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X-rays reveal termites' self-cooling, self-ventilating, self-draining skyscrapers

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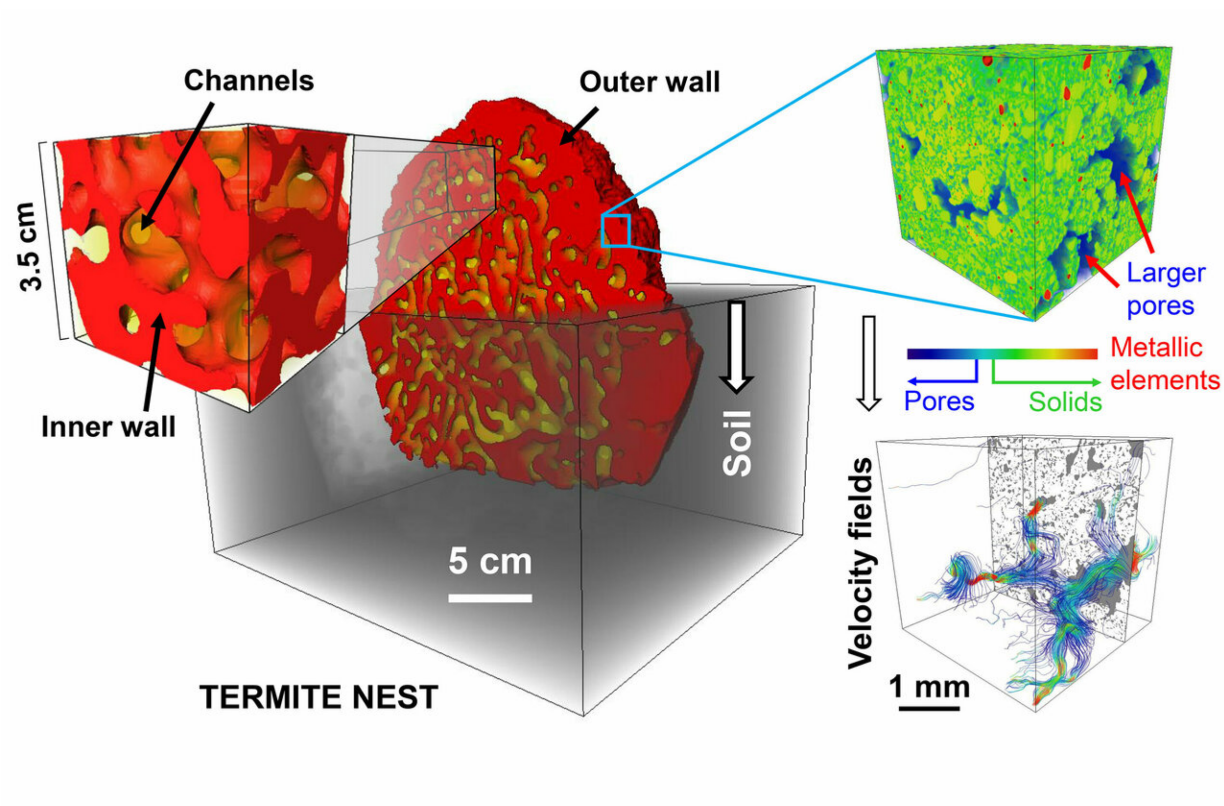

Multi-scale 3D X-ray tomography of termite nests reveals the secrets of their architecture which plays a significant role in ventilation, thermal regulation and water drainage after rainy periods. Credit: Kamaljit Singh

Many species of termites, whose societies are built on hierarchies of kings, queens, workers, and soldiers, live in towering nests that are ventilated by a complex system of tunnels.

The nests, also known as mounds, protrude from the ground like skyscrapers and can grow as tall as seven metres. They are also self-cooling, self-ventilating, and self-draining—but until now the mechanisms behind these climate control features has remained unknown.

A group of engineers, biologists, chemists and mathematicians lead by Imperial College London, the University of Nottingham, and CNRS-Toulouse have looked closer than ever before at how these nests work using 3-D X-ray imaging. They found small holes, or pores, in the walls of termite mounds which help them stay cool, ventilated, and dry.

Lead author Dr. Kamaljit Singh, from Imperial's Department of Earth Science & Engineering, said: "Termite nests are a unique example of architectural perfection by insects. The way they're designed offers fascinating self-sustaining temperature and ventilation controlling properties throughout the year without using any mechanical or electronic appliances."

In their new study, published in *Science Advances*, the researchers sourced termite nests from the African countries Senegal and Guinea and studied them using two types of 3-D X-ray imaging.

First, they scanned the nests at a lower resolution to measure the nests' larger features, like walls and corridors known as channels.

From the images they calculated the thickness of the nests' inner and outer walls, as well as the structural details of inner channels which termites use to get around the nest.

The researchers found that networks of larger and smaller pores in the nest walls help exchange carbon dioxide (CO_2) with the outside atmosphere to help ventilation. Larger micro-scale pores are found to be fully connected throughout the outer wall providing a path across the walls, and by using 3-D flow simulations, the authors showed how CO_2 moves through the nests to the outside.

The simulations showed that the large micro-scale pores in nest walls are useful for ventilation when the wind outside is faster, as CO_2 can leave freely. However in slower wind speeds, the larger pores can also help to release CO_2 through diffusion.

Dr. Singh said: "This is a remarkable feature that lets the nest ventilate regardless of the weather outside."

Nests are usually found in hotter regions, which means they must stay cool. Indeed, the authors found that the larger pores also help regulate temperatures inside nests. The pores, which lie in the outer walls of the nest, fill with air which reduces heat entering through the walls—similarly to how the air in double glazed windows helps keep the heat inside.

Considering the crucial role the pores play, the team also wondered what happens when it rains and the pores become blocked by water.

They found that the nests use 'capillary action' - where liquid flows through small spaces without external help from gravity—that forces rain water from the larger pores to the smaller pores. This ensures the larger pores keep stay open to keep ventilating the nest.

Dr. Singh said: "Not only do these remarkable structures self-ventilate and regulate their own temperatures—they also have inbuilt drainage systems. Our research provides deeper insight into how they manage this so well."

The scientists say the newly found architecture within termite nests could help us improve ventilation, temperature control, and drainage systems in buildings—and hopefully make them more energy efficient.

Co-author Professor Pierre Degond from Imperial's Department of Mathematics said "The findings greatly improve our understanding of how architectural design can help control ventilation, heat regulation, and drainage of structures—maybe even in human dwellings. They also provide a new direction for future research, and will eventually bring us one step closer to understanding mechanisms that could be useful in designing energy efficient self-sustaining buildings."

Co-author Dr. Bagus Muljadi from the University of Nottingham said: "We know that nature holds the secrets to survival. To unlock them, we need to encourage global, interdisciplinary research.

"This study shows that there is a lot more to learn from mother nature when it comes to solving even the most important 21st century problems."

More information: K. Singh el al., "The architectural design of smart ventilation and drainage systems in termite nests," *Science Advances* (2019). advances.sciencemag.org/content/5/3/eaat8520

Provided by Imperial College London

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