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Preventing deterioration of construction geo-materials; the new concept of biological self-healing for porous building stone

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Building stone and masonry is exposed to significant weathering processes over its lifetime. The rate and extent of deterioration is often governed by porosity – porous rocks (e.g. limestone) contain significant quantities of internal space allowing absorption and movement of moisture and other materials. The presence of moisture plays a significant role in deterioration via mechanisms such as changes in stress state through wet/dry or freeze/thaw cycles, dissolution or swelling of cementing minerals and transport of minerals. Such changes typically occur near exposed surfaces where moisture transport occurs. Deposition of salts or particulates in surface zones can impart additional stresses to the mineral structure and may limit moisture transport, thus preventing stress relief when trapped moisture expands with temperature. Differential stresses arising from variations in thermal properties between host rock and the precipitate may also result. Physical processes may be exacerbated by biological ones, where microorganisms cause physical and chemical changes such as filamentous organisms extending existing structural flaws, biological assemblages expanding and contracting in wet/dry cycles, or contribution to biochemical weathering by secretion of enzymes, acids etc. However, there is evidence that certain processes offer protection to the structure in the long term.

Mechanisms for protecting building stone are limited to surface coatings to bind loosened material and ideally limit water ingress into the pore matrix without hindering the ability of moisture to exit from the stone as vapour. However, treatments may limit this 'breathability' of the material, and can be limited to specific stones.

Although self-healing concepts have been applied to a range of materials, they have not been applied to construction geo-materials. Self-healing capabilities are ideally suited to porous geo-materials such as limestone, where accessibility for maintenance or renewal can be limited.

The potential for biological healing has led to the technique being considered (in cementitious materials) as part of a new class of self-healing construction materials. Biological self-healing would incorporate techniques able to sense damage or deterioration and adapt or repair themselves to restore their original properties or limit further deterioration. However, these methods must be durable, and operate when required after having been dormant for long periods of time.

The opportunities in geo-materials for biological self-healing are considerable due to their bioreceptivity and suitability for biomineralisation, as well as the extent to which such materials are in use worldwide.

This research explores the potential for extending biological healing of these materials to incorporate a capacity for self-healing. It investigates the efficacy of currently used mechanisms for self-healing, but in the geo-material environment. Calcite biomineralisation is used as the basic mechanism, where spores trapped within calcite are exposed by damage and germinate into cells which heal the damage, re-encapsulating themselves and resetting the cycle. Calcium carbonates or similar minerals play a significant role in the structure of porous building stones, and so this method is well-matched to the substrate.

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