学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

DEVELOPMENT OF AN ECO-FRIENDLY APPROACH FOR COASTAL EROSION PROTECTION USING BIO-MEDIATED TECHNOLOGY
(バイオメディエーション技術を用いた海岸侵食対策のための新しい環境配慮型アプローチの開発)

At present, coastal erosion is a major problem all over the world. Limitations of traditional countermeasures put an importance to develop an alternative sustainable and eco-friendly methods for coastal erosion protection. As an alternative countermeasure, bio-stabilization approaches drawn substantial attention for the researcher around the world which included MICP (Microbial Induced Carbonate Precipitation) and EICP (Enzyme Induced Carbonate Precipitation) methods. In the bio-stabilization technique as a consequence of bio-chemical reactions of urease enzyme calcium carbonate precipitated which act as a major cementing material in between the sand-soil particles and improve the physical properties of targeted materials (strength and stiffness). The objective of the research presented in this dissertation was to assess the viability of MICP and EICP technique as an eco-friendly potential alternative and effective countermeasures for the coastal erosion protection by distinguishing their mode of actions. Moreover, this study aimed to find out an appropriate or feasible conditions and methods that would be useful in making artificial beachrocks for coastal erosion protection in Greece and in Mediterranean countries, in an inexpensive, eco-friendly, and sustainable way. Natural jute fiber and watermelon seeds were also used as advanced bio-mediated technology in this study to increase the strength and durability of the treated samples. In future, the findings of this study could play an important source of information for commercial applications in protecting against coastal erosion and for other bio-engineering applications.

Chapter 1 and Chapter 2 presented the preface of the research work. Chapter 1 introduced the background, scope, objectives, originality, and significance of the research work.

Chapter 2 discussed the results of a systematic literature review on various aspects of the bio-mediated technology for coastal erosion protection, mechanism of MICP, EICP process and their subsequent compatibility for coastal erosion protection.

In Chapter 3, a baseline investigation and fundamental scientific approach of MICP technique were discussed using native ureolytic bacteria. Isolated native strains were evaluated for urease activity including whole-cell, supernatant and cell pellets and subsequently different environmental parameters (temperature, pH, culture duration, etc.) were also investigated. The sand solidification test (syringe) was also performed based on the findings, and the degree of solidification was quantitatively evaluated by the needle penetration test. The results revealed that urease activity of the identified strains relied on environment-specific parameters and, additionally, urease was not discharged in the culture solution but would discharge in and/or on the bacterial cell, and the fluid of the cells showed urease activity.

Chapter 4 addressed some of the leading limitations of using microbes for the source of urease enzyme and used alternative sources of urease enzyme that was extracted from watermelon seeds. The carbonate formation process is known as EICP process. Crushed and blended watermelon seeds (both dry and germinated) were used as a source of urease enzyme. Subsequently, their urease activity was also investigated with various environmental parameters (temperature, pH, etc.) and investigated the

carbonate precipitation trend. The effect of using magnesium chloride and their subsequent variation to the unconfined compressive strength (UCS) of the soil was also discussed in this chapter. The results of this study showed that, the lower molar ratio of calcium and magnesium chloride can significantly improve the UCS of the specimen which could be considered a significant outcome for different bio-geotechnical applications.

In Chapter 5, a comprehensive study was conducted to investigate the effect of adding plant-based natural jute fiber to the MICP-treated sand and the long-term performance of MICP-fiber treated samples were also investigated followed by wet-dry in distilled water (DW) and artificial sea water (ASW). The results of this study showed that, the added jute fibers could improve the engineering properties of the biocemented sand by MICP method. The durability results showed that the ASW damages were most significant than DW. However, fiber incorporation had a significant role on the strength improvement and long-term performance of MICP treated samples.

In Chapter 6, likewise MICP, fiber reinforce EICP method was studied as an alternative countermeasure and to understand their comparative performance in terms of strength and durability improvement. Similarly, to understand the long-term performance of EICP-fiber treated samples the influence of key climatic parameters wet-dry (WD) was also investigated using distilled water (DW) and artificial sea water (ASW). From the non-destructive tests, shear wave velocity tests, XRD and micro-structure analysis (SEM), results showed that, the fiber content significantly affected the engineering properties of EICP-treated soils more considerably than the fiber length. The durability results showed that the ASW damages were most significant than DW. However, fiber incorporation had a significant role on the strength improvement and long-term performance of EICP treated samples. The results of this study could significantly contribute to further improvement of the fiber-reinforced biocemented sand in the geotechnical engineering field applications.

In Chapter 7, the significant differences between MICP and EICP method followed by the mechanism of action was discussed. Based on the outcomes of the results discussed above, a novel methodology has been proposed for an effective coastal preservation method.

In Chapter 8, each chapter's findings are summarized, along with some suggestions for future work. In addition, based on the outcomes derived from the above works, the application guidelines are outlined regarding optimal MICP, EICP and fiber reinforce recipe, their subsequent implementation strategy and conditions, along with the evaluation process that would help to ensure the durability performance of MICP and EICP treated fiber reinforce samples for effective coastal erosion protection.