USE OF ECOFRIENDLY MICROBIAL BRICKS IN RC FILLER SLABS

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ABSTRACT. Filler Slab roofs are designed using the same principles as normal RCC, except for replacing part of the concrete by some alternative material in the tensile zone. Various filler materials, replacing Concrete, have been adopted. Bricks, being ecofriendly and easily available has also been used to fill the area between the reinforcement. These RC Filler slabs have the same durability problems as in normal concrete like crack formation. Sometimes, the use of local bricks aggravates the problem. Using Microorganisms to induce self-healing properties has been found to be a solution to the problem of formation and expansion cracks in building materials. At the same time, use of microorganisms in brick making is also found to be very useful. Use of such bricks in RC filler slabs may overcome the problems associated with formation and expansion cracks in RC filler slabs. This paper discusses the options of ecofriendly microbial bricks to reduce seepage and efflorescence in RC filler slabs.

Keywords: RC filler slabs, Microbial bricks.

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INTRODUCTION

RCC is one building material which transformed the construction industry because of its strength and durability. A house with RCC roofing was considered a lifelong asset. With time, particularly in the coastal regions, the problems of concrete started coming to the fore, and needed to be addressed. Mainly these problems were of water seepage, crack formation etc. Another major issue in RCC was the cost of construction and affordability. In many parts of India, having a RCC roof house is still a matter of prestige.

While many architects and engineers have been trying to bring the cost of construction down and making housing an affordable option, the choices are limited. That is where the filler slabs came into picture, and in the late 1980's in Kerala, many roofs were cast as filler slabs.

RC FILLER SLABS

Behaviorally, the RC filler slab acts like any other RCC slab, and as such does not pose any new problem not seen in regular RCC roof. Incidentally, even though all RCC roofs are a single monolith cast of concrete along with steel, the area between the steel reinforcements play no role in load transfer. Yet, we cast the roof in full because it cannot be cast with innumerable voids in between, considering the form work or the temporary supports that are required for casting the roof. Quality of construction at site is a pre-condition which can affect both the mainstream and the alternative practices [9]. There are many filler roofs done with several options like bricks, hollow blacks, mangalore tiles, mud pots or bowls, and even coconut shells as filler material. The criteria in selecting the material have largely been the cost and its looks. Moreover, the filler slab provides better sound and heat insulation [5].

Figure 1 A RC filler-slab roof being constructed with bricks as fillers

MICRO-ORGANISMS IN CONSTRUCTION WORK

The Construction industry has been on the lookout for ways to increase the durability of materials and products. As the traditional construction materials (such as concrete, bricks, hollow blocks, solid blocks, pavement blocks and tiles) are all produced from the existing natural resources and damaging the environment due to continuous exploration and depletion of natural resources, many researchers have looked for reusing the wastes in environmentally and economically sustainable ways [2,15]. Biomineralization is a process by which living organisms produce minerals. This process could be biologically controlled mineralization or biologically induced mineralization. Natural processes, such as weathering, faults, land subsidence, earthquakes, and human activities create fractures and fissures in concrete structures which can reduce the service life of the structures. A novel strategy to restore or remediate such structures is biomineralization of calcium carbonate using microbes such as *Bacillus* species [17].

Microorganisms contribute to the deterioration of the materials of construction, as well as concrete [14-15], which can happen due to the microbes utilizing the ions present in cement, minerals solubilization by metabolites, and enzymes breaking down the mortar. This has led into research on utilizing these very microbes into remediating building works. Recently, microbiologically induced calcium carbonate precipitation (MICCP) resulting from metabolic activities of some specific microorganisms in concrete to improve the overall behavior of concrete has begun to attract interest of researchers. Previous studies with aerobic microorganism (*Bacillus pasteurii* and *Pseudomonas aeruginosa*) showed a significant improvement (about 18%) in compressive strength of cement mortar [10-11]. MICCP comprises of a series of complex biochemical reactions (Stocks-Fischer et al. 1999). As part of metabolism, some bacterial species produce urease, which catalyzes urea to produce CO_2 and ammonia, resulting in an increase of pH in the surroundings where ions Ca^{2+} and CO_3^{2-} precipitate as $CaCO_3$. Possible biochemical reactions in medium to precipitate $CaCO_3$ at the cell surface that provides a nucleation site can be summarized as follows.

$$Ca^{2+} + Cell \rightarrow Cell\text{-}Ca^{2+} \quad (1)$$

$$Cl^{-} + HCO_3^{-} + NH_3 \rightarrow NH_4Cl + CO_3^{2-} \quad (2)$$

$$Cell\text{-}Ca^{2+} + CO_3^{2-} \rightarrow Cell\text{-}CaCO_3\downarrow \quad (3)$$

The potential of MICCP technology in restoration of cement mortar cubes, sand consolidation and limestone monument repair, reduction of water and chloride ion permeability in concrete, filling of pores and cracks in concrete, enhanced strength of bricks via urea hydrolysis pathway has been investigated by many researchers [2,4,12,13]. A novel technique for the remediation of damaged structural formations has been developed by employing a selective microbial plugging process in which microbial metabolic activities promote precipitation of calcium carbonate in the form of calcite [3, 8]. As a microbial sealant, $CaCO_3$ exhibited its positive potential to selectively consolidate simulated fractures and surface fissures in granites and sand plugging [18, 1]. The use of urease producing bacterial isolates like *Bacillus* species in remediation of concrete was studied by Achal et al. [1]. The study identified the positive effect of *Bacillus* sp. CT-5 on the compressive strength of Portland cement mortar cubes and an increase in resistance towards water penetration.

BIO - BRICKS

The deterioration of bricks happens due to the presence of voids and pores which subsequently results into cracks. Durability of bricks is related to its compressive strength and resistance to water permeation. The compressive strength of bricks depends on its textural and microstructural characteristics whereas the impermeability of water in bricks depends on its porosity. However, the microbial mineralization process is a slow process, and is subject to limitations of many environmental factors including temperature, pH, concentrations of donors and acceptors of electrons, concentrations and diffusion rates of nutrients and metabolites etc. The survival of bacteria within the building material influences the extent of calcification. Detailed microbial ecology studies are imperative in order to ascertain the effects of the introduction of new bacteria into the natural microbial communities, the development of the communities at short, mid and long term, and the eventual secondary colonization of heterotrophic microorganisms using bacterial organic matter and dead cells, such as actinomycetes, fungi, etc. Thus for enhancement in efficiency of microbiological remediation process, high but controllable precipitation of calcium carbonate is essential.

Incorporating microbes within the body of material will affect the extent of nutrient and oxygen availability to the microbes which in turn affects their biocalcification ability. During the initial curing period, the bacterial cells inoculated directly in the nutrient media readily utilized the available nutrients and became metabolically active. The voids and in-homogeneities in bricks at micro level allowed the gradual penetration of already metabolically active microbes along with the nutrients into the pores thereby facilitating the microbial calcite deposition into these pores. These metabolically active B. pasteurii cells precipitated calcite within the pores as well as on the surface of the bricks [6, 12]. The bricks manufactured by bacteria are better than many conventional brick manufacturing technologies because of self healing and eco-friendly characteristics [7].

BIO-BRICKS IN FILLER SLABS

In RC filler slabs, the development of cracks in concrete is common. Unlike in a full RC slab, the development of cracks increases seepage, because the concrete at the filled portions is not homogenic. RC filler slabs with ordinary bricks, if exposed to open, would require further finishing, for architectural reasons. In such cases, calcium precipitation or leaching of calcite would present an ugly surface. When ordinary bricks are used as fillers, the weaknesses in bricks also contribute to the seepage. In such cases, bacterial self-induced, self -healing properties would be beneficial. The calcium that otherwise would precipitate and leach from the surface would be microbially controlled to bond itself onto the surface of the concrete, thereby increasing the bond strength of the Brick-RC interface, and also reduce the seepage of water by healing of any cracks that would form at these interfaces.

CONCLUDING REMARKS

In Coastal areas, water seepage and discoloration in concrete roofs is a major problem. Also, the advantages of a filler slab get lost due the same problems. This is more so, when ordinary bricks are used as filler material. Use of microbial self healing properties could overcome these problems and help in ecofriendly and sustainable construction.

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