Hy-Fi, commissioned by the Museum of Modern Art and MoMA PS1, offers a captivating physical environment and a new paradigm for sustainable architecture. In 2014, we tested and refined a new low-energy building material, manufactured 10,000 compostable bricks, constructed a 13-meter-tall tower, hosted public cultural events for three months, disassembled the structure, composted the bricks, and returned the resulting soil to local community gardens. This successful experiment offers many possibilities for future construction.

“In terms of technology and sustainability, the idea of using agricultural waste in this brilliant, ingenious way—and drawing on the technologies of biology instead of the technologies of physics—is very impressive. And the method of bricklaying is very sophisticated.”

KENNETH FRAMPTON
Professor of Architecture at Columbia Graduate School of Architecture, Planning and Preservation

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**PLAN EXPLODED AXONOMETRIC CONSTRUCTION**

**REALIZATION & PROGRESS**

**SECTION**

**CONSTRUCTION**

- Re-used growing trays from brick manufacturing
- Compostable mycelium bricks
- Sustainable mortar
- Hemp-crete foundation bricks
- Steel diaphragm for hurricane tie-downs
- Reclaimed timber (NYC scaffolding boards)
- Reusable ground screws for foundation
We designed a new type of brick through an innovative combination of corn stalk waste and living mushrooms with root-like growth. The bricks are lightweight, low cost, and extremely sustainable. We then created the world's first large-scale outdoor construction out of this material. We used biological, physical, and computational technologies to test the material's durability, structure, and thermal performance, and to design a robust and viable temporary building.

“Hy-Fi reinvents the most basic component of architecture—the brick—as both a material of the future and a classic trigger for open-ended design possibilities... This material could become a staple for building in places where resources are very limited. It could be transformative.”

PEDRO GADANHO
Architecture Curator,
Museum of Modern Art

EMBODIED ENERGY (MJ/KG)*
Mycelium Brick: 0.2
Red Clay Brick: 4.5
Concrete: 4.7
Steel: 20.1
Glass: 15.0
Wood: 10.4

CARBON EMISSIONS (KG CO2 PER KG)*
Mycelium Brick: 0.04
Red Clay Brick: 0.24
Concrete: 0.16
Steel: 1.37
Glass: 0.85
Wood: 0.46

BRICK SPECIFICATIONS
Dimensions: 17” x 7” x 4”
Weight: 1.5 lb
Density: 7 lb/ft3
Compression Strength: No loss of material stiffness at up to 1000 psi
Modulus of Elasticity: 200 psi
Tension Strength: 30 psi
Moisture absorption: less than 3%
Thermal conductivity: 2-8 x less than concrete
Thermal diffusivity: 10-40 x less than concrete
Durability: After 3 years of exposure to UV and wet-dry cycles in accelerated aging chamber, the material exhibited the same mechanical properties

*Sources: NIST Building for Environmental and Economic Sustainability software, Inventory of Carbon and Energy Database, Ecovative Design.

INNOVATION & TRANSFERABILITY

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This new construction material grows out of living materials and returns to the earth through composting at the end of the structure’s lifecycle. The manufacturing process engages bio-technology, agriculture, and industrial manufacturing. The composting process engages the municipal solid waste stream. In contrast to typical short-sighted architecture, our project is designed to disappear as much as it is designed to appear.

“As a sustainable building material, this is exceptional. Unlike traditional biomass, this is not dependent on the sun for growth, decoupling it from the limitations of providing solar insolation and facilitating efficient production around a marvelous energy source—our organic waste.”

FORREST MEGGERS
Assistant Professor at Princeton School of Architecture and Andlinger Center for Energy and Environment

LAYERS OF PERFORMANCE

MANUFACTURING (BEGINNING OF LIFECYCLE): A GROWN BRICK
1. Laboratory (cultivate mycelium) 2. Agriculture (collect waste) 3. Manufacturing (turn bricks in mold) 4. Industry (grow at scale) 5. Construction (lay bricks on site)

DESIGNED TO DISAPPEAR

COMPOSTING (END OF LIFECYCLE): A BIODEGRADEABLE BUILDING MATERIAL
1. Deconstruction (remove bricks) 2. Processing (break apart bricks) 3. Composting (add food waste) 4. Renewal (harvest soil) 5. Growth (soil used for new planting)
Construction waste accounts for over 30% of landfill volume. Our project offers an alternative to this wasteful linear economy. We use low-value raw materials rather than high-value ones, we use almost no energy to create building blocks rather than using massive energy, and we return demolition material to the earth in 60 days rather than burying it in landfills for hundreds of years. This approach is related to the Circular Economy, and according to the World Economic Forum, it has the potential to decouple economic growth—and also construction—from resource consumption.

“...the construction and deconstruction demonstrate the lifecycle and the circular economy of these sustainable and renewable materials. Fittingly, one of the plants growing in the courtyard is corn, making a kind of symbolic closed-loop for this material.”

Andrew Dent
Vice President of Library and Materials Research at Material Connexion

Raw material, manufacturing, construction, composting, and replanting all within 150 miles

Future Applications
• wall insulation
• interior walls and partitions
• acoustical ceiling tile
• sound insulation panels
• temporary housing

Atmosphere
Natural Carbon Cycle
Soil
Plants
Waste
Production
Demolition
Construction
Typical Construction Process
New Construction Paradigm
From Linear to Circular Economy
Temporarily borrowing raw materials and energy from the Carbon Cycle, then returning them

Raw Material Cost (Per FT^3)
• Mycelium Brick: $1.25
• Red Clay Brick: $11.52
• Concrete: $1.89
• Steel: $1,343.04
• Glass: $272.73
• Wood: $10.73

Initial Tower Building
Height in meters: 13
Number of bricks: 10,000
Miles per hour of hurricane wind that the structure can withstand: 75
Percentage of volume that is compostable: 89
Days for brick to return to soil: 60
Cubic meters of soil produced: 40

Local Materials
Raw materials, manufacturing, construction, composting, and replanting all within 150 miles

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Future Applications
From bricks to other low-energy, compostable materials

Unsustainable
Sustainable
This project involves a multi-faceted engagement with people. It offers a direct relationship to regional agriculture and innovation culture, municipal artists and non-profits, and local community gardens. People working on the project included local artists, local trade school interns, international graduate students, construction professionals, engineering professionals, and non-profit organizations. All people involved were meaningfully engaged and fairly paid. The project also engaged a diverse public through its high-profile installation.

“The Living could have hired masters degree candidates at a volunteer basis, but they instead chose to engage Brooklyn Tech Triangle college students and working professionals in need of jobs at a competitive hourly salary, bolstering their confidence and providing them with fair wages.”

TORY HANNA
Employment Coordinator
Brooklyn Navy Yard
Development Corporation

“People working”

Designing
Create integrated design studio during construction

Manufacturing
Mass production of bricks in upstate New York factory

Training
On-the-job training for community interns

Building
NYC brick masons and Columbia graduate students

Collaborating
Multifaceted team teaching and learning from one another

Educating
Our team explaining the project and new material to visitors

Playing
Kids building alternate structures with our bricks

Socializing
Summer social events in Museum courtyard

Partying
Weekly music performances with 5,000 people

People visiting
Visitors to MoMA PS1 during installation: 52,500
Visitors to Museum of Modern Art during installation: 750,000
Hy-Fi offers a familiar-yet-completely-new building in the context of the glass towers and typical brick construction of New York City. The building creates mesmerizing light effects on its interior walls through reflected caustic patterns. The building frames the natural environment with a forward-looking perspective. The building plays with light, shadow, pattern, texture, and unique atmosphere. Both the architectural community and the general public have been enthusiastic about this design and this new vision for design and manufacturing. Overall, the building is full of wonder and optimism.

“Hy-Fi might be the first built example of one of the [icons] of computer-assisted design: interlocking, curving columns... It is also one of the most fully realized bio-buildings ever constructed. As such, its form is a proof-of-concept both formally and environmentally.”

AARON BETSKY
Curator and Dean of the Frank Lloyd Wright School of Architecture

SELECTED PUBLICATIONS

CONSULTING
Structural engineer: Arup
Organic materials: Ecovative
Daylighting materials: 3M
Construction: Art Domantay Artworks
Masonry: PMA Construction
Software: Autodesk Dynamo
Structural testing: Columbia Engineering
Carlton Strength and Materials Laboratory
Natural coating: Shabd Simon-Alexander
Natural weatherproofing: Silacote
Foundation supplier: Krinner
Salvaged material and compost: Build It Green!
Wind engineer: BMT Fluid Mechanics
Environmental engineer: Atelier Ten
Landscape consulting: SCAPES
Accelerated aging: Advanced Metal Coatings Incorporated
Fabrication: Associated Fabrication
Fabrication: LeeLAB Studio