Calcium Carbonate Precipitation by Using Plant-derived Urease for Soil Improvement

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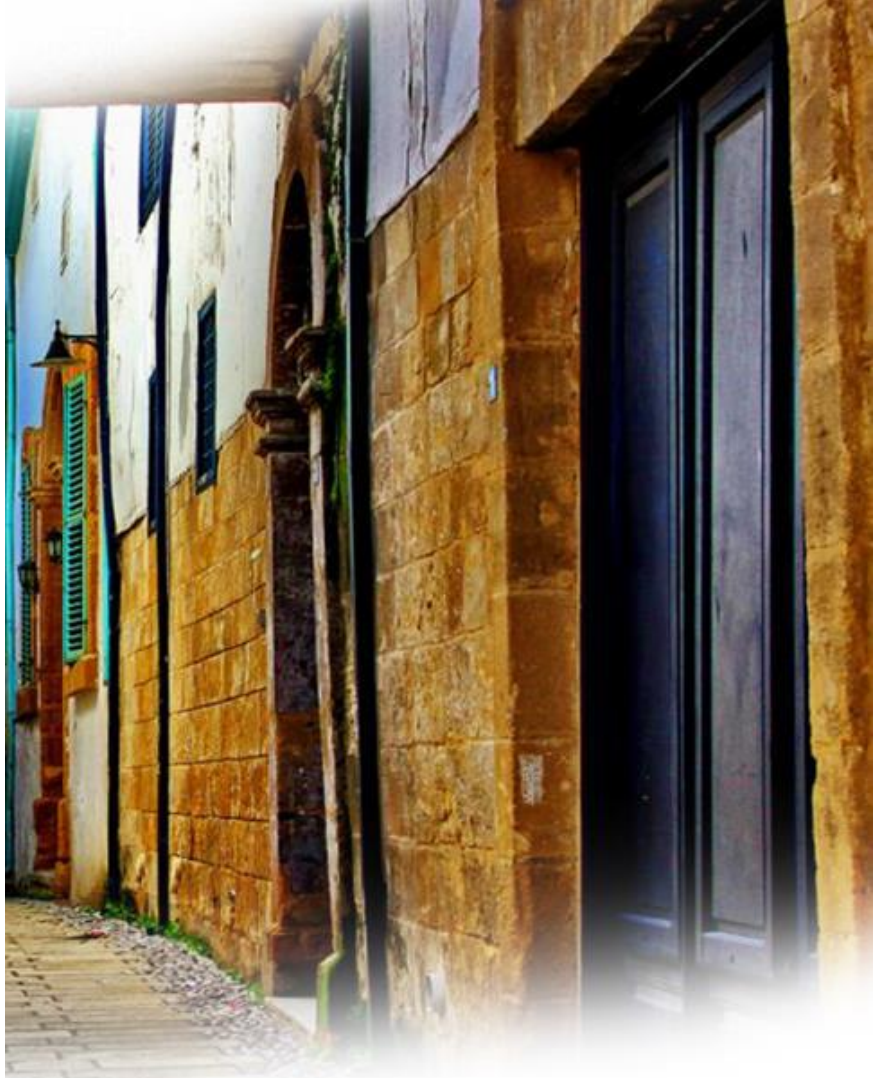


Outline

- What’s Bio-geotechnical Engineering?
- What’s EICP treatment?
- What’s EICP solution containing and applications?
- What's the mechanism of enhancing the geotechnical properties of soil?
- Potential Applications of EICP?
- Laboratory study.

What's Bio-geotechnical Engineering?

"It a novel geotechnical branch that aims to develop biology-based processes and products in order to substantially mitigate the pressure from the Geo & Civil Engineering activities on the environment"

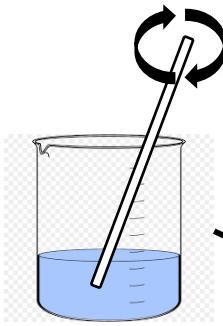
Delft University of Technology (TU Delft)

What's EICP treatment?

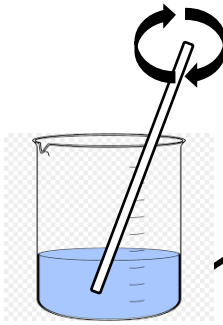
- EICP is precipitating the calcium carbonate ($CaCO_3$) using the urease enzyme, which is derived from plants (Chemically).

- Precipitating $CaCO_3$ between soil particles causes a reduction in permeability while simultaneously enhancing the stiffness, strength, dilatancy through filling pores, roughening particles and inter-particle bonding (Geotechnically).

What's EICP solution containing and applications?

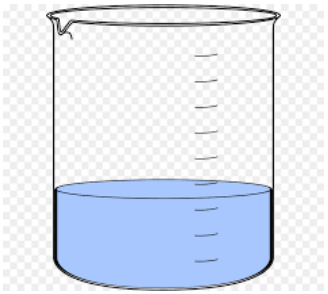


Solution A: Urea and $CaCl_2$



Solution B: Urease and Milk powder

EICP solution



Application

Loose Sand

Transformation

Cemented Beach Sand

What's the mechanism of enhancing the geotechnical properties of soil?

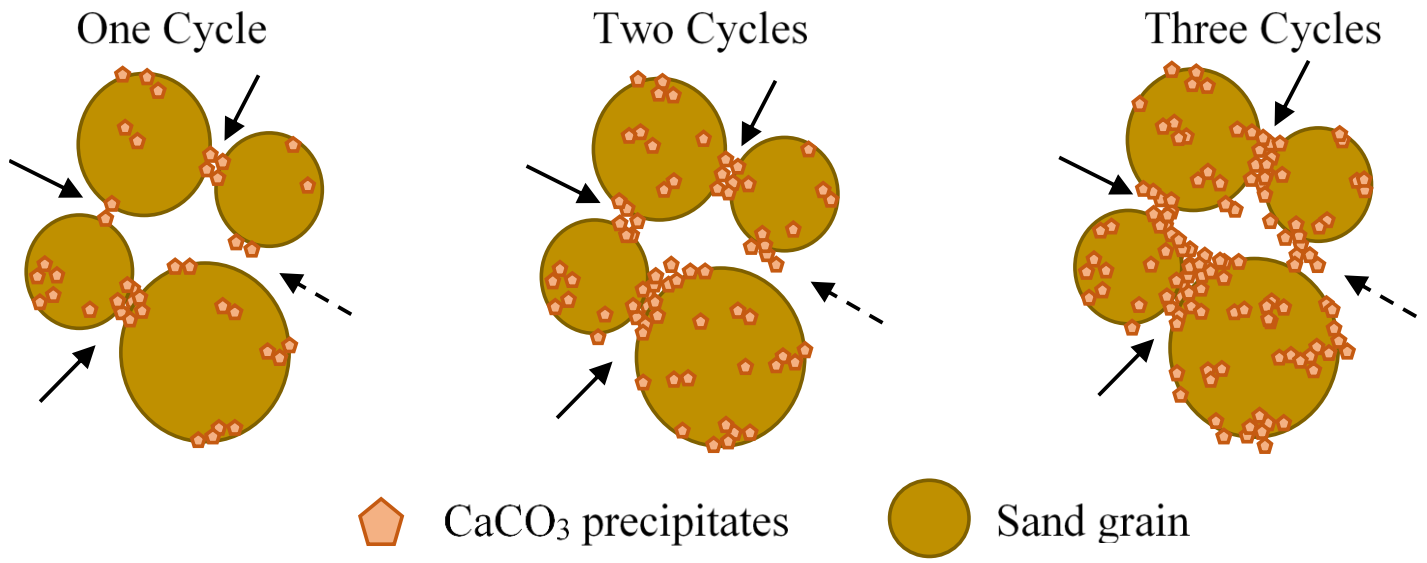


Figure 2: Schematic illustration of inter-particle binding at different cycles of treatment.

Potential Applications of EICP?

Liquefaction Mitigation

Fugitive Dust Control

Coastal Erosion Mitigation

And more ……. .

Applicability of Using EICP to mitigate the coastal erosion in Cyprus (Laboratory Study)

Aims

- The main objective of this study was to evaluate using enzymatic induced carbonate precipitation (EICP) for cementation of beach sand against water surface erosion and scour.
- The surface erosion resistance and scour were studied using mini-jet erosion test.

Using the EICP for Erosion Mitigation(Con.. .) (Methods)

The used soil in this study is natural beach sand obtained from Famagusta Bay, Cyprus. The summary of the physical properties of the beach sand presented in Table 1.

Table 1. Physical properties of the sand.

Property	Value
Effective diameter (D_{10}), mm	0.14 fr(mm)
Median diameter (D_{50}), mm	0.7
Uniformity coefficient (C_u)	6.42
Coefficient of curvature (C_c)	1.4
Minimum void ratio (e_{min})	0.562
Maximum void ratio (e_{max})	0.880
$CaCO_3$, %	62.50
Specific Gravity (G_s)	2.70
USCS Classification	SP

Using the EICP for Erosion Mitigation(Con.. .) (Methods)

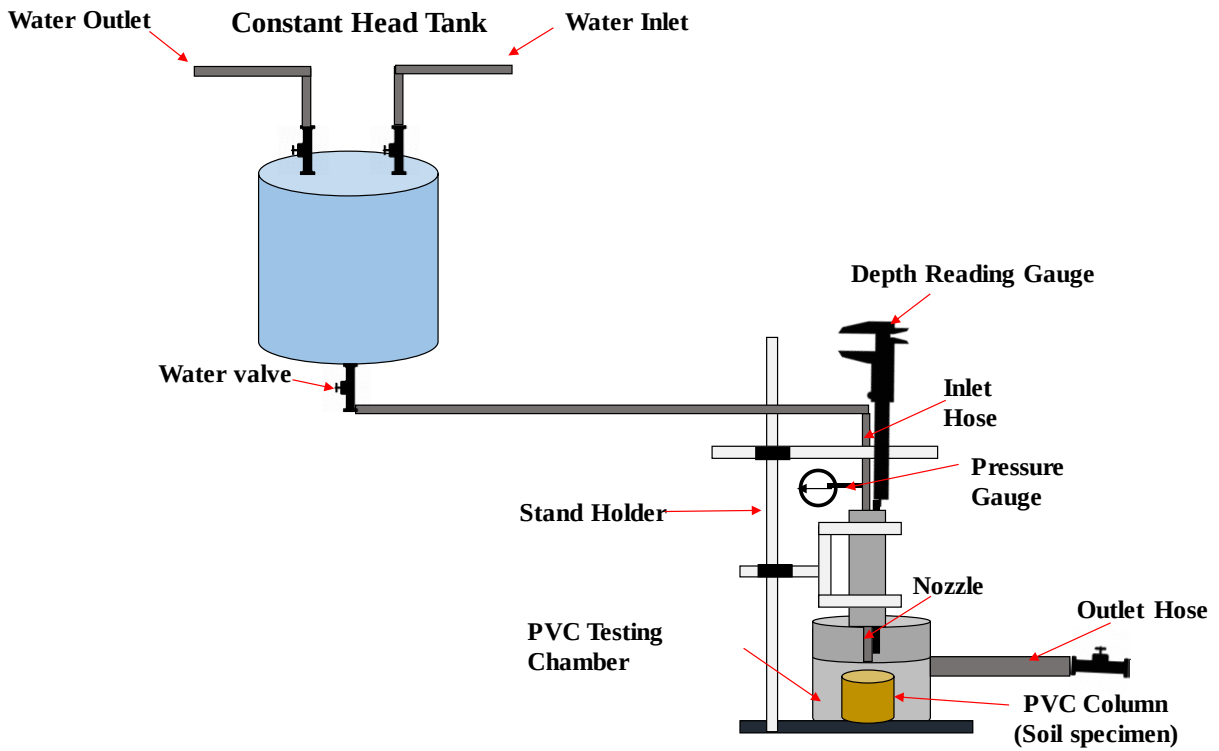


Figure 2. Shows a mini-jet erosion test set-up (According to Al-Madhhachi et al. 2013 and Montoya et al. 2018).

Using the EICP for Erosion Mitigation(Con.. .) (Methods)

The erosion rate was calculated using equation as follows (Partheniades, 1965; Hanson, 1990),

$$E_r = k_d (\tau_i - \tau_c)^{\alpha}$$

Er is the rate of erosion (m s^{-1});

k_d is the erodibility coefficient (cm^3 N^{-1} s^{-1});

τ_i is is the maximum shear stress which is generated by the jet velocity at the nozzle (Pa);

τ_c is the critical shear stress (Pa);

α is an exponent.

Using the EICP for Erosion Mitigation(Con.. .) (Methods)

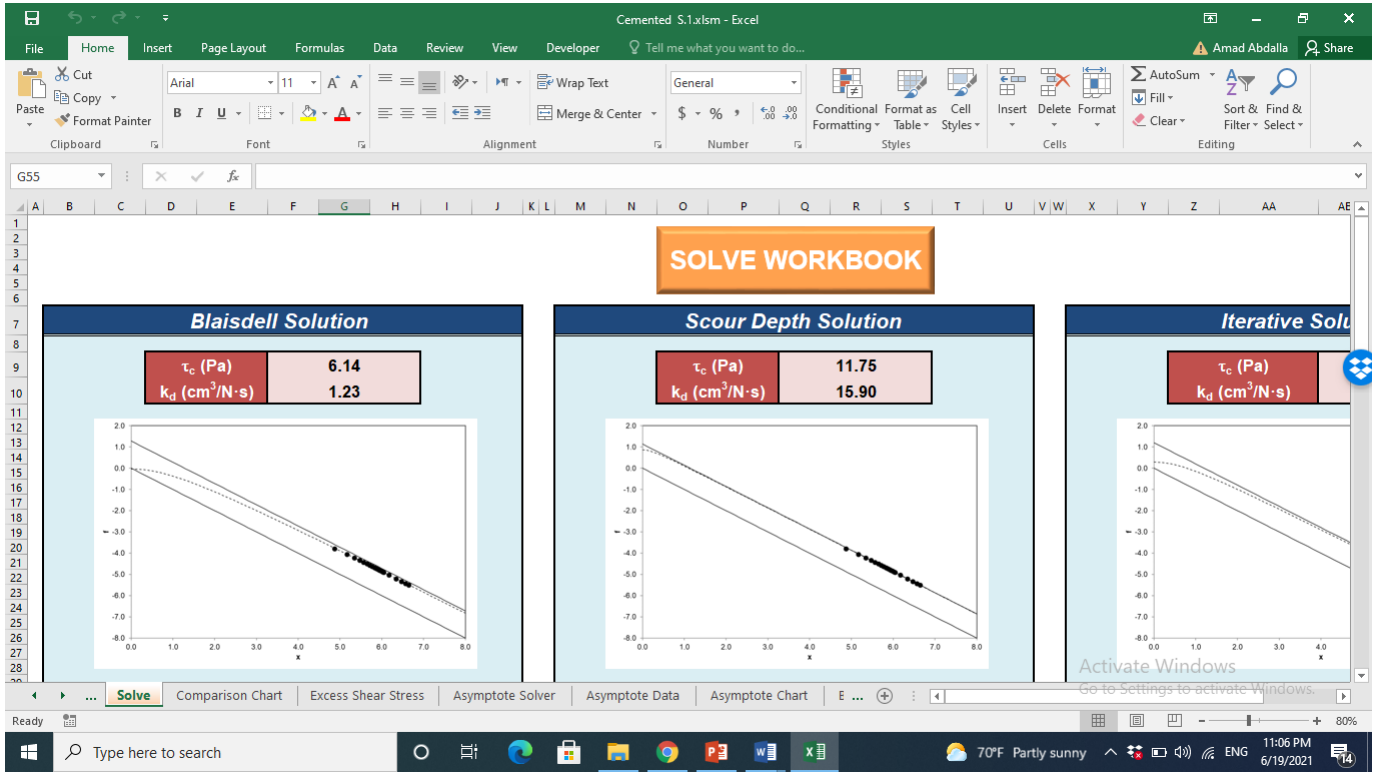


Figure 3. The program used for calculating erodibility parameters (Daly et al. 2013).

Using the EICP for Erosion Mitigation(Con.. .) (Methods)

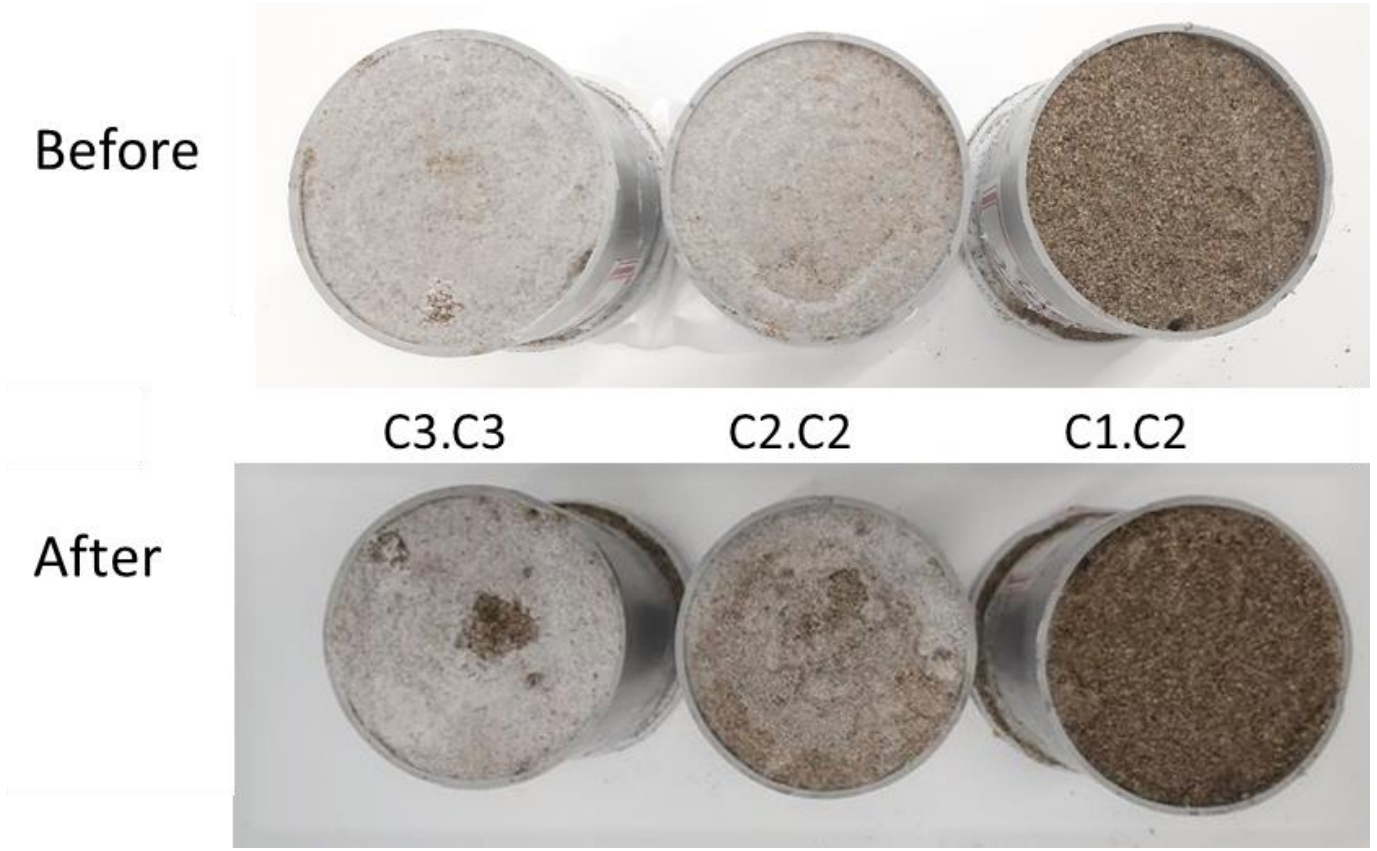


Figure 4. Treated samples before and after the Jet Erosion Test.

Using the EICP for Erosion Mitigation (Con.. .) (Results)

Table 2. Mini-Jet erosion test results for pure sand and different cycles of treatment.

Sample	Case	τ_i, Pa	τ_c, Pa	Kd, cm^3 /N-s	Erosion rate, mm/s		$CaCO_3$, %		Category
					Value	Mean	Value	Mean	
C0 S1	Control	10.87	0.03	274.36	29.75	31.66	-	-	Very Erodible
C0 S2	Control	10.87	0.07	310.74	33.57		-		Very Erodible
C1 S1	One Cycle	47.84	0.09	2.34	1.12	1.14	1.76	1.82	Very Erodible
C1 S2	One Cycle	47.84	0.17	2.43	1.16		1.87		Very Erodible
C2 S1	Two Cycles	69.59	2.62	1.14	0.76	0.77	2.564	2.61	Erodible
C2 S2	Two Cycles	69.59	1.19	1.14	0.78		2.661		Erodible
C3 S1	Three Cycles	69.59	8.96	0.68	0.41	0.36	3	3.05	Moderately Resistant
C3 S2	Three Cycles	69.59	11.71	0.53	0.31		3.1		Moderately Resistant

Using the EICP for Erosion Mitigation(Con.. .) (Results)

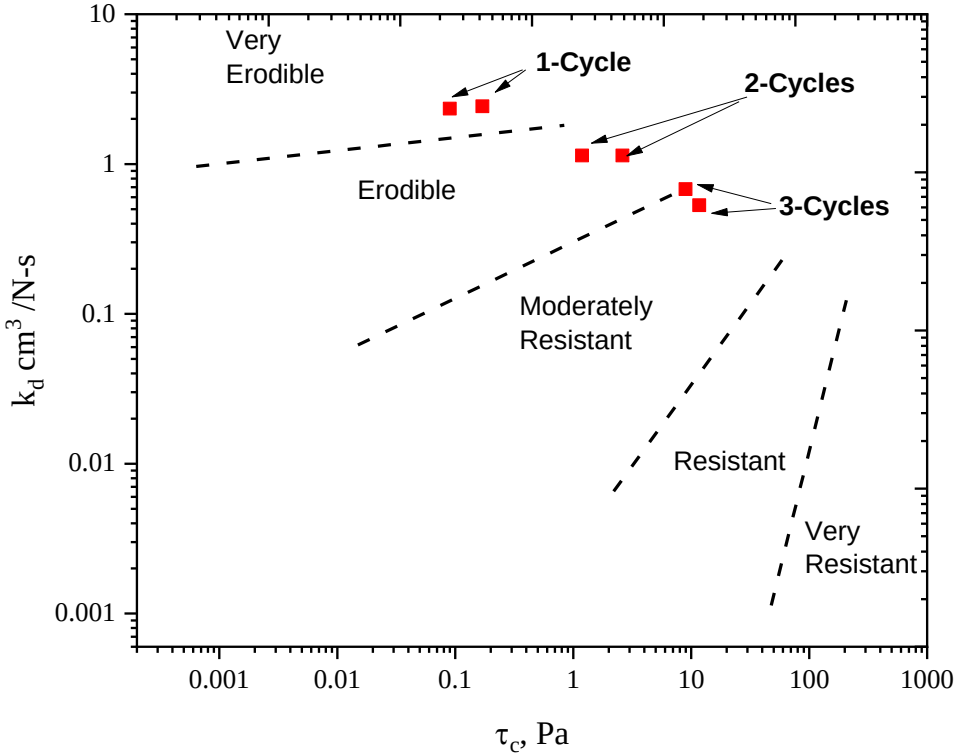
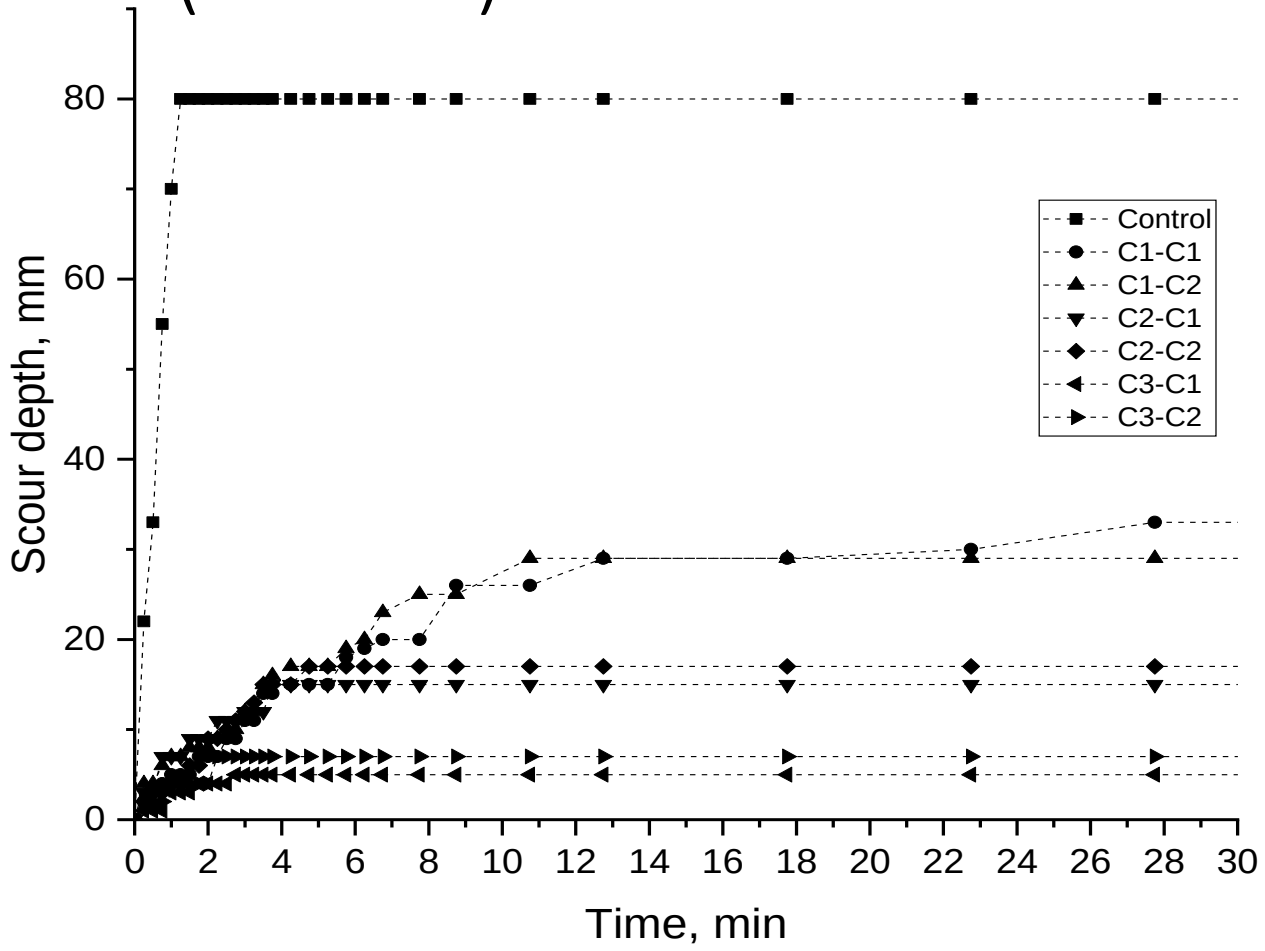


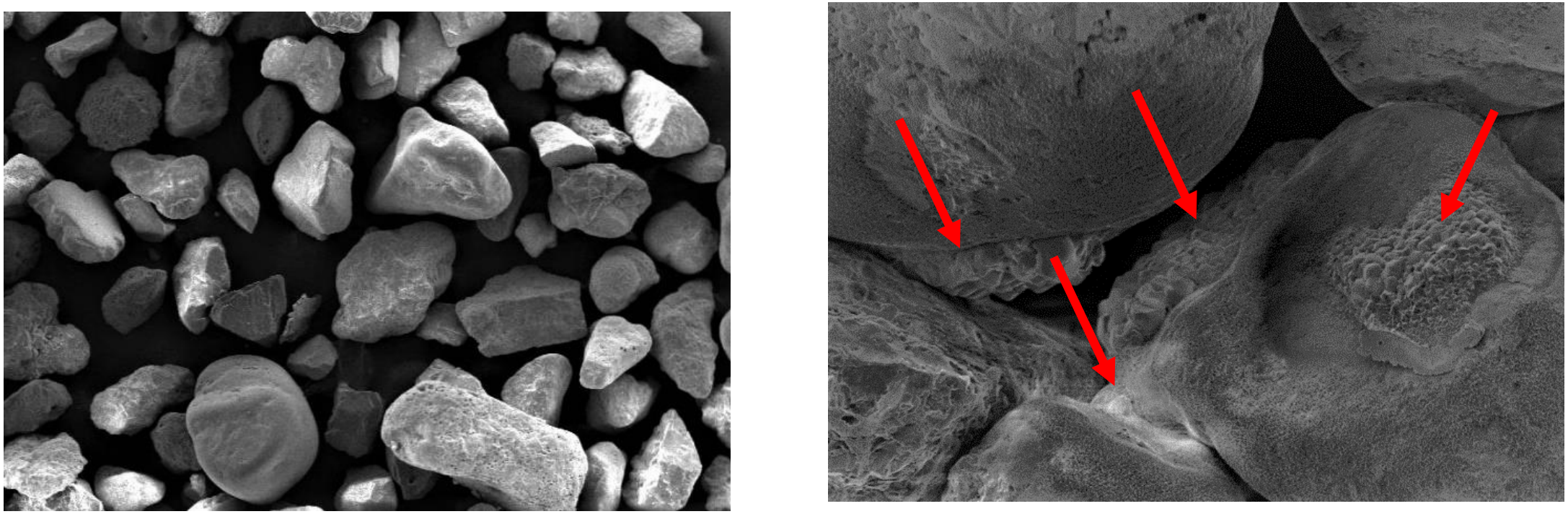
Figure 5. Categorization of treated samples according to Hanson and Simon's (2001) classification.

Using the EICP for Erosion Mitigation(Con.. .) (Results)

Figure 6. The scour depths with different time intervals under different conditions. Control was bare beach sand. C1C1 and C1C2 are samples treated with one cycle. C2C1 and C2C2 are samples treated with two cycles. C3C1 and C3C2 are samples treated with three cycles.



Using the EICP for Erosion Mitigation(Con.. .) (Results)



(a) (b)

Figure 7. SEM micrographs of (a) pure beach sand, (b) bio-cemented sand.

Using the EICP for Erosion Mitigation(Con.. .) (Results)

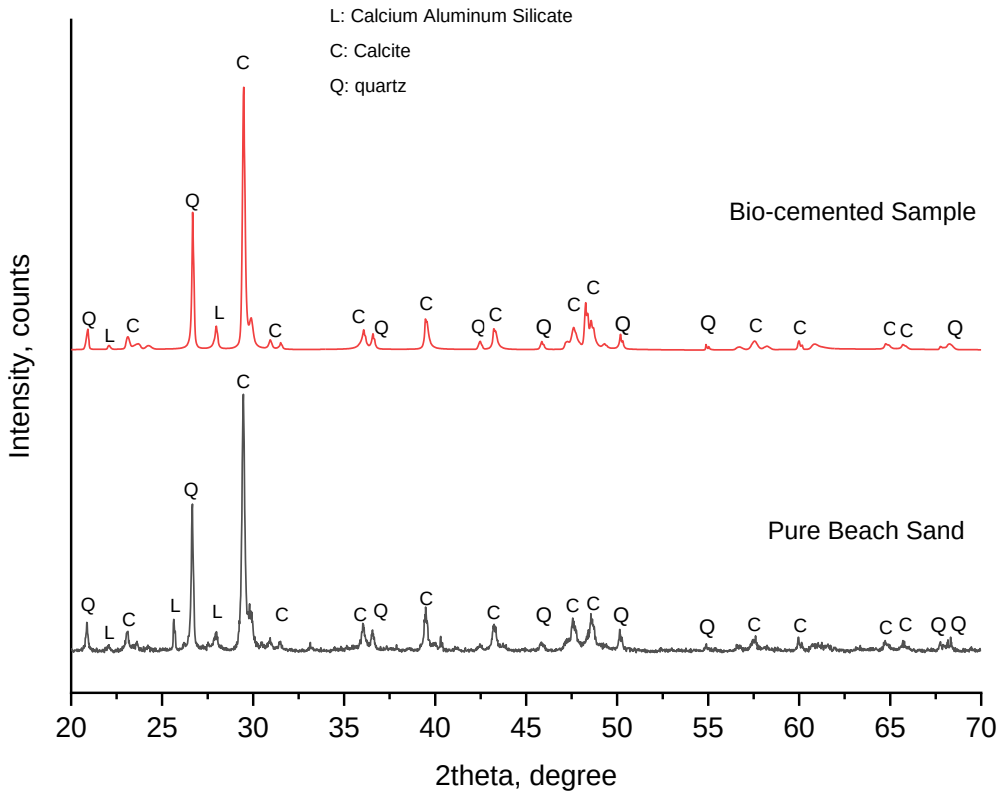


Figure 8. X-ray powder diffraction pattern of pure beach sand, and bio-cemented sand.

Using the EICP for Erosion Mitigation(Con.. .) (Conclusion)

The findings of this research indicate that the enzymatic-induced carbonate precipitation (EICP) can potentially be an effective technique in marine environment applications. Overall, these results show the applicability of EICP in coastal erosion mitigation.

References

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Thank you