
Abstract

Fiber cement composites exhibit complex mechanical behaviour resulting from interactions between fibers, cementitious matrices, pores and interfacial transition zones across multiple length scales. Traditionally, the development of new formulations has relied heavily on empirical testing, resulting in lengthy and resource-intensive optimization programmes. To accelerate innovation and support the transition towards design-driven materials engineering, a multi-scale micromechanical modelling framework has been developed for fiber cement products.

The proposed framework establishes quantitative links between microstructural mechanisms and macroscopic structural behaviour. At the microscale, single-fiber pull-out behaviour is described using established analytical approaches. The response of individual fibers is subsequently stochastically averaged to determine crack-bridging behaviour and the governing stress-crack opening relationship at the mesoscale. These mechanisms are then integrated into a structural model capable of predicting the flexural response of fiber cement composites.

To overcome the challenges associated with direct measurement of micromechanical parameters, inverse identification techniques were employed to derive model parameters from standard mechanical test data. The resulting framework was validated against experimental results for both autoclaved and air-cured fiber cement formulations demonstrating good agreement for modulus of rupture and load-displacement behaviour.

The model enables virtual evaluation of material formulations and fiber characteristics, reducing experimental trial-and-error while providing greater insight into the mechanisms governing composite performance. This approach represents a significant step towards predictive material design and accelerated development of next-generation fiber cement products.
