

Table 1 Characteristics of 6 plant species

Species		Photos				Type	Age	Diameter of	Thickness of bark			
		1	2	3	4			trunk(cm)	1	2	3	4
Acacia	A					Ridges	34	20.50	1.50	1.20	1.90	1.50
Walnut	B					Furrows	20	22.40	1.30	1.10	1.10	1.05
Cherry	C					Lenticels	30	25.00	1.50	1.20	1.40	1.60

Birch	D		Cracks	32	24.40	1.30	1.40	1.35	1.60
Poplar	E		Lenticels	26	22.90	1.40	1.50	1.40	1.20
Willow	F		Furrows	14	24.60	1.30	1.10	1.10	1.00

2.3 Data Extraction

Given the impedance tube diameter and the distance between the microphones, the result can be used in the frequency range of 150 Hz to 1500 Hz. The data was processed to one-third octave band averaged absorption values. In this study, for each trunk, the reported value is the average from the absorption coefficient of four cylindrical samples cut along the circumference of the trunk. In addition, each bark sample was measured four times including repositioning and resealing in the impedance tube.

3. Results

3.1 Absorption of bark

The results show that the tree barks considered in this work have a rather low absorption and only small differences can be found in between the different species. As Fig.2 shows, the absorption of tree barks are near 0.02-0.04, while there is no clear frequency dependence.

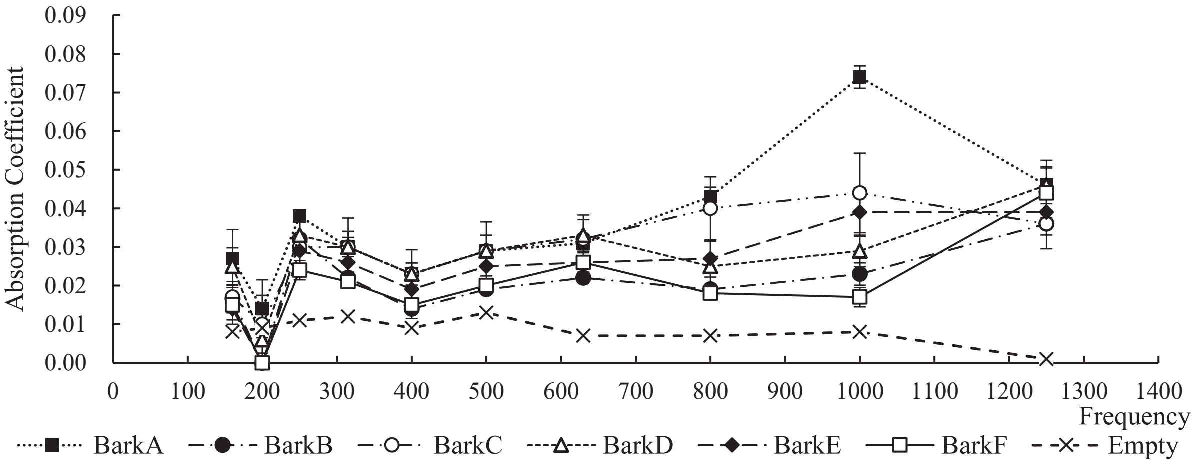
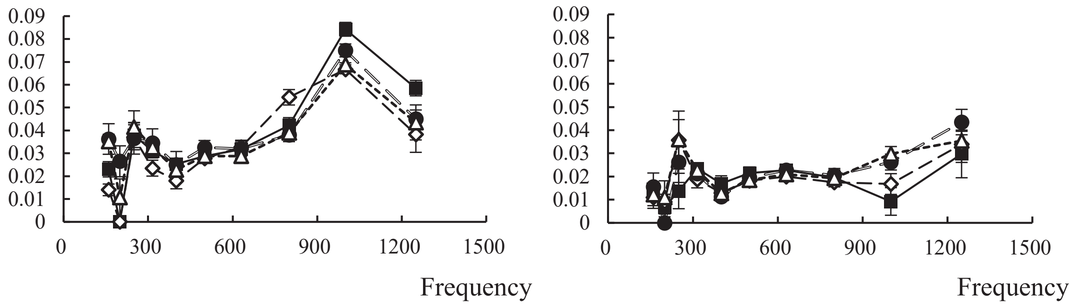


Fig.2 Absorption Coefficient for 6 plants

A three-way ANOVA analysis showed that the plant species and taking different bark samples at other parts along the trunk circumference are statistically significant effects, while the repeated repositioning of the same sample had no significant effect on the measurement results. Plant species had statistically significant effect on bark absorption coefficient for all one-third octave band in the frequency range of 150 Hz to 1500 Hz. Figure 3 shows the differences between the four samples of each trunk cross section. Note that the bark thicknesses can be different.



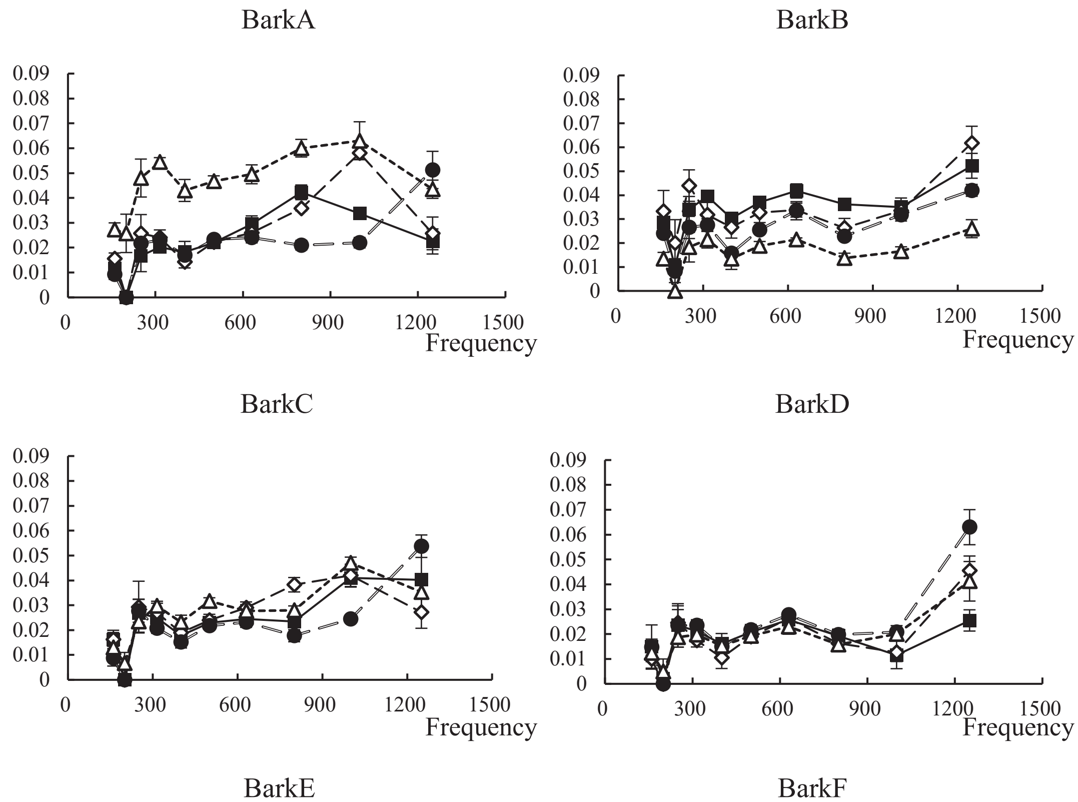


Fig. 3 The absorption coefficient of 4 bark samples taken at different positions along the trunk circumference, for the 6 species considered.

3.2 Factors influencing absorption

There are potentially multiple factors that can influence the sound absorption by tree bark. It could be of practical use to predict this absorption based on common characteristics like e.g. thickness of the bark, age, trunk diameter or bark roughness. The shape index (8, 9) was used to characterize the roughness of the bark; the closer this value is to 1, the better the bark cross section approaches a circle. Fig. 4 shows the bark roughness of the six trees considered.

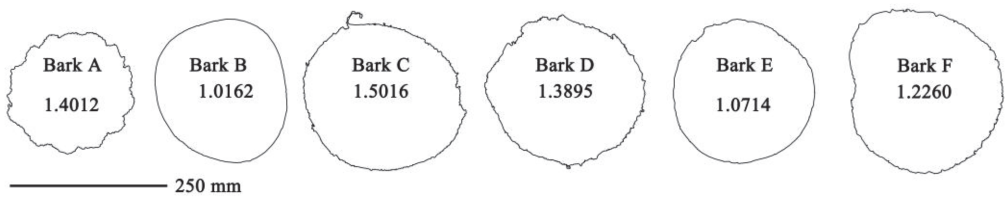


Fig. 4 The roughness of barks

Table 2 shows the correlation between a number of selected bark properties and the averaged absorption. Significant factors are the thickness of bark, tree age, diameter of the trunk and bark roughness. Except for the diameter of the trunk, these factors are positively correlated with the (averaged) absorption coefficient. Tree age is the best predictor for the absorption coefficient. Note, however, that these factors are not independent.

Table 2 Correlation between bark properties and absorption

	Thickness of bark, Ti(cm)	Age, Ai	Diameter of trunk, Di(cm)	Bark roughness, Ri
Absorption coefficient	0.533*	0.671**	-0.395*	0.521**

** Significantly correlated at the 0.01 level (both sides)
* Significantly correlated at the 0.05 level (both sides)

Multiple linear regression showed that the averaged absorption coefficient αi in the frequency range 500-1600Hz for a bark can be predicted from the following expression:

$$\alpha_i = 0.029255\ R_i - 0.0026156\ D_i + 0.057638, \ (R^2=0.486,\ F\text{-statistics}\ p=0.009) \qquad (1)$$

with Ri the bark roughness and Di the diameter of trunk. The absorption coefficient reduces with trunk diameter and increases with bark roughness. The effect of diameter could be caused by a deficiency in the way of measuring – smaller trunk diameters could have lead to a larger absorbing surface in the tube since it deviates more from a fully flat surface.

3.3 Moss-grown samples

The surface of barks are easily grown in forest stands. A sample has been tested where a part of the bark was grown with moss. As Fig. 5 shows, Bark1is the sample with moss on the surface, which has higher absorption than the other parts of the trunk circumference. This increased absorption is mainly found in the lower frequency range. Although the absorption of bark with moss increases, values stay below 0.1.

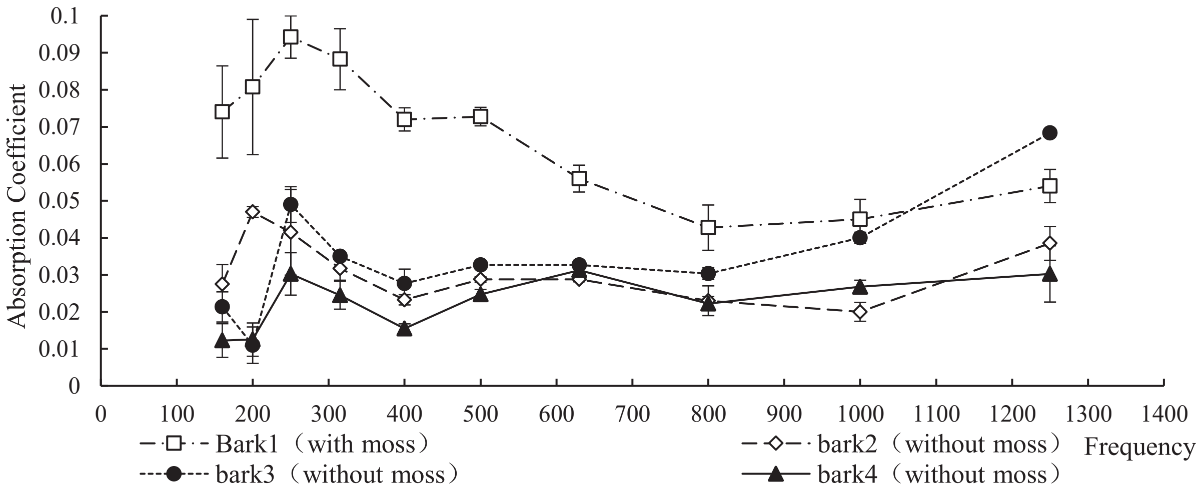


Fig. 5 The difference of absorption between bark with moss and without moss

3.4 Sample age

During the first 30 days after sample collection in the field, bark F was sealed in plastic to prevent water loss. Afterwards, the sample was allowed to dry in the air. Figure 6 shows the absorption coefficient of bark F at different moments. It can be seen that there is not much difference in absorption after 5 and 20 days. Afterwards, the absorption decreased slightly, which is most likely to be related to the reduction in bark thickness.

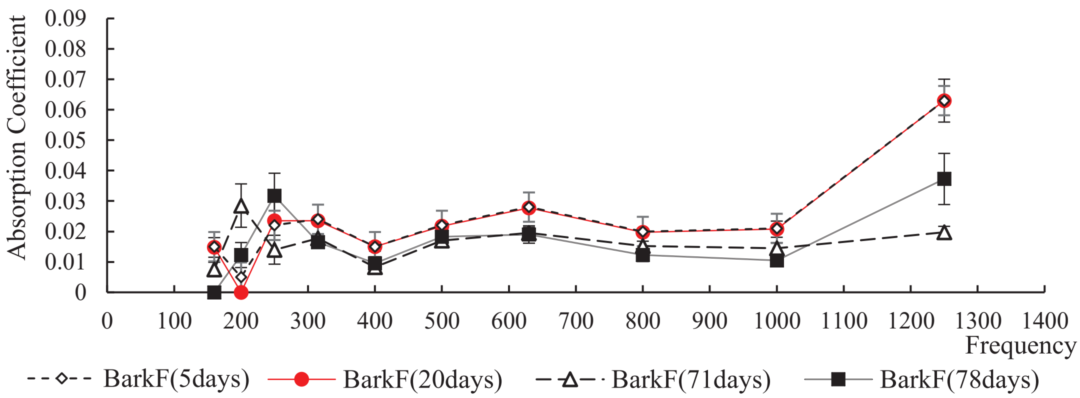


Fig. 6 The influence of sample age on bark F's absorption

4. CONCLUSIONS AND FURTHER WORK

Although the absorption of these six species is less than 0.1, statistically significant differences can be found in between species. Bark thickness, tree age, trunk diameter and bark roughness can be correlated with the absorption. Based on a multiple linear regression, bark roughness is the factor that was retained, together with trunk diameter. The latter is potentially a deficiency by measuring in the impedance tube.

In this study, all six species come from deciduous trees. Future work should include coniferous trees. In addition, other characteristics of the bark should be included to analyze the influencing factors.

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