

ISRM Specialized Conference



The 1st International Workshop on
Bio-Rock Mechanics

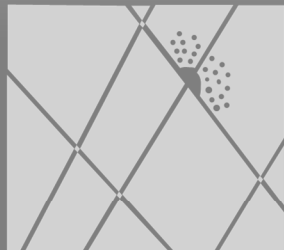
26-27 November 2025 | Okinawa JAPAN

50th Anniversary Memorial Hall
University of the Ryukyus

Organized by Commission on Bio-Rock Mechanics

Official Program & Abstracts





The 1st International Workshop on

BIOROCK MECHANICS

November 26-27, 2025 | Okinawa, Japan

The workshop introduces “bio-rock mechanics,” an emerging field bridging microbiology, geochemistry, and rock mechanics to uncover how microorganisms influence rock behavior and geo-hazards.

Official Program & Abstracts of the 1st International Workshop on Bio-Rock Mechanics

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PREFACE

On behalf of the Organizing Committee, I am delighted to welcome you to the First International Workshop on Bio-Rock Mechanics in Okinawa, Japan. We are honored to host Dr. Xiaohao Sun (The Hong Kong Polytechnic University) and Dr. Meghna Sharma (National Institute of Technology Hamirpur) as keynote speakers, who will present and discuss their latest research alongside the committee members. We are also honored to include nine general presentations and seven student presentations in the program, reflecting the active participation and enthusiasm of the research community in this emerging field.

Bio-rock mechanics is an emerging field that seeks to elucidate the effects of microbial metabolism and biological activity on the physical properties and mechanical behavior of rocks, exploring both theoretical and practical applications. In 2024, the International Society for Rock Mechanics (ISRM) established the “Commission on Bio-Rock Mechanics,” drawing international attention to this area, and in Japan, the Japanese Society for Rock Mechanics (JSRM) launched the “Special Committee on Bio-Rock Mechanics” in 2025, reflecting growing momentum for research in this field.

Microbial communities, including bacteria, algae, and lichens, colonize rock surfaces and utilize minerals as nutrient or energy sources. Their activity can lead to chemical and physical degradation of mineral particles, known as microbial weathering, while also inducing precipitation of carbonates and silicates within fractures, a process referred to as microbially induced mineralization or bio-mineralization. For instance, in subtropical limestone outcrops, algae biofilms have been shown to promote carbonate growth. Such interactions may contribute to geohazards like rockfalls or slope failures and suggest potential for developing technologies that enable self-organized repair of weathered rocks.

This workshop provides an international forum to explore the interactions between rock mechanics and biological processes. As an ISRM Specialized Conference, it aims to highlight the significance of this emerging academic field and strengthen global research networks. We hope this workshop will serve as a milestone in rock mechanics and rock engineering, fostering further progress and innovation in the field.



Hitoshi Matsubara, Ph. D
Chair, Organizing Committee of 1st Int. WS on Bio-Rock Mechanics

Conference Organization

Organized by

Commission on Bio-Rock Mechanics
International Society for Rock Mechanics and Rock Engineering (ISRM)

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Program – 26 November 2025 –

08:50~09:00: Opening Ceremony : Welcome Address, Opening Remarks

09:00~09:45: Keynote Lecture 1

Biom mineralization Induced Calcium Carbonate Precipitation for Sand and Dust Storm Control
Dr. Xiaohao Sun, *The Hong Kong Polytechnic University, China*

09:45~09:55: Ice Break

09:55~12:00: General Session 1 (Presentation time: 15 min, Discussion: 10 min)

Chairperson: Dr. Daisuke Asahina, *National Institute of Advanced Industrial Science and Technology, Japan*

G1-1: Beachrock Sedimentation Insights: Ion-dependent Effects and Biopolymer Influence on MICP
Lutfian R Daryono, Tomohiko Abe, Kazunori Nakashima, Satoru Kawasaki.

G1-2: Emerging Role of Calcium Phosphate Bio-cement in Geomechanics: A review
Sivakumar Gowthaman, Singarasa Jathursan, Satoru Kawasaki.

G1-3: Effect of Cementation Solution Concentration on Low-pH MICP Solidification of Tailing sand
Lai Yongming, Satoru Kawasaki and Liu Qian.

G1-4: Assessment of strength in biocemented model slope and effect of artificial rainfall on it
M. Azizul Moqsud.

G1-5: Investigation on the microbial-aided chemical interaction between CO₂ and igneous rocks under conditions for geological carbon sequestration
Xiurong Yang, Hiroaki Ito, Atsushi Sainoki.

12:00~14:00: Lunch

14:00~14:40: Keynote Lecture 2

Sustainable Biocementation and Bioremediation Approaches in Soil–Rock Stabilization: Advances and Future Scope

Dr. Meghna Sharma, *National Institute of Technology Hamirpur, India*

14:40~14:50: Ice Break

14:50~16:55: General Session 2 (Presentation time: 15 min, Discussion: 10 min)

Chairperson: Dr. Sivakumar Gowthaman, *Kyushu University, Japan*

G2-1: Bio-markers observed during earthquakes and their implications on regional tectonics
Ömer Aydan, Sinem Uğur, Halil Kumsar.

G2-2: An assessment of bacterial influence on the weathering process of natural construction stones
Adil Binal.

G2-3: Microbial filaments with calcareous coatings reinforcing sandstone in caves
Hitoshi Matsubara, Ibuki Nishimura.

G2-4: Numerical modeling for microbial weathering induced by cyanobacteria
Ibuki Nishimura, Hitoshi Matsubara.

16:55~: Meet at the registration desk and move to banquet venue

18:00~: Party Dinner

Program – 27 November 2025 –

09:15~11:00: Student Session (Presentation time: 10 min, Discussion: 5 min)

Chairperson: Dr. Ibuki Nishimura, *University of the Ryukyus, Japan*

S-1: Environmental Factors Influencing Microbial Calcium Carbonate Precipitation by *Sporosarcina pasteurii* ATCC 6453

Bozbeyoglu Kart N.N, Tepe M, Mercan Dogan N.

S-2: Development of a High-Strength One Treatment Enzyme-Assisted MICP Method with Casein Additives

Ritta Masuda, Toshiro Hata, Ryota Hashimoto.

S-3: Influence of co-cultured native marine ureolytic bacteria on calcium carbonate precipitation

Rahubadda Kankanamge Hiroshima Surangani, Anjula Buddhika Nayomi Dassanayake, Chulantha Lakmal Jayawardena, Niki Evelpidou, Satoru Kawasaki.

S-4: Sand solidification using ureolytic bacteria collected from beach rock

Taisei Ohgushi, Ibuki Nishimura, Hitoshi Matsubara.

S-5: Morphological characteristics of bacteria and CaCO₃ under microgravity by MICP

Yuru Chen, Tomoya Hamada, Chikara Takano, Kazunori Nakashima, Satoru Kawasaki.

S-6: Relationship Between Microbial Diversity and Mechanical Properties of Current Travertine Deposition in Kaklık Cave (Denizli-Türkiye)

Rumeysa Sonmezoglu, Nazime Mercan Dogan, Halil Kumsar.

S-7: Microbial Weathering and Its Effects on Uniaxial Compressive Strength and Creep of Tuff

Sora Shimabukuro, Kosaburo Hirose, Ibuki Nishimura, Takashi Ito, Hitoshi Matsubara.

11:00~11:10: Ice Break

11:15~: Concluding Remarks and Closing Ceremony and Lunch

Keynote Lectures

Biom mineralization Induced Calcium Carbonate Precipitation For Sand And Dust Storm Control



Xiaohao Sun

Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR, China

Sand and dust storms have been globally recognized as severe natural disasters, necessitating urgent implementation of effective control measures, including subsequent ecosystem restoration. Recently, biomineralization, specially microbially induced calcite precipitation (MICP) or enzymatically induced carbonate precipitation (EICP), has garnered significant attention in geotechnical and environmental engineering. In the context of sand and dust storm mitigation, biomineralization can form a surface crust layer that enhances resistance to wind erosion. The underlying mechanisms were first examined, followed by a series of laboratory experiments to identify optimal treatment conditions. Subsequently, a large-scale field application was conducted to evaluate the feasibility of using biomineralization for controlling sand and dust storms. Results demonstrate that this method is an environmentally friendly technology with three key advantages: (1) improved resistance to wind erosion due to the cementation effect of precipitated calcium carbonate; (2) enhanced water retention capacity resulting from reduced porosity and the formation of a protective crust layer; and (3) greater environmental compatibility that supports the growth of desert vegetation. Unlike conventional engineering approaches, biomineralization addresses their limitations and enables sustainable, long-term control of sand and dust emissions. Furthermore, it promotes ecosystem restoration and contributes to carbon sequestration. These findings establish a robust foundation for adopting biomineralization as a viable alternative strategy to control sand and dust storm and combat desertification over the long term.

Keywords

Sand and dust storm control; biomineralization; crust layer; field application; water retention

Sustainable Biocementation and Bioremediation Approaches in Soil–Rock Stabilization: Advances and Future Scope



Meghna Sharma

National Institute of Technology Hamirpur, India

The demand for low-carbon and sustainable soil stabilization method is increasing, which driven the path towards biologically based solutions in geotechnical engineering. Biocementation and bioremediation approaches have significant potential to overcome the challenges associated with conventional methods of ground improvement. The novel objective of the lecture is to cover the advances in biologically mediated solutions which harness urease producing bacteria or urease enzyme to enhance the strength of soils and rocks and immobilize the contaminants present in it. Additionally, it will cover a novel investigation from micro to macro to large scale implication of microbially induced calcite precipitation technique (MICP) for demonstrating the liquefaction resistance and rock like behavior of biocemented sands. It will cover a laboratory investigation of expansive soil stabilization using biostimulation techniques and recycled sanitary napkin fiber (SNF) as reinforcement. The presentation focuses on potential of enzyme induced calcite precipitation technique (EICP) for soil stabilization and wind erosion control. A glimpse of AI-MI techniques will be given for predicting calcium carbonate content and unconfined compressive strength in MICP-treated sands.

Keywords

Microbially Induced Calcite Precipitation (MICP); Enzyme Induced Calcite Precipitation (EICP); Bioremediation; Contamination Immobilization; Soil Rock Stabilization

General Session

G1-1

Beachrock Sedimentation Insights: Ion-dependent Effects and Biopolymer Influence on MICP

Lutfian R Daryono^a, Tomohiko Abe^a, Kazunori Nakashima^b, Satoru Kawasaki^b

^a *Engineering and Development Divisions, NITTOC Construction Co., Ltd., JAPAN.*

^b *Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University, JAPAN.*

The crucial parameters governing beachrock sediments and the transformative potential of artificial rock through microbial induced calcium precipitation (MICP), contributes significantly to understanding coastal geomorphological processes and sustainable coastal management practices. The intricate relationships between temperature, pH, salinity, and nutrient levels in the sea's surface along with their consequential impact on carbonate production, underscore the necessity for comprehensive research and management strategies to safeguard coastal ecosystems and support responsible coastal development. It is a combined approach to study of the biologically formed material sand processes that lead to the construction of hierarchically structured composite materials. Biominerals provide protection, structural support, and mechanical strength for the organisms. Calcium is the most common biomineral available in nature and is the main constituent of skeletal structures. The formation of biominerals is mainly associated with the organic macromolecules, which control the habit, polymorphism, and morphology of the crystals. Not much investigation has been carried out so far to investigate the effect of magnesium and sodium on the microbial inspired carbonate precipitation. Nevertheless, magnesium and sodium carbonate possess similar cementing ability as calcium carbonate, which can significantly affect the desired outcomes of MICP treatment. In comparison with the natural minerals, organic-inorganic hybrid materials have distinctive optical properties and higher mechanical strength. As a result of conducting MICP treatment on sandy beaches, including biopolymer carrageenan and ions dependencies effect, have an effect of polysaccharides carrageenan on CaCO₃ crystallization and sand solidification has a better cementation and strength could be achieved than conventional method of treatment samples. The inherent properties of MICP bio-cement treatment of aragonite and calcite, such as specific gravity and Mohr hardness than those crystals. At the extreme, excessively high concentrations of magnesium and sodium where the molar ratio was 1.0, the magnesium resulted in a significant reduction in the unconfined compressive strength (UCS).

G1-2

Emerging Role of Calcium Phosphate Bio-cement in Geomechanics: A review

Sivakumar Gowthaman^a, Singarasa Jathursan^b, Satoru Kawasaki^c

^a *Faculty of Engineering, Kyushu University, 744 Motoooka, Nishi-ku, Fukuoka 819-0395, Japan*

^b *Faculty of Technology, University of Jaffna, Ariviyal Nagar, Kilinochchi 44000, Sri Lanka*

^c *Faculty of Engineering, Hokkaido University, Kita 13, Nishi 8, Sapporo 060-8628, Japan*

Calcium phosphate bio-cement (CPB), a class of bio-mediated materials, has recently gained significant attention in geomechanics for its potential to address challenges in sustainable ground improvement and subsurface stabilization. Originally developed for biomedical applications, CPB offers tunable setting times, self-healing capabilities, low environmental impact, and compatibility with biological systems, making it an appealing alternative to traditional cementitious binders. CPB is a mineralization technique that relies upon the environmental alkalinity induced by the microbial- or enzyme-mediated urea hydrolysis. While bio-grouting has not been commercialized, many recent studies demonstrated that promising results have been obtained in the laboratory-scale experiments, showed its potential to reinforce soils and rocks, reduce permeability, and enable biogenic consolidation. This review presents an overview of the current state of research on CPB, focusing on its chemical formulations, mineralization mechanisms, and the factors influencing its performance

in geological materials. Furthermore, this review identifies key research gaps and technological bottlenecks, proposing a roadmap for the integration of the CPB into next-generation geotechnical engineering practices. By bridging bio-cementation science with geomechanics, CPB promises as a transformative material for resilient, low-carbon, and eco-friendly ground engineering.

G1-3

Effect of Cementation Solution Concentration on Low-pH MICP Solidification of Tailing sand

Lai Yongming^a, Satoru Kawasaki^b and Liu Qian^a

^a *College of Resource Engineering, Longyan University, Longyan, China*

^b *Faculty of Engineering, Hokkaido University, Sapporo, Japan*

The low-pH MICP technique has gained prominence due to its prolonged precipitation lag period that ensures better solidification uniformity. This study investigates the effect of cementation solution concentration on the solidification of tailing sand using a low-pH, single-phase microbially induced carbonate precipitation (MICP) method. The strength and uniformity of tailing sand solidified by the low-pH MICP method were evaluated under three cementation solution concentrations through different tests. Results showed that surface strength, calcium carbonate content, and cementation thickness all initially increased and then decreased with rising concentration, with an optimal value of 1.0 mol/L. The low-pH method effectively mitigated clogging issues observed in conventional MICP, improving distribution uniformity and enabling deeper cementation after multiple treatment rounds. After 10 rounds, the low-pH method achieved comparable strength to conventional methods but with significantly greater cementation thickness, demonstrating its potential for more uniform and effective tailing sand stabilization. Scanning electron microscope (SEM) images showed that when the cementation solution concentration was 1 mol/L, calcite crystals were smaller in size but more numerous and uniformly distributed. Conversely, at a concentration of 1.5 mol/L, the formed calcite crystals were the largest in size, but fewer in number and locally aggregated.

G1-4

Assessment of strength in biocemented model slope and effect of artificial rainfall on it

M. Azizul Moqsud

Department of Civil and Environmental Engineering, Yamaguchi University, Ube City, Japan

This study explores the effectiveness of biocementation in enhancing slope stability under artificial rainfall conditions. Biocementation, driven by microbial-induced calcium carbonate precipitation (MICP), was applied to a model slope to improve its structural resilience. Three identical slopes (48 cm length, 35.5 cm depth, 25 cm width) were constructed. One slope received a surface application of culture medium and nutrient solutions for 10 days; another was applied only nutrient solutions and while the other remained untreated. Both slopes were then subjected to artificial rainfall at a rate of 60 mm/h for 120 minutes. Surface erosion was monitored through photographs taken at 10-minute intervals to assess stability and erosion resistance. The treated slope exhibited significantly reduced soil displacement and erosion compared to the untreated slope, indicating improved stability. However, biocementation was unevenly distributed, with the lower portion of the slope showing minimal improvement. Soil penetration resistance measurements revealed values of 18 kg/cm² at the top, 22 kg/cm² at the center, and only 5 kg/cm² at the bottom, highlighting the need for more uniform treatment. Image analysis also revealed the surface stabilization after the rainfall for treated slopes. These findings demonstrate

the potential of biocementation as a sustainable and environmentally friendly alternative to conventional slope stabilization methods. Nonetheless, further research is necessary to refine application techniques, ensure consistent treatment across slope depths, and evaluate long-term performance under diverse environmental conditions.

G1-5

Investigation on the microbial-aided chemical interaction between CO₂ and igneous rocks under conditions for geological carbon sequestration

Xiurong Yang^a, Hiroaki Ito^a, Atsushi Sainoki^a

^a *Kumamoto University, Kumamoto city, Japan*

There is a significant demand for controlling CO₂ emissions to the atmosphere in order to mitigate the ongoing global warming. This requires effective CO₂ reduction strategies, including large-scale underground sequestration. However, such geological sequestration in deep underground involves various risks, such as the leakage of the injected CO₂ to the ground surface through pre-existing and/or newly developed fractures and reactivation of faults that cannot be detected with current monitoring technologies. These risks will be significantly reduced if the injected CO₂ can be mineralized and permanently fixed as carbonate rocks in deep underground. Hence, this study investigates the carbonation potential of three rock types, considering their potential: serpentinite, peridotite, and basalt, through a series of leaching and CO₂ sealing experiments. The leaching test revealed that essential cations (Mg²⁺, Fe²⁺, Ca²⁺, Al³⁺), which facilitate carbonate mineral formation, were released within one week, and their concentrations vary by rock type and exposure duration. Serpentinite exhibited the highest reactivity, rapidly releasing Mg²⁺ within a relatively short period with CO₂ exposure. Furthermore, the influence of microbial solution containing carbonic anhydrase (CA) on carbonate formation was evaluated with the sealing test. Thermogravimetric analysis (TGA) was employed to quantify the amount of CO₂ fixed with the carbonate formation. The results highlight microbial-aided carbon precipitation most likely occurs for all the rocks and the degree of carbonation is enhanced with the enzyme. This study sheds light on the development of geological carbon sequestration technology with special microbes.

G2-1

Bio-markers observed during earthquakes and their implications on regional tectonics

Ömer Aydan^a, Sinem Uğur^b, Halil Kumsar^c

^a *University of the Ryukyus, Okinawa, Japan*

^b *Fırat University, Elazığ, Türkiye*

^c *Pamukkale University, Denizli, Türkiye*

The authors made many observations on bio-markers during recent and past earthquakes. The bio-markers erosion cavities caused by various organisms such as limpets, sea-urchins, bi-valves, chitons, gastropods as well as corals. The recent earthquakes involve 2005 Nias in Indonesia, and 2023 Noto Peninsula in Japan, 2020 Kuşadası in Türkiye. Past earthquake involves the 1854 Ansei in Japan. The crustal uplift results in the remains of the organisms in erosion cavities, which may indicate their interval and amount of movement related to the magnitude of the earthquakes. The authors would present several examples of observations in Japan, Indonesia and Türkiye and discuss the implications of bio-markers on the characteristics of past earthquakes in this study.

G2-2

An assessment of bacterial influence on the weathering process of natural construction stones

Adil Binal

Hacettepe University, Department of Geological Engineering, 06800 Beytepe Campus, Ankara, Türkiye

Bacterial weathering, a type of biological weathering that significantly influences rock degradation, has recently gained increasing attention. Despite the limited number of studies on this subject, some have focused on rapid advancements in microbiology. The timeframe for biological weathering processes in mineral and rock samples, as well as the preferred minerals, remains unclear because of the diverse range of bacterial species and rock types. This study examined two bacterial species that actively participate in rock weathering and their interactions with three types of rocks used as building materials in our country. Granite, andesite, and limestone samples were exposed to *Bacillus subtilis* and *Bacillus pumilus* in sterile, isolated, and closed-system reactors. Laboratory experiments have also evaluated the effects of bacteria on the physical properties of rocks. Concisely, *Bacillus subtilis* was found to be more aggressive on limestone and andesite, whereas *Bacillus pumilus* was more aggressive on granite.

G2-3

Microbial filaments with calcareous coatings reinforcing sandstone in caves

Hitoshi Matsubara^{a, b}, Ibuki Nishimura^{a, b}

^a *Faculty of Engineering, University of the Ryukyus, Okinawa, Japan*

^b *Disaster Prevention Research Center for Island Region, University of the Ryukyus, Okinawa, Japan*

Inside Nishihara Cave, Okinawa in Japan, cyanobacteria colonize the crown and side walls, forming a biofilm that promotes calcium carbonate precipitation around their filamentous structures. This microbial-induced mineralization gradually strengthens the weakened sandstone and exhibits characteristics of natural self-

healing, indicating a sustainable, biologically mediated reinforcement process. The current study shows that minerals, including calcium ions from the host rock, migrate toward the microbial surfaces and crystallize to form protective coatings. Genetic analyses identify *Leptolyngbya* sp. as a dominant contributor to this calcification, highlighting the critical role of filamentous cyanobacteria in stabilizing rock surfaces. Microscopic observations reveal that the deposited calcium carbonate forms tubular and layered structures that interconnect over time, further enhancing the mechanical integrity of the sandstone. These findings illustrate a natural, long-term mechanism by which microbial activity mitigates surface weathering and reinforces sandstone surfaces, suggesting potential applications for bio-mediated geotechnical improvement.

G2-4

Numerical modeling for microbial weathering induced by cyanobacteria

Ibuki Nishimura^{a, b}, Hitoshi Matsubara^{a, b}

^a *School of Civil Engineering, University of the Ryukyus, Okinawa, Japan*

^b *Disaster Prevention Research Centre for Island Region, University of the Ryukyus, Okinawa, Japan*

Recent studies have reported that microorganisms inhabiting rocks may be involved in rock weathering, a phenomenon known as microbial weathering. However, capturing the dynamic interplay between microbial colony distribution and rock weathering at the microscale remains challenging for both lab-based experiments and field investigations. In this study, we simulated the spatial and temporal dissolution process of silicate incorporated in tuff driven by cyanobacteria and evaluated the relationship between their metabolism and microbial weathering. Our findings indicate that silicate dissolves on the surfaces of silicate mineral, and dissolution advances toward the bottom layer. Moreover, the bacteria inhabit the surface of the silicate minerals, increasing the pH through photosynthetic activity, diffusing alkaline conditions into the surrounding liquid, and contributing to the mining of silicate minerals.

Student Session

S-1

Environmental Factors Influencing Microbial Calcium Carbonate Precipitation by *Sporosarcina pasteurii* ATCC 6453

BOZBEYOGLU KART N.N^{a*}, TEPE M^b, MERCAN DOGAN N^b

^a Pamukkale University, Tavas Vocational High School, Plant and Animal Production Department, Denizli, Turkey

^b Pamukkale University, Faculty of Sciences, Biology Department, Denizli, Turkey

Calcium carbonate is one of the most abundant biominerals on Earth, primarily produced by microorganisms. It holds significant importance and potential for use in various industries and ecosystems. In this study, the calcium carbonate production potential of *Sporosarcina pasteurii* ATCC 6453, which is considered a model organism in microbial calcium carbonate precipitation, was investigated under varying environmental conditions (different pH, temperature, inoculation rates, incubation time, concentrations of urea and calcium sources, and shaking/static conditions). Additionally, the structure of the calcium carbonate produced by the bacterium was examined. According to the results obtained, the most influential factors in microbial calcium carbonate precipitation were the concentration of inorganic calcium and the amount of inoculated bacteria compared to other parameters. It was determined that the calcium carbonate produced by *S. pasteurii* ATCC 6453 was in the form of calcite.

S-2

Development of a High-Strength One Treatment Enzyme-Assisted MICP Method with Casein Additives

Ritta Masuda^a, Toshiro Hata^b, Ryota Hashimoto^c

^{a, c} Hiroshima University, Higashi-Hiroshima, Japan

^b Kyoto University, Kyoto, Japan

In this study, a high-strength, one-shot enzyme-assisted microbial-induced carbonate precipitation (MICP) method with casein additives was developed to preserve historical structures. Conventional MICP requires repeated treatments, which poses practical challenges. The objectives of this study were threefold: to verify the effectiveness of enzyme-assisted MICP, to enhance its strength with a single treatment, and to improve it further by incorporating casein. The experiments involved uniaxial compression tests, Ca²⁺ concentration measurements, and scanning electron microscopy (SEM) observations of the specimens with varying enzyme and casein concentrations. The results showed that these enzymes significantly promoted calcium carbonate precipitation, particularly at high concentrations. This leads to enhanced uniaxial compressive strength (UCS). A critical calcium carbonate precipitation rate of 4 % was identified for strength development. The addition of casein dramatically increased UCS (up to 300 kPa) by promoting calcium carbonate nucleation and crystal growth. This formed dense grape-like spherical particles. SEM confirmed that these microstructural changes increased the contact area, thereby improving the overall structural strength, densification, and water resistance. This novel one-step method leverages microorganisms, enzymes, and proteins and offers a cost-effective and efficient solution for soil improvement. This study addresses the limitations of the conventional MICP for cultural heritage conservation.

S-3**Influence of co-cultured native marine ureolytic bacteria on calcium carbonate precipitation**

Rahubadda Kankanamge Hiroshima Surangani^a, Anjula Buddhika Nayomi Dassanayake^b, Chulantha Lakmal Jayawardena^b, Niki Evelpidou^c, Satoru Kawasaki^d

^a Graduate School of Engineering, Hokkaido University, 060-8628, Sapporo, Japan

^b Department of Engineering, University of Moratuwa, Moratuwa, 10400, Sri Lanka

^c Department of Geology and Geoenvironment, National and Kapodistrian University of Athens, Panepistimiopolis, 15774, Athens, Greece

^d Department of Engineering, Hokkaido University, 060-8628, Sapporo, Japan

Microbially Induced Carbonate Precipitation (MICP) offers a sustainable approach to soil stabilization. Recent studies show that mixtures of bacteria achieve better CaCO₃ precipitation than single bacterial strains, but the mechanisms remain poorly understood, particularly the influence of urease activity and community composition on precipitation kinetics. This study investigates the precipitation kinetics of two native ureolytic bacteria, *Halomonas hydrothermalis* (T1, high urease activity) and *Marinobacter litoralis* (U3, comparatively lower urease activity), both individually and in co-culture at varying optical densities. Native strains isolated from coastal sands of Sri Lanka were evaluated for CaCO₃ precipitation in urea–CaCl₂ amended media. Bacterial proliferation was quantified over 48 hours (h) via colony counts. The results showed that T1 had higher growth, urease activity, and CaCO₃ precipitation than U3. In co-cultures, T1 dominated, increasing total microbial density beyond the sum of single strains. Precipitation kinetics modeled using a saturation-type regression revealed maximum rate constants ($K_{cal, max}$) increased from 0.090–0.095 h⁻¹ for single strains to 0.110 h⁻¹ in co-cultures. Normalized CaCO₃ precipitation per cell was higher in co-cultures than in single-strain cultures. These findings demonstrate that co-culturing native ureolytic bacteria enhances microbial density, urease activity, and CaCO₃ precipitation, providing a quantitative basis for optimizing MICP-based soil stabilization.

S-4**Sand solidification using ureolytic bacteria collected from beach rock**

Taisei Ohgushi^a, Ibuki Nishimura^{a, b}, Hitoshi Matsubara^{a, b}

^a Faculty of Engineering, University of Ryukyus, Okinawa, Japan

^b Disaster Prevention Research Center for Island Region, University of Ryukyus, Okinawa, Japan

Cement grout is widely employed to enhance the mechanical properties of fractured rock. However, issues include the inability to completely fill deep fractures and the potential leaching of hexavalent chromium from the cement. Therefore, the development of alternative technologies that are harmless to humans and have minimal environmental impact is required. Recently, MICP technology, which utilizes microorganisms to precipitate carbonates, has garnered attention as an environmentally friendly ground improvement technique, and its application in rock engineering is also anticipated. However, many of the microorganisms used in MICP are non-native species, and concerns have been raised about their potential impact on ecosystems upon introduction. In this study, we investigated the potential usefulness of rock-dwelling microorganisms native to Okinawa for MICP technology, with a focus on its applicability to the rock environment of Okinawa. The experiments were conducted using sandy soil to simulate the environmental conditions around the microbial sampling sites. The results confirmed that multiple microorganisms promote carbonate precipitation. Furthermore, the patterns of carbonate precipitation were found to vary depending on the type of microorganism.

S-5**Morphological characteristics of bacteria and CaCO₃ under microgravity by MICP**Yuru Chen^a, Tomoya Hamada^a, Chikara Takano^b, Kazunori Nakashima^b, Satoru Kawasaki^b^a Graduate School of Engineering, Hokkaido University, Sapporo, 060-8628, Japan^b Faculty of Engineering, Hokkaido University, Sapporo, 060-8628, Japan

Microbially induced carbonate precipitation (MICP) is considered a promising strategy for extraterrestrial construction, yet the lack of understanding of how microgravity affects bacterial morphology and mineralization makes it essential to investigate these processes. This study investigated the influence of simulated microgravity on bacterial morphology, dimensions, and CaCO₃ precipitation. Three ureolytic strains were cultivated under normal and simulated microgravity conditions using a three-dimensional clinostat. Bacterial morphology and CaCO₃ microstructures were characterized by scanning electron microscopy (SEM) combined with quantitative image analysis. The results showed that microgravity altered bacterial morphology, promoting higher bacterial density and more homogeneous distributions. Quantitative measurements demonstrated that microgravity mainly affected the major axis, with MY2-9 exhibiting pronounced elongation, MY3-21 showing moderate enlargement, and RII-2 remaining relatively stable. Distinct mineralization patterns were also observed: MY2-9 formed fused compact coatings, MY3-21 produced continuous dense layers, and RII-2 generated large plate-like crystalline aggregates with ordered structures. These findings provide new insights into how microgravity regulates microbial adaptation and biomineralization, advancing the fundamental understanding of MICP under space conditions.

S-6**Relationship Between Microbial Diversity and Mechanical Properties of Current Travertine Deposition in Kaklık Cave (Denizli-Türkiye)**Rumeysa Sonmezoglu¹, Nazime Mercan Dogan², Halil Kumsar³¹Advanced Technology Application and Research Center, Pamukkale University, Denizli, Türkiye²Department of Biology, Faculty of Science, Pamukkale University, Denizli, Türkiye³Department of Geological Engineering, Faculty of Engineering, Pamukkale University, Denizli, Türkiye

Investigation of the interaction between microbial diversity and mechanical properties of current travertines in Kaklık Cave (Honaz, Türkiye) was carried out in this paper. Inferred values of mechanical parameters of current travertine deposition at different locations in Kaklık Cave were obtained by using a non-destructive in-situ testing device called needle penetrometer. Travertine samples were collected from each needle penetration test point for metagenomics analyses. The inferred uniaxial strength values of the samples varied depending on sampling location. Samples taken from the cave ceiling (ATA3, ATA4 and ATA5) exhibited low uniaxial strength (0.390–1.210 MPa) and were characterized by the presence of calcium sulfate and bassanite. In these low-strength samples, the community was shaped primarily by acidophilic taxa—particularly *Ferroplasma* (Archaea) and *Ferrimicrobium*—with environmental *Mycobacterium* species as companions; Proteobacteria were not detected. In contrast, samples with higher uniaxial strength values (2.358–4.366 MPa) collected from vertical walls and travertine surfaces (ATA1, ATA2 and ATA6) exhibited higher microbial diversity and different community composition. These samples also had a high calcite content and contained microbial taxa associated with biomineralization. For example, *Perluclidibaca piscinae* was abundant in ATA1; *Brevundimonas alba* (16.4%) and *Pseudomonas fluorescens-protogens* (5.4%) in ATA2; and *Pseudonocardia seranimata*, *Brevundimonas alba* and *Sphingopyxis italica-witflariensis* (2.5%) in ATA6. These species are associated with CaCO₃ biomineralization. The findings indicate that samples with higher uniaxial strength are associated with greater microbial diversity and the dominance of biomineralizing bacteria, while sulfate-based, low-strength samples are characterized by acidophilic microorganisms.

S-7

Microbial Weathering and Its Effects on Uniaxial Compressive Strength and Creep of Tuff

Sora Shimabukuro^a, Kosaburo Hirose^b, Ibuki Nishimura^{c,d}, Takashi Ito^{c,d}, Hitoshi Matsubara^{c,d}

^a Graduate School of Engineering and Science, University of the Ryukyus

^b University of the Ryukyus, Faculty of Engineering, Technical Division, Technical Staff

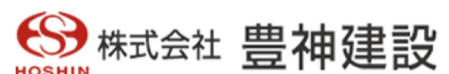
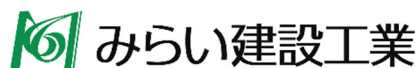
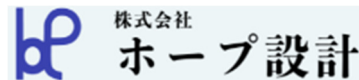
^c School of Civil Engineering, University of the Ryukyus, Okinawa, Japan

^d Disaster Prevention Research Center for Island Region, University of the Ryukyus, Okinawa, Japan

Rock weathering is a major factor contributing to slope failures and rockfalls, and clarifying its mechanisms is essential. Recent studies have reported that microorganisms inhabiting rocks facilitate weathering processes; however, their effects on the mechanical properties remain insufficiently understood. In this study, to evaluate the short- and long-term mechanical properties of tuff affected by microbial weathering, we conducted immersion weathering experiments using tuff and microorganisms collected from an outcrop in Hokkaido, Japan, followed by uniaxial compressive strength (UCS) tests and creep tests. According to the UCS tests results, the strength of the specimen immersed in the microbial medium decreased by more than 40% compared to both the initial condition and the specimen immersed in the sterile medium. During the creep tests, numerous acoustic emissions (AE) were recorded from the very beginning in the samples immersed in the microbial medium, indicating the generation and propagation of microcracks inside the rock. Furthermore, microstructural observations revealed that microorganisms tended to accumulate around iron (Fe) within the rock matrix, indicating that microbial activity is locally associated with matrix weathering. These findings demonstrate that microbial weathering not only significantly reduces the strength of tuff but also strongly affects its long-term deformation behavior. Thus, microbial activity should be regarded as a critical factor in slope stability assessments.

Acknowledgements

We are deeply grateful to our financial supporters.



Program at a Glance

26 November 2025

08:00 –	Registration
08:50 – 09:00	Opening
09:05 – 09:45	Keynote lecture 1
09:45 – 09:55	<i>Break</i>
09:55 – 12:00	General session 1
12:00 – 14:00	<i>Lunch</i>
14:00 – 14:40	Keynote lecture 2
14:40 – 14:50	<i>Break</i>
14:50 – 16:55	General session 2

Meet at the registration desk before going to the party venue

18:00 – **Party Dinner**

27 November 2025

09:15 – 11:00	Student session
11:00 – 11:10	<i>Break</i>
11:15 –	Closing