MULTI-PHYSICAL MODEL FOR DESCRIBING SELF-HEALING MORTAR CONTAINING BIOCHAR-IMMOBILIZED BACTERIA

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This work aims to analytically and numerically describe and predict the ability of a particular kind of bacteria (Bacillus sphaericus) to heal cracks in mortar.

The ureolytic bacteria induces microbial calcium carbonate by releasing urease enzyme, which in turn stimulates the degradation of urea into carbonate and ammonium; the carbonate then reacts with the calcium ions (in calcium nitrate) to produce calcite to heal cracks.

A novel feature of our study is that the bacteria is immobilized in biochar, which is the solid by-product of pyrolysis. The biochar and bacteria are included in the mortar mixture together with special nutrient solution; the mixture of bacteria and nutrients is called the “spore solution”. Our prior (and published) studies found that biochar-immobilized bacteria heal cracks more efficiently.

The modeling approach consists of 4 major steps or sub-models.

Firstly, a Pore Wall Bubbling model is created to describe the protrusion and expansion of pores in biochar. The predicted pore size distribution, hence porosity, was then used to calculate the overall porosity of the biochar-containing mortar using a second sub-model known as the Fractional Porosity Model.

Next, an absorption model was used to describe uptake of the spore solution and then estimate the spore concentration within the biochar of a certain theoretical porosity. Finally, the rate of healing of a hypothetical cylindrical crack in mortar was estimated from the rate of production of calcite (due to the spore concentration calculated above), which depends on the rate of urea hydrolysis - the latter of which was described using a hydrolysis-diffusion model solved using Galerkin’s finite element method.

Theoretical predictions agree very well with experimental results. Several deductions and possible improvements to the model are also suggested.