# Bamboo hybrids bolster timber

A relatively common material is not being embraced fully for building supplies. University of the West of England Senior Lecturer, and Founder of Amphibia BASE Ltd, **Hector Archila,** discusses.

Interest in bamboo is growing, through research and media campaigning about the material's environmental benefits, properties and its ability to replace wood, steel and carbon-fibre. But bamboo is not commonly used in high-performance applications or permanent structures, and its potential in construction remains untapped.

Academic and industrial research carried out in the UK aimed to address the challenges associated with using bamboo in durable, safe and cost-efficient structures. Further combining the grass with UK-grown wood could maximise use of this material and make economic sense for the domestic forest sector.

## Longitudinal strength

High bamboo scaffoldings used when working on Hong Kong's skyscrapers, and earthquake and typhoon-proof structures in Ecuador, Colombia and in the Philippines are a testament to the material's mechanical properties. While regarding bamboo as a green steel and drawing a like-by-like replacement for steel is fundamentally wrong, as I said in the previous work *Bamboo reinforced concrete: a critical review* on the website *Open Access*, July 2018, the axial stiffness-to-weight ratio of bamboo is remarkably high and almost the same as that achieved for steel ($25 \times 10^6 m^2 s^2$).

However, this only applies to the mechanical properties of bamboo in the direction of its fibres i.e. it is longitudinal only. In any other direction, radially or tangentially, bamboo is very weak and tends to split and crush, unlike steel, which is isotropic. This is not to say bamboo should be scrapped, but more carefully considered.

## Carbon credentials

Bamboo has a higher $CO_2$ absorption than other materials. Compared with a native British tree like Scots Pine, Guadua – a giant species of a tropical 'woody' bamboo endemic to South America – is able to absorb about five times more $CO_2$ in a given period.

The mean yield class for Scots Pine in the UK, as given by the Forestry Commission, is an increment of $10m^3$ per hectare per year, while for Guadua it is $45m^3$ per hectare per year. Scots Pine would reach maturity at around 40 years old, while Guadua would be ready to harvest aged between three-five years.

Bamboo could provide large quantities of feedstock material for construction products that retain the fixed $CO_2$ for long periods of time, for example in buildings where an effective lifespan ranges between 50-100 years. A way to unlock bamboo's potential is by combining it with complementary materials like wood, which can address its radial weakness and thin-walled section, while exploiting its high axial stiffness and maintaining its high carbon and environmental credentials.

A $2,000m^2$ warehouse using Guadua in Bogotá DC, Colombia.

All images Hector Archila



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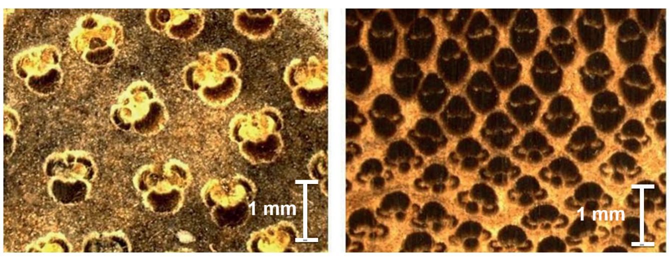
## Shooting ideas

Based on research carried out at the University of Bath, UK, Amphibia BASE is working to commercialise bamboo and demonstrate the business case for structural engineered bamboo products in the UK and worldwide. The key to making this a reality has been the use of thermo-hydro-mechanical (THM) technologies, which rapidly and efficiently transform bamboo into flat planks with higher density and improved mechanical properties.

THM technologies involve temperature, moisture content and mechanical pressure controls to modify the material's properties, for example its density and hardness, or to shape it into the desired form. Processing can be finished in 15 minutes, compared with three hours by conventional means. The company's THM process reduces the void spaces within bamboo conductive tissues, bringing the naturally scattered bamboo fibres closer together without causing cell damage – effectively densifying bamboo and producing a more homogeneous cross-section. This is evident from microscopy analysis of the material before and after THM densification. These are desirable features in structural engineering when designing and predicting the behaviour of materials in high-performance applications.

As a result of the THM process, the density and Young's modulus of bamboo are both increased almost two-fold from 540–890kg/cm$^3$ and 16.88-30.72GPa – the force applied in kilonewton per square millimetre – respectively. This straightforward densification process, reduces waste by 50%, as well as the high energy and labour intensity of conventional manufacturing processes of engineered bamboo products (EBPs) for non-structural applications. When laminating the THM densified bamboo, glue use is reduced from 30–3% per overall weight of the final product in some commercially available EBPs. These features were demonstrated in cross-laminated bamboo products G-XLam, manufactured by Amphibia BASE in the UK, at lab-scale.

| Control Guadua sample<br>Before THM | | Densified Guadua sample<br>After THM |
|---|---|---|




| 25.53% | Fibre surface | 47.78% |
|---|---|---|
| 540 kg/m$^3$ | Density (p) | 890 kg/ m$^3$ |

However, when densified bamboo is laminated on its own, the resulting product is very stiff, heavy, over-engineered and costly. The bending modulus of G-XLam 3 – three layers – obtained through testing was 23.68GPa, twice the value for the same property in cross-laminated timber (CLT) panels with the same three layers 11.6GPa. CLT is becoming increasingly popular for use in buildings reaching heights once thought unviable with timber. For instance, an 85.4m-high, all-timber tower designed by Voll Arkitekter was recently finished in Brumunddal, Norway, and is currently the highest tall timber building in the world. Overall, G-XLam panels have one-fifth of the thickness of CLT panels and double the density. By contrast, when a lower density timber is used, the number of laminations and product density can be reduced to an acceptable and cost-efficient level while retaining the stiffness and stability of the laminated product. Therefore, THM-densified bamboo can be used to strengthen low-density and low-strength wood, adding value to the final product and reducing the overall section of the structural timber product. This can also be applied to other low-density cores forming the hybrid composite.

## Maximise space

In the case of wood, statistics from 2018 by the Forestry Commission show about 70% of the sawn wood and 100% of the plywood and structural timber products used in construction in the UK were imported mainly from Europe. This is partly due to the low density, poor finishing and unsuitability of UK-grown wood, it being used mostly in low value-added applications, for example fencing. Timber experts may argue that in the UK, we need to loosen strength-grading standards for homegrown timber and establish a robust capacity to dry the wood for high value-added products such as CLT.

Around 50% of the forested areas of the UK is Sitka spruce. Due to the UK climate, Sitka grows very quickly, which does not allow for tissue consolidation and renders a low strength (C16) and lightweight timber that is commonly considered low-quality and value. However, when combining UK timber of lower strength class with THM-densified bamboo of higher stiffness, the resulting hybrid product can achieve properties equal to those achieved using timber from mainland Europe, for example in CLT panels. Although UK forests have recovered since the industrial revolution, there is limited land, thus the available timber.

## Growth opportunities

Wood-bamboo hybrids could significantly reduce the amount of wood required for engineered products and tackle quality and strength issues in UK-grown supplies. Further benefits include the support of the local UK forest industry and rural economy, the reduction of the UK's reliance on imported European timber and CLT elements, and the development of new markets locally and internationally. Also, exploitation of under-utilised and readily available bamboo resources in tropical countries using state-of-the-art technologies developed in the UK can offer a cost-effective and highly sustainable alternative to carbon and energy-intense conventional materials used in construction, such as steel and cement.

Technological challenges regarding adhesion and drying of home-grown wood to acceptable levels, which are key to the success of this commercial venture, are being addressed. Additionally, the use of the vast knowledge and expertise on timber for building applications helps tackle the current lack of internationally recognised standards for standalone structural bamboo products. Currently, funding and investment is being sought to develop a pilot facility that rolls out the technology and showcases the viability of producing wood-bamboo hybrids in the UK.

Above: Image displaying the increase in density and fibre surface per unit of area of a THM densified sample of Guadua.

Right: Bamboo-wood hybrids under development.



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