# Mycelium Woven Wall: Fabricating and Testing a Sustainable, Durable and Environmentally Friendly Alternative to Drywall

**Brandon Xu**

**Independent Researcher, Mountain View, California**

**ORCID 0009-0001-1410-3647**

## ABSTRACT

The construction and building industry accounts for 37% of global GHG emissions annually and drywall, a component of it, has a carbon footprint of 140.7 kg CO2/ton. In response, current studies are exploring cement boards, plywood, plastic panels, and cork as alternatives to drywall. This study uses mycelium-based composites as a potential sustainable alternative to drywall, aiming to reduce carbon emissions. A mycelium wall was created using biochar and aspen chip substrates, as well as additional supplements of sand and flour. The wall was then tested for its sound, fire, and water resistance performance and compared with drywall. Two samples were created and tested three times each. The mycelium wall on average blocked off 2.1 and 1.3 more decibels in the two trials of the sound resistance test. It resisted for 3.54 more seconds than the drywall in the fire resistance test, and only attained a moisture content of 7.6% compared to drywall 8.8% on average in the water resistance test. These results indicate that walls made from mycelium exhibit enhanced or similar basic sound, fire, and water resistance compared to conventional drywall, highlighting their potential amid fires, floods, or noisy environments.

Key Words: mycelium, construction sustainability, drywall, carbon emissions reduction

## 1. INTRODUCTION

The production and implementation processes of drywall are energy-intensive and damaging to the environment (Environmental Working Group, n.d.). For instance, gypsum drywall releases harmful chemicals such as formaldehyde and acetaldehyde, both carcinogens and crystalline silica, a carcinogen when inhaled (Huang et al, 2022). It also contributes to carbon emissions, with a carbon footprint of 140.7 kg CO2/ton (Fort et al, 2018). Furthermore, drywall production potentially poses health risks due to gypsum and silica contents (NIOSH, 2018) and is vulnerable to mold growth (May, n.d.). Previous studies have explored alternatives to gypsum drywall, focusing on more sustainable and less toxic materials. For instance, researchers have investigated plant-based composites, recycled materials, and industrial byproducts as substitutes (Tazmeen et al, 2024). While these innovations have shown promise, scalability, performance, and material consistency remain key challenges. Studies have recently shifted toward natural substances as potential building materials due to their renewability and reduced environmental impact. This direction opens the door to materials like plants and fungi, potentially suitable for sustainable construction.

Mycelium, which is a fungal thread located in the root structure of mushrooms, has been introduced as a potential source to provide an efficient alternative to traditional building materials (Corrales et al, 2023). Mycelium is biodegradable and will reduce lingering waste that will end up causing pollution. It consumes little energy and has a low carbon footprint (Nathler, 2023). Mycelium, especially with added substrates, can contain customized material properties and is a valid alternative for foams, timbers, and plastics (Jones et al, 2020). Organic materials like straw, sawdust, woodchips, cotton, rice husk, and others have been used as substrates for mycelium composites (Alaneme et al, 2023). Mycelium can be used in building applications, such as insulation, door cores, paneling, flooring, cabinetry, and other furnishings(Jones et al, 2020) because it is 80 times cheaper than conventional materials (Alemu et al, 2022). Mycelium can be molded into light biodegradable bricks for non-load bearing applications and thermal insulation, used in cladding for building facades, and paneling for sound insulation. According to studies, its application potentially reduces 72% of annual carbon emissions, saves 87.4% of energy in winter, and 55.9% in the summer (Fellah et al., 2024). Current studies using mycelium as a building material show less than adequate structural stability and quality in relevant applications. For example, mycelium's compressive strength is 30 psi while concrete is 4000 psi (Nathler, 2023).

To advance this research field, understanding the background of key substrates used with mycelium is essential. Based on research, this study focuses on the use of two substrates: biochar and aspen chips. Biochar is known to sequester CO2 because it is a form of carbon that can store CO2 for an extended time and provide many benefits (Moya, 2023). It can also contribute to more efficient growth of mycelium. The biochar substrate maintained optimal moisture content and pH levels vital for mycelium growth (Wan Mahari, 2020). Aspen chips on the other hand are valued for their structural reinforcement properties (Mackes et al, 2001). According to Mackes and Lynch, even though aspen chips are relatively low in density, they bond well and have sufficient strength when combined with other substrates for the desired strength property. In addition, hemp (2050 Materials, 2023) has recently been touted as a "game-changing" building material for its sustainability and insulating characteristics. Flour is also used in the development of mycelium, as it has been known to be a viable and inexpensive food source (Suzuki, 2016).

This study aims to create a mycelium wall using a unique 3:3:3 biochar, aspen chips, and mycelium/hemp mix combination. This wall will be tested for sound, fire, and water resistance. These results will be compared to drywall. The hypothesis proposes that this mycelium material will outperform traditional drywall in areas of sound, fire, and water resistance while providing overall environmental sustainability. This research will contribute to mitigating the impacts of construction materials, promoting healthier living spaces, and furthering sustainable construction practices.

## 2. METHODOLOGY

The hypothesis of this study was tested through a specific procedure displayed in Figure 1. It provides an overview of the mycelium wall preparation and testing as compared to normal drywall.

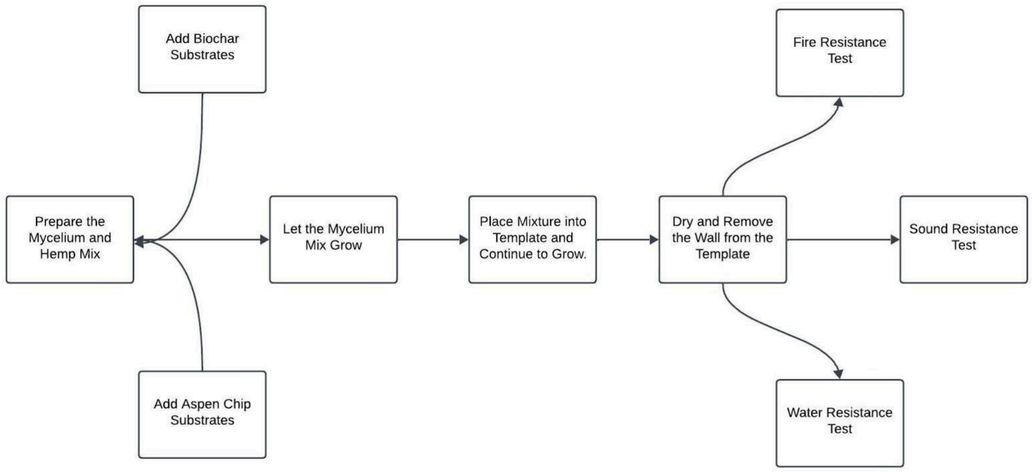



Figure 1: Overview of the preparation and testing steps for the mycelium wall

The preparation and testing process began with selecting mycelium cultures, which were then cultivated at 22.2°C in a closet away from sunlight to ensure consistent growth. The substrate materials biochar, aspen chips, and hemp were chosen, carefully prepared, sterilized, and inoculated with mycelium to promote colonization. Once fully colonized, the mycelium mix was molded into the desired shapes for testing and dried to achieve structural integrity. The testing phase involved evaluating the physical and mechanical properties of the mycelium-based materials including sound, fire, and water resistance. This systematic approach ensured that each step was meticulously executed to produce reliable data, paving the way for developing eco-friendly construction materials.

The initial step of the process begins with making the mycelium mix. All tools and surfaces were sanitized with 70% isopropyl alcohol to maintain cleanliness. 56.7 grams of flour and 0.71 liters of water were combined to form a slurry, then poured into the 1.36-kilogram bag of mycelium and hemp mix (Grow.bio, Green Island, New York). The bag was resealed above the filter respiration patch and shaken vigorously for one minute. The bag was placed in a clean, sun-free area at 22.2°C for 4 days to allow the mycelium mixture to grow fully. Figure 2(a) displays the mixture after the incubation period.

a) b) c) d) e) f)

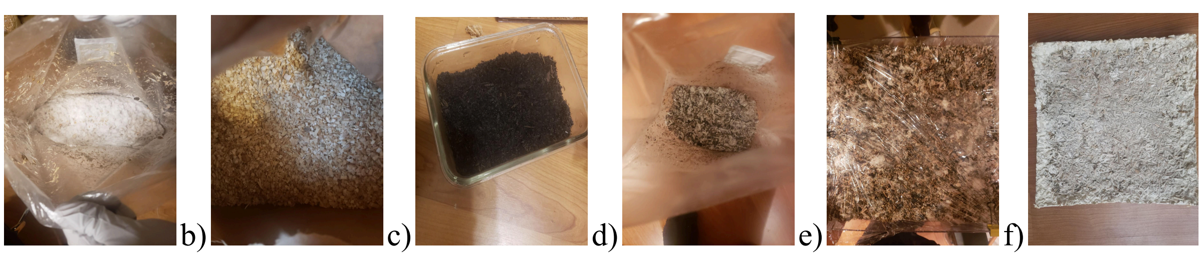


Figure 2: a) Picture of mycelium mix after 4 days of growing; b) Biochar before adding to mix; c) Aspen chips before adding to mix; d) Mycelium mixed with all substrates; e) Mycelium mix with substrates in the wall template; f) Mycelium wall after removed from the template.

Next, the mycelium and hemp were broken into smaller chunks to prepare for adding the substrates. 56.7 grams of flour were added for growth purposes, and mixed for one minute. 170.09 grams of sand were then introduced to act as a strengthening agent. The next substrate added was 393.3g (0.4L) of biochar to act as a mycelium growth agent and for future CO2 sequestration. Figure 2(b) displays the aspen chips used as mycelium substrate. The final substrate was 393.3g (0.4L) aspen chips to act as a further strengthening agent. Figure 2(c) displays the biochar used as substrates. The biochar and aspen chips were pasteurized by boiling at 71°C for an hour. Then the existing mix was sectioned by 33% and combined with 67% total of equal parts biochar and aspen chips. Figure 2(d) displays the Mycelium mixed with biochar and aspen chips. 42.52 grams of flour was added to serve as nutrition for the mycelium. The mixture was then allowed to grow for 4 days at 22.2°C in a closet away from sunlight to kickstart mycelium colonization.

To shape the material into a wall with the same thickness as drywall, the mixed material was placed into a storage tray (30.48 cm x 30.48 cm x 5.08 cm), filling up to 1.27 cm to replicate drywall thickness. Figure 2(e) displays the mixed mycelium and its substrates inside the wall template. The surface was smoothed over using a spatula and covered with plastic wrap for protection from environmental issues. Small holes were created in the plastic wrap for respiration. under the same controlled conditions, the material was allowed to grow for an additional 5 days for the form to grow its shape.

When the mycelium wall turned white indicating full growth, the material was removed from the mold and dehydrated in the oven at 82.2°C for 8 hours. Figure 2(f) displays the mycelium wall after being removed from the template. The moisture content was measured with a moisture meter and confirmed at 5% content, which was satisfactory according to instructions.

The entire process was repeated twice to ensure viable results. The performance testing for the two mycelium wall samples included sound, fire, and water resistance. These tests were selected as they are the basic materials tests required for all drywall evaluation.

The mycelium wall was placed on top of an opened box (20.32cm x 20.32cm) in a controlled noiseless environment for sound resistance. The sound source, which used a buzzing tone, was placed inside the box below the wall and the sound was turned on. The decibel levels were measured by a decibel meter (Aicevoos, Wuhan, China), as shown in Figure 3(a) from directly outside of the box and the results were recorded. This test was repeated three times for each wall. The data was recorded in the lab journal for further analysis.

A propane blowtorch was placed 30.38 centimeters from the mycelium wall sample for flame resistance. It was turned on and the flame was applied directly to the wall. The flame was stopped when the wall started to smoke, which indicated a basic burn scenario. The wall's temperature was then measured in degrees Celsius using an infrared thermometer, with the laser placed exactly at the center of the burn. Figure 3(b) displays the infrared thermometer used and the burned wall. The procedure was repeated three times for each wall. The data was recorded in the lab journal for further analysis.

The moisture content of the wall was measured by a moisture meter (RDINSCO, Hialeah, Florida) before the experiment for water resistance. A dropper filled with 5 ml of water was dropped on the wall at four different locations, and the moisture retention was recorded. After 24 hours, the moisture content measured in percentage of the wall was checked. Figure 3(c) (d) shows the water-dropping step and the moisture reading, respectively. This water-dropping was repeated in four locations for each wall, with three readings at each location. The data was recorded in the lab journal for further analysis.

For reliable comparisons, these tests were conducted with conventional drywall samples of the same size as the mycelium wall. They were subjected to the same tests to ensure consistent, accurate results.

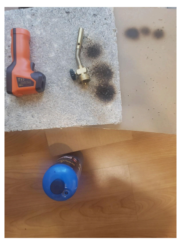
a)  b)  c)  d) 

Figure 3:

a) A decibel meter is placed on top of the mycelium that is on top of a box with the sound source inside in a controlled environment. b) Materials used for the fire resistance test. Brown spots indicate the area of burn and are tested for burn temperature; c) Picture of dropping water on the lower right corner of the mycelium wall; d) Moisture meter capturing the moisture content on the lower right corner(location 1) of the drywall. The bottom left, top right, and top left of the wall were respectively labeled Location 2, Location 3, and Location 4.

## 3. RESULTS

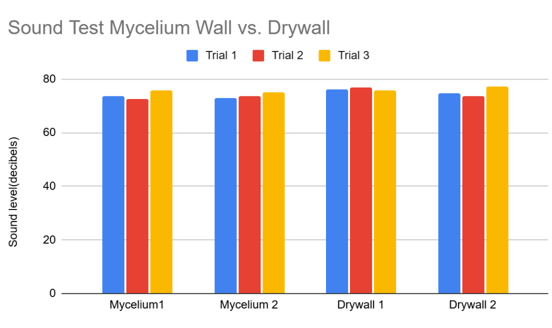



Figure 4: Sound absorption testing of novel mycelium wall in comparison to regular drywall.

As shown in Figure 4, in trials 1 and 2 of the sound test, the mycelium wall performed better than the drywall. In trial 3, similar levels of decibels were recorded for both walls. The results suggest that the mycelium walls are superior to drywall in sound resistance. Overall, the mycelium walls 1 and 2 averaged a decibel level between 74.1dB and 73.9 dB respectively, while the drywalls 1 and 2 averaged 76.2 dB and 75.2 dB respectively, showing that the mycelium blocked off more sound. To note, the testing was confirmed in a noiseless controlled environment for the most reliable outcomes.

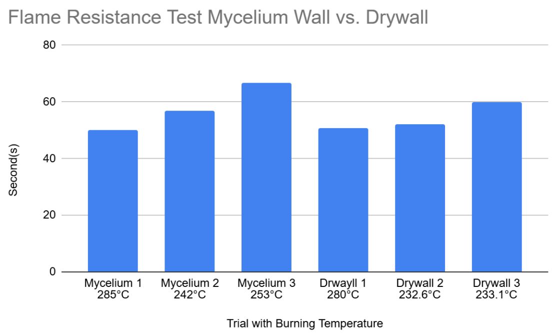



Figure 5: Fire resistance testing of novel mycelium wall in comparison to regular drywall.

In Figure 5, the temperature of both walls were measured as soon as smoke was observed emanating from the spot on the wall targeted by the propane torch. On average, the mycelium wall displayed a higher temperature of 260°C while the drywall averaged 248.6°C, throughout the 3 trials of the fire resistance test. The mycelium started burning at 50, 56.81, 66.66 seconds, averaging 57.82 seconds. The drywall started burning at 50.65, 52.12, and 60.06 seconds, averaging 54.3 seconds. To note, the testing was confirmed in a controlled, wind-free environment for the most reliable outcomes.

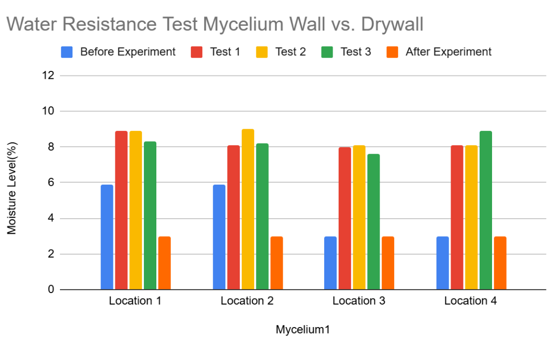



Figure 6: Water resistance testing of 1st novel mycelium wall for comparison to drywall

In Figure 6, the moisture content of the mycelium wall in location 3 was slightly below 8. In locations 1, 2, and 4 the moisture level remained between 8% and 9% during the experiment. In addition, before and after moisture readings were taken from each location. The measurement was done to ensure the area was dry or under 7% moisture before spraying the water, as recommended by the manufacturer (Grow.bio, Green Island, New York). The after measurement was done to determine if the moisture content would be reduced, or dried up, 24 hours later. All of the locations were reduced back to a dry moisture reading. To note, all the testing was done in the same room so variables like humidity and temperature remain constant for the most reliable outcomes.

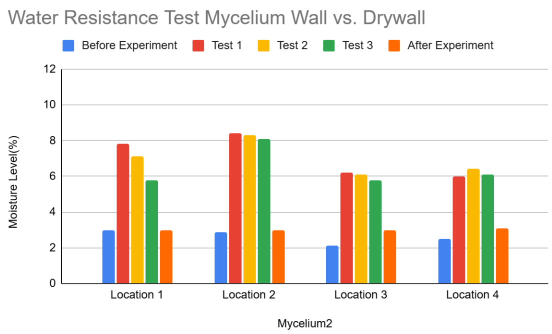



Figure 7: Water resistance testing of 2nd novel mycelium wall for comparison to drywall

In Figure 7, the moisture content of the mycelium wall remained around 6% and 8% in locations 1, 3, and 4 with the majority of the testings found to be around 6%. In location 2, the 3 moisture level testings were slightly above 8%. In Figure 6, the moisture level was more commonly around 8% and 9% with only 3 testings below that. In addition, before and after readings were taken from each location. The measurement was done to ensure the area was dry or under 7% moisture before spraying the water. The after measurement was done to determine if the moisture content would be reduced, or dried up, 24 hours later. All of the locations were reduced back to a dry moisture reading. To note, all the testing was done in the same room so variables like humidity and temperature remain constant for the most reliable outcomes.

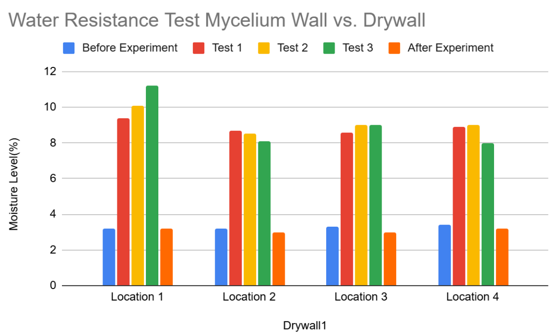



Figure 8: Water resistance testing of drywall 1 for comparison to novel mycelium wall

In Figure 8, the moisture content of the drywall remained around 8% and 9% during the experiment in locations 2, 3, and 4, however, in location 1 of Figure 8, the drywall had a higher exposure to moisture with an average of around 10% and a peak of 11%. In addition, before and after readings were taken from each location. The measurement was done to ensure the area was dry or under 7% moisture before spraying the water. The after measurement was done to determine if the moisture content would be reduced, or dried up, 24 hours later. All of the locations were reduced back to a dry moisture reading. To note, all the testing was done in the same room so variables like humidity and temperature remain constant for the most reliable outcomes.

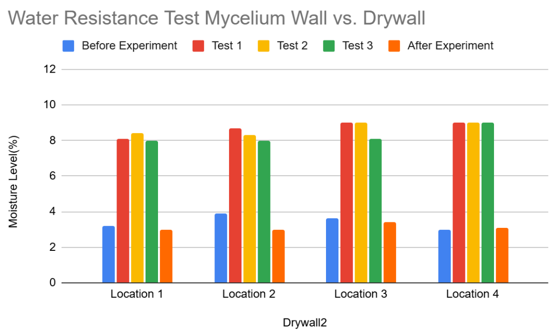



Figure 9:Water resistance testing of drywall 2 for comparison to novel mycelium wall

In Figure 9, the moisture content of the drywall remained around 8% and 9% during the experiment in all locations. It performed better than drywall 1 as it never peaked over 9%. While in Figure 8, drywall 1 peaked at 11% in location 1 indicating a higher absorption of moisture

The moisture content of the drywall in the experiment remained close to 8-9% and peaked at 11% in one of the walls, shown in Figure 8. In Figures 6 & 7, the moisture content of the mycelium wall remained under 9% and was found to be more common with a moisture level of less than 8% displaying its superiority to block water compared to drywall. In addition, before and after readings were taken from each location. The measurement was done to ensure the area was dry or under 7% moisture before spraying the water. The after measurement was done to determine if the moisture content would be reduced, or dried up, 24 hours later. All of the locations were reduced back to a dry moisture reading. To note, all the testing was done in the same room so variables like humidity and temperature remain constant for the most reliable outcomes.

## DISCUSSION

The results validate the hypothesis indicating that the mycelium walls can serve as an effective alternative to drywall because mycelium walls exhibit enhanced fire, water, and sound retardancy. Overall, the mycelium wall on average blocked off 1.3 and 2.1 more decibels in the two trials of the sound resistance test. It resisted for 3.54 more seconds than the drywall in the fire resistance test, and only attained a moisture content of 7.6% compared to drywall 8.8% on average in the water resistance test. The characteristics of mycelium in these three basic testing modes were explored in the results obtained. A key highlight is the improvement in these performance metrics when compared to drywall, suggesting that mycelium could offer a durable and efficient solution for construction.

There has been other research using mycelium as a building material. One such study investigated the fungi as a building block (Xing et al, 2018). The testing in this study focused on thermal performance. Another study conducted a literature review regarding mycelium content alone versus other conventional materials for property, sound, fire and moisture, and strength measurements (Alaneme et al, 2023). The results of this second study were favorable in comparison to cement, polymers, and gypsum. In an extensive review, no other studies have been found that created a drywall-type board out of mycelium and substrates. The results of this work compare favorably with the overall past research which shows the positive aspects of using mycelium in construction.

Despite the promising results, this study has its limitations. The small scale of the experimentation and the lack of long-term data on the performance of mycelium walls in real-world conditions are just a few areas that require further investigation. Future research should aim to address these gaps, possibly through larger-scale collaborations and production with construction companies to integrate mycelium walls into actual buildings. Additionally, exploring different types of mycelium, optimizing growth conditions, and developing more efficient manufacturing processes could further enhance the viability of mycelium as a drywall alternative. In previous studies, there have been results that undermine the strength and durability of mycelium. However, by using the right substrates and testing various concentrations of it, we can incorporate it with mycelium to optimize these mechanical properties. The mycelium will colonize the substrate particles to hold the composite together. This colonization will increase the overall stiffness of the wall (Soh et al, 2023). Suggested future work would include improving the mycelium wall's mechanical properties, testing the wall under real-world construction conditions, and exploring additional substrates for maximizing optimization.

## Conclusion

The findings of this study strongly support the potential of mycelium as a sustainable alternative to drywall. The improvements in sound, fire, and water resistance, combined with its ecological benefits, position mycelium as a material that could significantly impact the future of construction. To facilitate the industry's adoption of mycelium and other biocomposite materials, it is crucial to continue research, scale up production efficiently, and develop clear guidelines for the use of mycelium in construction. Policy support, through incentives for sustainable building practices or updated building codes, could also play a pivotal role in encouraging the widespread adoption of innovative materials like mycelium. The manufacturing and distribution of a mycelium wall product would have to be planned and financially supported for implementation. This planning would be accompanied by a thorough cost analysis and pro forma statements. The governing body in each country would have to approve the use of the mycelium wall and allow for testing and labeling provisions. Ultimately, the transition to more sustainable construction materials is not just an environmental imperative but a strategic move toward creating healthier, more resilient buildings for the future.

Mycelium walls indicate a promising step towards sustainable applications in the building industry and further developments could change the construction industry. The adoption of mycelium walls may reduce carbon emissions and could provide a sustainable option in the construction industry with natural elements like mycelium and components that can sequester $CO_2$ in biochar.

## Acknowledgements

Gratitude is expressed to mentors and contributors including Dr. Mark W. Oleksak, Susan Tatsui-D'Arcy, and Wayne Morgan, for their intellectual guidance and support throughout this research.

**References**


Alaneme, K. K., Anaele, J. U., Oke, T. M., Kareem, S. A., Adediran, M., Ajibuwa, O. A., & Anabaranze, Y. O. (2023). Mycelium-based composites: A review of their bio-fabrication procedures, material properties, and potential for green building and construction applications. *Alexandria Engineering Journal, 83*, 234–250. https://www.sciencedirect.com/science/article/pii/S1110016823008979

Alemu, D., Tafesse, M., & Mondal, A. K. (2022). Mycelium-based composite: The future sustainable biomaterial. *International Journal of Biomaterials, 2022*(8401528), 8401528. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8934219/

Delgado Corrales, B., Kaiser, R., Nerlich, P., Agraviador, A., & Sherry, A. (2022). *BioMateriOME: To understand microbe-material interactions within sustainable, living architectures* (Vol. 122, pp. 77–126). Academic Press. https://www.sciencedirect.com/science/article/abs/pii/S0065216422000508

EWG. (n.d.). Drywall. *EWG's Healthy Living: Home Guide*. https://www.ewg.org/healthyhomeguide/drywall/

Fellah, M., Ouhaibi, S., Belouaggadia, N., Mansouri, K., & Naji, H. (2024). Thermal insulation and energy performance assessment of a mycelium-based composite wall for sustainable buildings. *Case Studies in Construction Materials, 20*, e02786. https://www.sciencedirect.com/science/article/pii/S2214509523009671

Fořt, J., & Černý, R. (2018). Carbon footprint analysis of calcined gypsum production in the Czech Republic. *Journal of Cleaner Production, 177*, 795–802. https://doi.org/10.1016/j.jclepro.2018.01.002

Huang, L., Fantke, P., Ritscher, A., & Jolliet, O. (2022). Chemicals of concern in building materials: A high-throughput screening. *Journal of Hazardous Materials, 424*, 127574. https://doi.org/10.1016/j.jhazmat.2021.127574

Jones, M., Mautner, A., Luenco, S., Bismarck, A., & John, S. (2020). Engineered mycelium composite construction materials from fungal biorefineries: A critical review. *Materials & Design, 187*, 108397. https://doi.org/10.1016/j.matdes.2019.108397

Levitan, D. (2010). Refilling the carbon sink: Biochar's potential and pitfalls. *Yale E360*. https://e360.yale.edu/features/refilling_the_carbon_sink_biochars_potential_and_pitfalls

Mackes, K. H., & Lynch, D. L. (2001). The effect of aspen wood characteristics and properties on utilization. *Aspen Bibliography*. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=8619&context=aspen_bib

May, M. E. (n.d.). When is drywall a problem? *Poison Control*. https://www.poison.org/articles/when-is-drywall-a-problem-172

Moya, B. (2023, November 23). Biochar is carbon removal's jack of all trades. Here's why. *World Economic Forum*. https://www.weforum.org/stories/2023/11/biochar-carbon-removals-jack-of-all-trades-for-immediate-climate-action/

National Institute for Occupational Safety and Health. (2018). Engineering controls database - Control of drywall sanding dust exposures. *CDC.gov*. https://www.cdc.gov/niosh/engcontrols/ecd/detail31.html

Nathler, C. (2023, August 9). Will buildings in the future be built from mushrooms? *Digital for Good | RESET.ORG*. https://en.reset.org/mycelium-construction-material-benefit/

Soh, E., & Le Ferrand, H. (2023). Woodpile structural designs to increase the stiffness of mycelium-bound composites. *Materials & Design, 225*, 111530. https://doi.org/10.1016/j.matdes.2022.111530

Suzuki, E. (2016, September). How to grow objects with mushroom mycelium. *Core77*. https://www.core77.com/posts/55675/How-to-Grow-Objects-With-Mushroom-Mycelium

Tagamud, T. T., & Mir, F. Q. (2024). Sustainability through materials: A review of green options in construction. *Results in Surfaces and Interfaces, 14*, 100206. https://doi.org/10.1016/j.rsurfi.2024.100206

United Nations Environment Programme (UNEP). (2023, September 12). Building materials and the climate: Constructing a new future. *UNEP*. https://www.unep.org/resources/report/building-materials-and-climate-constructing-new-future

Wan Mahari, W. A., Nam, W. L., Sonne, C., Peng, W., Phang, X. Y., Liew, R. K., Yek, P. N. Y., Lee, X. Y., Wen, O. W., Show, P. L., Chen, W.-H., Chang, J.-S., & Lam, S. S.. (2020). Applying microwave vacuum pyrolysis to design moisture retention and pH-neutralizing palm kernel shell biochar for mushroom production. *Bioresource Technology, 312*, 123572. https://doi.org/10.1016/j.biortech.2020.123572

Xing, Y., Brewer, M., El-Gharabawy, H., Griffith, G., & Jones, P. (2018). Growing and testing mycelium bricks as building insulation materials. *IOP Conference Series: Earth and Environmental Science, 121*(2), 022032. https://doi.org/10.1088/1755-1315/121/2/022032

2050 Materials. (2023, August 21). Hemp: A game changer for the building industry. *2050-Materials.com*. https://2050-materials.com/blog/hemp-a-game-changer-for-the-building-industry/