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Micro-Pocket Embedded Carbon Capsulated Cement with Urea-Formaldehyde Microcapsules for Enhanced Performance in Construction Cement

Dhanush A[1], Dr. Essouradjane[2]
Amalorpavam Lourds Academy, India

Abstract: The innovative integration of Micro-Pocket Embedded Carbon Capsulated Cement (MPECCC) with Urea-Formaldehyde Microcapsules (UFMCs) marks a paradigm shift in construction material engineering. This research endeavors to explore the synergistic effects of combining carbon encapsulation within micro-pockets and the controlled release mechanisms offered by urea-formaldehyde microcapsules. The resulting material, herein referred to as MPECCC with UFMCs, presents a novel approach to address critical challenges in the construction industry, such as enhanced durability, improved mechanical properties, and innovative functionalities.

I. INTRODUCTION

The potential improvement of mechanical properties in hydraulic concrete through the incorporation of urea-formaldehyde microcapsules (UFMCs) presents a transformative avenue for advancing construction materials. Hydraulic concretes, known for their malleability before hardening, offer versatility in shaping structures and exhibit high compressive strength upon setting.

However, conventional concrete, with an average mass density of 2.3 tons/m³ and a hardening time of approximately 28 days, presents challenges such as weight and curing duration. This study explores mixtures of urea-formaldehyde microcapsules with Micro-Pocket Embedded Carbon Capsulated Cement (MPECCC) and investigates the resulting changes in texture and mechanical properties during the hydration process.

Several experimental studies have examined the incorporation of microcapsules, including urea-formaldehyde microcapsules, in cementitious materials. Previous research has explored the use of microcapsules for various purposes, including self-healing concrete, where encapsulated healing agents are released upon cracking [1–4]. However, the integration of urea-formaldehyde microcapsules in the context of Micro-Pocket Embedded Carbon Capsulated Cement (MPECCC) remains an unexplored area.

II. METHODOLOGY

The methodology employed for preparing cement paste mixtures, aligning with established laboratory practices for construction materials, involved a meticulous process. Specifically, 74.6 g of gray cement (procured from a local supplier, Madras chemicals. cpc 30 R,)

The sequential preparation process involved introducing sand into a rotary mixer for one minute, followed by the addition of cement, rotating the mixture for an additional 2 minutes. Subsequently, a solution containing water and urea-formaldehyde microcapsules underwent three rotation cycles of 5 minutes each. After each cycle, the mixture was allowed to stand for 3 minutes. The resulting concrete was then poured into molds to shape cylindrical samples with dimensions of 10 cm in height and 5 cm in diameter. These cylindrical specimens were designated for compression tests. Table 1 provides details on the number of specimens tested, considering varying water pH levels and sonication times, totaling 180 specimens. Control group specimens, without urea-formaldehyde microcapsules, were also included.

Parameter	Calculation	Quantity (g)
Urea-Formaldehyde	(0.15)3×6×1.2(0.15)3×6×1.2	0.24

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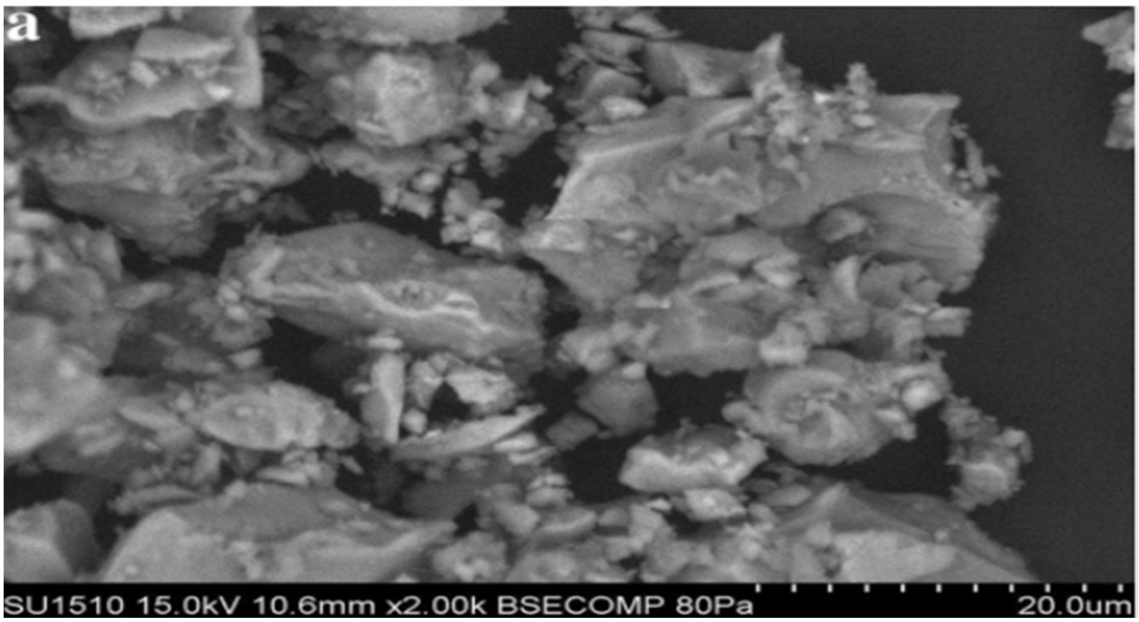
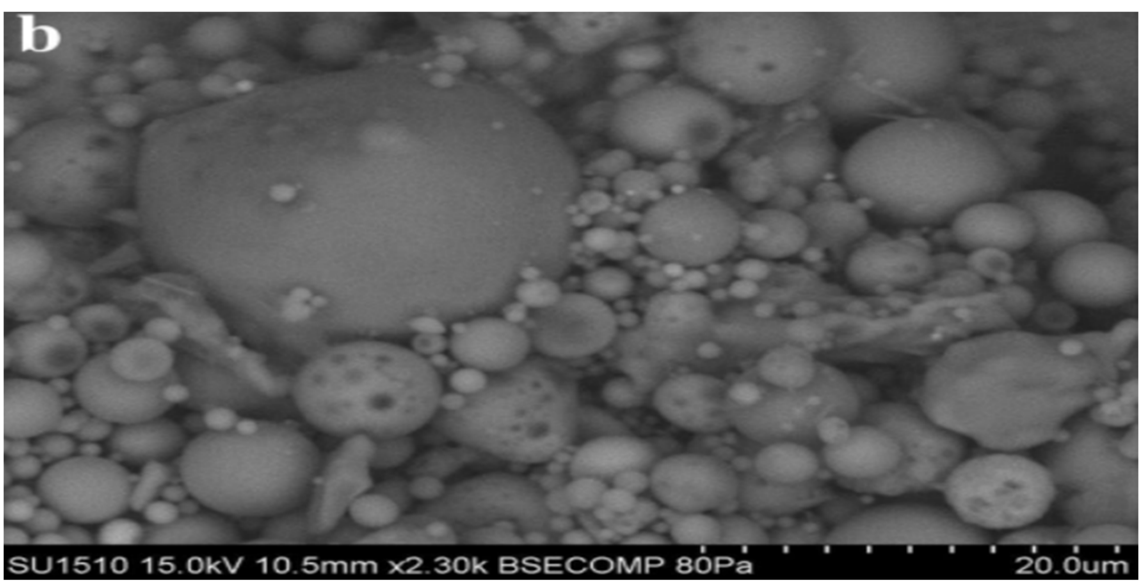
MPECCC	0.024×4330.024×433	10.4
Fine Aggregate Required	0.024×6140.024×614	14.7
Coarse Aggregate Required	0.024×11920.024×1192	28.6
Water Required	0.024×1860.024×186	4.5

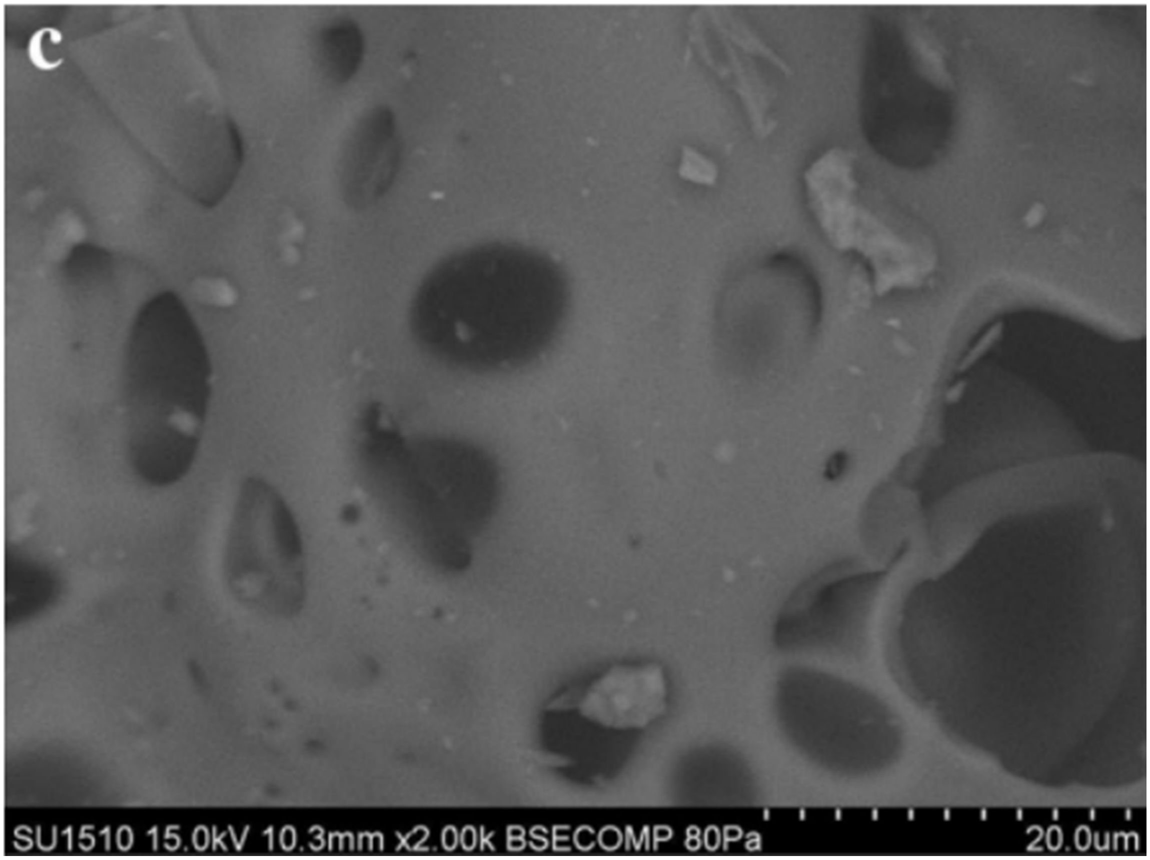
The ensuing mortars underwent testing at 3, 14, and 28 days of hydration. The pH of the water used in the cement and microcapsule mixture was adjusted using hypochlorous acid (HClO) and monitored with an electronic pH-meter. The compression strength test was executed using a Shimadzu universal press with a 5-ton capacity, aligning with the C39C/C39M standard under the American Society for Testing and Materials (ASTM) normative. This test method entailed the application of a compressive axial load on the specimens.



a SEM image of COMPOSITION - 2 at 2000X magnifcation, 20 µm scale and 15 kV accelerating voltage.



b SEM image of calcareous fy ash at 2300X magnifcation, 20 µm scale and 15 kV accelerating voltage.



c SEM image of perlite at 2000X magnifcation, 20 μm scale and 15 kV accelerating voltage

The comprehensive characterization of the novel construction material involves a series of physical tests aimed at elucidating its structural, mechanical, and durability properties. The integration of Micro-Pocket Embedded Carbon Capsulated Cement (MPECCC) with Urea-Formaldehyde Microcapsules (UFMCs) necessitates a thorough understanding of the material's behavior under various conditions. The following physical tests were conducted to unveil the intrinsic qualities of MPECCC with UFMCs.

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.72	2.65
Bulk Density (kg/L)	1.408	-
Loose Bulk Density (kg/L)	1.25	-
Water Absorption (%)	4.469	0.0651
Impact Value	26.910	-
Crushing Value	26.514	-
Fineness Modulus	3.38	2.84

The compressive strength of the specimens was evaluated using a Shimadzu universal press with a 5-ton capacity, adhering to the C39C/C39M standard under the INDIAN Society for Testing and Materials (ISTM) normative. This test measured the material's ability to withstand axial compressive loads, providing crucial insights into its structural integrity and load-bearing capacity.

Test Item	Standard Requirements	Test Results
Specific Surface Area (m^2/g)	200 ± 20	202
pH Value	3.7 – 4.5	4.12
Loss on Drying @ 105°C (%)	< 1.5	0.47
Loss on Ignition @ 1000°C (%)	< 2.0	0.66
Sieve Residue (%)	< 0.04	0.02
Tamped Density (g/L)	40 – 60	44
SiO_2 Content (%)	> 99.8	99.88
Carbon Content (%)	< 0.15	0.06
Chloride Content (%)	< 0.0202	0.009
Al_2O_3	< 0.03	0.005
TiO_2	< 0.02	0.004
Fe_2O_3	< 0.003	0.001

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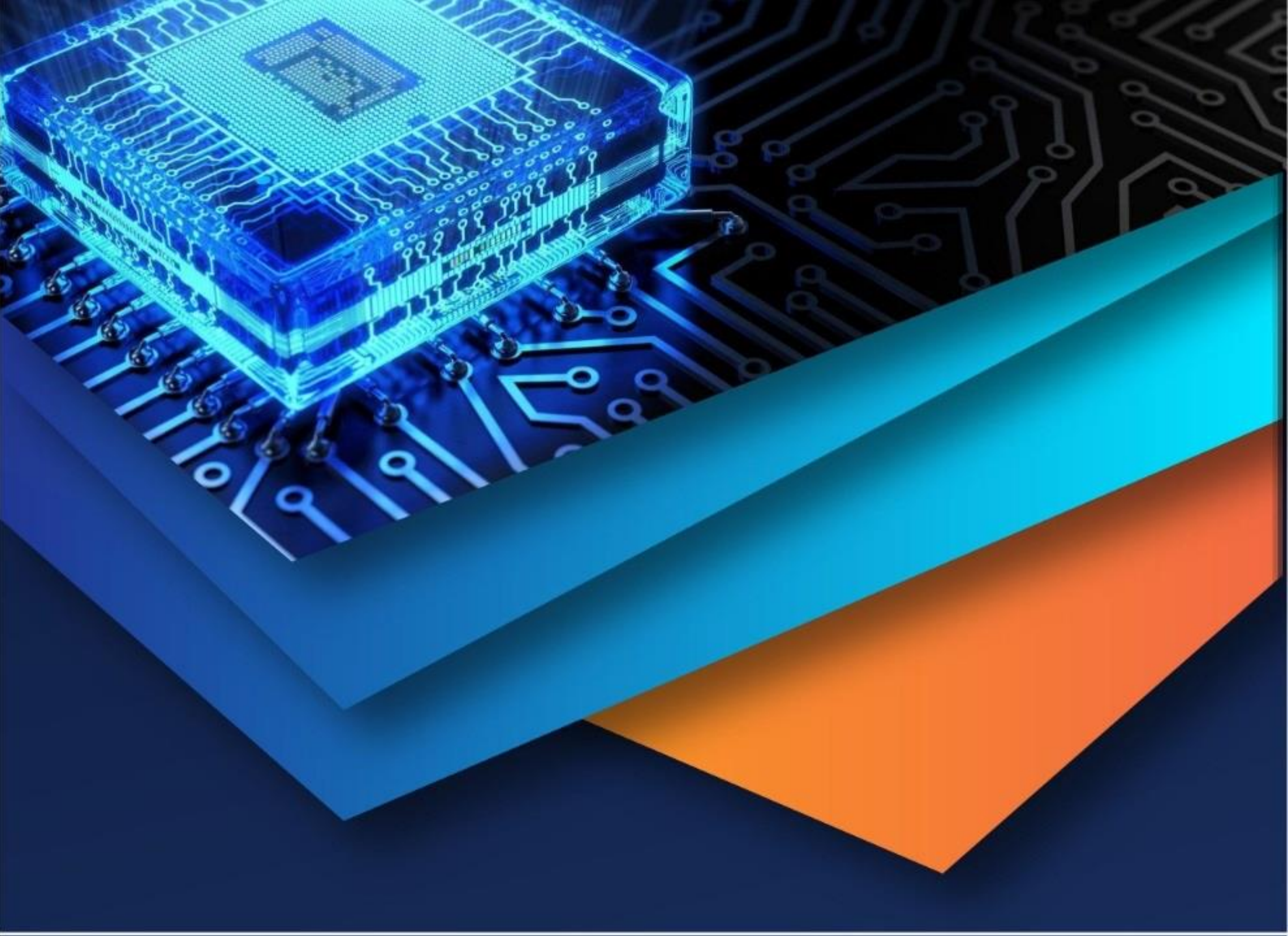

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