How traditional Indian building techniques can make modern cities more climate-friendly

November 19 2019

The so-called Meghalaya bridges often lead over steep valleys. Many are secured by railings and handrails also made from the aerial roots. Credit: Ferdinand Ludwig

Dense, humid broadleaf forests, monsoon-swollen rivers and deep ravines—in the Indian state of Meghalaya wooden bridges easily decay or are washed away in floodwaters. Bridges made from steel and concrete are pushed to their limits here as well. But bridges made of living tree roots can survive here for centuries. Prof. Ferdinand Ludwig of the Technical University of Munich (TUM) has investigated these special structures and proposes integrating this extraordinary building technique in modern architecture.

Inaccessible valleys and ravines lead from the North East India Meghalaya plateau to the wide plains of Bangladesh. In the monsoon months, the mountain streams in the forests swell into torrential rivers. In order to cross these rivers, the indigenous Khasi and Jaintia peoples have long built their bridges out of the living aerial roots of the Indian rubber tree Ficus elastica. "Stable bridges like these, made of closely intertwined roots, can reach more than 50 meters in length and exist for several hundred years," says Ferdinand Ludwig, professor of green technologies in landscape architecture at TUM.

He analyzed 74 such living bridges together with Thomas Speck, professor of botanics at the University of Freiburg. "There has already been a lot of discussion of the living root bridges in the media and in blogs, but there have only been a few scientific investigations up to now," says Ludwig. "Knowledge about the traditional Khasi building techniques has hardly ever been put down in writing in the past," adds Wilfrid Middleton from the TUM Department of Architecture. The researchers conducted interviews with the bridge builders in order to gain a better understanding of the building process. The researchers took several thousand photographs, which they used to create 3-D models, providing insight into the complex root structure. The team also mapped the locations of the bridges for the first time.

A bridge that builds itself

"The building process usually begins with a planting: A person planning a bridge plants a Ficus elastica seedling on the bank of a river or the edge of a ravine. At a particular point during the plant's growth, it develops aerial roots," says Speck. The aerial roots are then wound onto a framework of bamboo or palm stems and directed horizontally over the river. Once the roots have grown as far as the opposite bank, they are implanted. They develop smaller daughter roots which are directed to the bank, as well, where they are implanted. Due to constant plant growth and the application of winding techniques, the roots of the Ficus elastica form highly complex structures which create stable, safe bridges. Newly growing roots are integrated in the existing structure repeatedly.

The properties of the Ficus elastica play an important role, according to Speck. "The roots react to mechanical loads with secondary root growth. In addition, the aerial roots are capable of forming inosculations." This is a process in which trunks, branches and roots of one plant grow into the structure of a second plant. "Possible injuries result in inosculation and callus formation, a process also familiar from wound healing of trees. Thus, for example, two roots which are pressed together can grow together and inosculate," says Speck. The bridges are made and maintained by individuals, families or by communities that include several villages that use the bridge.

"Living bridges can thus be considered both a man-made technology and a very specific type of plant cultivation," says Speck.

A young and a slightly older aerial root were knotted into a network, which shortens and tightens them. Later the roots will grow together at this point. Credit: Ferdinand Ludwig

Building for future generations

It takes decades, if not centuries, to complete a living bridge made of Ficus elastica. Often, many generations are involved in the building process. "The bridges are a unique example of future-oriented building. We can learn much from this: Today, we are faced with environmental problems that will not only affect us, but also subsequent generations. We should approach this topic as the Khasis have," says Ludwig.

Living buildings can cool down cities

"The findings relating to the traditional techniques of the Khasi people can promote the further development of modern architecture," says Ludwig, himself an architect. He integrates plants as living building materials in his plans and structures. In 2007, he founded a new field of research centered on this approach called Baubotanik.

By integrating plants in building processes, people can better adapt to the impacts of climate change, he says: "Stone, concrete and asphalt heat up rapidly at high ambient temperatures, so that heat stress is particularly relevant in cities. Plants provide cooling and improve the climate in the city. Baubotanik means no extra space has to be created for plants; instead plants are much more an integral component of structures."

More information: Ferdinand Ludwig et al, Living bridges using aerial roots of ficus elastica – an interdisciplinary perspective, *Scientific Reports* (2019). DOI: 10.1038/s41598-019-48652-w

Provided by Technical University Munich