Raised, Heated Floor for Temporary Shelters and Camping

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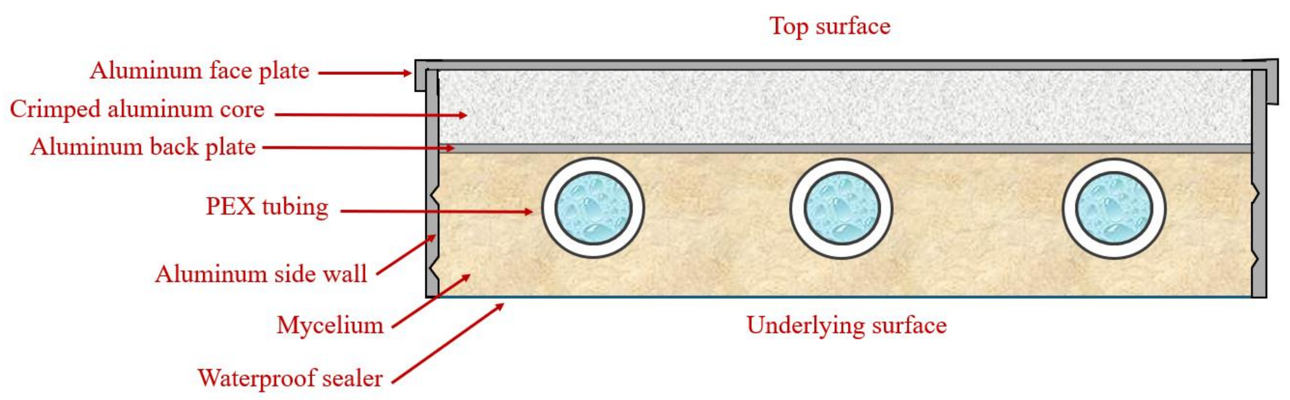
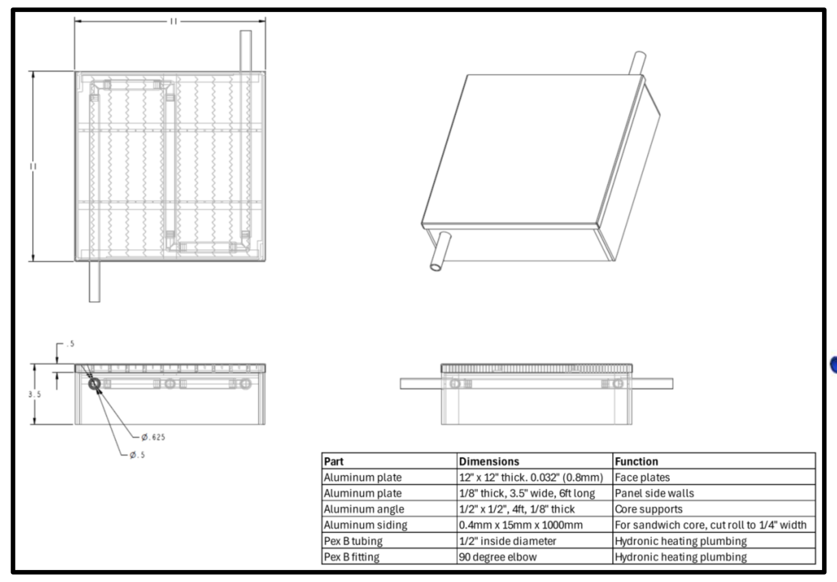
ABSTRACT

Inspired by stories from the Western North Carolina community and efforts by Bald Creek Relief, a nonprofit organization in Burnsville, NC, formed in response to the Helene disaster, this project focuses on designing and building a prototype panel for a modular raised heated platform. The platform aims to provide a strong, safe, and cost-effective heating solution for individuals living in tents and other temporary shelters during the colder seasons. Key design considerations include creating a modular, environmentally friendly, lightweight, non-flammable, and durable structure. A hydronic heating system was chosen for this design, not only to maintain a safe and low-cost product, but mainly due to water's high heat capacity (4.18 J/g·K). Meaning that water is able to transport the heat more efficiently throughout the system with minimal temperature change.

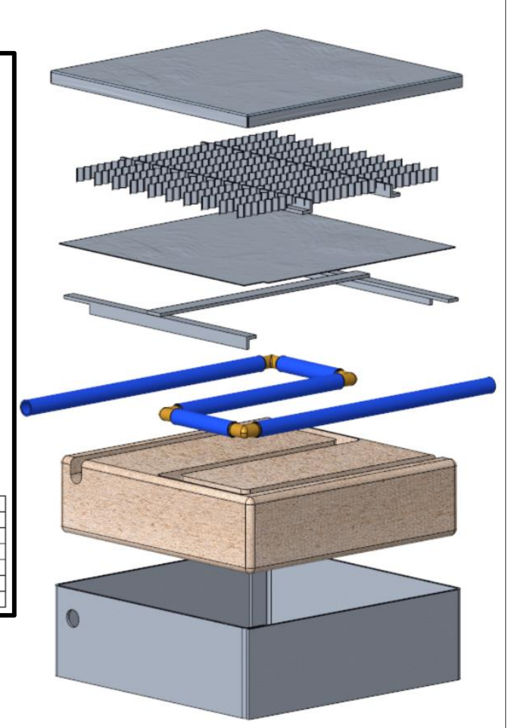


PROTOTYPE STRUCTURE AND DESIGN

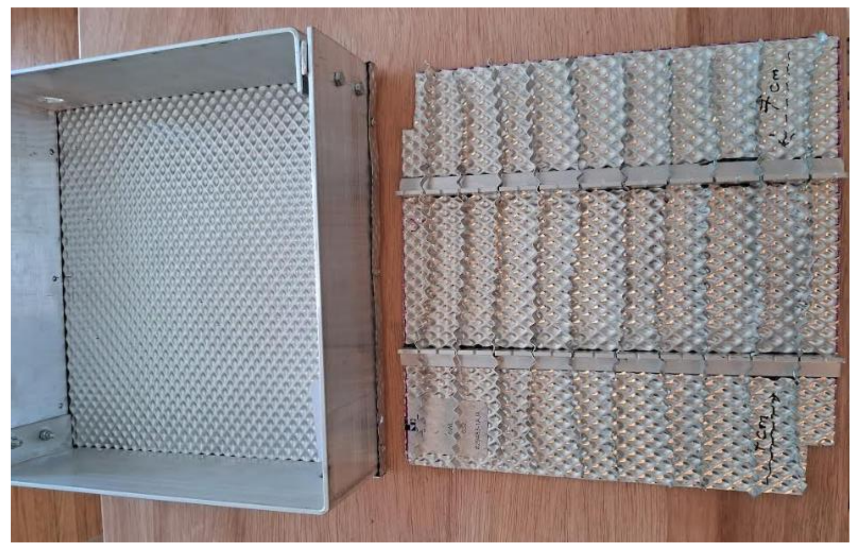
Aluminum was selected for the panel's structure and load-bearing surfaces due to its key advantages, including low cost, lightweight nature, recyclability, and high thermal conductivity. Additionally, by incorporating a sandwich panel design for the topmost layers provides a high strength-to-weight ratio, improved load distribution, reduced weight, and have an increased bending stiffness when compared to a solid sheet of aluminum or steel [1].



CAD Drawing and components table of Prototype



Exploded view of prototype design



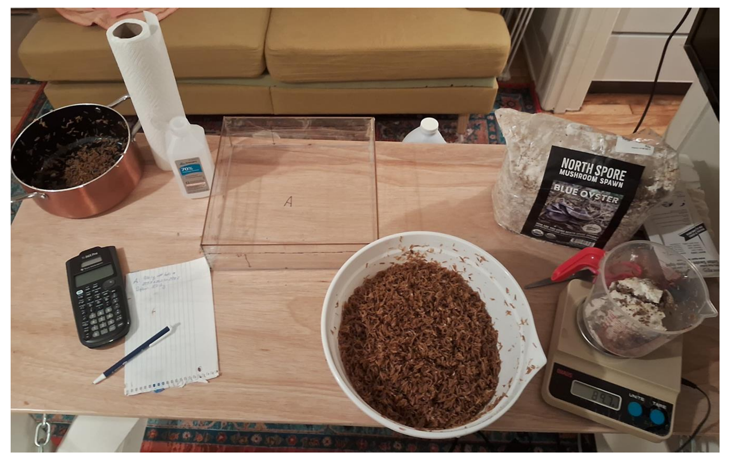
Actual prototype during build-phase

Mycelium Insulation

Mycelium is the root-like structure that is formed from the growth of fungi. This material is becoming a popular research topic and promising building material due to its high acoustic and heating insulation properties, as well as its low impact on the environment.

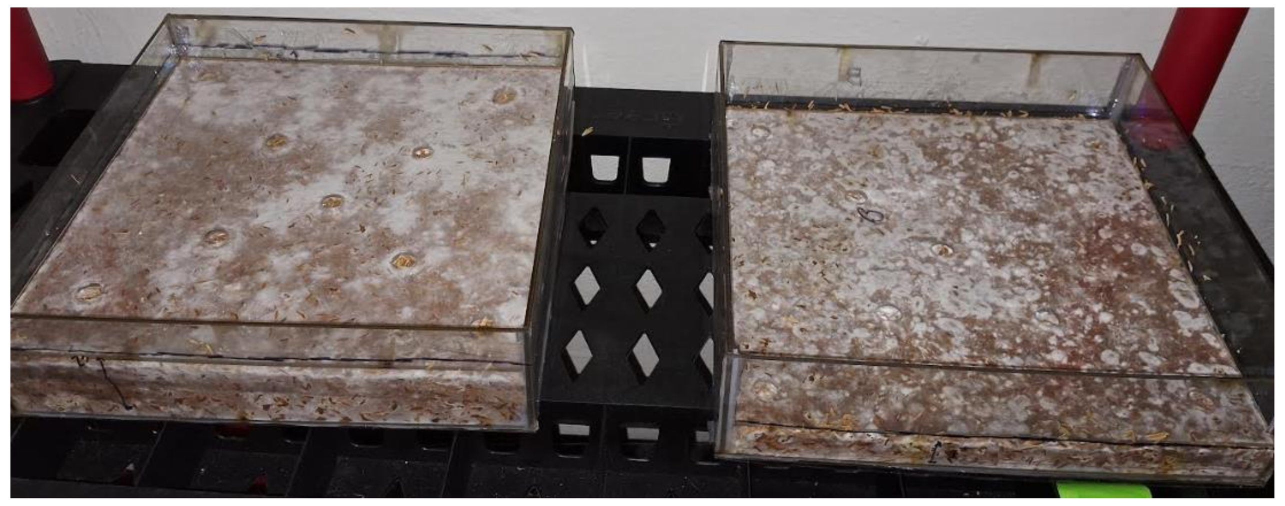
While mycelium is gaining attention and turning up on the market as pre-made panels for walls and flooring, the majority of these products are for sale in Europe and not the United States [2]-[4].

To assess the success, growth rate, and impact of varying thickness on the development of custom mycelium panels, two plexiglass forms were constructed with dimensions of 11" x 11" x 1" and 11" x 11" x 2". The author achieved this by creating a temperature- and humidity-controlled environment in their closet. Temperature and humidity levels were recorded multiple times per day to ensure a consistent growing environment was maintained. The mycelium preparation process for this experiment included pasteurizing the chosen substrate (rice hulls), disinfecting all surfaces, and combining the appropriate volume percentage of mushroom spawn (Pleurotus ostreatus — blue oyster mushroom), flour as an additive, and the moistened substrate.

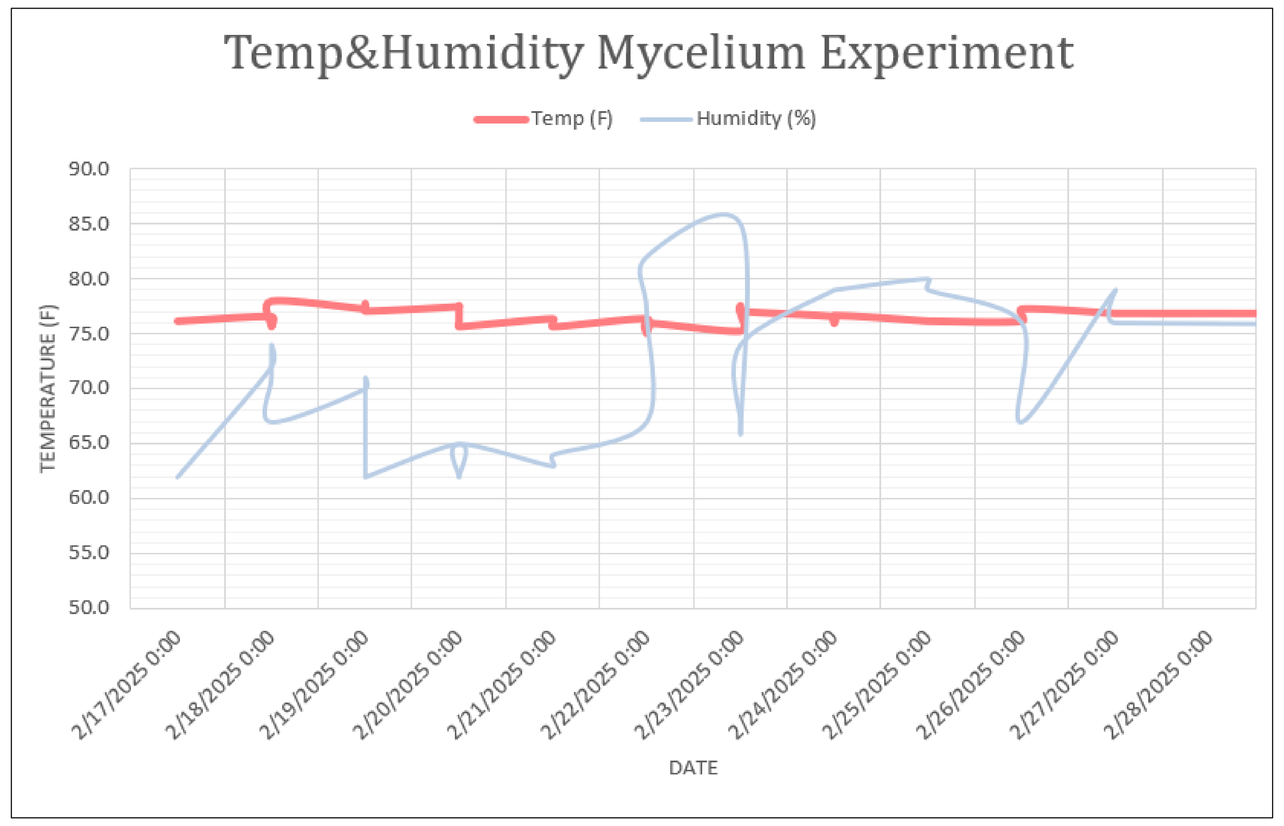


At-home mycelium preparation

Panel A Day 3



Panel A (left) and Panel B (right) Day 10



Theoretical Analysis of Prototype Thermal Conductivity

Calculating a theoretical value for the prototype's thermal conductivity is essential for predicting its performance in real-world conditions. A comparison between closed-cell polyurethane spray foam insulation and the mycelium insulation were calculated to form a more holistic study.

Calculating the total thermal resistance was an important step in determining the prototype's overall thermal conductivity. This was accomplished by summing the individual thermal resistances of each cross-sectional layer and applying the following equations:

$R_i = \frac{d_i}{k_i \cdot A}$ where

R_i = thermal resistance of the i^{th} layer of the panel $[\frac{m^2 \cdot K}{W}]$

d_i = thickness of the i^{th} layer [m]

k_i = thermal conductivity of i^{th} layer $[\frac{W}{m \cdot K}]$

A = cross-sectional area of i^{th} layer $[m^2]$

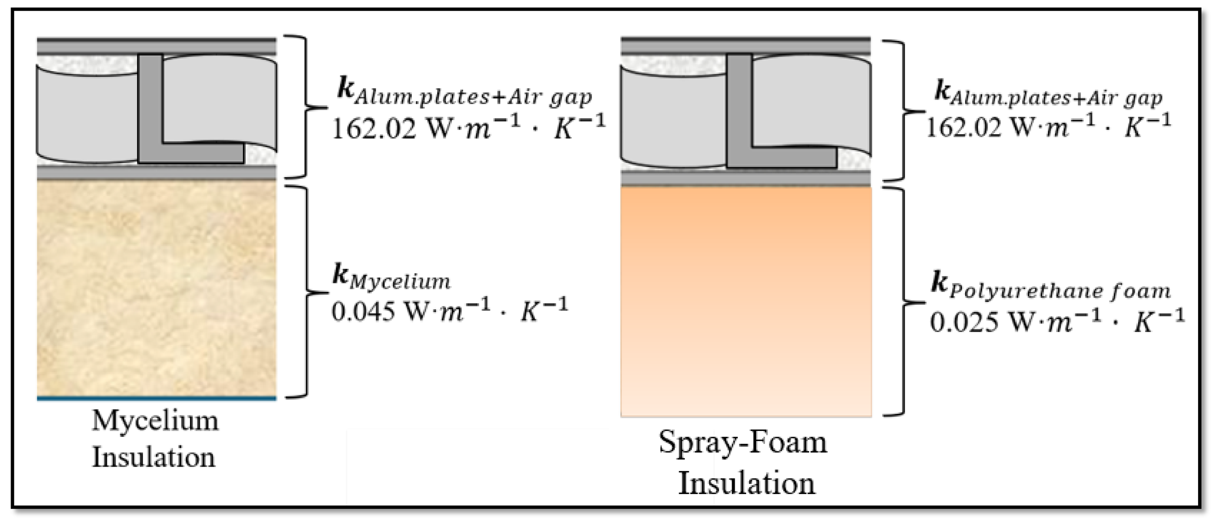
$$R_{total} = R_1 + R_2 + R_3 \ldots$$

$$k_{eff} = \frac{d_{total}}{R_{total} \cdot A}$$

A comparative analysis was conducted between closed-cell polyurethane spray foam insulation and mycelium-based insulation to provide a more comprehensive study. The below figure displays the calculated values for the thermal resistance and thermal conductivity of above discussed panel materials and foam vs. mycelium comparison.

	R $(\frac{m^2 \cdot K}{W})$	k $(\frac{W}{m \cdot K})$
Mycelium	82.38	0.045[5]
Aluminum faces	0.0229	162[6]
$Air_{77°F}$	144.18	0.026[7]
$Air_{35°F}$	154.39	0.024[7]
Closed-cell polyurethane foam	--	0.025[8]
Mycelium prototype (Total at 77°F)	226.58	0.0045
Mycelium prototype (Total at 35°F)	236.79	0.0043

Of importance for the design of this product, is the flow of heat where desired. In this case, a low thermal conductivity (high thermal resistance) is desired below the hydronic PEX heating tubes, and a high thermal conductivity (low thermal resistance) is desired above the tubing so that the heat may travel effectively to the user existing on the top-most surface of the raised heated panel.



Thermal conductivity image of mycelium versus spray-foam insulation

CONCLUSION and PROGRESS

While the immediate goal of this research is to design, build, and test a single prototype panel, the ultimate objective is to construct enough panels to create a full-scale platform and conduct real-world testing in its intended setting.

In terms of mycelium growth, it has been found that the air flow for experiment panels A and B were not sufficient and around day 12, additional holes were drilled into the bottom face of the plexiglass forms and the entire panels were flipped so that air flow and growth could be better distributed. Panels A and B are currently still growing.

Further testing is needed to evaluate and compare the thermal properties of spray foam and mycelium-based insulation. However, given that one of the key objectives of this project is to design and create a more environmentally friendly product, mycelium—a biodegradable insulation material—emerges as a more desirable option over polyurethane.

Upcoming goals include:

- Complete mycelium panel growth
- Install spray foam insulation within prototype for thermal imaging and empirical thermal testing using layered thermometers
- Perform Finite Element Analysis (FEA) of aluminum structure design
- Replace foam insulation with mycelium insulation to perform thermal testing such as thermal imagery and empirical thermal conductivity.
- Full-scale model design

References

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Acknowledgements

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