Scientists create 'fungi tiles' with elephant skin texture to cool buildings

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Credit: Nanyang Technological University

A team of scientists led by Nanyang Technological University, Singapore (NTU Singapore) have developed "fungi tiles" that could one day help to bring the heat down in buildings without consuming energy.

These wall tiles are made from a new biomaterial combining fungi's root network—called mycelium—and organic waste. Earlier research has shown that mycelium-bound composites are more energy efficient than conventional building insulation materials such as expanded vermiculite and lightweight expanded clay aggregate.

Building on this proven insulating property, the NTU Singapore team worked with local ecology and biomimicry design firm bioSEA to add a bumpy, wrinkly texture to the tile, mimicking an elephant's ability to regulate heat from its skin. Elephants do not have sweat glands and rely on these wrinkles and crevices on their skin to regulate heat.

In laboratory experiments, the scientists found that the cooling rate of their elephant skin–inspired mycelium tile was 25% better than a fully flat mycelium tile, and the heating rate was 2% lower. They also found that the elephant skin-inspired tile's cooling effect improved a further 70% in simulated rain conditions, making it suitable for tropical climates.

The construction industry accounts for nearly 40% of all energy-related emissions worldwide, so the search for eco-friendly insulation materials is critical. NTU's Associate Professor Hortense Le Ferrand, who led the study, said mycelium-bound composites could be a promising alternative.

Assoc. Prof. Le Ferrand, who holds a joint appointment at NTU's Schools of Mechanical and Aerospace Engineering (MAE) and Materials Science and Engineering (MSE), said, "Insulation materials are increasingly integrated into building walls to enhance energy efficiency, but these are mostly synthetic and come with environmental consequences throughout their life cycle.

"Mycelium-bound composite is a biodegradable material that is highly porous, which makes it a good insulator. In fact, its thermal conductivity is comparable to or better than some of the synthetic insulating materials used in buildings today.

"We worked closely with bioSEA to integrate natural design principles that can optimize its performance as a building insulator. The result is a promising proof of concept that takes us one step closer to efficient, sustainable, and cheaper passive cooling solutions in hot and humid conditions."

Dr. Anuj Jain, the Founding Director of bioSEA explained the inspiration behind the elephant-linked innovation: "Elephants are large animals that live in hot and sometimes humid tropical climates. To withstand the heat, elephants evolved to develop a skin that is heavily wrinkled which increases water retention and cools the animal by evaporation.

"We were inspired by how an elephant could cool itself in hot weather without sweat glands, and tried to see how we could replicate the same cooling mechanisms of shading, trapping cool air, and increasing the surface area for water to evaporate."

This study, published in *Energy & Buildings*, builds on Assoc. Prof. Le Ferrand's work on possible uses for mycelium-bound composites, such as for greener construction materials.

Turning fungi into a functional material

Mycelium-bound composites are created by growing fungi on organic matter such as sawdust or agricultural waste. As the fungus grows, it binds the organic matter into a solid, porous composite.

For this study, the NTU scientists used the mycelium of oyster mushroom (Pleurotus ostreatus)—a commonly found fungus—and bamboo shavings collected from a furniture shop.

These two components were mixed with oats and water and packed into a hexagonal mold with an elephant skin–inspired texture designed by bioSEA using computational modeling and algorithms to select the optimal design.

The mycelium tiles were left to grow in the dark for two weeks, then removed from the hexagonal mold and left to grow in the same conditions for another two weeks.

Finally, the tiles were dried in an oven at 48°C for three days. This final step removes any remaining moisture, prohibiting further mycelial growth.

Elephant skin–inspired texture improves heat regulation

Previous research has shown that mycelium-bound composites have thermal conductivity comparable to conventional building insulation materials like glass wool and extruded polystyrene.

To assess how an elephant skin–inspired texture affects the mycelium tile's heat regulation, the scientists heated mycelium tiles on a 100°C hot plate for 15 minutes and tracked temperature changes using an infrared camera.

They found that the elephant skin-inspired tile absorbed heat more slowly. When its bumpy textured surface faced the heat source, its temperature increased by 5.01°C per minute, compared to 5.85°C per minute when its flat surface was exposed to heat. As a control, the scientists also heated a flat mycelium tile and found it gained 5.11°C per minute.

To measure the tile's cooling efficiency, the scientists heated one side at 100°C for 15 minutes, then exposed it to ambient conditions (22°C, 80% humidity) and measured temperature changes on the tile's opposite side.

The elephant-skin-inspired tile cooled fastest when heated from the flat side, losing 4.26°C per minute. When heated from the textured side, its flat side lost 3.12°C per minute. The fully flat control tile lost 3.56°C per minute.

Based on these findings, the scientists recommended installing the tiles with the flat side adhered to the building façade and the textured surface exposed to external heat for optimal thermal performance.

Tiles perform better in wet weather

To simulate the effect of rain on the tiles, the scientists heated the tiles as described earlier. While allowing them to cool, the scientists sprayed water onto the tiles at one-minute intervals over a 15-minute period.

When misted on its bumpy side, the elephant skin–inspired tile lost 7.27°C per minute—a 70% improvement compared to its performance in dry conditions.

The scientists attributed this effect to the mycelium-bound composite's hydrophobic nature. "The fungal skin that develops on the tile's surface repels water, allowing droplets to remain on the surface rather than roll off immediately. This promotes evaporative cooling, increasing the cooling rate," explained Eugene Soh, an NTU researcher and the study's first author.

Building on this proof of concept, the scientists are now exploring ways to enhance the tiles for real-world use, such as increasing their mechanical stability and durability or using different mycelium strains.

The scientists are also working with local start-up Mykílio to scale up the size of the mycelium tiles and conduct outdoor tests on building façades.

A challenge they foresee in scaling up the production of the tiles is the time needed to grow the mycelium tiles. While it requires minimal energy resources, the process takes three to four weeks.

The scientists also expect high inertia towards using mycelium tiles as an alternative construction material due to the well-established infrastructure in production, storage, and transportation of common insulating materials.

Assoc. Prof. Le Ferrand said, "We've developed a promising eco-friendly alternative that transforms waste into a valuable resource while rethinking conventional thermal management materials. This opens the pathway for more elephant skin–inspired designs and the use of different mycelium strains to overcome the challenges that come with using mycelium tiles as an alternative construction material."

More information: Eugene Soh et al, Biodegradable mycelium tiles with elephant skin inspired texture for thermal regulation of buildings, *Energy and Buildings* (2024). DOI: 10.1016/j.enbuild.2024.115187

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