Mechanical and microstructural performance of low-carbon biobased insulation: Miscanthus-lime

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A. Introduction and background

The building sector remains a major energy consumer across Europe with a 40% share and 36% of carbon emissions; and constitutes a cornerstone in most energy policy measures and emissions reductions targets of 2050. In parallel, the UK has placed the energy efficiency at the heart of its strategy for emissions reductions from residential buildings. There is a huge untapped potential for the UK residential building stock energy retrofit including further insulation, for dwellings, that can be an opportunity for carbon sinks using biobased materials. Bio-based building materials are composites of vegetal particles embedded in a mineral or organic matrix. Their high multi-scale porous structure confers to them interesting thermal, hygroscopic and acoustic properties. This project highlights some mechanical compressive strength properties and microstructure of miscanthus – lime lightweight insulation composites.

B. Materials and Methods

Miscanthus bio-based composites are made with miscanthus particles and lime-based binders. The binder to aggregate mass ratio is 2.0 for all mixes. Lime binders were made of calcic lime (C), natural hydraulic lime (N), formulated lime (FLA 3.5), Cement (Ce), blast furnace slag (G) and fly ash (F). Mixes were designed for a final dry density in the range 400-500 kg/m3. The strength was tested after 60 days using an MCC8 multi-test compression machine on Φ100 mm x 200 mm height samples and the microstructure using TESCA VEGA 3 scanning electron microscope.

Fig. 1. Raw materials: hydrated lime, hydraulic lime and miscanthus particles.

C. Results and Discussions

Stress values at 5% strain (fc5) were considered for a comparative assessment of the influence of binder composition on strength development. Lime-based composites (mixes C and CN) show similar fc5 strength values. There is a slight increase in compressive strength for mixes incorporating fly ash and cement (Mixes CNF and CNO) due to a double hardening mechanism of carbonation and possible hydration of calcium alumina-silicates. CNG mixes show particularly low strength values. The initial young modulus values follow a pattern similar to that of fc5 strength. Mixes incorporating cement and fly ash (CNCe /CNF) exhibit relatively high strength (fc5) and stiffness values (Ein). The binder in these mixes exhibit a higher cohesion to miscanthus particles, stronger ITZ and resists powdering observed in lime-based binder (C and CN), as shown in Fig. 2.

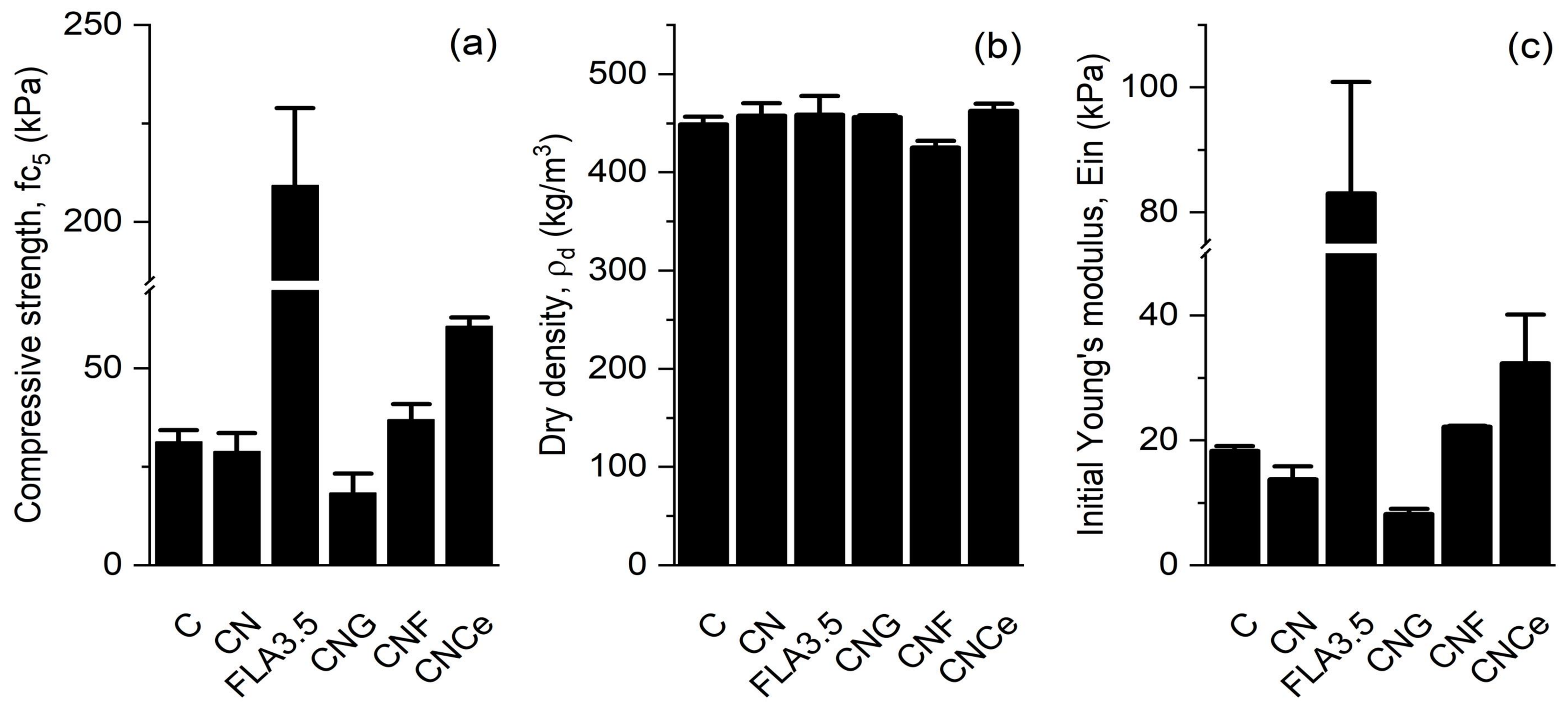

Fig. 2. The influence of binder composition on strength and stiffness of miscanthus concrete at 60 days of Indoor Standard Curing (ISC) conditions.

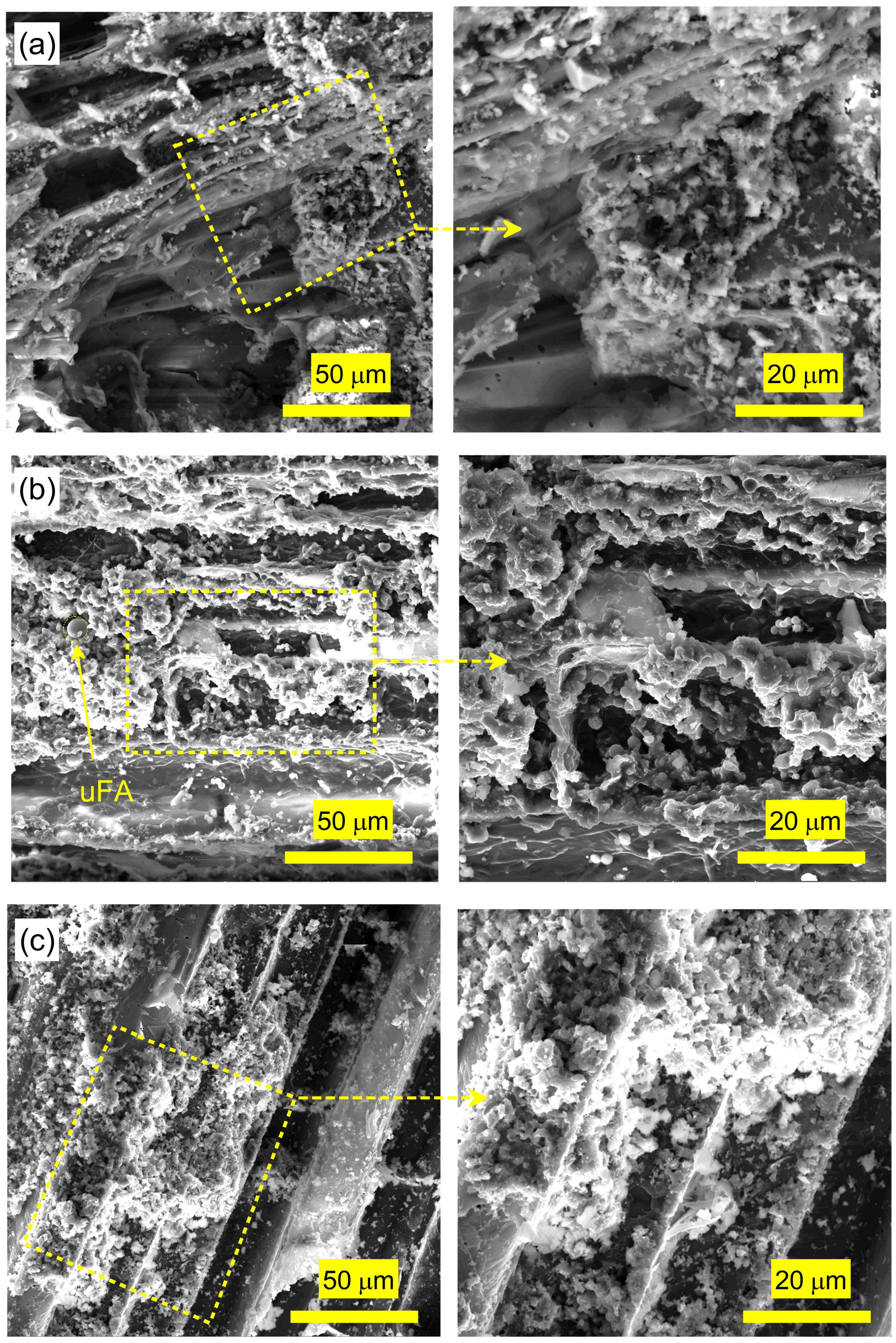

Fig. 3. The microstructure of the interface between miscanthus fibres and mineral matrices of lime based binders: (a) Mix CNG, (b) Mix CNF and (c) Mix CNCe.

D. Conclusion and Future directions

Ternary binder mixes (CNF and CNCe) exhibit high strength and stiffness values compared with lime-based matrices (C and CN). However, mixes containing GGBS (CNG) show low strength compared to the rest of the ternary binder matrices (CNF and CNO). It might be important to investigate increased temperature curing in combination with silicate and carbonate alkali activation of blast furnace slag mixes. There is a superficial deposition of mineral binders rather than a penetration of binder particles inside the pore structures of miscanthus, which are much larger than the former. Ternary binders incorporating GGBS, FA and cement (CNG, CNF and CNO) exhibit stronger interfaces and adhesion to miscanthus particles than simple lime binders (C and CN).

Further reading – Miscanthus Bio-insulation concrete (Miscrete)

[1] F. Ntimugura, R. Vinai, A. Harper, P. Walker, Mechanical, thermal, hygroscopic and acoustic properties of bio-aggregates – lime and alkali - activated insulating composite materials: A review of current status and prospects for miscanthus as an innovative resource in the South West of England, Sustainable Materials and Technologies. 26 (2020) e00211. https://doi.org/10.1016/j.susmat.2020.e00211.

[2] F. Ntimugura, R. Vinai, A.B. Harper, P. Walker, Environmental performance of miscanthus-lime lightweight concrete using life cycle assessment: Application in external wall assemblies, Sustainable Materials and Technologies. 28 (2021) e00253. https://doi.org/10.1016/j.susmat.2021.e00253.

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