Influence of resonance behavior of varied wood species used as components (bridge) in the construction of acoustic guitars in the traditional Maccaferri design

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Abstract
Traditional violin- and guitar builders consider it a fact that the bridge which transfers the vibrations of the strings to the resonance board has a significant influence on the sound of the instrument. In this context, one can assume that different timber species produce a defined sound, which can be related to the anatomical structure of the wood. The timbers used traditionally for the bridge are usually selected for their assumed positive acoustic behavior and also for their decorative appearance, dimensionally stability and high abrasion resistance. While it is fairly easy to determine the physical and mechanical properties of wood for acoustic use, it is more difficult to measure the influence of a single wooden component on the instrument's sound.

1. Introduction

The assessment of the acoustic properties of different individual components of musical instruments is very complex; in particular, the contribution to the acoustics of the component to be investigated is always influenced by the resonance behavior of other components. Furthermore, the construction as well as the constructional implementation may have a significant influence on the resonance behavior of the instrument. Therefore, an explicit assessment of an individual structural component is only possible if it can be assessed independently while all other components remain constant.

To understand the acoustic behavior of wood and wooden components in instruments, most investigations concentrate on the physical and mechanical properties of the wood species. Several investigations have shown that there is a significant relationship between the resonance behavior and the physical and mechanical properties of wood. This applies in particular to the density and the modulus of elasticity [1, 2, 4, 5, 6] as well as to the type and orientation of individual cell elements [1, 7, 9, 12]. *However, until today there have only been a small number of investigations that deal with the bridge of an Instrument [3, 8] or in particular the Bridge of an acoustic guitar.*

In the proposed study, six different species will be used for the bridge and assessed as to their individual contribution to the resonance behavior of the instrument. This analysis is carried out with an acoustic guitar of the traditional Maccaferri design (Sandner, 2015) with a soundboard made of European spruce. A peculiarity of the Maccaferri guitar, contrary to other traditional designs (Torres, Martin), is that the cord supporting bridge is neither glued nor pegged to the soundboard. Thus it is possible to substitute different bridges and assess their influence on acoustic properties independently. The aim of this study is to find out whether wood species with different anatomical cell structure used for the bridge exert a measurable influence on the resonance behavior of a traditional Maccaferri acoustic guitar.

2. Material and Methods

2.1 Species

To measure a high variability in the influence from the Bridge to the soundboard, timbers with the greatest possible variability in anatomical structure as well as the physical and mechanical properties were chosen. Three of the six timbers to be investigated (*Diospyros* sp., *Dalbergia nigra*; *Pterocarpus soyauxii*) are traditionally used for bridges in guitar building. The other three timbers, partially used for instruments (*Morus alba*) are chosen because of their difference in anatomical structure to the other timbers.

Table 1: Physical properties and structural key features (data according to Wagenführ 2006 and Haag 2016)

Timber-species*	Density g/cm³	Modulus of elasticity N/mm²	Brinell Hardness (HBII) N/mm²	Growth-rings	Storied structure	Ray Height µm
*Diospyros sp.**	1,15	13400	136	indistinct	absent	130-500
Dalbergia nigra *	0,97	8800-12900	92	indistinct	present	110-180
Pterocarpus soyauxii	0,80	10000-16600	29 … 47	indistinct	present	100-200
Morus alba	0,68	-	-	distinct	absent	150-1500
Robinia pseudoacacia	0,62	9000-13300	67 … 88	distinct	absent	150-1200
Taxus baccata	0,76	12.000-15000	65 …71	distinct	absent	80-230

*Approval for investigation of CITES protected species (Annex I and II) has been obtained

Diospyros sp., *Dalbergia nigra* and *Pterocarpus soyauxii* (Figure 1 A+B.) are tropical timbers with a high basic density (table 1.) whereas *Pterocarpus soyauxii* shows a significant difference in hardness. Those tropical timbers are all diffuse porous and have very small Rays. The Rays of *Diospyros* sp. and *Dalbergia nigra* sp., are multiseriate and those of *Pterocarpus soyauxii* (Figure 1B) are uniseriate. Furthermore the rays and fibers of the of *Diospyros* sp. are without orientation whereas the rays, axial parenchyma and fibers of *Dalbergia nigra* and *Pterocarpus soyauxii* show distinct storied structure.

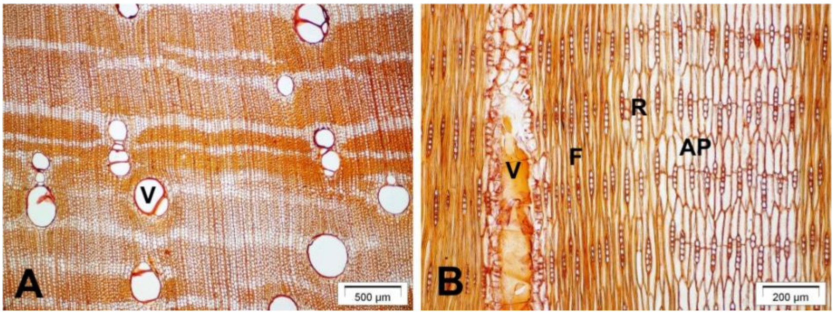


Figure 1. Padouk (*Pterocarpus soyauxii*) A – transverse section and B – tangential section with V = vessels, F – Fibres, R – Rays (storied structure) an AP – axial parenchyma (storied structure).

In contrast to the other hardwoods, *Robinia pseudoacacia* and *Morus alba* (Figure 2 A+B) are both ring porous which is due to their natural appearance in vegetative zones with frost periods. In that context, both of them show distinct growth rings. Furthermore, the rays show very high and broad structural appearance in comparison to *Diospyros* sp., *Dalbergia nigra* and *Pterocarpus soyauxii.*

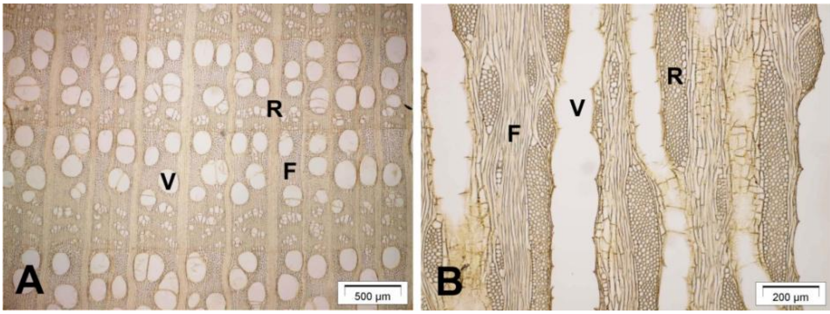


Figure 2. Black mulberry (*Morus alba*) A – transverse section and B – tangential section with V = vessels, F – Fibres and R – Rays (multiseriate).

The last chosen species, *Taxus baccata* (Figure 3 A+B) is a coniferous wood (Softwood) from the family of the Taxaceae. Coniferous wood do not have vessels. Coniferous timbers, such as *Taxus baccata* consist of up to 95 % of Tracheids. In comparison to the chosen hardwoods the rays are small.

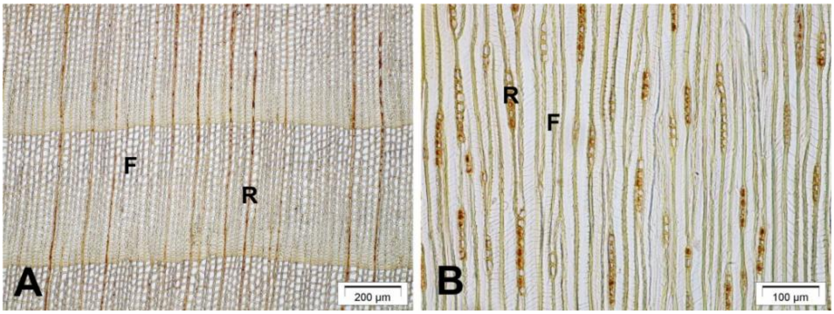
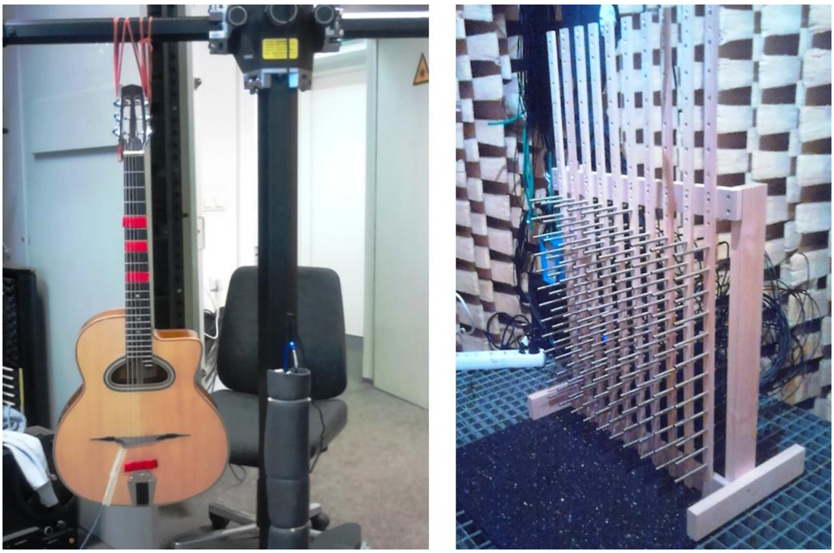


Figure 3. Yew (*Taxus baccata*) A – transverse section and B – tangential section with F – Fibres (tracheids with spiral grain) and R – Rays (uniseriat).

The raw wooden material for the bridges to be investigated was stored between 10 and 20 years. The equilibrium moisture content corresponds to an equilibrium between 8 and 10 %.

2.2 Measurements: (Niko)



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References

[1] Brémaud I. 2012. What do we know on "resonance wood" properties? Selective review and ongoing research. Societé Française `Acoustique 2012, Nantes, France

[2] Burmester A. 1965. Zusammenhang zwischen Schallgeschwindigkeit und morphologischen, physikalischen und mechanischen Eigenschaften von Holz. Holz als Roh- und Werkstoff 6: 227-236.

[3] Cremer L.: The physics of the violin. MIT Press, Cambridge MA, 1985. See chapter 9. [3] ZIENKIEWICZ, O.; TAYLOR, R.: *The finite element method – Volume 1: The basis*. 5. Edition. Butterworth-Heinemann, Oxford, 2000

[4] Dumand P & Baddour N. 2015. Experimental investigation on the mechanical properties and natural frequencies of simply supported Sitka spruce plates. Wood Sci. Tech. 49 (6): 1137-1155.

[5] Haines ME. 1979. On musical instrument wood. J. Catgut Acoust. Soc. 31: 23-32.

[6] Jansson E. 2002. Acoustics for violin and guitar makers. Chapter V: Vibration properties of the wood and tuning of violin plates. Kungl Tekniska Högskolan, Stockholm, Sweden, 38 p.

[7] Kubojima Y, Okano T & Ohta M. 1997. Effects of annual ring widths on stractural and vibrationalproperties of wood. Mokuzai gakkaishi 43 (8): 634-641.

[8] Reinicke W.: Die Übertragungseigenschaften des Streichinstrumentenstegs. Doctoral dissertation, Technical University of Berlin, 1973.

[9] Sailer B. 2015. Wachstumsanalytische Untersuchung des Haselwuchses der Fichte (*Picea abies*). Master thesis, University of Innsbruck, 45 p.

[10] Wagenführ, R. 2006. Holzatlas – Fachbuchverlag Leipzig. ISBN-13: 978-3-446-40649-0

[11] Woodhouse J.: On the „BridgeHill" of the Violin. Acta Acustica united with Acustica Vol. 91 (2005) 155-165

[12] Ziegler H & Merz W. 1961. "Hazel growth" – on the relationship between irregular secondary thickening and the distribution of rays. Holz als Roh- und Werkstoff 19 (1): 1-8

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