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Establishment of Characteristic Shear Strength Parallel to Fiber of Different Local Bamboo Species in the Philippines

Brian E. Bautista[1], Lessandro E.O. Garciano[1], and Luis F. Lopez[2]

[1] Department of Civil Engineering, De La Salle University, Manila, Philippines
[2] Base Bahay Foundation Inc., Makati, Philippines
brian_bautista_a@dlsu.edu.ph

ABSTRACT

The adoption of bamboo as an alternative to traditional building materials in the Philippines is hampered due to its non-inclusion in the local structural code. Given the inherent variability in the mechanical properties of bamboo, determining its characteristic strength is crucial in the development of the local bamboo structural code. The literature on the characteristic strength of bamboo is also limited. In this study, the characteristic shear strength of several economically viable bamboo species in the Philippines was established based on 220 shear test results. Two factors led to the choice of this mechanical property: (1) Shear strength parallel to fiber exhibits the highest degree of variation among mechanical properties; and (2) Shear is one of the governing forces on joint connections, and these connections are the weak points in bamboo structures when exposed to extreme loading conditions. All tests were conducted in accordance with the ISO 22157-1 (2017) shear test protocol. ISO 12122-1 (2014) was used to calculate the characteristic shear strength. The results showed that *Bambusa philippinensis* has the highest characteristic shear strength value (7.26 MPa) followed by *Dendrocalamus asper* (6.98 MPa), *Bambusa vulgaris* (6.46 MPa), *Bambusa blumeana* (5.15 MPa), and *Gigantochloa apus* (5.11 MPa). A comparison of the shear strength values using One-way ANOVA also revealed statistically significant differences in shear strength among these bamboo species, highlighting the importance of bamboo species identification in the structural design process.

KEYWORDS: Bamboo, Characteristic Shear Strength, ISO 22157-1, ISO 12122-1

INTRODUCTION

Philippines is the world's 6th largest exporter of bamboo and rattan products (Aggangan, 2015). In the local setting, one of the primary demands for bamboo for housing purposes arises from the need for new house construction and for repair and replacement of existing houses (Department of Science and Technology (DOST), 2020). The demand for bamboo is highest among rural households which combine bamboo with other low-cost construction materials. Because of the need for the use of bamboo especially for the modular housing components in the Philippines, there must be an effort to understand the bamboo species endemic in the Philippines. For one to fully utilize this as an alternative construction material, physical and material properties must first be established. The testing method to be used in this study is ISO 22157, Bamboo – Determination of Physical and Mechanical Properties. This testing method is established "to bring bamboo towards the level of an internationally recognized and accepted building and engineering material" (Harries et al., 2012). This testing method is proven invaluable as a basis to ensure that test results between researchers are comparable. Further, repeatability and minimizing inter-laboratory variation to the fullest extent possible is critical so that a description of bamboo materials is as uniform as possible; thereby creating a *lingua franca* among practitioners (Gauss et al., 2019). The next step from the international standardization is the creation of national bamboo standards specific to bamboo growing countries (Janssen, 2005). This study pushes for the development of local bamboo standard specific for the Philippine bamboo species.

The full utilization of bamboo as an alternative to traditional building materials in the Philippines is limited due to its non-inclusion in the local structural code. Determining its characteristic strength is crucial for developing a local bamboo structural code. Thus, this study analyzed the characteristic shear strength of economically viable bamboo species in the Philippines using 220 shear test results. Two factors led to the choice of this mechanical property: (1) Shear strength parallel to fiber exhibits the highest degree of variation among mechanical properties; and (2) Shear is one of the governing forces on joint connections, and these connections are the weak points in bamboo structures when exposed to extreme loading conditions. The characteristic shear strength values were evaluated based on the 5th percentile value with 75% confidence using non-parametric data analyzed using AS/NZS 4063.2 based on ISO 12122-1.

MATERIALS AND METHODOLOGY

The bamboo species are sourced by Base Bahay, Inc (BASE) and De La Salle University. The following bamboo species are sourced by BASE: (1) Gigantochloa apus (Local Name: Apus); (2) Bambusa philippinensis (Local Name: Laak); (3) Bambusa vulgaris (Local Name: Laak); (4) Dendrocalamus asper (Local Name: Botong); and (5) Bambusa blumeana (Local Name: Kawayan Tinik) from Tarlac. De La Salle University sourced the same Bambusa blumeana species but from a different source – Laguna. Due to limited resources and other researchers using the same bamboo culms for another study, sampling of bamboo specimens is standardized to (n = 30) samples. Gigantochloa apus, Bambusa philippinensis, Bambusa vulgaris and Dendrocalamus asper all have (n = 30) samples. However, an extensive sampling (n = 100) for a more reliable characterization is given to Bambusa blumeana sourced from Tarlac since it is one of the most abundant bamboo species in the Philippines. The Bambusa blumeana sourced from Laguna has (n = 12) samples. The use of a second source for Bambusa blumeana is carried out to further add to the body of knowledge and to check for comparability with the first source.

Samples are loaded using the set-up of ISO 22157 as shown on Figure 1a. Methodologies set forth herein are based on the same standard. Tests are carried out on a suitable testing machine capable of measuring compression load with a precision of at least 1%. The specimen is supported at its lower end over two opposing quadrants and loaded at its upper end over the other two opposing quadrants. Such set-up will induce shear failure on four shear planes. It must be noted that the centers of the upper and lower shear plates shall be aligned with the vertical axis of the test machine. This must also be fixed so that they may not move relative to each other. The use of 2 steel rods serves this purpose. Figure 1b shows a specimen tested for shear while Figure 1c shows a typical failure mode of the bamboo specimens.

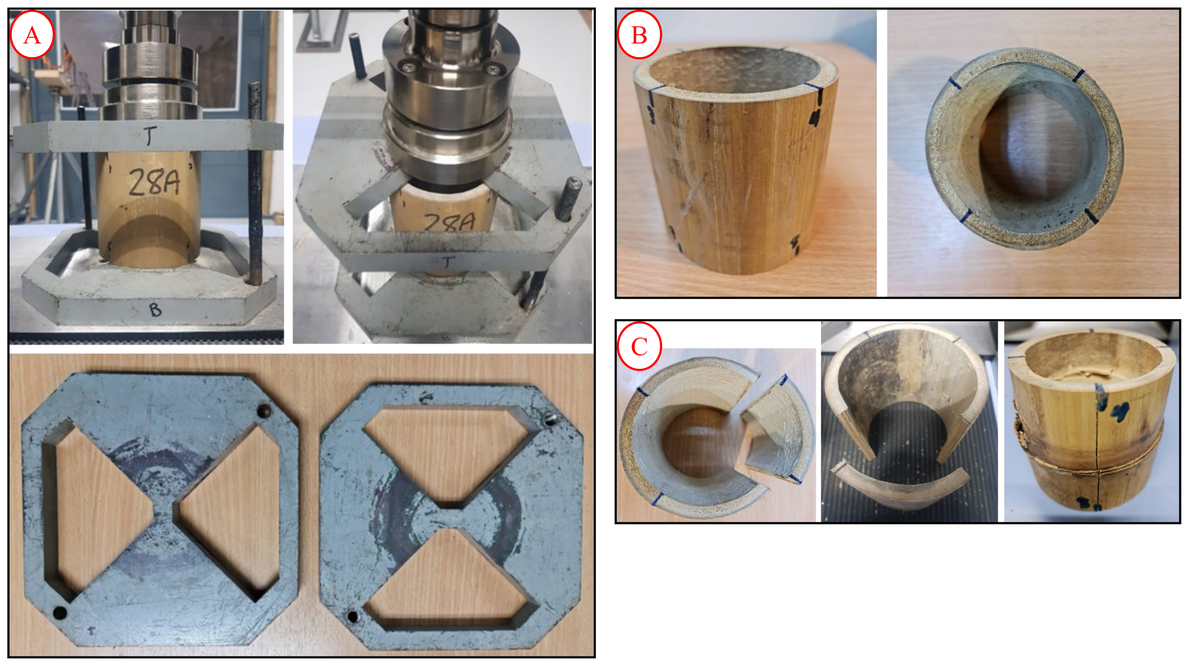

Figure 1.0 Shear Test Set-up: (a) ISO 22157 Set-up and Shear Plates, (b) Bamboo Test Specimen, and (c) Typical Mode of Failure

RESULTS AND DISCUSSION

The basis for the shear strength parallel to grain ($f_{v,c}$) should be the 5th percentile of the test report values according to (ISO 12122-1). Figure 2.0 shows the graphical representation of the characteristic shear strength parallel to grain ($f_{v,c}$) for all bamboo species used in this study. It can be observed from Figure 2.0 that the bamboo species with the highest characteristic shear strength ($f_{v,c}$) is the Bambusa blumeana (Kawayan Tinik) species from Laguna with $f_{v,c}$ = 9.56 MPa. However, this value should be taken cautiously as the number of samples for this species are very small (n = 12). The second highest characteristic strength is $f_{v,c}$ = 7.26 MPa for Bambusa philippinensis (Laak) species. This is followed by Dendrocalamus asper (Botong) species with $f_{v,c}$ = 6.98 MPa. Botong species is followed by Bambusa vulgaris (Lunas) species with $f_{v,c}$ = 6.46 MPa. Finally, the bamboo species with the two lowest characteristic strengths are Bambusa blumeana (Kawayan Tinik) species from Tarlac and Gigantochloa apus (Apus) species with $f_{v,c}$ = 5.15 MPa and $f_{v,c}$ = 5.11 MPa, respectively.

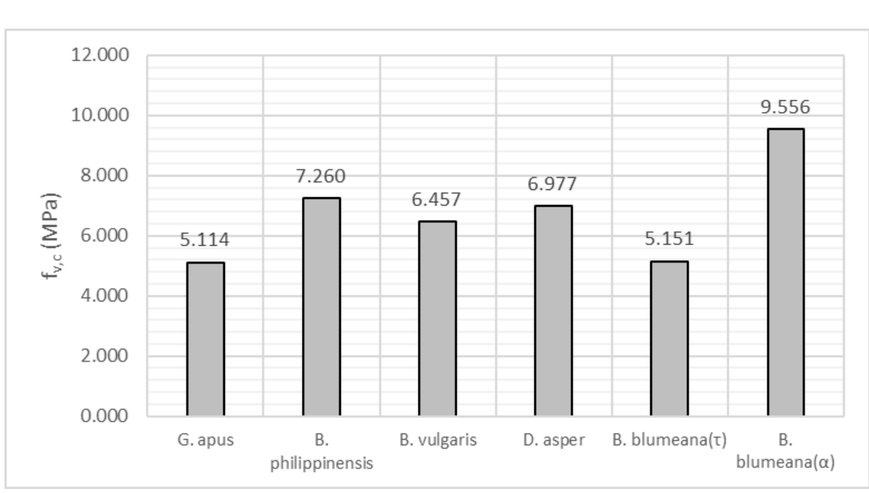

Figure 2.0 Characteristic Shear Strength Parallel to Grain ($f_{v,c}$) per Bamboo Species (τ - sourced from Tarlac and α - sourced from Laguna)

CONCLUSION AND RECOMMENDATION

A total of five (5) bamboo species were selected in this study to determine the shear strength parallel to grain using the (ISO 22157-1) shear test method. Characteristic strength is also determined for each bamboo species using (ISO 12122-1) as a future design reference especially in local practice. Based on the results, the characteristic shear strength of bamboo is about 34% to 51% higher than the some of the high strength structural timber of Philippine wood species even if we take the weakest bamboo species employed in this study.

It is recommended to extend this study to other mechanical properties of bamboo such as the tensile, compressive, and flexural strength. Another proposal is to check the effect of the position of the specimen along the bamboo culm on the shear strength of bamboo. It is also recommended to test other economically viable bamboo species in the Philippines and compare it with international bamboo species.

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