Sustainable Alternatives to Traditional Construction Materials in the Built Environment

Abstract:

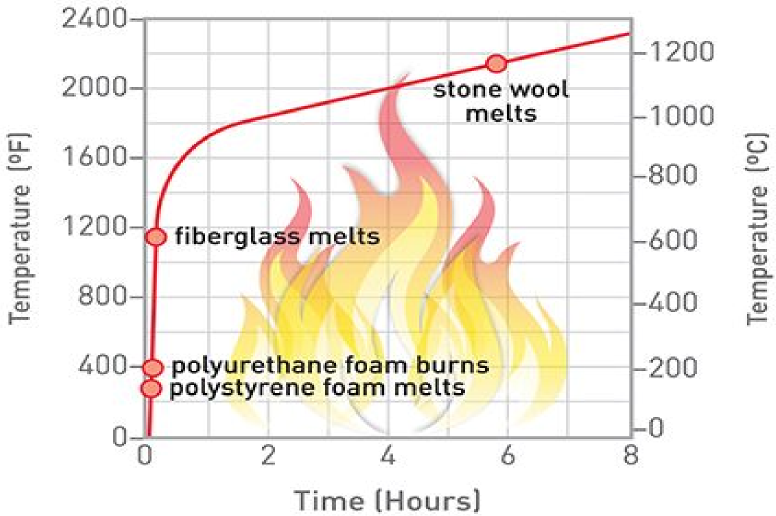
As proper insulation is crucial for all commercial buildings, it is important that the material used not only conserves energy through thermal insulation, but is also fire resistant and safe. Polystyrene, although highly used for its thermal performance, causes significant pollution and long lasting damage to the environment. This insulation material does not biodegrade; instead it breaks up into smaller microplastics which can expose surrounding life to harmful chemicals. This study aims to evaluate the extent to which mycelium, a more eco-friendly alternative, can surpass polystyrene in terms of its thermal performance and fire safety. In order to investigate this, two model homes with polystyrene and mycelium insulation were constructed. They were tested for fire damage and thermal performance using a controlled source of external heat. After exposing the controlled flame to the buildings, observations regarding the mass burned, burn rate, and other visual aspects will be used to assess which insulation material is more optimal. Our expected findings indicate that the mycelium based house will burn at a slower pace, and lose a smaller percentage of mass in comparison to the polystyrene based model home. This research study determined that mycelium is a more effective insulation material compared to conventional polystyrene, due to its superior fire resistance, greater structural stability, and environmentally sustainable nature. As a bio-contributing insulator, mycelium presents a viable step into a more eco-friendly future. Going beyond insulation, the success of mycelium as an insulation material can apply to innovations in other industries as well. In a world where eco-friendliness is becoming increasingly important, mycelium stands out as a strong alternative to traditional plastics and a sustainable look into the future.

Keywords: Mycelium Insulation, Polystyrene Foam, Thermal Conductivity, Fire Resistance, Sustainable Materials, Building Safety, Flammability, Eco-Friendly Construction.

Scientific Background:

Insulation materials are essential for energy efficiency and fire safety in commercial buildings. They help maintain stable indoor temperatures, reducing energy costs for heating and cooling. Polystyrene foam is a common insulation material because it is affordable, easy to install, and provides decent thermal insulation. However, polystyrene is made from petroleum and is highly flammable. When burned, it releases toxic fumes that are harmful to both human health and the environment. Its production and disposal also contribute to plastic pollution and greenhouse gas emissions. Due to these concerns, safer and more sustainable alternatives are being explored.

One promising option is mycelium-based insulation. Mycelium is the root-like structure of fungi that can grow on agricultural waste like corn husks and sawdust. It is biodegradable, renewable, and requires much less energy to produce than synthetic materials such as polystyrene. Research shows that mycelium's thermal conductivity is similar to polystyrene's. Additionally, mycelium's chitin-rich composition—a natural polymer found in crab shells—gives it fire-resistant properties. When exposed to fire, chitin helps form a protective char layer that slows burning and prevents flames from spreading, making mycelium more fire resistant than many synthetic options.



Fg. 1

Hypothesis:

If mycelium-based insulation is used instead of polystyrene foam in commercial buildings, it will demonstrate superior fire resistance due to its natural composition, while maintaining thermal performance that is comparable to polystyrene.

Rationale:

Polystyrene, a widely used insulation material in commercial buildings, is very low cost and it has a low thermal conductivity (0.029-0.039W/m.K). Despite these benefits, polystyrene foam is made from petroleum and can catch fire easily. Since it is highly flammable, treating it with flame retardants can release toxic gases. However, mycelium is an eco-friendly insulating alternative grown using agricultural waste, making it both biodegradable and sustainable. Unlike other synthetic materials, mycelium doesn't rely on fossil fuels and uses less energy to produce a flexible, moldable material suitable for most commercial buildings. Mycelium-based insulation has shown promise in providing thermal resistance (0.037-0.045 W/m.K) comparable to polystyrene foam (0.029-0.039 W/m.K), while also exhibiting natural fire resistance due to its rich chitin structure. Considering its comparable thermal performance and fire-resistant properties, mycelium insulation challenges materials like polystyrene, shifting construction materials towards sustainability.

Methodology:

To test the fire resistance of mycelium-based insulation compared to polystyrene foam, we'll build exactly two identical model houses. Both houses will have the same size, shape, structure, and layout in order to maintain consistency. The only difference between them will be the insulation material, with one using mycelium and the other using polystyrene.

Each model house will be exposed to a controlled flame under the same conditions. The tests will be conducted outdoors, above a non-flammable surface in order to ensure safety. Additionally, fire extinguishing equipment will be stored nearby in case of an emergency, in which case we will restart that trial of the experiment to ensure consistent results. We'll make sure both houses are placed at the same distance from the flame and exposed for the same amount of time. After the test, we'll weigh each house and also calculate the percentage of mass lost due to the burning. So this will help us to see which insulation material burned more, and which one resisted fire better.

To get reliable results, we will repeat the experiment at least three times for each house and take the average of the values. This helps reduce the impact of any small and random errors and makes the data more accurate.

Variables:

- Independent variable

  Type of insulation material (mycelium vs. polystyrene)

- Dependent variable

  Amount of material burned (measured by mass lost)

- Controlled variables:

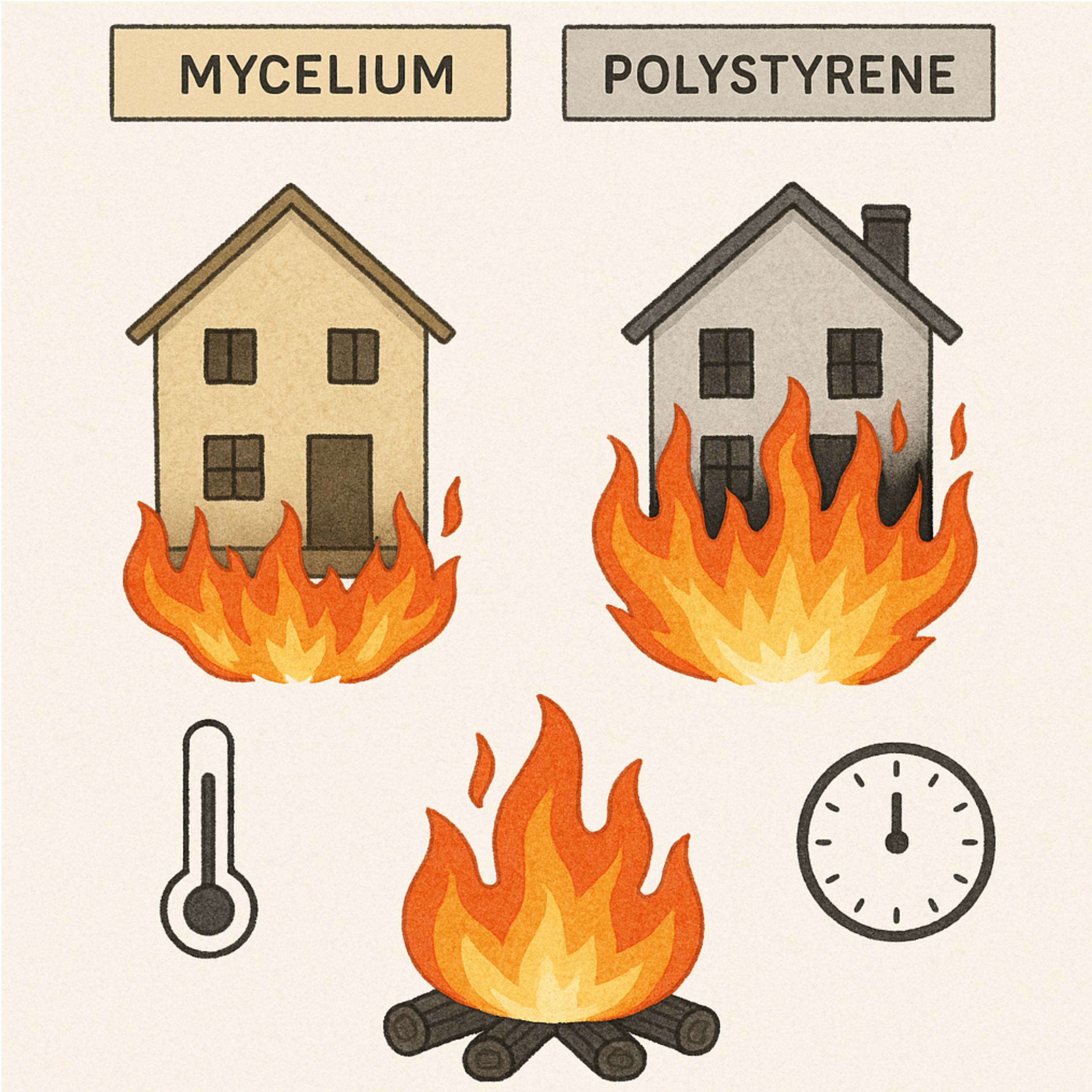
  Size and design of the houses

  Flame intensity and exposure time

  Materials used (besides insulation)

  Testing environment (same temperature, no wind)

This experiment will help show whether mycelium insulation is a safer, more fire-resistant option than polystyrene in building models.



Fg. 2

Conclusion:

This study aimed to explore how mycelium-based insulation compares to polystyrene foam by analyzing its thermal performance and fire resistance. The end goal was to provide a clear understanding on which building material would be most efficient to use for commercial buildings, by experimenting on model homes. Based on the results, mycelium showed promising fire-resistant properties, charring rather than melting or releasing toxic fumes like polystyrene. While polystyrene offered slightly better thermal insulation, the difference was not significant enough to outweigh mycelium's environmental and safety benefits. Therefore, mycelium-based insulation may serve as a more sustainable and safer alternative for commercial construction, especially in settings where fire resistance and eco-friendliness are priorities. Further testing on durability, cost, and large-scale application would help solidify its role in the building industry.

Definition Sheet:

Mycelium: The vegetative, thread-like network of fungal hyphae that can be cultivated on organic substrates and used to create sustainable composite materials.

Polystyrene Foam: A lightweight, petroleum-derived polymer foam widely used for thermal insulation but known for its environmental persistence and flammability.

Thermal Conductivity: A physical property indicating the rate at which heat energy is transmitted through a material, typically measured in watts per meter-kelvin (W/m·K).

Fire Resistance: The capability of a material to withstand heat and flames without igniting or degrading significantly over a specified duration.

Chitin: A structural polysaccharide found in fungal cell walls and arthropod exoskeletons, which contributes to material robustness and flame retardancy by forming a protective char layer upon heating.

Biodegradable: The ability of a substance to be decomposed naturally by microorganisms, resulting in environmentally benign byproducts.

Sustainability: The practice of utilizing resources in a manner that meets present needs without compromising the ability of future generations to meet theirs, emphasizing environmental preservation and resource renewal.

Agricultural Waste: Residual organic materials produced by farming activities, such as stalks, husks, and sawdust, which can be repurposed as raw materials in bio-based products.

Flame Retardant: Chemicals or treatments applied to materials to inhibit or delay ignition, reduce flame spread, and decrease heat release during combustion.

Controlled Flame Test: An experimental procedure where samples are exposed to a standardized flame source under regulated conditions to assess fire performance metrics.

Insulation: Materials installed within building structures to reduce heat transfer between interior and exterior environments, enhancing energy efficiency and occupant comfort.

Renewable Resource: Natural resources that can regenerate or replenish over time through ecological processes, ensuring long-term availability.

Synthetic Material: Human-made substances typically derived from chemical synthesis, often involving fossil fuel feedstocks and characterized by specific engineered properties.

Eco-friendly: Describes products or processes that have minimal negative impact on ecosystems and promote environmental health.

Thermal Performance: The effectiveness of an insulating material in resisting heat flow and maintaining desired temperature conditions.

Carbon Footprint: The total volume of greenhouse gases emitted directly or indirectly by an individual, organization, process, or product, commonly expressed in CO_2 equivalents.

Toxic Fumes: Hazardous gases and volatile compounds released during the combustion or degradation of materials, posing risks to human health and the environment.

Mass Loss: The reduction in material mass, often measured during fire testing, indicative of the degree of combustion or degradation.

Fire Retardancy: The inherent or enhanced property of materials to resist ignition and slow down the progression of fire.

Model Building: A scaled or simplified physical representation of a structure used for experimental testing or demonstration purposes.

Independent Variable: The experimental factor that is intentionally varied or manipulated to observe its effect on the dependent variable.

Dependent Variable: The outcome or response measured in an experiment, which is affected by changes in the independent variable.

Controlled Variables: Experimental factors that are kept constant to ensure that observed effects are due to the independent variable alone.

Combustion: A chemical process of rapid oxidation releasing heat and light, commonly referred to as burning.

Greenhouse Gases: Atmospheric gases such as carbon dioxide and methane that trap heat within the Earth's atmosphere, contributing to global warming.

Volatile Organic Compounds (VOCs): Organic chemicals that easily vaporize at room temperature, often emitted from industrial processes and posing health and environmental concerns.

Chitin-rich Structure: A composite material with a high concentration of chitin, contributing to mechanical strength and thermal stability under heat exposure.

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