Did You Say, "Build it with Mushrooms"?

By Shaina Saporta, P.E. and Matt Clark, C.Eng., P.E.

Arup was an Outstanding Award Winner for the Hy-Fi project in the 2015 NCSEA Annual Excellence in Structural Engineering awards program (Category – Other Structures).

In January 2014, David Benjamin of The Living approached us to ask if Arup would be interested in supporting their entry into the MoMA Young Architects Program competition. The only information? They had an "unusual" idea.

Each summer, MoMA PS1 in Queens, New York, selects the centerpiece installation of the summer concert series from their Young Architects Program, an annual competition for innovative and promising new architects. And The Living's idea for the 2014 season was indeed unusual – to build the installation out of mushroom bricks.

These bricks are grown by Ecovative out of Mushroom Material. Ecovative's innovative process mixes mycelium, the root structure of a fungus, with agricultural waste like corn husks in various shaped molds. As the mycelium continues to grow it binds with the agricultural waste, creating a rigid material similar to synthetic packing products. Ecovative's goal is to replace these and eventually other, synthetic commodities with their sustainable, biodegradable product. At the time, the Mushroom Material was only being used for packaging, so there was no data on the bricks' structural properties to support Arup's design work. Testing would be essential to making this project a reality.

So they started with the basics. The first test consisted of an engineer standing on a brick to determine an approximate allowable compressive stress. From there, Arup started defining the height of the installation. They also immediately began a rudimentary creep test. With the short design time – from initial meeting to on-site in five months – gathering as much data as quickly as possible would be key in delivering the project. Over the following months, Arup worked with Ecovative, The Living, and Columbia University's Carleton Strength of Materials Laboratory to test iterations of bricks.

Compression tests were performed from initial testing through delivery of materials to the site, all to ensure the final product was consistent with design assumptions. Shear tests were done on various mortar types, including testing organic mortars such as a wheat paste. Cyclic compression testing was done to understand if any of the compression deformation was elastic. An assembly test of a small section of wall was used to validate design assumptions. Testing was extensive and carried on through the entire process of design, informing the work and providing opportunities to revisit assumptions.

Initial compression tests indicated the bricks were very soft but did not demonstrate any loss of stiffness or spalling at very large strains. Stiffness increased at large strains as the material compressed, removing void volume. The stiffness at low strains, however, was very low. Different material mixes and grow methods were tested to improve the material performance. The design modulus of elasticity for the final mushroom mix was 140psi.

With the low elastic modulus, the structure was governed by serviceability and stability concerns. BMT Fluid Mechanics helped by looking at a risk-based approach to wind loads, allowing for reduced design wind pressures in conjunction with a storm-action plan. Even with reduced design wind pressures, a mushroom structure of this size, nearly 41 feet in height, was too flexible under wind load. A timber frame structure was introduced to stiffen the structure under lateral loads. The frame was made of built-up sections of salvaged scaffolding planks and tied together at the tops with a steel perimeter plate which acted as the diaphragm. Foundations at the base of each frame consisted of ground screws.

With 5 weeks on-site, construction had to be both quick and efficient. The crew, led by Art Domantay, consisted of both architecture students, recent graduates and experienced professional masons and builders. Working together, the team mixed old and new construction methods with the traditional lime mortar and new mushroom bricks.

Dubbed the most 'Instagram-able' spot of the summer by the director of MoMA PS1 (#hyfi), the installation captured the imagination of the public. At the weekly summer parties, people would engage with the structure. Not content just to look, the innovative material had visitors touching the structure, even climbing it! Information and displays nearby told the story of the compostable structure, allowing the curious to explore the science behind the mushroom brick.

And at the end of the summer, the tower disappeared. The scaffolding frame was dismantled to be used by others, the ground screws were removed, and the mushroom bricks composted back into the earth. So often as structural engineers, our success is in the permanence of our work. The success of this project was in its ability to physically disappear while hopefully making a lasting impact on our industry. Mushroom bricks won't replace steel or concrete, but they will challenge us to think about new materials. What other materials can we build with?▪

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