Appendix

Appendix A. Fungal Growth Experiment in Potato Dextrose Broth Solution

In the initial phase, our objective was to quantify the growth rate of the fungus within a liquid medium (potato dextrose broth). Specifically, this project aimed to measure the rate of change in mycelium radius over time. The culture dish utilized in the experiment had a diameter of 90 mm. Table 1 displays the amounts of potato dextrose broth solution and proportions of sodium silicate solution (Si) in the experiment.

Table A1. Experimental Proportions in Round 1

ID	Potato Dextrose Broth solution	Sodium Silicate /Potato Dextrose Broth (%)	Sodium Silicate Solution
SS1-1; SS1-2	30mL	0	0
SS2-1; SS2-2	30mL	1%	300µL
SS3-1; SS3-2	30mL	2 %	600µL

Figure 1 shows the white mycelium (a cluster of fungal fibers) that was observed in the petri dishes during the first three days. As depicted in the images, the addition of Si source noticeably delayed fungal growth. With each 1% increase in sodium silicate solution, the progression of fungal growth was delayed by approximately two days. Starting from Day 4, the growth of SS-1 and SS-2 ceased to exhibit significant changes. Even with the highest addition of 2% Si source by volume, the fungus continued to survive and grow. However, due to irregularities in mycelium formation, accurately measuring the fungal growth rate proved challenging in this experiment. This irregularity stemmed from fungal spores dispersing easily into the solution and initiating growth from various locations within the petri dish, as illustrated in the images. Despite efforts to refine the experimental setup and procedures, no significant improvements were achieved.

Figure A1. Fungal Growth in the First Round of Experiments

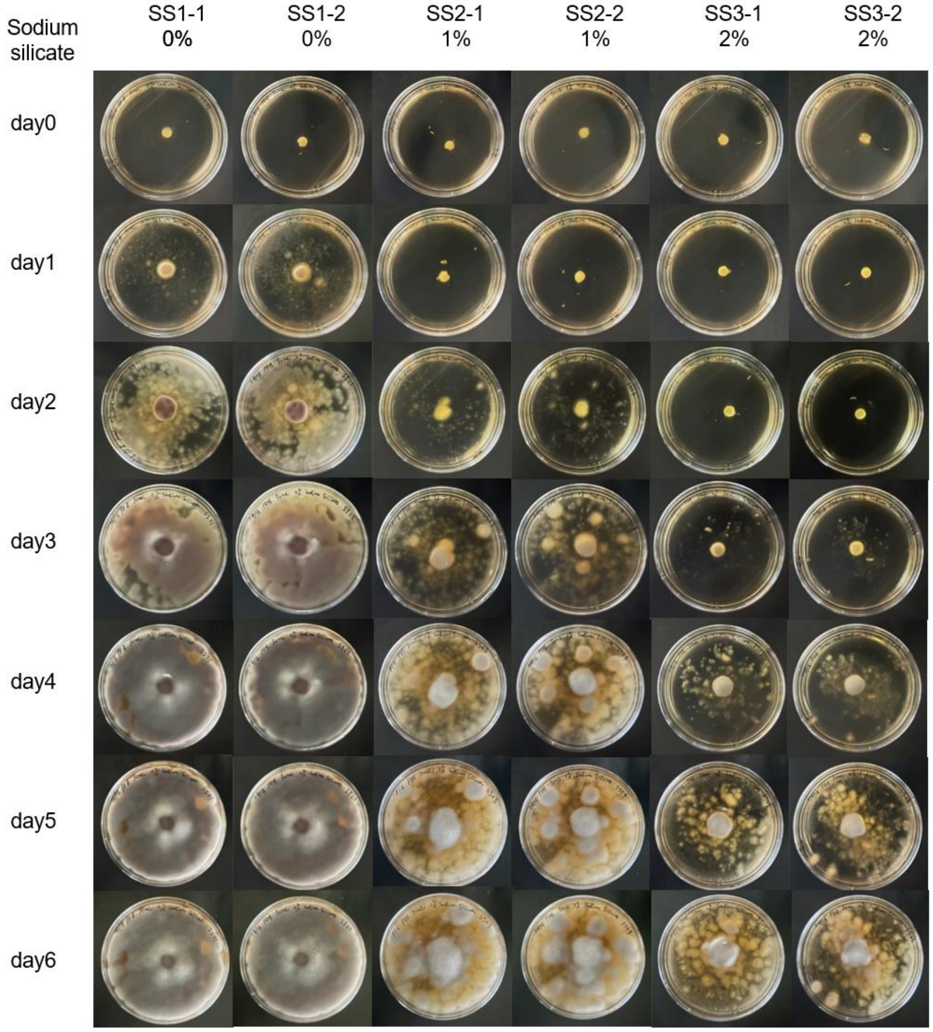

Table 2 shows round 2 of the experiment which reduced the volume of potato dextrose broth solution to minimize the floating and movement of inoculum within the medium. Results from this round of research, however, as Figure A2 shows, remained suboptimal.

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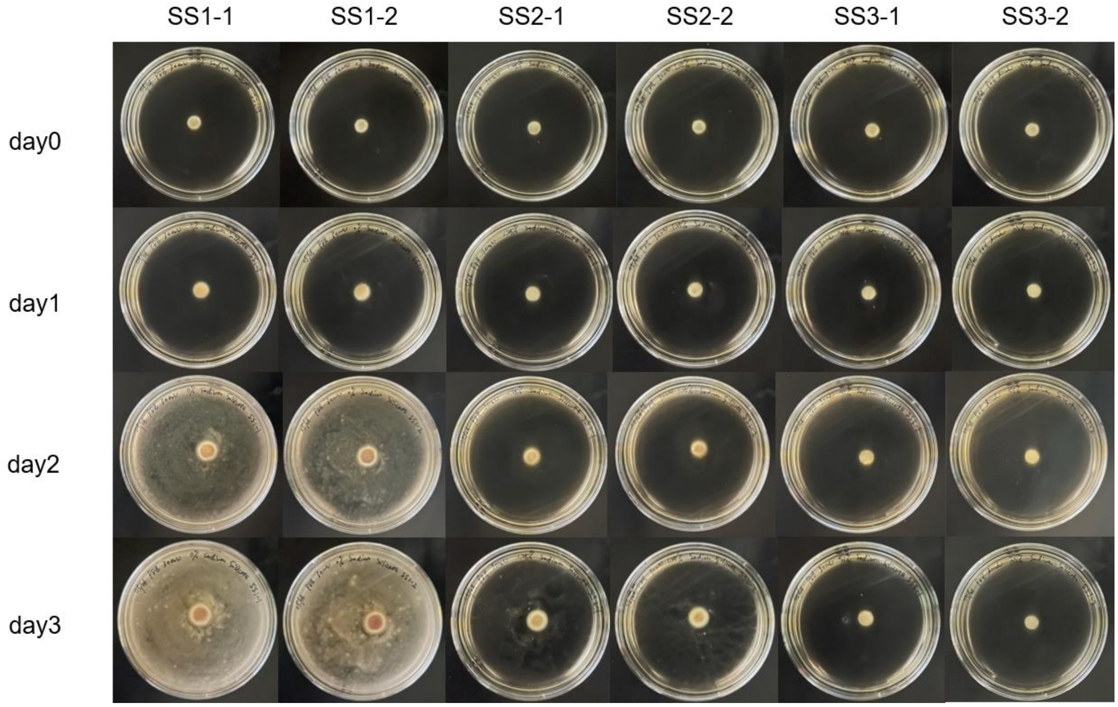
Table 2. Experimental Proportions in Round 2

ID	Petri Dish Size	Potato Dextrose Broth Solution	Sodium Silicate/ Potato Dextrose Broth (%)	Sodium Silicate Solution
SS1-1; SS1-2	90mm	20mL	0	0
SS2-1; SS2-2	90mm	20mL	1%	200µL
SS3-1; SS3-2	90mm	20mL	2%	400µL
SS4-1; SS4-2 (forceps)	60mm	10mL	0	0
SS5-1; SS5-2(forceps)	60mm	10mL	1%	100µL
SS6-1; SS6-2 (forceps)	60mm	10mL	2%	200µL

Figure A2. Fungal Growth in Reduced Volume of Potato Dextrose Broth Solution



Note. Potato dextrose broth solution volume was reduced to 20 ml.

In groups SS4, SS5, and SS6, inoculation tools were substituted with forceps instead of loops, and smaller culture dishes were utilized due to the unavailability of the original 90 mm dishes. Initially, as Figure A3 shows, fungal mycelium exhibited steady growth over the first two days. After Day 4, however, as Figure A4 shows, growth became unmanageable.

Figure A3. Day 2 Fungal Growth in Potato Dextrose Broth Solution Inoculated With Forceps

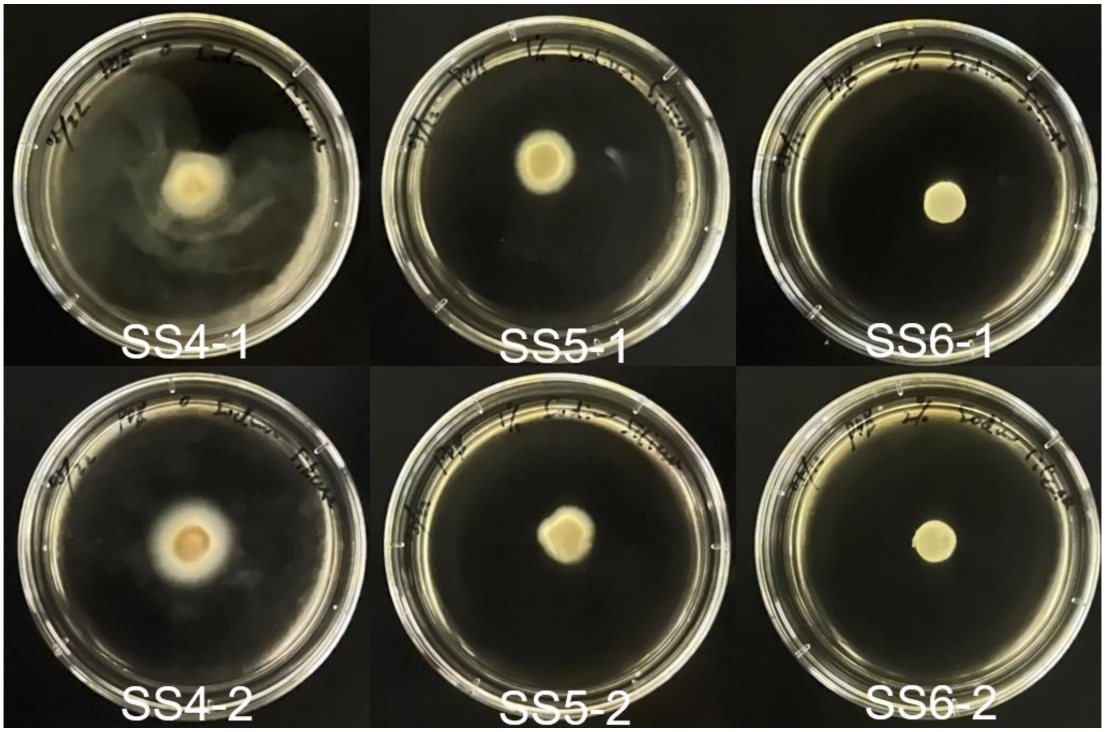
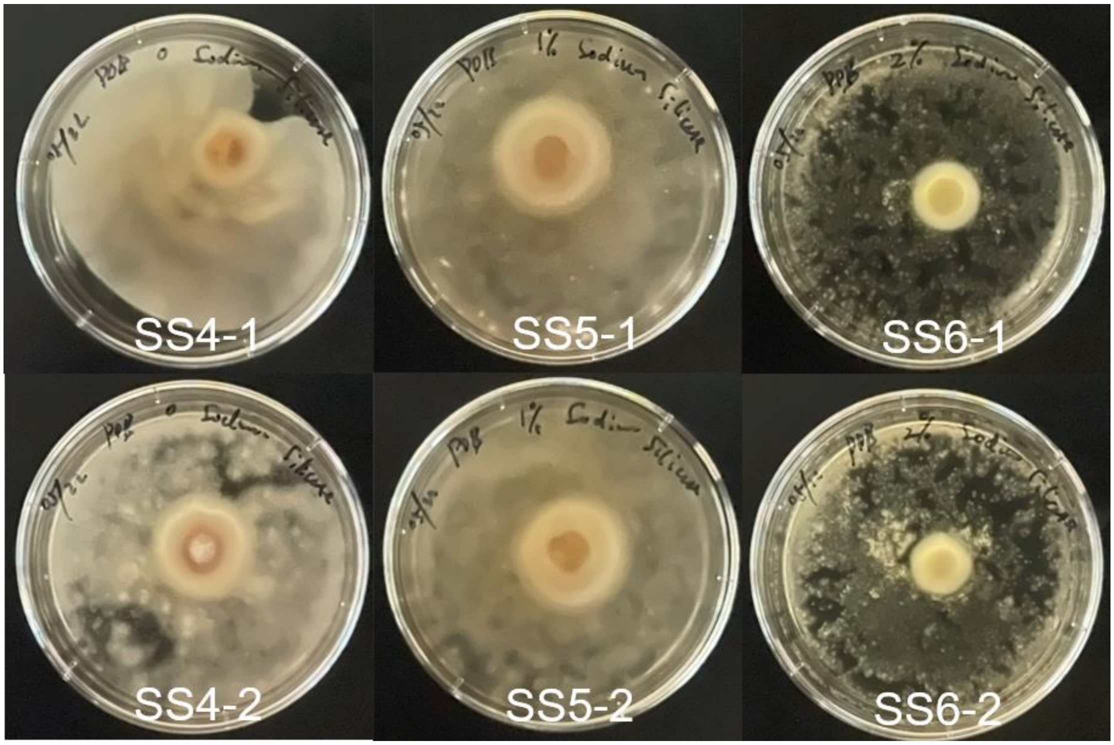


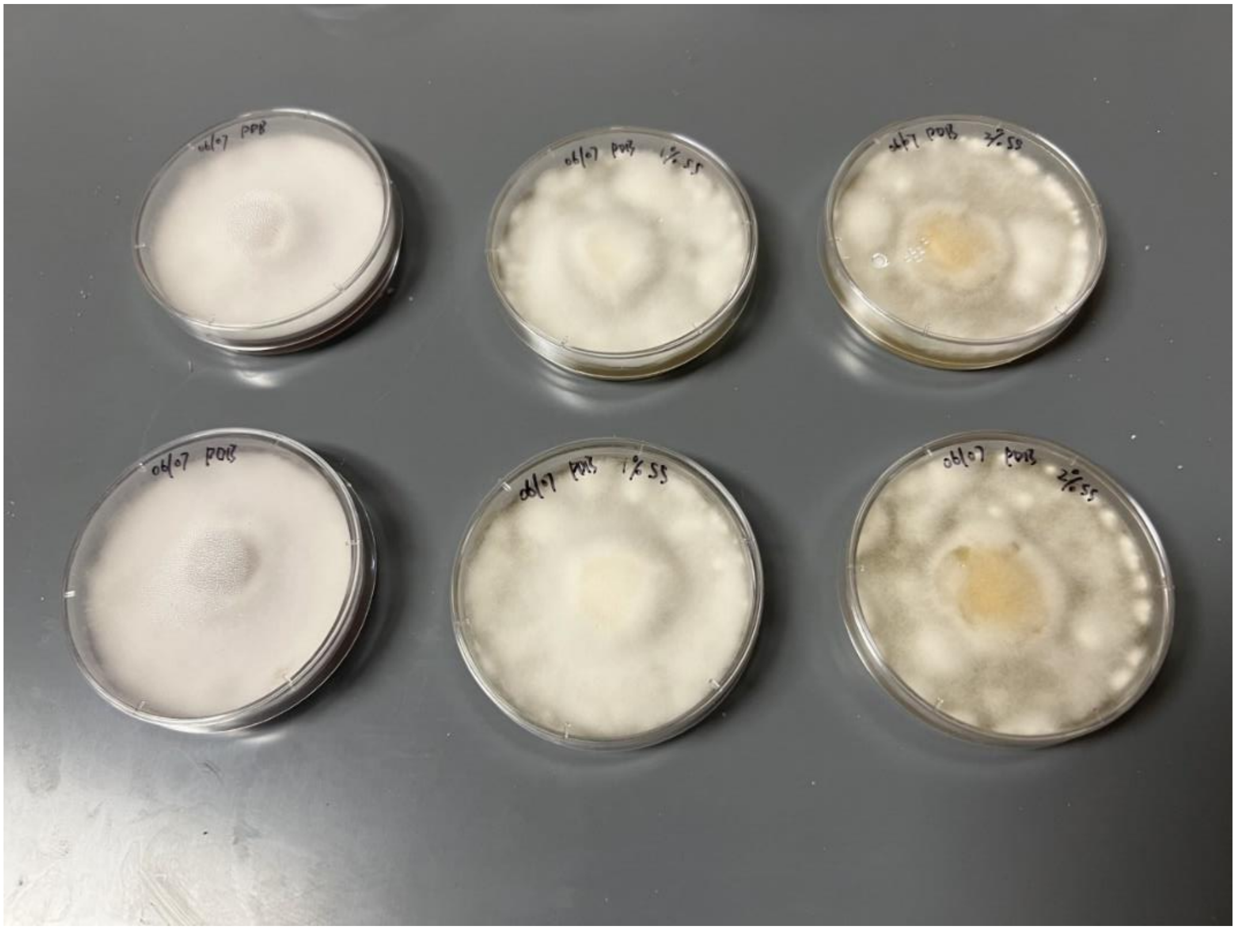
Figure A4. Day 4 Fungal Growth in Potato Dextrose Broth Solution Inoculated With Forceps



Appendix for *Zhang, X. (2024). Fire-Resistant and Energy-Efficient Fungi-Based Building Materials: Towards Hazard-Mitigating Housing. (Natural Hazards Center Mitigation Matters Research Report Series, Report 19). Natural Hazards Center, University of Colorado Boulder.* **https://hazards.colorado.edu/mitigation-matters-report/fire-resistant-and-energy-efficient-fungi-based-building-materials**

On the seventh day, the mycelium in all three sample groups completely covered the culture dish. However, the groups differed in terms of mycelium thickness, with the order being 0%, < 1%, < 2% sodium silicate solutions. Given the challenges in measuring fungal growth rates in potato dextrose broth solution, we used the mycelium film grown on potato dextrose agar for fire resistance testing.

Figure A5. Day 7 Fungal Growth With Si Source Inoculated With Forceps



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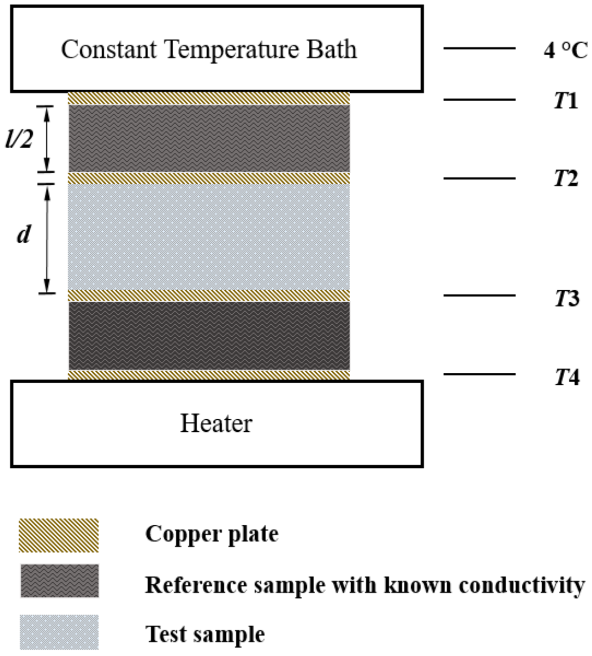
Appendix B. Thermal Conductivity and Specific Heat Capacity Testing Setup

1. Thermal conductivity

The thermal conductivity of mycelium-composite brick was determined using the divided bar method. This method involves generating axial heat flow through the apparatus depicted in Figure C1 which includes a heater as a heat source at the bottom and a constant temperature bath at the top. The test sample was connected in series with reference samples via copper plates, with temperature sensors placed in the copper plate layer. Once thermal equilibrium was achieved, the temperature differences across the copper plates provided a direct indication of the thermal conductivity of the materials. In this study, the thermal resistance of the copper plates was considered negligible. An acrylic glass reference sample with a known thermal conductivity of 0.17 W/(m·K) was used.

Figure B1. Schematic of Cross-section of Experimental Setup [32]



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The thermal conductivity of the test sample was determined using Equations 1-4, which are based on the continuity of heat flux across the reference samples and the test sample:

$$K = \frac{d\ K_S}{l\left(\frac{\Delta T_2}{\Delta T_1 + \Delta T_3}\right)} \tag{1}$$

$$\Delta T_1 = T_2 - T_1 \tag{2}$$

$$\Delta T_2 = T_3 - T_2 \tag{3}$$

$$\Delta T_3 = T_4 - T_3 \tag{4}$$

Where,

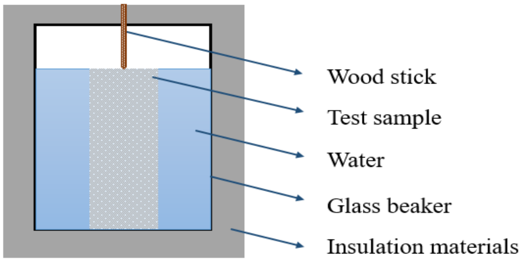
- *K* represents the thermal conductivity of the test sample.
- *d* is the thickness of the test sample.
- K_s denotes the thermal conductivity of the reference sample.
- *l* is the combined thickness of the two layers of reference samples.
- ΔT_1, ΔT_2, ΔT_3 refer to the temperature differences observed between two adjacent copper plates.

These parameters are essential for calculating *K* based on the heat flux continuity across the reference and test samples.

2. Specific heat capacity

The specific heat capacity represents the amount of heat required to raise the temperature of a material per unit mass by 1°C. It is a crucial parameter indicating how responsive a material is to thermal changes. In this experiment, samples were initially placed in an oven for 24 hours to stabilize at a temperature of 60°C. This ensured consistency in starting temperatures before further testing. When transferring the heated sample into a chamber containing cold water and glass, heat exchange occurred until thermal equilibrium was reached within the system. To ensure the sample remained fully submerged in water, a wooden stick was used due to its buoyancy compared to the sample. The chamber was extensively insulated to minimize heat exchange with the surroundings. Under the assumption of perfect thermal insulation, any heat lost by the warmer body equals the heat gained by the cooler body. Thermal sensors were strategically placed in the water and on the chamber to monitor the temperature changes over time and determine the final equilibrium temperature.

Figure B2. Schematic of Cross-Section of Experimental Setup



Appendix C. Theoretical Basis for Thermo-Hydraulic Processes

The theoretical framework for the heat and moisture balance equations (excluding air flux in the envelope) is summarized as follows:

The equation governing heat transfer and temperature changes within the material is:

$$(\rho \cdot C + C_w \cdot w) \cdot \frac{\partial T}{\partial t} = \nabla \left[\left(\lambda + \delta_v \cdot L \cdot \varphi \cdot \frac{\partial P_s}{\partial T} \right) \cdot \frac{\partial T}{\partial x} - \left(\delta_v \cdot L \cdot P_s \cdot \frac{\varphi}{\rho_w \cdot R_v \cdot T} \cdot \frac{\partial P_C}{\partial L_{P_c}} \right) \cdot \frac{\partial L_{P_c}}{\partial x} \right]$$

The equation governing moisture transfer and moisture storage is:

$$\frac{\partial w}{\partial P_c} \cdot \frac{\partial P_c}{\partial L_{P_c}} \cdot \frac{\partial L_{P_c}}{\partial t} = \nabla \left[\left(\delta_v \cdot \varphi \cdot \frac{\partial P_s}{\partial T} \right) \cdot \frac{\partial T}{\partial x} + \left(-\delta_v \cdot P_s \cdot \frac{\varphi}{\rho_w \cdot R_v \cdot T} - D_l \cdot \frac{\partial P_C}{\partial L_{P_c}} \right) \cdot \frac{\partial L_{P_c}}{\partial x} \right]$$

Boundary conditions:

(outside)

$$q_e = h_e \cdot (T_e - T_{Se}) + q_l + q_r + q_s + q_{rain}$$

$$g_e = \beta_e \cdot \left(\varphi_e P_{s,e} - \varphi_{s,se} P_{s,se} \right) + g_{rain}$$

(inside)

$$q_i = h_i \cdot (T_{si} - T_i) + L \cdot \beta_i \cdot \left(P_{s,si} - P_{s,i} \right)$$

$$g_i = \beta_i \cdot \left(\varphi_{s,si} P_{s,si} - \varphi_{s,i} P_{s,i} \right)$$

ρ = specific density [kg/m^3] =99 kg/m^3

c = specific heat capacity of the material [J/(kg·K)] =10200 J/(kg·K)

c_w = specific heat capacity of water [J/(kg·K)] = 4200 J/(kg·K)

w = moisture content [kg/m^3]

T = absolute temperature [K]

Appendix for *Zhang, X. (2024). Fire-Resistant and Energy-Efficient Fungi-Based Building Materials: Towards Hazard-Mitigating Housing. (Natural Hazards Center Mitigation Matters Research Report Series, Report 19). Natural Hazards Center, University of Colorado Boulder.* https://hazards.colorado.edu/mitigation-matters-report/fire-resistant-and-energy-efficient-fungi-based-building-materials

t = time [s]

λ = thermal conductivity [W/(m·K)]=0.40 W/(m·K)

L = latent heat of evaporation [J/kg] = $2.5 \cdot 10^6$ J/kg

δ_v = water vapor permeability of air [s]

ϕ = relative humidity [-] $= \exp\left(\frac{-P_c}{\rho_w \cdot R_v \cdot T}\right)$

p_s = saturation pressure [Pa]$= \exp\left(65.8094 - \frac{7066.27}{T} - 5.976 \cdot ln(T)\right)$

ρ_w = density of water [kg/m^3] = 1000 kg/m^3

R_v = gas constant of water [J/(kg·K)] = 461.89 J/(kg·K)

p_c = capillary pressure [Pa] $= -\frac{2\sigma \cdot \cos\theta}{r}$

σ=surface tension of liquid-vapor interface=(75.9-0.17*(T-273.15)) $\cdot 10^{-3}$ N/m

r= capillary radius

L_{pc} = logarithmic capillary pressure [Pa]

D_l = moisture (conductivity) permeability [kg/(s·m·Pa)]$= \rho_w \frac{r^2}{8 \cdot \eta}$

Appendix D. Envelop Specifications and Input Temperatures

The envelope specifications for buildings with regular insulation and fungi-based composite insulation are provided in Table C1 and C2, respectively. The daily temperature data used for Multiphysics simulation is shown in Table C3.

Table D1. Envelop Specifications in Regular Foam Insulation Building

	Thickness (m)	Thermal Conductivity (W/m K)	Density (kg/m^3)	Heat Capacity (J/Kg K)
Wall (outdoor to indoor)				
Wood siding	0.01	0.14	530	900
Wall insulation	0.06	0.07	10	1400
Concrete block	0.1	0.51	1400	1000
Roof (outdoor to indoor)				
Plasterboard	0.01	0.16	950	840
Roof insulation	0.11	0.07	12	840
Roof deck	0.02	0.14	530	900
Floor (outdoor to indoor)				
Insulation	1	0.07	10	1400
Concrete slab	0.08	1.13	1400	1000

Table D2. Envelop Specifications in Fungi-Based Insulation Building

	Thickness (m)	Thermal Conductivity (W/m K)	Density (kg/m^3)	Heat Capacity (J/Kg K)
Wall (outdoor to indoor)				
Wood siding	0.01	0.14	530	900
Wall insulation	0.06	0.07	55	9000
Concrete block	0.1	0.51	1400	1000
Roof (outdoor to indoor)				
Plasterboard	0.01	0.16	950	840
Roof insulation	0.11	0.07	55	9000
Roof deck	0.02	0.14	530	900
Floor (outdoor to indoor)				
Insulation	1	0.07	55	9000
Concrete slab	0.08	1.13	1400	1000

Table D3. Temperature Input in Multiphysics Model

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
-12.68	-14.13	-15.14	-16.02	-16.78	-17.43	-17.99	-18.05
9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
-14.73	-9.1	0.65	9.84	17.72	24.2	27.62	27.45
17	**18**	**19**	**20**	**21**	**22**	**23**	**24**
21.39	15.5	10.62	6.62	3.07	0.17	-2.24	-4.33

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