Engineered bamboo: The promising material for building and construction application in Indonesia

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Abstract. There is a rising gap between supply and demand of wood as building and construction materials. The search of alternative materials to fill in the gap is an urgent concern. Bamboo is one of locally abundant resources; 88 out of 135 species growth in Indonesia is an endemic. It is a renewably material and has comparable characteristics to wood. Notable efforts to reduce the variability of raw bamboo have led to the improved physical and mechanical properties of the engineered bamboo. Laminated bamboo and hybrid laminated bamboo-wood had superior wood strength in comparison to the raw materials. Laminated bamboo produced from andong (Gigantochloa pseudoarundinacea (Steud.) Widjaja), mayan (Gigantochloa robusta Kurz), vertically laminated andong bamboo comparable to wood strength class I, I-II and II, respectively. Furthermore, hybrid laminated bamboo-wood andong-manii (Maesopsis eminii Engl.), andong-mayan-jabon (Anzocephalus cadamba (Roxb.) Miq.) comparable to wood strength class II and III, respectively. The properties improvement of engineered bamboo demonstrates the potential application of laminated bamboo as a substitution for building and construction material.

1. Introduction
Timber is a primary product sourced from forest that has made a huge economic contribution for the country. However, the unsustainable forest management practices have led to the scarcity of timber supply. Log production from natural forest in 2007 was 31.5 million m$^3$ [1] and decreased to 5.8 million m$^3$ in 2015 [2]. Annual timber demand was as much as 60 million m$^3$. A scarcity of timber, particularly the common commercial timber, forced prices up.

Investigations have been carried out on the searching of renewable materials that can substitute timber. Bamboo is a lignocelullosic material that has the potential to substitute timber. It has been widely used traditionally in the nation, thus it has a strong cultural value [3,4]. Moreover, bamboo being one of the fastest growing species in the globe has ecological, comparable mechanical characteristics, social-economic values [5].

A wide range of bamboo utilization has been reported elsewhere, including furniture, musical instruments, basket, erosion control, fence, beam, roofs skeleton, walling/ceiling [6]. The utilization of bamboo, however, is restricted due to the natural shape and low durability to fungi and insects attacks[7]. The improvement in preservation and manufacturing technologies overcome the limitation through engineered bamboo manufacturing. Laminated bamboo and hybrid laminated bamboo wood demonstrated competitive physical and mechanical properties. Thus, it is suitable as a wood alternative to substitute building and construction materials.
This paper briefly summarizes the potential prospect of bamboo as a wood substitute in Indonesia. It is intended to provide data and information on bamboo potential for building and construction materials and government strategy on the development of engineered bamboo in Indonesia.

2. Bamboo potential and development strategy in Indonesia
Bamboo is abundantly found in the country. It grows in community garden and in forest area, on slope hills to valleys and other areas [8]. Bamboo is a member of the Poaceae family and Bambusoideae subfamily. There are as much as 1,250 bamboo species in at least 75 genera. Of those species, 135 species are found in Indonesia. Species endemic to Indonesia is 118 species of sympodial bamboo [9][10]. Table 1 depicts 76 bamboo species that are considerably important. Bamboo materials suitable for industry should be targeted at cost effective and the easiness to cultivate [11]. The latter is aimed to ensure the sustainability of bamboo production in a large scale. The following species were suggested in bamboo industry: petung (Dendrocalamus asper), tali (Gigantochloa apus), ater (Gigantochloa atter), hitam (Gigantochloa atroviolacae), mayan (Gigantochloa robusta), andong (Gigantochloa. pseudoarundinacae), peting (Gigantochloa levis), yellow ampel (B. vulgaris v. striata), green ampel (B. vulgaris v. vitata) and duri (B. blumeana) [11].

| No | Genera         | Number of important species |
|----|---------------|----------------------------|
| 1. | Arundinaria   | 1                          |
| 2. | Bambusa       | 19                         |
| 3. | Cephalostachyum | 1                       |
| 4. | Chimonobambusa | 2                        |
| 5. | Dendrocalamus | 6                          |
| 6. | Dinochloa     | 1                          |
| 7. | Gigantochloa  | 18                         |
| 8. | Melocana      | 1                          |
| 9. | Nastus        | 3                          |
| 10. | Neololeba     | 1                          |
| 11. | Phyllostachys | 3                          |
| 12. | Pleioblastus  | 2                          |
| 13. | Pseudosasa    | 1                          |
| 14. | Schizostachyum | 14                        |
| 15. | Semiarundinaria | 1                       |
| 16. | Shibatea      | 1                          |
| 17. | Thyrsostachys | 1                          |

Source: [11]

2.1. Bamboo for building and construction materials
Bamboo is a promising lignocelullosic material for use in building and construction materials as it is renewable, light, strong, and relatively low cost material. The utilization of bamboo in building and construction is ranging from foundation, flooring, walling, roof and scaffolding. As it can be seen in Table 2, only particular bamboo species are meet the requirement for building and construction materials.
Table 2. Bamboo species for building and construction materials

| No | Scientific name                                      | Local name |
|----|-----------------------------------------------------|------------|
| 1  | Dendrocalamus asper [Schultes f.] Backer ex Heyne   | Betung     |
| 2  | Gigantochloa apus [J.A.& J.H. Schultes] Kurz         | Tali       |
| 3  | Bambusa tera bambosi [L.] Voss.                     | Ori        |
| 4  | Dendrocalamus giganteus Wallich ex Munro             | Sembilang  |
| 5  | Bambusa blumeana [J.A. & J.H. Schultes]             | Duri       |
| 6  | Dendrocalamus latiflorus Munro                      | Taiwan     |
| 7  | Gigantochloa atter [Hassk] Kurz                     | Ater       |
| 8  | Gigantochloa balui [K.M. Wong]                      | Buluh abe  |
| 9  | Gigantochloa levis [Blanco] Merill                   | Peting     |
| 10 | Gigantochloa manggong Widjaya                       | Manggong   |
| 11 | Gigantochloa pseudoarundinaceae [Steudel] Widjaya   | Gombong    |
| 12 | Gigantochloa robusta Kurz                           | Mayan      |
| 13 | Gigantochloa scortechinii Gamble                    | Buhul kapal|
| 14 | Schizostachyum brachycladum Kurz                    | Tamiang    |
| 15 | Schizostachyum lima [Blanco] Meriil                  | Buhul toi  |
| 16 | Schizostachyum zollingeri Steudel                    | Lampar     |

Source: [11,12]

2.2. Bamboo characteristics

Bamboo is a wonder grass; it grows in a rapid cycle and has a wide range of utilization. It was revealed that bamboo could grow up to 1 meter in a day; it is also can be harvested in 3—5 year period and is a self-renewing resource [13]. Conversely, the productivity rate of tree is not as high as bamboo and for some species tree needs more than 40 years to be yielded.

Bamboo is a versatile material, it is inexpensive, resilient, lightweight, straight, easy to carry, and has superior strength compared to steel [14]. Moreover, it can be obtained easily and only needs a simple fabrication, thus it has been widely traditionally used for many years.

In spite of its advantages, its natural shape, dimension, and morphology limit the optimum utilization of bamboo. The inferior flexibility in the lateral direction demonstrates large bending [13]. Bamboo should be treated prior to its utilization since it is prone to powder post beetle attacks [15]. It was reported that the addition of 0.5% permethrin in the adhesive effectively increased the powder post beetle mortality rate [15]. Further, the preservation of bamboo can be carried out through water soaking, lime washing and chemical preservative methods.

2.3. Bamboo development strategy

The sustainability of bamboo production obviously depends on the availability of production factors. One of the main factors is the accessibility to sustained supply of raw bamboo material. The Government of Indonesia is committed to developing bamboo utilization as one of the substantial non timber forest products. Initiated by the Environmental Bamboo Foundation, a-thousand-bamboo villages program were launched to establish ‘restoration economies’ in 1,000 communities all over Indonesia, using bamboo as a keystone species for conservation and sustainable livelihood [16]. The program, supported by the Ministry of Environment and Forestry, is a framework to create the integrated bamboo industry between upstream, middle and downstream industry [16].

Similarly, local governments support the economic and ecological restoration through the development of bamboo plantation. As it can be seen in Table 3 the government of Bangli allocated more than 200 ha area for bamboo plantation. While in Kintami the area is located in forest area, other subdistricts have their plantation outside the forest area [17].
Table 3. Bamboo development potential in Bangli Regency, Bali

| No | Subdistrict | Area (ha) | Existing | Projected | Total area (ha) |
|----|-------------|-----------|----------|-----------|----------------|
| 1. | Bangli      | 1,202.3   | 72.1     |           | 1,274.4        |
| 2. | Susut       | 532.95    | -        |           | 532.95         |
| 3. | Tembuku     | 713.65    | 41.0     |           | 754.65         |
| 4. | Kintamani   | 4,045.28  | 93.0     |           | 4,138.28       |
|    | Total       | 6,494.18  | 206.1    |           | 6,700.28       |

Source: [17]

Yogyakarta, owing plentiful traditional bamboo craftsmen and abundant bamboo plantation in forest area and its surrounding, is considered as one of the crucial non-timber forest product provinces. The Ministry has facilitated the development of bamboo plantation in another 80 ha area or almost 30% from the existing bamboo plantation (Table 4) [18].

Table 4. Bamboo development potential in Yogyakarta Province

| No | Regency     | Area (ha) | Existing | Projected | Total area (ha) |
|----|-------------|-----------|----------|-----------|----------------|
| 1. | Sleman      | 94.80     | 30.00    |           | 124.80         |
| 2. | Bantul      | 66.20     | 10.00    |           | 76.20          |
| 3. | Kulon Progo | 55.30     | 20.00    |           | 75.30          |
| 4. | Gunung Kidul| 4.25      | 20.00    |           | 24.25          |
|    | Total       | 220.55    | 80.00    |           | 300.55         |

Source: [18]

3. Engineered bamboo as a promising material substitution

The comparable mechanical properties of bamboo to softwood make it favourable to be used as building materials. To defeat the geometry drawbacks of bamboo, many efforts were made, including the converting process of a hollow shape into a thick planar shape. Laminated bamboo is a structural bonding of bamboo strips that arranged in vertically or horizontally direction [19]. The dimension and the utilization of this engineered bamboo, however, are more flexible compared to its natural shape. To form a lumber-like shape, laminated bamboo should be sourced from relatively thick wall bamboo and straight culm. There are at least six bamboo species that are commonly used for laminated bamboo and performed comparable physical and mechanical properties (Table 5).

Table 5. Suggested bamboo species for laminated bamboo

| No | Scientific name                      | Local name |
|----|--------------------------------------|------------|
| 1. | *Dendrocalamus asper* [Schultes f.] Backer ex Heyne | betung     |
| 2. | *Gigantochloa pseudoarundinacea* [Steudel] Widjaya | andong     |
| 3. | *Gigantochloa levis* [Blanco] Merill | peting     |
| 4. | *Gigantochloa robusta* Kurz | mayan     |
| 5. | *Dendrocalamus strictus* (Roxb.) Nees | batu      |
| 6. | *Gigantochloa apus* [J.A.& J.H. Schultes] Kurz. | tali      |

Source: [11,20–27]

The hybrid laminated bamboo-wood (HLBW) incorporates the advantages of bamboo and wood in one composite product. The HLBW of andong (*Gigantochloa pseudoarundinacea* (Steud.)Widjaya) and jabon (*Antocephalus cadamba* Miq.) fell in strength class III, which is greater than jabon (strength class IV) [27]. This result was similar to the HLBW of mayan (*Gigantochloa robusta* Kurz.) and jabon [27]. Table 6 summarizes the strength class of engineered bamboo in accordance to [28].
Table 6. Strength class of laminated bamboo and hybrid laminated bamboo-wood

| No  | Engineered bamboo                        | Strength class |
|-----|------------------------------------------|----------------|
| 1.  | Three-ply laminated andong board         | I              |
| 2.  | Three-ply laminated mayan board          | I-I            |
| 3.  | Vertically three-ply laminated andong beam | II            |
| 4.  | Five-ply laminated batu bamboo beam      | I              |
| 5.  | Seven-ply laminated batu bamboo beam     | I              |
| 6.  | Two-ply hybrid laminated mayan-jabon beam | III           |
| 7.  | Two-ply hybrid laminated andong-jabon beam | III           |
| 8.  | Vertically hybrid laminated andong-manii beam | II           |
| 9.  | Five-ply laminated tali-mayan lumber     | III            |

Source: [11,20–27]

As it can be seen in Table 6, the engineered bamboo of three-ply laminated andong board, five-ply and seven-ply of batu bamboo beam performed superior strength class (class I) which is comparable to bangkirai (*Shorea laevis* Ridl.), resak (*Vatica spp.*.) and ulin (*Eusideroxylon zwageri* Teijsm & Binn). Engineered bamboo which categorized in strength class II had the potential to substitute teak (*Tectona grandis* Linn. F) and balam (*Palaquium obtusifolium* Burck.).

4. Conclusion and recommendation

This paper concisely summarizes the potential of bamboo in Indonesia to substitute building and construction materials. It is worth noting that, of 88 endemic bamboo species, as much as 16 species are desirable as building and construction materials. The application of laminated technology improved the mechanical characteristics of bamboo. The engineered bamboo has a potential as building and construction alternative materials. To sustain the production of engineered bamboo, the supply of bamboo raw material should be secured. This can be accomplished by performing national strategy on bamboo plantation development, such as the establishment of “a thousand bamboo villages” and other local initiatives that bring in together the goodness of this green gold resource for the livelihood and environment.

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