Strategies for Smart Ecosystem Restoration and Ocean Sustainability

From Knowledge to Competitiveness

Portugal-US Partnerships 2026 Summit

MIT Portugal Program

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Climate Science + Climate Change

Sustainable Cities

TOWARDS SMART MARINE STRUCTURES

Structural Functionalities | **Biological Functionalities** | **Sustainability**

From Conductive Concrete (E3C) to Living Reefs – Engineering with Nature for a Sustainable Ocean

E3C incorporating industrial by-products such as EAFS aggregates and fly ash, and conductive fibers, including recycled carbon fibers.

Self-healing via **M**ineral **A**ccretion **T**echnology - **MAT**

Self-monitoring
Remote damage detection

Biomimetic Surface via **M**ineral **A**ccretion **T**echnology - **MAT**

Ecosystem Restoration

Coastal Protection

Renewable Energy Integration

Dynamic Ocean Monitoring

Circular Solutions

1. MOTIVATION & CHALLENGES

Marine ecosystems face growing pressures, while marine structures struggle with durability, resilience, and ecological compatibility.

Marine Ecosystem Loss

- Overfishing
- Marine pollution
- Rising temperatures
- Loss of biodiversity

Structural Challenges

- Corrosion
- Remote locations
- Difficult monitoring and repair
- Biofouling
- Toxic coatings

We need smarter, more resilient, and environmentally friendly solutions for marine structures

2. METHODOLOGY

Electrically **C**onductive **C**ementitious **C**omposite - **E3C**
for marine applications

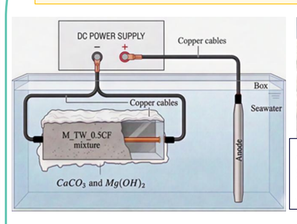
- **19.81 Ω·cm** Electrical Resistivity
- **30.55 MPa** Compressive Strength
- **4.68 MPa** Flexural strength

Seawater: *20–30 Ω·cm*
Conventional Concrete: *~10^9 Ω·cm*

3. RESULTS

MAT in uncracked specimens

Current Density 13.4 A/m²



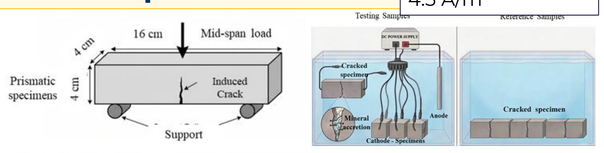
Natural Seawater 3 days

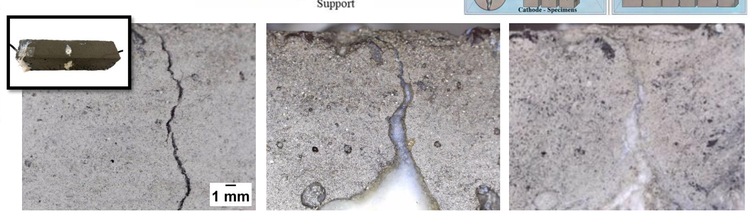
Artificial Seawater 30 days

MAT in cracked specimens

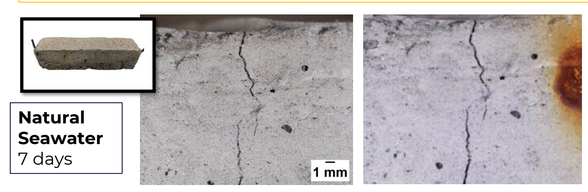
Current Density 4.5 A/m²

Natural Seawater 7 days





Without MAT in cracked specimens



Natural Seawater 7 days

4. CONCLUSIONS & ONGOING WORK

E3C shows potential for:

- ✓ Self-sensing for remote structural health monitoring
- ✓ Self-healing via MAT
- ✓ Bioactive surfaces through MAT-induced mineral accretion.
- ✓ Combine structural performance with long-term marine durability and **N**ature-**I**nclusive **D**esign (**NID**)

Ongoing Work:

- ➢ Long-term Durability Tests
- ➢ Advanced Characterization (SEM/XRD)
- ➢ Scale-up and prototype reef to *in situ* tests

5. KEY INNOVATIONS

Article
Journal of Cement-based materials

European Patent Application
24203667.1

International Patent Application
PCT/IB2024/059548

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