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Lignin biopolymer-bound soil composite (BSC): a sustainable, recyclable, carbon-negative, construction material

Stanford University's Lepech Research Group has developed a sustainable, recyclable, carbon-negative construction material that binds soil with lignin, a natural biopolymer, instead of Portland cement. Biopolymer-bound soil composites (BSC) are formed by mixing soil aggregate, biopolymer, and solvent, then desiccating the mixture into a solid structural component. Lignin, a hydrophobic biopolymer abundant in regions with high cement demand, provides enhanced moisture resistance. Compared to Portland cement, lignin BSC requires less energy and heat, uses low-cost feedstocks, and unlike concrete, is explicitly recyclable.

Stage of Development – Prototype
The Lepech Research Group have produced standard clay-fired size bricks that meet strength requirements for non-structural construction applications as defined by ASTM.

Applications

- Non-structural building materials and modular construction components:
  - Pavements and pavers
  - Roofing tiles
  - Non-load-bearing walls/elements
  - General soil improvement/stabilization
  - Potential extraterrestrial construction (regolith-based aggregate use)

Advantages

- Near-negative carbon footprint
- Low-cost waste stream feedstock - utilizes waste material rather than mined/processed raw materials
- Lower processing temperatures and lower energy use
- Built-in end-of-life recyclability
- Enhanced moisture resistance

Publications

- Miao, B.H., et al. Development of biopolymer composites using lignin: A sustainable technology for fostering a green transition in the construction sector. Cleaner Materials (2024).
- Miao, B.H., et al. Life cycle assessment and design of LignoBlock: A lignin bound block on the path towards a green transition of the construction industry. Journal of Cleaner Production (2024).
- Miao, B.H., et al. Recycling of lignin-based biocomposites: Improving sustainability and enhancing material strength. Resources, Conservation and Recycling (2025).
- Miao, B.H., et al. Solvent selection enables sustainable and affordable lignin biocomposite for cement-free construction. Cleaner Materials (2026).
- Miao, B.H., et al. AI-powered non-destructive testing for smart manufacturing of carbon-negative biopolymer-bound soil composite. Communications Engineering (2026).

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