Abstract

Concrete is the most widely used material in the world, and its production and transport are responsible for 8% of global carbon emissions. It is inherently brittle and requires frequent repair or replacement, which is expensive and generates large volumes of CO2. A self-healing cement paste can help overcome this problem. Inspired by the highly efficient process of CO2 transfer in biological cells, this talk introduces a method to develop a self-healing mechanism in a cementitious matrix using trace amounts of the enzyme Carbonic Anhydrase (CA). CA catalyzes the reaction that forms calcium carbonate crystals with thermomechanical properties like those of the cementitious matrix. The crystal growth rate using this method is orders of magnitude faster and more efficient than bacterial methods, enabling the healing of significant flaws on timescales that are orders of magnitude shorter. Our enzymatic mechanism led to the development of the carbon-negative Enzymatic Structural Material (ESM), offering a new pathway to replace concrete. Moreover, ESM production can be a viable carbon sequestration method. ESM exhibits high water stability relative to other biologically inspired construction materials, with a strength of approximately 25 MPa, comparable to the compressive strength of structural concrete. Importantly, ESM production consumes 8.5 kg of CO2 per m3, in contrast to traditional concrete production, which emits approximately 400 kg of CO2 per m3. These properties make the technology especially well-suited to cement-based prefabricated solutions, where controlled factory conditions allow precise enzyme dosing and curing. The self-healing mechanism can extend the service life of thin, crack-sensitive elements such as fiber-cement roofing sheets and cementitious boards for modular and façade systems, where micro-crack sealing directly reduces water ingress, efflorescence, and freeze–thaw damage. Cast ESM panels and blocks offer a carbon-negative alternative for non-structural and semi-structural prefabricated components, while enzymatic healing can be incorporated as an additive in conventional precast roofing tiles and wall boards to improve durability and reduce warranty repairs. This talk will discuss pathways from lab-scale results toward pilot-scale prefabrication, including dosing, demolding, and quality-control considerations relevant to industrial production.