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Acoustical properties of *petung* bamboo for the top plate of guitars

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ABSTRACT

In this paper, the use of *petung* bamboo (*Dendrocalamus asper*) as an alternative material for the top plate of acoustic guitars was evaluated. In the first research stage, the analysis was carried out on *petung* bamboo splits, which were treated with three different preservation conditions, namely unpreserved, preserved by boiling in water and preserved by boiling in a solution of 5% borax and boric acid. The vibration damping ratios and the sound radiation coefficients of these three types of splits were measured. It was found that their vibration damping ratios were not significantly different, whereas the sound radiation coefficient of the *petung* bamboo splits preserved in borax and boric acid was 40–60% higher than the other two variants. Based on this result, in the second research stage, three acoustic guitars with top plates from the borax–boric acid preserved *petung* bamboo, spruce, and pine were constructed. The top plate frequency response function of the three guitars was evaluated. Here, the spruce guitar was used as a reference for the generally preferred guitar sound characteristics, whereas the pine guitar was included as a sample of guitar made from local Indonesian wood. The results showed that the frequency response function of the *petung* bamboo guitar were generally five times lower than that of the spruce guitar, but two times higher than that of the pine guitar. The response amplitudes of the bamboo guitar were significantly higher than those of the spruce and pine guitars for frequencies between 200 and 400 Hz. Based on the results, it is concluded that *petung* bamboo has the potential to be applied as an alternative material for guitar top plates. However, since the bamboo guitars exhibits different resonances, the produced sound will have distinctive characteristics compared to the sound from guitars with spruce top plates.

1. Introduction

Based on years of experience, spruce (*Picea* sp.) has become the most preferred choice for the top plates of acoustic guitars [1]. Spruce is valued not only for its ability to produce high quality sound, but also for its beautiful wood grain. However, this type of wood is not easily available in Indonesia and, hence, Indonesian guitar luthiers must import spruce at a relatively high price. It has become a general interest for Indonesian guitar luthiers to find alternative materials for the construction of this musical instrument. A number of them have experimented on using local woods for their guitar top plates [2], but the choice of wood is still mainly based on trial-and-error and on the wood's aesthetic appeal.

In fact, several studies outside of Indonesia have characterized woods for musical instruments, providing data on the mechanical, acoustical and vibrational properties of various types of woods [3–6]. More recent works have published material property charts on which acoustic properties such as the speed of sound, the characteristic impedance, the sound radiation coefficient, and the loss coefficient are plotted against one another for various woods [1,7]. Based on these charts, it could be analyzed and explained why certain species of woods are more preferred than others for different types of musical instruments and parts.

The acoustical and vibrational characteristics of string musical instruments made of wood have also been investigated by many researchers [8–11]. The methods of research comprise of modal analysis, finite element analysis, as well as acoustical analysis, which enabled the extraction of parameters such as frequency response, mode shapes, and damping behavior. Further, the relation between the vibrational properties of guitars and the subjective response of respondents were studied in [12], whereas the influence of acoustic and mechanic characteristics of materials on the sonority of guitars was reported in [13].

In a previously published work [14], the acoustical properties of local Indonesian woods such as acacia (*Acacia mangium*), mahogany (*Swietenia mahagoni* Jacq.), pine (*Pinus merkusii* Jungh et De

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Vr.), *sengon* (*Albizia chinensis*) and *sonokembang* (*Dalbergia latifolia*) were discussed. The results indicated that local pine wood can be a suitable alternative material for the top plate of acoustic guitars. However, when considering availability, wood generally has low growth rates. Good quality wood for acoustic guitars may need 30–40 years to mature. On the other hand, bamboo is a fast growing type of grass, which can be harvested after 3–5 years. Of around 1250 types of bamboo known in the world, it is estimated that at least 159 types are found in Indonesia, among which 100 of them are endemic to this country [15]. In Indonesia, bamboo is used for various purposes, ranging from structural elements to art. For traditional musical instruments, bamboo can be used in its original cylindrical form or made into splits.

Wegst have carried out a study on the characteristics of bamboo for musical instruments [16]. She stated that bamboo is the only material worldwide with a mechanical and acoustical property profile that simultaneously satisfies all design criteria and functional requirements of all classes of musical instruments. However, further discussion on the influence of bamboo on the properties of soundboards was not given. Another study by Yoshikawa and Waltham [17] also provided the vibroacoustic properties of bamboo related to musical instruments, but the discussion was mainly on the use of bamboo for the body of woodwind instruments.

One of the problems in the use of bamboo is its susceptibility toward pests and diseases, which include powderpost beetle, termite and fungi. According to Liese [18], unprotected bamboo can be damaged within 4–7 years. Since bamboo culms do not produce any toxic substances during their lifetime, unlike the heartwood of many trees, the whole culms can be destroyed. Therefore, preservation of bamboo is an important requirement to ensure longer utilization.

In this paper, the use of *petung* bamboo (*Dendrocalamus asper*) as an alternative material for the top plate of acoustic guitars was evaluated. In the first stage, the study was carried out on the *petung* bamboo splits, with the aim to analyze two acoustical characteristics considered important in the selection of materials for musical instruments [1], namely sound radiation coefficient and vibration damping ratio. To observe the influence of preservation on these parameters, the bamboo splits were treated with three different preservation conditions, namely unpreserved, preserved by boiling in water and preserved by boiling in a solution of 5% borax and boric acid. In the second stage, we evaluated characteristics of acoustic guitars with top plates made from *petung* bamboo, focusing on the analysis of the top plate frequency response function. These characteristics were then compared to those of acoustic guitars with top plates from spruce and pine.

2. Materials and methods

2.1. Considerations for choosing petung bamboo

Among many types of bamboo available in Indonesia, *petung* bamboo was regarded as the suitable choice for this research. *Petung* is a type of bamboo very easily found in Indonesia, with diameters reaching 200 mm, internode lengths of 40–60 cm and wall thickness of 25–41 mm. This choice was taken based on consideration of the intended application, which is to later on make the bamboo splits into a thin laminate for the guitar top plate.

A classical acoustic guitar top plate measures approximately 490 mm × 370 mm × 2.5 mm at its largest dimensions [8]. Therefore, a laminate of at least this size will be required, consisting of long, thin, rectangular bamboo splits arranged side by side and glued together, such that the longitudinal bamboo grain is parallel to the length of the laminate. The rectangular bamboo splits will be made by dividing the cylindrical bamboo culms longitudinally into a number of splits, and then trimming the curved parts to make the splits rectangular. With the relatively large diameter of *petung* bamboos, wider rectangular splits can be achieved. Hence, less number of bamboo splits can be used for the required width of the laminate, which should reduce the effect of gluing toward the properties of the bamboo top plate. Furthermore, the relatively long internodes of the *petung* bamboos will better enable to avoid having bamboo nodes, which have disordered grain direction, on the guitar top plate.

2.2. Preparation of bamboo splits for the first research stage

The *petung* bamboos used in this research were harvested from the border of Watukelir Sukoharjo and Wonogiri in Central Java, Indonesia. *Petung* bamboos 3–5 years of age were selected to obtain culms as straight as possible. After harvesting, the culms were cut off 1 m from the base, whereas the next 10 m were used and the rest discarded. The cylindrical culms were then cut into curved splits 25 mm wide and 2.5 m long. The splits were sun-dried until they reached air-dry condition, in which the moisture content in the bamboo is in equilibrium to the moisture content of the open air. This process took approximately two weeks, subject to the weather condition. Some of these air-dry *petung* bamboo splits were put away as the unpreserved bamboo specimens.

For the preserved bamboo specimens, some of the air-dry *petung* bamboo splits were then put in a large container of only water, and the rest in a large container of solution of 5% borax and boric acid. The liquid in both containers are enough to submerge all the bamboo splits. The containers were then heated until the liquid boiled, and the boiling process was continued for a further 60 min. Afterward, the splits were taken out of the containers and sun-dried until they reached air-dry condition.

The air-dry *petung* bamboo splits, both unpreserved and preserved, were then trimmed using a splitter and a planner machine into rectangular splits measuring 500 mm × 20 mm × 5 mm. As seen in Fig. 1, the above process removed the outer bamboo skin. These splits were then prepared into specimens for the tests.

2.3. Sound radiation coefficient

Sound radiation coefficient, also known with the term acoustical admittance, refers to the ability of a material to radiate sound. The higher the sound radiation coefficient of a material, the louder the sound it can produce [1]. This parameter is mainly influenced by the modulus of elasticity E (MPa) and the density ρ (kg/m^3) of the material. The sound radiation coefficient R (m^4/kg s) is calculated according to the equation

Fig. 1. Air-dry *petung* bamboo splits.