Visualizing heat flow in bamboo could help design more energy-efficient and fire-safe buildings

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Credit: Pixabay

Modified natural materials will be an essential component of a sustainable future, but first a detailed understanding of their properties is

needed. The way heat flows across bamboo cell walls has been mapped using advanced scanning thermal microscopy, providing a new understanding of how variations in thermal conductivity are linked to the bamboo's elegant structure. The findings, published in the journal *Scientific Reports*, will guide the development of more energy-efficient and fire-safe buildings, made from natural materials, in the future.

The building sector currently accounts for 30-40% of all carbon emissions, due to both the energy-intensive production of the materials (predominantly steel and concrete), and the energy used in heating and cooling the finished buildings. As the global population grows and becomes increasingly based in towns and cities, traditional building approaches are becoming unsustainable.

Renewable, plant-based materials such as bamboo have huge potential for sustainable and energy-efficient buildings. Their use would dramatically reduce emissions compared to traditional materials, helping to mitigate the human impact on climate change. This approach would also help keep carbon out of the atmosphere by diverting timber away from being burnt as fuel.

The study involved scanning cross-sections of bamboo vascular tissue, the tissue that transports fluid and nutrients within the plant. The resulting images revealed an intricate fibre structure with alternating layers of thick and thin cell walls. Peaks of thermal conductivity within the bamboo structure coincide with the thicker walls, where chains of cellulose—the basic structural component of plant cell walls—are laid down almost parallel to the plant stem. These thicker layers also give bamboo its strength and stiffness. In contrast, the thinner cell walls have lower thermal conductivity due to cellulose chains being almost at a right angle to the plant stem.

"Nature is an amazing architect. Bamboo is structured in a really clever

way," said Darshil Shah, a researcher in Cambridge University's Department of Architecture, who led the study. "It grows by one millimetre every ninety seconds, making it one of the fastest growing plant materials. Through the images we collected, we can see that it does this by generating a naturally cross-laminated fibre structure."

Madrid airport bamboo. Credit: Unsplash

While much research has been done on the cell structure of bamboo in relation to its mechanical properties, almost none has looked at how cell structure affects the thermal properties of the material. The amount of heating and cooling required in buildings is fundamentally related to the properties of the materials they are made from, particularly how much heat they conduct and store.

A better understanding of the thermal properties of bamboo provides insights into how to reduce the energy consumption of bamboo

buildings. It also enables modelling of the way bamboo building components behave when exposed to fire, so that measures can be incorporated to make bamboo buildings safer.

"People may worry about fire safety of bamboo buildings," said Shah. "To address this properly we have to understand the thermal properties of the building material. Through our work we can see that heat travels along the structure-supporting thick cell wall fibres in bamboo, so if exposed to the heat of a fire the bamboo might soften more quickly in the direction of those fibres. This helps us work out how to reinforce the building appropriately."

At present, products such as laminated bamboo are most commonly used as flooring materials due to their hardness and durability. However, their stiffness and strength is comparable to engineered wood products, making them suitable for structural uses as well. "Cross-laminated timber is a popular choice of timber construction material. It's made by gluing together layers of sawn timber, each at a right angle to the layer below," said Shah. "Seeing this as a natural structure in bamboo fibres is inspiration for the development of better building products."

The team of researchers, from the University of Cambridge and the University of Natural Resources and Life Sciences Vienna, also plans to look at what happens to heat flow in bamboo when its surface is burned and forms char. The use of scanning thermal microscopy to visualise the intricate make-up of plants could also be useful in other areas of research, such as understanding how micro-structural changes in crop stems may cause them to fall over in the fields resulting in lost harvests.

Shah is a member of the University of Cambridge's interdisciplinary Centre for Natural Material Innovation, which aims to advance the use of timber in construction by modifying the tissue-scale properties of wood to make it more reliable under changing environmental conditions.

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