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concrete

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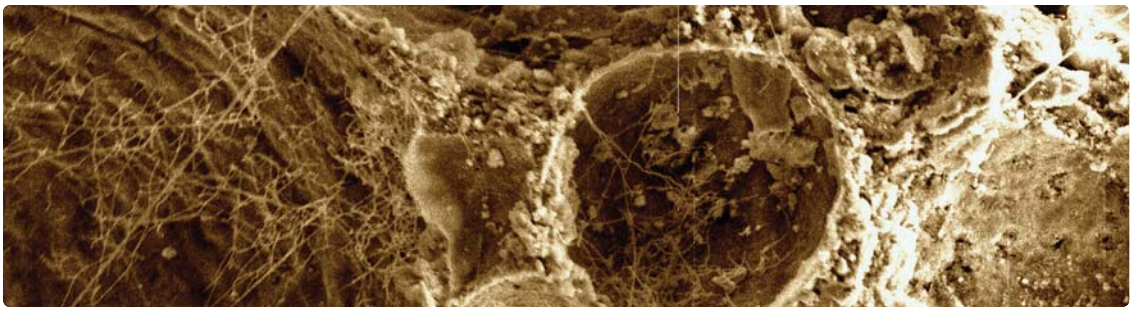
Something old something new

Park Hill Sheffield refurbishment

UK Concrete Show Preview

(Photo: Daniel Hopkinson)



A study into microbial growth within new marine concrete

Peter Hughes is a final-year PhD student at the University of Central Lancashire investigating marine biofouling and its implications for the durability of marine concrete.

Microbial growth and the ability of some species to tunnel into concrete surfaces leads to degradation, increased porosity and decreased durability. However, recent research into the use of certain micro-organisms for the improvement of durability has drawn the attention of research groups all over the world and an informative review has been given by De Muynck *et al*[1].

Most research in this field has reported on the addition of bacteria into the matrix as a self-healing addition[2], or has involved the study of micro-organisms within the matrix following environmental exposure; however, this study is the first to report observations of filamentous bacterial growth within new, unplaced synthetic-fibre-reinforced marine concrete (see Figure 1). Durability of marine concrete – part of a larger study[3] – is arguably its principal property; it is important that concrete should be capable of withstanding the harsh conditions throughout the expected life of a structure.

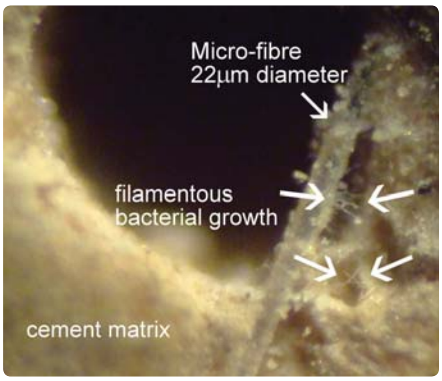


Figure 1: Filamentous bacterial growth on underside of fibre (arrowed) within new concrete.

Previous experimental evidence indicates that porous, exposed concrete creates a favourable environment for microbial colonisation because aquatic organisms including algae and bacteria adhere to its inner and outer surfaces. They produce branching networks that vary greatly in size, from as little as 350µm in diameter (see Figure 2). In some species (eg, *Ulva*), such fine filaments may collect together to form tubular thalli up to 25µm in diameter. Concrete structures exposed in tropical and subtropical seas have been shown to be subject to the same bioerosive forces as carbonate substrates. Many of the species implicated in calcium carbonate breakdown have been demonstrated to be capable of bioeroding concrete. The aim of this study was to observe and report filamentous bacterial growth within a new, unexposed cement matrix and to discuss its origins and how its presence may affect future performance. To achieve this aim, new test cube specimens of concrete destined for use at a coastal protection scheme in the UK were examined using light microscopy and scanning electron microscopes (SEM).

Concrete specimens

The compressive strength class was C35/45, BS 8500-1[4] exposure class XS3, XF4, XC3, XC4 and a water/cement ratio of 0.45. The minimum cement content was 340kg/m^3, CEM IIIA, with 50% GGBS and a chloride class 0.2. Cubes (150 × 150 × 150mm) were made with concrete supplied by the manufacturer and air cured at 20°C inside the laboratory for 28 days. Some cubes were dry diamond cut into 25mm lengths, then washed and examined. Some cubes were broken into smaller pieces, approximately 10mm^3, suitable for microscopic examination. Locally sourced 20mm coarse limestone aggregate (older Palaeozoic) was used in the production of the concrete. Marine dredged sand was extracted from a beach on the north-west coast of England, and blended with crushed

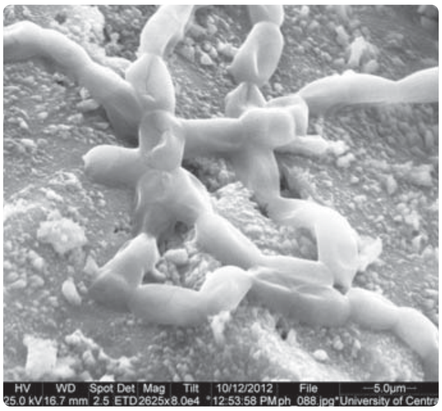


Figure 2: Extensive microbial surface fouling; filamentous bacterial growth can be seen on the surface of sand from within new concrete.

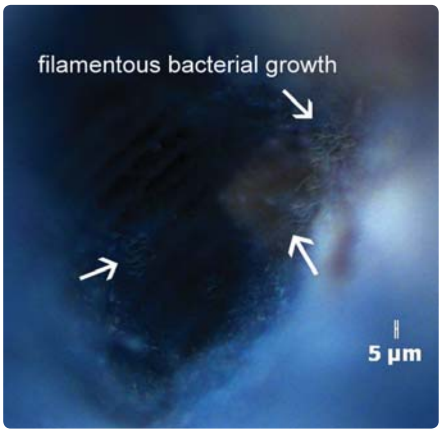


Figure 3: Filamentous growth in a void from within new concrete.

limestone for use as fine aggregate by the concrete manufacturer. The sand was washed by the concrete manufacturer with sea water to reduce silt content and then screened to remove any significant debris such as litter and driftwood. Beach sand samples were collected by hand 1km landward from the dredging area for comparisons.

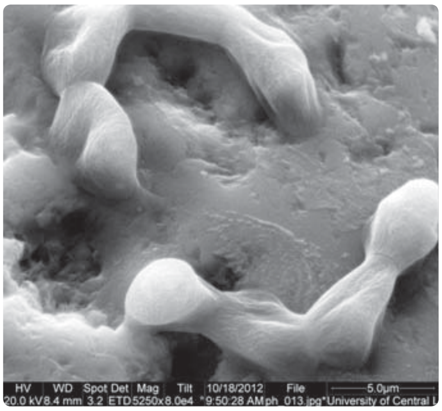


Figure 4: Filamentous bacterial growth on the surface of sand within unplaced concrete.

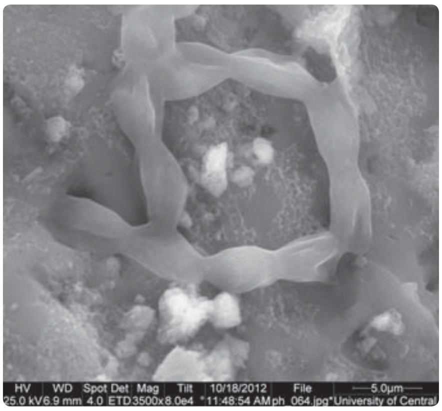


Figure 5: Filamentous bacterial growth out of the surface of sand within new concrete.

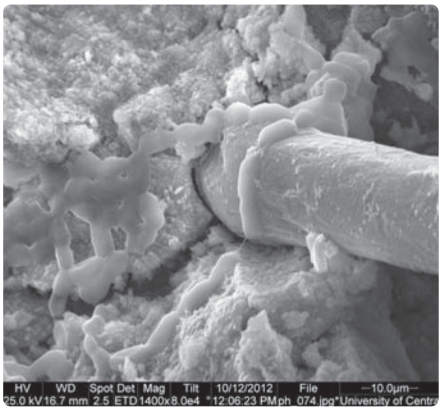


Figure 6: Filamentous bacterial growth on the surface of a micro-fibre within unplaced concrete.

Observations

The SEM micrographs illustrate microbial growth within the concrete. Figure 3 shows a water void with filamentous growth on the rippled walls of the chamber. EDX analysis distinguished between remnants of synthetic fibres within the matrix and micro-organisms; fibre results differed from micro-organism, showing 86% carbon and 14% oxygen. Figure 4 shows attached filaments on the surface of new sand. Figure 5 illustrates a chain-like structure of cells approximately 350μm in diameter climbing the surface of the fine aggregate.

Discussion

Although bacteria, and particularly acid-producing bacteria, have been traditionally considered as harmful organisms for concrete, an alternative perspective is that the growth of micro-organisms may afford some level of protection from weathering and erosion. As discussed by De Belie and De Muynck[5], the ability of certain bacteria to promote the precipitation of calcium carbonate has been used advantageously for consolidation of concrete and stone. Previous research has illustrated a reduction of the capillary permeable porosity and an increased resistance to damage processes such as chloride ingress and carbonation by this biodeposition procedure.

Material from marine deposits around the coast of Great Britain has been used in concrete production for several decades. However, no provision is made in the current Standards for the control of microbial growth within or on the surface of beach sand (see Figures 4 and 5).

Research by Steele *et al*[6] found viable algal cells buried to a depth of 0.2m below the sand surface in a Scottish sea loch. A similar finding occurred 200km from the source of the marine aggregate used in the study mix, in Lough Neagh, where high concentrations of living algal cells were found attached to sand grains down to 0.5m below the sand surface.

Considering the constant mixing of sediment at a beach surface, it may follow that microbial endoliths could occupy some of the beach extraction used in the production of the concrete examined in the current work.

Beach sand samples from the vicinity of the dredging site (the source of fine aggregate used in the concrete production) were examined under the microscope and found to be colonised by filamentous microbial growth. The existence of microbial populations that live on or within sand is well documented.

MPA–Cement warns that washed beach sand is generally unsuitable by itself for good-quality concrete, due to the single-sized grading, but this can be overcome by blending aggregates.

While aggregates for unreinforced concrete can be washed with sea water, as was the case in this study, for reinforced concrete the aggregates must be carefully washed with potable water to remove excess chloride from sea salt; however, they will still retain shell fragments and organic matter that can affect the water demand of the mix. The organic content refers only to water-soluble organic compounds derived from decaying vegetation, tests for which no longer appear within Standards.

Preliminary results

The preliminary results of this on-going study suggest that the blanket use of marine-sourced aggregates should be reconsidered for concrete that is to remain in contact with sea water, particularly mass (unreinforced) concrete. Washing in water may only partly remove some of the epilithic biomass present on the surface of the aggregate, possibly leaving endolithic micro-organisms (see Figure 6) to continue and thrive.

It has been reported that some micro-organisms such as algae have resting stages (spores and zygotes) that allow cells to lay dormant in unfavourable environments, even freezing conditions, or to survive in ephemeral pools. Previous research found that even after soils had air-dried for 35 years, green algae could be cultured.

Therefore the microbial content may need to be controlled in structures subject to permanent wetting by sea water to control growth on and inside the matrix. BS EN 12620[7] is the predominant specification concerning the use of aggregates for concrete supported by UK national guidance document PD 6682-1[8]. This guidance should consider undesirable elements such as micro-organisms more closely and place precise limits on their presence. For marine concrete structures there is a tangible risk that microbial growth will remain on or within the beach fine aggregate, leading to increased colonisation and the bioerosion of concrete. ●

● Acknowledgements

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The Editor welcomes comments from readers – is bioerosion of concrete a serious issue? Should PD 6682-1 place limits on microbes on aggregates? E-mail: editorial@concrete.org.uk

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