Contents

DEEP INSIGHT INTO MECHANICAL BEHAVIOR AND MICROSTRUCTURE MECHANISM OF SERPENTINE-MAGNESIUM OXIDE CARBON SEQUESTRATION FOAMED LIGHTWEIGHT SOIL

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ABSTRACT

Serpentine could be used as a potential low-carbon binder. The use of lightweight construction materials has increasingly attracted attention in road engineering. This paper developed a novel technique of foamed lightweight soil using serpentine tailings, reactive magnesium oxide (RMC) and carbon dioxide (CO_2) foams, so called serpentine-magnesium oxide carbon sequestration foamed lightweight soil (SC-FLS). The impact of serpentine proportions on the mechanical behavior and microstructure of SC-FLS is investigated. Hydration of Serpentine and RMC was evaluated by isothermal calorimetry. Compressive strength results were used to assess the mechanical performance of SC-FLS samples. Quantification of hydrate and carbonate phases was conducted via XRD and TGA to examine the potential of SC-FLS in carbon sequestration. An optimal design was determined for serpentine content by the combination of the above tests. Results highlight the capacity of SC-FLS to sequester CO_2 actively.

Keywords: MgO; Serpentine; Carbon sequestration; Mix design

Fig. 1 Schematic diagram of samples preparation

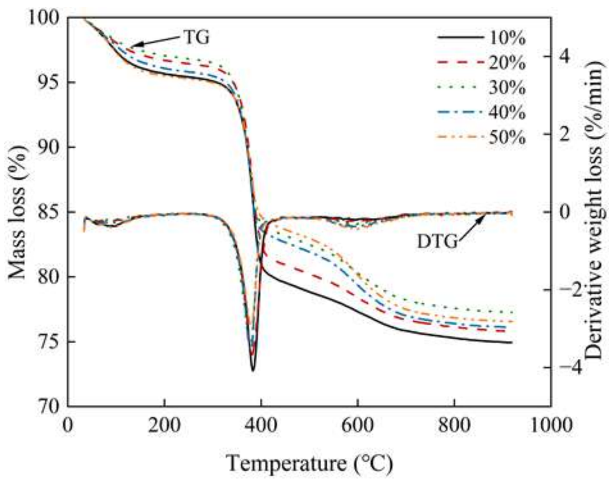

Fig. 2 TG and DTG results of SC-FLS samples

EXPLORING THE USE OF POLYMERIC BINDERS FOR SOIL STABILISATION IN THE CONSTRUCTION OF SPORTS INFRASTRUCTURES TO REPLACE CONCRETE

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ABSTRACT

Concrete is widely used in construction, but it has high emissions and is expensive. Furthermore, in applications that do not require a high load-bearing material and can benefit from the flexibility of the surface, concrete is not the optimum material. Polymers are now widely used in the construction of secondary roads and soil stabilization. In this research, we explored the practicality of using polymer binders for preparing substrate in the construction of sports courts. We used Styrene -Butadiene – Acrylic copolymers in water-based emulsion form. Unconfined Compressive Strength (UCS) test was used to compare the mechanical strength and elastic behavior of the soil stabilized using polymers and concrete that was usually used in this application. Samples were examined after soaking in water and cycles of drying to predict the impact of flooding. A cost-benefit analysis was completed to compare the two methods. Mechanical strength achieved using polymers was lower and the stabilized soil would be more susceptible to floods and weather events. However, higher elasticity created by polymers in comparison with concrete substrate can reduce impact and benefit athletics. In regional Australia, construction of sports courts using concrete is very expensive, and most small communities and schools cannot afford a court. Using polymers, these courts can be constructed at lower cost and using small equipment.

Keywords: Polymer, Emulsion, soil stabilization, Concrete

Figure 1- Schematic process of using polymers in the construction of affordable and sustainable sport infrastructure

COMPLETE PARTICLE SIZE DISTRIBUTION OF CDG SOIL WITH EXTENDED WET SIEVING METHOD

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ABSTRACT

Particle size distribution (PSD) is an important parameter of general soils for geo-engineering and geo-science, and it can be used for estimating the physico-mechanical behaviours of soil. The traditional standard wet sieving method can only determine the PSD of gravel and sand in CDG soil with particle sizes larger than 0.063 mm. This study extends the wet sieving method to determine the complete and continuous PSD of CDG soil with particle sizes from 60 mm to smaller than 0.0008 mm. The extended method uses five steps to separate the CDG soil into 13 sub-groups of gravel and sand materials, and 10 sub-groups of silt and clay materials. The smallest particle size sub-group is from 0.0008 mm to 0.0000 mm. The complete PSD of the CDG soil is calculated from the dry masses of the individual and separated materials of 23 sub-groups. The particle size, Atterberg limit, permeability, and chemical element of silt and clay materials with different particle size ranges are tested and investigated. The test methods include stereomicroscopic observation, physical and chemical properties tests. The test results further confirm the extended wet sieving method and provide new insight for sustainable construction materials.

Keywords: Particle size distribution (PSD); Completely decomposed granite (CDG); Wet sieving; Physical and chemical properties.

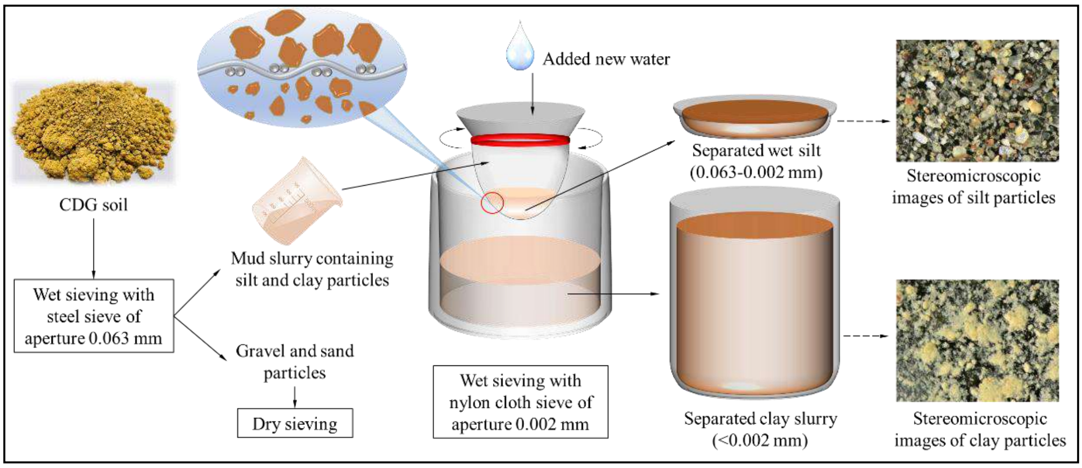

Fig. 1 Illustration of the extended wet sieving method

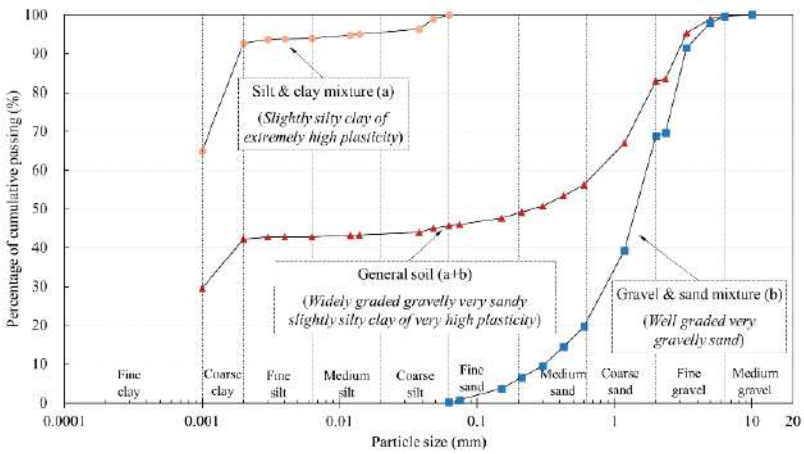

Fig. 2 PSD curves of the CDG soil, its gravel and sand portion, and its silt and clay portion

LABORATORY INVESTIGATION OF CDG SAND FOR FINE AGGREGATES IN PORTLAND CEMENT CONCRETE

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ABSTRACT

Completely decomposed granite (CDG) is a worldwide distributed in-situ weathered soil. This study adopts an extended washing and sieving method and uses snail mixture and steel sieves and/or cloth sieves to mechanically separate the CDG soil into its constitutional particles. The particles include gravel, sand, silt, and clay. The potential use of CDG sand as fine aggregate in the fabrication of Portland cement concrete is examined and evaluated in accordance with Hong Kong standards for fine aggregate. Four types of sand properties are tested. They include geometrical properties, physical properties, chemical properties, and mechanical properties. Laboratory tests are gradation test, SEM observation, stereomicroscope observation, shape analysis, magnesium sulphate soundness test, bulk density test, water absorption test, chemical elements test, drying shrinkage test, effect of organic substances test and alkali silica reaction test. Results of these tests illustrate that all the properties of the CDG sand well meet the standard requirements and can be used as fine aggregates in Portland concrete.

Keywords: Completely decomposed granite (CDG); Fine aggregate; Portland cement concrete; Physical properties; Chemical properties.

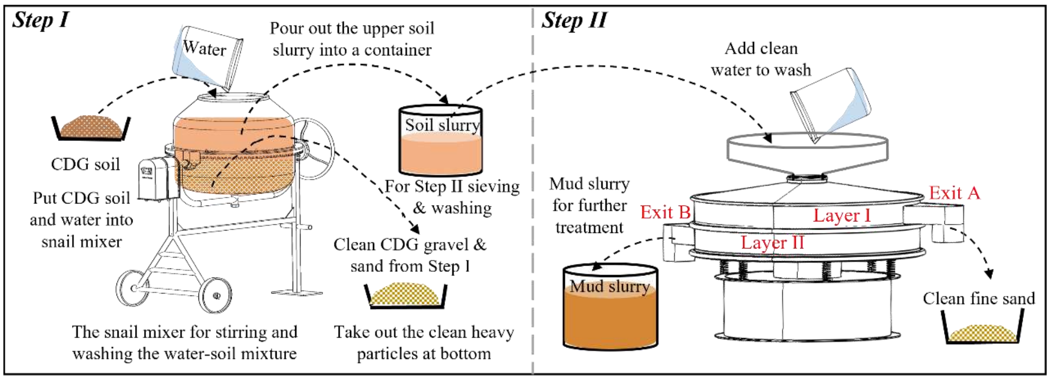

Fig. 1 Flow chart for the step I, step II for washing and sieving method

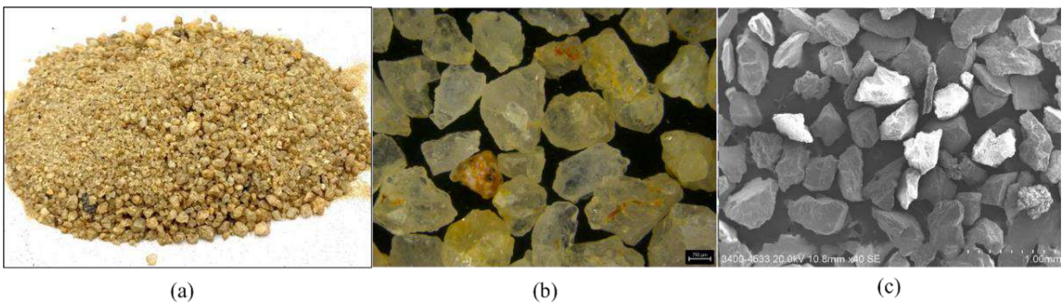

Fig. 2 (a) Photograph of CDG gravel and sand; (b) Stereomicroscope image of CDG sand with particle size of 1.18 – 2 mm (x 7.8 magnification); (c) SEM image of CDG sand with particle size of 0.212 – 0.3 mm (x 40 magnification)

DESICCATION CRACKING OF EXPANSIVE SOIL SUBJECTED TO DIFFERENT TEMPERATURE CONDITIONS

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ABSTRACT

Soil cracking is a natural phenomenon that weakens soil structure, leading to disasters. The formation of cracks in expansive soil is influenced by various factors, with temperature being a crucial environmental factor. In this study, we conducted a series of tests on the drying crack characteristics of saturated expansive soil slurries with thicknesses of 5mm and 10mm at three temperatures: 20°C, 40°C, and 60°C. Digital cameras were used to capture the characteristics of the dried cracks, and computer image processing techniques were applied to extract relevant quantitative data on the cracks, to investigate the effect of different temperature conditions on the shrinkage crack characteristics of expansive soil. Based on the test results, it was observed that as the temperature rose, the rate of soil water evaporation increased while the time it took for evaporation to stabilize decreased. The increase in temperature led to a gradual increase in crack area, width, and fractal dimension, while crack length remained constant. Additionally, thicker soil layers resulted in larger crack areas, lengths, and fractal dimensions, while exhibiting slower evaporation rates and longer stabilization times.

Keywords: Expansive soil, Cracks, Temperature factors, Quantitative analysis.

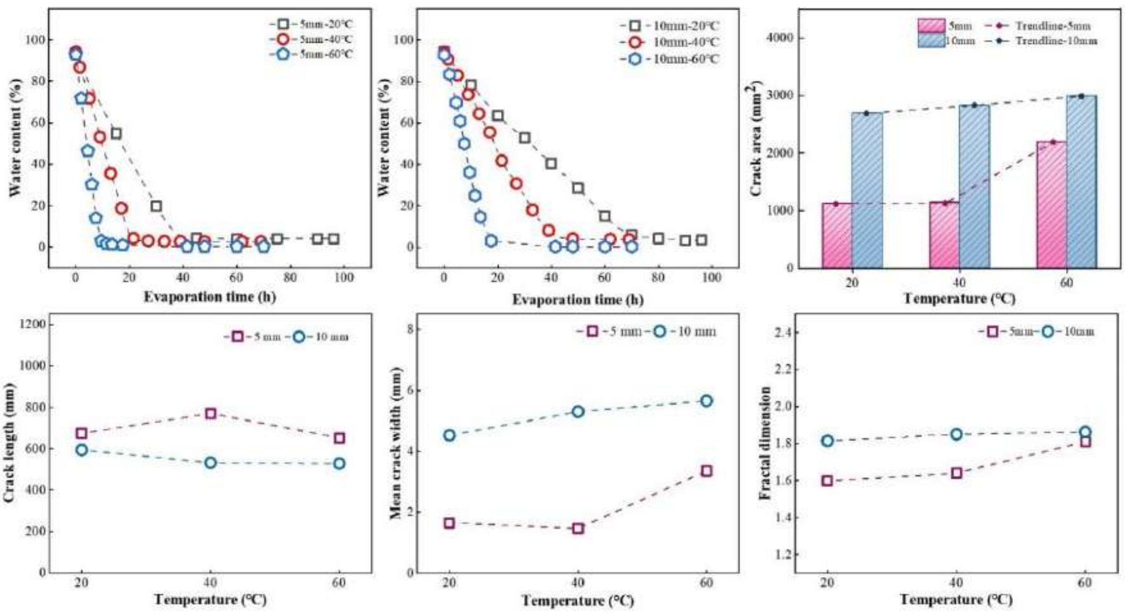

Fig. 1 Soil water evaporation curve and soil crack parameter variation curve under different temperatures

ANOMALOUS DIELECTRIC BEHAVIOR IN NA-MONTMORILLONITE INTERLAYER: A MOLECULAR DYNAMICS STUDY

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ABSTRACT

Na-montmorillonite (Na-Mt) expansion clays have been widely studied because of the importance in high-level radioactive waste (HLRW) management and isolation of contaminated sites. The interlayer dielectric behavior of Na-Mt is important for its swelling property but is not well understood. Here, molecular models of Na-Mt are constructed and the hydration studies are carried out by molecular dynamics (MD) simulation, with emphases placed on the interlayer dielectric behavior in Na-Mt during hydration process. The results show that the interlayer water under nanoconfinement exhibits dielectric depletion, which is attributed to the in-plane dipole−dipole electrostatic interactions of the interfacial water. Combining linear response theory and fluctuation-dissipation dielectric function, the local dielectric constants in Mt interlayer is obtained (Fig. 1). In hydrated Mt interlayer, the dielectric constant increased with the increment of basal space and interlayer water density, and the distribution characteristics of dielectric constant is closely related to the hydrogen bond and water density profile. These results provide a clear insight into the anomalous dielectric behavior in Na-Mt interlayer from a molecular view.

Key word: montmorillonite, interlayer behavior, local dielectric constant, molecular dynamics.

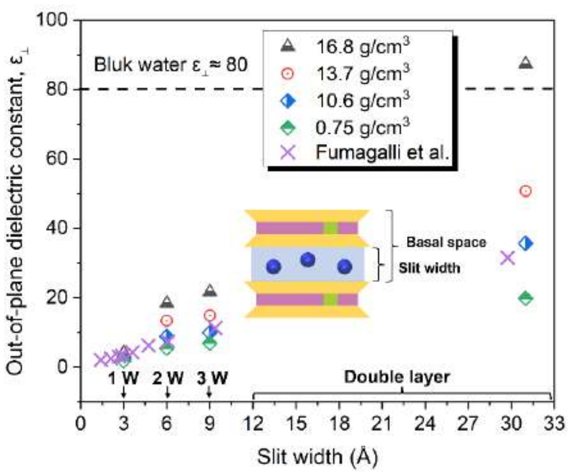

Fig. 2 Dielectric constant of interlayer water under crystal surface confinement

INVESTIGATIONS ON RHEOLOGICAL CHARACTERISTICS OF THE FLY ASH BLENDED CLAY SOIL

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ABSTRACT

In recent times, the mechanical properties of soil microstructures have been examined using rheological techniques. This study attempts to explore the rheological characteristics of the Fly Ash (FA) blended reconstituted soil. A series of experimental tests were conducted in the Amplitude Sweep Test through the Anton Paar-Modular Compact Rheometer (MCR) with a parallel-plate sensor system. From the experimental investigation, it is observed that FA significantly influence the shear behaviour, structural stability and stiffness of reconstituted soil. Due to the variation in the packing density of the reconstituted soil, the yield point decreases continuously as the composition of the FA increases. After the flow point, the samples possessing the higher stability and gel-like character exhibit higher flow strain which is observed with the increase in FA content.

Keywords: Rheological characteristics, fly Ash, reconstituted soil.

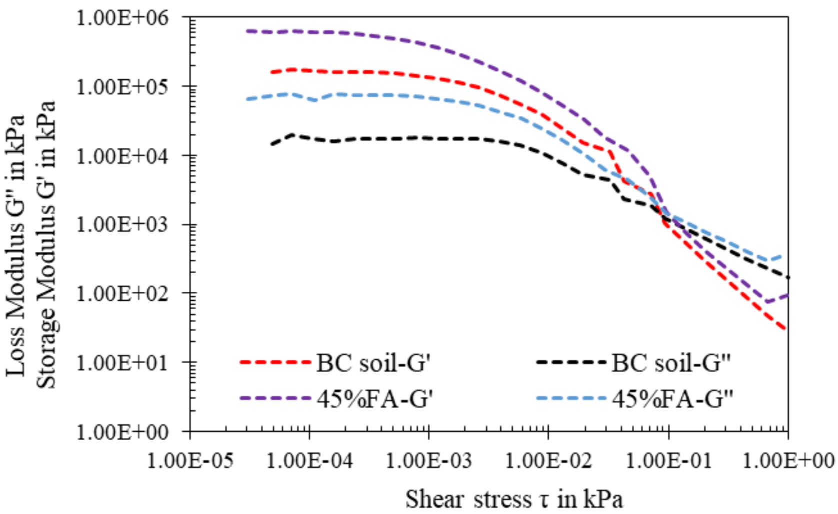

Fig. 1 Amplitude sweep test data for BC soil and 45% FA blended soil.

THE VOLUME CHANGE BEHAVIOR OF COMPACTED BENTONITE UNDER THE COMBINED EFFECT OF SUCTION CYCLE AND TEMPERATURE

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ABSTRACT

During the operation of geological disposal of high radioactive waste, the bentonite used as the buffer/backfill material will undergo cyclic changes in temperature and suction. In order to study the volume change behavior of bentonite in this condition, a series of suction cycle tests were conducted under free swelling boundary and controlled temperature of 20℃, 40℃ and 60℃. This work included single wetting-drying cycle tests, multiple wetting-drying cycles tests and multiple drying-wetting cycles tests. Results showed that irreversible volume strain accumulated during the wetting-drying path, that is, the volume under the wetting path was smaller than the volume under the corresponding suction in the drying path. At a higher temperature, the accumulated volume strain during the cycling process decreased. Accumulation of volume strain was observed during multiple cycles under different suction paths, and as the number of cycles increased, the accumulated volume strain per cycle decreased. However, compared to multiple wetting-drying cycles, multiple drying-wetting cycles showed more accumulated volume strain. The volume changes of the samples under free swelling boundary also showed significant anisotropy. The degree of anisotropy was evaluated by defining the anisotropy coefficient. Results showed that the anisotropy of the samples volume changes weakened as the number of cycles increased. In addition, the anisotropy during multiple wetting-drying cycles was weaker than that during multiple drying-wetting cycles.

Keywords: Compacted bentonite, temperature, suction cycle, volume change, anisotropy

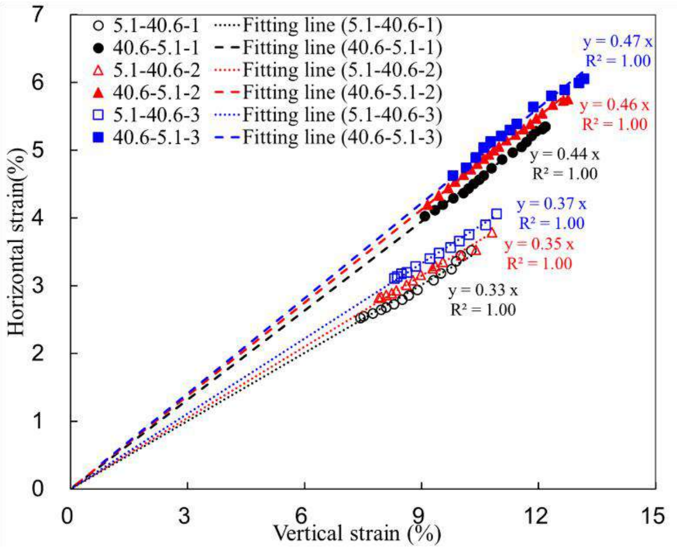

Fig. 1 Relationship between horizontal strain and vertical strain during multiple suction cycles tests (40℃)

A general criterion for strength prediction of waste ash stabilized soil

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ABSTRACT

Dredged marine deposits after stabilization are supposed to serve as fill material in land reclamation, by which the shortage of fill sand can be alleviated. Waste ashes with effective chemicals are regarded as green binders to replace cement for soil stabilization considering the high carbon footprint in the cement industry. However, there are so many different ashes that could be used for soft soil stabilization, for instance, sewage sludge ash (SSA), coal fly ash (CFA), bagasse ash (BA), etc. Due to numerous types of ashes and varying mix proportions, it is impossible to test the mechanical properties of all the ash-stabilized soil with different formulas. Therefore, studying the similarities among stabilized soil with different influencing factors including different types of ashes and mix proportions, is highly valuable. In this study, unconfined compression tests were systematically performed on stabilized marine deposits treated by SSA to study the mechanical behavior and strength development. Based on the strength results, a general criterion incorporating a modified basicity coefficient (*MKb*) is proposed to build a linkage between the chemical composition of binders, the mix proportion, and the strength of the stabilized soil. Literature results on CFA, BA, and cement are used for the validation of the criterion.

Keywords: Sewage sludge ash; Marine deposits; Unconfined compressive strength; Modified basicity coefficient; Strength criterion

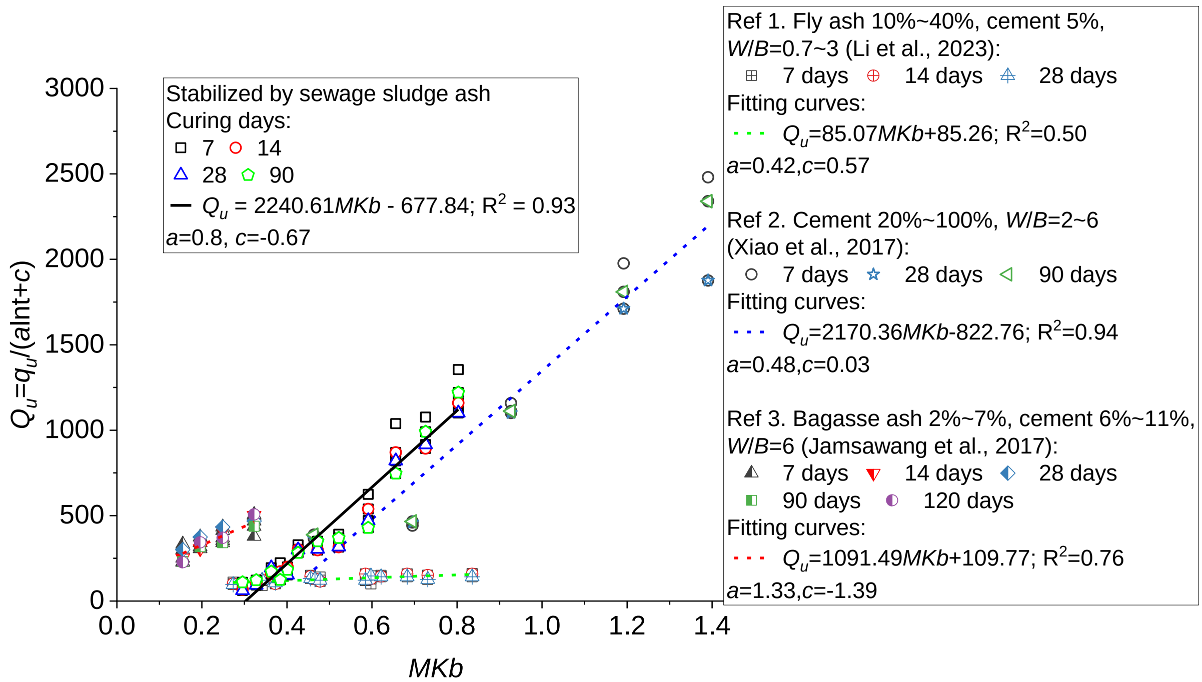

Fig. 1 The relationship between uniform strength Q_u and modified basicity coefficient *MKb* of sewage sludge ash stabilized soil and literature results (Jamsawang et al., 2017; Li et al., 2023; Xiao et al., 2017)

PORE STRUCTURE OF ALKALI RESIDUE-BASED LIGHTWEIGHT SOIL AND ITS INFLUENCE ON PHYSICAL AND MECHANICAL PROPERTIES BASED ON X-RAY COMPUTED TOMOGRAPHY

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ABSTRACT

The purpose of this study is to investigate pore structure characteristics of alkali residue-based lightweight soil and its influence on physical and mechanical properties. In this study, laboratory tests were conducted to acquire physical and mechanical parameters. The pore parameters of alkali residue-based lightweight soil were calculated through X-ray computed tomography. The 3D pore structure and pore net-work model were established to directly reflect the microscopic characteristics. The results show that alkali residue-based lightweight soil has a homogeneous pore distribution and an excellent thermal insulation performance. As the wet density increases, porosity and pore size decrease, and pore shape gradually tents to become more spherical. The Flow value, compressive strength, and thermal conductivity decrease as the porosity and pore diameter increase, whereas the water absorption and resistivity increase. In addition, the water absorption increases with the increase in absolute permeability and volume ratio of connected pores. At last, owing to the gravity and surface tension drainage, the liquid film thickness decreases, leading to merging of the foams under the pressure difference between the them, eventually resulting in the formation of connected pores.

Keywords: Alkali residue-based lightweight soil; X-ray computed tomography; Pore; Compressive strength; Thermal conductivity.

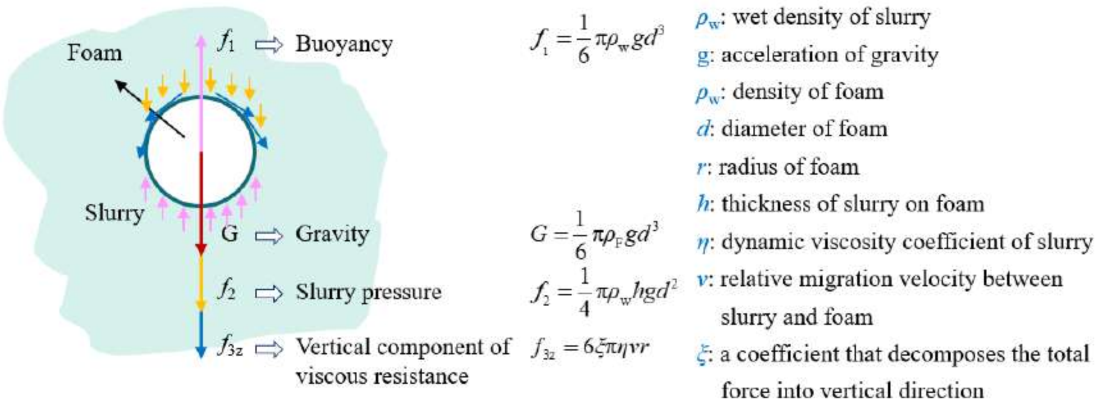

Fig. 1 Illustration of the proposed method

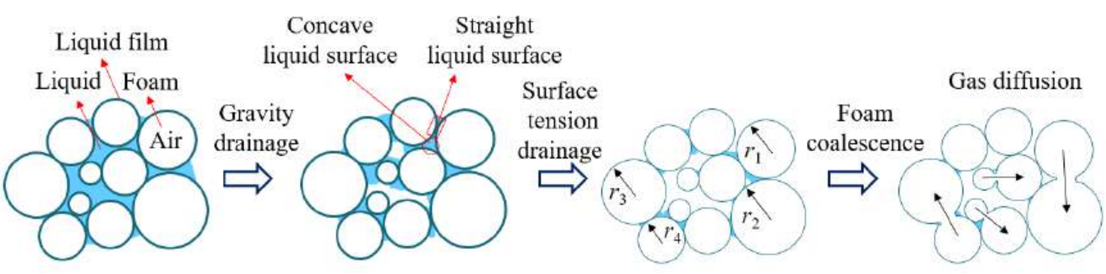

Fig. 2 Deviatoric stress evolution

HYDRO-MECHANICAL BEHAVIOR OF COMPACTED EXPANSIVE STIFF CLAY SUBJECTED TO WETTING AND DRYING CYCLES

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ABSTRACT

Expansive stiff clays are inevitably subjected to wetting and drying cycles during earthwork, which can significantly threat the engineering safety. In this study, the hydro-mechanical properties of compacted Nanning stiff clay during wetting-drying cycles were investigated, focusing on a comprehensive analysis on swelling-shrinkage volumetric behavior, hydraulic conductivity and microstructure evolution. The results indicated that the evolution of total swelling or shrinkage strains was influenced by the combined effects of vertical stress and the number of wetting-drying cycles, which can be described by the definition of the size of swelling and shrinking domains. Furthermore, the swelling kinetics analysis showed that the normalized proportion of strain and duration time of the initial swelling phase escalated while the corresponding values in the primary swelling phase dwindled with increasing cycle numbers. These phenomena were predominantly ascribed to the evolution of microstructure, which was corroborated by microscopic test findings, evincing a significant reduction in cumulative pore volume and a transfer from an initial quasi-monomodal distribution to a fairly uniform one, characterized by a prominent peak pore size. Based on the results, the microscopic mechanisms of compacted stiff clay during wetting-drying cycles were proposed for better understanding the macroscopic volumetric behavior.

Keywords: stiff clay; volumetric behavior; wetting-drying cycle; microstructure

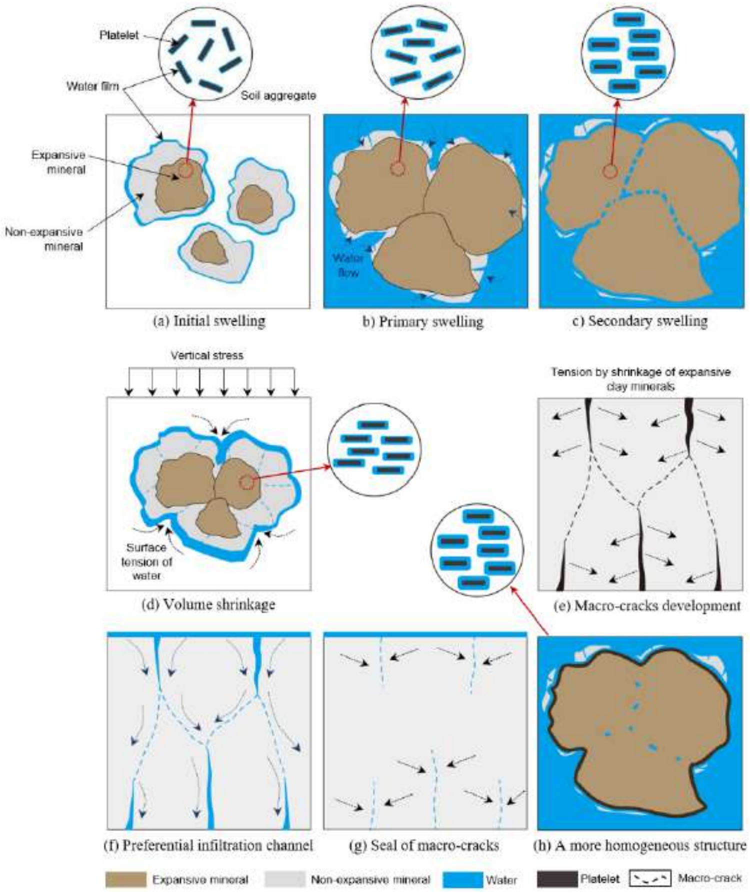

Fig. 1 Conceptual model of soil structure development during wetting-drying cycles

EFFECT OF FLY ASH AND SUPER-ABSORBENT POLYMER ON FLUIDITY AND STRENGTH DEVELOPMENT IN CEMENTED DREDGED CLAY WITH HIGH WATER CONTENT

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ABSTRACT

To effectively realize the engineering resource utilization of dredged clay with high water content, the cement, fly ash (FA) and super-absorbent polymer (SAP) have been applied to improve the solidified strength of this soil. It is worth noting that the pumping level during soil solidifying should be considered together with the solidified strength, but the pumping level (the index is fluidity) of solidifying soil is often ignored. This paper presents an investigation of correlation between fluidity of solidifying soil and strength of solidified soil mixed with cement, FA and SAP. Results show that the cement, FA and SAP significantly influence the fluidity and strength of dredged clay with high water content, characterized by a decrease in the fluidity and an increase in the unconfined compressive strength (UCS). Microstructures reveal that the hydration reaction of cement, water transfer, water absorption and the pozzolanic reaction of FA result in the thickness of water films thinning, the cementation bonding enhancement and the pore volumes reduction, respectively. Based on this influence mechanism, a comprehensive prediction model for the slump flow and UCS is proposed, which can provide an important guidance for the flow and solidification treatment of the dredged clay with high water content.

Keywords: Dredged clay; Fly ash (FA); Super-absorbent polymer (SAP); Fluidity; Compressive strength

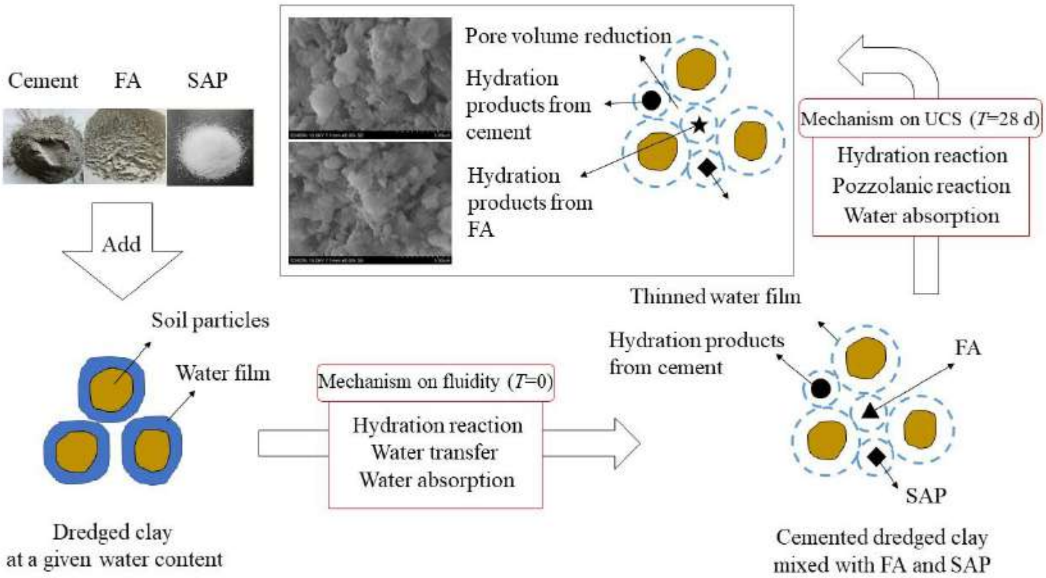

Fig. 1 Behaviors of cement, FA and SAP in the dredged clay

Effect factors and mechanisms of carbonating magnesium oxide for recycle concrete aggregate cementation

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ABSTRACT

The use of reactive magnesium oxide (MgO) as the binder in porous civil material demonstrated significant advantages due to its low production temperature and ability to carbonate by industrial waste gas, leading to significant strength rapidly. At the same time, recycled concrete aggregates (RCA) have inferior qualities and fewer application compare with nature aggregates, mainly due to the porous nature of the attached cement mortar. This paper investigates the potential of carbonating reactive magnesium oxide (MgO) to serve as a sustainable recycled concrete aggregates (RCA) cement method.

The enhancement of cementation was investigated through different sample preparations and curing conditions: magnesium mixing ratio (5%-15%), water to cement ratio (0.73-5), compact energy, curing duration (0-28days), mechanical strengthening of aggregates. The curing condition is 20% CO_2, 75% humidity and 20 degrees temperature. UCS results were supported with PH, electric conductivity, HNO_3 acid digestion analyses, SEM, XRD and TGA. The results show that CO_2 concentration at 20% can produce the strength up to 7.5MPa after 3days. Drier mixers perform better in shorter curing duration whereas larger w/c ratio have more potential at longer curing duration. The existence of attached cement mortar has positive effect on strength growth. Magnesite, nesquehonite and calcite are the main product of carbonization.

Keywords: Recycled concrete aggregate, Microstructure , Carbonation, Compressive strength, MgO

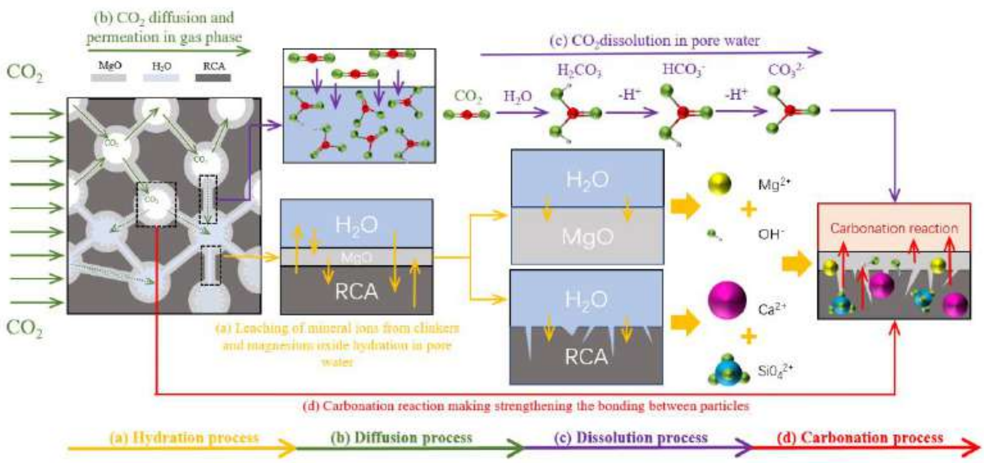

Fig. 1 Illustration of physical and chemical carbonation processes of MgO-RCA mixture

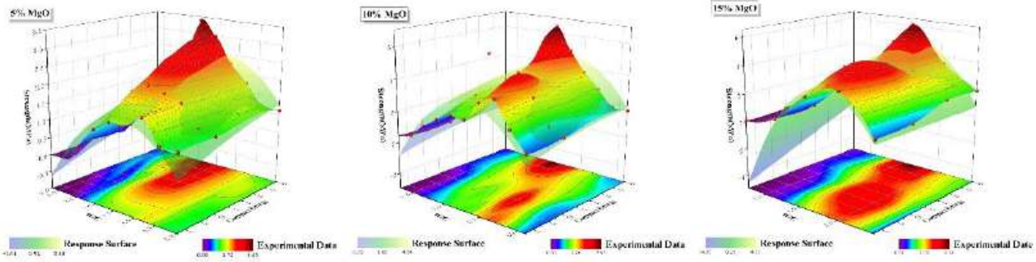

Fig. 2 UCS of different MgO mixing ratio and W/C

IDENTIFICATION OF REPRESENTATIVE ELEMENTARY VOLUME IN INHOMOGENEOUS GEOTECHNICAL MATERIAL BASED ON MICROSTRUCTURE PARAMETERS

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ABSTRACT

Determination of representative elementary volume (REV) is essential for the study of permeability of inhomogeneous geotechnical materials. However, previous studies did not have a unified determination criteria of REV. In this study, we first created digitized samples of geotechnical materials with different inhomogeneity coefficients (Cu). The ratio of the sample length (L) and the controlled grain diameter (d60) were employed to represent the sample size (Fig. 1). The permeability of geotechnical materials is closely related to its microstructure. We calculated the pore structure parameters for different sample sizes, and the REV values of samples at different Cu were obtained. Fig. 2 presents the recognition result of REV when Cu = 4. On this basis, the relationship between Cu and REV can be established. To verify the correctness of the proposed relationship between REV and Cu, computed tomography test and constant head permeability test were carried out. When Cu is known, the corresponding REV scale given in this study can reflect the permeability at the laboratory scale. The results of this study provide a new path to determine REV.

Keywords: Representative elementary volume; micro-structure parameters; permeability; coefficient of nonuniformity

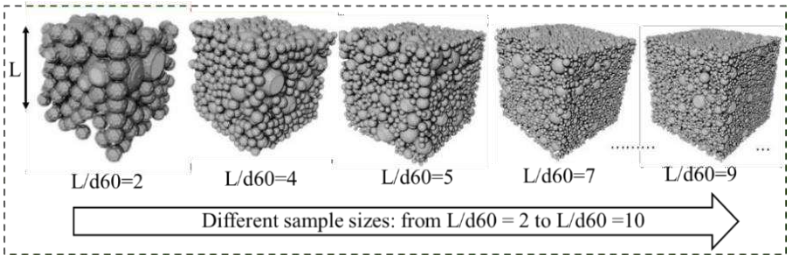

Fig. 1 Digital sample modeling of geotechnical materials at different sample sizes

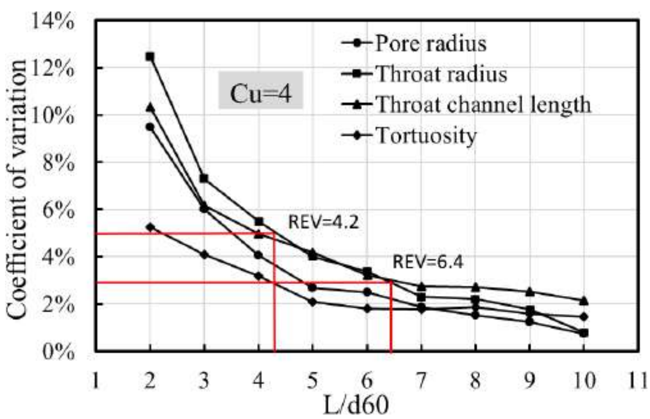

Fig. 2 Determination of REV under different pore structure parameters when Cu = 4 (the coefficient of variation indicates the acceptable level of variation in material properties)

Micromechanics-based constitutive modelling of granular materials accounting for fabric evolution

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Abstract

Micromechanical studies of granular materials have demonstrated the importance of their microstructure to their behaviour. This microstructure is often characterized by fabric tensors. Experimental and computational studies have shown that the fabric can change significantly during deformation. Therefore, the evolution of fabric is important to constitutive modelling. Current fabric evolution laws for granular materials have generally been developed for continuum-mechanical models, and use a loading index multiplier associated with a yield surface. Such evolution laws cannot be employed with micromechanical models that do not involve an explicit macro-scale yield surface. This study develops an evolution law for fabric anisotropy, based on observations from experiments and DEM simulations from literature. The proposed evolution law considers the effects of inherent anisotropy, void ratio, stress ratio, loading direction and intermediate principal stress ratio. In the critical state, the value of the fabric anisotropy depends only on the Lode angle. The predicted evolution of fabric anisotropy is in good agreement with results of DEM simulations, showing both hardening and softening behaviour and describing the influence of the initial void ratio. The proposed evolution law can be embedded into micromechanics-based constitutive relations as well as conventional continuum-mechanical models. As an example, a well-established micromechanical model (in which the fabric is considered as constant) has been extended by accounting for the variations in fabric, in combination with the proposed fabric evolution law. The performance of this enhanced micromechanical model has been demonstrated by a comparison between the predicted behaviour and experimental results from literature for Toyoura sand under various loading conditions.

Keywords: granular material, fabric, micromechanics, constitutive modelling

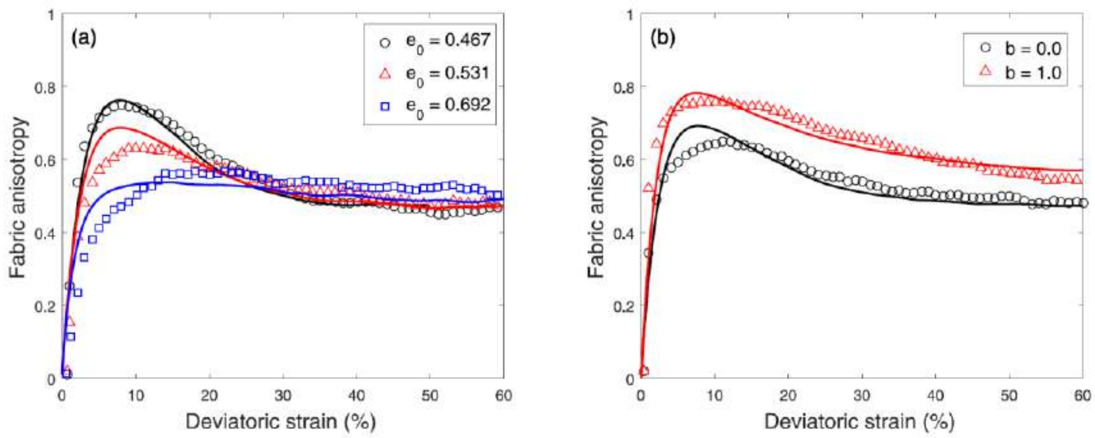

Fig. 1. Comparison of fabric anisotropy obtained from DEM simulations (Yang and Wu, 2016) (symbols) and predicted by the fabric evolution law (solid lines); initial samples are isotropic: (a) influence of initial void ratio e_0 on fabric evolution under confining pressure of 1000 kPa in triaxial compression; (b) influence of loading path on fabric evolution for samples of initial void ratio $e_0 = 0.546$ under confining pressure of 500 kPa.

Progressive failure process analysis of anisotropy sand with micropole hypoplastic model considering macro-meso incorporation

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Abstract

Soil has multi-scale characteristics and should be regarded as heterogeneous material. The coupling analysis method of discrete element (DEM) and finite element (FEM) should be used to describe its strength and deformation.In this study, a macro-meso incorporation hypoplastic model is established based on anisotropy critical state theory. This model establishes the relationship between the macroscopic and mesoscopic levels using fabric tensors. Subsequently, a DEM plane strain model and a FEM plane strain model are established respectively. DEM model is used to obtain the fabric distribution pattern of the specimen. Then, based on the distribution of FEM meshes, the mesoscopic law is discretized so that each integration point corresponds to the discretized data. Furthermore, the internal length scale is incorporated into the constitutive model using the micropolar theory to analyze the progressive failure process and the rotation of elements inside and outside the shear band. The results indicate that the macro-meso incorporation hypoplastic model and its methodology can effectively describe strain localization and progressive failure processes. The internal length scale is identified as the main factor influencing the width of the shear band. The anisotropic fabric influences the shape of the shear band, with circular and elliptical particles tending to form an "X" shear band, while square and triangular particles tend to form a single shear band.

Keywords: hypoplastic constitutive model; micropole theory; fabric evolution; shear band; finite element

STRESS-INDUCED ANISOTROPIC SUPER-SUBLOADING SURFACE MODEL FOR STRUCTURAL CLAY BASED ON UNIFORM YIELD CRITERION

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ABSTRACT

To characterize the complex mechanical behavior of natural structural soft clay, a novel elastic-plastic constitutive model was proposed to produce its mechanical properties such as structural, over-consolidation, dilatancy or shrinkage softening, and stress-induced anisotropy. The shape function $g(\theta)$, which can uniformly describe the four yield criteria of Mohr-Coulomb, Drucker-Prager, Lade-Duncan, and Matsuoka-Nakai, is introduced into the super-subloading yield surface model to modify the M value so that the M value can change with the change of Lode Angle θ in the new model. The plastic deviatoric strain increment was selected as the iteration variable. The stress integration algorithm of the new model was developed by Newton-Raphson iteration, and the UMAT subroutine was written and successfully integrated into the commercial finite element software ABAQUS. The results show that: 1) The new model can simulate natural soft clay's structural behavior, over-consolidation, dilatancy, and stress-induced anisotropy, exhibiting good agreement with experimental data. 2) The stress integration algorithm of the new model presents rapid convergence, minimal iterations per incremental step, high computational precision, and stable, reliable operation. 3) The new model unifies four yield criteria to various failure modes, with a clear physical significance and simple expression, facilitating broad engineering applicability.

Keywords: structural soil; anisotropy; unified yield criterion; super-subloading yield surface; stress integration algorithm

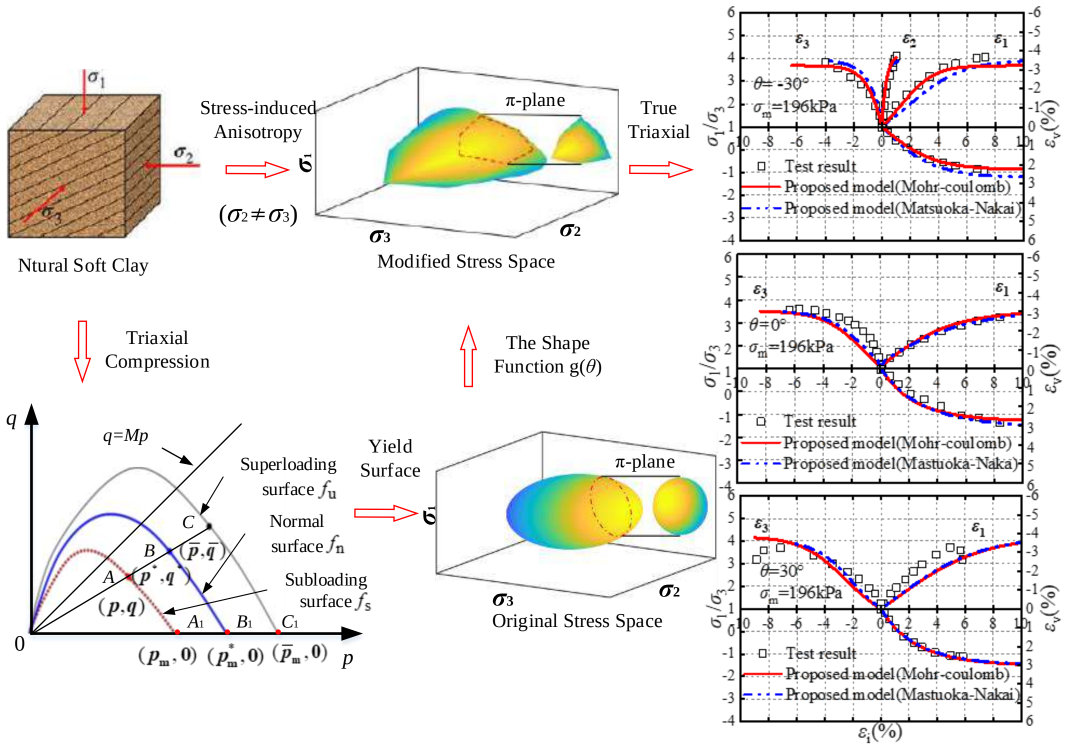

Fig. 1 Illustration of the proposed method

A LABORATORY SCALED INTEGRATED ANALYSIS OF SHEAR STRENGTH PARAMETERS OF DUMP MATERIALS

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ABSTRACT

The shear strength of dump materials significantly influences the stability of overburden dump materials which is crucial for the proper functioning of surface mining activities. The primary factors that govern the shear strength parameters include particle size, packing, material density, and moisture content. In this study, systematically designed experiments are conducted in the laboratory on reconstituted dump samples to understand the complex interactions among the factors that affect the cohesion and angle of internal friction. From the research findings, the variations of shear strength parameters across the vertical section of dump slopes are analysed. It was revealed that the cohesion varies in a wide range when subjected to different particle sizes and bulk densities, while particle packing affects the angle of internal friction. Additionally, it has been observed that there exist two extreme packing configurations for which the void ratio of the dump materials is maximum and minimum when the particles of different size ranges are packed in certain specific proportions. With the incorporation of scale effects and packing density method, the particle packing configurations and the in situ density variations with dump height are theoretically determined.

Keywords: Dump material, shear strength, density, particle packing, particle size

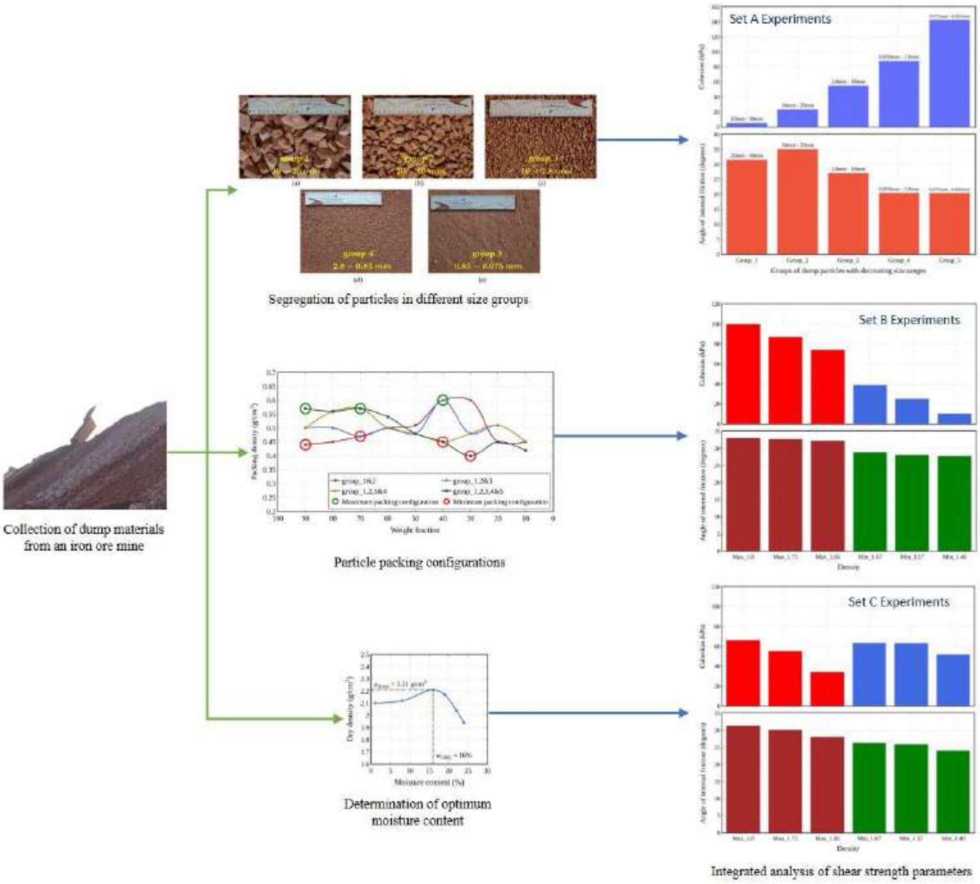

Fig. 1 Flowchart highlighting the design of experiments along with critical results

Elastoplastic Constitutive Model for Overconsolidated Clays with an Advanced Dilatancy Relation

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ABSTRACT

The dilatancy behavior of overconsolidated (OC) clays is a key factor in determining their strength and deformation characteristics. Acknowledging the limitations of previous dilatancy relations for clays, a novel dilatancy relation is proposed that can effectively captures the changes in dilatancy point, volume dilatancy and contraction with the overconsolidation ratio (OCR). As the OC clays recovers to the normally consolidated (NC) state, the proposed dilatancy relation can smoothly change to that of the modified Cam-clay (MCC) model. It ensures a unified description of the dilatancy relation between OC clays and NC clays. Furthermore, the dilatancy relation can be easily incorporated into the constitutive model of the boundary surface concept. Combining boundary surface and generalized plasticity theory, this advanced dilatancy relation is integrated into a new elastoplastic constitutive model for OC clays, which effectively captures the strain hardening and softening, volume contraction and dilatancy, and accumulation of negative pore pressure with the degree of overconsolidation. The proposed model is validated utilizing drained triaxial compression and extension, undrained triaxial compression and extension, as well as complex stress path tests for clays with various OCRs. The results demonstrate that the model performs well in simulating both strength and volume behavior of the clays.

Keywords: Dilatancy behavior; Overconsolidation clays; Novel dilatancy relation; Elastoplastic constitutive model; Generalized plasticity theory.

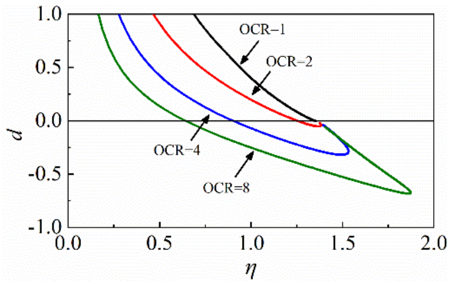

Fig. 1 Dilatancy relationship of OC clays with different OCRs

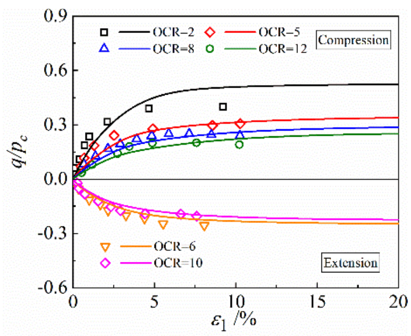

Fig. 2 Model simulations and experimental results under undrained triaxial compression and extension

A STIFFNESS DEGRADATION METHOD FOR MODELLING LONG-TERM RATCHETING RESPONSE OF WIND TURBINE FOUNDATIONS IN SAND

Zhiwei Gao[1#] and Scott Whyte[2]

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ABSTRACT

Long-term cyclic loading from environmental conditions can lead to excessive permanent rotation of offshore wind turbines (OWTs) due to the ratcheting response of sand. A practical hybrid strain accumulation approach termed the bounding surface stiffness degradation method (B-SDM), for finite element analysis (FEA)-based design of OWTs under cyclic loading is presented. This method includes a base elastoplastic constitutive model that captures the stress-strain relationship in the first load-unload cycle and a cyclic strain accumulation scheme for modelling the subsequent cycles (Fig. 1). The presented approach allows for a versatile overlay scheme that calculates cyclic strain accumulation to be applied to a range of base elastoplastic models. The base constitutive model is based on the bounding surface concept and considers strain-hardening and plastic volume change before failure. The method has been validated by single-element test data on sand and used in finite element modelling of monopile response in cyclic loading (Fig. 2). When the monopile response is modelled in 3D FEA, the conventional step-by-step modelling approach is used until the end of the first regular cycle. Strain accumulation in subsequent cycles is modelled using the B-SDM, in which the plastic modulus and dilatancy relationship are scaled based on a strain accumulation law.

Keywords: Sand, cyclic loading, stiffness degradation

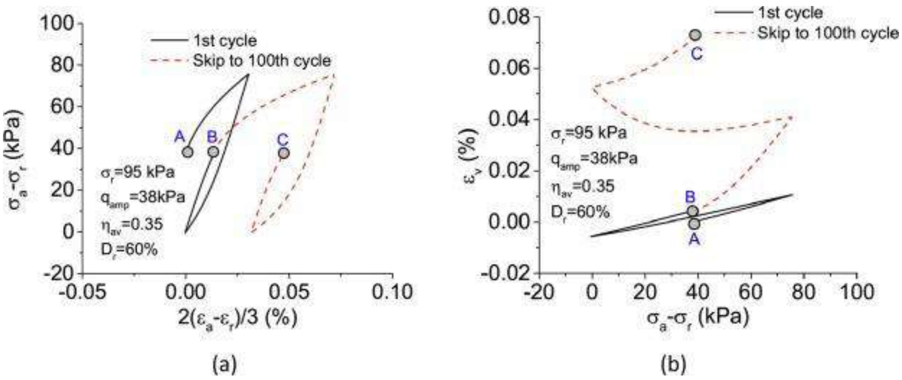

Fig. 1 Illustration of the stiffness degradation method

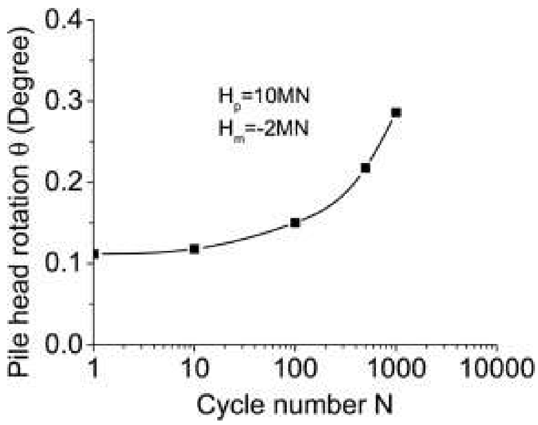

Fig. 2 The relationship number of cycles and pile head rotation in a single packet of storm load

CONSTITUTIVE MODELING OF SOLID- AND FLUID-LIKE TRANSITIONAL BEHAVIOR OF SAND

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ABSTRACT

The solid- and fluid-like transitional behaviour of granular soils under low stresses is of significant importance for the prediction and mitigation of natural hazards like landslides and earthquakes. This presentation will be focused on the constitutive modelling of such transitional behaviour. As illustrated in Fig. 1, the proposed modelling framework is based on a fundamental additive decomposition of stress into rate-independent static parts governing solid-like behaviour at high confining stresses, and rate-dependent dynamic parts controlling fluid-like response at low stress levels. The former component is described by a critical state-based, state-dependent elastoplastic model, while the latter part is modelled via combining viscoplasticity and μ-I rheology for dense granular flow. To assess the performance of the proposed modelling framework, creep tests on Toyoura sand under low confining stresses are performed, as shown in Fig. 2. Main findings from these experimental investigations are discussed, which emphasize the effects of stress levels on the rheological characteristics of granular soils. The comparison between model simulations and test observations is presented at last.

Keywords: constitutive relations, granular materials, critical state, rheology, viscoplasticity.

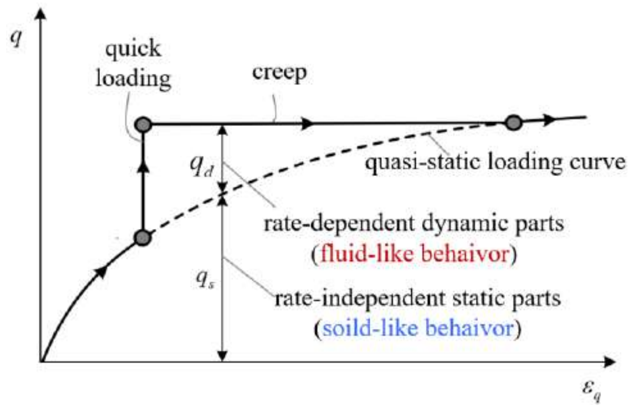

Fig. 1 Illustration of proposed constitutive modeling framework.

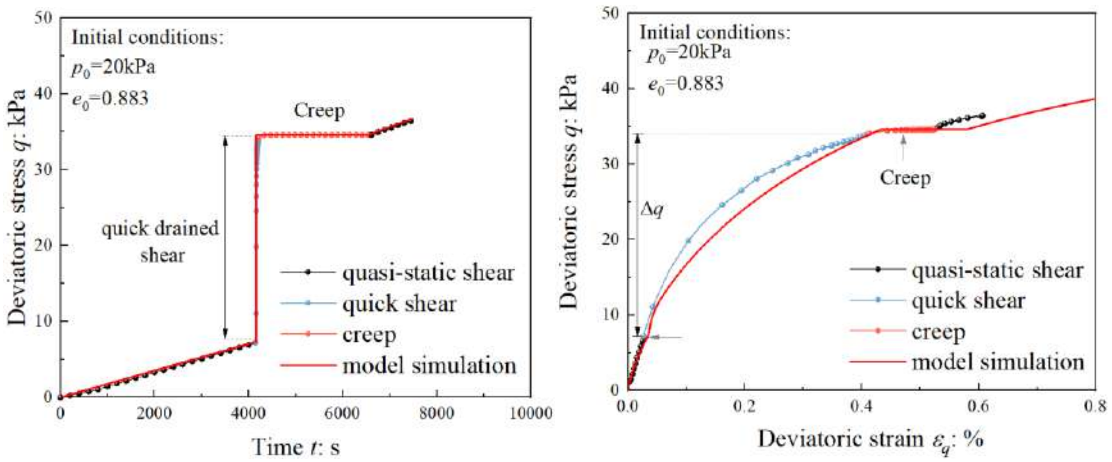

Fig. 2 Creep test of sand under low confining stresses and its simulations.

WATER-RETENTION AND SHEAR-STRENGTH BEHAVIORS OF UNSATURATED SOILS WITH DUAL-POROSITY

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ABSTRACT

Dual-porosity microfabrics can affect the hydro-mechanical characteristics of unsaturated fine-grained soils. This work first presents experimental studies on the soil-water retention curve (SWRC) and stress-strain-strength of Nanyang expansive soils. The mercury intrusion test is used to correlate macroscopic hydraulic responses to soil microstructures. Test data show the samples with dual-porosity microfabrics exhibit bimodal SWRC. We further present a bimodal SWRC equation for fine-grained soils. This model discriminates capillary and adsorptive water-retention mechanisms and accounts for the effects of dual-porosity on capillary water. The last part of this work employs capillary saturation to define suction stress by upscaling the suction from pore-scale stress to macroscopic one. Then the suction stress is used to examine the uniqueness of strength parameters for dual-porosity soils under various suctions. Much differing from the unsaturated soils with unimodal SWRC characterized by unique shear strength envelopes, the soils with bimodal SWRC always display bi-linear strength envelop. A novel strength criterion is introduced to estimate the contribution of suction to the shear strength for dual-porosity soils.

Keywords: Unsaturated soils, Shear strength, Soil-water retention curve, Dual-porosity

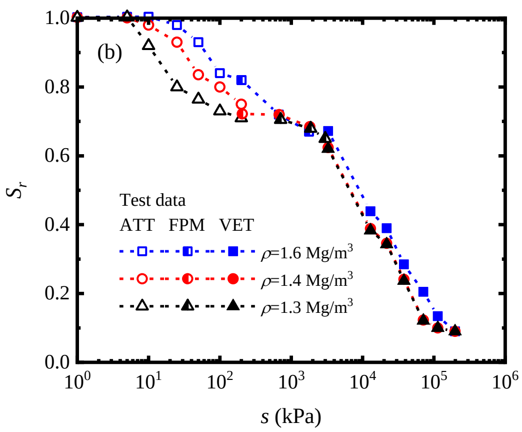

Fig. 1 SWRC of fine-grained soils with dual-porosity structure during the drying test

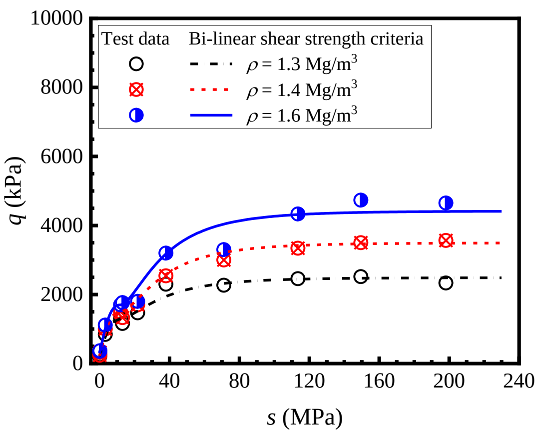

Fig. 2 Comparison between the unsaturated bi-linear shear strength criterion and the measured strength data

A CWFS BOUNDING SURFACE MODEL FOR ROCKS CONSIDERING A MODIFIED ROWE'S STRESS-DILATANCY AND FINITE STRAIN CONCEPT

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ABSTRACT

In order to describe the mechanical responses of rocks reasonably, a bounding surface model is proposed, with the CWFS (cohesion weakening and friction strengthening) concept and a modified Rowe's stress-dilatancy rule being introduced. The bounding surface model to applied to avoid calculation errors caused by the estimation of elastic-plastic boundary. In order to model the brittle/ductile response of rock under both low and high confinements, the CWFS concept is employed to describe the softening mechanism of the Mohr-Coulomb type bounding surface. To provide better simulation results on the volumetric response of rocks, the proposed model is coupled with a modified Rowe's stress-dilatancy rule. Besides, the finite strain concept is also introduced to provide a more precise description on the deformation of rocks under extreme high confinements or high stress conditions, the mechanical responses of which are characterized with highly-nonlinear and extremely large deformation. The proposed constitutive model has been validated by comparing modelling results with experimental data. Good agreement among modelling results and testing data demonstrates that, the proposed bounding surface model is capable to capture responses of porous rock under various stress conditions and better mechanical responses have been achieved by introducing the modified Rowe's dilatancy rule.

Keywords: bounding surface, CWFS, finite strain, stress-dilatancy, rock.

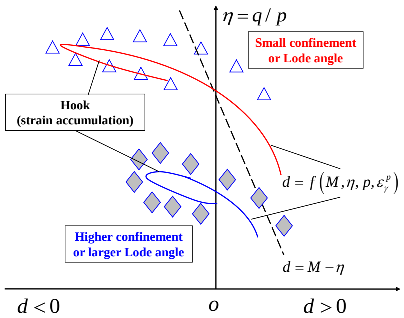

Fig. 1 Illustrations of the modified Rowe's stress-dilatancy rule

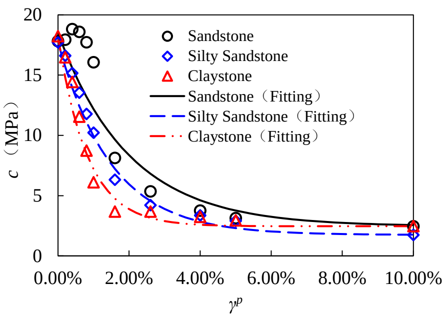

Fig. 2 Cohesion degradation on some rock samples

A HYPOPLASTIC MODEL OF GRANULAR SAND CONSIDERING GRAIN BREAKAGE AND WETTING EFFECT

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ABSTRACT

We present an extended hypoplastic model for the granular sand accounting for both grain breakage and wetting effect. The degree of grain breakage is accessed by the relative breakage ratio, which is the function of plastic potential energy. The variable critical state line (CSL) is adopted to reflect the effect of grain breakage on the dilatancy and strength. In addition, the wetting-dependent degradation of solid hardness is used to explore the wetting effect on the process of creep and stress relaxation. The model ability is validated by comparing the model simulation with the experimental data under various test conditions.

Abstract must be only workable on Microsoft Word (.doc and .docx) and submitted through the Email: iges.2023dec@polyu.edu.hk.

Keywords: Hypoplastic model; Grain breakage; Wetting effect; Variable CSL; Creep.

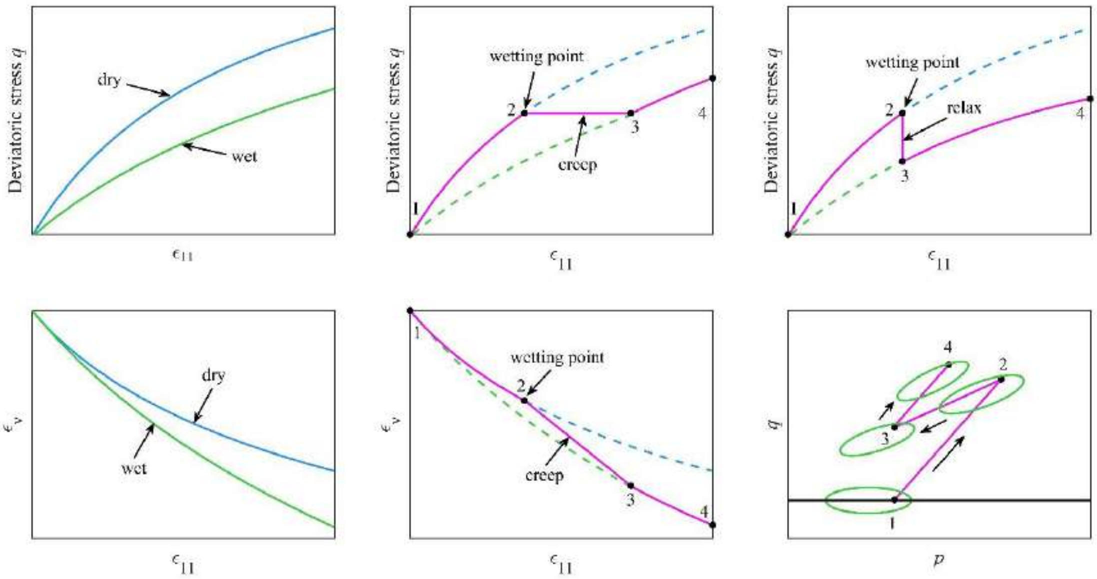

Fig. 1 Wetting effect on creep and stress relaxation

COMPRESSION BEHAVIOR OF CLAYEY SOILS WITH INITIAL HIGH WATER CONTENTS

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ABSTRACT

The compression behavior of very soft soils is of great importance for finite strain consolidation analysis. However, limited investigations of the compression features were reported. In this study, a modified apparatus based on the standard oedometer cell is designed firstly by incorporating a slight plexiglass cap, adding a fixed pulley and the weight tray, and replacing the traditional displacement measurement device using the non-contact laser displacement sensor. The enhanced oedometer apparatus was utilized to perform oedometer tests on two kinds of clayey soils. A minimum vertical stress of 0.025 kPa is applied on the soils, with a maximum initial water content of over eight times the liquid limit. The compression curve features and the effect of initial water content on the compression indexes were then discussed. The test results show that initial water content has great influence on the compression and creep parameters, e.g., C_c, Cs, and C_α. The compression curves of kaolinite clay with high initial water contents indicate that the C_c is changing with the effective stress increasing. Finally, a non-linear compression function with a compression limit that can capture the compression characteristics of soft soils better than the function with a constant compression index was proposed and verified.

Keywords: very soft soils; compression behaviour; improved oedometer apparatus; small stress; compression limit

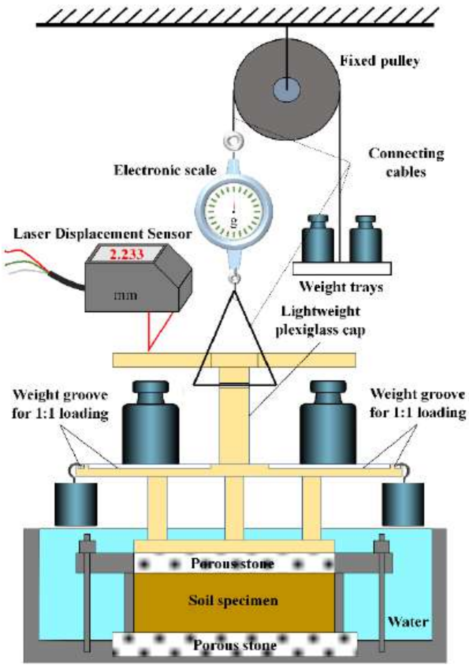

Fig. 1 Modified small stress oedometer system

MODELING THE TEMPERATURE-DEPENDENT BEHAVIOR OF HONG KONG MARINE DEPOSITS

Zejian Chen[1#], and *Jian-hua* Yin[2]
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ABSTRACT

Temperature plays a significant role in the stress-strain behavior of soils, especially the clayey soils under energy geo-structures and offshore pipelines. This study focuses on the modelling of temperature-dependent behavior of Hong Kong marine deposits (HKMD). Based on experimental results, a new thermal visco-plastic (TEVP) model is developed, considering the thermal elastic behavior, thermal creep behavior, as well as the structuration of clayey soils. Simulations on the one-dimensional and triaxial behavior of the soils subjected to various temperature and loading conditions were conducted for verification of the model. The TEVP model was then implemented in finite element models to simulate the fully thermo-hydro-mechanical coupled responses of typical Hong Kong marine deposits and its interactions with energy geo-structures considering long-term service and temperature cycles. The effects of heat exchange between the geo-thermal walls, piles, and the surrounding soil ground were discussed.

Keywords: temperature, clay, visco-plasticity, constitutive model, energy geotechnics

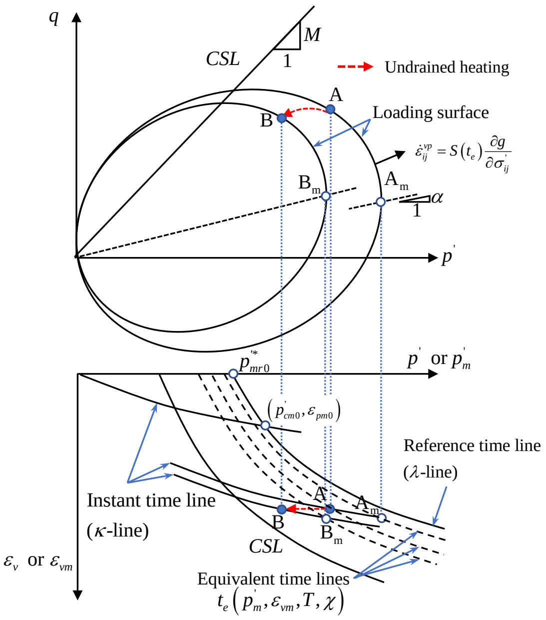

Fig. 1 Illustration of the thermal elastic visco-plastic model

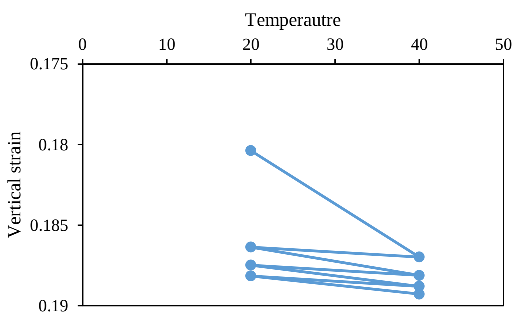

Fig. 2 Modeling the accumulative strain of HKMD due to thermal cycles

UNDRAINED CYCLIC RESISTANCE AND STIFFNESS OF ANISOTROPICALLY CONSOLIDATED CALCAREOUS SAND

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ABSTRACT

Calcareous soil deposits, which are the foundation materials for oil platforms, breakwaters, and onshore or offshore transportation infrastructures, are often under anisotropic stress conditions and thus sustain an initial static shear stress before undergoing cyclic loading during their service period. A series of cyclic triaxial tests were performed to investigate the anisotropic consolidation effect on undrained shear characteristics of a calcareous sand that has a similar grading curve to that of the standard siliceous Toyoura sand. The results exhibit that various stress conditions may lead to two distinct cyclic response patterns, namely the cyclic mobility and residual deformation accumulation. It is demonstrated that the anisotropic consolidation can either enhance or reduce the cyclic resistance and stiffness, depending on the relative density. The calcareous sand responses are compared to those of the siliceous Toyoura sand with similar relative densities. An interesting finding is that the calcareous sand is marginally stronger and stiffer than Toyoura sand at low degrees of anisotropic consolidation stress state; this trend reverses when the initial shear stress becomes large, under which the former typically has a lower resistance and stiffness than the latter.

Keywords: calcareous sand; anisotropic consolidation; cyclic resistance; stiffness; response pattern.

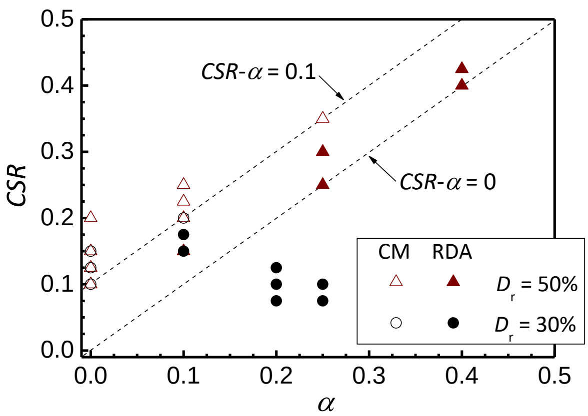

Fig. 1 Summary of cyclic response patterns and stress conditions

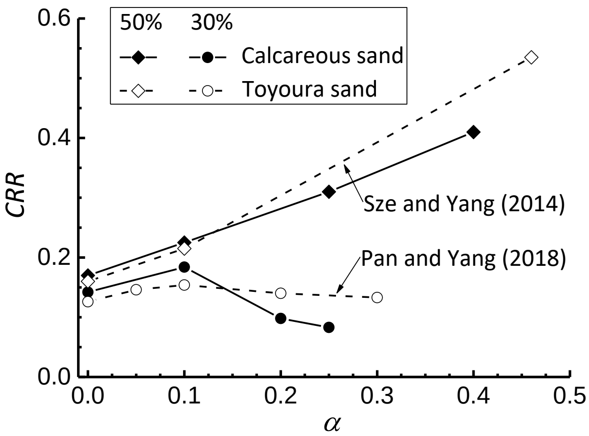

Fig. 2 Relationship between cyclic resistance ratio (*CRR*) and initial shear stress ratio (α)

RECENT ADVANCES AND APPLICATION OF HYPOPLASTICITY

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ABSTRACT

Understanding and modelling of the mechanical response of geomaterials has been the subject of several studies, one of which is the development of suitable constitutive models to mathematically describe the mechanical behaviours of soils. This presentation provides an overview of the latest advancements and practical applications of hypoplastic models. Six hypoplastic models, tailored to characterize various soil characteristics, will be presented. These models encompass considerations such as consolidation history for overconsolidated soils, structural effect for loess, inherent anisotropy for anisotropic clay, cementation for methane hydrate-bearing sands, time-dependency for sands and clays, and rate-effects for fast granular flows. Furthermore, the proposed hypoplastic model is adopted to characterize the mechanical behaviours of clastic shear zone soil in slow-moving landslides. This comprehensive exploration of hypoplastic constitutive models and their practical applications offers valuable insights into their growing significance within the field of geomaterial mechanics.

Keywords: Hypoplastic model, Overconsolidation, Rate-dependency, Inherent anisotropy, fast granular flow

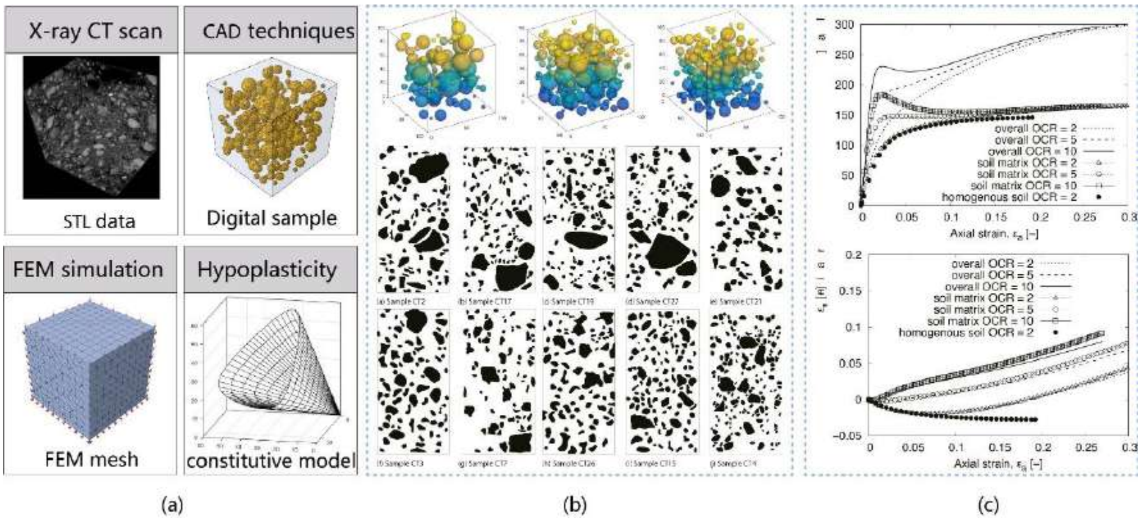

Fig. 1 Multiscale modeling of clastic shear-zone soils with the hypoplastic constitutive model: (a)modeling procedure, (b) 3D and 2D numerical models of clastic shear-zone soils, and (c) stress-strain curves of the soil matrix and clastic soils.

(For any further information, please contact the Secretariat: iges.2023dec@polyu.edu.hk)

INFLUENCE OF PARTICLE SHAPE ON THE MECHANICAL PROPERTIES OF SAND UNDER TRUE TRIAXIAL SHEARING

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ABSTRACT

Particle shape varies due to complex physical and sedimentation process, further affecting the contact mode under loading. The macroscopic mechanical properties of sand are influenced by microscopic particle shape. This study carries out true triaxial tests on mixture of silica sand and round (crushed) glass beads, examines the effect of particle shape on the mechanical properties of sand under three-dimensional stress condition. In combination of dynamic particle image analysis technique to quantitatively analyse the particle shape, the varying tendency of particle shape parameters with glass beads content is acquired. The coupled effect mechanisms between the intermediate principal stress and particle shape on the macroscopic mechanical response are investigated. The test results show that the glass beads-silica sand mixture with regular particle shape effectively suppresses the dilation characteristics of the mixture. For a given medium principal stress level, the peak friction angle of the glass beads-silica sand mixture increases with increasing particle shape irregularity, and the large principal strain corresponding to the peak strength decreases with increasing particle shape irregularity. In this experimental study, the varying tendency in peak strength of glass beads-silica sand mixture accompanied by the variation in the intermediate principal stress can be well predicted by the classical failure criterion.

Keywords: true triaxial test; particle shape; failure criterion

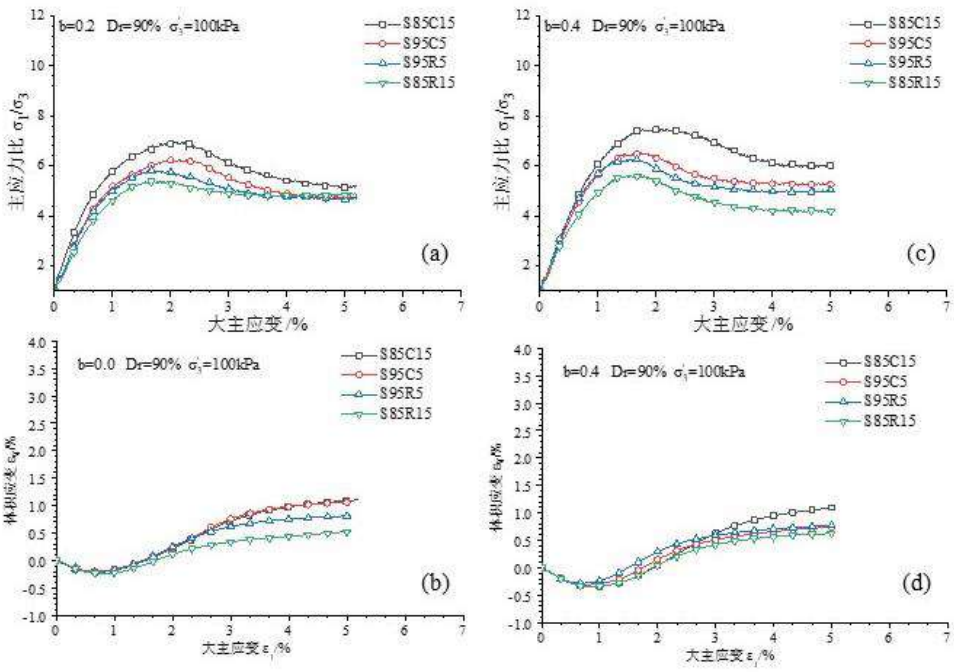

Fig. 1 Stress-strain curves of silica sand-glass beads mixture in true triaxial shear test

ANISOTROPIC ELASTO-PLASTIC COUPLING MODEL CONSIDERING FABRIC EVOLUTION

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ABSTRACT

For many solids, such as rocks, soils, and concrete, even within very small stress/strain range, the elastic response is also dependent on the experienced plastic process history, which is known as elastic-plastic coupling. Fabric anisotropy, a measure of the internal structure, is a distinct feature of soils that affects the mechanical responses significantly. Experimental evidences have clearly indicated that the initial anisotropic stiffness ratio of clay, quantified by G_{hh}/G_{hv}, is not equal to unity, as manifested by the oblique effective stress path at very small stress ratio in undrained tests. Furthermore, the ratio may gradually evolve during subsequent loading process companioned by the accumulated plastic deformation. In fact, the fabric of clay contains both the reversible and irreversible components, both evolving with the plastic deformation. To realistically describe the evolution of reversible and irreversible parts of anisotropy, this study develops an elasto-plastic coupled model within the framework of anisotropic critical state theory. By employing a unified fabric tensor and its evolution law, the model can desirably describe the evolution of anisotropic stiffness ratio and coupling effects on clays' mechanical responses. The predictive capability of the model is validated through the comparisons of model responses with the experimental data.

Keywords: Elasto-plastic coupling, fabric, reversible and irreversible strain, anisotropic stiffness ratio, plasticity

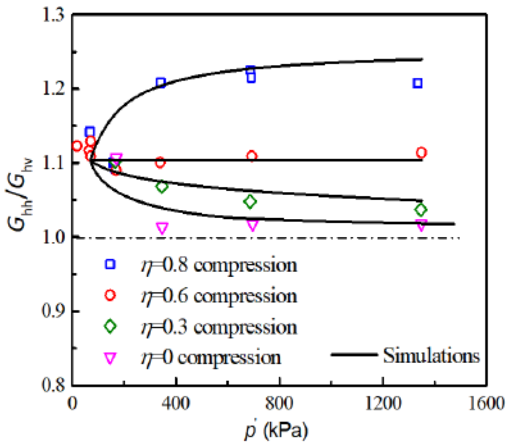

Fig. 1 The evolution of anisotropic stiffness ratio of Lucera Clay

Long-term mechanical characteristics and creep damage model of Jinping marble at different depths considering excavation disturbance

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ABSTRACT

This paper quantitatively analyzes the evolution law of the rock stress environment during the tunnel excavation, conducts long-term mechanical behavior simulations of the rock at different depths considering excavation disturbance, and explores the characteristics of creep deformation, creep rate, and long-term strength of Jinping marble at different depths. Research has shown that the creep process of marble is always in an expansion state, which is more obvious at high stress. The failure mode of the sample gradually transitions from splitting failure to conjugate shear failure, and then gradually transforms into macroscopic shear failure with a single failure section. As the burial depth increases, the deformation caused by excavation disturbance to the specimen and its ratio to the deformation when the specimen loses its bearing capacity increase, indicating that excavation disturbance has a significant impact on the deformation of deep surrounding rock. The paper proposes a creep damage factor that includes accelerating creep initiation time and creep failure time, and derives a creep nonlinear damage constitutive model for Jinping marble considering excavation disturbance at different depths. This nonlinear creep model has fewer parameters that are easy to obtain. It can better describe the accelerating creep characteristics of rock at different depths, especially for a more accurate description of the long-term creep mechanical behavior of deep rock.

Keywords: Rock creep, Excavation disturbance, Different depths, Creep damage model

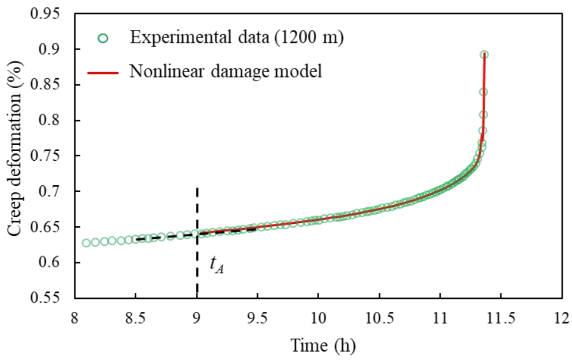

Fig. 1 Nonlinear creep model for accelerating creep stage of marble at different depths (e.g., 1200 m)

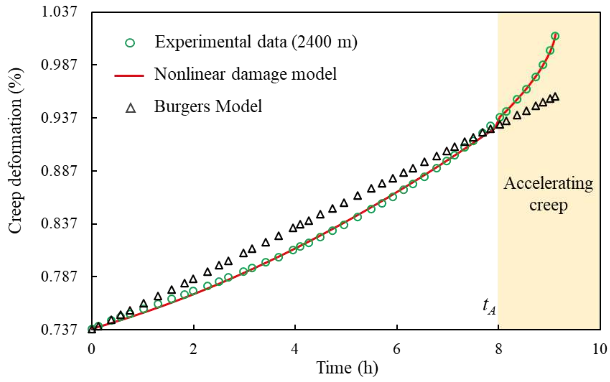

Fig. 2 Nonlinear damage model compared to Burgers model at the last stress level (e.g., 2400 m)

DESCRIPTION OF NON-COAXIALITY OF SAND INCORPORATING MATERIAL PROPERTY-DEPENDENT POTENTIAL THEORY

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ABSTRACT

It is well acknowledged that the plastic potential theory plays one of the kernel roles in the elastoplastic constitutive modelling of geomaterials. However, there implies coaxiality between principal stress direction and incremental plastic strain due to irrational isotropic assumption of material. In this paper, a novel property-dependent plastic potential theory for sand involving inherent fabric anisotropy is proposed incorporating the strain distribution rule with the micro-fabric property of sand to reasonably and simply describe the relation of non-coaxiality and anisotropy, and the associated influence of rotational principal stress axes. Incorporating the fabric tensor into the potential theory to address the effect of inherent anisotropy using the method of macro-micro combination, the proposed plastic potential theory could elaborate the macro-mechanical property of sand involving the initial anisotropic fabric, and the isotropic and anisotropic features of materials could be depicted unified naturally, with clearer physical meaning. The capability of the established theory to capture the non-coaxial response is analysed and verified under true triaxial stress conditions.

Keywords: plastic potential theory; initial fabric anisotropy; material property-dependent; sand

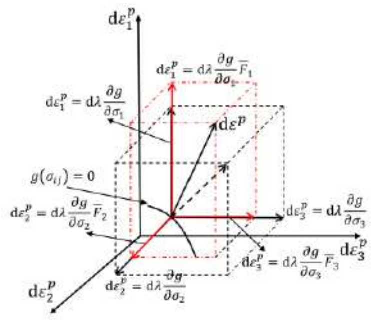

Fig. 1 Illustration of plastic strain increment of property-dependent plastic potential theory.

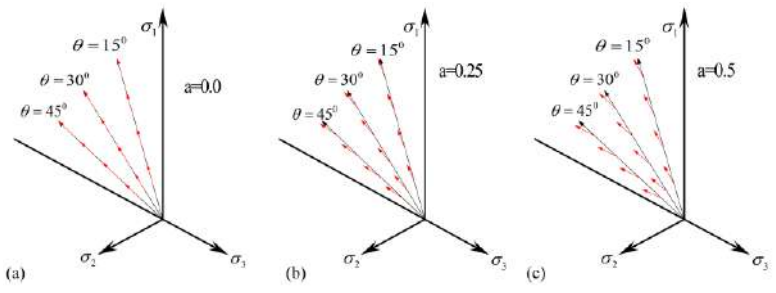

Fig. 2 The deviation between stress increment and strain increment: (a) a=0, (b) a=0.25, (c) a=0.5.

RISK ANALYSIS OF DAHUA LANDSLIDE BASED ON RELIABILITY THEORY

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ABSTRACT

The Dahua landslide of the basic geological conditions and the basic physical and mechanical parameters of rock mass is briefly introduced. With the landslide partition, considering the correlation coefficient influence on reliability index **β** by the cohesion **c** and friction angle coefficient f, the damage probability of the landslide is obtained using the simulation method of Monte-Carlo and First Order Second Moment (FOSM). In view of three load coupling conditions of the natural weight, rainstorm, Ⅶ earthquake, the instability of landslide probability is estimated. Then, the hazard probability and scope of landslide are analyzed and calculated, and the loss consequence of landslide is estimated by LEC Method. The corresponding treatment scheme is put forward to provide reference for engineering construction.

Keywords: reliability; landslide; disasters; risk analysis；LEC method

A HYDRODYNAMIC MODEL OF CHEMICAL DISSOLUTION OF POROELASTIC MATERIALS

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ABSTRACT

Geomaterials, under certain hydrochemical environment, might be vulnerable to chemical dissolutions which tends to weaken the strength of geomaterials and potentially causes catastrophic failures. As the ionic species in the pore fluid evolve during dissolution, we introduce the mass fractions of all the ionic species as independent state variables into the hydrodynamic procedure and develop a mathematically rigorous and thermodynamically consistent modelling framework to address the impact of solid dissolutions on the constitutive properties of poroelastic geomaterials. The development is foundational in that it focuses only on saturated poroelastic systems without accounting for the particle crushing, localised plasticity, and surface tensions. However, the theory can be further expanded to deal with such inelastic features under various saturation regimes. For simplicity, the density-dependent linear elasticity is adopted whereby the stiffness degrades as the solid skeleton dissolves and pore fluid pressure is governed by both osmolarity and compressibility. The developed model generalizes the empirical mass transport equations to account for the coupled diffusive phenomenon induced by the gradients of both pressure and ionic concentrations. Numerical analysis following the standard finite element method has been performed to study the long-term dissolution-induced deformation. Experimental observations of the long-term debonding tests of calcarenite under both oedometric and unconfined conditions are used to validate the model performance.

Keywords: dissolution, thermodynamics, hydrodynamics, porous media, chemomechanical coupling.

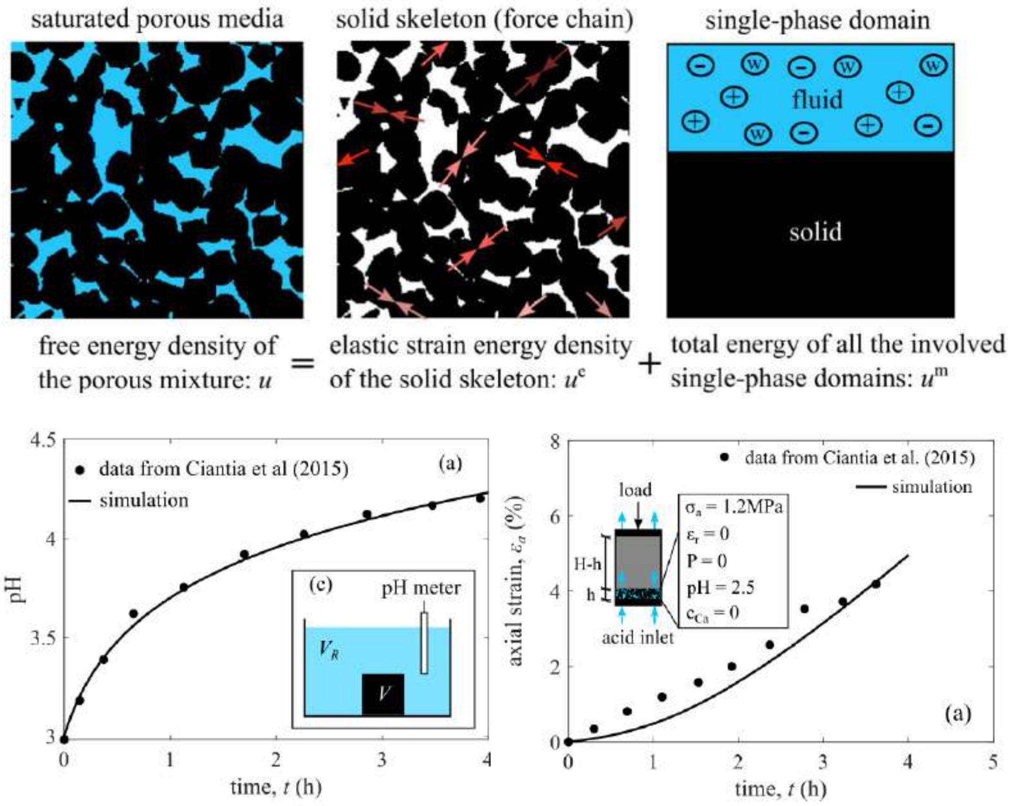

Fig. 1 Energy separation of the hydrodynamic model and its prediction performance

METHANE HYDRATE-BEARING SEDIMENTS: FROM DEM SIMULATION TO CONSTITUTIVE MODELLING

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ABSTRACT

Methane hydrate (MH) consists of methane trapped within water crystals, making it one of the most promising energy resources to address current and future energy needs. However, the mechanical properties of MH-bearing sediments (MHBS) are remarkably intricate and rely on MH saturation, temperature, water pressure, and chemical conditions. To ensure the safe and effective exploration of MHBS, it is vital to develop a solid understanding of their mechanical properties and preemptively identify gas hydrate-drilling related hazards. We first explored the effects of hydrate cementation and intermediate principal stress on the mechanical behavior of grain-cementing type MHBS under both drained and undrained conditions using the Discrete Element Method (DEM) and the coupled Computational Fluid Dynamics-Discrete Element Method. Then, we proposed a constitutive model for MHBS based on insights drawn from the DEM simulations and preexisting laboratory experiments. This model is an extension of the SANISAND-C model that was originally developed for sands with low cement content. It successfully captures the mechanical properties of MHBS that takes into account various hydrate occurrence habits (hydrate-cementing, pore-filling, and grain-coating) and environmental factors (temperature, pore pressure, and salinity).

Keywords: Constitutive model; Plasticity; Methane hydrate; Cementation; Discrete element method.

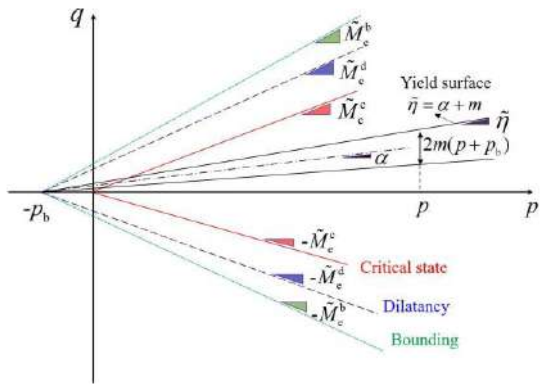

Fig. 1. Schematic illustration of the model surfaces

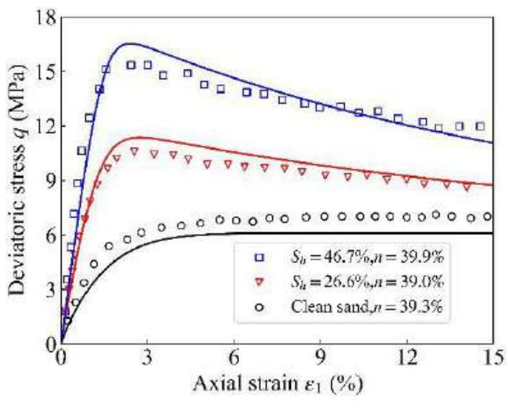

Fig. 2 Model predictions compared with laboratory tests on MHBS

Anisotropic Rock Mechanics and Engineering Application

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ABSTRACT

Anisotropy is the fundamental property of engineering rock mass. Academic research and practical engineering application in hydropower projects are conducted systematical. These studies and investigations cover various aspects such as deformation characteristics, strength properties, constitutive models, coupled mechanical models for anisotropic behavior, and multi-scale numerical simulation methods and their engineering applications. In terms of deformation characteristics, it was derived anisotropic Boussinesq solutions and established a back-analysis method based on bearing plate tests. It was proposed an analytical solution for determining anisotropic deformation parameters. Case studies from the Baihetan Hydropower Station indicate that the primary factors controlling anisotropic deformation are column tilt, the EDZ region, intralayer dislocation zone and size effects. For strength characteristic of anisotropic rock mass, the relationship between anisotropic rock strength and acoustic wave velocity has been established, along with numerical simulation methods for both continuous and discontinuous media. In anisotropic rock mechanics constitutive models, classical isotropic criteria have been extended to anisotropic mechanics through the spatial distribution of strength parameters. A microstructure tensor based anisotropic yield criterion and an anisotropic nonlinear model considering the tensile strength of tensor bands was established based on the microstructure tensor theory. A mechanical model for anisotropic damage was developed by combining tensor yield function with anisotropic damage. In coupled mechanical models, orthogonal joint rock mass seepage-stress physical configurations have been explored. Furthermore, the permeability of anisotropic rocks and derived permeability tensors from joint spatial distributions are characterized. Dual-medium seepage simulations specific to anisotropic rocks was executed. Multi-scale numerical simulation methods suitable for large-scale hydropower projects have been illustrated, overcoming challenges in constitutive models and parameter values for continuous media. These studies have been applied in Baihetan Hydropower Station with case studies demonstrating the scientific and effective application related to anisotropic rock mechanics.

Keywords: anisotropic rock mechanics; deformation; strength; hydromechanics coupling; creep; Baihetan hydropower project

Modeling of monotonic and cyclic behaviors of sand under small and normal confining stresses

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ABSTRACT

Soil is commonly confined under very small stress at shallow depth of ground and in small scale 1g model test. Considering Toyoura sand as example, it shows relatively less compressibility under small confining stress (<50 kPa) than normal confining stress (50~1000 kPa) in bothstatic and dynamic conditions. To investigate the mechanical behavior of Toyoura sand under different confining stresses (CS), a series of element tests were conducted. These tests were performed on loose and medium dense sand by applying isotropic consolidation and unloading conditions, under the confining stress ranged from very small to normal values (5 kPa~700 kPa). It is found that the gradient of *e*-ln*p* curves of both loose and medium dense Toyoura sands consolidated under 700 kPa is about 2.5 times of the specimens consolidated under 50 kPa. While during unloading, the gradient of *e*-ln*p* curves of specimen consolidated under 700 kPa is about 3 times of the specimen consolidated under 50 kPa. Based on these test results, a new model is proposed, and a new power function relationship between void ratio and confining stress is established. The proposed model is verified by isotropic consolidation tests, drained monotonic triaxial tests, and undrained cyclic triaxial tests.

Keywords: Small confining stress; constitutive model; monotonic and cyclic triaxial tests; Toyoura sand.

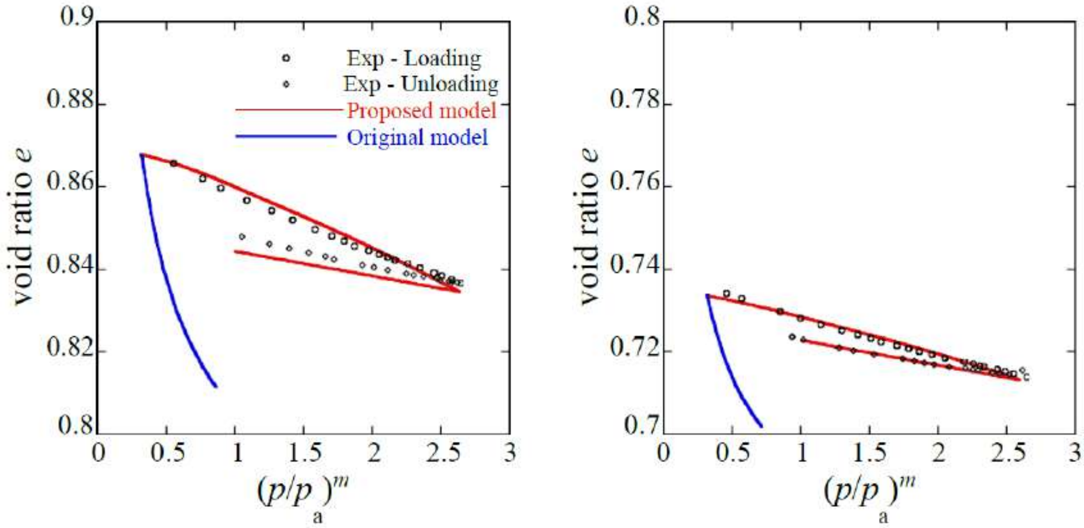

Fig. 1 Comparison between test and simulated isotropic consolidation and unloading

INVESTIGATION ON THE PROPAGATION OF COMPLEX MULTIPLE FRACTURES IN ROCKS

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ABSTRACT

Engineering rock disasters are frequently triggered by the propagation and coalescence of pre-existing multiple fractures within rock masses. However, the unique characteristics of the engineering hard rock environment and the complexity of its multiple fracture systems have imposed limitations on most numerical methods used to simulate rock fracture behavior, as they are presently confined to small scales and a restricted number of fractures. To address the challenge of modeling complex multiple fracture propagation, we propose a stress-based crack propagation criterion that integrates the maximum circumferential stress with a Mohr-Coulomb failure criterion, incorporating a tensile cut-off. Additionally, we have developed a dynamic mesh regenerating and interface adding method to represent multiple crack topologies, utilizing the concept of ideal electron interactions influenced by Coulombic forces. Moreover, an improved potential function-based algorithm has been established to simulate crack surface contact mechanisms. These novel algorithms have been implemented in the Cellular Automata Software for engineering Rockmass fracturing process (CASRock), successfully demonstrating the accurate reproduction of the initiation, propagation, and mutual interactions of complex multiple cracks within rock masses.

Keywords: rock complex multiple fracture; simulation; propagation criterion; mesh generation; contact.

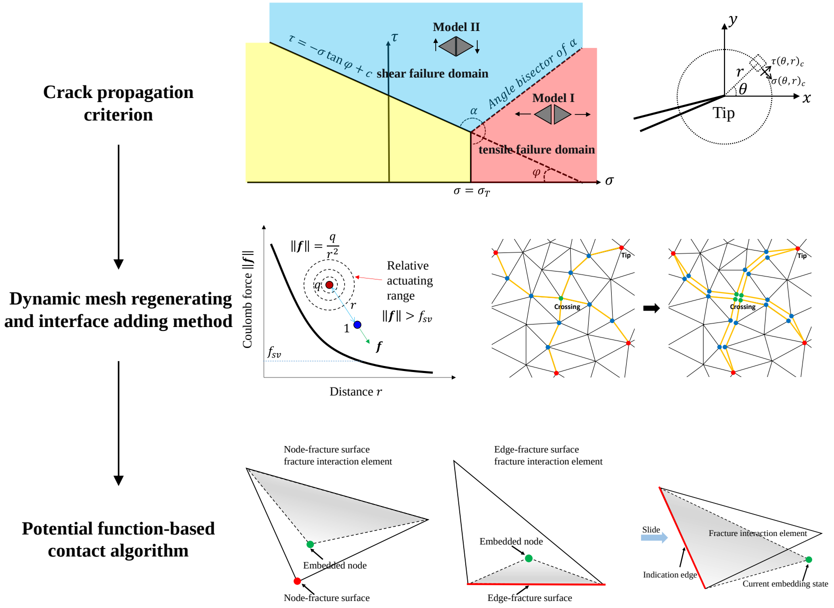

Fig. 1 Illustration of the proposed method

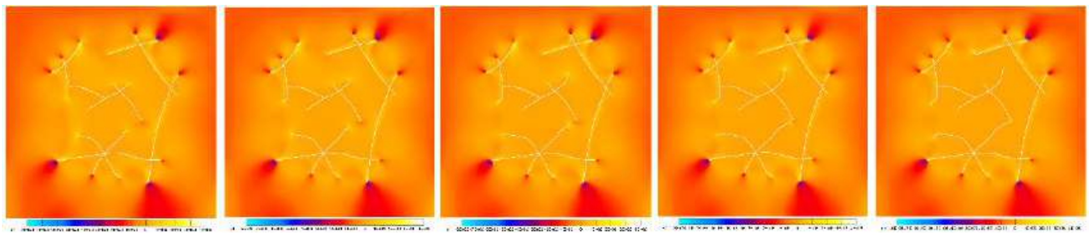

Fig. 2 Reproduction of the propagation of complex multiple fractures in rocks

A BOND-LEVEL ENERGY-BASED PERIDYNAMIC MODEL FOR BRITTLE FRACTURE IN GEOMECHANICS

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ABSTRACT

In this work, we propose a bond-level energy-based peridynamic model for capturing brittle fracture phenomena in geomechanics, which deals with the numerical simulation of initiation and propagation of mixed mode fracture in rocks. In our model, we develop a dilation function to capture both volumetric and deviatoric deformations. We proceed to define the nonlocal stresses to obtain the isotropic and deviatoric forces commensurate with the deformations. We then come up with a new failure model to link computational peridynamics with some phenomenological failure criteria, which is highly relevant for both brittle and quasi-brittle rocks. Finally, several numerical examples of mixed-mode fractures are presented to show the performance of our model.

Keywords: Ordindary state-based peridynamics, Nonlocal stress tensor, Energy-based failure criteria, Mixed-mode fracture, Rock materials.

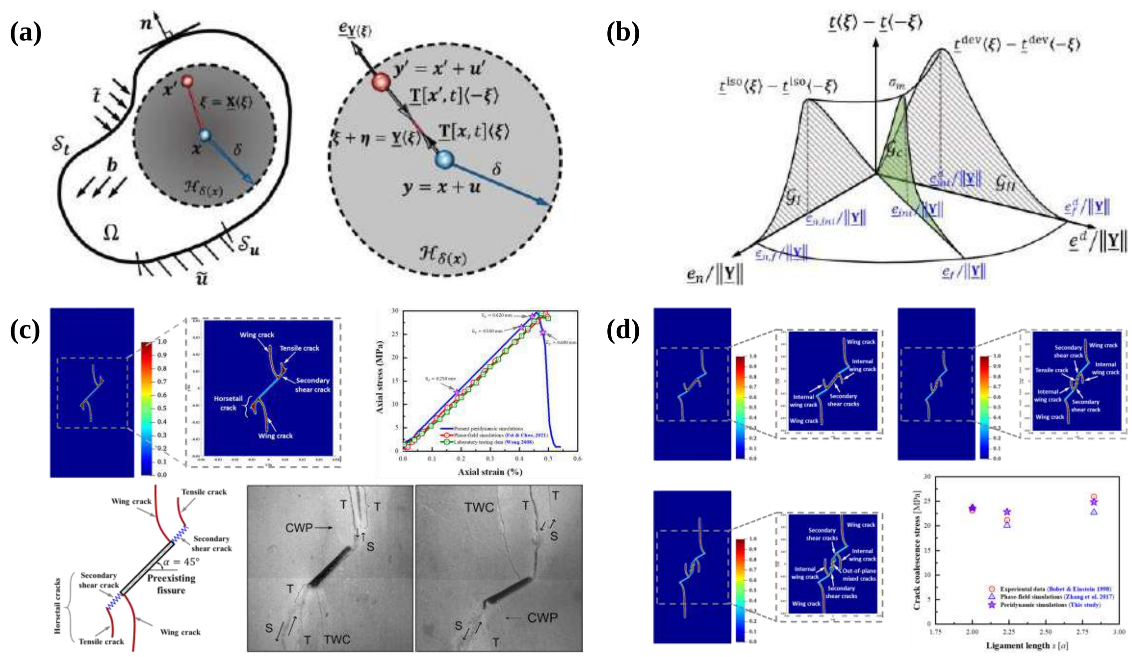

Figure 1. (a) Schematic diagram of state-based peridynamic model; (b) schematic illustration of mixed-mode fracture in brittle and quasi-brittle rocks; (c) numerical results of crack initiation and propagation; and (d) numerical results of crack propagation and coalescence.

FINITE PARTICLE METHOD FOR STRUCTURAL COMPLEX BEHAVIOUR ANALYSIS

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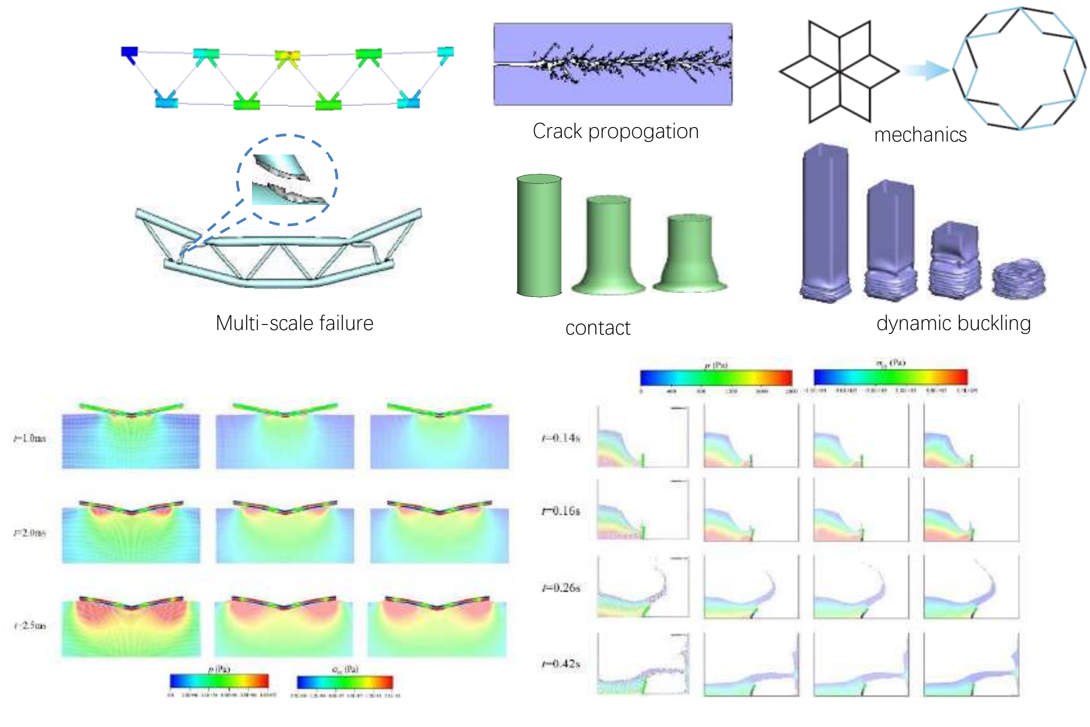
ABSTRACT

Finite Particle Method (FPM) is a recently proposed method for structural behaviour analysis. Different from the traditional methods generated from continuum mechanics and variational principles, the FPM is based on the vector mechanics. With the description of point values and path units, the FPM models the physical body composed of finite particles whose motions are described by Newton's second law. In the FPM, no iterations are necessary to follow nonlinear laws, and no matrices are formed or solved. These features make the FPM have more advantages than traditional methods in the complicated behaviour analysis of structures, including dynamic responses, geometric nonlinearity, material nonlinearity, buckling or wrinkles failure, mechanism motion, contact and collision, fluid-solid coupling etc. A graphics processing unit (GPU)-based parallel algorithm is proposed for the FPM analysis frame. Furthermore, the algorithm's performance is investigated via a large-scale contact problem, and the maximum speedups of total computational time and contact calculation reach 28.5 and 77.4, respectively, relative to commercial finite element software Abaqus/Explicit running on a single-core central processing unit (CPU). The contact calculation time percentage of the total calculation time is only 18% with the FPM, much smaller than that (50%) with Abaqus/Explicit, demonstrating the efficiency of the proposed method. Fig.1 shows some examples of the complex behaviour analysed by FPM.

Keywords: finite particle method; fracture; large deformation; GPU-based parallel algorithm; fluid-solid coupling.



Fluid-soid coupling

Fig. 1 FPM for structural complex behaviour analysis

ANALYSIS OF SOIL SPATIAL VARIATION BASED ON COUPLED MARKOV CHAIN AND GENERAL REGRESSION NEURAL NETWORK

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ABSTRACT

Gaining a comprehensive understanding of underground soil characteristics remains challenging due to the limited information that can be obtained in real practice. In this study, we proposed an algorithm, which combines the capabilities of the general regression neural network and the Markov chain method to reconstruct underground stratification patterns using limited borehole data. The technique of general regression neural network is employed to assess geological variations across inclined orientations, while the Markov chain method is leveraged to analyse shifts in soil types with changing depths. The proposed method is intuitive and can effectively predict geological features. Additionally, this method can be extended into three-dimensional scenarios without imposing high computational demands. One real-world case was evaluated to validate the performance of the proposed model. Furthermore, we utilized the principles of information entropy theory to quantify stratigraphic uncertainty as shown in Fig. 1. The findings provide a visual depiction of the distribution of stratigraphic uncertainty. A practical implication of this research is to identify the potential additional borehole locations. Incorporating these locations can help mitigate the stratigraphic uncertainty at construction sites.

Keywords: Soil stratification, stratigraphic uncertainty, spatial variation.

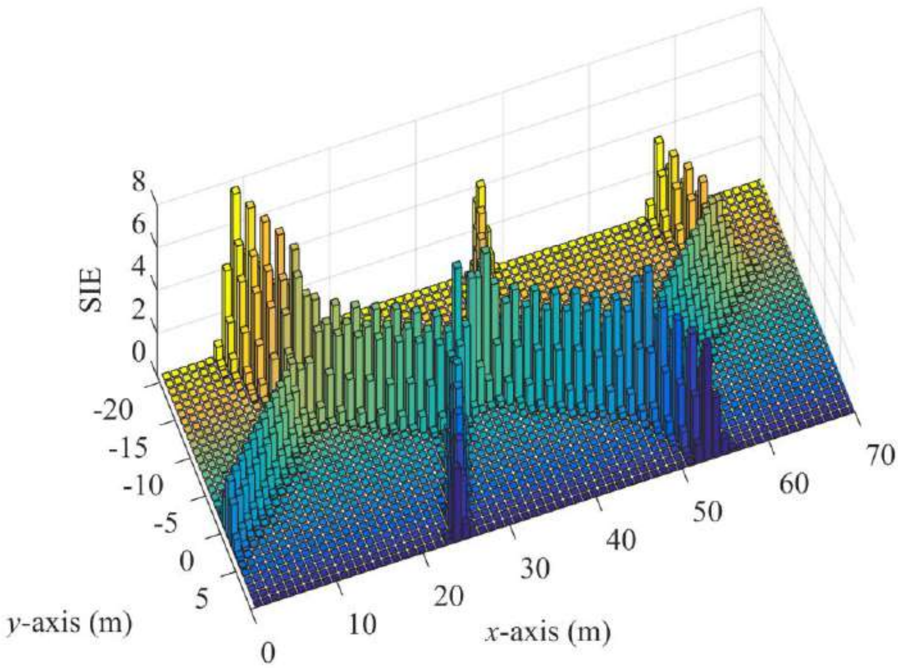

Fig. 1 Summation of information entropy along with depth

GRAIN-SCALE MODELLING OF SANDSTONE FAILURE USING REALISTIC MICROSTRUCTURES FROM CT-SCAN DATA

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ABSTRACT

Many widely used numerical models of rock failure based on mesoscale properties tested in laboratory neglect microstructure effects. They therefore cannot explain grain boundary and pore effects on rock failure and consequently are inadequate for models of rock destruction that exploit point and indentation stresses (e.g., water jet drilling). To investigate microscale failure mechanisms of granular rocks in diverse scenarios, we develop a novel numerical workflow consisting of a computerized tomography (CT) based microstructure construction approach (see Figure 1) and a complementary mechanical numerical approach. The construction approach extracts the realistic rock microstructure and transforms the large voxel number CT-scan data into significantly fewer triangular/tetrahedral elements. The combined finite-discrete element method (FDEM) with grain-based model (GBM) is adopted to solve the mechanics. The novel numerical workflow is first validated by a 2D Brazilian tensile test and then is applied to understanding the sandstone failure mechanisms in the context of water jet drilling where the rock is drilled by a high-speed jet with a diameter of only several grain size (see Figure 2).

Keywords: Grain-scale modelling; CT-scan data; Combined discrete-finite element method; Rock microstructure

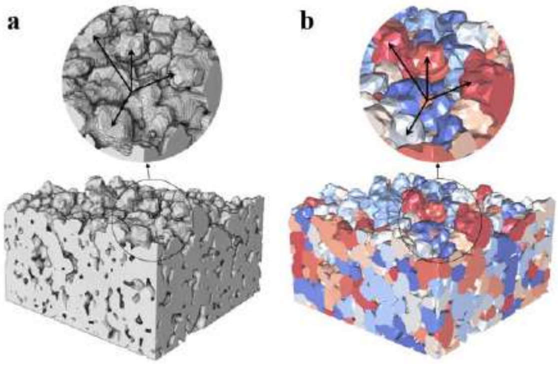

Fig. 1 Construction of sandstone microstructures for grain-scale modelling: (a) CT-scan data, and (b) tetrahedra-based numerical sandstone microstructures.

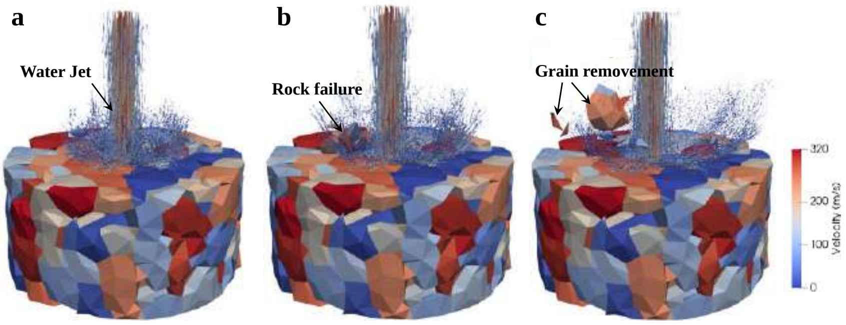

Fig. 2 Grain-scale modelling of water jet drilling in sandstone.

A NOVEL HYDRO-MECHANICAL COUPLED MULTIPHYSICS APPROACH FOR SEEPAGE FLOW INDUCED INTERNAL EROSION AND FAILURE OF LOOSE GRANULAR DEPOSITS

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ABSTRACT

The groundwater-induced internal erosion of the finer soil fraction played a significant role in initiating the collapse of the slope. However, developing a robust computational model to accurately capture the complex processes involved in unsaturated seepage, particle migration, and the evolving hydro-mechanical properties of soils, leading to the prediction of slope failure initiation, remains a challenging task. In this study, a comprehensive three-phase five-component mathematical model (see Fig. 1) was formulated based on mixture theory to describe the multiphysics phenomena associated with seepage erosion in unsaturated porous media. The proposed computational framework was solved using an enhanced stabilized finite element method and validated against analytical solutions of benchmark tests. Through this approach, the spatio-temporal evolution of the eroded zone and the hydro-mechanical response in flume tests conducted on loose steep artificial slopes were successfully identified. The results demonstrated that volumetric settlements and shear sliding were the major consequences of internal erosion, with the degradation of soil near the slope toe accelerating the slope's sliding failure. Neglecting the phenomenon of internal erosion in the soil would delay the onset of slope failure and underestimate the severity of slope collapse (see Fig. 2). The proposed computational framework proved to be efficient in predicting the initiation of slope failure induced by seepage erosion.

Keywords: internal erosion; slope failure; unsaturated porous media; seepage flow; stabilized finite element method.

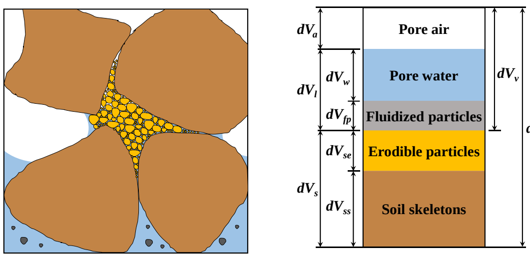

Fig. 1 Conceptual representation of a three-phase five-component model for unsaturated porous media

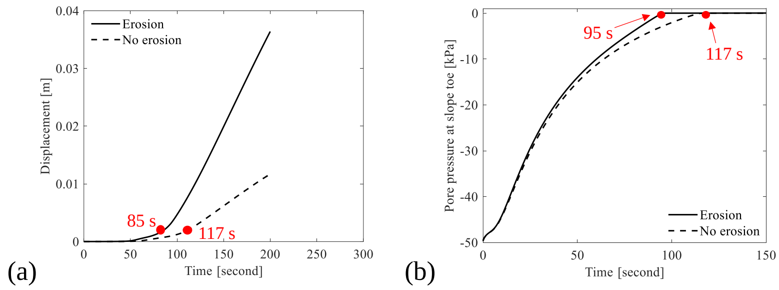

Fig. 2 Temporal variation of (a) displacement magnitude and (b) pore water pressure at slope toe for the cases considering and without internal erosion

NUMERICAL STUDY FOR STRAIN LOCALIZATION AND CRACK PROPAGATION OF GEOMATERIALS BASED ON IGA

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ABSTRACT

For geomaterials, strain localization and crack propagation are the precursors to the progressive failure and major cause for failure of various geotechnical structures (such as landslide and foundation instability). Combined with the Biot-Cosserat continuum theory and phase field approach, the isogeometric analysis (IGA) is developed to simulate the strain localization and crack propagation occured in geomaterials in this study, respectively. The numerical results demonstrate that Biot-Cosserat-IGA can solve the ill-posed problem as strain localization occured and effectively alleviate the mesh distortion in the shear bands when materials experience large deformation, and provides a smooth pore pressure gradient field to ensure the local mass balance of pore fluids and accurate simulation of the volumetric strain of the element. To reduce the high computing cost in the application of phase field models in geotechnical engineering, we propose an adaptive IGA of the phase-field model for simulating rock fracture using a novel refinement criterion and an improved data transfer operator. The proposed method is shown to decrease the calculation time and storage requirements by over 90% compared to the uniform refinement in most cases, and the computing time of incorporating non-equal order cells is 35.23% less than that of the equal order case.

Keywords: strain localization; crack propagation; IGA ; phase field approach; Biot-Cosserat continuum.

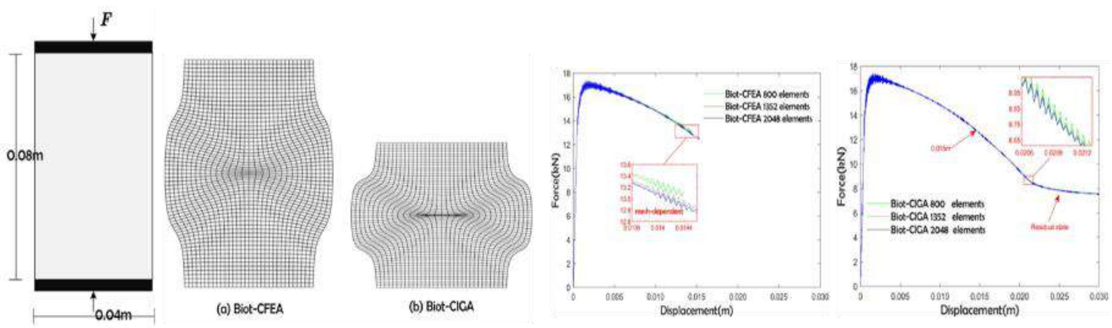

Fig. 1 The numerical results of the Biot-Cosserat-IGA

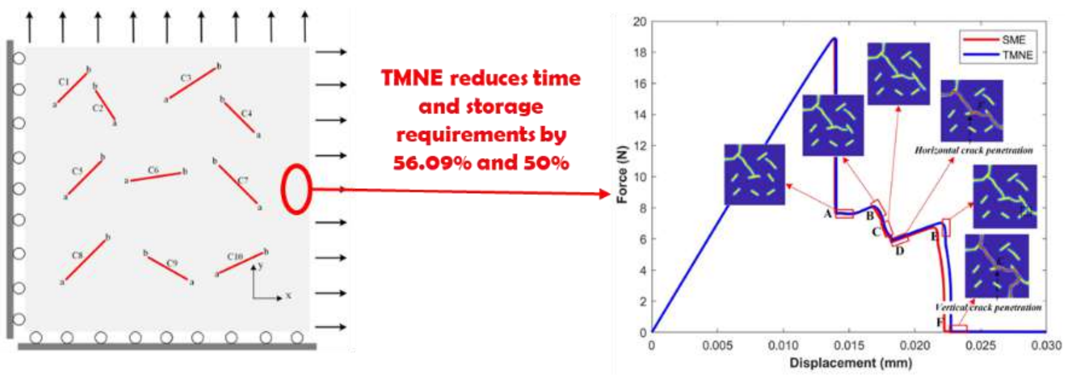

Fig. 2 The numerical results of the adaptive IGA of the phase-field model for simulating rock fracture

DAMAGE AND CRACKING MODELING IN POROUS MEDIA WITH THM COUPLING AND ENGINEERING APPLICATION

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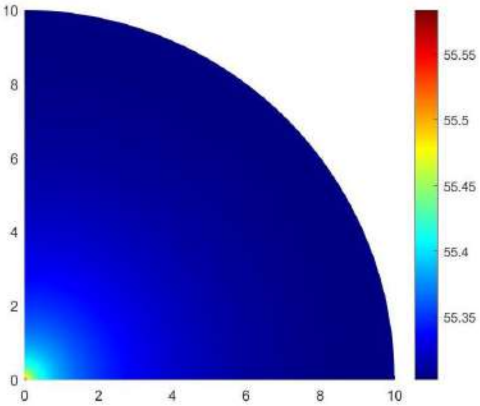
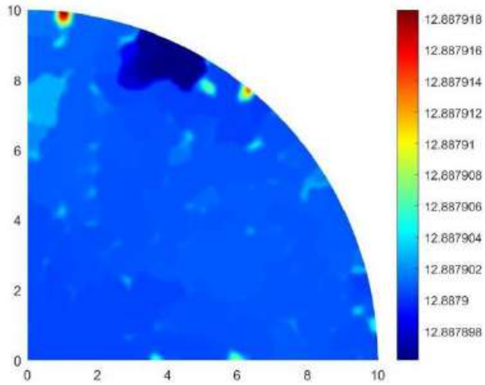
ABSTRACT

Cracking is the main mechanism of failure of brittle materials. Its description is crucial for the durability analysis of structures. In cohesive materials, the failure is generally due to the transition from diffuse damage to localized cracks. In the first part, we present a micromechanics inspired damage model. It takes into account properly the unilateral effect due to crack open-closure and friction-damage coupling. Particular attentions are paid on effects of pore fluid pressures on damage evolution kinetics. Based on such damage model, in the second part, we present a numerical method based on the variational principle of fracture mechanics. However, the specific emphasis is put on modelling of shear and mixed cracks in rock materials under compression-dominating stresses. Again, the effect of pore pressures is taken into account. Finally, some application examples are presented. In particular, the thermo-hydromechanical responses and the evolution of damaged zones due to excavation, heating around underground galleries are investigated, in the context of geological disposable of nuclear waste.

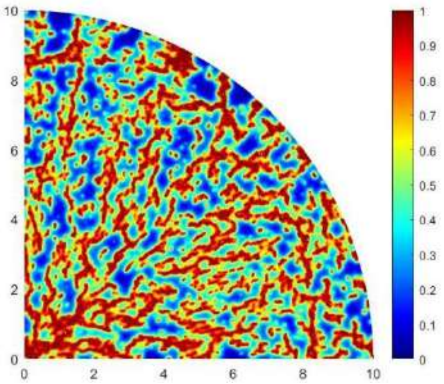
Keywords: Damage, Cracking, Phase-field, porous materials, THM coupling



(a) Temperature



(b) Pore pressure



(c) Tensile damage

Fig. 1 An example of tensile damage due to increase of temperature in saturated heterogeneous porous material under undrained condition

Suffusion characteristics of gap-graded granular materials: effects of particle size ratio and fines content

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ABSTRACT

Suffusion is a progressive process and can trigger severe engineering disasters, such as dam failure and uneven settlement and sinkholes. While the geometric condition is inherent to the soil, its influence on the suffusion resistance has not been thoroughly studied. This study investigates suffusion by conducting a series of coupled computational fluid dynamics and discrete element method (CFD-DEM) simulations with different fines contents and particle size ratios. The change of local void fraction is analyzed by Voronoi tessellation, while changes in contact network efficiency are monitored through various coordination number measures and contact force proportions. The results reveal that specimens with larger fines content and particle size ratio tend to lose more fine particles and experience greater volume deformation. The increased severity of suffusion with the rise in particle size ratio can be attributed to the widening disparity in local pore characteristics between coarse and fine particles, while the impact of fines content can be attributed to the varying contribution of fines to the soil skeleton.

Keywords: Suffusion; CFD-DEM; Voronoi tessellation; Local void fraction; Contact types

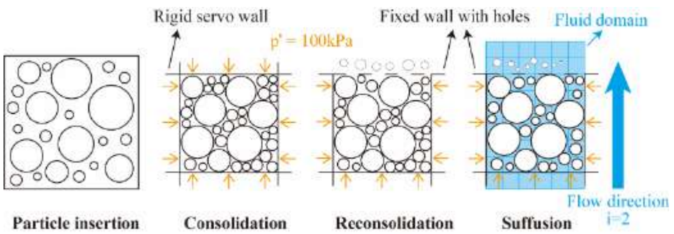

Fig. 1 Procedure of Simulation

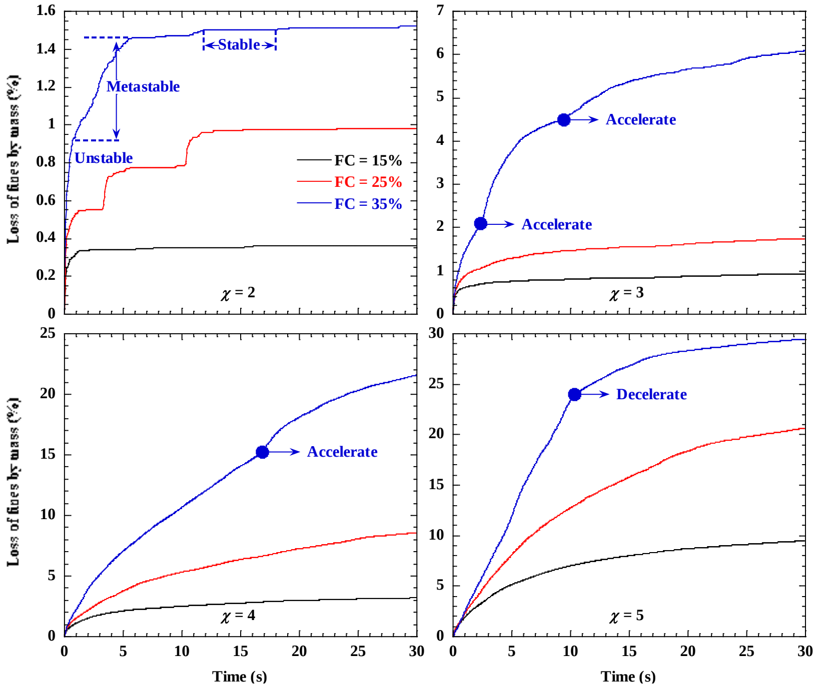

Fig. 2 Accumulated loss of fines by mass over time

LAGRANGIAN CONTINUUM MECHANICS-BASED SIMULATION FOR PARTICLE SIZE SEGREGATION IN GRANULAR FLOW

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ABSTRACT

In this work, the particle size segregation in granular flows is investigated with smoothed particle hydrodynamics. We first present the Lagrangian description continuum mechanics-based governing equations, including the linear momentum conservation and the segregation-diffusion equation. Then, the hybrid continuum surface reaction scheme is introduced to formulate the concentration-related inhomogeneous Neumann boundary condition on the boundary. A two-stage strategy is proposed to advance the boundary particle searching and normal direction identification. Moreover, an accurate segregation flux gradient along the boundary with C1 consistency is achieved based on the Taylor series. Our SPH model is validated with a shear box experiment. The model is finally applied to investigate the segregation mechanism in bidisperse-sized granular flows in a rotating drum.

Keywords: Particle size segregation; Hybrid continuum surface reaction scheme; Inhomogeneous Neumann boundary condition; Smoothed particle hydrodynamics

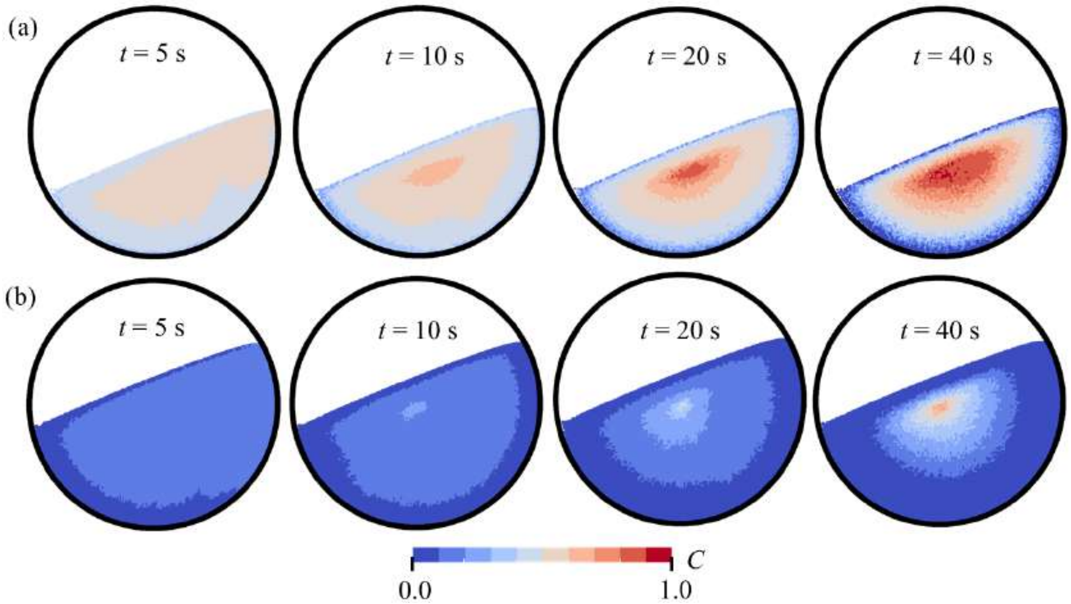

Fig. 1 Snapshots of segregation evolution in a rotating drum initialized with (a) equal volume (C_0 = 0.5) and (b) equal number (C_0 = 0.11)

TWO-FLUID MODELING OF HIGH-WATER SLURRY'S SEDIMENTATION AND CONSOLIDATION UNDER VACUUM PRELOADING

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ABSTRACT

The high-water content slurry, a mixture of liquid and particle phase (soil particles), displays significant flow and solid deformation characteristics under varying water contents. To simulate slurry's dewatering and thickening under vacuum preloading with prefabricated vertical drains (PVDs), this work adopts a two-fluid model (TFM) within the computational fluid dynamics (CFD) framework. The viscous flow of slurry, the interaction force between the liquid and solid phase, and the compression of the solid phase are both implemented into the model. Model validation is achieved by comparing simulation results with two real-world experiments. The simulation results quantify the vacuum pressure's progression and "soil column" development (solid phase) during the vacuum preloading process. The dependence of soil column phenomenon on sludge's water content, soil properties, and the applied vacuum pressure is explored and analysed. A further advantage of the proposed model is its low computational demands, making it suitable for representing large-scale engineering projects under diverse boundary and load conditions.

Keywords: vacuum preloading; slurry; fluid-driven particle flow; TFM; consolidation

THE DEVELOPMENT OF JC-JHB-DLSM MODEL AND ITS APPLICATION IN HIGH-VELOCITY PENETRATION OF GEOMATERIALS

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ABSTRACT

In the course of high-velocity penetration, projectiles often induce severe impact effects while causing damage to both the target and projectile. Distinctive in its simplicity of modelling, meshless nature, computational efficiency, and straightforward implementation, Distinct Lattice Spring Model (DLSM) has been extensively adopted to address complex deformation such as explosions and penetration. To discern the dynamic response characteristics of projectile-target interactions during penetration, a coupling approach is employed, integrating the Johnson-Cook failure model and the Johnson-Holmquist-Beissel (JHB) failure model with DLSM. In this approach, the Johnson-Cook damage model is applied to model dynamic responses of projectile, while the JHB damage model is employed for brittle target materials, reproducing the penetration processes involving materials of differing properties. The capability of the developed JC-JHB-DLSM has been validated through simulations involving metallic projectiles impacting metallic targets at varying velocities. The resultant damage features, crater depth, and volume are meticulously compared with experimental results to ascertain the applicability of the model in scenarios of substantial plastic deformation due to impact. Furthermore, the applicability of the JC-JHB-DLSM approach in diverse material dynamics impact problems is extended through simulations of metallic projectile impacts on granite targets across different velocities.

Keywords: high-velocity penetration, Johnson-Cook failure model, Johnson-Holmquist-Beissel failure model, DLSM model, dynamic responses.

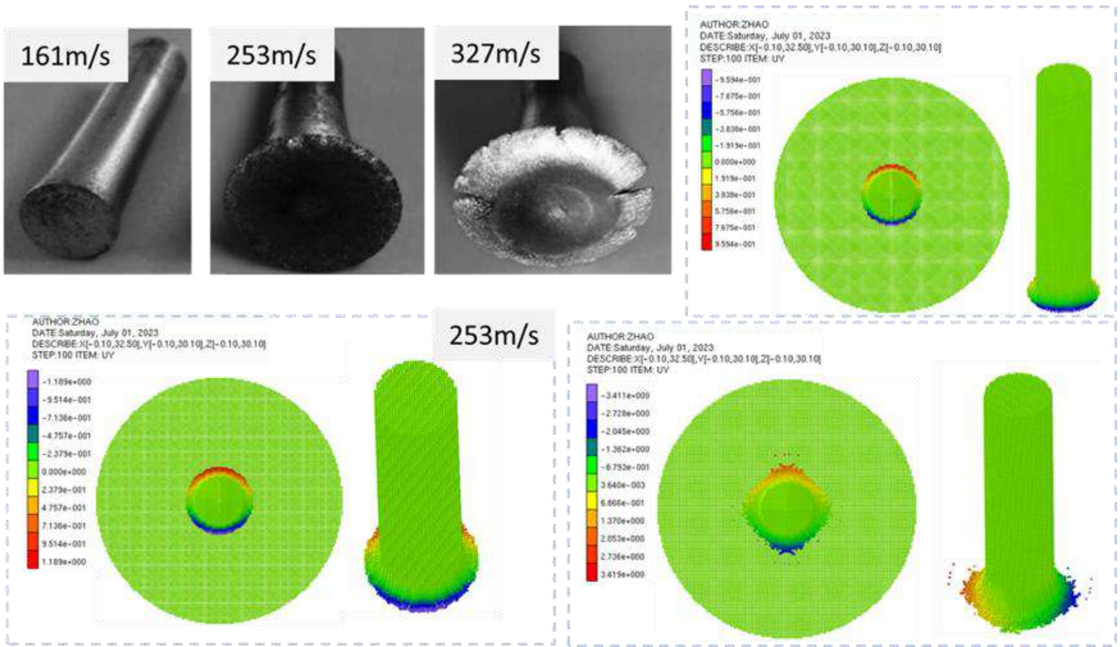

Fig. 1 The deterioration status of the metal bar subjected to difference impact speeds: comparison between numerical modelling and experimental results

RAY-TRACING DISCRETE ELEMENT METHOD

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ABSTRACT

We introduce a novel, efficient and robust approach, the ray-tracing discrete element method (RTDEM), for direct numerical simulations of granular materials. To accelerate RTDEM simulations on graphics processing units (GPUs), advanced algorithms have been developed to leverage the specific ray-tracing cores equipped on RTX GPUs. RTDEM is composed of two variants: sphere-RTDEM and mesh-RTDEM, which respectively model spherical and arbitrarily shaped particles. Sphere-RTDEM is particularly useful for simulating large-scale geotechnical problems, such as landslides and debris flow. Our performance tests have shown that sphere-RTDEM can achieve a 1000x speedup for simulations of dry debris flow (Fig. 1) compared to commercial software particle flow codes (PFC). Mesh-RTDEM uses triangular meshes to represent arbitrary shapes and introduces energy-conserving contact models, such as vertex-potential and facet-potential models, to enable robust contact resolution. These contact models benefit from our novel discrete potential field functions. Moreover, we have proposed shape templates to efficiently tackle arbitrarily shaped particles with extreme size ratios (Fig. 2). RTDEM is poised to be a next-generation tool for modeling large-scale granular systems with ease and efficiency, which has been implemented in our numerical computing platform SudoSim.

Keywords: disrete element method; arbitrary shape; large-scale simulation; GPU; ray tracing

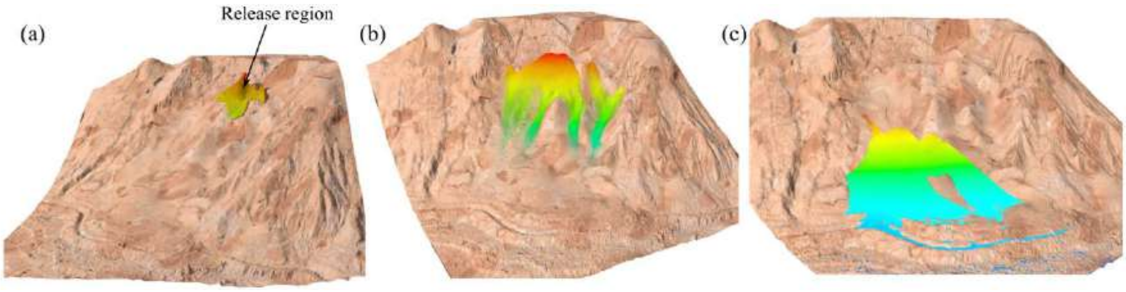

Fig. 1 Simulation snapshots of dry debris flow (1.6M particles and 0.12M triangular facets) at different time instants: (a) 0 s, (b) 10 s and (c) 100 s.

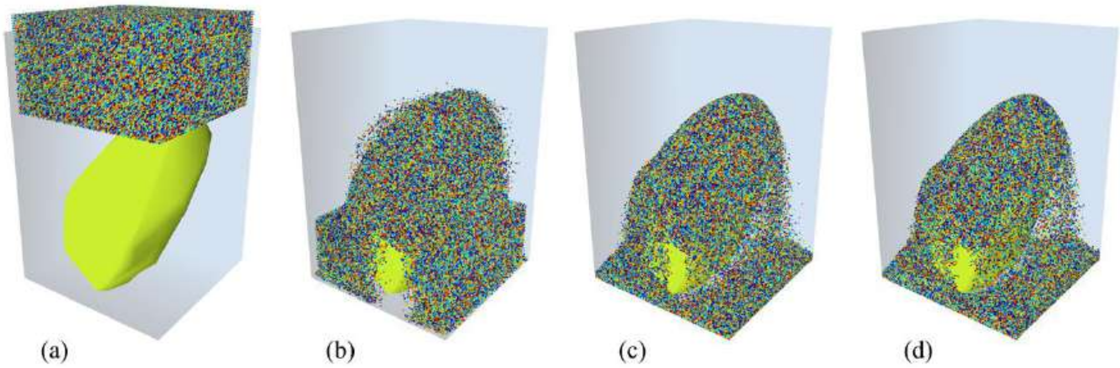

Fig. 2 Configurations of 0.2M small particles impacting a big particle (with a size ratio of 100 : 1) within a box at different time instants: (a) 0 s, (b) 1 s, (c) 2 s and (d) 3 s.

AN EFFICIENT MATERIAL POINT METHOD FRAMEWORK BASED ON THE AFFINE MATRIX

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ABSTRACT

The material point method (MPM) has proven to be an effective numerical approach for simulating extreme events involving large deformations. Although numerous MPM variants have been proposed to enhance the capability of MPM, its application is currently limited by issues of computational efficiency and stability. This study presents an innovative affine matrix-based MPM scheme (AM-MPM) that can substantially promote the computational efficiency of MPM while maintaining exceptional stability. The proposed scheme is featured by its use of the affine matrix as a first-order approximation of the velocity gradient in the subsequent step and the direct computation of associated strain/stress for particles. This approach reduces the information interpolation between particles and grid nodes from two times to a single time, significantly leveraging computational efficiency. The proposed MPM scheme is firstly validated by the quasi-static compaction under self-weight and then applied to various classical problems involving large deformations, including biaxial compression test, column collapse, the impact of two rings, and the twisting of a 3D elastic column. The performance of the proposed scheme in terms of accuracy and efficiency is also discussed in detail.

Keywords: Material point method, Affine matrix, Computational efficiency, Stability, Large deformation

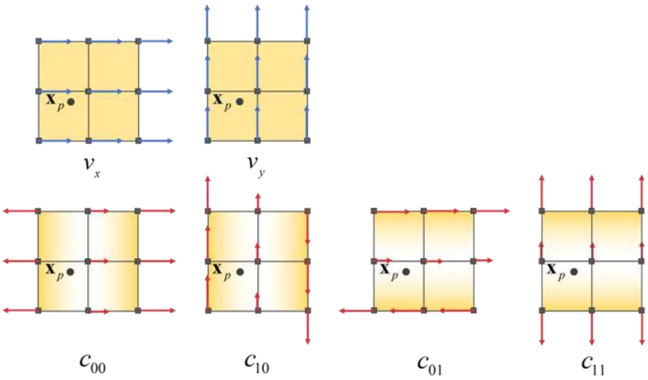

Fig. 1 Illustration of the affine velocity field of material point p. The arrow indicates the projected velocity of the material point's affine velocity field at each node

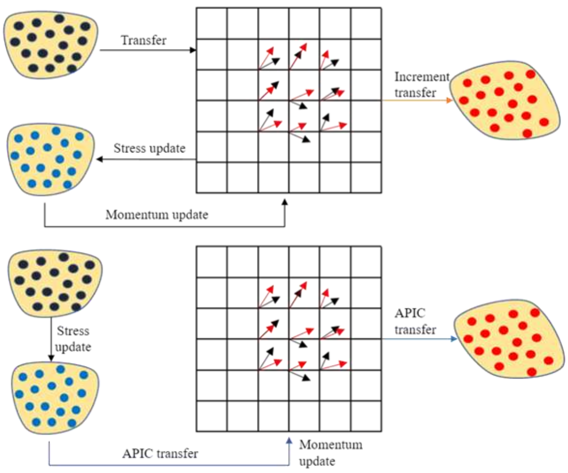

Fig. 2 Data transfer between grid nodes and particles

A SEMI-IMPLICIT MPM FOR MODELING THE THERMAL EFFECT IN SATURATED POROUS MEDIA

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ABSTRACT

Thermal variations in liquid-infiltrated porous systems can trigger natural geohazards, such as permafrost thawing or hydrate dissociation-induced landslides. However, modeling and understanding the interactions of heat transfer, liquid flow, and solid deformation in such multiphysics coupling geological processes remain challenging, especially under conditions of extreme deformations and failures. This study presents a stable semi-implicit material point method (MPM) for thermo-hydro-mechanical simulation of large deformation problems in saturated porous media. The **u**-**v**-*p*-*T* governing equations are formulated within the framework of a one-point two-phase MPM and solved using a novel and efficient staggered solution scheme. The scheme solves the energy balance equation first, and the resulting temperature is then used to advance the solution of the hydromechanical equations using the fractional step method. This approach facilitates equal-order interpolations of displacement and pressure fields and accommodates both incompressible and weakly compressible fluids. The performance of the proposed method is demonstrated through three benchmarks, including the non-isothermal consolidation and point heat source problems, as well as a large deformation example involving the progressive failure process of a thermally sensitive slope. The proposed framework can be readily extended to include more complicated phenomena, such as multiphase flow and phase transition. Overall, this study provides a robust and efficient method for simulating thermo-hydro-mechanical processes in porous media. The proposed method's ability to handle extreme deformations and failures and accommodate incompressible and weakly compressible fluids makes it a valuable tool for studying natural geohazards and other geological processes.

Keywords: Thermo-hydro-mechanical coupling, material point method, large deformation, porous media

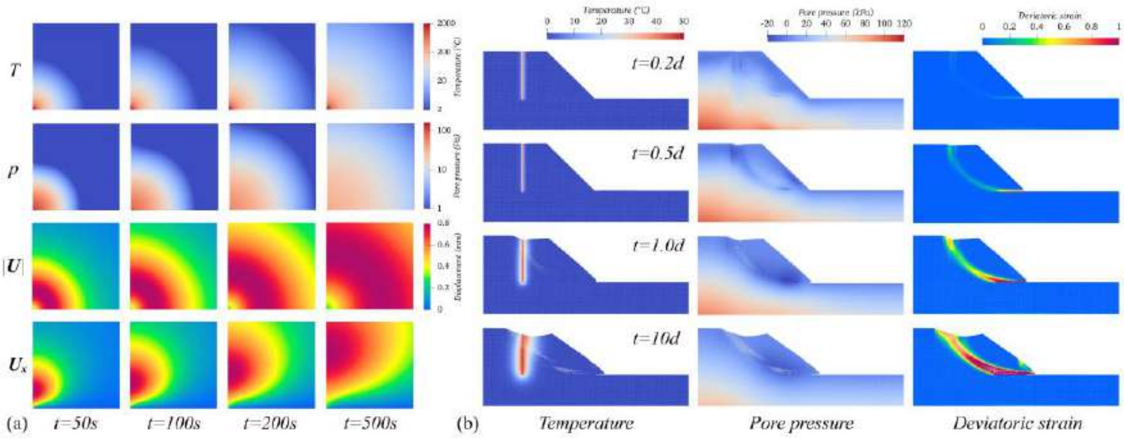

Fig. 1 Simulation results of (a) the THM response of saturated soil around a deeply buried point heat source (applied to the bottom-left corner of the one-fourth domain in an axisymmetric configuration) and (b) the progressive failure process of a thermal-sensitive slope subjected to heating.

COUPLED PERIDYNAMIC MODELING OF HYDRAULIC FRACTURING IN SOLIDS

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ABSTRACT

Hydraulic fracturing in solids constitutes an important physical process in many industrial operations. Numerical modeling of such process remains a challenging research topic, given the intricate interplay between the fluid flow, solid deformation, and fracturing. The rapid development of peridynamics theory in the past decade has offered a promising approach for modeling fracturing in solids. The original peridynamics theory is based on a total-Lagrangian theory with assumption of small deformation. Recently, a variant of peridynamics theory, which is based on a semi-Lagrangian formulation, has been developed with a potential for modeling large deformation of materials including fluid flow. In this work, we utilize both total- and semi-Lagrangian peridynamics theories to simulate fluid-driven fractures where the former is used for simulating deformation and fracturing in solid and the latter for modeling fluid flow. A coupling scheme has been developed for fluid-solid interactions. The novel computational approach is then validated with the Kristianovich-Geertsma-De Klerk (KGD) problem and a hydraulic fracturing experiment with respect to the crack propagation speed and fluid pressure.

Keywords: peridynamics, hydraulic fracturing, fluid-solid interaction.

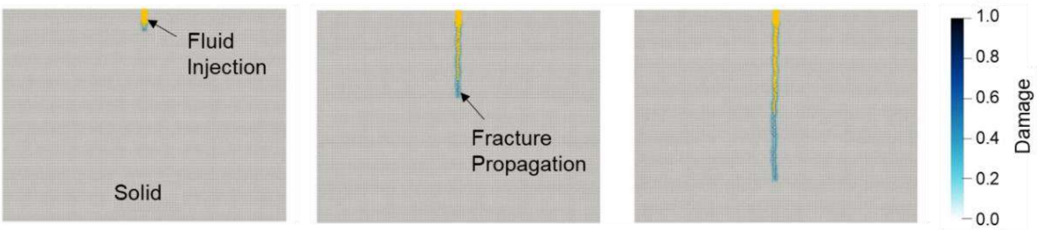

Fig. 1 Simulated progress of hydraulic fractures in solid.

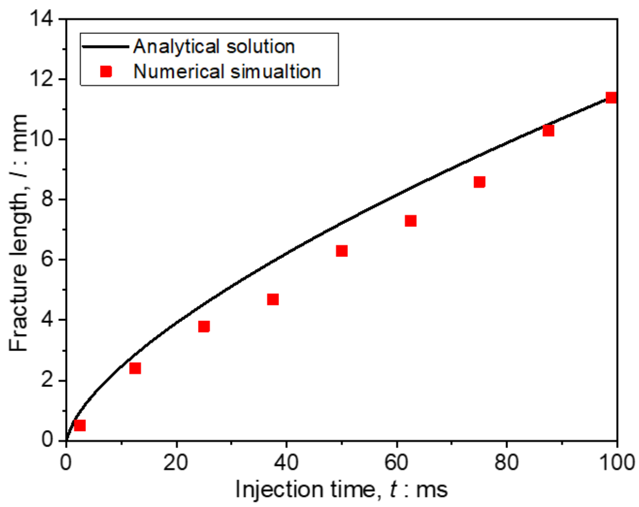

Fig. 2 Fracture propagation compared with analytical solution.

STUDY ON INITIATION PROCESS OF MORAINE SOIL WITH DIFFERENT PARTICLE MORPHOLOGY USING CFD-DEM

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ABSTRACT

As the main source of glacial debris flow, moraine soil has the characteristics of poor roundness and sorting, which easily form glacial debris flow under the infiltration of glacial meltwater. However, the mechanism of glacial debris flow is still not fully understood, as it contains complicated solid-liquid interactions, which are difficult to study by experimental methods. In this paper, according to the particle morphology and gradation characteristics of the moraine soil obtained from typical disaster sites of glacial debris flow on the Karakoram Highway, the numerical method of coupled CFD-DEM is adopted to study the initiation process of moraine soil with different particle shapes under the infiltration of meltwater from a microscopic view. The influence of particle morphology on displacement field, slope change and particle gradation change were presented. The phenomenon of local blockage was explored through fluid flow velocity, and the interaction between particles was explored by comparing the transformation of force chain. The conclusion of this paper is beneficial for the understanding and prevention of glacial debris flow.

Keywords: Moraine soil; CFD-DEM coupling method; Polyhedral particles; Infiltration

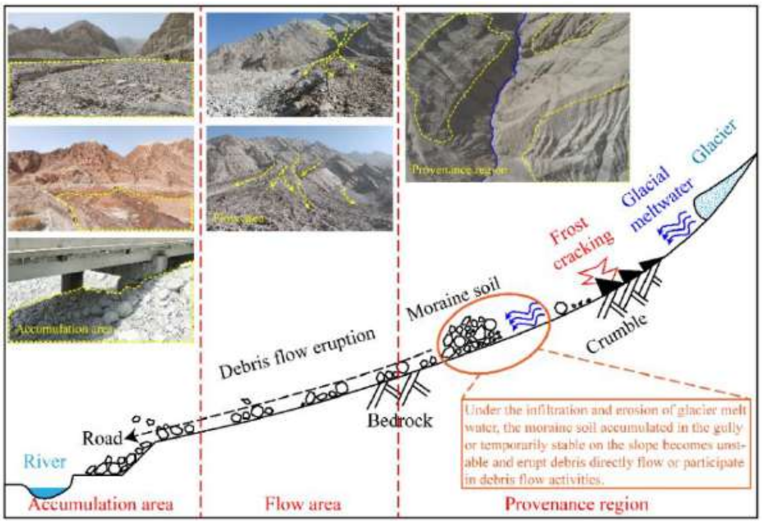

Fig. 1 Formation mechanism of glacial debris flow.

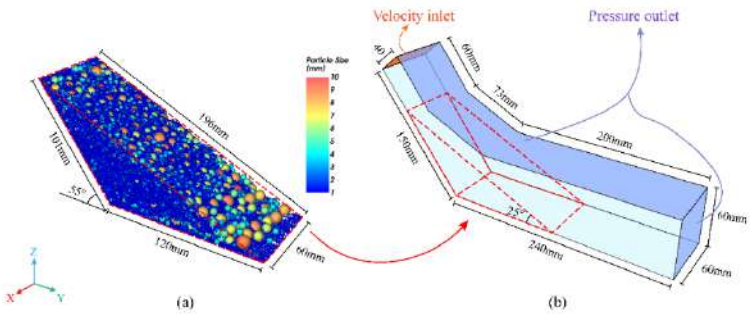

Fig. 2 (a): Initial particle deposition slope. (b): Domain of CFD and DEM.

THE LAW OF INFILTRATION OF RHEOLOGICAL BENTONITE SLURRY THROUGH SANDS

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ABSTRACT

Bentonite grouting is widely used in engineering projects. Due to filtration effects and rheological blocking, the infiltration patterns of bentonite are diverse, making its infiltration development mechanisms still unclear. This paper systematically analyzes the infiltration process of rheological bentonite slurry in sandy soil under various grouting conditions. Moreover, based on the methylene blue titration method, the quantitative distribution of bentonite content in the infiltration zone was determined. The results indicate that the relative size of sandy soil pores to bentonite particles is a key factor controlling the type of infiltration and the formation of filter cake. The smaller the grain size of the sand sample, the higher the bentonite content in the infiltration zone, resulting in a shorter final infiltration distance. Additionally, this study proposes a model that can predict the infiltration distance for different types of infiltration. An analytical solution was provided, combining the Herschel Bulkley fluid constitutive equation, particle mass conservation equation, and seepage motion equation, which aligns well with the experimental results. This allows for accurate predictions of the infiltration front's temporal evolution for different types of infiltration processes.

Keywords: Infiltration; Bentonite grouting; Rheology; Filter cake; Methylene blue titration test; Herschel Bulkley Model

DEVELOPMENT OF JOHNSON-HOLMQUIST-BEISSEL MODEL IN DISCONTINUOUS DEFORMATION ANALYSIS AND ITS APPLICATION IN PROJECTILE PENETRATION (249-184)

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ABSTRACT

Mohr-Coulomb criteria, which has been employed in discontinuous deformation analysis (DDA), is insufficient for studying the dynamic responses of brittle materials. To better replicate the failure process upon projectile penetration, the parameters in Johnson-Holmquist-Beissel (JHB) constitutive model are redefined utilising DDA's calculation parameters. And JHB model is further implemented and validated in a self-developed DDA program. The result of the bonding unit test, which is used to validate the constitutive model's functionality in the programme, are highly congruent with those of the references. To demonstrate the model's applicability, the proposed JHB-DDA model is utilised to simulate and analyse projectile penetration under various scenarios. Typical factors such as residual velocities after different initial velocity penetrations, damage effects for different projectile nose coefficients (calibre-radius-head, CRHs), and target thickness, are investigated. The penetration results are in good agreement with the theoretical/numerical solutions in literature. The developed JHB-DDA model has considerable advantages over LS-DYNA in terms of explicit representation of material damage. Reasonable numerical results demonstrate that the developed JHB-DDA model can be utilised as an effective tool for predicting projectile penetration.

Keywords: Disk discontinuous deformation analysis; Johnson-Holmquist-Beissel Model; Projectile Penetration; Dynamic Fracture Process;

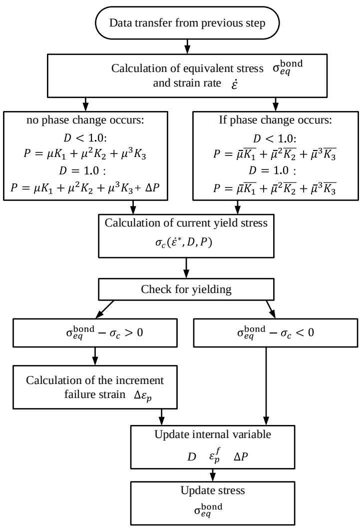

Fig. 1 The flowchart for calculating bonding unit stress with the implementation of JHB model

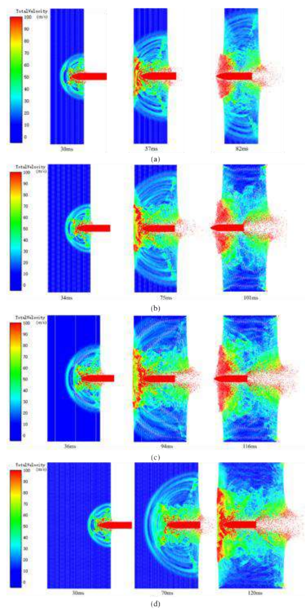

Fig. 2 Penetration results for cases with different thickness: (a) 300mm, (b) 400mm, (c) 500mm, and (d) 600mm

FROM SEDIMENTATION TO CONSOLIDATION OF KAOLINITE: A MOLECULAR DYNAMIC STUDY （249-315）

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ABSTRACT

The consolidation of clay is the main measure for reclamation project, which is related to the compressibility, permeability, and coupling effect of clay-water. However, the mechanism of consolidation of clay remains unclear. This study focuses on the microscopic consolidation property of kaolinite using Molecular Dynamics (MD) simulation method. The nano-scale consolidation model was established to reproduce the sedimentation to consolidation. According to the different distribution of water film in pores, the consolidation process could be divided into different stages: (1) in the process of sedimentation and primary consolidation, the drainage occurred continuously except the strongly bound water; (2) just a part of the strongly bound water could be drained during the secondary consolidation. The attraction between clay-water gradually increased with the loss of pore water in all consolidation processes. The minimum consolidation stress which can cause significant consolidation was found to be 0.1 GPa in a narrow throat of about 1 nm at nano-scale. Besides, the evolution of interparticle spacing between kaolinite particles during the consolidation process was analyzed to reflect the role of interparticle water on the pore water pressure and effective stress.

Keywords: Kaolinite, Consolidation, Molecular dynamics, Bound water

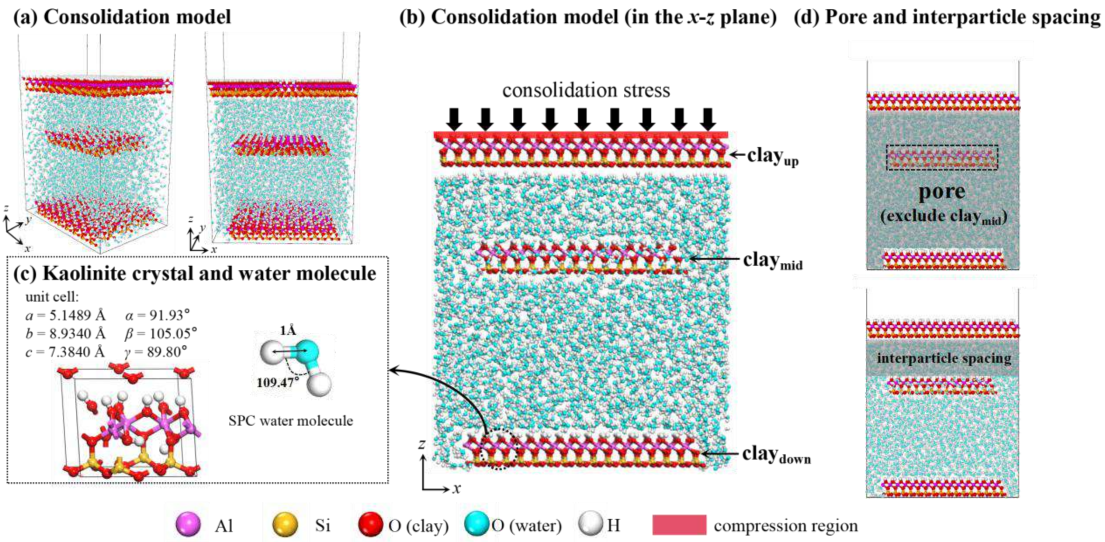

Figure 1: The simulation model.

MODELLING GRANULAR MATERIALS WITH PHASE TRANSITION: FROM LANDSLIDE TO DEBRIS FLOW (249-134)

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ABSTRACT

Granular materials are omnipresent in our daily life. The same granular material can behave like solid, and fluid, which poses formidable challenge to the constitutive models and numerical methods. Traditionally, constitutive models for the solid- and fluid-like behaviour have been developed for the respective flow regimes in different engineering/scientific disciplines with hardly any intersections. A single constitutive model capable of describing the transient behaviour during phase transitions in both solid-like and fluid-like regimes is a challenging task with enormous application potential. We take on this challenge with a simple yet genius ansatz by decomposing the stress rate into a frictional and collisional part, which gives rise to an unconventional constitutive model with the 2nd order strain rate similar to the acceleration of motion. It serves as an excellent classifier for steady and transient motions. The field equations are established in rate form for the first time and discretised by an SPH model. Advanced solution techniques are developed based on multi-GPU acceleration for high fidelity simulation of large-scale problems. The constitutive model is calibrated by laboratory experiments on natural granular materials and their transparent surrogate.

Keywords: Granular materials; phase transition; hypoplastic model; SPH simulation

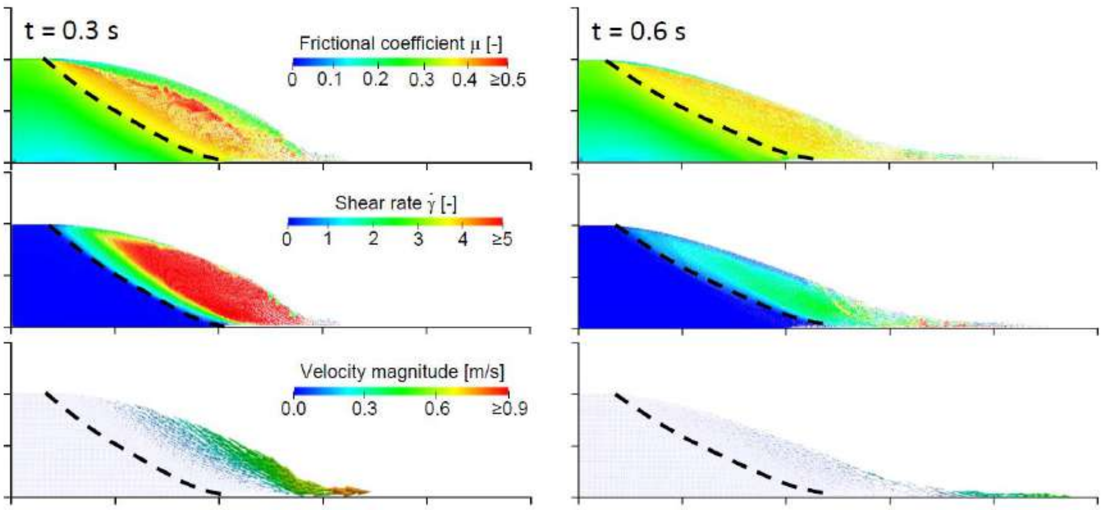

Fig. 1 Validation-dry granular column collapse

THE CONTINUOUS TO DISCONTINUOUS SIMULATION OF ROCK FAILURE BY THE 2D ADAPTIVE RDFA APPROACH

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ABSTRACT

This study presents a hybrid rock discrete fracture analysis (RDFA) approach that integrates the rock failure process analysis method and the discrete element method. RDFA can simulate the complex interactions of rock continuous-discontinuous behaviors, including rock fracture and fragmentation, based on continuum mechanics, statistical damage theory, and contact theory. RDFA also implements a nodal updating scheme that adapts the nodes at critical crack tips in real time. This scheme captures the crack evolution and propagation while satisfying the strength criteria. Furthermore, RDFA accounts for the heterogeneity of rock masses by separately considering damage and failure attributes. Specifically, it synchronizes damage at the elemental scale and crack propagation at the joint scale. To validate the accuracy of stress and strain calculations, RDFA is verified by the Brazilian test, showing good agreement with the analytical solutions. Then, the samples with single and double flaws are subjected to uniaxial compression. The outcomes, such as fracturing patterns, failure modes, and critical strengths, are compared with the experimental and numerical results, confirming the effectiveness of RDFA in modelling rock fracturing.

Keywords: rock failure; continuous-discontinuous modelling; adaptive node adjustment; crack propagation

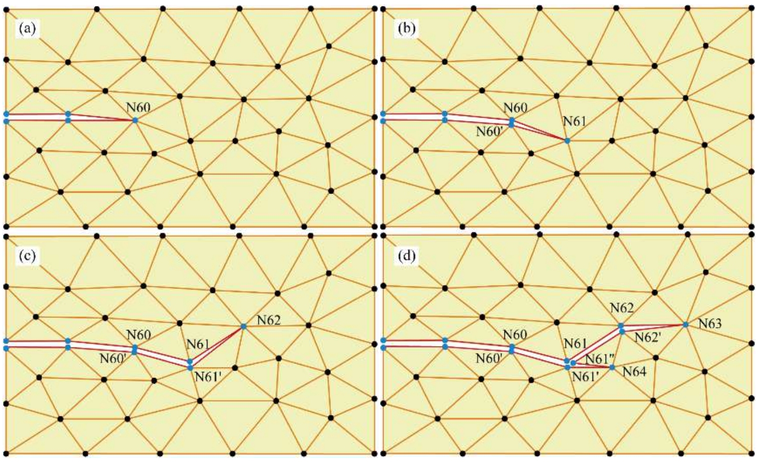

Fig. 1 Illustration of the adaptive RDFA approach

Time series method for profiling of London Clay with MWD data

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Abstract

The study investigates the ground conditions surrounding an old cast iron tunnel in the London Clay strata. While previous research has examined the correlation between borehole investigation and MWD drilling parameters, the unsatisfactory results due to the random variations prompted further investigation. To achieve this, the time series method is used to address these random variations by converting the MWD data from depth series to time series. The curve of drilling depth with net drilling time can be obtained and further divided into linear segments with constant penetration rates. These segments represent homogeneous geomaterials and their variation along the instrument borehole can be effectively compared with the lithological units identified from rotary-cored samples. Additionally, a drilling strength system ranging from grade I to VI is proposed for the London ground geomaterials. Overall, the consistent results presented in this study give a clear understanding of ground investigation and construction not only in London but also in other urban areas.

Keywords: Drilling & Drillholes, Measurement While Drilling (MWD), Time-series method, Site investigation, London Clay

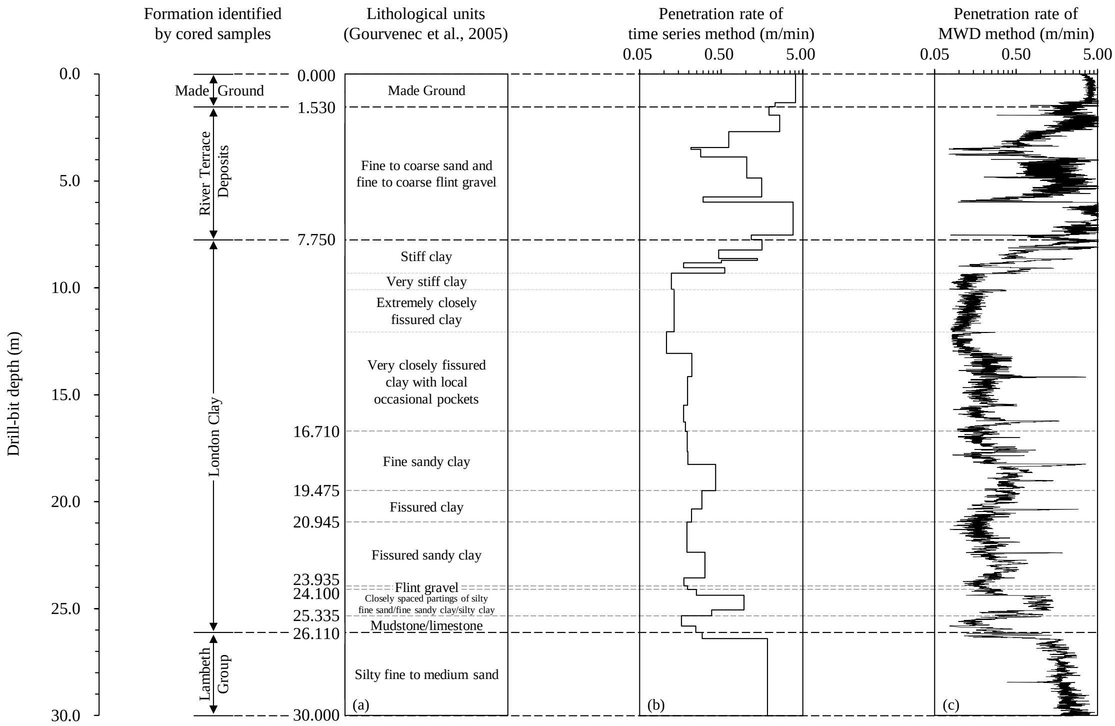

Fig. 1 Comparison of London Clay profiling results among (a) rotary-cored samples, (b) time series method and (c) MWD method.

UAV IMAGES-BASED LANDSLIDE BOUNDARY AND CRACK RECOGNITION IN DANGCHUAN, CHINA

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ABSTRACT

Unmanned Aerial Vehicle (UAV) technique has been widely applied in geohazards assessment. In this study, we will illustrate the advantages of the UAV technique in the remote sensing and recognition of landslides, through a case study of the landslide identification in the Dangchuan region, China. In November 2018, an UAV photogrammetry-based survey was undertaken to obtain the high-resolution images of the Dangchuan region, Gansu, China. First, the multi-scale image segmentation technique is employed to segment the images collected. Based on a comprehensive consideration of the features of colour, texture, and morphology, an information extraction rule is established to classify these landslide features and six landslides are preliminarily extracted in the studied region. Next, the landslide surface crack recognition model developed previously by the authors is adopted for detecting the landslide cracks in the studied region, and a distribution map of the landslide surface cracks is constructed. Finally, the results of the landslide boundary extraction and the landslide surface crack recognition are integrated, from which the landslide boundaries in the studied region can be ascertained. The images recognition results are further validated through a field survey. This survey indicates that 69.8% of the landslide area can be successfully detected with the image method presented.

Keywords: UAV; Landslide; Image recognition; Landslide boundary; Landslide crack.

SMART MONITORING AND FORECASTING OF CONFINING PRESSURE ON SHIELD TUNNEL SEGMENTS DURING THE CONSTRUCTION PERIOD

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ABSTRACT

The confining pressure is the main source of the internal force of the shield tunnel. Estimating confining pressure accurately holds a pivotal role in the analysis of the shield tunnel structure. Popular belief prefers to consider the confining pressure constant rather than variable along with time. However, the pressure will change dynamically due to the variation of contact between soil and tunnel, underground water level, or internal load during construction. In this study, the complete time histories of confining pressure during the whole construction period, at the top, middle, and bottom of the shield tunnel lining, were acquired through the smart monitoring system on site, and the regulation of changes in confining pressure was discussed. Further, the models based on the fusion of the long short-term memory framework, particle swarm optimization algorithm, and the multi-output recursive strategy were constructed to forecast the 7-day history of confining pressure. Results show the proposed models have better prediction performance than other traditional models. The number of output layer units impacts the prediction performance of models greatly. Relatively speaking, the models with 6~8 units in the output layer have the more stable prediction performance.

Keywords: Shield tunnel; Confining pressure; Smart monitoring; Time series forecasting

Fig. 1. Preinstallation of pressure cells and field implementation

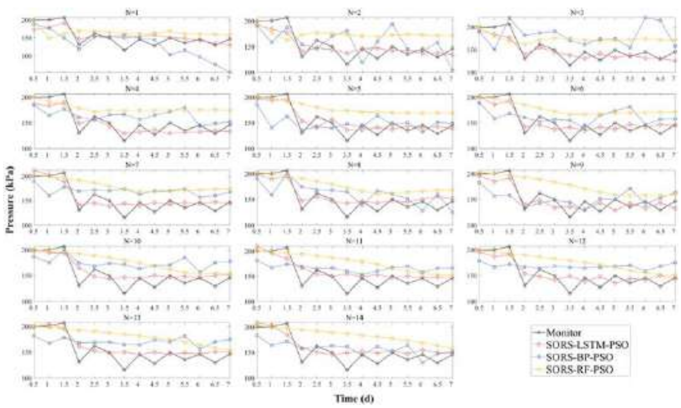

Fig. 2 Comparison among the proposed model and other traditional models

DETECTING GROUND THERMAL CONDUCTIVITY VIA A NOVEL THERMAL RESPONSE TEST

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ABSTRACT

The accurate measurement of ground thermal conductivity is crucial for a variety of geotechnical engineering activities toward sustainable development. A special challenge is posed by the often significant heterogeneity and variability of the geological media at a site. By employing the fiber optic sensing technology, we proposed a novel in-situ method, so-called actively heated fiber optics-based thermal response test (ATRT), to offer the possibility of efficiently estimating the thermal conductivity of layered strata and adapting to the observation requirements in complex strata systems. In this study, we investigated the governing factors of ATRTs including the heating power and duration, borehole radius, grout thermal conductivity, and cable positions by conducting both numerical and physical model tests. The results indicate that the heating power should be in the range of 15–40 $W \cdot m^{-1}$, considering the accuracy of the temperature measurement. Grouting with a higher thermal conductivity than that of the ground improves the test efficiency. The borehole radius and cable position induce errors by changing the heat-transfer process. A heating duration of greater than 60 min should be employed, considering multiple factors. We conclude that a standardized ATRT could serve as an advanced in-situ investigation technique for various applications considering ground thermal conductivity, such as the evaluation of shallow geothermal energy potential, estimation of groundwater flow, etc.

Keywords: Ground thermal conductivity; Fiber optic sensing; ATRT; Influencing factors

A FEASIBILITY STUDY OF CROSS-BOREHOLE PASSIVE-SEISMIC WAVEFORM TOMOGRAPHY

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ABSTRACT

Cross-borehole seismic tomography enables high-resolution imaging of subsurface structure via the analysis of seismic waves propagate between boreholes. Despite its potency, this geophysical technique has limitations such as restricted coverage and environmental considerations due to the use of active seismic sources. To mitigate these challenges, we introduce a passive seismic tomography approach. This method employs the inversion of cross-correlation functions (CCFs) derived from seismic ambient noise to explore shear-wave structures between boreholes. Based on seismic interferometry theory, which approximates Green's functions through ambient noise CCFs, our proposed technique derives velocity structures by minimizing waveform difference between the observed and the simulated CCF. The method's workflow is illustrated in Figure 1. Furthermore, Figure 2 showcases outcomes from two numerical checkerboard inversion tests, underscoring the method's efficacy in detecting and monitoring detailed structural changes between boreholes.

Keywords: cross-borehole, passive seismic, waveform tomography, ambient noise, cross-correlation.

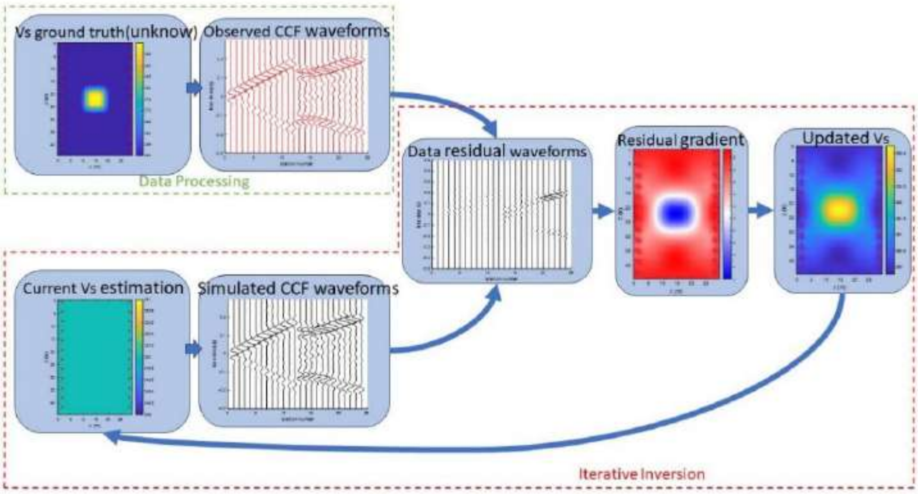

Fig. 1 The workflow of the proposed method

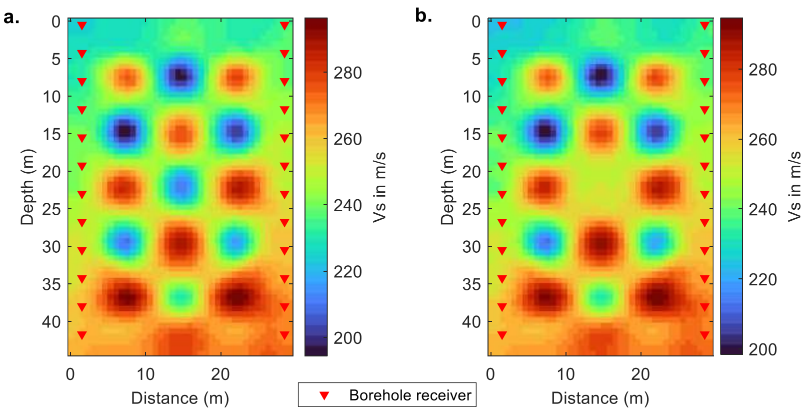

Fig. 2 Results of two numerical inversion tests. a.) Test with a low-Vs anomaly at the center of the true model, as b.) Test without a low-Vs anomaly at the center of the true model.

DEVELOPMENT OF LANDSLIDE DEEP DEFORMATION MONITORING SYSTEM BASED ON FIBER OPTICAL SENSING TECHNOLOGY

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ABSTRACT

Establishing an efficient and scientific system for the prevention and control of natural disasters is always an urgent task. The conventional sensing technologies can no longer meet the needs of geotechnical engineering due to the inherent limitations of accuracy, resolution and durability. In order to deal with the extreme working environments of deep sea, deep earth and deep space, the sensing technologies are required to perform with the properties of high accuracy, high temperature resistance, corrosion resistance and timeliness. With the fiber optical sensing technology developing, various kinds of sensors and devices are proposed for deep deformation monitoring of landslides. In this study, new in-situ inclinometers are developed based on the principles of conjugate beam, equal strain beam, magneto-strictive effect, Hall effect, Micro-Electro-Mechanical System (MEMS) and Optical frequency Domain Reflection (OFDR), respectively. The calibration results indicate the good performance of these devices compared with the results of high-precision equipment or the actual values. Subsequently, an online platform system that includes the functions of monitoring, forecasting and early warning is established, which is based on the technologies of fiber Bragg grating, distributed fiber optic sensor, MEMS and the Internet of Things (IoT), providing strong support for the scientific decision-making of government. The accuracy and reliability of proposed technologies are also proved in the slope deformation monitoring in Dalian and Fushun, China. These field cases demonstrate the unique advantages of fiber optical sensing technology in multi-field monitoring of geotechnical engineering.

Keywords: fiber optical sensing; deep deformation; in-situ inclinometer; landslide

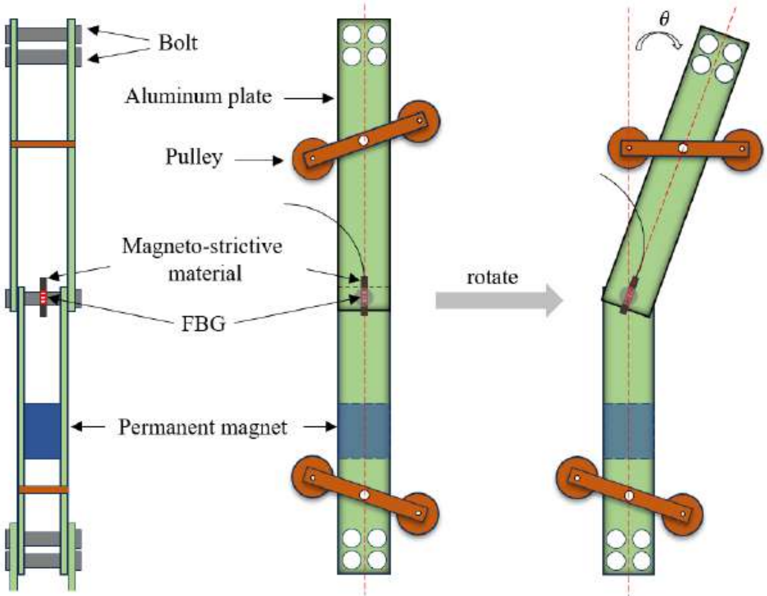

Fig. 1 Magnetic sensing in-situ inclinometer diagram

MONITORING THE VIBRATION RESPONSE OF AN EARTH PRESSURE BALANCE SHIELD FOR REAL-TIME DETECTION OF GROUND PROPERTIES

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ABSTRACT

Real-time detection of ground properties via vibration monitoring has recently emerged as a promising approach in tunneling practice. Its underlying physics is that the vibration response of a shield machine is triggered by the penetration of cutting tools into the ground, implicitly reflecting the properties of the excavated ground. Despite its potential, the capacity of vibration monitoring for identifying various ground classes remains largely unexplored due to the scarcity of measured data. Here, we attempt to provide a comprehensive vibration dataset of an Earth Pressure Balance (EPB) shield tunneling through three distinct ground classes. A vibration monitoring system is designed and implemented in the Changsha Metro Line 1 North Extension. Through vibration data analysis, a novel framework for detecting ground properties via vibration response is developed. The framework encompasses two functions: ground class identification and ground interface detection. The former develops a support vector classifier to incorporate the vibration amplitude and advance rate for identifying various ground classes. The latter utilizes mean square frequency and spectrum flatness to quantitatively distinguish homogenous ground from composite ground. The reliability of the proposed framework is assessed using borehole data, demonstrating its ability to accurately capture the properties of the excavated ground.

Keywords: Earth pressure balance shield; Vibration monitoring; Ground property detection.

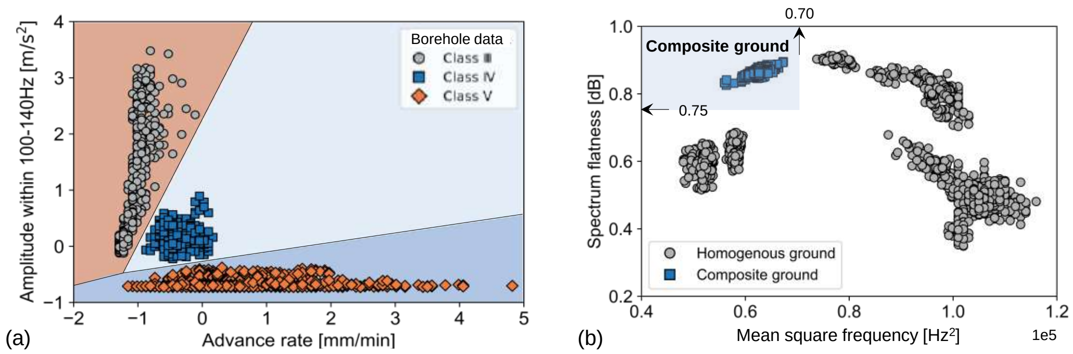

Fig. 1. Assessment of the reliability of the proposed framework using borehole data: (a) ground class identification, and (b) ground interface detection.

RISK ASSESSMENT MODEL FOR LARGE DIAMETER SLURRY BALANCE SHIELD TUNNEL CONSTRUCTION

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ABSTRACT

This study proposes a risk assessment and management model for slurry balance shield induced ground deformation by integrating STPA (System Theoretic Process Analysis) and VIKOR (Serbian abbreviation for Visekriterijumsko kompromisno rangiranje) method. The STPA method was utilized to identify the potential factors that contribute to ground deformation. Q-value related to risk grade was calculated by VIKOR, and the field measured value and corresponding Q-value were fitted to obtain the principle of risk level classification. The proposed model was applied to the Chunfeng Tunnel in Shenzhen. The risk assessment results are consistent with the field deformation monitoring. Then, the deficiency that the model cannot take into account some special cases is discussed. By sensitivity analysis, the recommended values of parameter λ of the evaluation model are 0.3,0.4 and 0.5. Finally, the model is introduced into the BIM platform of Shenzhen Chunfeng Tunnel to realize 3D visualization management. The proposed model provides effective ideas and methods for ground deformation risk assessment and management.

Keywords: Ground settlement; Risk assessment; Slurry balance shield tunnel; STPA-VIKOR method; Visualization management.

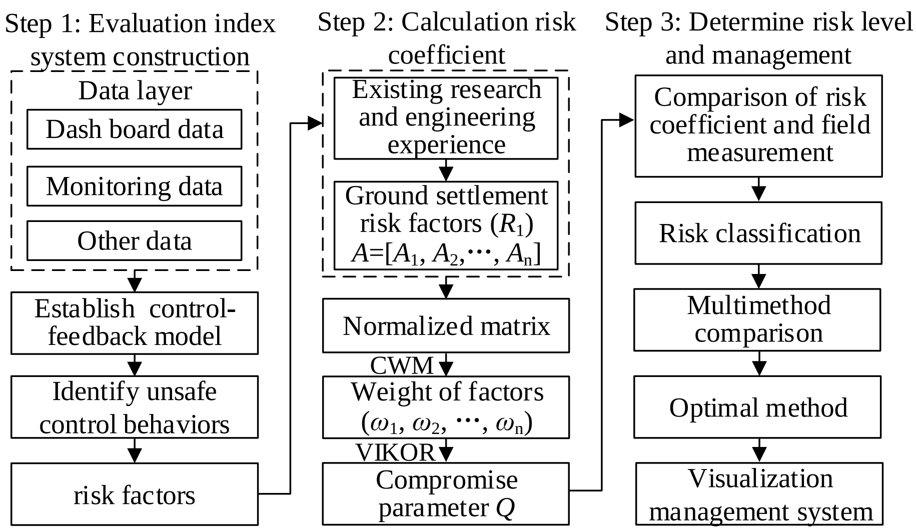

Fig. 1. Framework of SBS tunnel settlement risk assessment

Title: Advanced Marine Pressure Sensor Design with Elastic Diaphragm and Femtosecond Fiber Grating for High-Precision Pressure Monitoring

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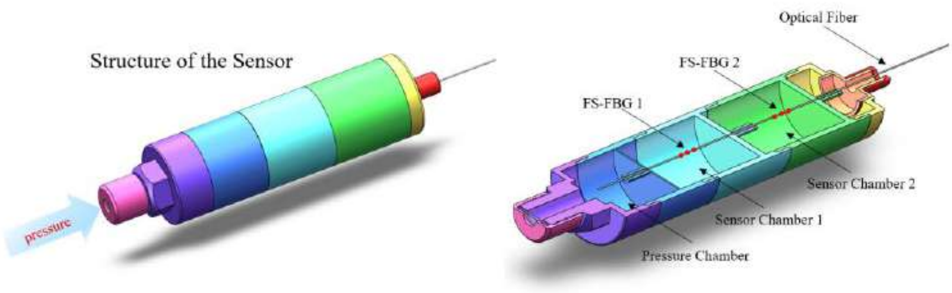
ABSTRACT

This paper introduces the design of a novel marine pressure sensor based on an elastic diaphragm and femtosecond fiber Bragg grating(FS-FBG). The sensor employs a pre-stressed FS-FBG orthogonal connection with the diaphragm structure, utilizing a modular design that the strain grating and temperature-compensated grating into separate chambers. A novel pre-stressing encapsulation method for FBG sensors has been proposed. This method enables precise adjustment of the pre-stress applied to the grating during the packaging of the FBG sensor and ensures the stability of the pre-stress. The sensor's performance has been established through theoretical calculations, establishing a relationship between the wavelength shift of the femtosecond fiber Bragg grating (FS-FBG) and pressure values. The influence of Poisson's ratio, elastic modulus, and diaphragm dimensions on sensor performance has been evaluated to facilitate optimization during the design process. Finite element simulations have verified the feasibility of the design and predicted the sensor's response and failure modes under various loads. Calibration test results demonstrate a direct proportional relationship between the sensor's wavelength and pressure. Within a pressure range of 1 MPa, the sensor exhibits 99.9% linearity and a sensitivity exceeding 10 pm/kPa, which is 2000 times higher than that of bare fiber. This advancement offers a highly accurate method for monitoring seawater pressure effectively.



Schematic diagram of the structure of the sensor

GRANULAR SOIL MODULUS EXTRACTION FOR INTELLIGENT COMPACTION USING MACHINE LEARNING WITH SOIL-STRUCTURE INTERACTION CONSIDERATIONS

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ABSTRACT

In the modern realm of geotechnical engineering, Intelligent Compaction (IC) is emerging as an instrumental technique in the real-time quality control of compacted soil layers. IC's rising popularity is largely credited to its unparalleled efficiency and its capability to provide full-area coverage. This technology hinges on its ability to gauge the uniformity of compaction across expansive tracts of land, based on the roller's dynamic response. However, the terrain of accurate real-time soil modulus determination during the compaction process is riddled with challenges. The root of these challenges stems from the multi-layered and composite nature of soil, coupled with the intricacies in the dynamic equation of motion and the nonlinear response of the soil. A robust suite of over 5,000 three-dimensional numerical simulations was conducted. These simulations were meticulously designed to encapsulate a diverse array of variables, including differing frequencies, amplitudes, weights, lift thicknesses, and granular soil states. The data accrued was then interfaced with the newly proposed extended support vector regression (X-SVR). The outcome was a cutting-edge method poised to predict the real-time unloading-reloading modulus of compacted soil during the compaction process. The methodology proposed could predict both single and double-layered soil stiffness with remarkable accuracy. This was achieved by melding the X-SVR algorithm with the Gegenbauer and Gaussian kernels, utilising the drum's acceleration response and inherent roller properties. To encapsulate, this study not only showcases the precision of our inverse solver in predicting soil stiffness but also underscores its potential in real-time applications. By integrating the novel kernel-based X-SVR machine learning algorithm, we present a tool that facilitates real-time quality control, invaluable for roller operators on-site. The implications of our findings are profound, offering practicing engineers an evidence-backed mechanism to decipher roller drum acceleration data, thereby enabling accurate estimates of compaction levels and inherent ground stiffness during the compaction.

Keywords: Intelligent compaction, Machine-learning, Numerical modelling, soil modulus

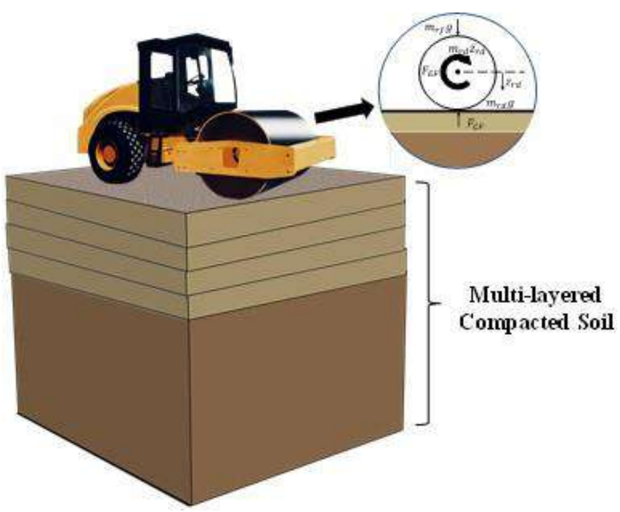

Fig. 1 The 3D illustration of the interaction between the drum and multi-layer soil strata

VIBRATION MONITORING AND REINFORCEMENT EFFECT EVALUATION OF VIBRO-REPLACEMENT STONE COLUMNS ON THE DEEP DAM FOUNDATION: A CASE STUDY

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ABSTRACT

Vibro-replacement stone columns (VSCs) are often adopted to reinforce deep overburden layers to form a composite foundation, improving the seismic capacity of deep dam foundations. Present evaluation methods for evaluating the reinforcement effect of deep dam foundations have several disadvantages, including spot-like tests, limited detection depth, and time-consuming of post-construction. Using the vibration excited by the vibrator during the compaction process, a new method is proposed in this paper to predict the reinforcement effect based on the small strain shear modulus and the Hardin formula, which consists mainly of two parts: vibration monitoring and wave velocity inversion. The paper illustrates the processes of vibration monitoring technique and the basic theory of the proposed assessment method. Compared to classical methods, new proposed method has merits in terms of wider detection range and real-time assessment, providing reference for better evaluation of working performance of VSCs-reinforced composite foundation.

Keywords: vibro-replacement stone columns, composite foundation, vibration monitoring, reinforcement effect, deep dam foundation

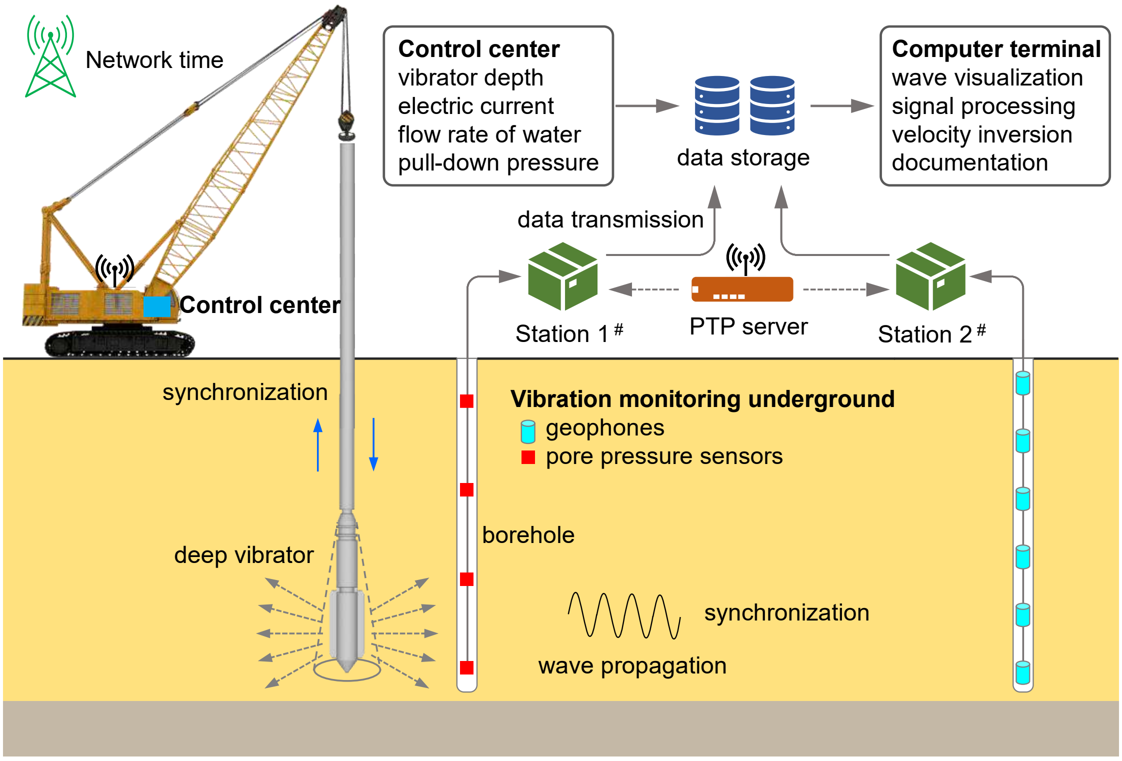

Fig. 1Illustration of the new evaluation method for deep dam foundation through vibration monitoring

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DETECTING GROUND THERMAL CONDUCTIVITY VIA A NOVEL THERMAL RESPONSE TEST

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ABSTRACT

The accurate measurement of ground thermal conductivity is crucial for a variety of geotechnical engineering activities toward sustainable development. A special challenge is posed by the often significant heterogeneity and variability of the geological media at a site. By employing the fiber optic sensing technology, we proposed a novel in-situ method, so-called actively heated fiber optics-based thermal response test (ATRT), to offer the possibility of efficiently estimating the thermal conductivity of layered strata and adapting to the observation requirements in complex strata systems. In this study, we investigated the governing factors of ATRTs including the heating power and duration, borehole radius, grout thermal conductivity, and cable positions by conducting both numerical and physical model tests. The results indicate that the heating power should be in the range of 15–40 W·m-1, considering the accuracy of the temperature measurement. Grouting with a higher thermal conductivity than that of the ground improves the test efficiency. The borehole radius and cable position induce errors by changing the heat-transfer process. A heating duration of greater than 60 min should be employed, considering multiple factors. We conclude that a standardized ATRT could serve as an advanced in-situ investigation technique for various applications considering ground thermal conductivity, such as the evaluation of shallow geothermal energy potential, estimation of groundwater flow, etc.

Keywords: Ground thermal conductivity; Fiber optic sensing; ATRT; Influencing factors

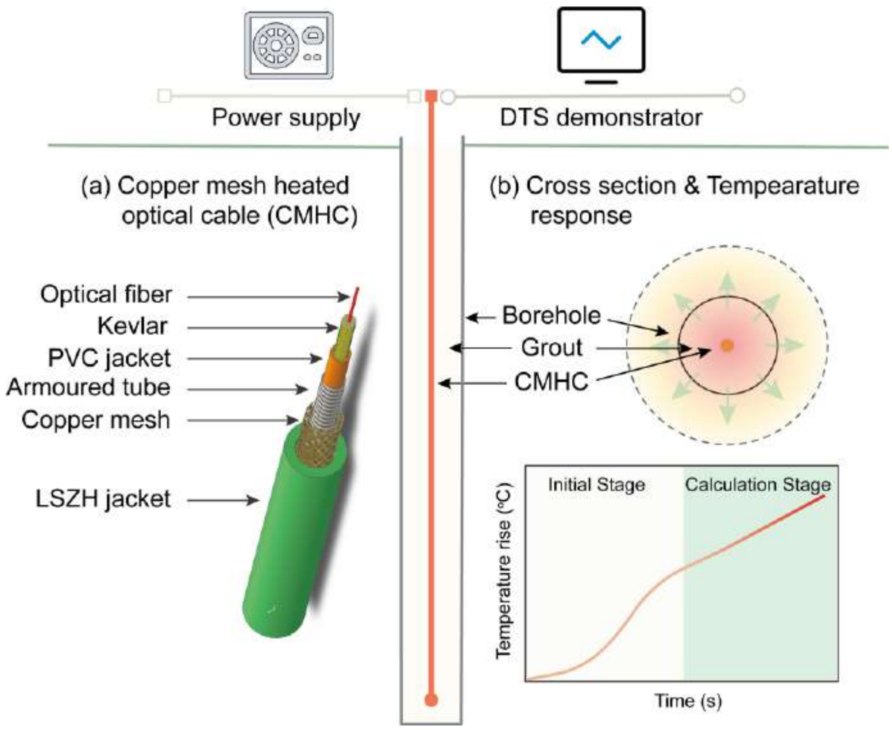

Fig. 1 Schematic diagram of ATRT system

EFFICIENT MACHINE LEARNING METHOD FOR EVALUATING COMPRESSIVE STRENGTH OF CEMENT STABILIZED SOFT SOIL

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ABSTRACT

To meet the design strength of cement stabilized soft soil (cement soil) in different application environments, numerous field and indoor geotechnical tests are often conducted. These tests not only result in the unreasonable use of materials, cost and time, but also cause serious environmental pollution problems. This study aims to propose an efficient machine learning model to evaluate the compressive strength of cement soil. Firstly, a database containing 566 samples was developed by literature collection. Secondly, eight machine learning models were established to train and test the database, as well as evaluated for the generalization ability using six performance indicators. Finally, the optimal model was selected to conduct the correlation importance analysis of feature variables using shaply additve explanations and partial dependence plots, and compared with the typical empirical model. The results indicated that the compressive strength of cement soil was better predicted by extreme gradient boosting model (the determinate coefficient of model in the test set was 0.93). The cement content, water content, curing age and fine grain were the main feature variables influencing the compressive strength. A reliable database and machine learning model are proposed, which have practical reference for the design and construction of cement soil in soft foundation projects.

Keywords: Cement stabilized soft soil; compressive strength; machine learning; performance evaluation; shaply additve explanations

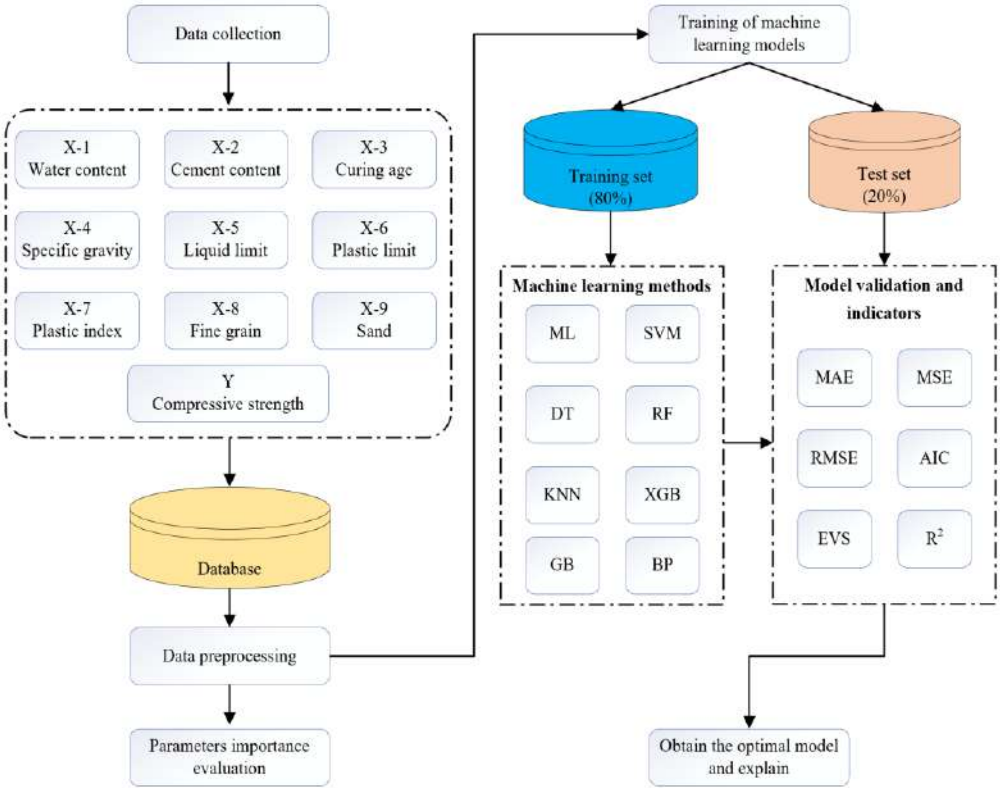

Fig. 1 Methodology flow of models.

INTELLIGENT IDENTIFICATION OF STRATUM CHARACTERISTICS DURING SHIELD TUNNELLING BASED ON PCA-GMM MODEL

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ABSTRACT

Real-time identification of geological conditions ahead the tunnel excavation face during shield tunnelling can help to set appropriate operational parameters, which guarantees tunnel quality via avoiding construction accidents and ensuring construction safety. The traditional geological prediction methods require additional testing equipment, construction space and time. This paper proposed an identification method based on PCA-GMM (Principal Component Analysis-Gaussian Mixture Model) that identifies geological conditions by using shield tunnelling parameters. The research was conducted via relying on Zhuhai Sanzao tunnelling project. The relationship between tunnelling parameters and geological features was explored using the proposed PCA-GMM model and then geological characteristics was identified based the clustering results using silhouette coefficients. Since this identification from PCA-GMM model is based on the principle of mechanical correlation between tunnelling parameters and geological features, PCA-GMM model can identify soil layer with large mechanical property gaps. The results indicate that PCA-GMM model can identify silty sand layer from silty layer. For those layers with less difference of mechanical property, such as clayey silt layer and the silty clay layer, the identified result is not satisfactory. Even though, the proposed identification method can guide the adjustment of shield operational parameter.

Keywords: Stratum Characteristics Identification, Principal Component Analysis, Gaussian Mixture Model, Clustering, Shield Tunnelling.

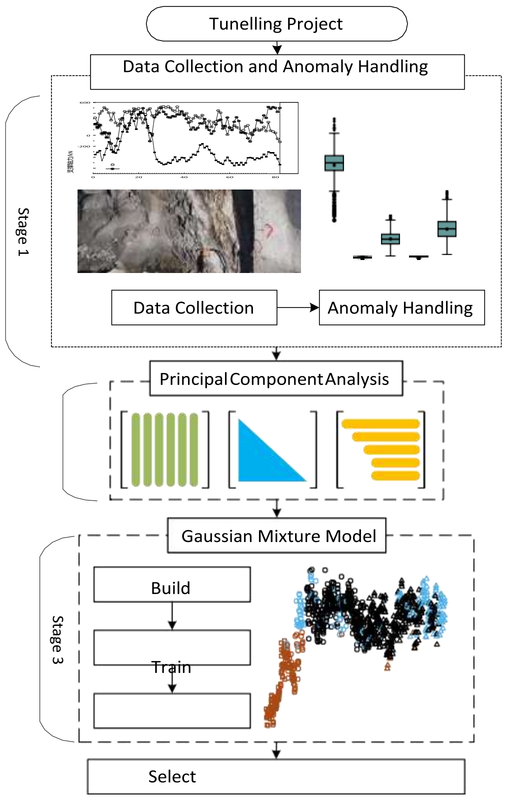

Fig. 1 Framework of PCA-GMM based stratum identification method

Real-time prediction of slurry balanced shield machine attitude based on LSTM neural network

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ABSTRACT

This paper presents a real-time prediction framework for estimating the attitude of a slurry balanced shield machine using an LSTM (Long Short-Term Memory) neural network. The analysis incorporates nine operational parameters and five geological factors that impact the shield attitude. The developed models are applied to examine a field case of shield tunnelling in Shenzhen City, China. In this study, we propose a dynamic and automated approach that leverages the power of LSTM neural networks to predict the attitude of the shield machine in real-time. The proposed framework utilizes historical data collected from sensors installed on the shield machine to train the LSTM network. Experimental results demonstrate that the LSTM-based approach achieves accurate and timely predictions of the shield machine's attitude, enabling early detection of potential deviations and allowing for prompt corrective actions. The developed framework provides a valuable tool for tunnelling engineers and operators, improving the overall safety and efficiency of slurry balanced shield machine operations.

Keywords: Slurry balanced shield machine; Shield attitude; Intelligent models; Empirical analysis; Tunnel excavation

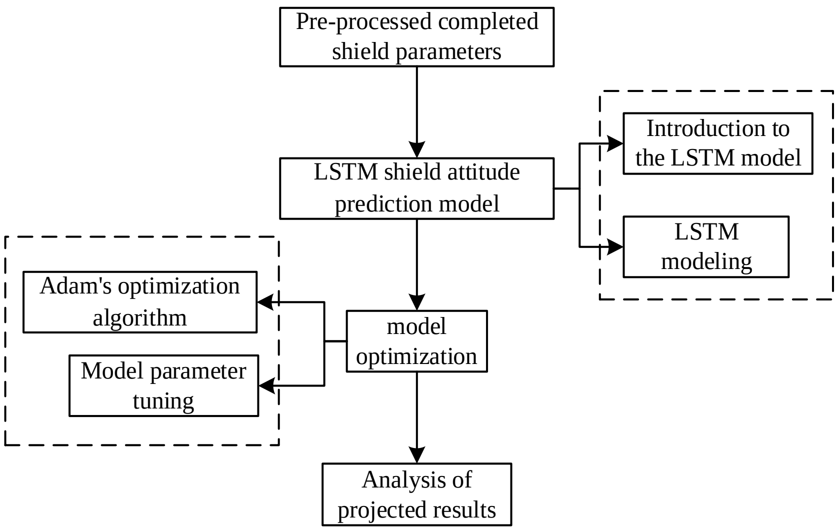

Fig. 1 Technology roadmap

RESEARCH ON ROCK CONSTITUTIVE MODEL BASED ON STACKING MODEL FUSION AND SHAP INTERPRETATION

Luyuan Wu[1#], *Jianhui Li*[1], *Jianwei Zhangr*[1], *Zifa Wang*[2], *Xiaohui Yang*[3], *Jingbo Tong*[1], *Fei Ding*[1]
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ABSTRACT

Accurate rock mechanical models are crucial for analyzing the mechanical behavior of rock materials and the stability of underground engineering. It is difficult to accurately describe the complex mechanical behaviors of rocks based on the traditional method of rock constitutive model, and the machine learning method provides a new way to construct a more accurate constitutive model.To this end, a rock constitutive model based on the stacked integrated CBR-XGB-LGB algorithm is proposed. In this study, a series of rock samples obtained from the Yuanzigou coal mine in Shaanxi Province were Indoor compression test, a total of 130 sets of rock mechanics test data were obtained after data preprocessing. With $M,\rho, E,\sigma_3, \varepsilon_3, \sigma_1$ as the input parameters of the model, and ε_1 as the output parameter to build the model, using cross-validation and Bayesian optimization algorithm for Update the weights and errors of the model. In addition to the stacking model, constitutive models based on RF, XGB and LGB single algorithms were established for comparison. The results show that the Stacking model has stronger learning and generalization ability than the single algorithm model. In addition, the importance and contribution of the input variables affecting the constitutive model are quantitatively analyzed by introducing the SHapley Additive exPlanations interpretation method. The proposed constitutive model is accurate and robust in expressing the mechanical behavior of rock, and can provide a new method to study rock constitutive model.

Keywords: Rock constitutive model;Stacking ensemble learning;SHapley Additive exPlanations;Bayesian optimization;

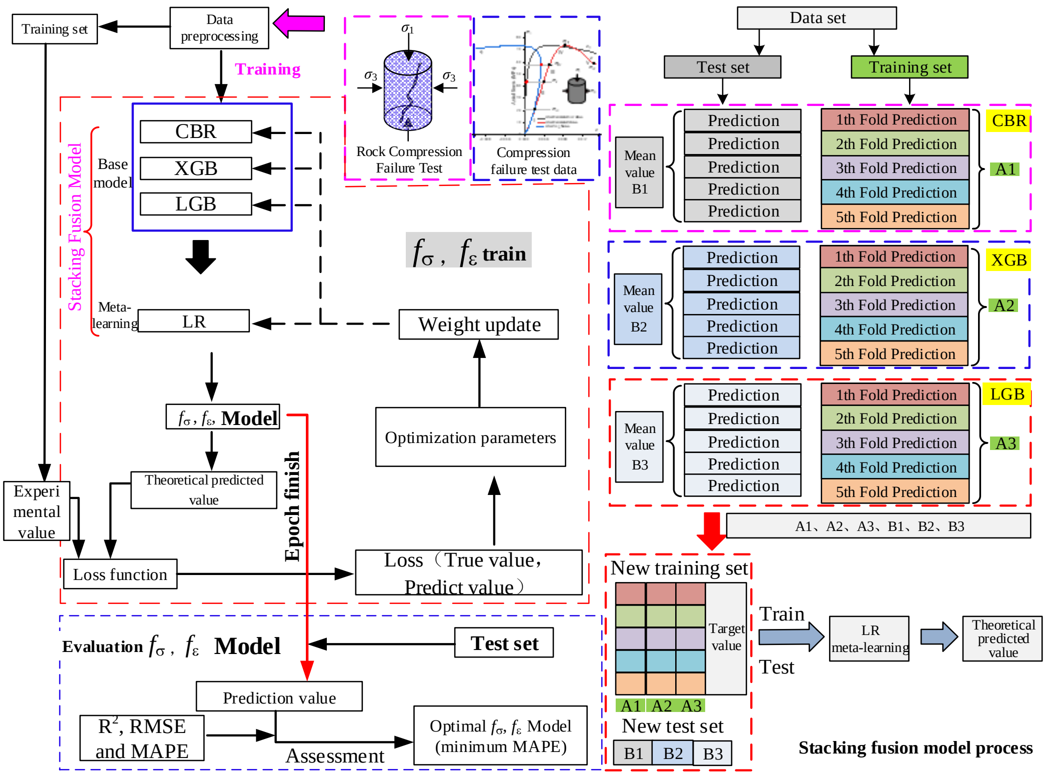

Fig. 1 Technology roadmap of intelligent rock constitutive model training based on Stacking fusion model

PHYSICS-GUIDED NEURAL NETWORK FOR DETECTING THE NATURE OF CONCRETE MATERIALS

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ABSTRACT

This work presents a physics-guided neural network for modeling the chloride diffusion in concrete by formulating a prediction method that ensures the physical constraints are accurately represented. Physical constraints are evolved as a loss term for guiding the training procedures and mitigating the data needed to train model. The boundary conditions and the governing equations in the physical constraints are integrated with the neural network training function for producing the loss term (Fig. 1). The reliability and feasibility of the presented model are verified using a 2D numerical approach. Results showed that the suggested method can successfuly simulate the behavior of chloride transport and predict the diffusion coefficient of concrete with high accuracy. The results of the proposed method is outstanding and efficient, showing its prospective for further applications. The applications of such technique to the spatial and temporal domain observed its potential as a novel method to investigate the concrete properties and detect the chloride concentration within the concrete samples.

Keywords: physics-guided neural network; chloride diffusion; concrete; numerical approach.

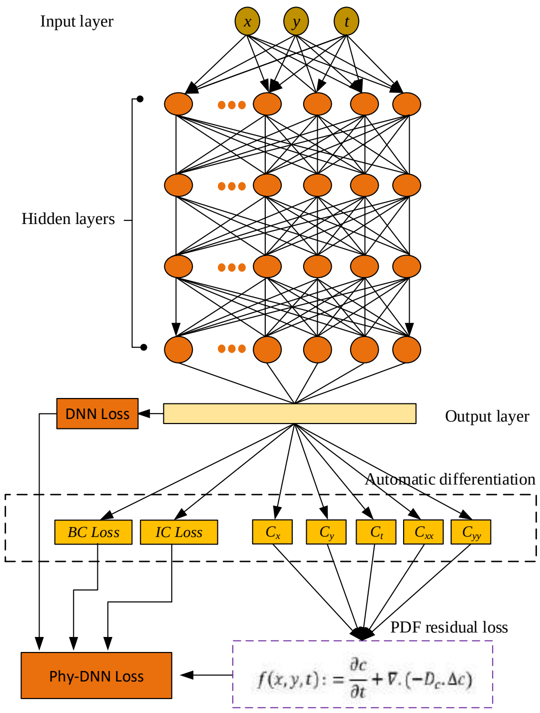

Fig. 1 Schematic diagram of the proposed model.

DATA-DRIVEN CONSTITUTIVE MODELLING OF GRANULAR SOILS CONSIDERING MULTISCALE PARTICLE MORPHOLOGY

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ABSTRACT

This paper adopts a micro-tomography (μCT)-based discrete element method (DEM) technique to generate a large database comprising 216 DEM simulations. This technique includes particle morphology extraction by X-ray μCT, morphology reconstruction and gene mutation by spherical harmonic-based principal component analysis (SH-PCA) and sophisticated DEM simulations of triaxial tests. Different degrees of morphological gene mutation, initial packing state, and confining stress condition were considered in the generated database. Based on this database, three neural network models, i.e., the backpropagation neural networks (BPNN), long short-term memory neural networks (LSTM), and gate recurrent unit neural networks (GRU) were utilized to predict the constitutive behaviours of granular soils. After training and testing, all trained models can reasonably predict granular soils' deviatoric stress-volumetric strain-axial strain relationship. The effects of particle morphology at different length scales, sample initial packing state, and confining stress condition can be well captured. Furthermore, all three models are tested by the μCT experimental data. The excellent consistency between model prediction and experimental results reflects these algorithms' feasibility, capability and generalization for the constitutive modelling of granular soils.

Keywords: X-ray micro-tomography; Discrete element method; Particle morphology; Neural network; Granular soils.

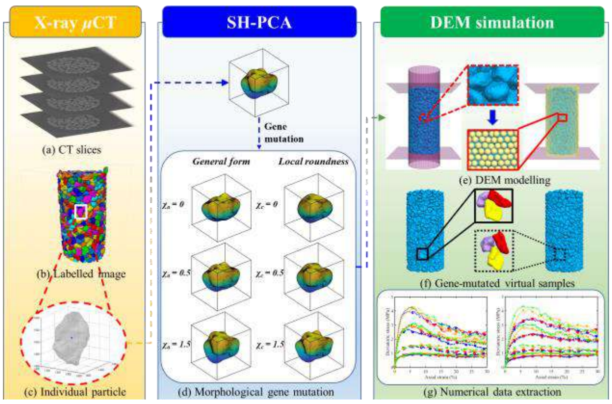

Fig. 1 Schematic plot of the μCT-based DEM technique to generate a database for machine learning-based investigations

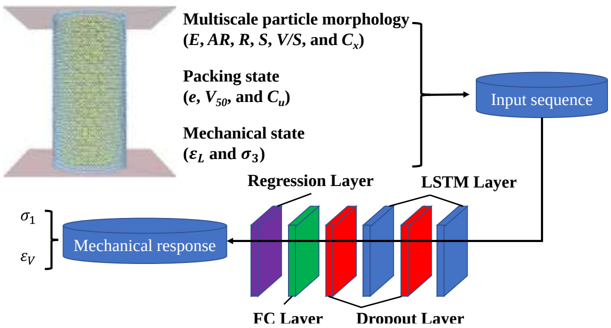

Fig. 2 Schematic plot of LSTM to constitutive modelling of granular soils

DATA-DRIVEN AND PHYSICS-INFORMED BAYESIAN LEARNING OF SPARSE SITE INVESTIGATION AND SETTLEMENT MONITORING DATA

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ABSTRACT

A digital twin of a geotechnical project (e.g., a reclamation or ground improvement project) is a virtual model that aims to continuously learn from actual observations (e.g., site investigation and monitoring data) and improve model prediction (e.g., spatiotemporally varying consolidation settlement). However, real geotechnical observation data obtained from a site are often spatially sparse (e.g., site investigation data) and spatiotemporally varying (e.g., settlement monitoring data). The sparse and spatiotemporally varying data pose great challenges for continuous learning of data and improvement in model prediction. To address these challenges, this study proposes a novel data-driven and physics-informed Bayesian learning framework that automatically develops ground models from spatially sparse site investigation data, performs geotechnical analysis, and integrates geotechnical analysis results with limited, but spatiotemporally varying, settlement monitoring data to improve model prediction in a systematic and quantitative manner. The proposed method contains three key components: (1) data-driven ground modeling by Bayesian compressive sampling (BCS) using sparse site investigation data as input; (2) finite element modeling (FEM) of consolidation settlement that incorporates domain knowledge; and (3) Bayesian sparse dictionary learning of settlement monitoring data together with FEM results (see Fig. 1). The performance of the proposed method is illustrated using a real ground improvement project. Results show that the proposed approach performs well.

Keywords: Machine learning; Digital twin; Bayesian method; Dictionary learning; Compressive sampling

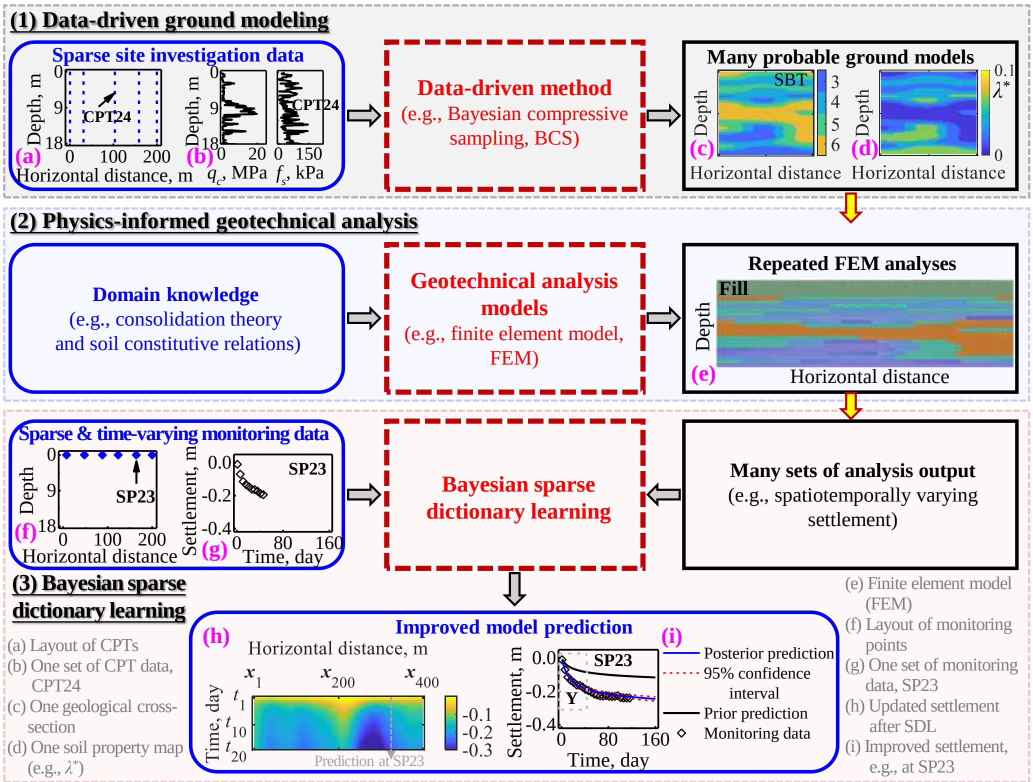

Fig. 1 Data-driven and physics-informed Bayesian learning framework

DIGITAL RISK ASSESSMENT OF ROCK TUNNEL FACE: COMBINING COMPUTER VISION AND DATA-DRIVEN

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ABSTRACT

This study will showcase a novel approach to risk assessment for rock tunnel excavation projects, specifically addressing the challenge of quantitative tunnel face risk assessment. Our approach utilizes computer vision to quickly and accurately extract key features of the rock tunnel face, eliminating the need for manual assessment. By combining computer vision and data-driven, we are able to assess the rock mass rating of the tunnel face with a high level of precision. Our approach has shown to effectively obtain dynamic safety factors during tunnel excavation. This study will demonstrate the benefits of digitizing the risk assessment process, highlighting the potential for the increased efficiency and accuracy in rock tunnel excavation practice.

Keywords: computer vision, rock tunnel, risk assessment, data driven

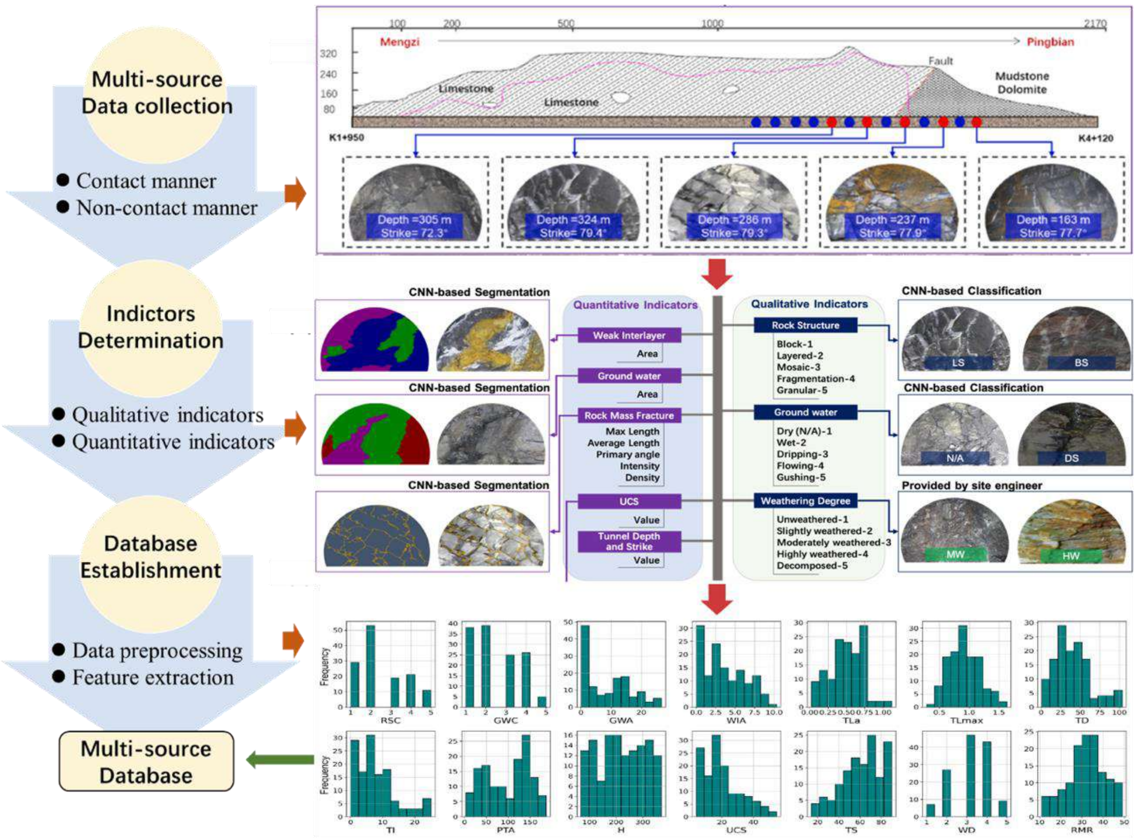

Fig. 1 Establishment of multi-source datasets in rock tunnels

NOVEL MODEL FOR RISK ASSESSMENT OF SHIELD TUNNELLING IN SOIL-ROCK MIXED STRATA

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ABSTRACT

Shield tunnelling faces numerous potential risks particularly in complex geological environments. In this study, we propose a novel fuzzy model for predicting the risk levels of tunnelling in soil-rock mixed strata (see Fig.1). The proposed model incorporates the fuzzy set pair analysis (FSPA) method into the fuzzy c-means (FCM) clustering, to overcome the limitation of the traditional data normalisation. Tunnelling data, deformation data, and vibration data are employed to build an index system with the mutual information (MI) algorithms for feature selection. The intercriteria correlation (CRITIC) is employed to weight the indicators, and the FSPA method is adopted to calculate the connection number. The results are then classified by the FCM with a modified objective function considering the importance of risk indicators to derive the risk level of each ring in real time. The proposed model is applied to a case study of a shield tunnelling project in Guangzhou, China. As shown in Fig. 2, the analysis results indicate a higher risk level from Ring 1572 onwards, with careful regulation of thrust force and earth pressure required. The proposed novel method provides a practical and reliable tool for guiding risk decisions in the tunnel construction.

Keywords: shield tunnel; construction safety; risk assessment; FSPA; FCM

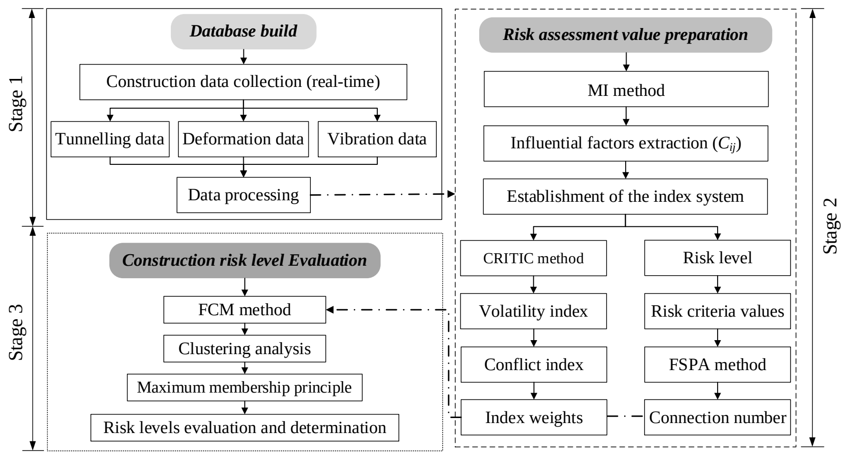

Fig. 1 Research frame for risk assessment of shield tunnelling in soil-rock mixed strata.

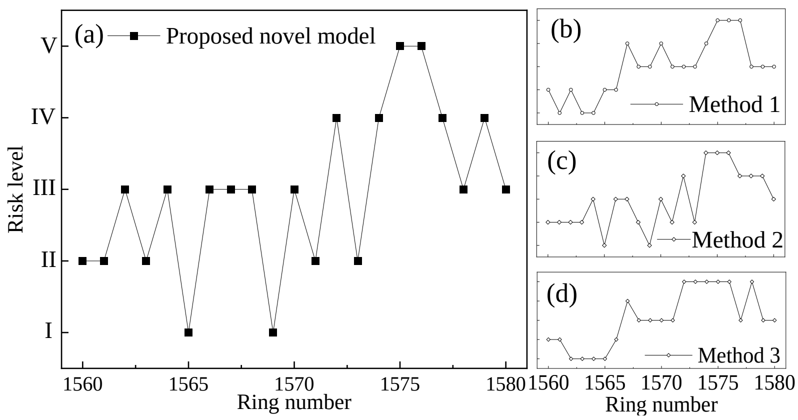

Fig. 2 Construction risk levels from Ring 1560 to 1580 using four methods: (a) the proposed method; (b) method 1 (modified FCM); (c) method 2 (FCM with FSPA); (d) method 3 (FCM).

EVALUATION OF THE COLLAPSE SUSCEPTIBILITY OF LOESS USING MACHINE LEARNING

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ABSTRACT

Loess is well-known as a problematic soil due to wetting-induced collapse, which results in many geotechnical problems. This study evaluates the collapse susceptibility of loess using the Multi Expression Programming (MEP) and Back-Propagation Neural Network (BPNN). The analysis of wetting-induced loess collapse showed that the gravimetric water content at the initial state (w_0), net vertical stress ($\sigma - u_a$), void ratio at the initial state (e_0), void ratio at the liquid limit state (e_L), and plastic index (I_p) were selected as input variables. To train and test the two algorithms, over 200 oedometrically soaking tests were collected and divided into two groups. Both the training group and the testing group comprise 100 collapse potential data. MEP and BPNN can accurately predict the collapse potentials of loess, as demonstrated by their high R^2 (>0.88) values and small MAE (<0.008) and RMSE values (<0.012). According to ASTM D5333-03 (2003), the degree of loess collapse is classified with accuracie of 98% and 90% for MEP and BPNN respectively. Moreover, sensitivity analysis was conducted to reveal the relative importance of variables. The machine learning is expected to assist the code of practice ASTM D5333-03 (2003) in achieving an efficient site-investigation of collapsible loess.

Keywords: machine learning; loess; collapse susceptibility; ground improvement; site-investigation.

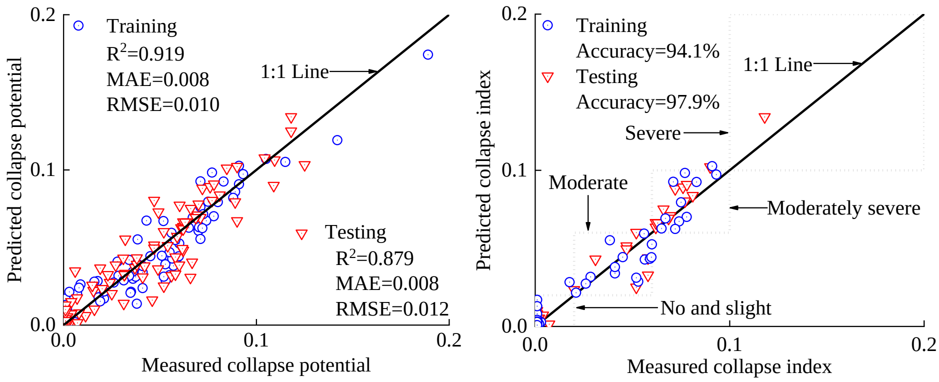

Fig. 1 Comparison between measurements and predictions using the MEP: (a) collapse potential; (b) collapse index

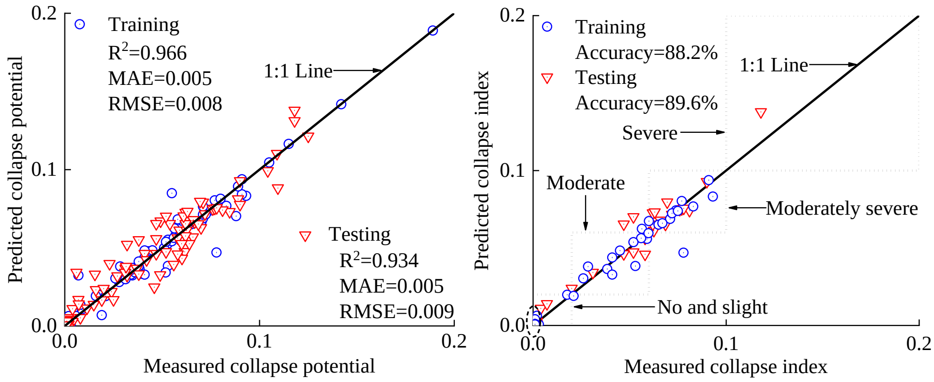

Fig. 2 Comparison between measurements and predictions using the BPNN: (a) collapse potential; (b) collapse index

OPERATION OPTIMIZATION FOR AQUIFER THERMAL ENERGY STORAGE SYSTEM BASED ON A SURROGATE MODEL – ASSISTED METHOD

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ABSTRACT

Abstract: Aquifer thermal energy storage system (ATES) uses seasonal storage of cold and warm groundwater in aquifers for space heating or cooling. In this study, a hybrid optimization workflow for the sustainable operation of ATES is proposed by combining thermo-hydro-mechanical numerical model, surrogate model, and multi-objective optimization technologies. Firstly, a 3D numerical model is constructed based on TOUGH-FLAC3D with a thermo-elastoplastic constitutive model, and validated through field data. Then, optimization variables and constraints are determined considering land subsidence and hydraulic impacts as well as thermal recovery efficiency. Afterwards, simulations are performed using 'Box-Behnken' experimental design to minimize the number of simulations, and surrogate model based on numerical results is developed using multivariate regression analysis. Finally, the surrogate model is integrated with a multi-objective optimizer based on imperialist competitive algorithm (ICA) to find the optimal groundwater extraction and injection rates as well as injection temperature, in order to meet all environmental constraints and maximize thermal recovery efficiency. In addition, the performance and capability of the proposed workflow are demonstrated by obtaining the optimum operational strategy for the cooling and heating cycle operation of a field - scale ATES with four wells installed in Shanghai, China.

Keywords: Aquifer thermal energy storage (ATES); optimal operational variable; numerical simulation; surrogate model; multi-objective optimization

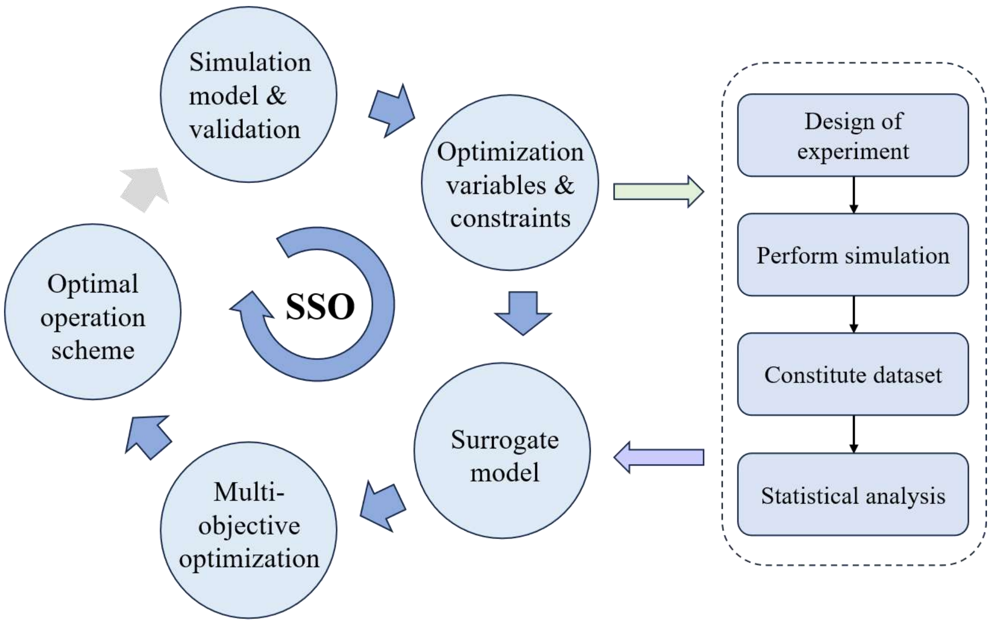

Fig. 1 Workflow for coupled simulation, surrogate model and optimization (SSO)

STATIC STATE ANALYSIS OF EARTH-ROCKFILL DAMS CONSIDERING SPATIAL VARIABILITY BASED ON RANDOM FOREST FILTER

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ABSTRACT

Deformation can effectively reflect the operating condition of earth-rockfill dams (ERDs), so it is crucial to establish a reliable deformation prediction model for ERD condition assessment. At present, inverse methods are widely used in the field of ERDs due to their high computational efficiency and accuracy. However, the current static inverse analysis mostly assumes that the soil or rockfill material parameters inside the dam body are spatially consistent and does not consider the spatial variability stem from its nature. Meanwhile, several studies have shown that the use of studies that deviate from the true material properties can affect the results of deformation analysis and be detrimental to the assessment of the behavior of ERDs during operation. Therefore, it is necessary to study the effect of spatial variability of material parameters on the deformation to make sure of their design and operation. To address this issue, this paper proposes a new method for static inversion considering the spatial variability of rockfill material properties based on the sensitivity filter of the spatial response of material parameters by Random Forest, and further investigates the relationship between the deformation response of the dam body and the distribution of material parameters.

Keywords: Operation; Inversion; rockfill; Spatial variability; Random Forest

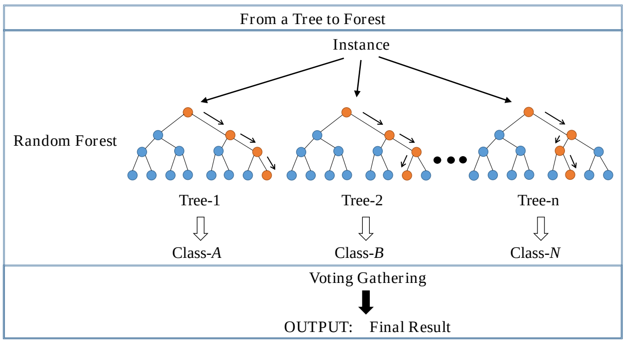

Fig. 1 Basic concept of Random Forest

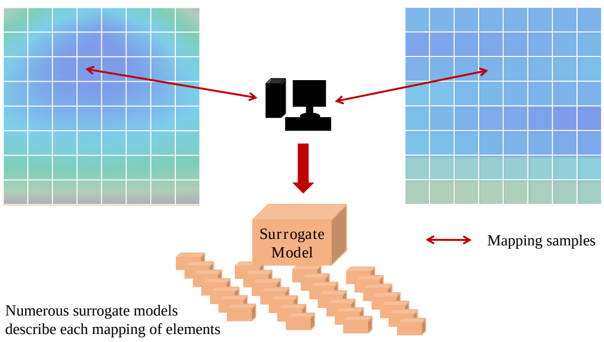

Fig. 2 Generation of samples for random Forest filtering

A QUALITY INDEX FOR CONSTRUCTION BIG DATA IN EPB SHIELD TUNNELING

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ABSTRACT

The massive quantity of data generated continuously during the EPB shield tunneling process can be utilized for tunneling performance prediction and operation optimization through the development of data-driven models. However, the quality of these data determines an upper bound of the accuracy of developed data-driven models, it plays a critical role in ensuring accurate predictions and informed decision-making. Despite its importance, there is currently no universally accepted method for assessing the quality of data in EPB shield tunneling. Herein, we proposed a concise formulation of a quality index for construction big data in EPB shield tunneling, which is defined as the average value among three distinct sub-terms, i.e., Representativeness, Diversity, and Informativeness. Representativeness originated from the harmfulness of the outliers on the data quality and the developed models, which quantitatively pertains to the number of outliers between clusters. Diversity is assessed by the area of the convex hull that encloses the dataset, measuring the breadth of variation within the dataset. Informativeness evaluates the information richness of the dataset in terms of training data-driven models, it can be quantified by the uncertainty of the predictions generated by the developed model. The effectiveness of the quality index is quantitatively demonstrated by examining its correlation with the performance measures of the developed data-driven models in three scenarios. The strong positive correlation coefficient > 0.90 between the quality index and the developed model's performance illustrates the capability of the quality index to accurately capture the dataset's potential for developing precise data-driven models.

Keywords: Construction big data; EPB shield; Quality index; Data-driven models

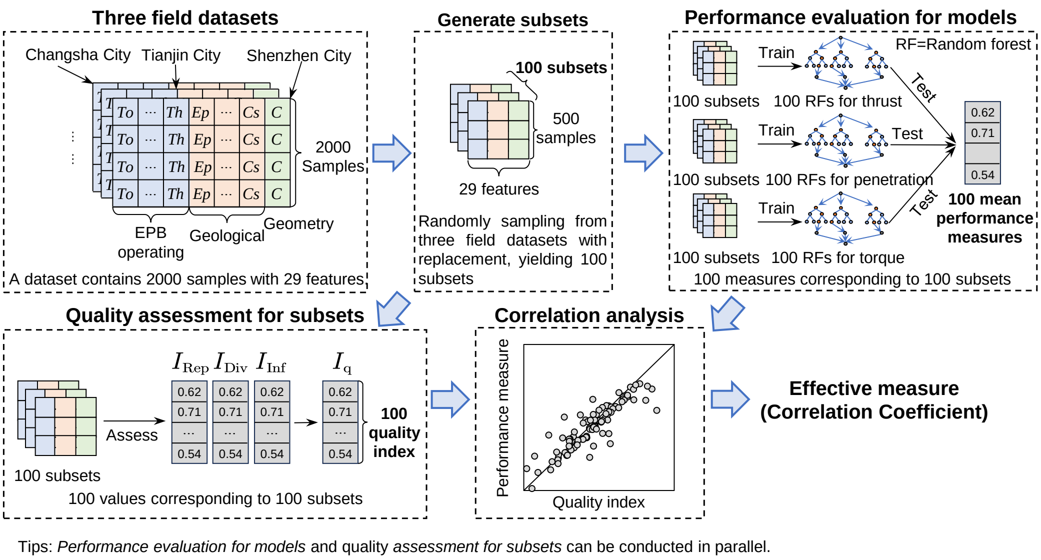

Fig. 1 Evaluation procedure for effectiveness of the proposed quality index.

PREDICTING SHALLOW UNDERGROUND TEMPERATURE BASED ON THE PSO-XGB HYBRID OPTIMIZATION TECHNIQUE: A CASE STUDY OF CHANGCHUN CITY (CHINA)

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ABSTRACT

Accurate prediction of shallow ground temperature is of great significance for reducing investment risks and promoting the development and utilization of shallow geothermal energy. In this study, a hybrid model based on Particle Swarm Optimization (PSO) and Extreme gradient boosting (PSO-XGB) was developed and compared with single models including K-Nearest Neighbors (KNN), Support Vector Regression (SVR), Random Forest (RF), and Extreme gradient boosting(XGB). Latitude and longitude coordinates, annual average rainfall, annual average temperature, and distance to faults were used as input features for predicting the temperature at a depth of 100 meters underground. The performance of the models was evaluated using metrics such as Mean Squared Error, Root Mean Squared Error, Coefficient of Determination, and Mean Absolute Error. The results showed that the PSO-XGB hybrid model outperformed the single models in terms of predictive performance. Therefore, the developed PSO-XGB hybrid model demonstrates strong potential for application in the field of shallow ground temperature prediction.

Keywords: Underground temperature prediction, PSO-XGB hybrid model, XGB, KNN, SVR, RF

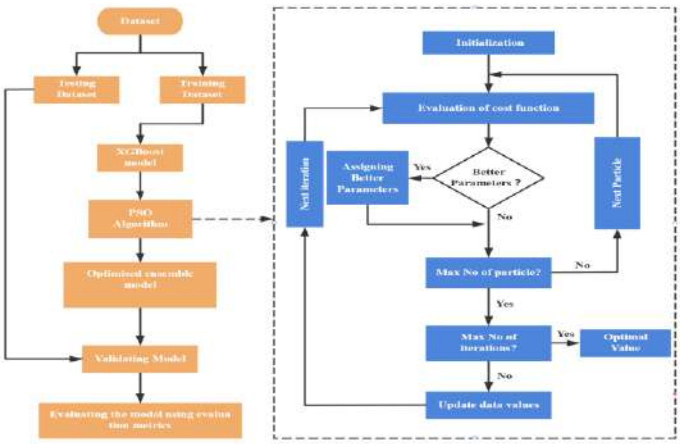

Fig. 1 Basic flowchart of PSO-XGB

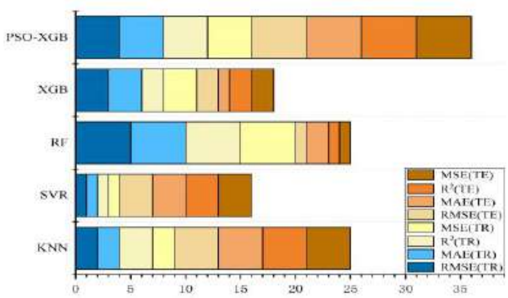

Fig. 2 Ranking of Different Model Indicators.

INTELLIGENT IDENTIFICATION AND CLASSIFICATION OF GRANITE RESIDUAL SOIL BASED ON CNN

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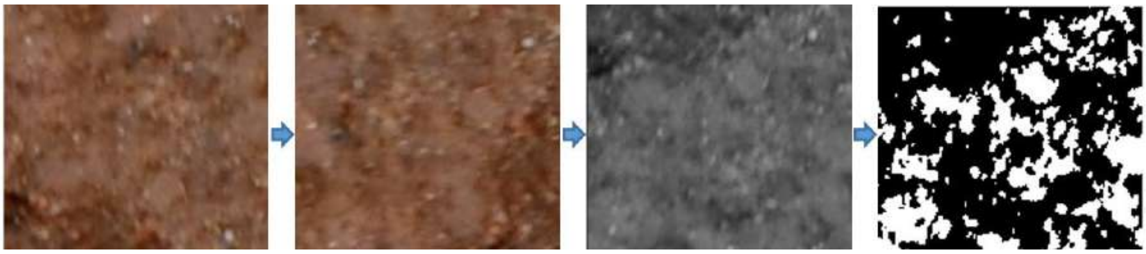
ABSTRACT

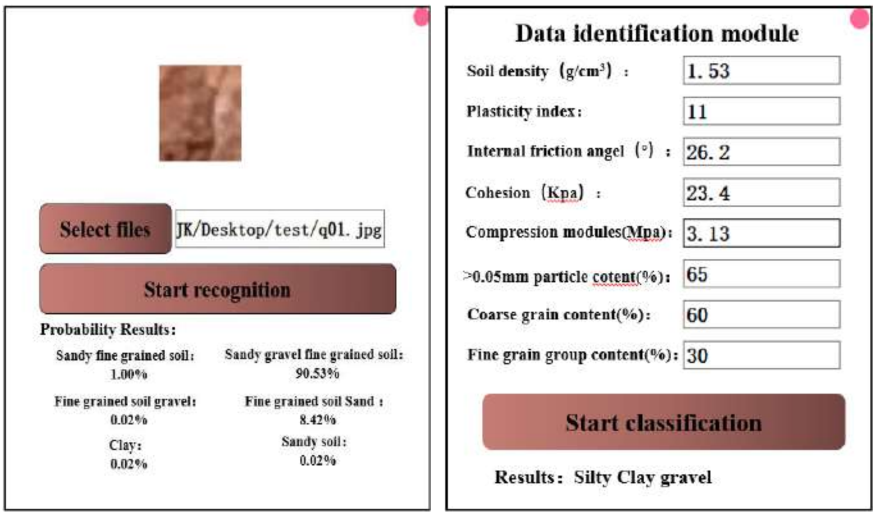
The identification and classification of soil is the most basic work of soil mechanics. With the accumulation of geotechnical classification database and knowledge, deep learning and image recognition technology have been applied in geotechnical engineering. Not only can rapid and intelligent identification and classification improve the efficiency of work, but also reduce the inaccuracy caused by human judgement. Through sampling and basic physical experiments, image acquisition and processing, classification and labeling work of granite residual soil in Guangdong. The input layer data of intelligent identification and classification of granite residual soil were obtained. Using BP neural network and convolution neural network(CNN) optimized by RMSProp algorithm, an intelligent identification and classification program of granite residual soil was designed based on the Gui user interface of PyQt framework. An on-site image recognition and multi-classification method based on granite residual soil was established, which provides a new way for soil identification and classification in geotechnical investigation.

Keywords: Granite residual soil; Convolutional neural network; Deep learning; Classification of soil; Image recognition.



(a) Original image (b) Enhancement image (c) Gray processing (d)Binary processing

Fig. 1 Picture processing example display



(a)Image recognition module (b)Data identification module

Fig. 2 Application module

IMPROVED PHYSICS-INFORMED NEURAL NETWORKS-BASED MODELING: APPLICATION TO UNSATURATED INFILTRATION BEHAVIOR PREDICTION

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ABSTRACT

Accurate characterization of soil moisture dynamics in the infiltration zone holds great significance for geotechnical practice. Nowadays, the physics informed neural network (PINN) is popular for solving Richards equations (RE) today because they are meshless, physics-constrained, and data-driven. Although it has been successfully applied to modeling 1D infiltration problems, further study is needed to determine its ability to handle more complex boundary conditions and multidimensional problems. In this paper, we examine the effects of gradient-enhanced RE residuals and RE decomposition residuals on the PINN loss function. We compare two loss-enhanced PINNs, GPINN and DPINN, to the baseline PINN for modeling unsaturated infiltration. As a result, both GPINN and DPINN can improve PINN calculation accuracy by one order of magnitude, and DPINN is more efficient than GPINN.

Keywords: Machine learning, unsaturated infiltration, physics informed neural network, neural network, Richards equation

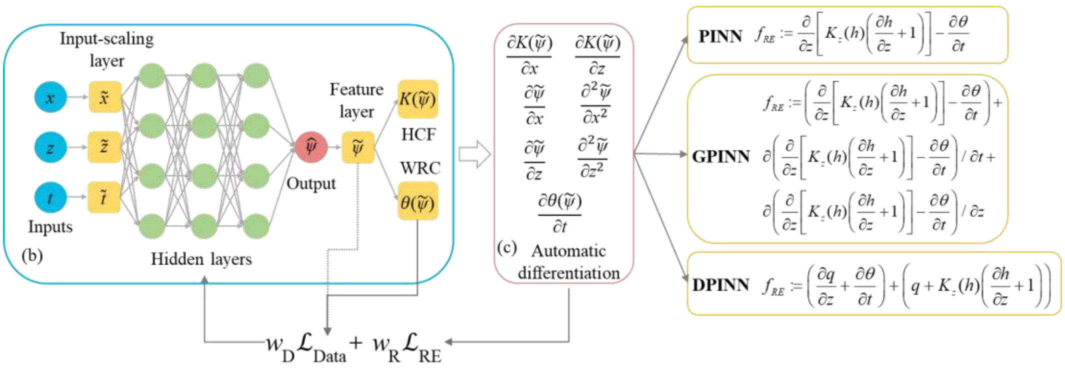

Fig. 1 Illustration of the proposed method

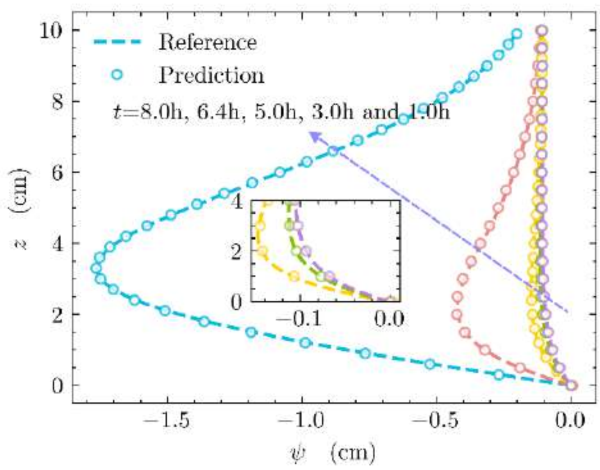

Fig. 2 Comparison of the reference (represented by hollow circles) and DPINN prediction (dashed lines) under different times (t=8.0h, 6.4h, 5.0h, 3.0h, and 1.0h).

DATA-DRIVEN MULTISCALE MODELLING OF GRANULAR MATERIALS VIA TRANSFER LEARNING

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ABSTRACT

Data-driven approaches have the potential to revolutionize the constitutive modelling of granular materials. However, the challenge of data scarcity hinders the development of this emerging constitutive modelling paradigm. In this study, we propose two transfer learning-based strategies to leverage all available constitutive knowledge to assist material modelling. One approach utilizes phenomenological constitutive models to artificially generate massive stress-strain and volumetric strain data to train a base model, which is then repurposed to the data from particle-scale numerical simulations via transfer learning. The other approach involves using available data on similar materials to train a base model, which is then applied to other targeted materials with limited data. We test the proposed transfer learning methods on both discrete element modelling (DEM) of representative volume elements (RVEs) and FEM×DEM hierarchical multiscale modelling of boundary value problems (BVPs) of granular materials. The trained data-driven material model is embedded in implicit FEM simulations to validate its accuracy, efficiency, and stability. The results demonstrate that transfer learning can be an effective strategy to achieve high-quality machine learning predictions with limited data. The transfer learning strategy presented in this study is expected to be widely applicable to small data-driven material modelling.

Keywords: Granular materials, DEM, Transfer learning, Data-driven material modelling, FEM×DEM Multiscale modelling

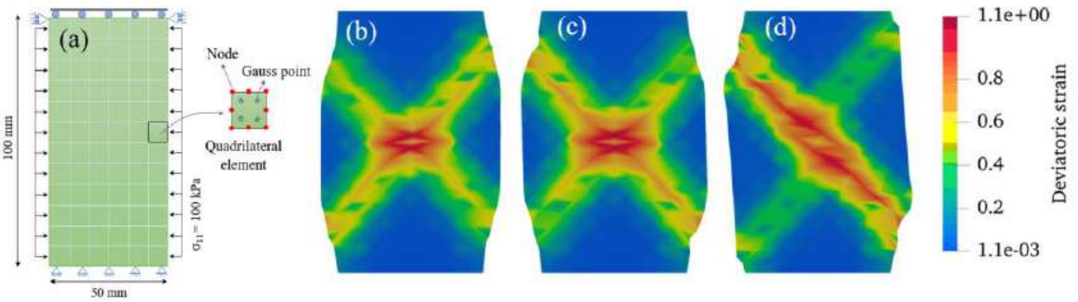

Fig. 1 Transfer learning-empowered data-driven multiscale modelling of granular materials: (a) FEM mesh partition for biaxial shear tests with rough loading ends; the distribution of accumulated deviatoric strain for (b) hierarchical multiscale modelling coupled FEM×DEM, (c) transfer learning-based FEM×ML simulations and (d) FEM×ML simulations without knowledge transfer

AUTOMATIC CLASSIFICATION OF SOIL INTERNAL CRACKS BASED ON HIGH FREQUENCY GPR B-SCAN AND DEEP CONVOLUTIONAL NEURAL NETWORK

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ABSTRACT

The number of contaminated sites requiring treatment has increased dramatically, posing significant challenges in terms of restoration and disposal. Studying the strong heterogeneity and dominant percolation of contaminated soil is crucial for improving treatment efficiency and optimizing remediation plans. Unlike traditional detection methods such as CT scanning, tracer tracking, and borehole sampling, high-frequency Ground penetrating radar (GPR) provides a rapid, accurate, and nondestructive solution for detecting the distribution of soil cracks. This paper establishes a comprehensive research framework for nondestructive detection of dominant seepage channels in low-permeability contaminated soil. Advanced GPR technology is used to monitor the dominant seepage model in a laboratory environment, where the soil contains benzene organic matter with a permeability of 2.5×10^{-9} m/s and volumetric water content of 0.05, 0.1, and 0.15. To address the challenge of processing a large number of GPR images and improve classification efficiency, this research also establishes AlexNet, VGG16, ResNet34, and ViT B/16 models based on deep convolutional neural networks. These models automatically classify the three dominant seepage channels. The results show that through the filters, range gain, offset and wavelet packet decomposition of the GPR image, the accuracy and frames per second (FPS) of ResNet34 are higher, reaching 92.6% and 143.3, respectively. Therefore, ResNet34 is selected as the automatic classification model for GPR images of soil crack distribution, partially solving the soil crack detection problem.

Keywords: Ground penetrating radar, Crack detection, Convolutional neural network, Classification.

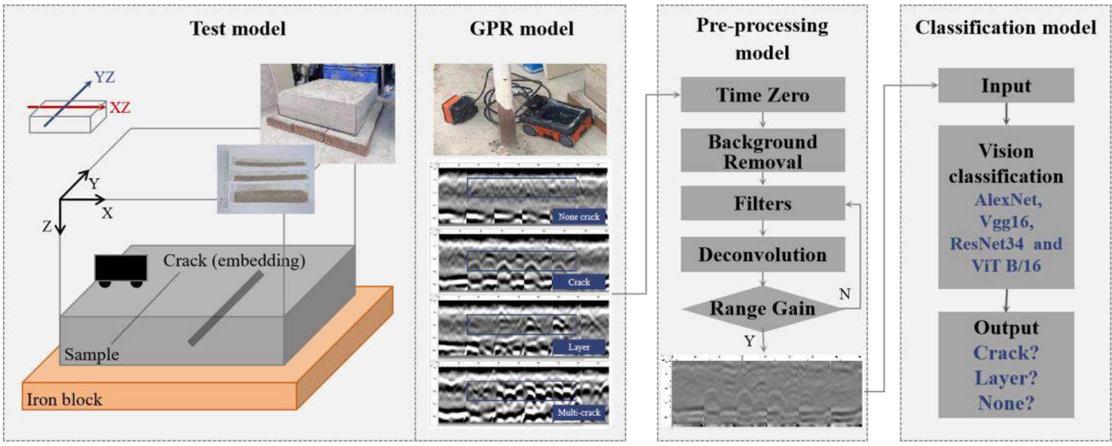

Fig. 1 Illustration of the proposed research framework

DEVELOPMENT AND USE OF DATABASES OF GEOTECHNICAL INFORMATION FOR DATA-CENTRIC GEOTECHNICS

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ABSTRACT

In recent years, the interest in data-driven research has been particularly growing in geotechnical engineering. This has led to an emerging field, data-centric geotechnics. It is centered on real data from which knowledge is extracted by data science and then used to urge the digital transformation of geotechnical engineering. This paper presents an extensive review on the development and use of databases of geotechnical information that lies at the very heart of data-centric geotechnics. Geotechnical information includes subsurface exploration results, performance testing or monitoring data of geo-structures, comparison of numerical analyses with in situ measurements, and a synthesis of thirty-four prediction events. Use of these database are associated with two fundamental aspects of geotechnics. The foremost is site characterization which can be implemented by the more classical statistics (e.g., regression analysis of dataset from subsurface exploration carried out at multiple sites) or a modernized version of statistics (e.g., machine learning of generic geotechnical database pooled by site-specific data). This paper suggests a concept of physics-informed and data-driven ground model that (a) integrates geology, geophysics and geotechnics and (b) interprets all related data (direct and indirect) to reduce the uncertainty of the quantification of relevant parameters both at and between boreholes. The second is performance prediction by empirical, theoretical or numerical models. Performance databases (e.g., foundation load tests) are commonly used to build empirical correlations between the quantity of interest and relevant parameters, calibrate theoretical methods as well as numerical analyses with sophisticated constitutive models, develop more accurate methods of analysis and design, and assess the variability of predictions. The results show that the vast majority of the methods of analysis are biased and imprecise on the safe side. Besides the impressive ability of numerical tools for complex and sophisticated analyses with relative ease and efficiency, the reality that geotechnical analysis/design is often data-limited with high degree of uncertainty should not be overlooked and the complexity of model should match the data available. In addition, engineer's judgment in the selection of model and the values of relevant parameters plays an important role in geotechnical prediction. Finally, it is concluded that data-centric geotechnics provides an efficient solution to decrease the gap between geotechnical research and practice.

MAPPING URBAN SUBSURFACE FOR SUSTAINABLE GROWTH: A MACHINE LEARNING APPROACH

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ABSTRACT

In the pursuit of sustainable urban development, precise subsurface stratigraphy knowledge is crucial, especially in densely populated areas. This study endeavours to address the challenge of predicting the distribution of soil/rock layers in urban environments through harnessing the potential of machine learning techniques. By leveraging a big dataset of boreholes distributed across Singapore (~20,000 effective boreholes), this research introduces two contributions. Firstly, the Multi-scale Meta-learning Model (M3) introduces an innovative approach by combining the strengths of generic geological attributes with location-specific features. This fusion enhances the accuracy of predicting the elevation of geological interfaces. Secondly, inspired by graph network learning, a novel classification model is proposed to incorporate digitized grids and the principle of neighbourhood aggregation. This model is able to predict the occurrence of non-ordered layers, concurrently facilitating full stratigraphic prediction for any given location. These approaches provide valuable resources for fostering sustainable urban growth and intelligent infrastructure planning. Ongoing efforts encompass the development of a software that integrates both methods, facilitating a streamlined implementation process for geotechnical/geological engineers. As urban landscapes continue to evolve, the developed software aspires to stand as a dependable digital-twin for urban expansion, aligning with the principles of sustainability and adaptability.

Keywords: Subsurface Stratigraphy; Machine Learning; Borehole Data.

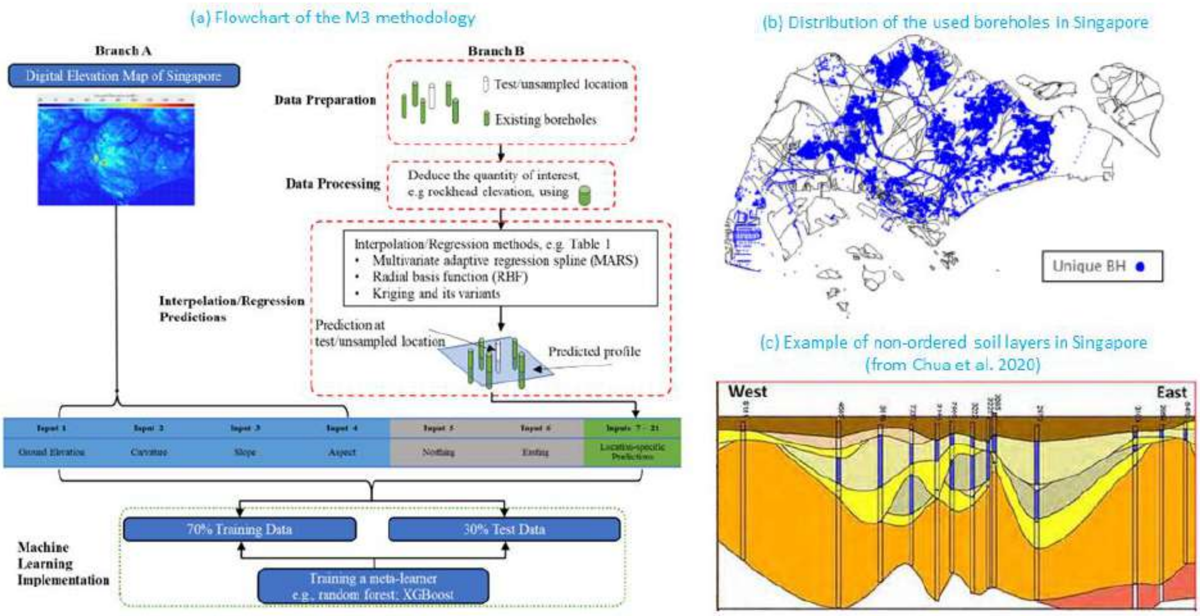

Fig. 1 Illustration of the Proposed Method, Utilized Borehole Data, and a Non-Ordered Layer Example

MACHINE LEARNING ALGORITHMS IN ROCK STRENGTH PREDICTION: A NOVEL METHOD FOR DYNAMIC COMPRESSIVE STRENGTH OF ROCKS UNDER FREEZE-THAW CYCLES

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ABSTRACT

At present, the dynamic compressive strength (DCS) of freeze-thaw rocks is mainly obtained through indoor experiments, and its shortcomings such as long time, high cost, and dependence on rock samples have always been criticized. Therefore, combining artificial intelligence technology to develop a more accurate and convenient DCS prediction model for freeze-thaw rocks is an exploratory attempt. Based on this, this paper proposes a DCS prediction model for SSA-RF freeze-thaw rock masses. Firstly, based on 216 sample datasets, principal component analysis (PCA) was used to reduce the dimensionality of 10 influencing factor indicators (freeze-thaw cycles, confining pressure, impact force, dry density, natural water content, water absorption rate, average dry weight, porosity, longitudinal wave velocity, and strain rate); Secondly, five mainstream machine learning algorithms (Support Vector Machine (SVM), Decision Tree (DT), K-Nearest Neighbor Algorithm (KNN), Reverse Neural Network (BP), and Random Forest (RF)) were used to train the DCS intelligent prediction model of freeze-thaw rocks, and the best two algorithms were selected based on evaluation indicators for further optimization and comparison; Finally, five optimization algorithms (Sparrow Search Algorithm (SSA), Grey Wolf Optimization Algorithm (GWO), Bacterial Foraging Optimization Algorithm (BFO), Particle Swarm Optimization Algorithm (PSO), and Whale Optimization Algorithm (WOA)) were used to perform hyperparameter optimization on the two initially selected algorithms. And a comprehensive evaluation and comparative analysis were conducted on the generalization ability of the optimized model using root mean square error (RMSE), mean absolute error (MAE), mean absolute percentage error (MAPE), and coefficient of determination (R^2). The research results show that the RMSE, MAE, MAPE, and R^2 of the SSA-RF model test set are 8.61, 5.83, 0.05, and 0.94, respectively. Its generalization is better than the other nine models, and its running time is relatively minimal. The prediction model proposed in this study has good applicability for DCS prediction of freeze-thaw rock masses in cold regions, providing a new approach for the combination of machine learning and rock mass engineering in cold regions.

Keywords : Rock mass engineering in cold regions; Freeze-thaw cycle; Dynamic compressive strength; Hybrid machine learning algorithm; prediction model

RELIABILITY OF DATA-CENTRIC APPROACH IN GROUND IMPROVEMENT DESIGN: EVIDENCE FROM JET GROUTED COLUMNS DIAMETER ESTIMATION

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ABSTRACT

Various machine learning methods have been developed to predict the variability of jet grouting columns, which is vital for ensuring the reliability of underground constructions as well as mitigating/preventing geohazards. Despite the ever-growing tendency of enhancing these approaches' performance (through model-centric paradigms), no huge improvement is observed on their predictive ability. This study investigates the reliability of Data-centric systems. The effect of data centricity is examined following key ideas advocated by *Andrew NG*, including (i) addressing the consistency of the y label; (ii) removing noisy samples or improving the quality of inputs x, and (iii) carrying out data augmentation. The latter is achieved through Monte Carlo simulations, while the system is tested through a deep learning model. Then, relationships for reliable estimate of jet grouting columns diameter are derived via polynomial regression approach. Finally, the pattern of error for each jet grouting system is determined through uncertainties propagation and a series of Monte Carlo simulations. This study enables revealing how data-centricity approach can influence the reliability of ground improvement design in general and jet grouting technique, in particular. This can promote data standardization for future uses.

Keywords: Data-centric approach, ground improvement, Jet Grouting.

Fig. 1 Principle and effect of data-centric strategy

DATA ASSIMILATION METHODS FOR HIGH-DIMENSIONAL CREEP PARAMETER RELATED TO HETEROGENEOUS ROCK MASS IN LCGX HYDROPOWER PROJECT

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Abstract

Rock creep models are widely utilized to understand time-dependent deformation, involving a range of creep parameters that describe the complex stress-strain behavior of rocks. The inherent heterogeneity of natural rocks presents significant challenges in achieving accurate and consistent parameter estimation and model state prediction. In this study, we initially conducted laboratory creep experimental on rock samples from the F115 fault influence zone of the LCGX Hydroelectric Station and obtained experimental data. Subsequently, during the numerical modeling phase, we employed geostatistical random field theory to generate a large amount of log-normally distributed creep parameters, considering the heterogeneity of the rock, constituted a high-dimensional numerical model with numerous creep parameters. These high-dimensional numerical experiments incorporated Bayesian-based Data Assimilation (DA) methods, including Ensemble Smoother with Multiple Data Assimilation (ESMDA) and Iterative Local Updating Ensemble Smoother (ILUES), for the estimation of these numerous creep parameters. ESMDA and ILUES have shown excellent performance in model calibration, but ILUES performs better in rheological parameter estimation, especially, ILUES excelled in addressing the issue of equifinality, where different parameters yield similar outcomes. The findings of this research hold considerable significance for the study of uncertainty estimation in the field of rock mechanics.

Keywords: Rock Creep Tests, Numerical Simulation, Data Assimilation, Spatial heterogeneity, Uncertainty analysis

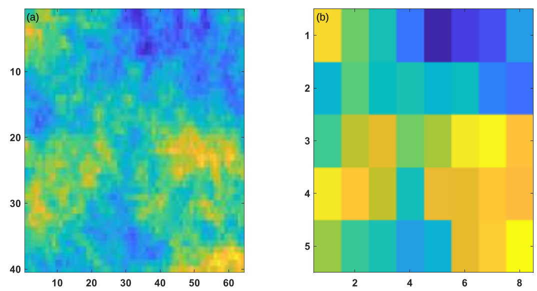

Fig. 1 Schematic Diagram of Creep Parameter Random Field

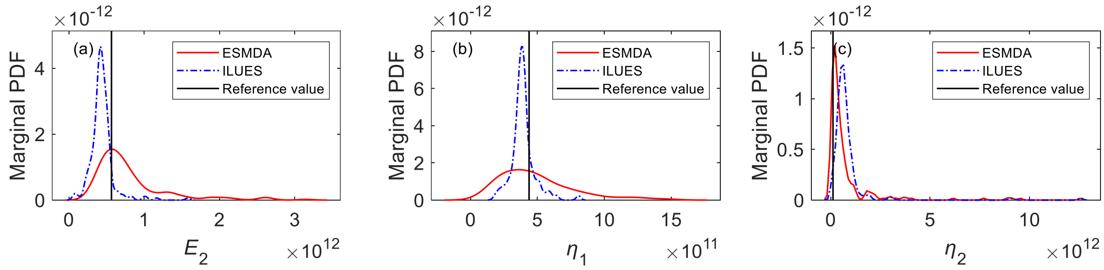

Fig. 2 Posterior Probability Density Plot of Burgers Creep Parameters (For a Specific Zone)

USING THE ACOUSTIC EMISSION SYSTEM TO PREDICT THE SEVERE FAILURE OF ROCK BASED ON EMPIRICAL STATISTICS AND MACHINE LEARNING METHODS

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ABSTRACT

In order to effectively predict the time and energy of the loading failure process of brittle rock, uniaxial compression acoustic emission tests were conducted on two kinds of small-sized brittle rocks, granite and red sandstone. Based on the empirical statistical method, a prediction model for predicting rock failure time and energy is established by using acoustic emission ringing count data and stress-strain curve. Based on the machine learning method, the Long Short-Term Memory (LSTM) neural network is constructed. The acoustic emission amplitude data is used as input to predict the amplitude signal at the future moment and determine the rock failure time. The prediction model and LSTM are used to predict the failure time and energy of large-scale granite and sandstone. Compared with the actual results, the error of failure time predicted by empirical method and machine learning method is about 200 s, and the error of failure energy predicted by empirical method is about 100 J. The error is within an acceptable range.

Keywords: failure time, failure energy, prediction model, empirical statistics, machine learning

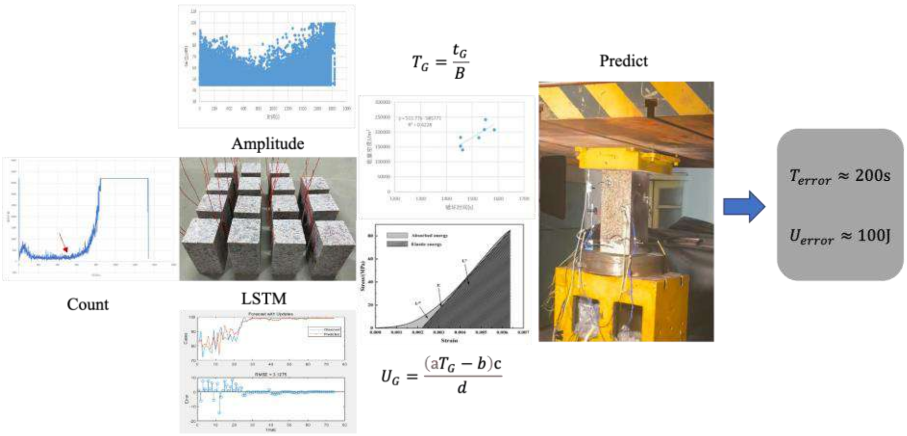

Fig. 1 Prediction of granite failure time and energy

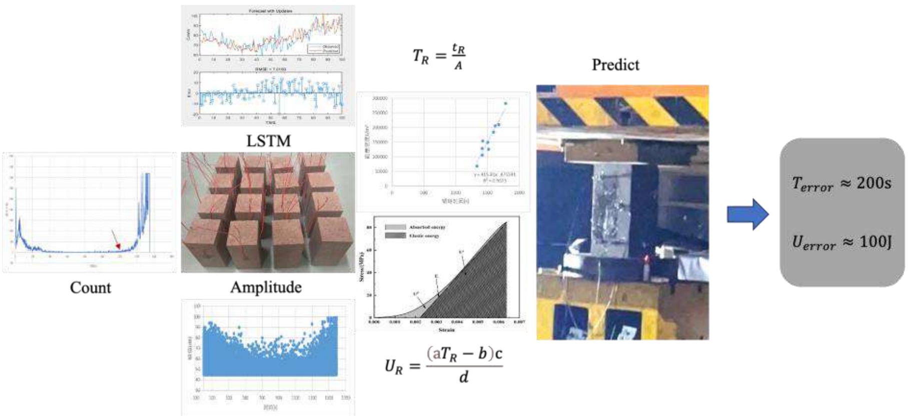

Fig. 2 Prediction of sandstone failure time and energy

TCN AND LSTM NEURAL NETWORK FOR PREDICTING PATH-DEPENDENT CONSTITUTIVE BEHAVIOURS OF IDEALIZED GRANULAR SOILS

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ABSTRACT

The constitutive response of granular soils, exhibiting complicated nonlinearity, is deemed to initial state and path-dependent in geotechnical engineering research. As a data-driven methodology, deep learning (DL) provides a higher possibility in time-related prediction. In this paper, Temporal Convolution Neural (TCN) Network, a type of 1D-Convolutional Neural Network (CNN) and Long Short-Term Memory Neural Network (LSTM-NN), are employed to establish the high-dimensional relationships of granular soils from micro to macro levels subjected to multiple stress paths. This work consists of following steps. CTC-model is firstly applied to calibrate the accuracy of DEM simulation against real experimental data. Secondly, multitudes of DEM simulations on idealized granular soils considering the effects of particle size distribution, initial void ratio, confining pressure and loading paths are performed to enlarge datasets. Afterwards, the prediction performance of two trained DL model is evaluated through the variables of principle stress, volumetric strain, deviatoric fabric and mechanical coordination number against the DEM-based datasets. Finally, A full-scale comparison on the generalization ability between the proposed TCN and LSTM-NN on account of extrapolated tests is presented, highlighting the differences in these two time-dependent DL models. The results demonstrate that both DL-based models are capable of accurately predicting the high-dimensional constitutive behaviours of idealized granular soils with different initial states, as well as reproducing the mechanical response under complicated stress paths.

Keywords: Deep learning, LSTM, TCN, Granular soils, Constitutive behaviour, Multiple stress paths

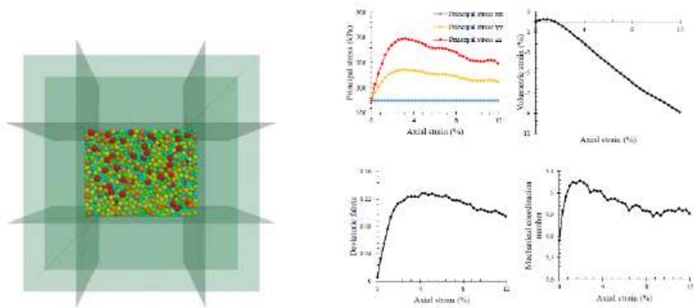

Fig. 1 Granular sample under constant σ_3-constant b (b=0.5, p=200kPa, e=0.55)

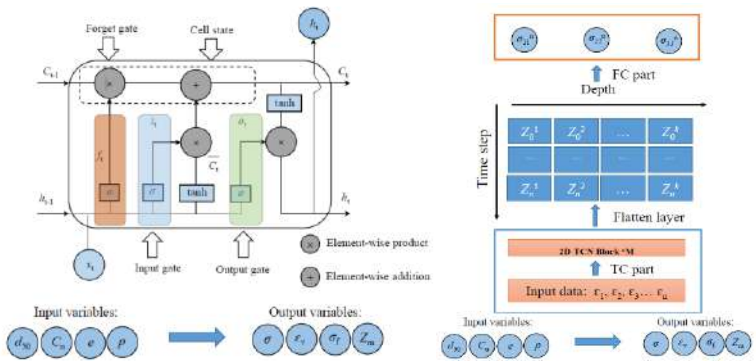

Fig. 2 The architecture of the LTST-NN and TCN

INVESTIGATION OF THE INFLUENCE OF REPRESENTATIVE ELEMENTARY VOLUME (REV) SCALE ON THE 3D PORE SYSTEM OF SOIL

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ABSTRACT

Representative elementary volume (REV) is a microscale volume that represents the macroscopic behavior and characteristics of the entire porous medium. It allows for the analysis and prediction of phenomena occurring at the microscale on a macroscopic scale. In this study, the three-dimensional pore structure of residual granite soil was reconstructed using digital 3D imaging technology. The permeation process was simulated by capturing a cubic REV, and the influence of the distribution of macropores, mesopores, and micropores on the permeability coefficient was investigated. The simulation results indicate that to effectively reflect the grayscale properties, volumetric porosity, fractal dimension, and permeability of actual samples, the optimal REV scales should not be less than 5000μm, 6000μm, 2500μm, and 5000μm, respectively. Beyond these scales, the simulated results gradually approach the original uncut CT data. If the scales are lower, it would result in unrealistic threshold segmentation and permeability simulation results.

Keywords: Representative elementary volume,3D Pore System, permeability.

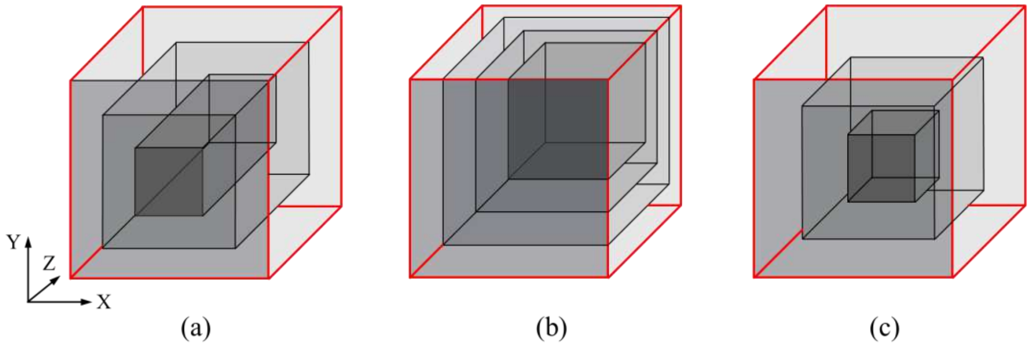

Fig.1. Schematic Diagram of Three Types of Subvolume Selection Schemes

EVALUATION OF SOLDIER PILE TIEBACK WALL BASED ON P-Y CURVE METHOD (249-340)

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ABSTRACT

In this paper, the numerical analysis based on p-y curve method is performed on the design of the soldier pile tieback retaining wall for VDOT I-66 Expressway. The user-defined soil p-y curves are first used to characterize the force-displacement relationships of the nonlinear springs assigned to the embedded portion of the test pile, then the numerical analysis results obtained by LARSA 4D are validated by the computer program LPILE, and finally the validated p-y curves are applied to the design of the soldier pile tieback wall under investigation. The finite element (FE) analysis program LARSA 4D is used to generate the 2-D FE model of the soldier pile tieback wall. The FE analysis results are further compared to the theoretical analysis results in accordance with the analysis procedure specified in AASHTO LRFD. It is observed that for the soldier pile tieback wall in the case study, the theoretical method specified in AASHTO LRFD overestimates the axial forces in the tiebacks, yet underestimates the shear and bending moment along the length of the pile. The analysis results based on p-y curve method are further compared with the m method approach which is commonly used for pile foundation design in China.

Keywords: p-y curve method, soldier pile tieback wall, AASHTO LRFD, m method

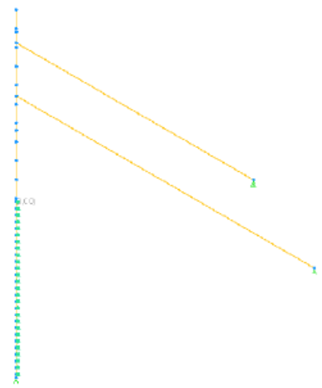

Fig. 1 LARSA model of soldier pile tieback wall

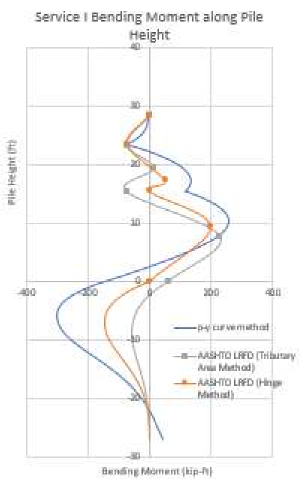

Fig. 2 Comparison on Service I moment along pile depth

STRESS-DISPLACEMENT-MICROSTRUCTURE CHARACTERISTICS AND FEM MODELLING OF SAND-STRUCTURE INTERFACE

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ABSTRACT

The microstructure of sand-structure interface would evolve, resulting in the state dependence of its stress-displacement behavior. A series of monotonic and cyclic interface direct shear tests on the sand-steel interface under constant normal stiffness (CNS) and constant normal load (CNL) were carried out, where the evolution of the microstructure within interface was analyzed using high-resolution image identification system. It was found that different extents of interface dilatancy occurred under monotonic tests with CNS and CNL. Higher extent of dilatancy and microstructure evolution took place under CNL, where the particle probabilistic entropy increased with the shear displacement. When subjected to cyclic shearing, the interface with initial state under the critical state line exhibited contraction and dilatancy alternately. As the load cycles increased, the microstructure within the interface evolved, with an alternately increase or decrease in the particle probabilistic entropy, which resulted in an overall contraction of the interface. Thus, microstructure evolution influences the interface dialatancy. To capture these phenomena, a microstructure-dependent dilatancy state line was proposed, based on which a nonassociated kinematic hardening elastoplastic model for sand-structure interface was developed. FEM implementation of the developed model was then carried out. Simulations of the test data revealed that the model can reasonably capture the dilatancy and softening, etc., of the interface, especially the strong contraction under cyclic loads.

Keywords: interface; microstructure; dilatancy; state parameter; constitutive model.

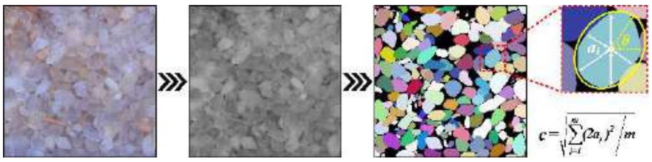

Fig. 1 Illustration of the image processing procedures

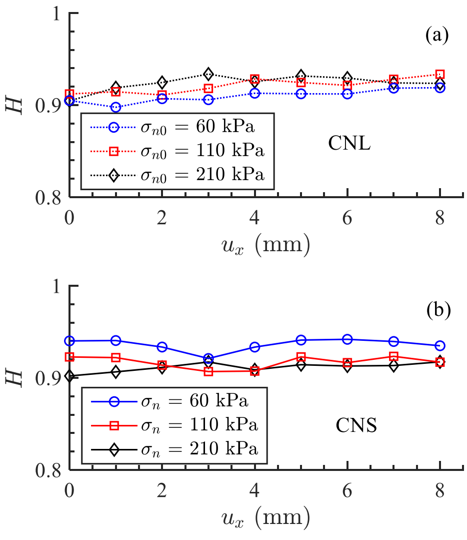

Fig. 2 Variation of the fabric scalar *H* during shearing

FAST RELIABILITY PREDICTION FOR AN OPERATING SHIELD TUNNEL EMBEDDED IN THREE-DIMENSIONAL HETEROGENOUS SOILS

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ABSTRACT

Abstract: With the rapid development of urban rail transit, operating shield tunnels will inevitably be affected by temporary ground surface surcharge. The solution based on deterministic analysis cannot consider the inherent uncertainty of soil parameters, while probabilistic evaluation methods provide an effective means to solve such problems. Based on the Timoshenko beam theory, this paper proposes a simplified method for evaluating the reliability of tunnel stability embedded in 3-D heterogenous soil under the ground surface surcharge. By capturing the inherent uncertainty of soil mechanical parameters through random variables, combined with LHS sampling technology, the reliability of operating tunnels after disturbed by ground surface surcharge can be quickly and efficiently predicted. The accuracy of the proposed method was verified by comparison with the response surface method and the first order second moment method.

Keywords: Operating Shield Tunnel; Reliability Analysis; Soil Uncertainty; Random Variable; Timoshenko beam.

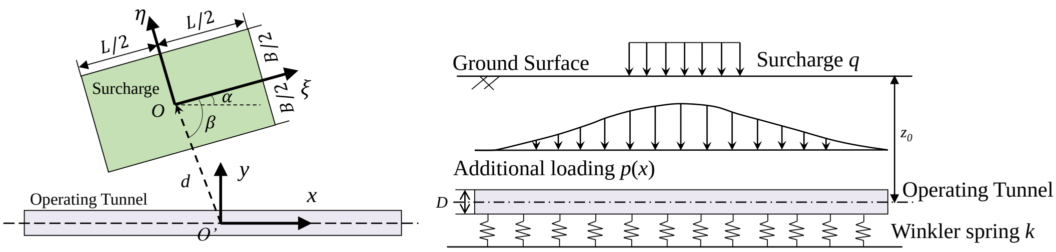

Fig. 1 Simplified calculation model of tunnel

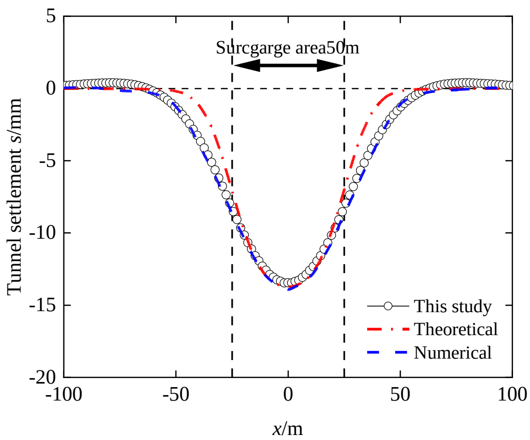

Fig. 2 Verification of calculation results

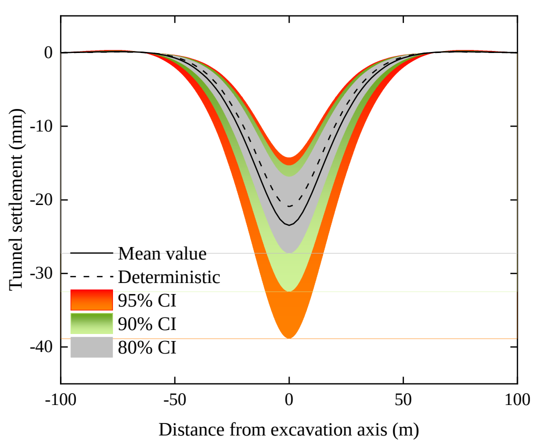

Fig. 3 Confidence interval of tunnel deformation

SLIP-LINE FIELD SOLUTION FOR THE BEARING CAPACITY OF A PIPELINE ON CLAYEY SOILS: FROM HILL TO PRANDTL MECHANISM

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ABSTRACT

The shear strength or friction at the pipe-soil interface may influence the failure mechanism of clayey soils and the corresponding bearing capacity of a partially-embedded pipeline. As indicated by numerical results, a transition from the Hill to the Prandtl mechanism can be identified with the increase of the shearing strength at the pipe-soil interface. There may exist a correlation between the rigid zone underneath the pipe and the shear stress along the pipe-soil interface. To construct the failure mechanism of the pipeline foundation, the shape and size of the rigid zone underneath the pipe are derived theoretically. Based on the constructed failure mechanism and the slip-line field theory, an analytical solution is obtained for the pipeline's ultimate bearing capacity. A comparison is then made between the present slip-line field solution and the one provided in the DNV recommended practice. It is indicated that the present solution may slightly underestimate the ultimate bearing capacity. Such disparity becomes more remarkable for larger pipe embedment and higher shear strength at the pipe-soil interface.

Keywords: Submarine pipeline, Bearing capacity, Slip-line field solution, Interface friction, Failure mechanism.

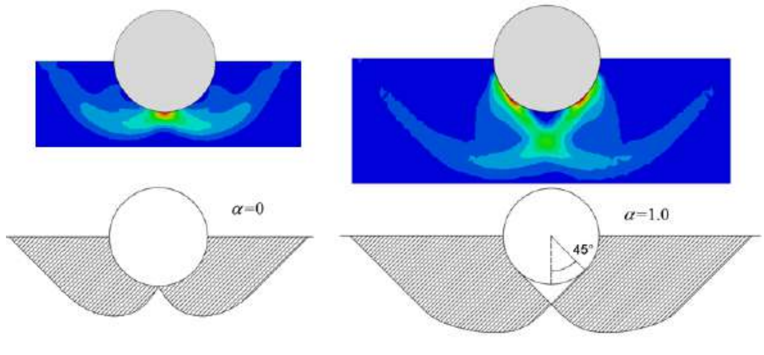

Fig. 1 Two typical failure mechanisms: (a) Hill mechanism for the smooth pipe-soil interface, (b) Prandtl mechanism for the rough pipe-soil interface.

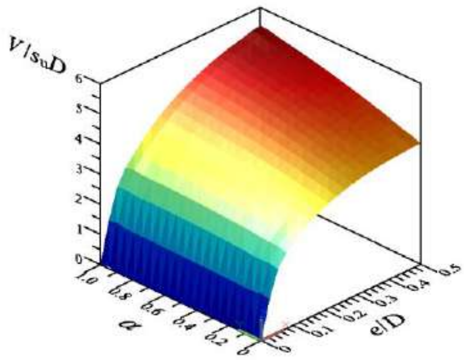

Fig. 2 Variation of the normalized ultimate bearing capacity (V/s_uD) with the interfacial friction ratio (α) and the embedment-to-diameter ratio (e/D) of the pipe.

EXPERIMENTAL STUDY ON THE ROLE OF INTERFACIAL SUCTION IN UPLIFTING A BURIED PIPE FROM CLAYEY SOILS

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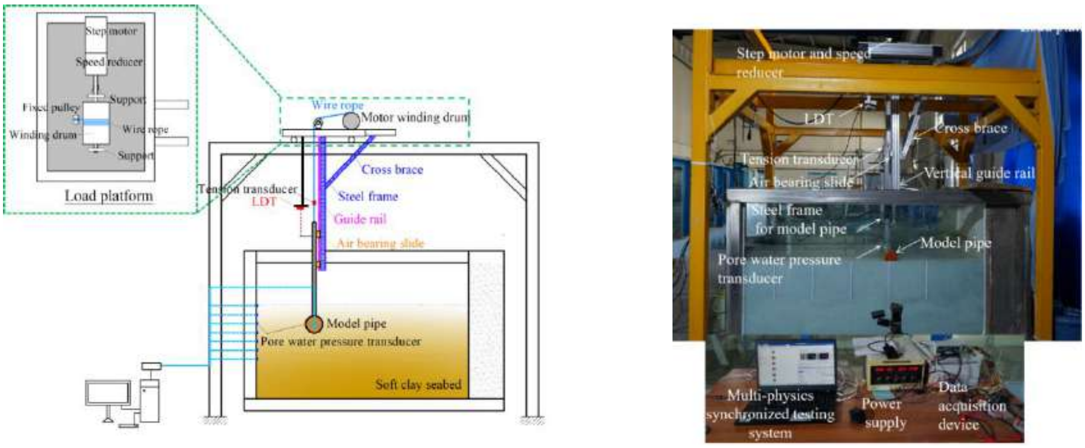
ABSTRACT

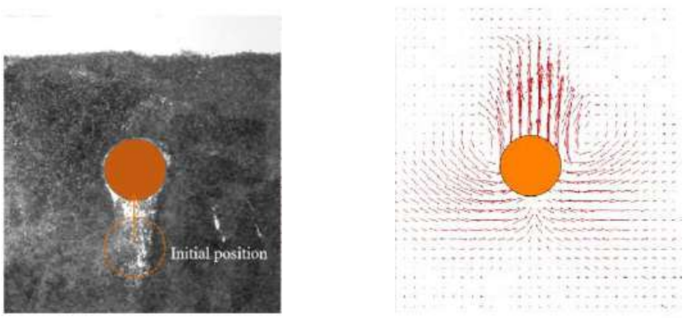
The uplift capacity of buried pipes is a great concern in the design of submarine pipelines against upheaval buckling. The uplift capacity can be substantially increased by the suction force triggered along the pipe-soil interface, especially in a clayey seabed. In previous studied, the pipe-soil interface used to be simplified as either immediately-separated or not-separated-at-all. The role of interfacial suction in uplifting a buried pipe has not been well understood. In this study, a series of displacement-controlled pipe-soil interaction tests were conducted to examine the soil resistance against uplifting the buried pipe in clayey soils. Experimental observations indicated that an enclosed cavity was formed beneath the pipe with the increase of the uplifting displacement, which was accompanied by the generation of excess pore-pressures in the soil around the pipe. Such negative pore-pressure induced an interfacial suction onto the pipe, which may contribute significantly to the uplift resistance for up to 85% of the total resistance. Parametric study is further made on the effects of main influential factors (e.g., the uplifting rate, the initial embedment of the pipe, and the undrained shear strength of the soil) on the interfacial suction and the corresponding uplift bearing capacity of the buried pipe.

Keywords: Submarine pipeline, clayey soil, uplifting capacity, interfacial suction.



(a) (b)

Fig. 1 Displacement-controlled pipe-soil interaction test: (a) Schematic diagram; (b) Photograph of the facility.



(a) (b)

Fig. 2 (a) Uplifting the buried test pipe; (b) Incremental soil displacement field around the pipe

NUMERICAL MODELING OF SOIL-PIPE INTERACTION OF SINGLE PIPELINE AT SHALLOW EMBEDMENT IN CLAY BY HYPOPLASTIC MACROELEMENT

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ABSTRACT

Nowadays, the numerical analysis of submarine pipelines of offshore oil and gas industry is a big challenge in engineering design. A simple, fast and accurate numerical tool is proposed in this article based on the macroelement concept. The novel macroelement is within the framework of hypoplasticity and can consider static monotonic combined (multi-directional) loads for shallow embedded pipelines in clay. The incremental nonlinear constitutive formulas are defined in terms of generalized forces and displacements and an enhanced function of failure surface is introduced. A series of empirical formulas are proposed to describe the stiffness variation trends for soil-pipeline interaction. Model predictions show that the proposed macroelement is proved to be an efficient alternative approach compared to the traditional finite element analysis. The computational cost is thus much reduced for pipeline design.

Keywords: Pipeline, Clay, Soil-pipeline interaction, Hypoplasticity, Macroelement

RESEARCH ON THE DENSITY OF UNDERWATER SAND AND GRAVEL FILLINGS BASED ON GEOTECHNICAL CENTRIFUGAL TESTS

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ABSTRACT

Underwater dumping of loose particles is often used in the construction of hydraulic conservancy projects, such as the Baihetan project cofferdam, the second phase deep water cofferdam of Datengxia, and the Nianpanshan cofferdam. The density of underwater dumping materials is one of the most basic physical parameters in cofferdam engineering design. There are still difficulties in accurately measuring the density of underwater dumping materials. Taking the underwater dumping project of a hydropower station dam in the Han River as the prototype conditions, several centrifugal tests were conducted on sand gravel and sand mixtures. Based on the CKY200 large-scale geotechnical centrifuge model test platform, a single embankment vertical blockage underwater filling test device in a centrifuge field has been developed. Tests results show that when the particle grading of the filling material is good, the underwater filling material has a higher compactness, which can reach a dense state. The greater the depth of filling, the greater the compactness formed. When vertical compression is applied to the upper part of the backfill, the compactness of the backfill, especially in shallow areas, is significantly improved. The research results provide a basis for the design and construction of underwater dumping and filling water conservancy.

Keywords: water conservancy project; centrifugal model test; sandy gravel mixture; density

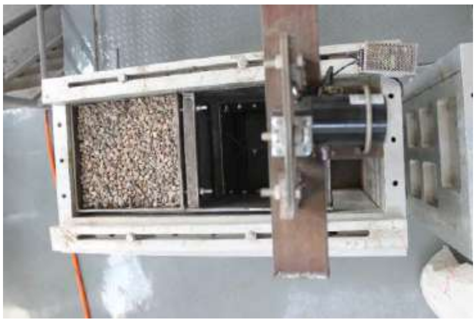

Fig. 1 Auxiliary device for centrifugal test

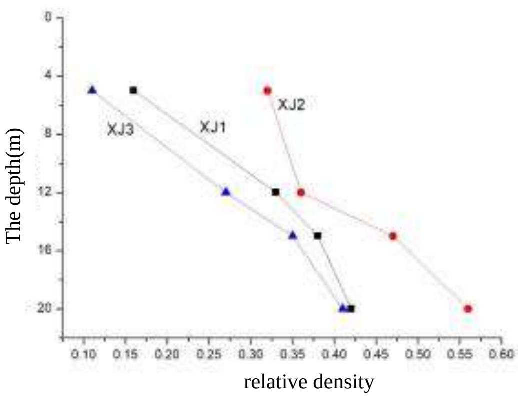

Fig. 2 The relationship between density and depth

SHEAR BEHAVIOUR OF SAND-STEEL INTERFACE UNDER STEADY HEAT FLOW

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

The shear behaviour of interface between soil and energy pile during heat exchange was simulated experimentally, using a tailor-made direct shear apparatus with a cylindrical shear surface. With separate temperature control of central steel pile and surrounding sand (see Fig. 1), two types of thermal conditions were reproduced on a representative interface unit: isothermal condition and under steady heat flow. Test results indicate that the peak shear stress generally increases with an increase in interface temperature, while it also depends on the temperature difference between the pile and soil (Fig. 2). On the other hand, the displacement corresponding to the peak stress and the friction angle at the interface remains unaffected under heat exchange. Moreover, through preliminary analysis using cavity expansion theory, it is shown that different thermal conditions induce variations of the normal stress at the interface, thus changing the peak shear stress. The radial temperature gradient in the soil also plays an important role in changing normal stress at the interface.

Keywords: Cylindrical interface, heat flow, shear behaviour, normal stress.

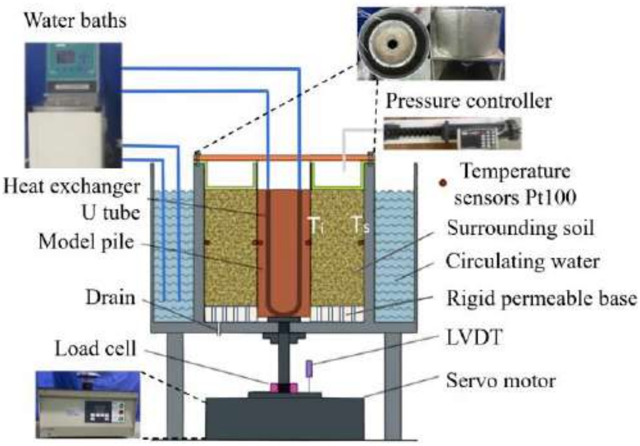

Fig. 1 Illustration of the newly-designed cylindrical shear apparatus

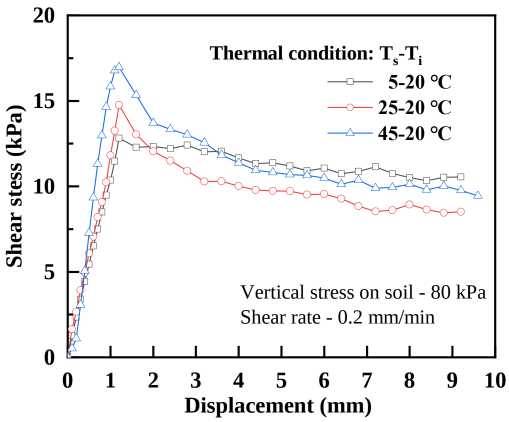

Fig. 2 Shear stress-displacement curves under steady heat flow

NUMERICAL ANALYSIS OF LOAD TRANSFER CONSIDERING FILLING RICE STONE IN THE GAP BETWEEN BETWEEN THE DRIVE PIPE AND PILE CASING WITH FULLY ROTARY CAST-IN-PLACE CONSTRUCTION TECHNOLOGY IN KARST REGIONS

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ABSTRACT

How to guarantee perpendicularity of bridge piles in Karst regions, is a key problem in pile construction, full rotary cast-in-place piles technology is adopted in Guinan high speed railway project in Guangxi autonomous region, a novel controlling procedure is put forward, with which rice stones are filled in the gap between the drive pipe and pile casing, the filling probably make an impact on pile load transfer. With comparison of experimental results, a FLAC coupling with PFC numerical model is built including three karst caves at different position. The numerical results show that, the filling in the gap produces side resistance, leads to decrease of pile settlement, rice stones flow to caves during pullout of drive pipe, more stacking quantity in deep caves due to gravity, because of loosening of filling close to caves, side resistance reduces substantially.

Keywords: pile perpendicularity; Karst cave; rice stone filling; FLAC3D-PFC3D coupling analysis; full rotary cast-in-place pile; settlement of a pile at the top; axial force of a pile

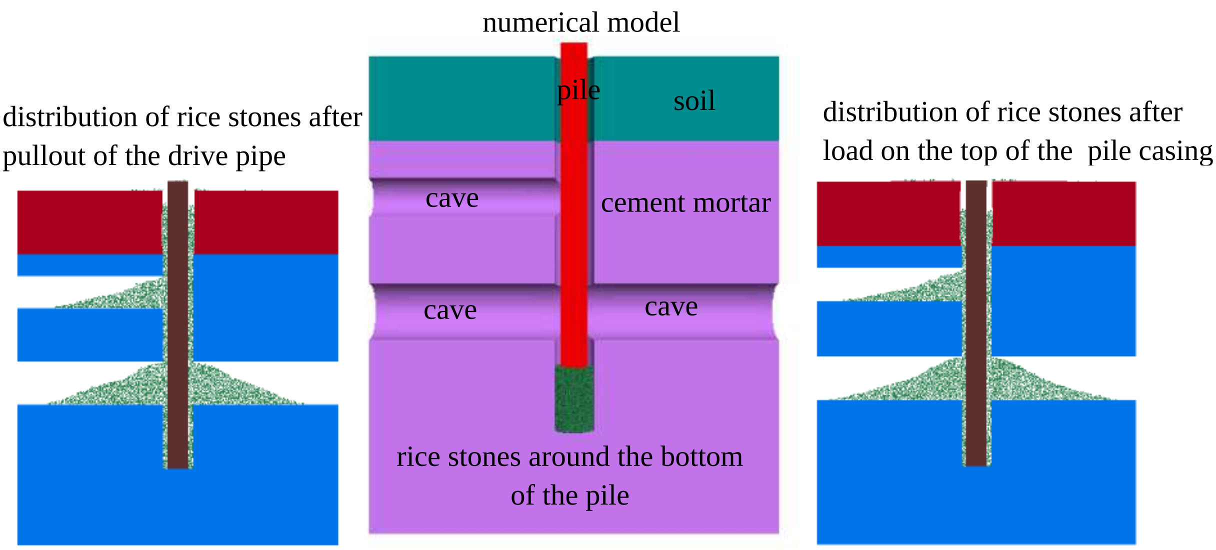

Fig. 1 Sketch of numerical FLAC^{3D} coupling with PFC^{3D} model

BUCKLING FAILURE MECHANISM AND CRITICAL BUCKLING LOAD PREDICTION METHOD OF SUPER-LONG PILES IN SOFT-CLAY GROUND IN DEEP WATER

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ABSTRACT

Buckling may be a possible failure mode of super-long piles in soft-clay ground in deep water as concerned by several researchers. Although there are many studies on the failure mode of super-long piles in sands or silts deposits, few studies have been carried out thoroughly on mechanical mechanism of buckling instability in soft-clay ground in deep water and the corresponding calculation method. In this paper, first, the Riks Arc-Length method in ABAQUS was evaluated and verified using the FEM simulation and the analytical results from Bhattacharya. It is observed that buckling failure is indeed one of failure modes of super-long piles in soft-clay ground. And then, the buckling capacities of super-long piles were assessed due to various influential parameters. The results show that the critical buckling load of super-long piles increases with the increase of elastic modulus and embedding rates of piles, and the increase of elastic modulus and cohesion of soil, while decreases with the increase of slenderness ratios of piles and horizontal loads. Finally, a prediction method of the critical buckling load for super-long piles was presented based on the above sensitivity analysis for influential parameters and the Euler buckling formula, and the criterion for buckling instability for super-long piles was proposed as well.

Keywords: Super-long piles; soft-clay ground; 3D finite element analysis; failure mode; critical buckling load.

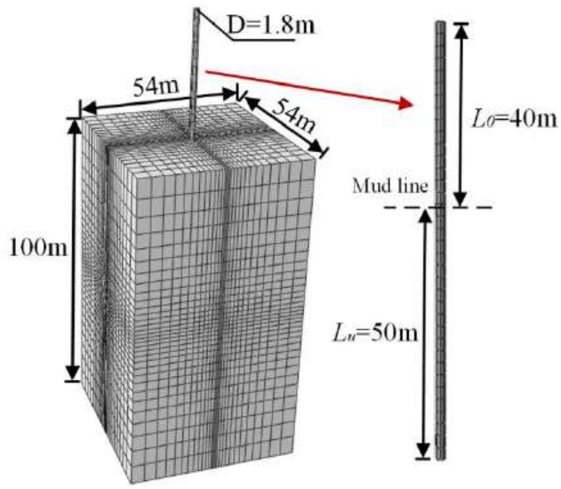

Fig. 1 The whole numerical calculation model

PHENOL CONTAINMENT BY NOVEL VERTICAL CUTOFF WALL BACKFILL: COUPLED HYDRAULIC CONDUCTIVITY, DIFFUSION BEHAVIOR AND MICROSTRUCTURE CHARACTERISTICS

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ABSTRACT

A novel soil-bentonite backfill in vertical cutoff wall is proposed for containing phenol in groundwater at contaminated sites. The backfill consists of sand and bentonite modified with tetramethylammonium and carboxymethylcellulose, labelled as STCMB backfill. The study aimed to evaluate the impact of phenol solution on hydraulic conductivity (*k*) of the backfill through flexible-wall permeability tests. Additionally, double-reservoir diffusion tests were conducted to back-calculate the effective diffusion coefficient (D^*) and partition coefficient (K_p) of phenol for the proposed backfill. As a control, the backfill composed of sand soil and conventional bentonite, labelled as SCB backfill were also tested. The results showed that the *k* of the STCMB backfill decreased by 0.91 times when the permeating liquid was shifted from tap water to phenol solution. In contrast, the *k* of the SCB backfill increased by 1.61 times when permeated with phenol solution compared to tap water. The D^* values for the STCMB and SCB backfills were 4.0×10^{-10} m^2/s and 3.0×10^{-10} m^2/s, respectively, whereas the K_p values were 2.0 mL/g for the STCMB backfill and 0.75 mL/g for the SCB backfill. The mechanisms of modified bentonite were further investigated through transmission elector microscopy and Fourier transform infrared spectroscopy analyses.

Keywords: hydraulic conductivity, diffusion behaviour, backfill, modified bentonite, microstructure

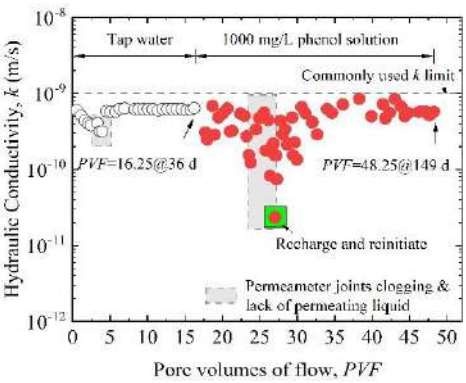

Fig. 1 Variations in the hydraulic conductivity of STCMB backfill permeated with tap water and phenol solution

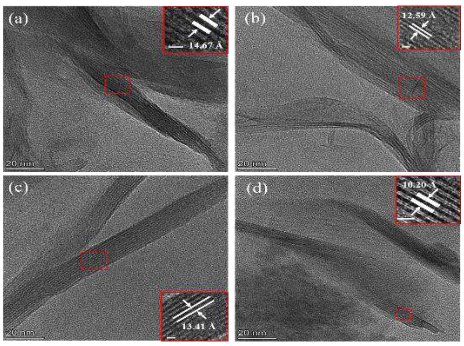

Fig. 2 TEM images of air-dried powder for (a)TCMB, (b) CMB, (c) TMB, and (d) CB

INFLUENCE OF ORGANIC MATTERS CONTENT ON THE SPECIFIC GRAVITY OF SHANGHAI SOILS

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ABSTRACT

Shanghai soils are deltaic sedimentary soils, and the soils contain amounts of organic matters (OM). OM content and specific gravity are important properties for soil classification, and ignition loss test is the standard test to determine OM content in Shanghai standard. However, the specific gravity can be affected by OM, and the ignition loss test is considered inaccurate due to the presence of crystal water. To accurately determine the OM content and clarify its influence on the specific gravity of Shanghai soils, the 10 soil samples are obtained from 1-7 layers of Shanghai soils. Chemical titration tests (dichromate oxidation) and ignition loss tests are conducted to measure OM and crystal water contents; the specific gravity of both original soils and ignited soils (devoid of OM) is also measured. The test results indicate that all the samples are classified as inorganic soils because their ignition losses are less than 5 %; the ignition loss values exceed the OM contents defined by the chemical method; the specific gravity of the ignited soils are larger than the values of the original soils, and the gap enlarges with the ignition loss.

Keywords: Shanghai soils, Organic matters, Specific gravity.

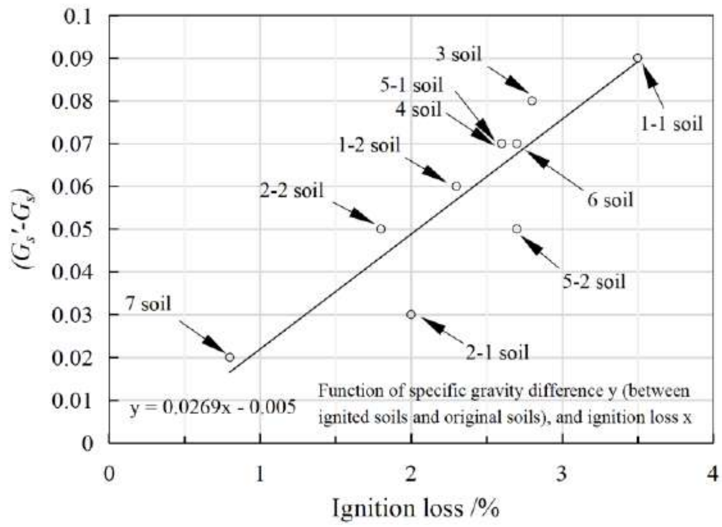

Fig. 1 The relationship between ignition loss and the specific gravity difference value (G_s'-G_s) of the ignited soils and the original soils (G_s' is the specific gravity of the ignited soils and G_s is the specific gravity of the original soils)

Long-term change in groundwater level considering underground structure in a certain region at Shanghai

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ABSTRACT

Groundwater level is long-termly influenced by the blocking effect of existing underground structures in operational period. Numerical simulation considering real distribution of underground structures in a certain region at Shanghai is conducted to analyze the above-mentioned effect. The hydraulic conductivity of the soil containing underground structures is calculated according to the volume rate of underground structure in each element based on the effective medium theory. The simulated groundwater level fit the monitored value well. The contour lines of groundwater level in phreatic aquifer (Aq0) and the first confined aquifer (AqI) are flexural and smooth respectively due to dense and sparse distribution of underground structures existed in Aq0 and AqI. To analyze the effect of additional underground structures distribution on groundwater level, four specific distribution types classified into concentrated, sub-concentrated, sub-scattered, and scattered distribution type, are assumed. The regional average groundwater level in AqI all increases compared with the real distribution case. The relationship between the proportion of area with the groundwater level change (P_a) and the difference of groundwater level between real and specific distribution (d_l) is discussed. The value of P_a where $d_l < 0$ decreases but where $0 < d_l < 0.1$ m increases with more scattered distribution.

Keywords: Groundwater level; Underground structures; Distribution type; Blockage effect; Shanghai

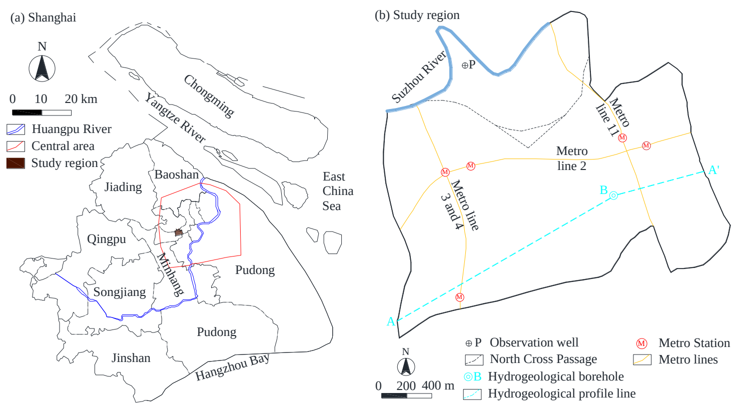

Fig. 1 Schematic diagram of study region

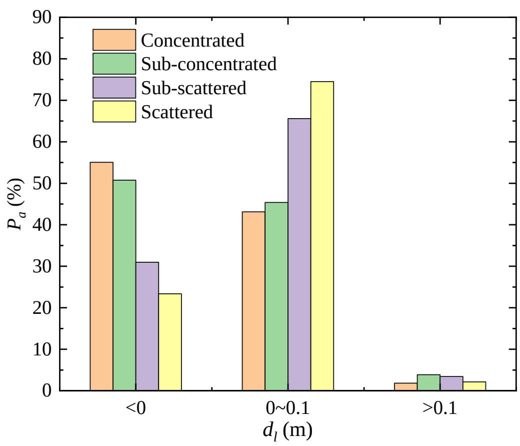

Fig. 2 Relationship between P_a and different range of d_l

Experimental study on mechanical properties and microstructure of Pb^{2+} contaminated red clay solidified by fly ash-active MgO-CaO

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ABSTRACT

In the process of heavy metal-contaminated soil treatment, curing agents produce deficiencies in resource utilization, and this thesis adopts a mixture of curing agents for the effective treatment of lead-contaminated soil. Based on tests such as unconfined compressive strength and electron microscope scanning, the effects of various factors such as lead ion concentration, dry density, curing agent admixture, and maintenance time on the mechanical strength and microstructure of the cured contaminated soil and the evolution pattern were investigated. The results show that FA-activated MgO-CaO can effectively enhance the unconfined compressive strength of Pb2+ contaminated soil, the generation of hydration products such as MSH gel and CSH gel is one of the necessary conditions for the increase of the strength of cured contaminated soil, the increase of Pb2+ concentration slows down the hydration reaction but the development of hydration process is continuous. The generation of hydration products allowed the filling of inter-particle pores and enhanced inter-particle bonding, resulting in a denser microstructure and enhanced integrity of the Pb2+ contaminated soil, and a substantial increase in macroscopic mechanical properties. The research results can provide a theoretical basis for the application of green and low-carbon composite materials in practical projects such as curing contaminated red clay.

Keywords: Activated MgO; CaO; Fly ash; Compressive strength; Microscopic mechanism.

DYNAMIC CHARACTERISTICS AND DAMAGE MECHANISMS OF EXPANSIVE SOIL – RUBBER MIXTURE UNDER COUPLING EFFECT OF FREEZE-THAW CYCLES AND EXTERNAL LOAD

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ABSTRACT

Expansive soils, as a type of problematic soil, appear in many geological regions, and they are often encountered by roadway projects in seasonal frozen regions. Recycled rubber, benefitted from its elastic nature, can be suitable for alleviating the effect of expansion and contraction and improving the resilience of the soil when subjected to cyclic load. Low-temperature dynamic triaxial tests were conducted in this paper to investigate the effect of rubber content (RC) and rubber size (d_0) on the dynamic properties and the damage law of the expansive soil-rubber mixture under the influence of freeze-thaw cycles. The findings of the study indicate the following: (1) the stress-strain relationship of the ESR exhibits notable hysteresis, i.e., energy dissipation; (2) At a given strain level, the dynamic stress of ESR is slightly lower than that of plain expansive soils; and thus, the dynamic shear modulus decreases with the increase of RC; (3) The damage factor, was defined based on the principle of continuum damage mechanics and strain equivalence. The rubber size affected the optimum rubber contents, and RC = 5%, d_0 = 0.100 mm and RC = 10%, d_0 = 0.178 mm were found to be a preferable combination for better damage resistance.

Keywords: Waste Rubber; Expansive Soils; Freeze-thaw; Damage Evolution; Dynamic Properties.

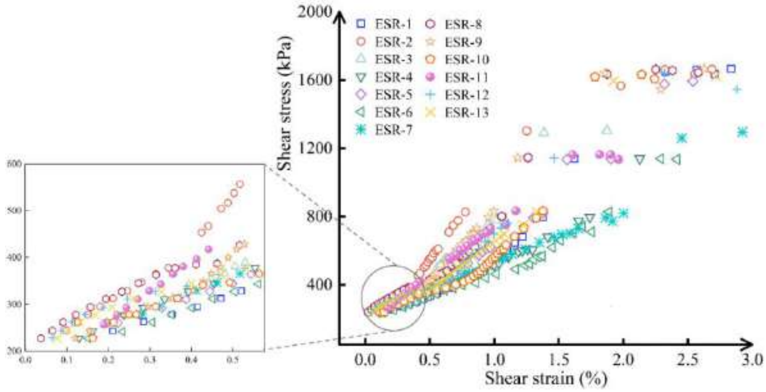

Fig. 1 Stress-strain curve of expansive soil-rubber under freeze-thaw cycles

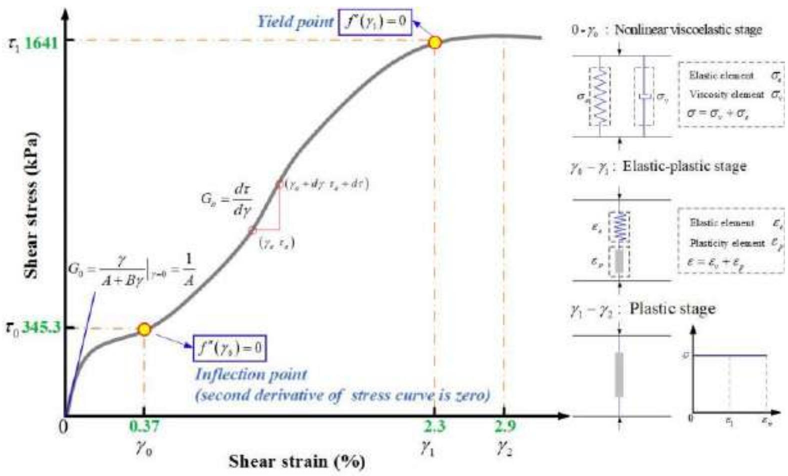

Fig. 2 Typical stress-strain skeleton curve of ESR during loading with the characteristic points illustrated

MODELLING OF REMOVAL OF COPPER AND LEAD METALS IN LOESS UNDER THE EFFECTS OF SOLID-PHASE ADSORPTION AND DESORPTION

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ABSTRACT

The electrokinetic (EK) technology coupled with the biological permeable reactive barrier (termed bio-PRB hereafter) has been proposed for the first time to address the focusing effect that remains challenging in traditional remediation technologies. The bio-PRB that incorporates the enzyme-induced carbonate precipitation (EICP) treatment applies to the EK technology as an adsorbent. Although the EK-PRB technology is proven effective in heavy metal removal according to our experimental data founded on an EK reactor, the adsorption and desorption properties of the loess and their implications on the diffusion and migration of copper (Cu) and lead (Pb) metals contained are still unclear. In the present work, the mentioned issues were explored through a numerical modelling considering the effects of solid-phase adsorption and desorption. Results indicated that the simulated results were generally in line with the experimental data. Cu^{2+} and Pb^{2+} were adsorbed by clay minerals in the loess, which resulted in a very low remediation efficiency of below 10%. To this end, ethylene diamine-disuccinic acid (EDDS) was applied to promote the chelation between EDDS and heavy metals, allowing their desorption from clay minerals. The simulated results showed that $EDDS^{n-}$ ($n \geq 3$) chelate with Cu^{2+}/Pb^{2+} to form $Cu(EDDS)^{(2-n)+}/Pb(EDDS)^{(2-n)+}$. $Cu(EDDS)^{(2-n)+}/Pb(EDDS)^{(2-n)+}$ show negative valence and start migrating toward the anode, improving Cu and Pb removals by the bio-PRB. In light of the above, the remediation efficiency increased from 10% to above 50% after EDDS intervened in the EK-PRB remediation. The findings explore the underlying mechanism affecting Cu and Pb removals, widening the horizon of application for the EK-PRB technology.

Keywords: electrokinetic remediation, enzyme-induced carbonate precipitation, solid-phase adsorption, biological permeable reactive barrier, modelling

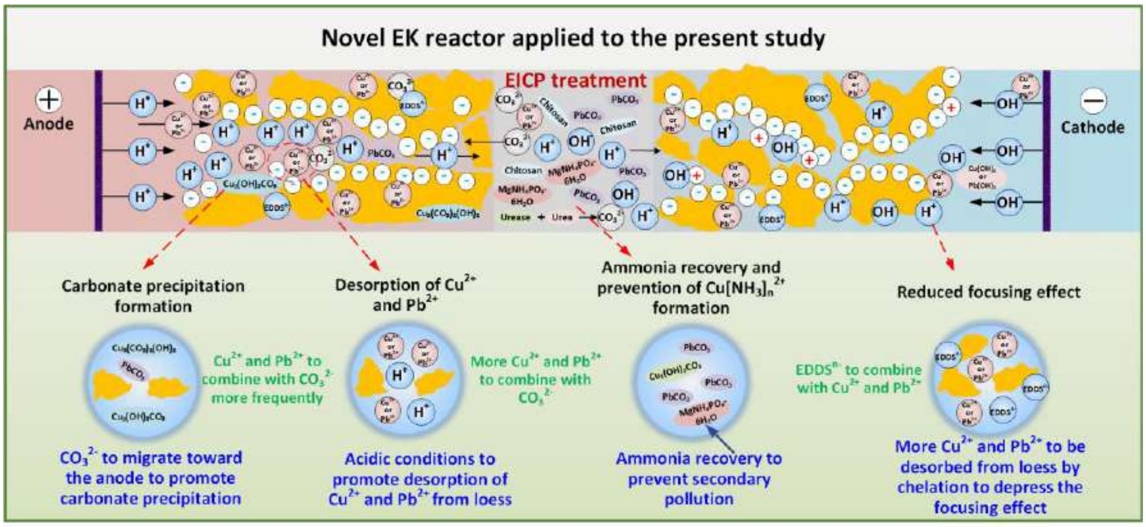

Fig. 1 Schematic illustration of underlying mechanism affecting Cu and Pb removals

OXALIC ACID ACTIVATED BONE MEAL FOR IMMOBILIZATION OF PB AND CD CONTAMINATED SOILS

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ABSTRACT

Bone meal (BM) is a cost-effective and low-carbon material to remediate heavy metal contaminated soils. However, its immobilization efficiency for heavy metals still needs improvement. The activation of oxalic acid on BM is evaluated to create an oxalic acid-activated bone meal (ABM) for enhancing the immobilization efficiency. The effect of activation on the immobilization ability of lead (Pb) and cadmium (Cd) in the soil is investigated by TCLP test. The main difference in the mechanism of Pb/Cd immobilization between using the ABM and BM is identified by chemical products. The results indicate that the ABM possesses a higher solubility than the BM. The activation of bone meal achieves its optimal effect when using 1 mol/L oxalic acid solution with a liquid-solid ratio of 2:1. The resulting TCLP leachability shows that the ABM performs a significant enhancement in the immobilization of Pb in soil compared with the BM. The leachate concentration of Pb from ABM immobilized soils is able to meet the regulatory limits applied in China and U.S., which also is 30% to 75% lower than that from BM immobilized soils. The XRD analysis shows that heavy metal phosphates are the primary products of Pb and Cd immobilized by ABM, whereas heavy metal carbonates are the main products after the immobilization by BM.

Keywords: Heavy metals; bone meal; activation; oxalic acid; leachability; immobilization.

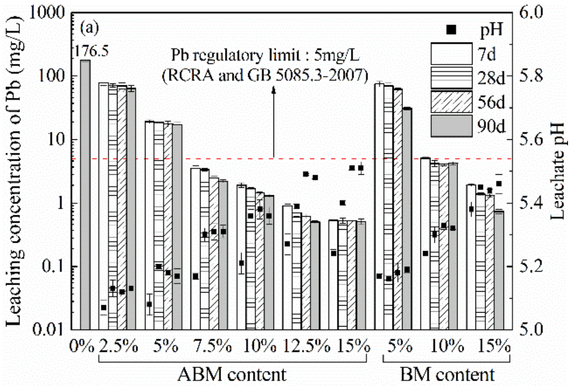

Fig. 1 Pb concentrations leached from the ABM/BM immobilized soil at different curing times.

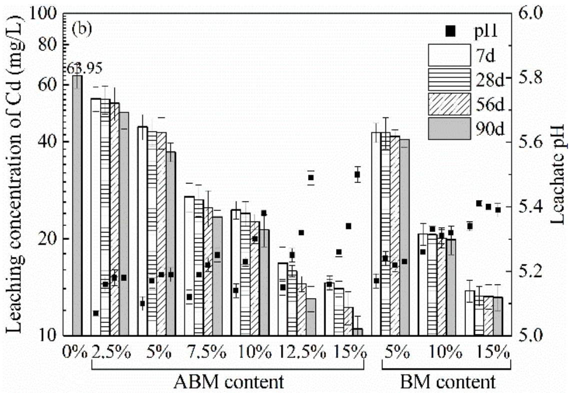

Fig. 2 Cd concentrations leached from the ABM/BM immobilized soil at different curing times.

PREPARATION OF GEOPOLYMER BRICK WITH COPPER MINE TAILINGS UNDER LOW-TEMPERATURE CONDITIONS

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ABSTRACT

The purpose of this study is to assess the performance of substantially increasing the amount of copper mine tailings (CMT) without natural sand through the principle of geopolymer reaction. The test materials are mainly CMT, fly ash (FA), kaolin (KL) and ordinary Portland cement (OPC), which are proportioned and combined to realize the resource utilization of bulk solid waste. Through unconfined compressive strength (UCS) and physical property tests, it is found that the CMT sample with 10% OPC and 20% FA or only with 30% FA can meet the requirements of brick under the curing condition of 60 °C. The sample prepared by 70% CMT and 30% FA requires longer curing age to achieve stable UCS. The mineralogical characterization and micromorphology indicate the coexistence of C-S-H, C-A-S-H and N-A-S-H in the products of geopolymerization under low calcium material system. In addition, the sample prepared by 70% CMT and 30% FA has the advantages of more solid waste reduction (100%), lower cost (166.3 CNY/t), and lower carbon dioxide emission (73.3 kg/t). It is feasible to prepare environment-friendly geopolymer brick from CMT without OPC, natural sand and clay in a low energy consumption way.

Keywords: copper mine tailings, geopolymer, industrial wastes, curing, Characterization techniques.

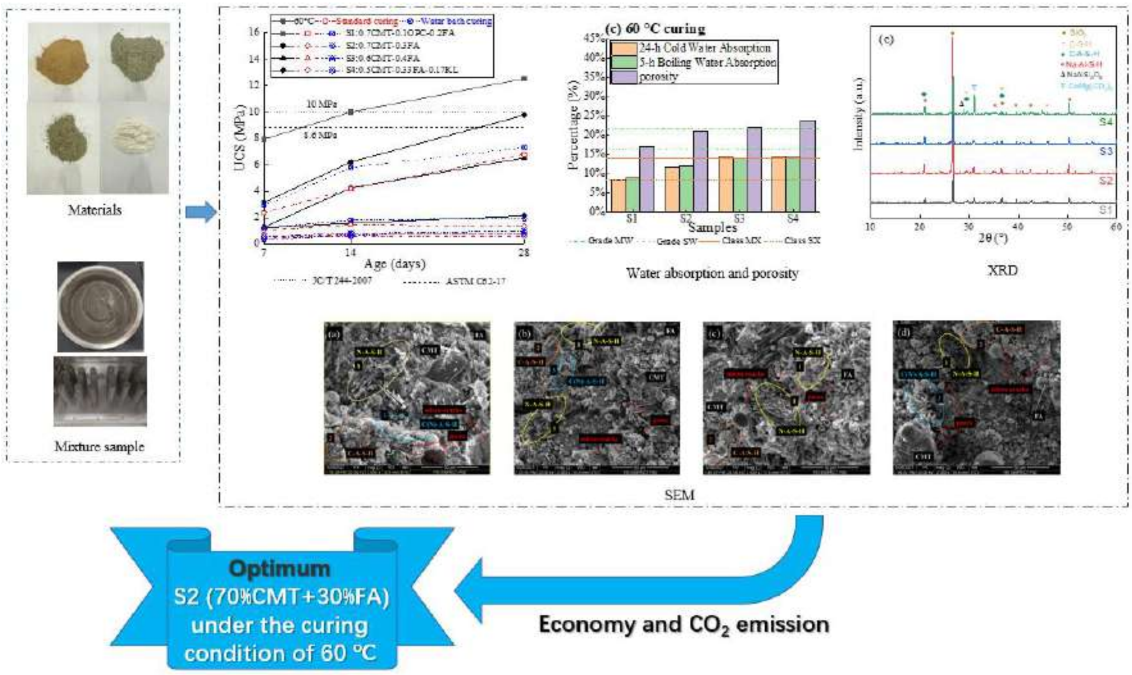

Fig. 1 Illustration of the proposed method.

GAS PERMEABILITY OF POLYACRYLAMIDE AMENDED GEOSYNTHETIC GLAY LINER IN THE COVER BARRIES WITH CALCIUM SOLUTION ACTION

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ABSTRACT

This study evaluated two types of geosynthetic clay liners (GCLs)-commercial GCL and polyacrylamide (PAM)-amended GCL, for use as cover barrier materials for controlling contaminated soil gas spillage at contaminated sites. Bentonite in cation-rich in situ soils tends to suffer from weakened swelling and gas-barrier impermeability. The results showed that the specific gravity (G_s) of the modified GCL was slightly reduced, but the liquid limit (w_L) was significantly increased compared with the unmodified GCL. As the concentration of $CaCl_2$ solution increases, the gas permeability (k_a) of both GCLs increases. PAM-amended GCL gas permeability (k_a) was found to increase from 9.02×10^{-10} to 3.27×10^{-8} m/s, with a greater concentration of $CaCl_2$ in the pore solution. The unamend GCL gas permeability (k_a) exceeds the permeability value based on Darcy's law after the pore solution CaCl2 concentration increases. Scanning electron microscopy (SEM) and energy spectroscopy (EDS) analysis showed that PAM hydrogels filled the intergranular pores of GCL coated in bentonite particles. X-ray diffraction (XRD) results showed that PAM could not enter the montmorillonite platelets. The mass loss of bentonite particles within PAM-amended GCL TGA between 200°C-400°C was higher than that of unamend bentonite. The microscopic properties elucidated the mechanism of the excellent gas barrier properties of PAM-amended GCL.

Keywords: Geosynthetic clay liner, Polyacrylamide, Gas Permeability, Calcium Chloride, Macroscopic Properties

TENSION-HEALING MECHANISM OF DESICCATION CRACKS IN A CLAYEY SOIL

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ABSTRACT

Desiccation cracks initiate and propagate during the drying process and healing occurs during the wetting process. In this study, the tensile behaviour of clayey soils during desiccation cracking process was investigated using a fibre Bragg grating (FBG)-based restrained ring. The processes of water evaporation, tensile stress variation, surface crack initiation and propagation were monitored during the drying period. Moreover, the healing behaviour of a cracked soil considering different wetting rates was also investigated. The dynamic process of crack healing was monitored during wetting. Experimental results show that both the evolution of tensile stress and graphic variation show three typical periodic features that are well matched with soil vertical deformation, lateral shrinkage and cracking. With decreasing water content, tensile stress gradually increases at first and then increases more rapidly. Once the tensile stress reaches the peak value, desiccation cracks initiate and a sudden reduction in tensile stress is observed. Finally, the tensile stress reaches a residual stage. In terms of the healing behaviour, both the healing rate during wetting and the degree of healing after wetting increase with increasing wetting rate. The healing of desiccation cracks with a lower wetting rate is mainly due to the wetting-induced swelling of soils. However, that with a higher wetting rate is dominated by both swelling and disintegration.

Keywords: tensile; healing; desiccation cracking; clay.

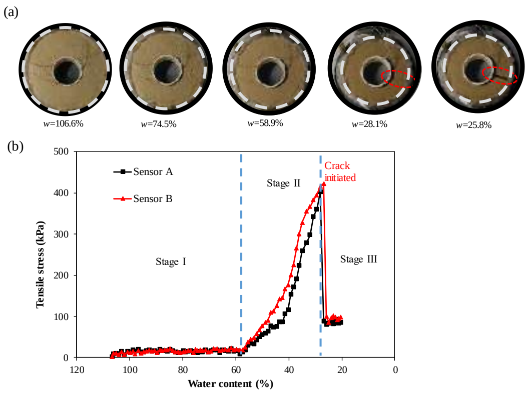

Fig. 1 Mechanical and graphic evolution of cracking in desiccation process

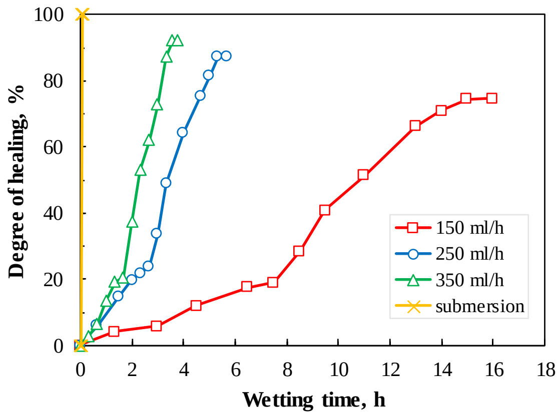

Fig. 2 Change in degree of healing with the elapsed wetting time for samples treated with different wetting rates

EFFECTS OF CHEMICAL SOLUTIONS AND LEACHATES ON THE SWELLING BEHAVIOR OF HYDROPHILIC SEALS USED IN GEOMEMBRANE CUTOFF WALLS

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ABSTRACT

The swelling capacity of hydrophilic seals used in geomembrane cutoff walls is critical for decreasing the flow rates of contaminated groundwater. This study investigated the effects of chemical solutions and bauxite liquor on the swelling ratio of hydrophilic seals. The influence of types of ions, cationic valence state, ionic strength, ionic concentration, electrical conductivity, and pH on the swelling ratio of hydrophilic seals were discussed. Results showed that the swelling ratio of the hydrophilic seal increased against time immersed in the monovalent cation solutions. However, the swelling ratio increased first and then decreased against time immersed in the multivalent cation solutions. The swelling ratio of the hydrophilic gaskets soaked in the DIW were the highest, followed by the monovalent cation solutions, and the multivalent cation solutions. The swelling ratio of the hydrophilic seal decreased with increasing ionic strength, ionic concentration and electrical conductivity with the exception of organic acids. Mechanisms for decreased swelling ratio under different chemical solutions and bauxite liquor exposure were ascertained based on the microstructure and weight changes quantified by scanning electron microscope (SEM) coupled with energy dispersive spectrometry (EDS) analyses and weight loss tests.

Keywords: geomembrane cutoff wall, hydrophilic seals, swelling behaviour, sodium polyacrylate

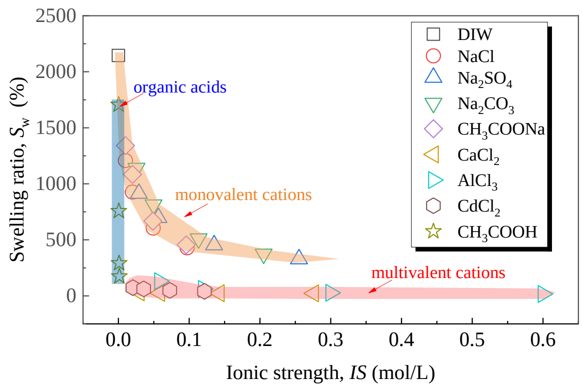

Fig. 1 Effects of ionic strength of chemical solutions on the swelling ratio of hydrophilic seals.

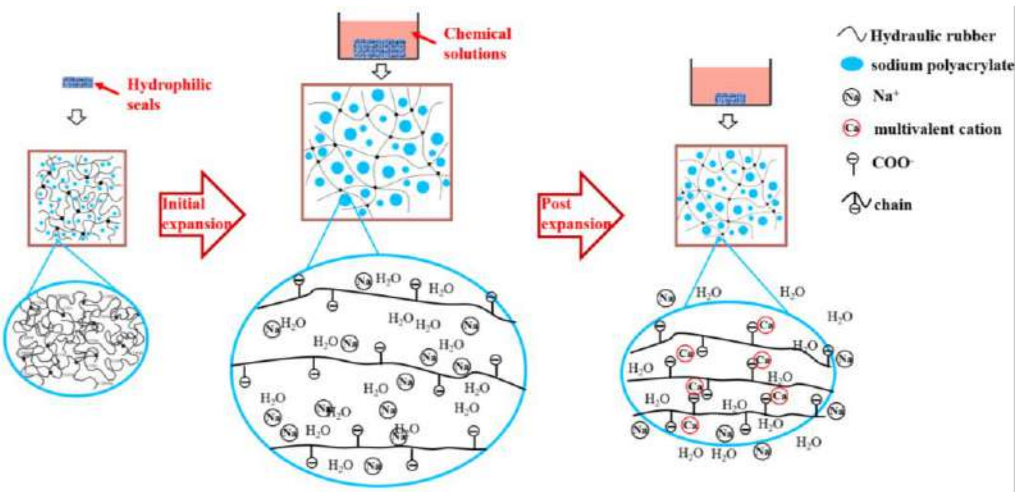

Fig. 2 Mechanisms for decreased swelling ratio under different chemical solutions.

CHEMICAL COMPATIBILITY AND HYDRAULIC CONDUCTIVITY OF POLYANIONIC CELLULOSE-MICRO ZERO-VALENT IRON AMENDED BENTONITE FOR VERTICAL CUTOFF WALL APPLICATIONS

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

This study examines the chemical compatibility and hydraulic conductivity of polyanionic cellulose (PAC)-micro zero-valent iron (mZVI) amended bentonite (PMB) in the presence of organic pollutant solutions. The aim is to assess its potential for vertical cutoff wall applications. Hydraulic performance of the PMB filter cake was evaluated in tap water (TW) and dichloroethane (DCE) solutions through MFL tests. The findings indicate that an increase in mZVI dosage resulted in a decrease in moisture content corresponding to the target slump height. Moreover, the free swell index (FSI) decreased with higher mZVI dosage in dichloroethane and dichloroacetic acid solutions. Notably, PAC-amended backfill exhibited a hydraulic conductivity (k) less than 10^{-9} m/s when permeated with a DCE solution, whereas k increased with higher mZVI dosage. Scanning electron microscopy (SEM) with energy dispersive spectrometry (EDS) analyses revealed that PAC hydrogels filled the intergranular pores of PAC-mZVI-amended backfill and formed a thin coating over the mZVI particles. However, X-ray diffraction (XRD) results demonstrated no intercalation of PAC and mZVI into montmorillonite platelets. Fourier transform infrared spectroscopy (FTIR) confirmed the effective amendment effect of PAC. This study highlights the potential of PAC-mZVI-amended bentonite for environmentally sensitive engineering applications.

Keywords: Polyanionic cellulose, Hydraulic conductivity, Chemical compatibility.

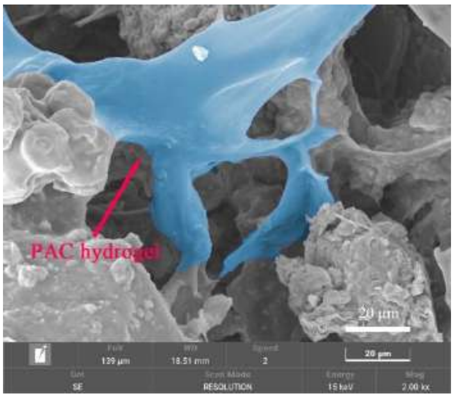

Fig. 1 SEM images of PMB backfill after hydraulic conductivity testing

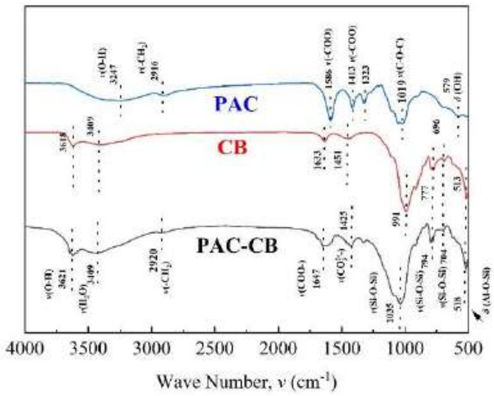

Fig. 2 FTIR spectra of PAC, CB and PAC-CB

INVESTIGATION OF HYDRAULIC CONDUCTIVITY OF PAC AMENDED BENTONITE IN CADMIUM NITRATE SOLUTIONS

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ABSTRACT

In the realms of geotechnical and geoenvironmental engineering, vertical cutoff walls known for their low hydraulic conductivity are extensively employed. Soil-bentonite (SB) slurry trench cutoff walls have emerged as a prevalent choice to confine contaminated groundwater. The objective of this study is to investigate the free swell index (*FSI*) and hydraulic conductivity (*k*) of a novel polymer amended bentonite consist of conventional bentonite and PAC (referred to as "PB") in various concentration (1-20 mmol/L) of $Cd(NO_3)_2$ solutions and tap water. The unamended conventional bentonite (referred to as "CB") was also evaluated for comparison purpose. The free swell index test and modified fluid loss test were conducted to investigate the *FSI* and *k* of PB and CB exposed to $Cd(NO_3)_2$ solutions and tap water. Noted that the *k* of filter fake with PB or CB was assessed via modified fluid loss test. The results showed that the *FSI* and *k* of both PB and CB indicated a negative impact with increasing concentration of $Cd(NO_3)_2$ solutions. The PAC amendment increase the FSI of CB with 27% to 79% and decrease the *k* around 1 order of magnitude, whether in $Cd(NO_3)_2$ solutions or tap water. The PAC could improve the chemical compatibility of conventional bentonite.

Keywords: Vertical cutoff wall; Hydraulic conductivity; Bentonite; Polyacrylamide cellulose;

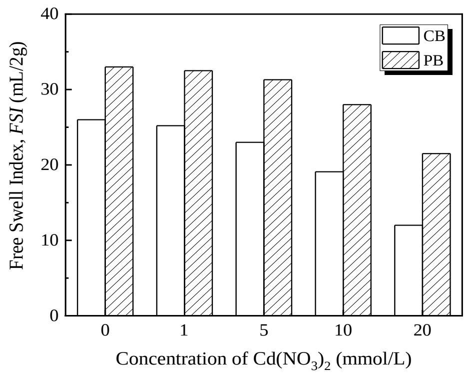

Fig. 1 *FSI* of PB andCB in cadmium nitrate solutions

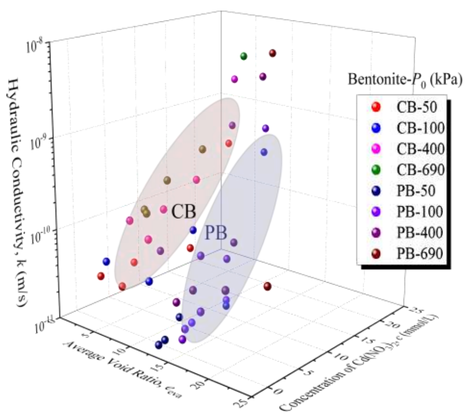

Fig. 2 Hydraulic conductivity, average void ratio and cadmium nitrate solution concentration of filter cake under different stress

SPATIAL AND TEMPORAL TRANSPORT LAWS OF LIGHT NONAQUEOUS PHASE LIQUIDS IN LOW-PERMEABILITY SOILS

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ABSTRACT

In order to grasp the dynamic distribution and transportation law of LNAPL after leakage in clay, an indoor two-dimensional model box test was conducted. The resistivity change of the soil was monitored by electrical resistivity tomography, and the transportation and distribution characteristics of LNAPL during and after the filling process were obtained. The test results show that the transport stage and concentration trend of LNAPL in the soil can be judged by the relative resistivity change. During the filling process, LNAPL spreads from the leakage source to the surrounding soil, and the range of the high concentration contamination area gradually expands. At the end of the filling process, the location of the high concentration contamination zone in the clay gradually shifted downward. The diffusion rate of LNAPL was significantly reduced when the LNAPL front entered the clay layer containing capillary water. This study can provide a reference for exploring the transportation and distribution law of LNAPL in clay, and determining the diffusion range and content change of LNAPL.

Keywords: clay; light non-aqueous liquid; electrical resistivity tomography; space-time migration law

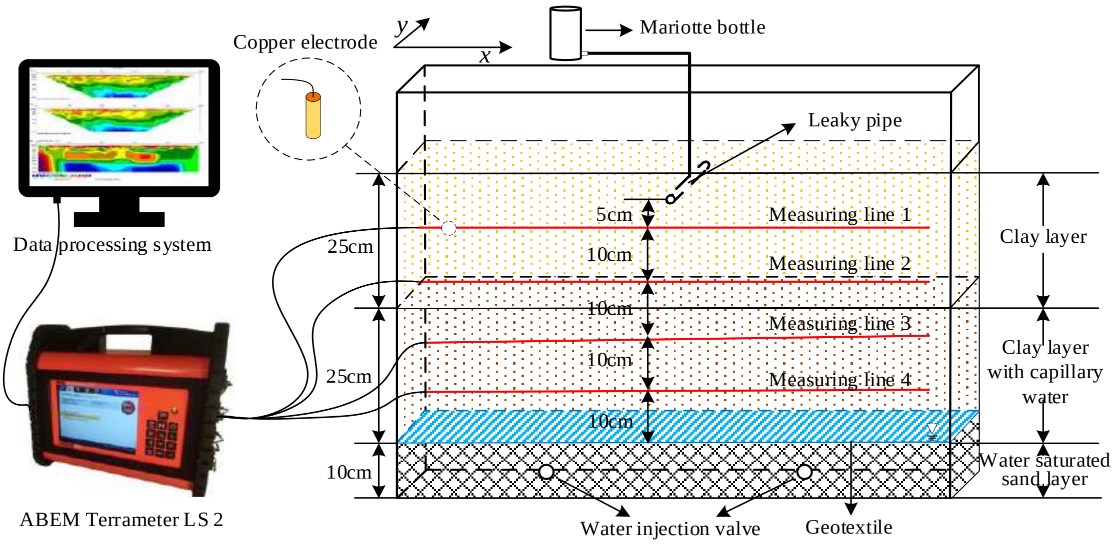

Fig. 1 Illustration of soil layer layout and detection system

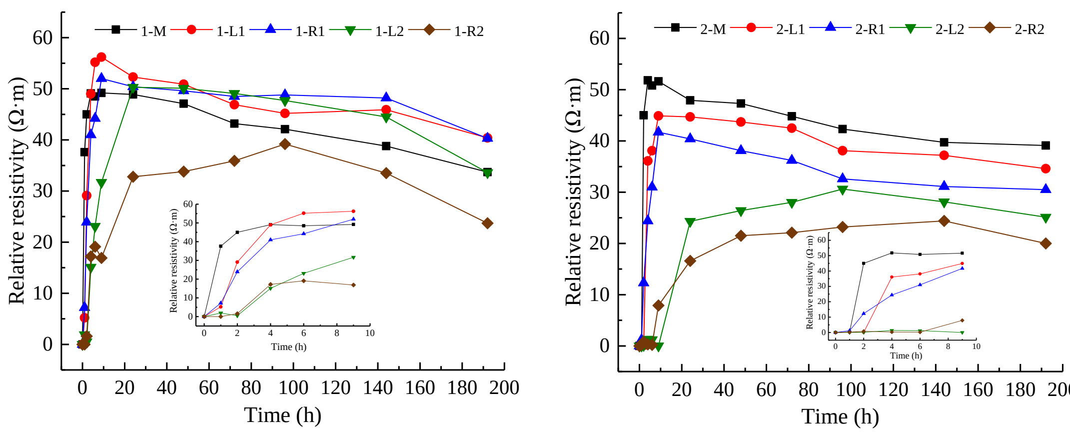

Fig. 2 Change curve of relative resistivity of soil at fixed point during LNAPL migration

REACTIVE CHEMO-HYDRO-MECHANICS FOR MODELLING AGGRESSIVE FLUID PRESSURIZATION

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ABSTRACT

Aggressive fluid injection into rock is a common operation in various geo-engineering applications, particularly those related to energy extraction from the subsurface. These applications involve highly complex physico-chemical processes that operate across different scales, influencing the stress distribution and permeability of the matrix. A fundamental question arises in a technical context: how can we effectively model the expansion of cavities in a stressed medium subjected to internal fluid pressure, while also considering the infiltration of aggressive substances from the imposed chemical environment? To address this question, we propose a comprehensive chemo-hydro-mechanical model that captures the intricate interactions between chemical mass removal, damage evolution, material strength degradation and the alteration of the internal hydraulic field due to chemical erosion. The rock behavior is governed by chemical alterations in both elastic and plastic domains, employing the concept of reactive chemo-elasticity and a postulate that the size of the yield locus depends on the accumulated mass removal. The rate of chemical dissolution at a continuum scale is described as a function of the specific surface area of the solid-fluid interface which is affected by the irreversible micro-cracking process and the local acidity. The irreversible evolution of damage is coupled to the hydraulic field through the generation of porosity resulting from mass removal, thereby influencing the transport of acids. By developing and applying this coupled model to properly constrained conditions, we aim for a better understanding of the complex behavior of chemically reactive geomaterials under Multiphysics feedback (Fig. 1) by e.g., an aggressive fluid injection.

Keywords: Cavity expansion; chemical erosion; micro-cracking; acid delivery.

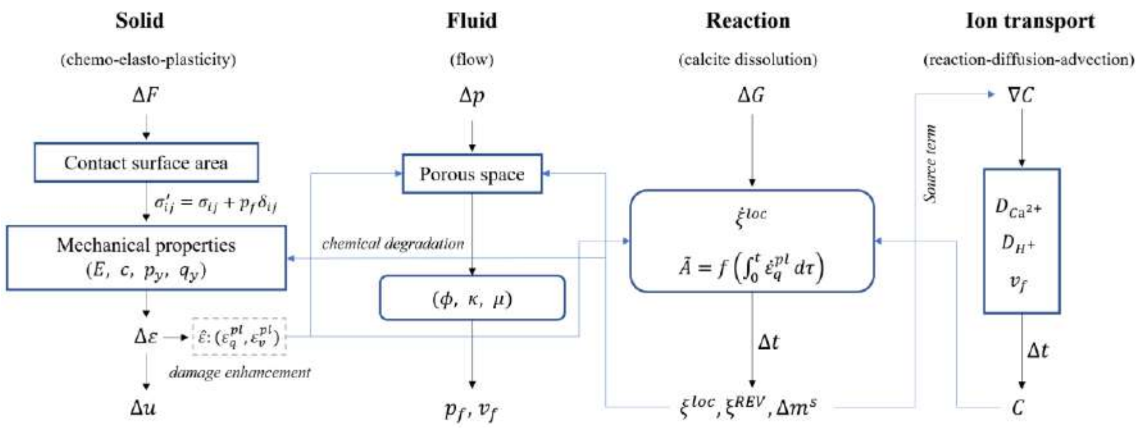

Fig. 1. Schematic diagram illustrating the coupled chemo-hydro-mechanical feedbacks of a reactive rock subject to fluid pressurization and infiltration of chemical agents.

PHYSICAL ORIGINS OF ENHANCED WATER VISCOSITY IN CLAYEY SOILS

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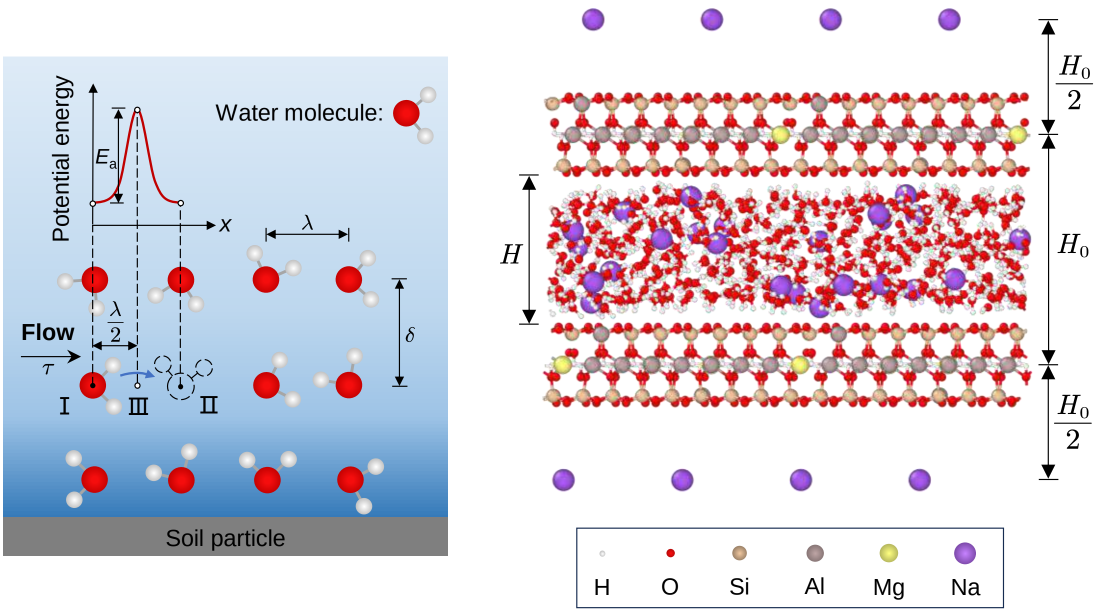
Abstract

Water viscosity is a fundamental variable which plays a crucial role in determining soil hydraulic properties, such as hydraulic conductivity and diffusion coefficient. It is widely recognized that the viscosity of water near clayey soil particle surfaces is significantly higher than that of bulk water, primarily attributed to the enhanced activation energy. Yet, the underlying physical mechanisms responsible for this enhanced activation energy remain unclear. Herein, we attempted to elucidate the origins of this enhanced activation energy by exploring the internal interactions among water molecules viz internal water potential, in order to provide an explanation for the enhanced water viscosity. Subsequently, we proposed a soil water viscosity model based on the activation energy theory and the thermodynamic formulation of internal water potential. Molecular simulations are utilized to validate the proposed model, where the activation energy is determined by the slope of the Arrhenius curve. The simulation results indicate that the proposed model can well predict the enhanced soil water viscosity and activation energy of clayey soils. Moreover, the nonequilibrium molecular simulation is employed to calculate the soil water flow velocity and hydraulic conductivity. It reveals that overlooking the enhanced water viscosity in clayey soils leads to a substantial overestimation of flow velocity and hydraulic conductivity, by up to 1.8 and 1.7 times, respectively.

Keywords: Viscosity, Activation energy, Internal water potential, Molecular simulation, Clayey soils.



(a) (b)

Fig. 1. (a) Illustration of pore water flow; and (b) Initial configuration for the molecular simulation.

INFLUENCE OF EXTRACTION AND INJECTION CONDITIONS ON PERFORMANCE OF THERMAL ENHANCED SOIL VAPOUR EXTRACTION

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ABSTRACT

Thermal enhanced soil vapour extraction (T-SVE) is an in-situ remedial technique, which can address the limitation of contaminant mass transfer and soil permeability to some extent. The relative humidity of injected air, the heating temperature at the thermal well and the extraction pressure are important design parameters of a T-SVE system that decide the temporal and spatial distributions of soil temperature and NAPL saturation. Using a thermal-hydraulic-chemical coupled model with interphase mass transfer of contaminant and water evaporation/ condensation, this study then investigated the effects of relative humidity, heating temperature and extraction pressure on the performance of T-SVE. The results showed that the higher the relative humidity of injected air, the higher the heating temperature of soil, and the two showed a linear correlation. Therefore, it is necessary to consider the heating temperature at the thermal well in the engineering design, but the evaluation of the relative humidity of the air in the injection condition cannot be ignored.

Keywords: T-SVE, relative humidity, heating temperature, removal rate.

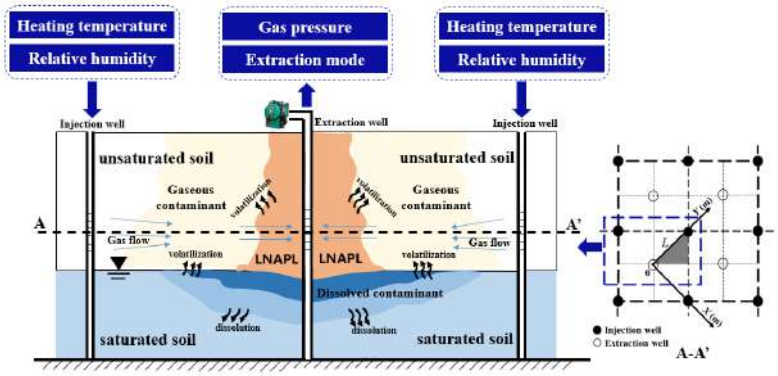

Fig. 1 Schematic of a T-SVE process with extraction and injection conditions

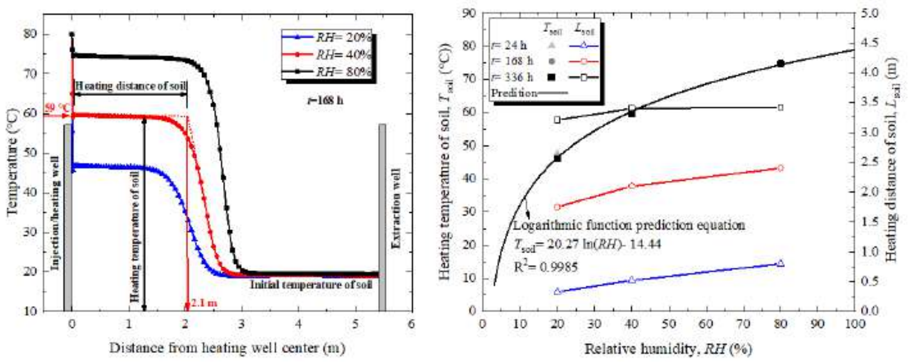

Fig. 2 Variation of soil temperature with distance from heating well centre under different relative humidity of injected air

SILICA FUME AND GYPSUM COUPLED ACTION IN THE CEMENT-STABILIZED CONTAMINATED CLAY UNDER SALINE AND ALKALINE ENVIRONMENTS

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ABSTRACT

The disposal of industrial solid waste is increasingly challenging due to the rising land occupation and environmental pollution. Controlling the remediation quality of cement-stabilized contaminated clay (CSC) in saline and alkaline environments is quite difficult. This study investigated the strength and hydraulic conductivity of silica fume (SF) incorporation in cement-stabilized clay. Combined the desulphurization gypsum powder (DGP)-to-cement ratio was recommended at 20%, and the composite cementitious agent (abbreviated as CSG) was obtained. CSG was composed of cement, SF and DGP with the optimal ratio of 1:0.25:0.20. From both saline and alkaline environments, the leaching concentration of Pb^{2+} in the leachate from CSG-stabilized contaminated clay (CSGSC) was lower than that from CSC. Microstructure analysis indicated that the SF can facilitate a hydration reaction to produce massive amounts of calcium silicate hydrate (C-S-H) gels which will adsorb and encapsulate Pb^{2+}. The DGP can react with aluminate minerals to form ettringite (AFt), where Pb^{2+} can be immobilized by either replacing Ca^{2+} or can became physically encapsulated. The Friedel's salt formed in stabilized clay in a saline environment has strong chemical adsorption and physical encapsulation to reduce the leaching of Pb^{2+}.

Keywords: Industrial solid waste; silica fume; desulphurization gypsum powder; heavy metal contaminated clay; leaching behaviour.

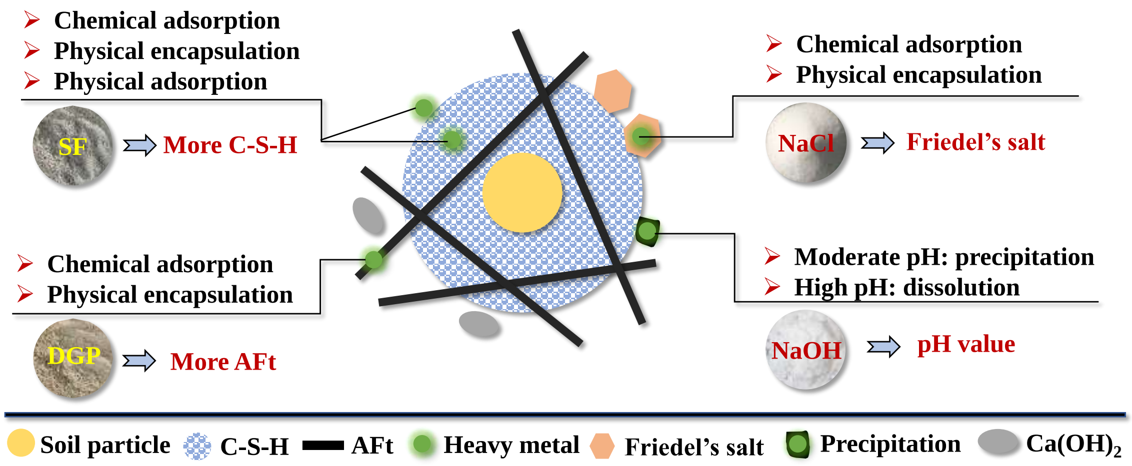

Fig. 1 Conceptional sketch of CSG-stabilized heavy metal contaminated soil

STUDY OF LEACHATE AND LANDFILL GAS MIGRATION IN HIGH SATURATED LANDFILLS CONSIDERING THE EFFECT OF BUBBLE GENERATION AND LIQUID-GAS FLOW

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ABSTRACT

Landfilling is an important way of disposing of waste and the migration of leachate and landfill gas in landfills has a significant impact on the safe operation of landfills. In highly saturated landfills, the migration of leachate and landfill gas is very complex, which is associated with the process of bubble generation and liquid-gas flow. In this paper, a bubble generation model and a two-fluid model considering the effect of porous media in a high saturated landfill are proposed, and the solvers are compiled and operated based on the finite volume method. The generation, accumulation, and rise of bubbles and liquid-gas flow processes in the high-saturation zones of landfills are reasonably modeled, and the effects of biodegradation and porous characteristics of waste on the processes of bubble rise and liquid-gas flow are analyzed. The results show that the characteristics of porous media and the biodegradation process have an important influence on the migration of leachate and landfill gas. The pressure level of leachate and landfill gas in high saturated zone increases as the porosity decreases, and the effect of bubble accumulation becomes more pronounced. The gas production rate determines the water level and gas flow rate, which has significant effect on the pressure accumulation rate and the critical flow time of bubbles. When the gas production rate is faster, the critical flow time for bubbles to rise is shorter.

Keywords: High saturated landfills, leachate and landfill gas, bubble generation, two-phase flow, porous media

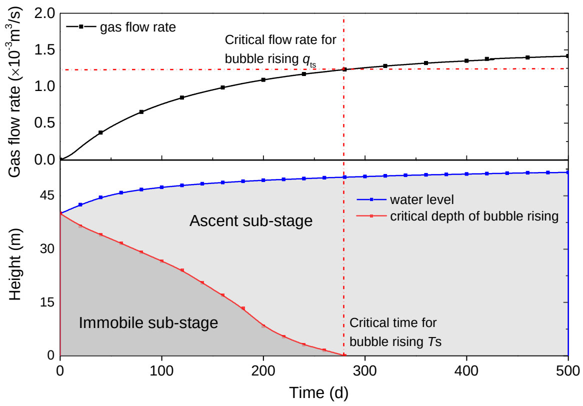

Fig. 1 Variation of landfill gas flow rate and critical flow depth at leachate water level with time

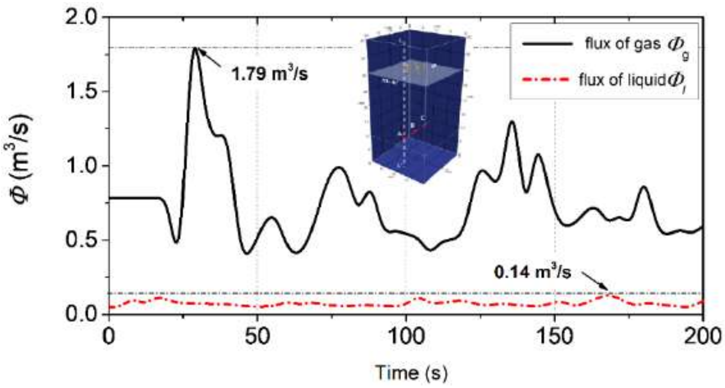

Fig. 2 Time course of liquid-gas flow through mm' plane

EXPERIMENTAL STUDY ON COD REMOVAL EFFICIENCY OF TEXTILE WASTEWATER USING GEOMATERIALS

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ABSTRACT

Abstract: Textile wastewater poses a significant environmental challenge due to its high chemical oxygen demand (COD), colour, and toxicity. Conventional treatment methods often struggle to effectively remove the diverse range of pollutants in textile effluents, including COD, chloride, total alkalinity, and sulphates. In recent years, geomaterials have emerged as a promising approach to wastewater treatment. This study examines the efficacy of naturally occurring geomaterials, namely fly ash, red soil, raw kaolinite, thermally activated kaolinite, and acid-activated kaolinite, as adsorbents for the treatment of textile wastewater, focusing on their adsorption capacities, kinetics, and efficiency in removing various dyes and pollutants commonly present in textile effluents, with a specific emphasis on COD reduction. The experimental analysis showed that geomaterials like fly ash, red soil, and kaolinite could be effectively used as absorbents to treat textile wastewater. Out of these three geomaterials, red soil has shown the most significant result in the reduction of COD of the textile wastewater as the removal efficiency obtained was 47.8% as compared to 25.5% and 15.5% for fly ash and kaolinite, respectively.

Keywords – Textile wastewater, chemical oxygen demand (COD), fly ash, red soil, kaolinite.

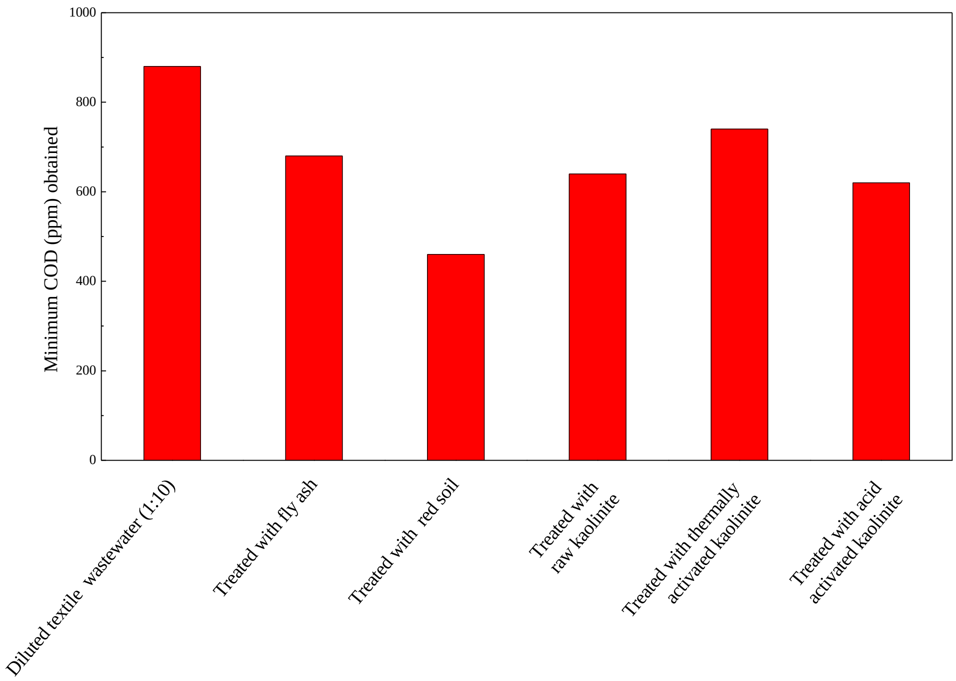

Fig. 1 Variations in the COD values of the sample using different types of absorbents

IN-SITU POLYMER MODIFICATION METHOD TO IMPROVE THE BARRIER PROPERTY OF CA-BENTONITE UNDER CHEMICALLY AGGRESSIVE ENVIRONMENT

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ABSTRACT

Polymer-modified bentonite (PMB) can achieve superior barrier property to conventional bentonite for containing chemically aggressive leachate generated from solid waste landfills. The manufacturing of PMB typically uses the natural, high-quality sodium bentonite (NaB) due to its excellent hydrophilicity. However, the calcium bentonite (CaB), which is of poor hydrophilicity, is much more abundant in the world especially in Europe and Asia. This study proposed a method for synthesizing the polymer modified bentonite. The microstructures of PMB were analyzed using TGA, XRD, TEM and SEM techniques to reveal PMB's mechanism. The results showed that the CaB without polymer modification was highly permeable to aggressive solutions, i.e., the hydraulic conductivity (k) to 3.4% NaCl solution was high, = 2.76×10^{-7} m/s. In contrast, the PMB exhibited much superior barrier property, with k to 3.4% NaCl solution and trona ash leachate < 10^{-11} m/s, which is 4 orders of magnitude lower than that of the conventional CaB. Microscopic analyses indicated that monomers were successfully polymerized and grafted onto the bentonite surfaces as designed and, thus, increased PMB's swelling capability under even very aggressive environment. The successful modification of CaB in the present study broadens the application of CaB for advanced barrier material fabrication.

Keywords: geosynthetic clay liner, polymer, bentonite, permeability, chemical compatibility

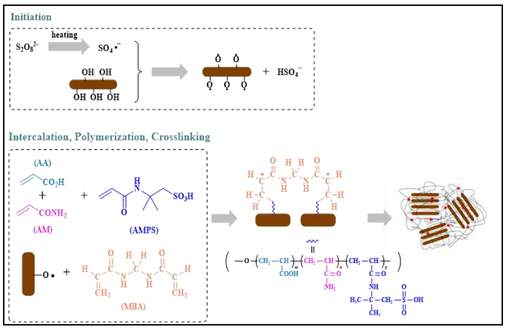

Fig 1. Proposed reaction mechanism for the CaB-based PMB.

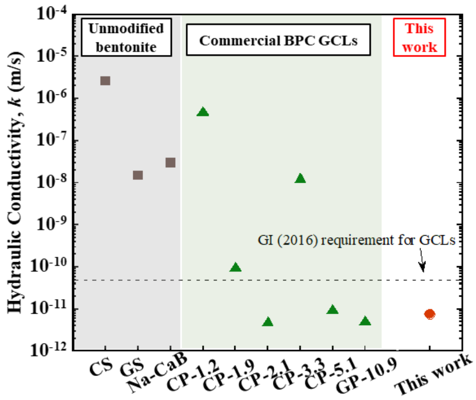

Fig. 2. Hydraulic conductivity of the proposed CaB-based PMB versus the commercial NaB-based PMB GCLs permeated with very aggressive trona leachate.

EXPLORATION OF POLLUTANT ADSORPTION AND ANTI-SEEPAGE BY MULTI-SCALE AND MULTI-METHOD

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ABSTRACT

The anti-seepage defects in the barrier landfill of chromium-contaminated sites. Traditional bentonite materials cannot effectively adsorb hexavalent chromium, and their impermeability performance is unstable under complex service environments, which can easily lead to landfill barrier failure, causing ecological pollution and endangering human health. The proposal aims to solve the following three key scientific problems using the molecular dynamic method combined with microscopic analysis, model and field test. Prepare polymer polymerized modified bentonite based on impermeability stability and organic modified bentonite for chromium directional adsorption. Establish a molecular solid-liquid interaction model between modified montmorillonite and hexavalent chromium leachate, to verify the inner connection between the microstructure characteristics and the adsorption performance of the modified montmorillonite. Clarify the migration mechanism of hexavalent chromium in composite liners under complex service environments. It is expected that the research results can enrich the research on adsorption mechanism of heavy metals, improve the hexavalent chromium handling effect, and have great significance for the planning and design of the anti-seepage gaskets and the safety barrier in landfill sites of the chromium-related pollutants.
Keywords: Modified bentonite; Chromium-contaminated sites; Molecular simulation; Composite anti-seepage

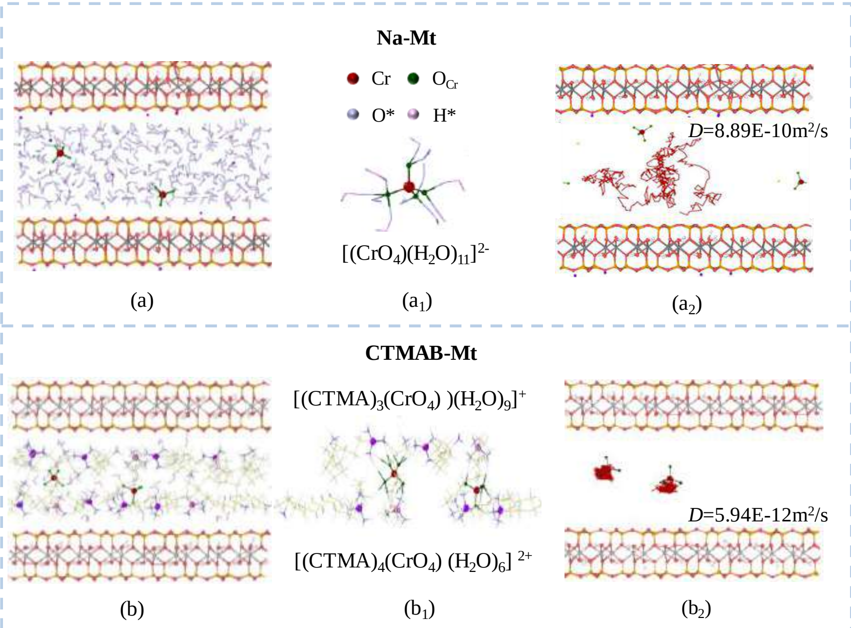

Fig. 1 Snapshot of stable structure, chromate complexes and trajectories of Na-Mt and CTMAB-Mt adsorbed chromate ions

SIMULATED LUNAR SOIL CONTAINING WATER ICE IN POLAR REGIONS OF THE MOON AND ITS PREPARATION METHOD

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ABSTRACT

Research has shown that water exists on the lunar sphere, and studying the physical and mechanical properties of water containing ice lunar soil plays a crucial role in the polar landing of lunar exploration, the construction of lunar bases, and the exploitation of lunar polar resources. Due to the disturbance of in-situ water ice lunar soil, water ice will undergo phase transition and escape, making it difficult to sample and return. Therefore, there is an urgent need to prepare a lunar soil water ice simulation material with similarity, equivalence, uniformity, and coverage on the ground, and conduct research on its physical and mechanical properties in the simulated lunar surface environment on the ground. Focusing on the chemical composition, particle morphology, physical and mechanical properties, ice content, and other characteristics of real lunar soil, a lunar polar simulation soil suitable for in-situ environmental experimental conditions of the moon is developed through water vapour infiltration freezing. The prepared simulated lunar soil containing water ice has the advantages of high fidelity, low cost, environmental protection, and no pollution, which can effectively simulate the physical and mechanical properties of lunar polar soil under low gravity environment.

Keywords: Simulated lunar soil; water ice; Lunar polar region; mechanical properties

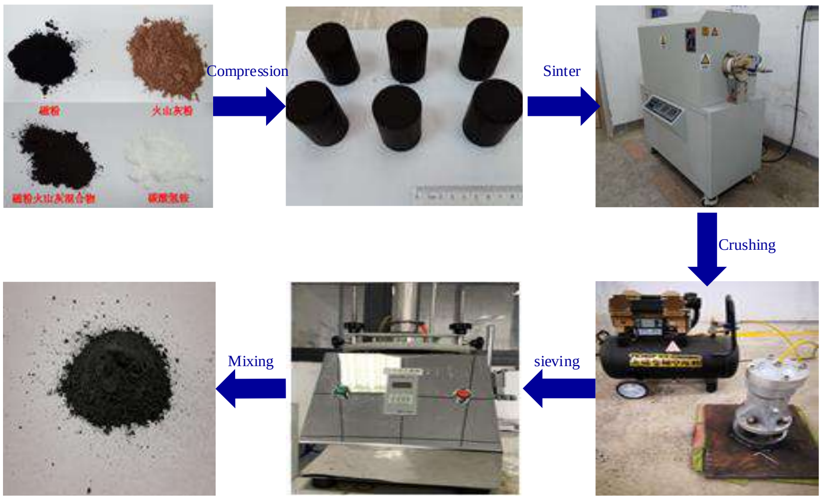

Fig. 1 Preparation process of dry lunar soil

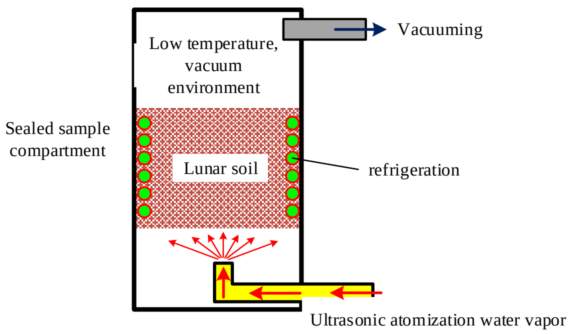

Fig. 2 Preparation of lunar soil containing ice

GAS PERMEABILITY OF POLYACRYLAMIDE AMENDED GEOSYNTHETIC GLAY LINER IN THE COVER BARRIES WITH CALCIUM SOLUTION ACTION

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

This study evaluated two types of geosynthetic clay liners (GCLs)-commercial GCL and polyacrylamide (PAM)-amended GCL, for use as cover barrier materials for controlling contaminated soil gas spillage at contaminated sites. Bentonite in cation-rich in situ soils tends to suffer from weakened swelling and gas-barrier impermeability. The results showed that the specific gravity (G_s) of the modified GCL was slightly reduced, but the liquid limit (w_L) was significantly increased compared with the unmodified GCL. As the concentration of $CaCl_2$ solution increases, the gas permeability (k_a) of both GCLs increases. PAM-amended GCL gas permeability (k_a) was found to increase from 9.02×10^{-10} to 3.27×10^{-8} m/s, with a greater concentration of $CaCl_2$ in the pore solution. The unamend GCL gas permeability (k_a) exceeds the permeability value based on Darcy's law after the pore solution CaCl2 concentration increases. Scanning electron microscopy (SEM) and energy spectroscopy (EDS) analysis showed that PAM hydrogels filled the intergranular pores of GCL coated in bentonite particles. X-ray diffraction (XRD) results showed that PAM could not enter the montmorillonite platelets. The microscopic properties elucidated the mechanism of the excellent gas barrier properties of PAM-amended GCL.

Keywords: Geosynthetic clay liner, Polyacrylamide, Gas Permeability, Calcium Chloride, Macroscopic Properties

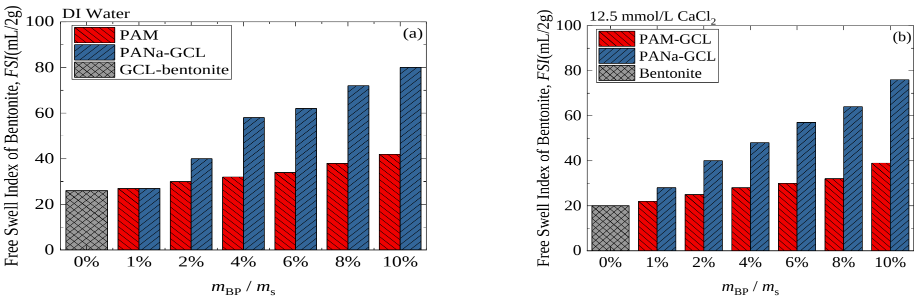

Fig. 1 Free swell indices of bentonites in tap water, distilled water, and 12.5 mmol/L $CaCl_2$ solution

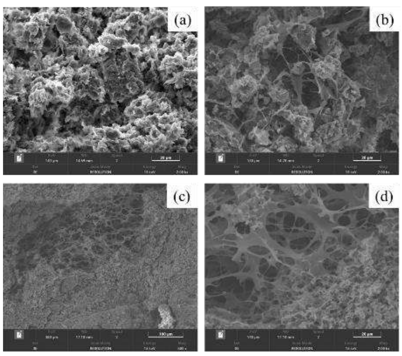

Fig. 2 Field emission scanning electron microscope (FESEM) images of (a)GCL, (b)PAM-GCL, (c)PANa-GCL (500x), (d) PANa-GCL (2000x)

EXPERIMENTAL STUDY OF ALKALI ACTIVATED SLAG ENHANCED COMPACTED CLAY COVERING BARRIER LAYER

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ABSTRACT

In order to improve the performance of the covered barrier compacted clay cover (CCC) in the contaminated site, industrial solid waste including calcium carbide slag, mineral powder, magnesium oxide, quicklime and bentonite was added into the compacted clay. The improvement effect of the compacted clay was analyzed respectively through unconfined compressive strength tests, flexible wall permeability tests and soil gas permeability tests. The results show that the unconfined compressive strength (q_u) of the improved samples with curing times of 28 days can be increased by 5-12 times compared with the unimproved compacted clay(UCC). The q_u of 60d curing increased by 6.0%-56.7% compared with 28d curing, and the order of strength enhancement ability was MgO > calcium carbide slag > quicklime. The modified compacted clay has higher brittleness and deformation resistance, and the E_{50} and q_u of the same modified clay samples at different curing ages have obvious linear relationship. After curing for 28 days, the tap water permeability coefficient k_F of each improved sample reached 10^{-10} m/s, and the improvement of alkali activated GGBS could increase by more than one order of magnitude. Compared with compacted clay, the gas permeability coefficient (k_g) of soil improved by alkali activated GGBS decreases by one order of magnitude, reaching 10^{-8}m/s. According to the analysis of environmental and economic benefits, the net CO_2 emission of the improvement scheme mixed with industrial solid waste calcium carbide slag and GGBS can be reduced by more than 88% compared with other improvement schemes.

Keywords: Clay cover, Carbide slag, GGBS, Permeability coefficient, Gas barrier property

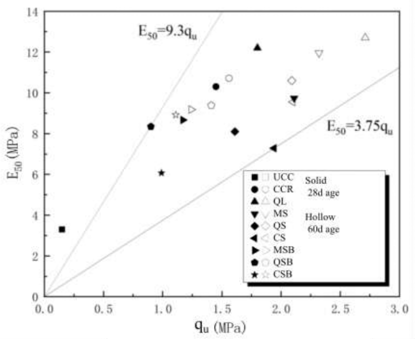

Fig. 1 The relationship between E_{50} and q_u

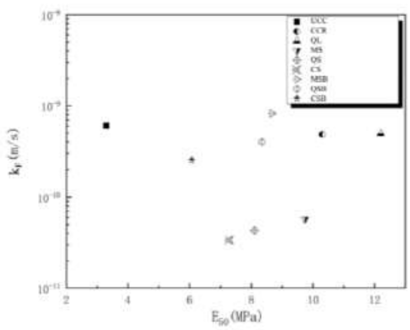

Fig. 2 The relationship between k_F and E_{50}

A STUDY ON THE WATER-ROCK COUPLING CHARACTERISTICS IN DEEP IN-SITU ENVIRONMENT OF JINPING MARBLE

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ABSTRACT

Investigating the water-rock coupling characteristics in deep in-situ environments is crucial for understanding the mechanical behavior of rocks under high-stress conditions. This study focuses on the Jinping marble and utilizes the extremely deep water environment of the China Jinping Underground Laboratory (CJPL). A deep high-pressure water-rock coupling experimental apparatus was employed to subject the Jinping marble to pressurized immersion treatments with varying solvent conditions (pH=7, 8, 9) and immersion durations (1, 23, 60, 100 days) at a depth of 2400 m. Comprehensive macroscopic and microscopic mechanical tests were then conducted on the treated marble samples. The results from macroscopic testing, specifically static fracture toughness evaluation, demonstrated a decrease in Type I fracture toughness with longer immersion periods. Notably, rock samples treated with neutral solvents displayed more significant degradation compared to those treated with alkaline solvents. Furthermore, the decline in mechanical properties was more pronounced in rock samples subjected to unpressurized immersion compared to in-situ stress immersion treatment. Microscopic analysis using nano-indentation testing revealed a reduction in mineral hardness and elastic modulus with increasing immersion duration, consistent with the macroscopic mechanical findings. The fracture surfaces of rock samples treated with pressurized immersion predominantly exhibited transgranular fractures, accompanied by intergranular fractures as secondary features. It was also observed that the presence of surface cementitious material increased relatively in samples treated with higher alkaline solvents. Overall, this study offers valuable insights into the water-rock coupling behavior of rock under deep in-situ conditions, providing essential data for assessing the long-term stability of deep engineering projects.

Keywords: Deep rock mechanics; Water-rock coupling; Multiple scale; Fracture toughness; Microscopic testing analysis.

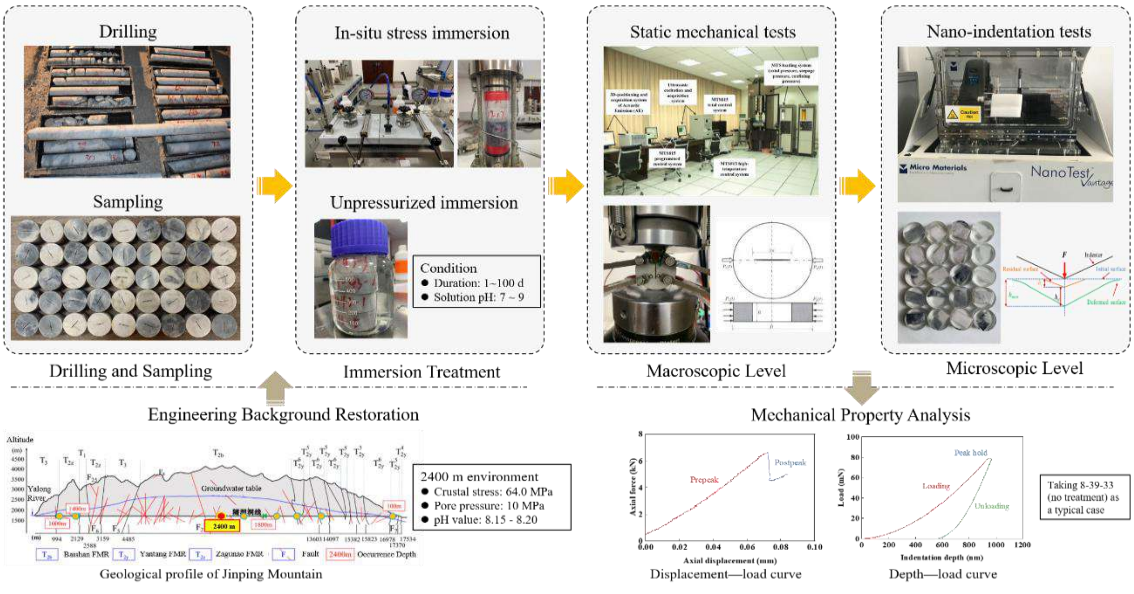

Fig. 1 Overview of methods and analysis

EMISSION OF VOLATILE ORGANIC COMPOUNDS FROM THE INTERMEDIATE COVER AT A LARGE-SCALE MUNICIPAL SOLID WASTE LANDFILL IN HANGZHOU, CHINA

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ABSTRACT

Volatile organic compounds (VOCs) may contribute to odour pollution and global warming. A one-year field investigation of VOCs composition and concentration emitted from landfill intermediate cover was conducted using self-developed static chambers. A total of 15 monitoring points was deployed and 97 samples were analysed. Forty-eight types of VOCs were detected, including hydrocarbons, aromatic hydrocarbons, terpenes, halogenated hydrocarbons, sulfur compounds and oxygenated compounds. The highest VOCs concentration was found in summer which reached 6.42 mg/m^3. It exceeded the limit value for fugitive emission. The high temperature would promote waste degradation and increase diffusion coefficient. Since the content of plastic, rubber and paper reach 59.2% in one-year-old waste, the generated aromatic hydrocarbon was identified as the main component of VOCs. The order of surface flux obtained in this study (benzene < toluene < ethylbenzene < o-xylenes < m-p-xylene) is consistent with the trend of permeability coefficients through GMBs experimentally obtained by previous researches. However, the values of diffusion coefficients obtained from field may differ by 1~2 orders of magnitude from those obtained in laboratory tests due to atmospheric temperature changes and geomembrane seams and ageing. This study provides a valuable database for landfills that can be used for future environmental management.

Keywords: landfill gas, volatile organic compounds, intermediate cover, field investigation

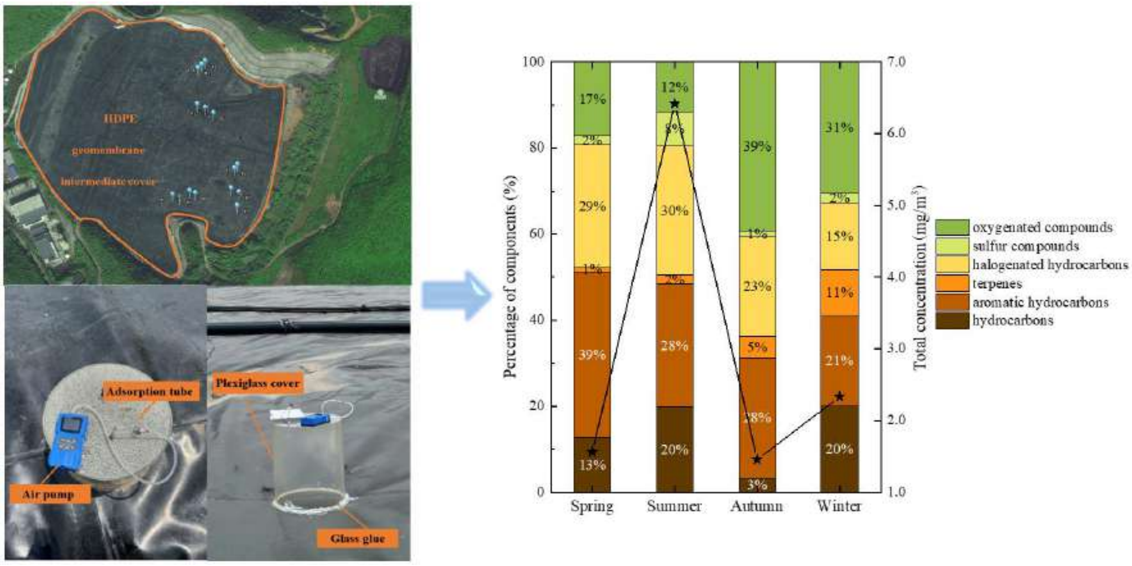

Fig. 1 Illustration of field investigation

STABILITY-PRESERVING AND CONSERVATION-PRESERVING ALGORITHM FOR HMC FULLY COUPLED PROBLEMS

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ABSTRACT

The numerical solution of the hydro-mechanical-chemical (HMC) fully coupled equations in porous media faces significant challenges due to spurious oscillation in pore pressure and concentration caused by locking and convection dominance. This study proposes a combination of two different discretization schemes: (1) the Galerkin discretization for the soil skeleton deformation, and (2) the finite volume method (FVM) for solute transport and fluid flow on the dual mesh, named G-FVM, where the approximations of skeleton displacement , pore pressure , and concentration are established by NMM, are able to reflect the compressible and incompressible deformation. In this way, the proposed method guarantees mass conservation of solute at the level of cells, which is essential to eliminating unphysical oscillations, as well as the stability of skeleton deformation. Typical examples of chemo-osmotic consolidation and chemo-mechanical consolidation are simulated to verify the accuracy of the proposed method. By comparing the numerical solutions of 1D and 2D chemo-mechanical consolidation problems with the full Galerkin method, it is suggested that the G-FVM is a reliable and effective computational approach for HMC coupling problems in porous media, even with a large Péclet number.

Keywords: Hydro-mechanical-chemical coupling; Numerical manifold method; Galerkin method; Finite volume method; porous media.

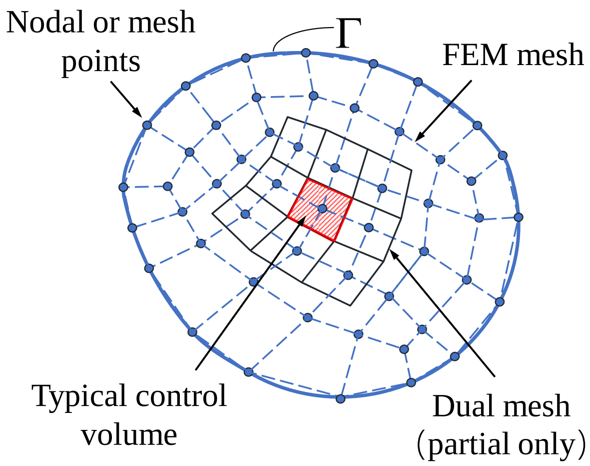

Fig. 1 A quad finite element mesh (primal mesh) and node-centered quad control domains (dual mesh)

VIBRATION IMPACT ASSESSMENT OF SHIELD TUNNELING IN SOIL-ROCK STRATA

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ABSTRACT

Within the scope of Xuzhou Metro Line 6, where the tunnel traverses beneath Zhaijing Village, this research collects, analyzes, conducts spatial investigations. The research aims to elucidate the propagation mechanism of vibration generated during shield tunneling. It specifically focuses on the soil-rock composite strata. Along the tunneling route, monitoring points are strategically placed. TC4580 blast vibration monitors employed for the collection and storage of vibration signals. The analysis focuses on the peak velocity of the gathered vibration signals, employing geological survey methods. The investigation employs Fourier and continuous wavelet transforms. It examines the time-domain and frequency-domain responses of these vibrations in both longitudinal and transverse directions. The findings significantly underscore the impact of both the distance from the vibration source and the complexity of strata on the trajectory of vibration propagation. Recognizing the distance and damping attenuation of vibrations during their propagation within the strata is crucial when formulating effective vibration isolation strategies for subway construction endeavors.

Keywords: Shield tunneling; Vibration propagation; Soil-rock strata; Metro construction; Tunnel-induced vibrations.

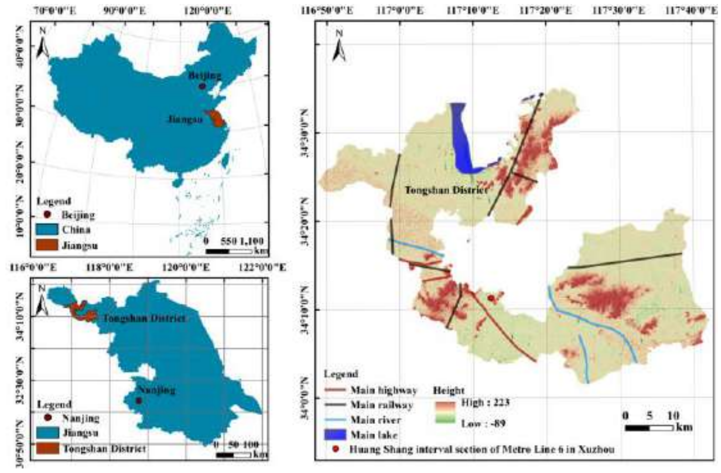

Fig. 1 Elevation of the study area

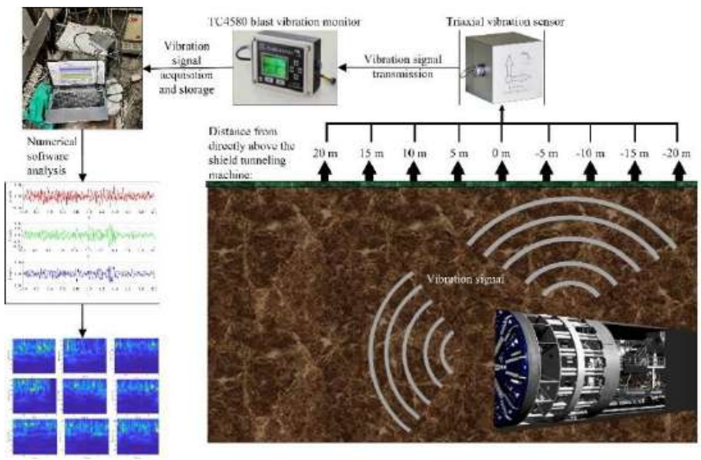

Fig. 2 Vibration signal acquisition and processing

MECHANICAL RESPONSES IN ROCKS WITH DIFFERENT LITHOLOGIES UNDER MINING LOADING-UNLOADING: AN INSIGHT BY ENERGY DAMAGE AND ULTRASONIC CHARACTERIZATION

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ABSTRACT

Underground coal mining disasters are generally caused by the deterioration in mechanical properties of coal and overlying rock exposed to mining loading-unloading, while their differential mechanical deterioration and catastrophic mechanisms remain unclear, leading to inefficient of coal resources exploitation and utilization. Hence, uniaxial loading-unloading tests with ultrasonic measuring are performed on coal and roof sandstone; the mechanical responses are investigated using energy damage analysis and ultrasonic characterization. Sandstone yields a greater strength and deformation modulus, showing a brittle failure, while coal possesses a larger Poisson's ratio and exhibits ductile failure. The higher (lower) crack initiation (damage) stress level in coal reflects its faster crack propagation than sandstone. Energy evolution analysis shows that coal has a worse elastic energy storage ability but its energy dissipation is more severe, and the energy-type catastrophic criteria is concluded for coal and sandstone based on elastic energy ratio. A new damage variable is defined by cumulative dissipated energy and input energy, with inducing the damage energy release rate, the damage evolution model under uniaxial loading-unloading is obtained, indicating that coal experiences a greater damage degree but is less dependent on energy release rate. Furthermore, the differential energy controlling mechanisms of instability between coal and sandstone are revealed, i.e., coal is controlled by pre-peak energy dissipation and post-peak energy release, while the sandstone is dominated by the post-peak rapid energy release. Meanwhile, different wave velocity evolution patterns are generalized, where the denser sandstone yields a higher stress sensitivity of wave velocity. Comprehensively utilizing dynamic elastic parameters, intactness index and disturbance damage factor, the structural degradation process is quantitatively characterized, demonstrating that the structural deterioration occurs in the unloading and final loading failure stage, and coal shows progressive pattern while sandstone possesses transient one. Finally, the quantitative relationships between wave velocity and stress, energy and damage are established.

Keywords: Coal mining; Uniaxial loading-unloading; Mechanical behavior; Energy evolution; Damage analysis; Ultrasonic characterization.

FATE AND TRANSPORT OF PFAS THROUGH LANDFILL LINER SYSTEM

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ABSTRACT

Per-polyfluoroalkyl substances (PFAS) are emerging organic contaminants and have become a rising concern for landfill facilities. The objective of this study was to quantify the fate and transport of selected PFAS with varying properties with one compaction liner soil as well as high density polyethylene (HDPE) geomembrane (GM). A series of laboratory tests were conducted, which included static and kinetic batch adsorption tests. Twenty PFAS with varying chain lengths and functional groups were studied. The measured K_d was larger for longer chain lengths and perfluoroalkyl compounds compared with shorter chain lengths and polyfluoroalkyl compounds. PFAS with sulfonamide functional groups showed the strongest sorption followed by sulfonic and carboxylic acid functional groups. The diffusion coefficients of PFAS showed an inverse relationship with an increase in molar mass/number of carbons in the chain.The results show that the clay mineral in liner soil have a high soprtion of PFAS (~12 to 40 L/kg), while the PFAS have low diffusion conefficent through HDPE GM (1.1×10^{-18} m^2/s to 4.7×10^{-17} m^2/s). The migration of PFAS through landfill composition liners may take hundreds of years. Overall, the composite liner system is very effective to prevent the migration of PFAS.

Keywords: PFAS, landfill liner, partition coefficient, diffusion coefficient, migration

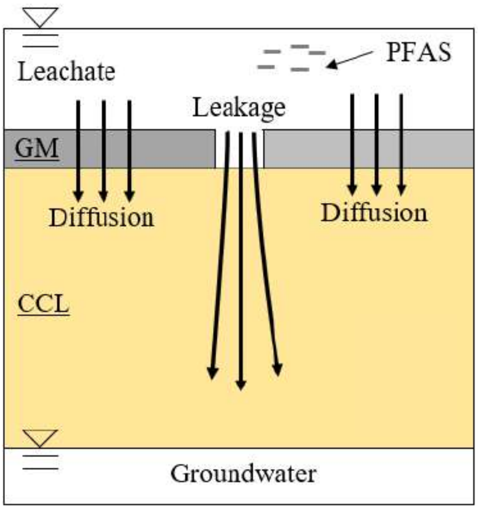

Fig. 1 Migration of PFAS through landfill liner system

AN INDIRECT METHOD OF CARBONATING MAGNESIA FOR SOIL STABILIZATION AND CO_2 CAPTURE

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ABSTRACT

Traditional MgO carbonation (MgO and gaseous CO_2), also called as direct carbonation, is a promising and sustainable technique in construction area. However, using this technique to treat infield soils (particularly for clayey soils) encounters problems in CO_2 diffusion, carbonation conditions, and mixing process on a large scale. To address such problems, this study proposed a new method (indirect carbonation method) that using $NaHCO_3$ as a CO_2 carrier to carbonate MgO, and then the carbonated MgO was applied to treat soils. Fig.1 presents the comparison between the direct and indirect carbonation processes. The engineering properties of the stabilized soil were investigated. Discussion on the technical feasibility of this new method was conducted. The results showed that the soil with MgO+$NaHCO_3$ produced better mechanical performance than that with OPC due to the formation of various magnesium carbonates. The new method could be more convenient to operate on-site than the traditional carbonation method. Overall, this method could be an updated version of traditional MgO carbonation.

Keywords: MgO carbonation; soil stabilization; $NaHCO_3$; strength; CO_2 capture.

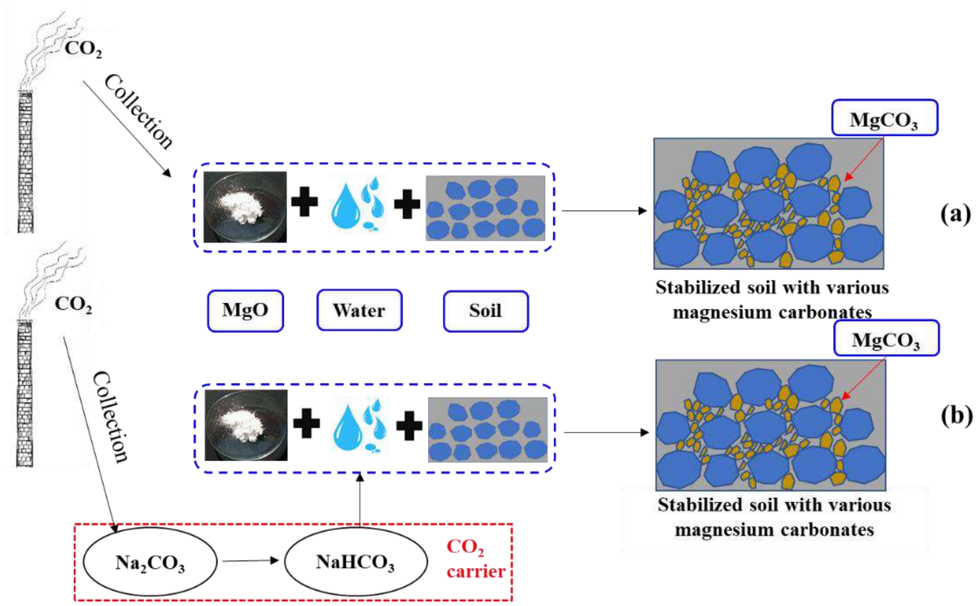

Fig. 1 The schematic of the carbonation processes for (a) MgO+CO_2 (direct carbonation) and (b) MgO+$NaHCO_3$ (indirect carbonation).

ANALYTICAL MODEL FOR THE MITIGATION OF VOC VAPOR WITH HORIZONTAL PERMEABLE REACTIVE BARRIER IN THE CONTAMINATED SITE CONSIDERING NON-UNIFORM SOURCE

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ABSTRACT

Volatile organic compound (VOC) vapor released from the contaminated groundwater can migrate in the vadose zone and may pose a threat to human health. For controlling VOC vapor contamination in the vadose zone, the horizontal permeable reactive barrier (HPRB), as a novel low-carbon mitigation technology, has great development potential. The VOC concentration distribution at the contaminated groundwater always exhibits spatial variability, which needs to be considered for estimating the mitigation effect of HPRB. Considering the non-uniform distribution of VOC concentration at the contaminated groundwater, a two-dimensional transient analytical model was proposed to simulate the mitigation of HPRB for the VOC vapor in the contaminated site. The influence of non-uniform source characteristics and soil layer parameters on the mitigation effects of HPRB has been investigated. The results show that HPRB has a better mitigation effect for the contaminated sites with the deeper source or the lower effective diffusivity of the local soil. The asymmetrical distribution of source concentration results in a disparity in the position of the peak vapor concentration at the ground surface and the source. The vapor concentration at the ground surface decreases exponentially with the increase of the HPRB thickness.

Keywords: Horizontal permeable reactive barrier; Non-uniform source; Volatile organic compound; Vapor migration; Analytical model

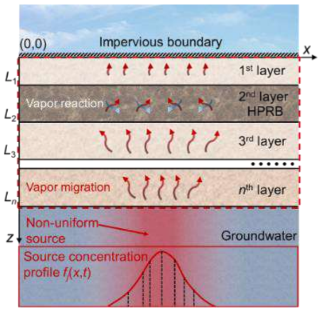
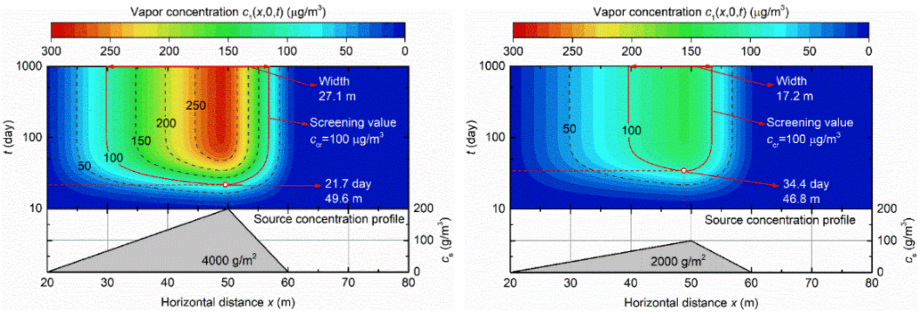


Fig. 1 Schematic diagram of mitigation effect of HPRB for the vapor released from the non-uniform source



(a) (b)

Fig. 2 Vapor concentration distribution at the ground surface for the non-uniform source with (a) high peak concentration and (b) low perk concentration

THERMOPHYSICAL BEHAVIOR OF SANDSTONE AND GRANITE RESERVOIR UNDER THE COUPLING OF PRESSURE AND TEMPERATURE AND ITS IMPACT ON THE GEOTHERMAL PRODUCTION

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ABSTRACT

The thermal properties of geothermal reservoir rock significantly the thermal extraction performance of hydrothermal and enhanced geothermal systems (EGS). Firstly, the thermal conductivity of Gonghe granite, Kangding granite, and Songliao sandstone was measured under different temperatures and axial stresses, and the characteristics of specific heat capacity and thermal expansion coefficient were tested at different temperatures. Secondly, a numerical model was used to model the heat extraction process based on the experimental data. Finally, the evolution of extracted temperature, pressure, and total heat extracted with thermal extraction time was studied for the hydrothermal and EGS. It shows that temperature weakens the thermal conductivity of rock, while stress enhances it. The high-porosity rocks are more sensitive to stress. However, the thermal conductivity decrease under high stress. The temperature enhances the heat storage capacity and thermal deformation of rocks, with larger mineral particles exhibiting stronger thermal deformation ability. It was found that changing the thermal conductivity of rock does not affect the heat extraction performance of the hydrothermal system and EGS. Increasing the specific heat capacity of rock can increase production temperature, prolong the lifetime of the geothermal reservoir. The outcomes help to support a basis for the design and construction of geothermal engineering.

Keywords: Hydrothermal system; Enhanced geothermal system; Thermal properties; Total heat extracted

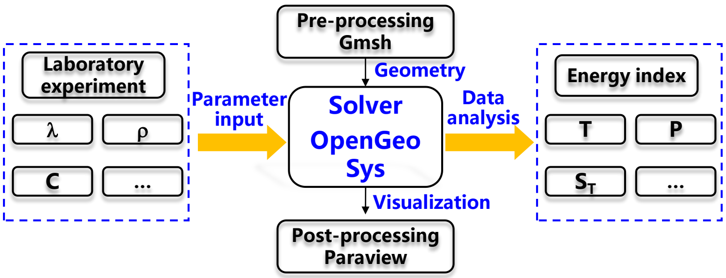

Fig. 1 Flow diagram of thermal extraction numerical model implementation

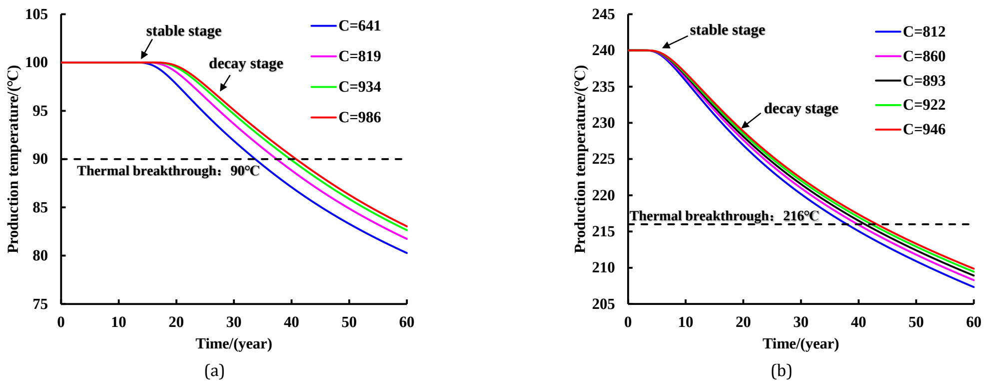

Fig.2. Temperature decline curve under various specific heat capacity. (a) sandstone reservoir;(b) granite reservoir.

INVESTIGATING LEACHATE MIGRATION AND EFFICACY OF COMPRESSED AIR DRAINAGE IN NO FOOD WASTE CONTENT LANDFILLS THROUGH ELECTRICAL RESISTIVITY TEST

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ABSTRACT

In landfill dewatering using pumping wells, obstructions from waste materials like plastics and textiles often block the wells, particularly in landfills without food waste content. Based on high-density electrical resistivity testing, this study analyses leachate migration and the effect of compressed air drainage wells on improving leachate management. Test results reveal that electrical resistivity mainly ranged over 1.0 and 25 Ω·m and moisture content over 0.2 and 0.6. Over two months of monitoring, electrical resistivity decreased near pumping wells and increased nearby. At greater distance, resistivity decreased moderately, showing vertical pumping reduces leachate content but alters distribution. After two years, electrical resistivity significantly increased at 8 m depth and beyond 15 m, while it decreased between 8 and 15 m depth, suggesting internal waste migration may lead to leachate accumulation. This study advances understanding of landfill leachate and offers insights into managing related environmental risks.

Keywords: Compressed air drainage well; No food waste content (NFWC); Electrical Resistivity Test (ERT); Leachate migration

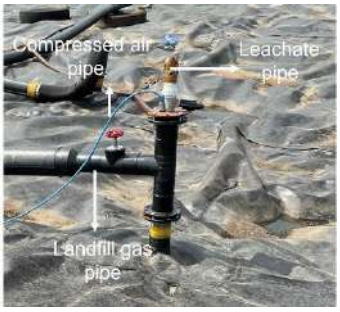

Fig. 1 Compressed air drainage well at the Taohuashan landfill

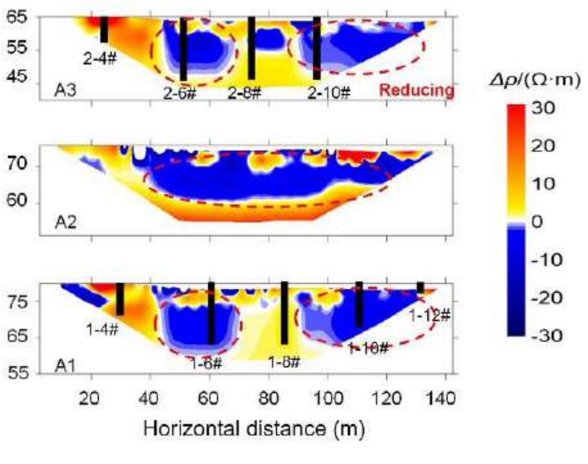

Fig. 2 Temporal evolution of line A1-A3 resistivity changes over two years

EXPERIMENTAL STUDY OF LANDSLIDES IN STABLE GENTLE SOIL SLOPES TRIGGERED BY PRESSURIZED PORE-GAS

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ABSTRACT

This paper presents 11 flume tests to study the landslide triggered by pressurized pore-gas in gentle soil slopes. The 11 flume tests encompass variations in slope declination angles and injections. One test employs air injection to produce gas triggering. Seven tests inject H_2O_2 solution into cement powder core to generate gas in the slope. The injection holes and cement core are covered by a layer of saturated soft clay forming a trap for the generated gas to build up its pore-gas pressure. The pore-gas pressure is the driving force to cause the landslide. Three additional tests with water injection are perfomed as contrast tests. The failure behaviours with time are analyzed using captured videos. The test results show a small mass of pressurized gas can trigger the landslide in the gentle soil slope without large volume of water. The pressurized pore-gas can induce soil upheaval phenomena during the landslide. Such pore-gas triggering is generally not noticeable since it can disappear rapidly without tracing. In addition, the landslide with large mass of liquid injection had noticeable liquid leakage from slope toe, while the leakage did not appear in the landslide trigged by a small mass of liquid and gas.

Keywords: Landslide; flume test; gentle soil slope; triggering factor; pore-gas

Table 1. 11 Flume tests in stable gentle soil slopes

Tests	Declination angle (°)		Fill soil			Injection				Failure results
	Sliding base	Front slope surface	Initial clay water content	Cement layer length L_{ce}(mm)	Soil mass weight (g)	Injection Type	Injected volume (mL)	Injected time (s)	Injection rate (mL/s)	
1	15	34.8	65 %	0	17393	Air	2350 (STP*)	60	36.2 to 41.1 (STP*)	Soil upheaval + landslide with less travel distance
2	15	34.8	65 %	450	15387	35 % $H_2O_{2(aq)}$	900	224	4.02	Soil upheaval + landslide with liquid leakage from slope toe
3	15	34.8	65 %	320	16001	35 % $H_2O_{2(aq)}$	805	192	4.19	
4	10	29.8	65 %	450	15387	35 % $H_2O_{2(aq)}$	190	47	4.04	
5	15	34.8	65 %	320	16001	35 % $H_2O_{2(aq)}$	600	472	1.27	
6	15	34.8	70 %	450	15624	35 % $H_2O_{2(aq)}$	63	15	4.2	Landslide without liquid leakage
7	10	29.8	65 %	450	15387	35 % $H_2O_{2(aq)}$	63;63;63;	15;15;15	4.2	Soil upheaval + Landslide without liquid leakage from slope toe
8	10	29.8	70 %	450	15624	35 % $H_2O_{2(aq)}$	63;63;	15;15	4.2	
9	15	34.8	70 %	450	17383	Water	63;	15	4.2	No failure
10	15	34.8	65 %	320	16001	Water	5910	1500	3.94	Landslide with liquid leakage
11	15	34.8	65 %	320	16001	Water	1860	1500	1.24	Crack

*Note: STP means standard conditions for temperature(0°C) and pressure (101.325 kPa)

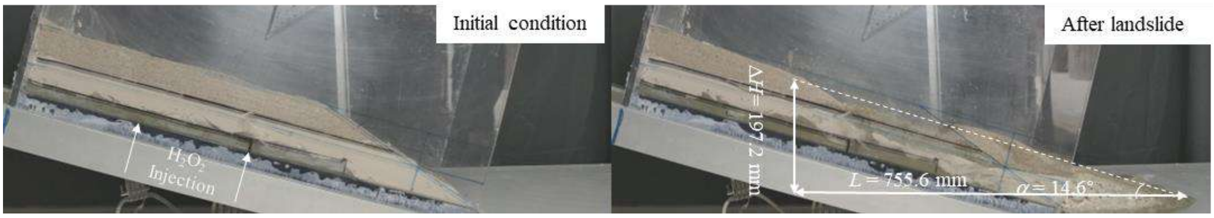

Fig. 1 Photograph of the gentle soil slope in the flume in Test 2

WAVES AND THEIR TRANSITIONS IN SNOW AVALANCHES ON REAL TERRAIN

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ABSTRACT

Waves occur in many avalanches on earth and other planets. The dynamic nature of waves makes them dangerous in geological flows, as their local velocity and height could be much larger than other part of the flow. Extensive research on granular waves has been conducted using theoretical and numerical approaches with idealized assumptions. However, the mechanism of waves in realistic complex situations remains intangible, as it is challenging to capture granular waves on real terrain. Here, we leverage a recently developed hybrid Eulerian-Lagrangian numerical scheme and an elastoplastic constitutive model to tackle the multi-physics processes involved in waves of snow avalanches, including erosion, deposition, and flow instability induced by terrain irregularity. This enables us to naturally capture roll waves and erosion-deposition waves in large-scale snow avalanches on real terrain. The simulated wave features show satisfactory consistency with the field data measured with radars. Going beyond the field measurements, new insights into the transition between roll waves and erosion-deposition waves are revealed from the simulation. This study offers a novel and promising pathway toward understanding wave mechanisms in complex granular flows like snow avalanches.

Keywords: Snow avalanche, roll wave, erosion-deposition wave, numerical simulation

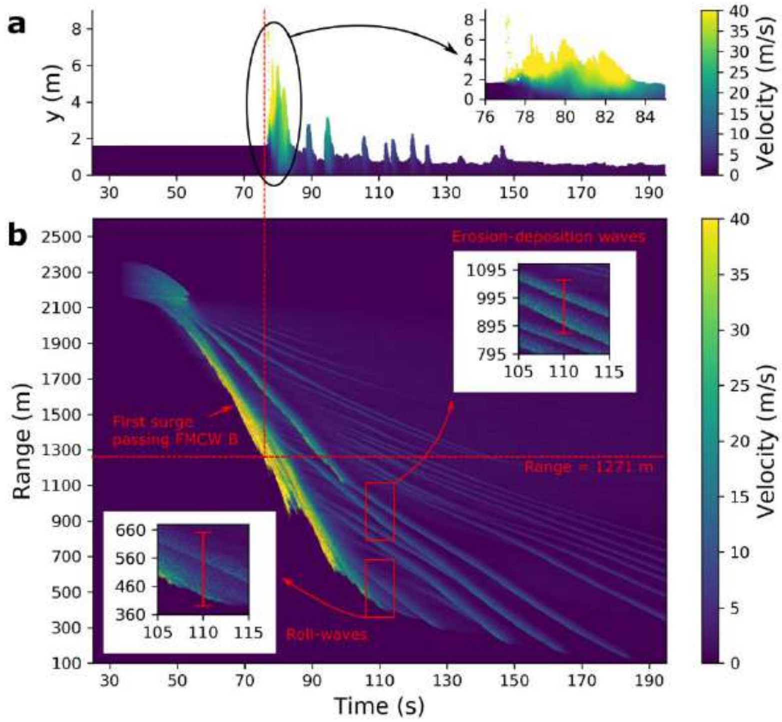

Fig. 1 a. Flow height evolution at a fixed position along the avalanche path; b. the variation of wave features in the spatial-temporal space

ANALYSIS OF LANDSLIDE-INDUCED WAVE BY A NOVEL HYBRID MPM+SPH METHOD

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ABSTRACT

Impulse waves caused by landslides pose a significant threat to human life, property, and infrastructure. Following the construction of the Baihetan Hydropower Station in China in 2022, numerous unstable slopes were identified in the reservoir area, with the slope of Wangjiashan being the most notable. This paper investigates the potential impact of the Wangjiashan landslide-induced wave in the Baihetan Reservoir by using a novel hybrid numerical method. The material point method analyzes the deformation and sliding velocity of the potential Wangjiashan landslide, while the smoothed particle hydrodynamic method simulates the impulse wave propagating in reservoir. Our results reveal that an 80% reduction in the landslide's initial strength will result in a maximum runout distance of approximately 188 m and a maximum sliding speed of 16.17 m/s. The impulse wave reaches the residential area at t = 75 s with a velocity of approximately 2.5 m/s after the Wangjiashan landslide occurs. The impulse wave has two crests at the residential area, with maximum wave height of 4.238 m and 2.915 m, respectively. Moreover, particular topographic features of the residential area amplify the risk of landslide-induced wave. Our simulation indicates that the residual strength of the landslide material has a significant impact on wave height. A 28% increase in residual strength results in a 62% reduction in the maximum wave height. Therefore, detailed geotechnical investigation and testing are crucial for assessing the risk of landslide-induced waves. Our study provides important information for assessing this risk in the Wangjiashan area and is critical for ensuring safety in the Baihetan Reservoir of China.

Keywords: Landslide-induced wave; Baihetan Reservoir; Hybrid MPM+SPH method; Wave propagation

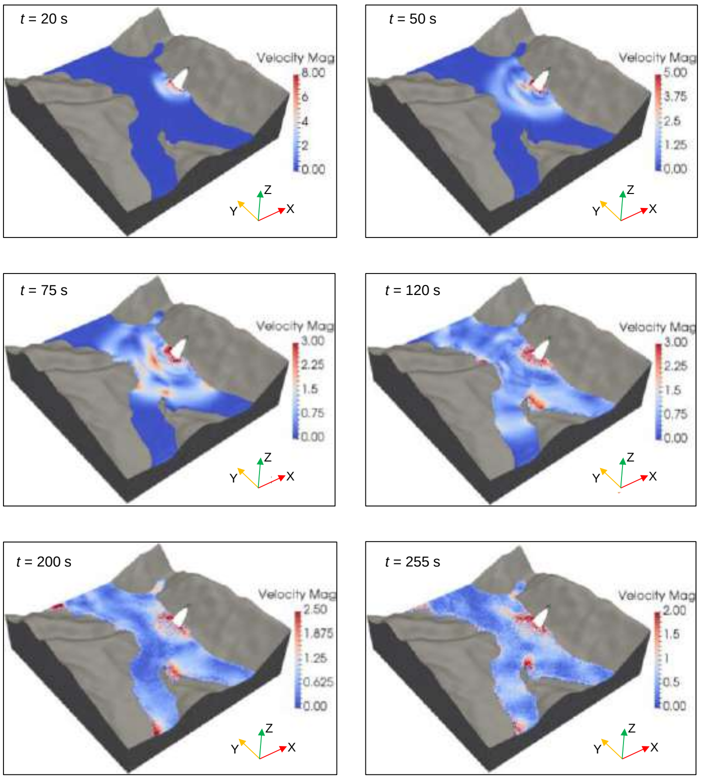

Fig. 1 Simulation results of the Wangjiashan landslide-induced wave propagation at the 825 m a. s. l. of reservoir water level.

DYNAMIC PROCESS OF BAIGE LANDSLIDE BLOCKING RIVER EVENT BASED ON THE FDEM-SPH COUPLING METHOD

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ABSTRACT

In this study, the 11 October 2018 Baige landslide blocking river event was reconstructed using a three-dimension model based on the FDEM-SPH coupling method. In the numerical model, the dynamic process of the landslide was simulated by FDEM, while the behaviour of the river water was simulated by SPH method. The method was first validated by a laboratory test that a rigid block sliding into water, and the block sliding as well as the impulse wave propagation process in the simulation was consistent well with the laboratory test, indicating the method was reasonable. Then, it was used to simulate Baige landslide blocking river. Simulation results based on the calibrated-parameter show both the landslide deposit area and the water-eroded area agree well with the results of the field investigation. The peak average speed of the landslide was 35 m/s. The variation of accumulated friction dissipation and fracture energy of the sliding mass with time were also shown. The landslide triggered a wave after the sliding mass ran into the river, and the behaviour of the wave was controlled by the subsequent mass movement. The evolution mechanisms of high-level landslide-induced waves in deep river valleys are proposed in this paper.

Keywords: Landslide blocking river, Dynamic process, Numerical simulation, Fluid-solid coupling

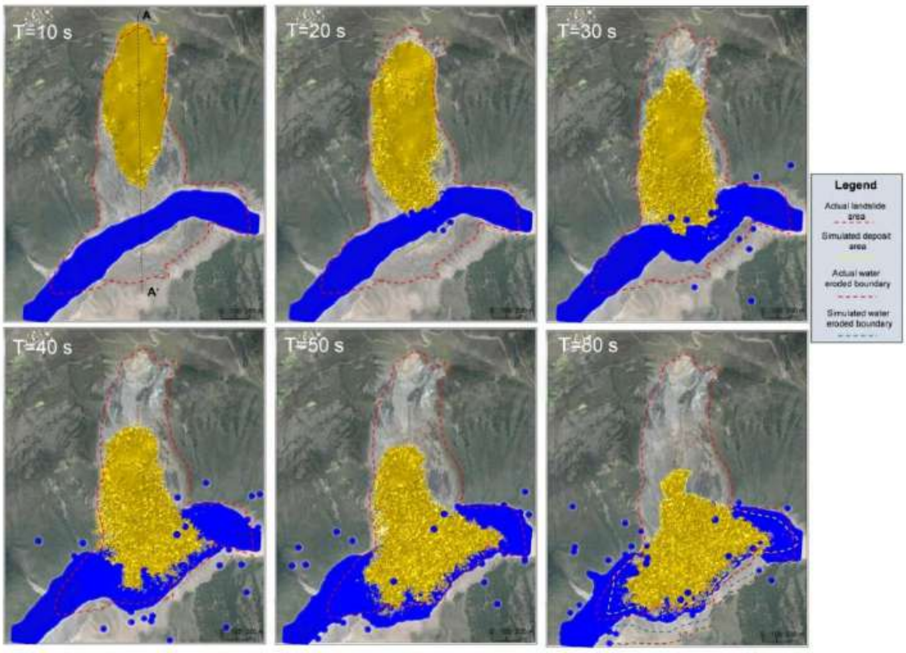

Fig.1 Dynamic process of the Baige landslide blocking river

COUPLED THERMAL-HYDRAULIC-MECHANICAL-CHEMICAL MODEL IN NATURAL GAS HYDRATE RESERVOIRS

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ABSTRACT

During exploitation, changes in the physical and mechanical properties of natural gas hydrate reservoirs can affect long-term stability. To investigate the evolution of the physical and mechanical properties of the reservoir during depressurization, COMSOL Multiphysics was used to simulate the depressurization process based on a thermal-hydraulic-mechanical-chemical (THMC) coupled model. Two cases, Masuda's hydrate-bearing core experiment and the W17 drilling platform in the Shenhu area (South China sea), are studied separately. The results showed that the peak gas and water production rates of both indoor and in situ-scale depressurization occurred at the early stage of extraction and then dropped sharply. In a simulation of 1000-day extraction process, reservoir subsidence in the first 60 days accounts for more than 50% of the total subsidence. By analysing the stress paths at two monitoring points at the top of the hydrate-bearing reservoir, 1 m and 10 m from the extraction well, and combining them with the Mohr-Coulomb strength criterion, it is clear that there is no risk of shear damage during depressurization. The results of this paper can provide a reference for estimating the gas production and geological risk of the target reservoir.

Keywords: natural gas hydrate, multi-field coupling model, gas production, subsidence

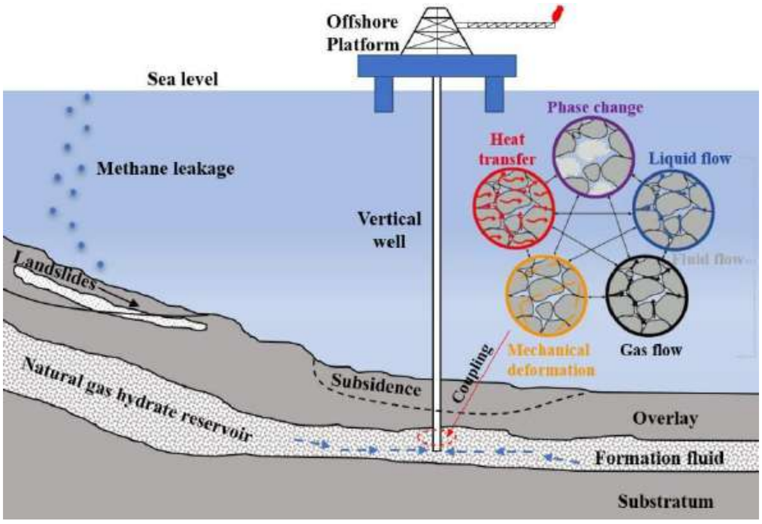

Fig. 1 Schematic diagram of depressurization exploitation for natural gas hydrate

SOIL-ROCK INTERFACE SHEAR BEHAVIOUR MOBILIZING FLOW SLIDING WITHIN BASAL SHEAR ZONES

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ABSTRACT

Basal sheal failure in landslides and faults often manifests itself through localized deformation at the interface between soil and rock. We study the mechanical behaviour of soil-rock interface with ring-shear tests and large-scale direct shear tests by considering the stress level and rate state during landslide acceleration. The tests are carried out with different interface asperities including such artificial material like concrete and natural material like limestone. The interface frictions show a weakening tendency with increasing shear velocity, conjointly affected by interface asperities and stress level. The smooth interface sample shows stronger loss of shear resistance particularly in the regime of high flow rate. The weakening mechanism modulated by soil-rock interface is explained by the extremely low viscosity along the bimaterial interface, which is evidenced by surface morphography.

Keywords: Basal shear zone; soil-rock interface; viscous flow; bedding landslides

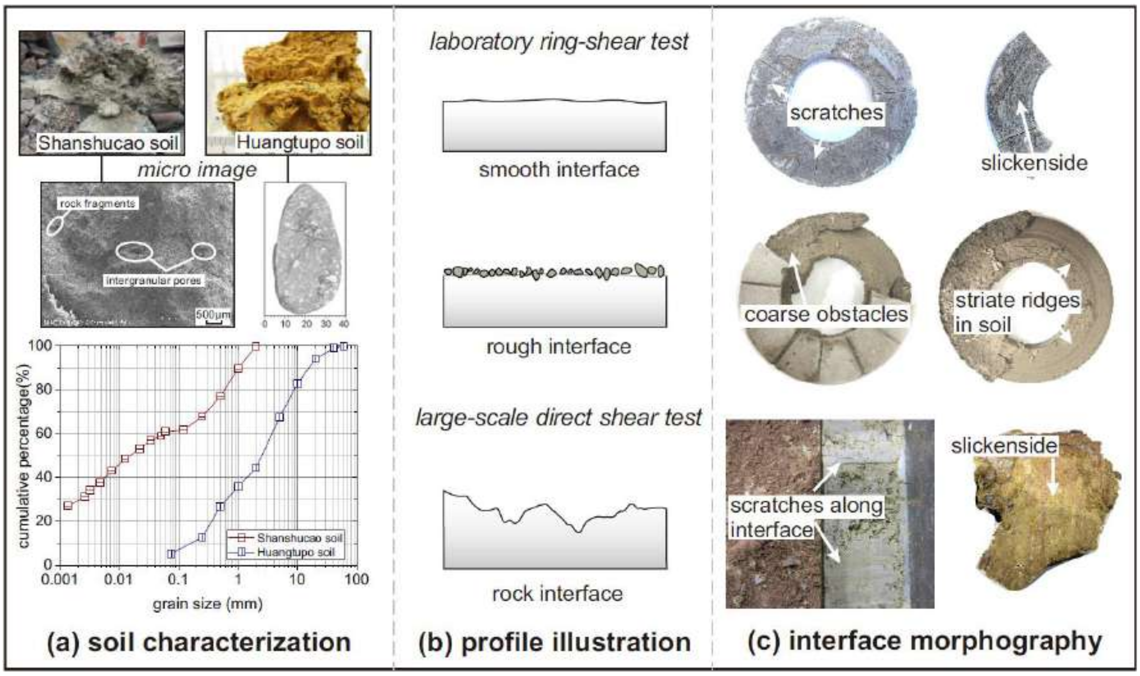

Fig. 1 The material characterization of two shear-zone soils, the profile illustration of different tested methods, and the interface morphography after mechanical tests.

RISK ASSESSMENT MODEL OF ADJACENT BUILDINGS IN SLURRY SHIELD CONSTRUCTION

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ABSTRACT

Aiming at the safety risk of slurry shield tunnel construction in complex urban environment, a new risk assessment model is proposed to predict the risk level of adjacent buildings during tunnelling. Fig. 1 shows the flow chart of risk assessment model, which applies the analytic hierarchy process (AHP) and entropy weight method (EWM) to the multi-criterion compromise ranking method (VIKOR), overcomes the subjectivity of traditional risk assessment methods, and realizes the combination of subjective and objective risk assessment. The model uses AHP to construct the risk structure level, establishes a risk assessment index system of five factors, and calculates the subjective weight of each index. Then, EWM is used to correct the weights of each index, optimize the risk assessment model. Finally, VIKOR is used to consider the ambiguity and uncertainty of the hierarchical boundary, so as to realize the prediction of the risk level of the adjacent buildings in each ring. The proposed model is applied to case study of a slurry shield tunnel project in Guangzhou, China. Compared with the traditional risk matrix approach in Fig. 2, the results show that the sensitivity and accuracy of the optimized evaluation model are higher and more consistent with the actual situation. This method can be used for risk management to guide subsequent shield construction operations.

Keywords: Slurry shield tunnel; risk assessment; analytic hierarchy process; entropy weight method; multi-criterion compromise ranking.

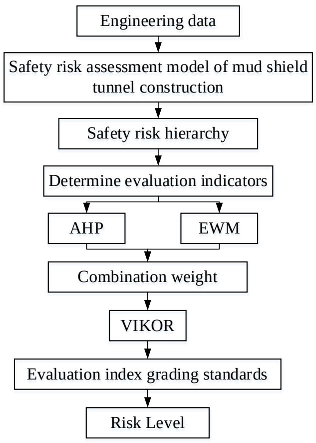

Fig. 1 Flow chart of risk assessment model

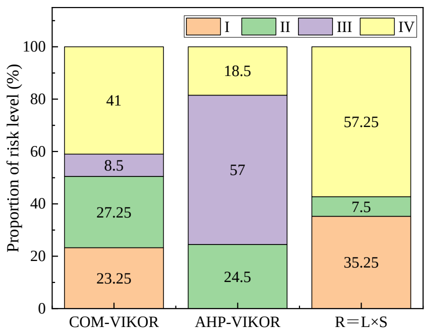

Fig. 2 Comparison chart of the proportion of risk levels of different methods

GEOGRAPHIC OBJECT-BASED IMAGE ANALYSIS (GEOBIA) FOR LANDSLIDE IDENTIFICATION USING MACHINE LEARNING ON GOOGLE EARTH ENGINE

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ABSTRACT

Landslides significantly threaten human life and infrastructure, requiring accurate and timely identification for effective hazard assessment and management. In this research, we propose an innovative approach to enhance the identification of landslides, a critical factor in safeguarding human life and infrastructure. Our method integrates Geographic Object-Based Image Analysis (GEOBIA) with advanced machine-learning techniques. The process encompasses Simple Non-iterative Clustering (SNIC) for precise image segmentation, Gray Level Co-occurrence Matrix (GLCM) for extracting vital textural data, and Principal Component Analysis (PCA) for dimension reduction. Machine learning algorithms—Support Vector Machine (SVM), Random Forest (RF), and Classification and Regression Trees (CART)—are harnessed for accurate classification. The potency of Google Earth Engine (GEE) bolsters geospatial data utilization and computational capabilities. SNIC segmentation enables meticulous object-level scrutiny by breaking down images into super-pixels. GLCM captures intricate textural details, while PCA refines the understanding of landslide features. SVM emerges as the most effective algorithm, boasting an 89.01% accuracy, surpassing RF (87.82%) and CART (73.31%) in landslide detection. Our approach amalgamates SNIC, GLCM, PCA, and SVM within the GEOBIA-GEE framework, showcasing substantial promise for advancing landslide identification, risk assessment, and proactive mitigation strategies.

Keywords: Landslide identification, Geographic Object-Based Image Analysis, Machine Learning, Google Earth Engine

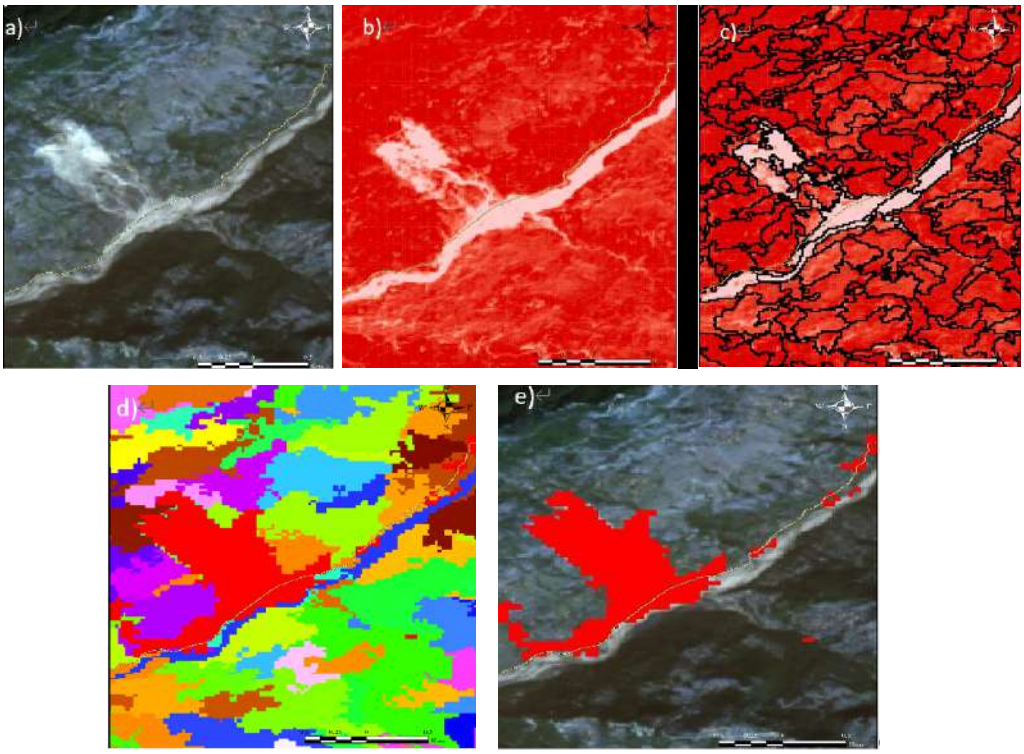

Fig. 1 (a) RGB image, (b) CIR image, (c) SNIC object-based segmented image, (d) GLCM clustered image, and (d) SVM trained image for landslide detection within the study area.

A HYBRID DEEP LEARNING NETWORK FOR LANDSLIDE SUSCEPTIBILITY ASSESSMENT

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ABSTRACT

Landslides occur frequently and pose a major threat to human life and property. The landslide susceptibility mapping is an important and effective tool in predicting landslides. This research proposed a novel deep learning framework for landslide susceptibility assessment using an improved deep belief networks (Laplace's function sparse regularized continuous deep belief network, LSCDBN) with two intelligent optimization algorithms (grey wolf optimization and whale optimization algorithm, GWO and WOA). This framework addresses the challenges of feature homogenization for continuous input variables for landslide condition factors, limited historical landslide samples, and local optima in the training process. To facilitate this investigation, a meticulous compilation of existing landslide occurrences was used to create a database comprising 18 landslide conditioning factors, including geomorphology, hydrological, geological, and climatic conditions. The information gain ratio method was used to assess the landslide conditioning factor. To compare the performance of the model, a set of statistical indicators were employed, including root mean square error (RMSE) and area under the receiver operating characteristic curve (AUC). The results demonstrate the superior performance of both the LSCDBN-GWO model (AUC = 0.952, RMSE = 0.182) and LSCDBN-WOA model (AUC = 0.964, RMSE = 0.174) when compared to the alone LSCDBN model (AUC = 0.913, RMSE = 0.291). This due to the global search of the optimization algorithm avoids local optimization. It is noteworthy that the performance of the LSCDBN model outperformed that of lone machine learning (SVM, BP, RF, and LR) and deep learning algorithms (RNN and CNN) due to the sparse regular terms to address feature homogenization. Furthermore, the LSCDBN-GWO and LSCDBN-WOA models emerged as the superior choices in a comparative analysis with alternative models incorporating CNN in conjunction with GWO and WOA algorithms. Therefore, it is evident that the proposed LSCDBN-WOA framework can generate models that are optimally suited for landslide susceptibility assessment.

Keywords: Landslide Susceptibility Assessment, Deep Learning, Machine Learning, GIS, Greywolf Optimization Algorithm, Whale Optimization Algorithm

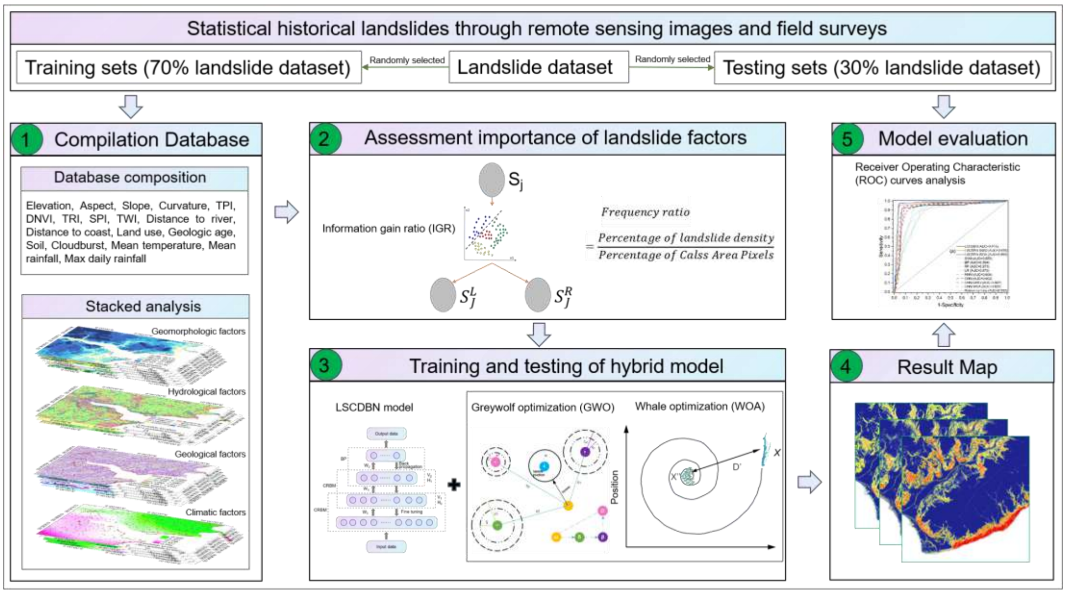

Fig. 1 Illustration of the proposed method

NUMERICAL SIMULATION AND COST OPTIMIZATION OF ANTI SLIP PILE REINFORCEMENT FOR FULLY WEATHERED GRANITE LANDSLIDES

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ABSTRACT

Using the strength reduction method, the effects of different anti-slide pile design parameters, such as pile spacing and embedment depth, on the stability of the reinforced slope are discussed. Genetic algorithms are employed to generate a method for quickly identifying the optimal design parameters for anti-slide piles, with the goal of spending the most economical cost for the piles under the constraint that the safety factor of the reinforced slope still meets the safety requirement. The research results indicate the following findings. (1) Pile spacing is positively correlated with the slope displacement and peak internal force, while the embedment depth is negatively correlated with the slope displacement. (2) According to the changes in displacement and the safety factor, the stress analyses of the pile body and the inter-pile soil arch, and the economic factors, the optimal pile spacing and embedment depth for the Fanling landslide are determined as 7 to 7.5 m and 8 m, respectively. (3) With the optimization program, the cost of anti-slide piles is reduced by approximately 6.38% while conforming to safety and stability requirements. The results afford certain application and promotion values by providing theoretical references and technical guidance for similar anti-slide pile reinforced slope projects.

Keywords: Anti-slide pile; Cost optimization; Machine learning; Completely weathered granite landslide; Stability analysis.

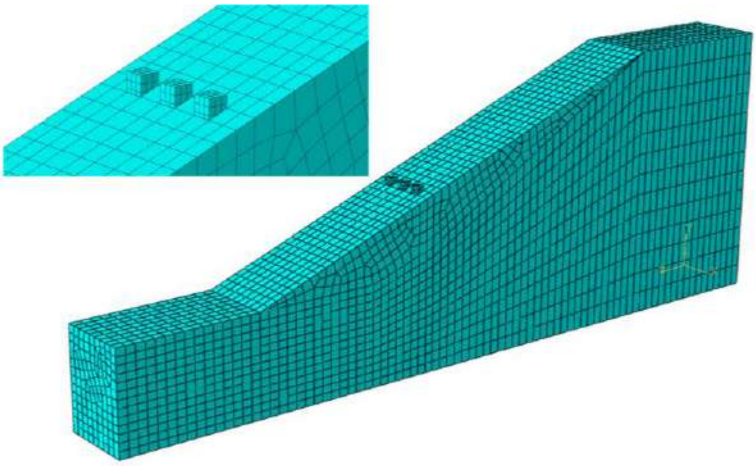

Figure 1. Schematic diagram of anti-slide pile reinforcement slope model.

MITIGATION MEASURE OF TIRE-DERIVED AGGREGATE FOR JOINTED RIGID PIPES UNDER DIFFERENTIAL GROUND MOVEMENTS

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ABSTRACT

Highly compressible and lightweight materials, such as tire-derived aggregates (TDA), geofoams or straws, can be placed around buried pipes to reduce the mobilized loads either from the soil prism or from differential ground settlements. Compared to continuous pipelines, the failure modes of jointed rigid pipes are more complex, including pipe barrel cracking, and joint leakage caused by joint axial pull-out or rotation. In this study, a calibrated three-dimensional finite element model is employed to analyze the failure modes of jointed rigid pipes under normal faults, and determine the maximum allowable offset distance for four distinct fault crossing positions. Additionally, the efficiency of TDA mitigation in reducing the chance of pipe failure is evaluated parametrically through different installation configurations, sizes, and TDA densities. It is found that the most detrimental fault crossing occurs at approximately 3/4 of the pipe barrel, where excessive bending moment leads to longitudinal cracking. The installation of TDA enhances the maximum allowable offset distance for jointed pipelines substantially by almost 100%. TDA mitigation prevents structural failure of pipelines, while exerts nearly negligible influence on the kinematics of joints. Finally, the most pronounced loading reduction for pipes is achieved by employing TDA with lower compactness combined with full-surrounded configuration.

Keywords: Bell-spigot joint, Vitrified clay pipe, Tire-derived aggregates (TDA), Mitigation measure, Normal fault

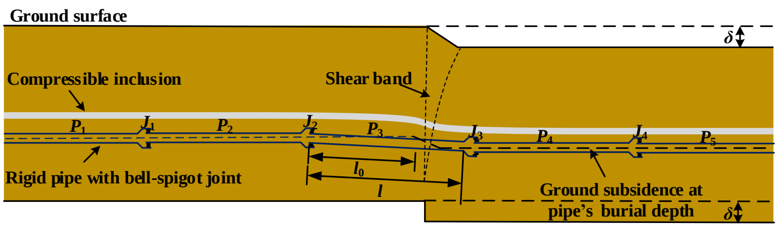

Fig. 1 Schematic diagram for normal fault-jointed pipeline interaction under imperfect trench installations.

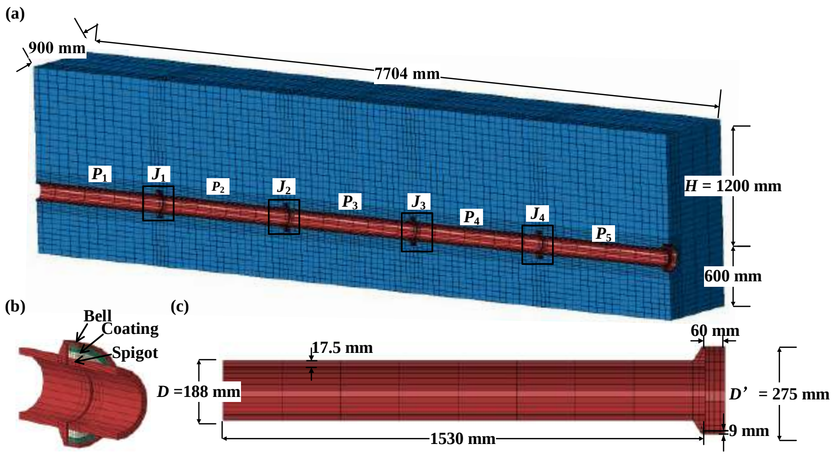

Fig. 2 Sketch of 3D finite element model: (a) finite element mesh discretization; (b) joint model; (c) barrel model.

MODELING OF PUMPING-INDUCED TENSILE EARTH FISSURES BY COUPLED QUASI-STATIC MATERIAL POINT METHOD

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ABSTRACT

Pumping-induced earth fissuring is a typical geo-hazard, causing great damage to infrastructure and huge economic loss. Due to the discontinuity and evolution of earth fissuring, however, it is a great challenge to numerically simulate the initiation and propagation of earth fissures. Considering the advantages of the material point method and the properties of soil fracture, this paper presents a coupled quasi-static material point method to simulate pumping-induced tensile earth fissures. In this method, the locations and the propagation orientation of earth fissures are unnecessary to be given in advance. Instead, soil fissure behaviors are driven by the real-time stress field affected by soil consolidation. An earth fissure initiates in the region of maximum tensile stress, and it propagates in the direction of the maximum circumferential stress around the fissure tip. The proposed method is applied to a large physical model experiment, reproducing the initiation, propagation, and arrest of pumping-induced earth fissures with the presence of a bedrock ridge. The simulated fracture time (24 h after drainage), location (right above the bedrock ridge), final length (165 mm), and morphology evolution (from straight to zigzag) of the main fissure are in agreement with the experimental results.

Keywords: pumping-induced earth fissure; coupled quasi-static material point method; soil fracture

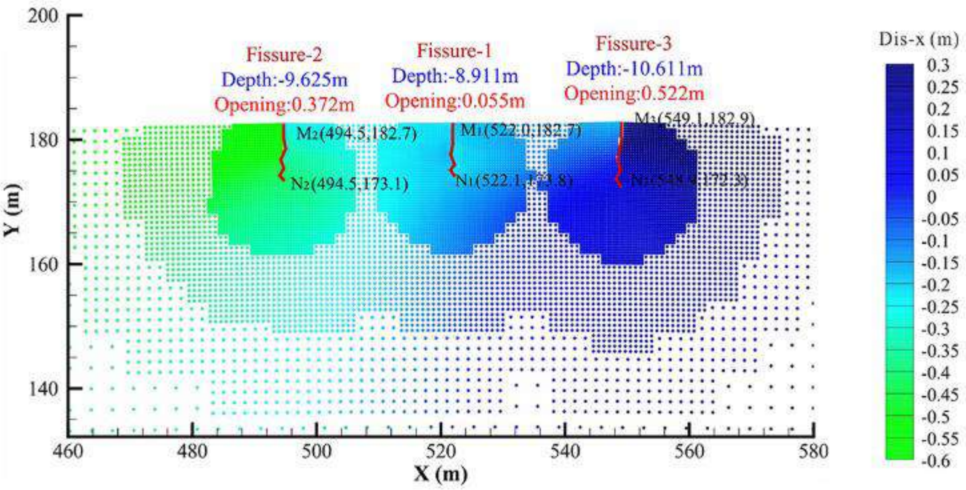

Fig. 1 Simulated earth fissures

TRANSITIONS IN IMPACT AND RESPONSE MODES FOR GEOPHYSICAL FLOW MITIGATIONS

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ABSTRACT

Geophysical flows impacting countermeasures present multiphase multiway interactions that vary depending on the type of flow and the barrier. Previously, assessing specific processes in physical experiments and computational investigations has been challenging, leaving the whole picture of essential mechanisms largely unexamined. This study devised a unified framework utilizing coupled computational fluid dynamics and discrete element method (CFD-DEM) to model debris flows/avalanches/floods, muddy flows, and rock avalanches interacting with flexible, slit, and rigid barriers. Through physics-driven numerical metrics, we: (*i*) proposed the barrier-centric design diagram under runup and pile-up modes, (*ii*) attained dual-index quantification of impact mode shifts, (*iii*) measured the unjammed-jammed transitions, (*iv*) uncovered the bi-linear laws governing flexible barrier impacts, and (*v*) pinpointed flexible barrier load-deflection mode shifts. Furthermore, we assembled several diagrams providing holistic insights, facilitating a quantitative comprehension of how flow properties (e.g., materials, rheology, and impact dynamics) dictate the transitions of these previously unidentified mechanisms and modes. This work illuminates formerly concealed processes and quantifies several undiscovered mechanisms in geophysical flow abatement. The findings hold the potential to substantially impact related research and transform the present empirically-driven engineering design practices in geophysical flow mitigations.

Keywords: Geophysical mass flows, Impact mode transitions, Unjammed-jammed transitions, Load-deflection mode transitions, CFD-DEM

Acknowledgments: This research was supported by the Research Grants Council of Hong Kong, SAR, CHINA (Grant No.: R5037-18) and by grants (CD7A and CD82) from the Research Institute for Land and Space of Hong Kong Polytechnic University.

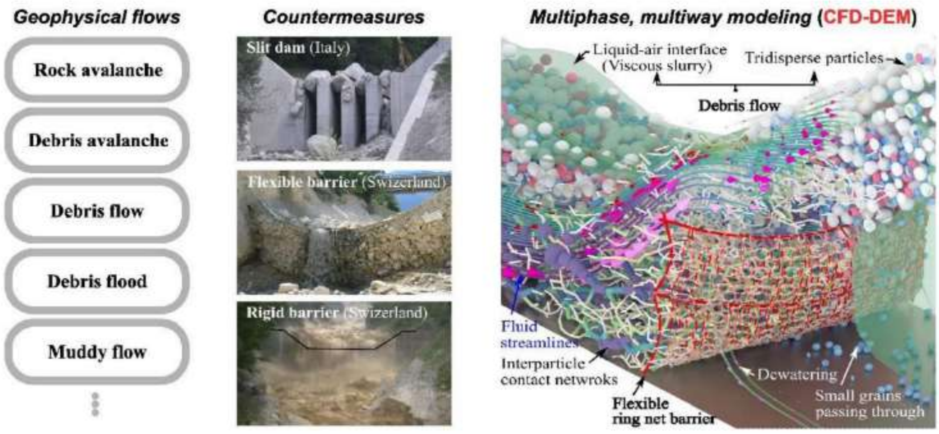

Fig. 1 A unified research platform using the CFD-DEM method for geophysical flow mitigation

STABILITY ANALSIS AND REINFORCEMENT ON HIGH SOIL-LIKE SLOPE UNDER THE EFFECTS OF TROPICAL TYPHOONS AND RAINSTORMS

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ABSTRACT

Short-term and heavy typhoons and rainstorms, frequently occurring in tropical areas, may render high soil-like slopes unstable and hazardous due to the rise in groundwater levels within the slope body. The reduction in the matric suction of the slope and the rapid increase in the pore pressure will weaken the strength of the strata, and a landslide may thus happen to the slopes. Reinforcement, including anchor bolts and anti-slide piles, should be conducted to prevent the slope from being damaged. Based on Maiwan water conservancy engineering in Hainan, China, finite element analysis is performed to investigate the impacts of various typhoons and rainstorms on the stability of slopes with varied heights and overburden thicknesses, and the efficiency of the corresponding measures with varied reinforcement depths is also assessed. Moreover, advice is given to the practical use of slope engineering based on the analysis results.

Keywords: soil-like slope; typhoon and rainstorm; stability; finite element analysis; reinforcement

Fig. 1 Slope reinforcement measures for Maiwan Water Conservancy Engineering

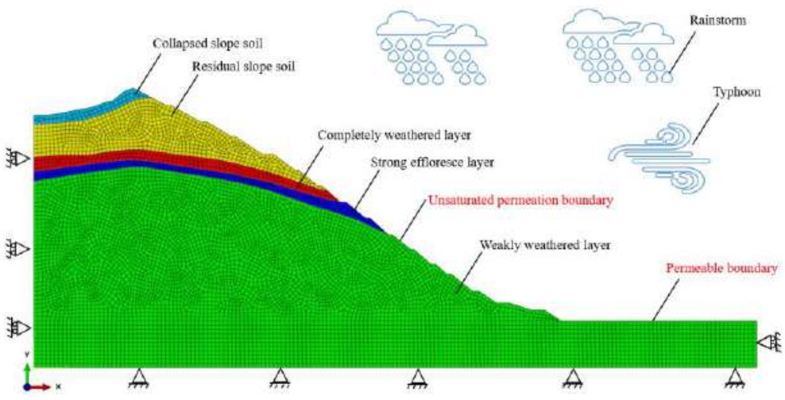

Fig. 2 FE model for the soil-like slope

RESEARCH ON INDOOR EXPERIMENTAL STUDY OF THREE-DIMENSIONAL CRACKS DEVELOPMENT IN STEPPED SOIL SITES

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ABSTRACT

The site of Jingtou Mountain in Yuyao, Zhejiang Province, is dominated by marine silt soil, and under the influence of long-term natural environmental damage, the cracks of the step-like soil site are seriously developed in the display stage. Physical simulation experiments of structural evolution were carried out in order to approximate the three-dimensional fracture evolution characteristics of step-like soil sites and obtain the best slope ratio. The results of physical simulation experiments showed that during the wetting process, marine silt mainly underwent three structural evolution stages: fracture germination, fracture non-homogeneity and fracture development. During the wetting process, the cracks on the top, bottom and slope surfaces of the step slope gradually heal, and vertical cracks appear on the top line of the step slope and the bottom line of the step slope. During the drying process, the healing cracks reopened, the large polygon cracks continued to increase, the wet front migrated downward, and the overall fracture pattern did not change significantly. When the slope inclination angle is 75°, there are more fine cracks in the cracks of the step soil site, and there are fewer cracks in the large polygons, and the display effect is better.

Keywords: wet-dry cycle; stepped soil sites; cracks development

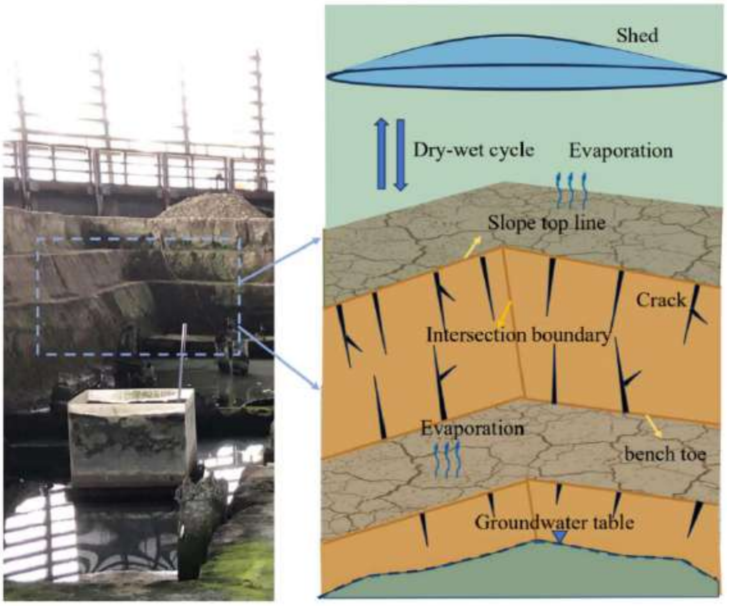

Fig. 1 Soil cracking under the cycle of dry and wet

Original paper ID： Three-dimensional crack development indoor experimental study of stepped earth sites(249-308)

EFFECTS OF THE BURN TEMPERATURE AND COMBUSTION OF ORGANICS ON POST-WILDFIRE DEBRIS FLOW MOBILITY

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ABSTRACT

Wildfire-induced changes to soil and vegetation decrease infiltration and increase runoff, making slopes susceptible to the occurrence of post-wildfire debris flows. However, current hazard assessments fail to account for the influence of burn temperature and organic combustion on the rheology and movement of these debris flows. To address this gap, a series of experiments was conducted to examine how burn temperature and organic combustion affect the rheology of debris mixtures. Kaolinite clay, with and without organics, was subjected to temperatures ranging from 100 to 400 °C and subsequently mixed with water to form debris mixtures with solid concentration of 35% and 40%. The rheological properties of these debris mixtures were measured and input into a smoothed particle hydrodynamics (SPH) solver. The findings revealed that burn temperature and organic combustion significantly reduced the yield stress and viscosity by up to 90% compared to unburned debris. Consequently, the velocity and distance traveled by burned debris increased by a factor of up to 4. These results demonstrate that existing hazard assessments may underestimate the mobility of debris flows if the effects of burn temperature and organic combustion are not taken into account.

Keywords: Wildfire; Debris flows; Rheology; Mobility

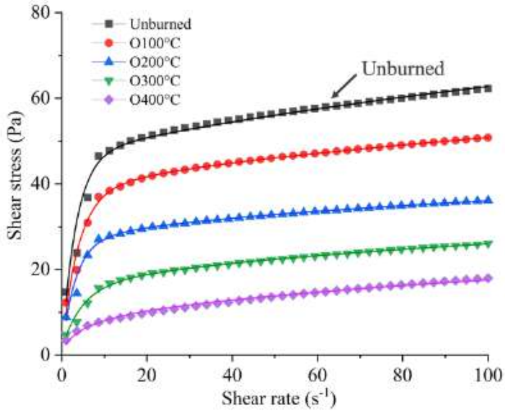

Fig. 1 Shear rate versus shear stress for debris mixtures with combusted organics at a solid concentration of 40% subjected to different burn temperatures

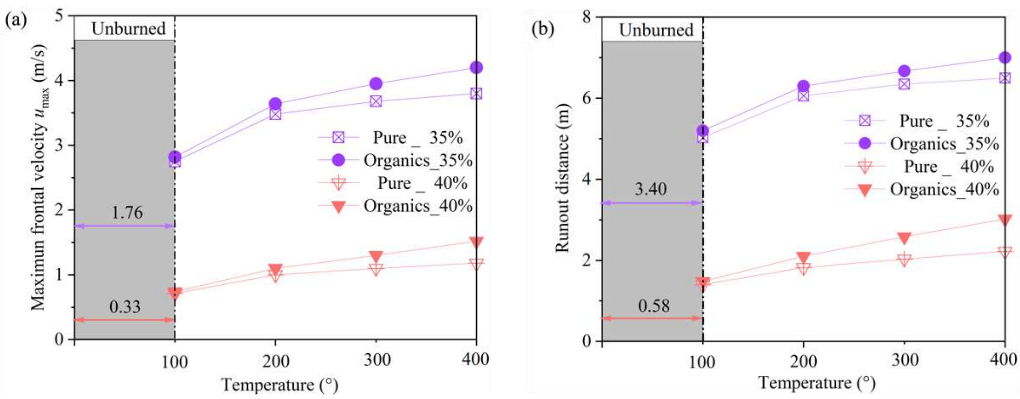

Fig. 2 Effects of burn temperature and organics combustion on (a) computed maximum frontal velocity, and (b) final runout distance

A GENERAL BASAL SLIP MODEL FOR GEOPHYSICAL GRANULAR FLOWS ON SMOOTH AND ROUGH TOPOGRAPHY

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ABSTRACT

Geophysical granular flows involve granular materials surging down natural terrain with complex topography. While the modelling of flow rheology has received much attention, a universal constitutive relation of flow-bed interaction is still missing. Here, we focus on the topographical base roughness that is about the same size as grain size and incorporate the characterization of its geometric features into a closure sliding law. In discrete element method (DEM) simulations, we systematically generated bases from smooth to extremely rough using fixed particles with varying particle size and spatial distribution (Fig. 1). By conducting granular column collapse tests in different conditions over various base roughness, a universal basal slip length relation is proposed to correlate the slip velocity with local flow properties, where the slip length only depends on base roughness. This slip length boundary model was later implemented in continuum modelling for granular flows. Results from using this dynamic boundary model show better agreements of runout and velocity profiles with laboratory tests and DEM simulations (Fig. 2), compared with other commonly used models like no-slip and Coulomb friction boundary. In the future, this new physics-based boundary model is expected to improve the estimation for runout and velocity of landslide-related geohazards.

Keywords: Geophysical granular flows; Base roughness; Slip length; Multiscale modelling.

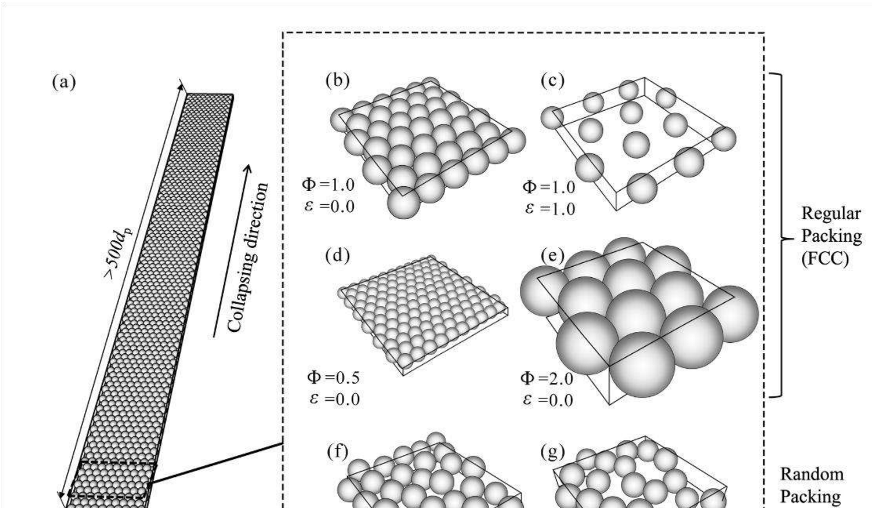

Fig. 1 Illustration of base generation in DEM simulations of granular column collapse tests: (a) example of a whole base using fixed particles with diameter d_b, of which the width is 10 times flowing particle diameter d_p and the length is larger than 500 d_p; (b-e) examples of base particle assembly generated in face-center cubic (FCC) packing with varying size ratio $\Phi = d_p/d_b$ and spacing ε; (f-g) examples of base particle assembly generated in random packing with varying compactness c.

Effects of geometry configuration and material properties on entrainment rate and deposit morphology: an experimental study

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ABSTRACT

Debris flows can grow in size and speed magnitude as they are capable of entraining a large amount of bed materials, resulting in a longer overall runout and impact force. In the present study, a series of flume experiments are carried out to investigate the key factors that affect the entrainment rate. These controlling variables comprise chute inclination, source material mass, packing density of the erodible bed, viscosity of the interstitial fluid and particle size composition (i.e., by varying the mass proportion of gravel, coarse sand and medium sand). After the experiments, a 3-D scanner is adopted to capture and reconstruct the deposit morphology, with measure of the overall runout, lobe height and width. The entrainment depth is determined by inserting a transparent Plexiglas board into the bed and removing the mass beyond. Results show that the bed material is significantly mobilised and entrained at about 10~20 cm downstream the rigid-erodible bed transition, with magnitude increases with increasing pore fluid pressure, slope angle and initial total mass while has a negative correlation with packing density of the bed. However, the effect of interstitial fluid viscosity on entrainment remains complicated, with an optimal critical value identified.

Keywords: Debris flow; Entrainment rate; Deposit morphology; Pore pressure.

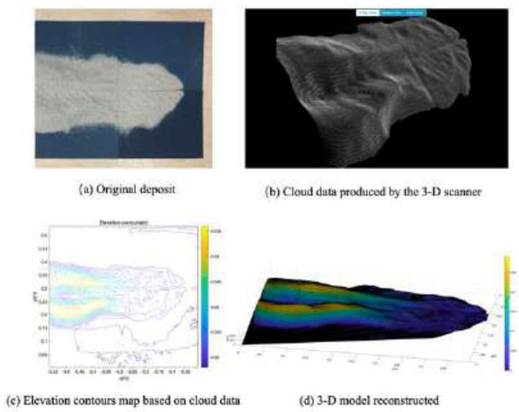

Fig. 1 Deposit model reconstruction through 3-D scanning technique

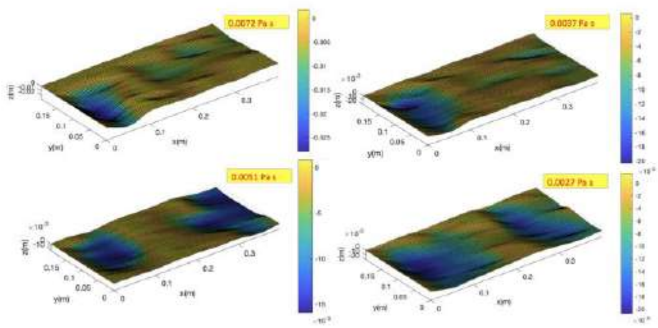

Fig. 2 Effect of viscosity on scour depth and pattern

MITIGATION MEASURE OF TIRE-DERIVED AGGREGATE FOR JOINTED RIGID PIPES UNDER DIFFERENTIAL GROUND MOVEMENTS

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ABSTRACT

Highly compressible and lightweight materials, such as tire-derived aggregates (TDA), geofoams or straws, can be placed around buried pipes to reduce the mobilized loads either from the soil prism or from differential ground settlements. Compared to continuous pipelines, the failure modes of jointed rigid pipes are more complex, including pipe barrel cracking, and joint leakage caused by joint axial pull-out or rotation. In this study, a calibrated three-dimensional finite element model is employed to analyze the failure modes of jointed rigid pipes under normal faults, and determine the maximum allowable offset distance for four distinct fault crossing positions. Additionally, the efficiency of TDA mitigation in reducing the chance of pipe failure is evaluated parametrically through different installation configurations, sizes, and TDA densities. It is found that the most detrimental fault crossing occurs at approximately 3/4 of the pipe barrel, where excessive bending moment leads to longitudinal cracking. The installation of TDA enhances the maximum allowable offset distance for jointed pipelines substantially by almost 100%. TDA mitigation prevents structural failure of pipelines, while exerts nearly negligible influence on the kinematics of joints. Finally, the most pronounced loading reduction for pipes is achieved by employing TDA with lower compactness combined with full-surrounded configuration.

Keywords: Bell-spigot joint, Vitrified clay pipe, Tire-derived aggregates (TDA), Mitigation measure, Normal fault

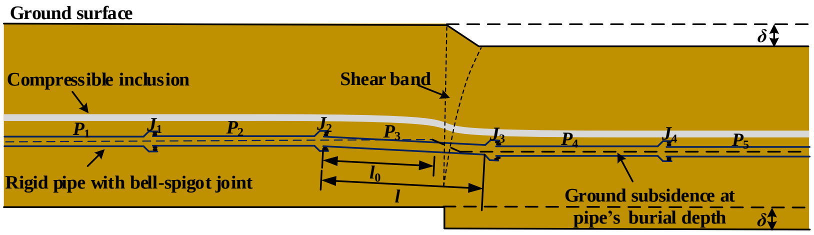

Fig. 1 Schematic diagram for normal fault-jointed pipeline interaction under imperfect trench installations.

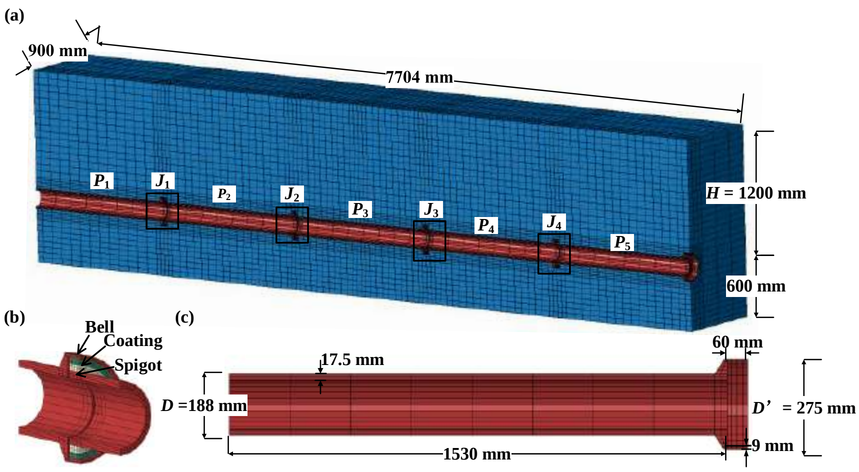

Fig. 2 Sketch of 3D finite element model: (a) finite element mesh discretization; (b) joint model; (c) barrel model.

MESOSCOPIC INTERPRETATION OF FINES CLOGGING-INDUCED PERMEABILITY CHANGES OF COMPLETELY DECOMPOSED GRANITE

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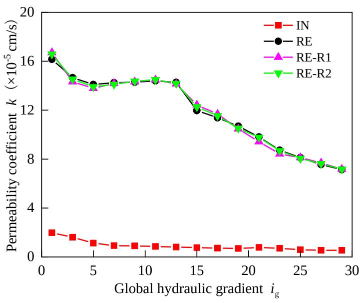
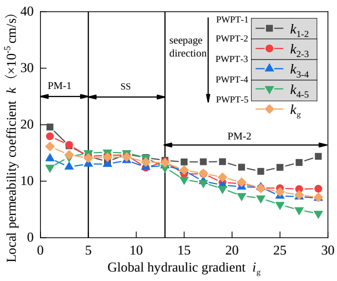
ABSTRACT

Completely decomposed granite (CDG) widely exists in subtropical and tropical zones where geo-hazards occur frequently. Fines clogging under seepage flow causes pore structure changes that alter the soil permeability. However, the mesoscopic interpretation of fines clogging-induced permeability changes is lacking. In this study, the CDG specimens were scanned via micro-computed tomography (CT) before and after the permeation test. The number, volume, shape factor, inclination angle and seepage tortuosity of the pores were measured. Additionally, the evolution of global and local permeability coefficients of CDG specimens were analyzed. The results show that the pores in intact CDG are nonuniform, exhibiting that the seepage tortuosity is 3.7 times higher than that of reconstituted CDG. Consequently, the permeability coefficient of intact CDG is approximately an order of magnitude smaller. Furthermore, the migrated fines clogged downstream, leading to the division of pores into multiple isolated small pores. As a result, the void ratio in the upstream zone increased by 35%, while that in the downstream zone decreased by 40%. Moreover, the local permeability coefficient along the seepage path within the reconstituted CDG is decreased. The findings can explain the permeability changes at the mesoscopic scale, which contribute to geo-hazard assessment and mitigation.

Keywords: Completely decomposed granite, permeability coefficient change, fines clogging, micro-CT scanning, three-dimensional pore structure.

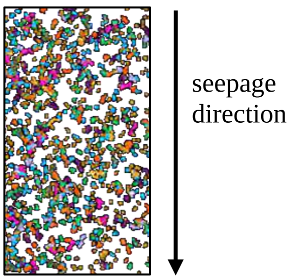


(a) Global permeability coefficient

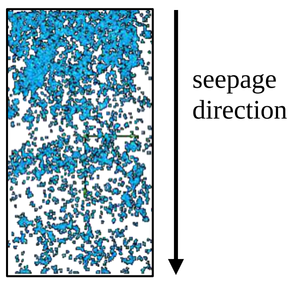


(b) Local permeability coefficient

Fig. 1 Evolution of permeability coefficient of CDG



(a) Before the permeation test



(b) After the permeation test

Fig. 2 The pore structure changes of CDG

ASSESSING THE RISK OF LAND SUBSIDENCE HAZARD ON GAS AND OIL PIPELINES IN IRAN

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ABSTRACT

Land subsidence, as the gradual sinking of the ground surface, can have severe consequences for many infrastructure and lifelines. However, among all lifelines, oil and gas pipelines are one of the most vital lifelines for industrial and domestic purposes, due to their severe vulnerability to land subsidence hazards in several countries. Therefore, this study aims to evaluate the risk to these critical lifelines caused by the varying levels of land subsidence occurrence. To achieve this purpose, first, the land subsidence susceptibility map (LSSM) will be prepared and characterized for Iran's country for the first time on country scale using the ArcGIS software environment. Afterwards, according to the land subsidence occurrence level, the critical region of Iran are identified in the proposed LSSM. In order to pinpoint the most vulnerable oil and gas pipeline in Iran, the pipeline layers are overlaid with the LSSM, as depicted in Fig. 1. Finally, a new index called the Land Subsidence Risk Index (LSRI) is proposed to determine the risk of these lifelines based on the length of the pipelines passing through critical areas. Consequently, the study results can aid employers in assessing land subsidence risks, budget planning, and preventing pipeline breakdowns.

Keywords: Land subsidence, Lifelines, Oil and gas pipelines, ArcGIS.

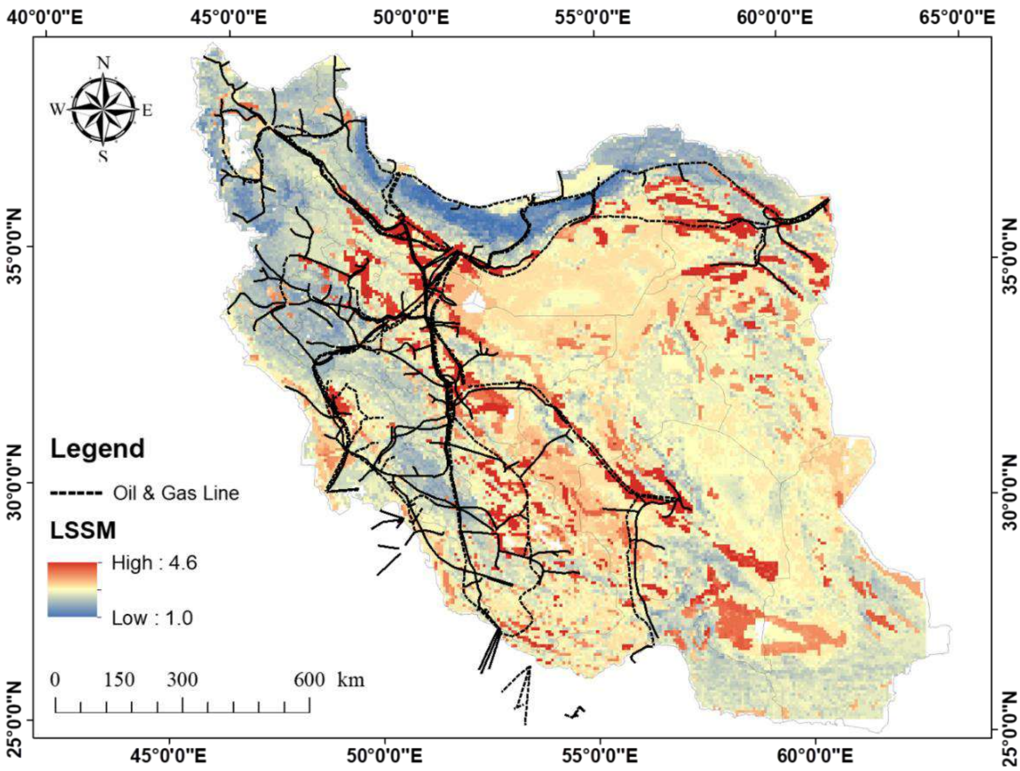

Fig. 1 The most prone oil and gas pipelines to the land subsidence hazard all around Iran.

SEISMIC RESPONSE ANALYSIS AND RESILIENCE STUDY OF COMPOSITE STRATA TUNNEL BASED ON FINITE ELEMENT METHOD

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ABSTRACT

Earthquakes, as one of the most destructive and unpredictable natural disasters, pose significant challenges to engineers designing underground structures. The consideration of seismic loads in their design is essential to ensure their safety and resilience against potential seismic events. Consequently, analyzing the response of tunnels to earthquakes and establishing a resilience evaluation index is crucial in guiding the project towards greater safety and stability. In this paper, the numerical simulation method is used to analyze the impact of earthquake based on a certain composite strata tunnel. To study the seismic response, the seismic wave is selected according to the seismic code of China highway tunnel. In addition, this seismic wave is scaled from 0.1 g to 1.0 g to perform non-linear incremental dynamic analysis (IDA), and thus to assess the tunnel response under increasing levels of ground shaking intensity. An resilience assessment model for tunnels subjected to earthquakes is applied. The proposed model synergizes tunnel resilience in withstanding and recovering from earthquake disasters to assessment the robustness of the tunnel under different seismic scenarios and the recovery speed and level of the tunnel under different damage degree.

Keywords: Tunnel, Resilience, Composite strata, Numerical simulation, Seismic response

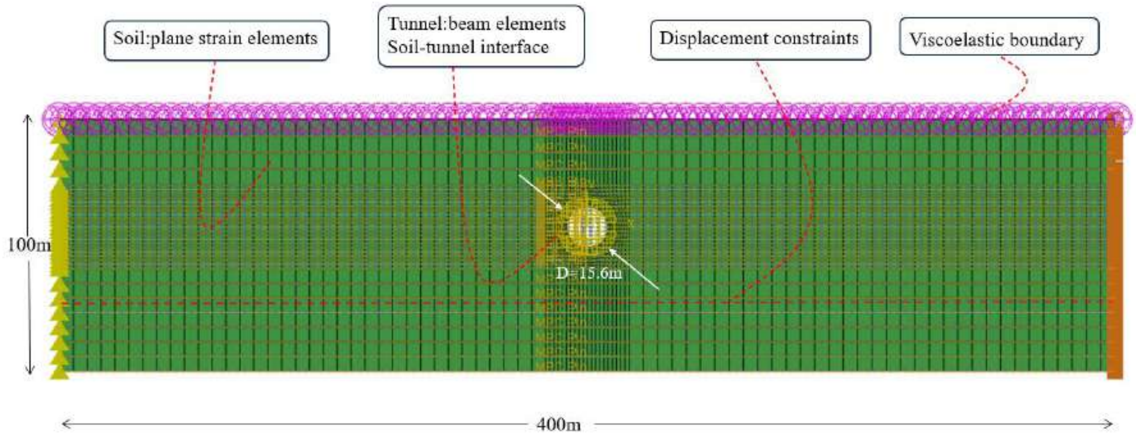

Fig. 1 Numerical model layout in ABAQUS

QUANTIFYING THE IMPACT OF CLIMATE CHANGE ON RISKS OF RAINFALL-INDUCED LANDSLIDES

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

Rainfall-induced landslides are a major geo-hazard in Hong Kong. Due to climate change, the intensity, duration, and frequency of extreme rainfalls are projected to increase in Hong Kong based on simulation results from global climate models (GCMs). As a result, the landslide risks are expected to increase. Quantifying the impact of climate change on landslide risks is crucial for landslide risk management. This study develops a practical method for quantifying annual probabilities of rainfall-induced landslides at a specific slope under a series of projected climate change scenarios based on simulation results from GCMs. This study uses rigorous slope seepage and stability models, instead of simplified thresholds (e.g., a monthly rainfall threshold to represent slope failure) for slope modelling. Regional GCM outputs are statistically downscaled to a specific slope using rainfall data measured at the slope site as baseline scenario. Non-stationary generalized extreme distributions are used to model annual frequency of extreme rainfalls. The results indicate that the annual slope failure probability tends to increase with the projected increase in extreme rainfalls. The increase of annual slope failure probability is primarily driven by the increase in annual frequency of heavy rainstorms at the upper tail of probability density function.

Keywords: Rainfall-induced landslides; Risk assessment; Climate change; Generalized extreme value; Annual failure probability

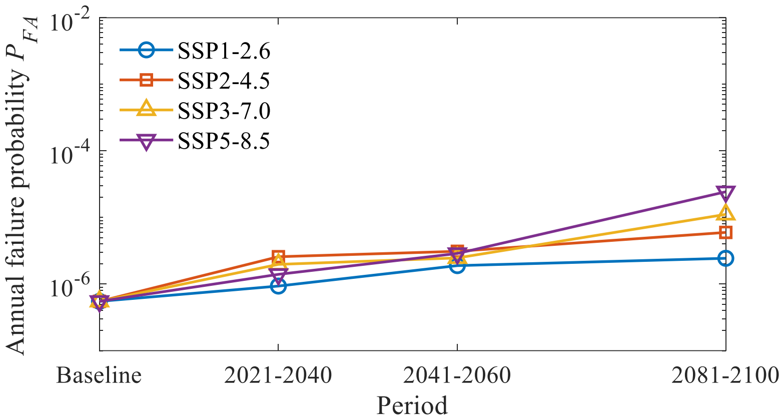

Fig. 1 Annual failure probabilities of a slope at Bride Pool Road for different projected climate change scenarios

ON INNOVATIVE THINKING WITH APPLICATIONS IN GEOTECHNICAL ENGINEERING

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ABSTRACT

This research summarized six innovative thinking modes in the research of engineering problem: 1) transplantation innovation, 2) combination innovation, 3) refinement innovation, 4) extension innovation, 5) local change innovation, and 6) original innovation (see Fig. 1). Gradually increasing innovation level from 1 to 6; 1-5 is generally a 1-N innovation, while 6 is a 0-1 innovation; However, it is not absolute. If 1-N changes greatly, it can also be an innovation of 0-1. For example, Terzaghi's consolidation theory starts with the assumption of effective stress, and then the combination of seepage mechanics and solid mechanics achieves the original innovation, which solves the problem of stress and deformation of soft soil that has not been solved by predecessors. Although this approach, i.e., effective stress, has been proven to be trustworthy, the development of direct measurement method has remained at an embryonic stage for 10 decades due to innovation difficulties. With the development of optical fiber technology, this centennial unsolved case has been effectively resolved in recent years by Hong Kong based researchers (Yin et al, 2020; Tan and Yin, 2022), as shown in Fig. 2. Their work provides an experimental confirmation to the Terzaghi's hypothesis, a contribution which is an unprecedented achievement in the field of soil mechanics after the seminal work of Terzaghi. Therefore, Yin group's contribution can be thought of as an innovation of 0-1. Then, we summarize the innovative research work of my team in geotechnical engineering, especially in the intelligent construction of tunnel engineering in recent years: from the application of artificial intelligence algorithm to analyze geotechnical engineering data to the innovative research thinking method of modifying neural network activation function to improve calculation efficiency, and artificial intelligence to identify stratum characteristics and parameters.

Keywords: Scientific research way; six innovative methods; measurement of effective stress; modern informatic technology; smart and sustainable cities.

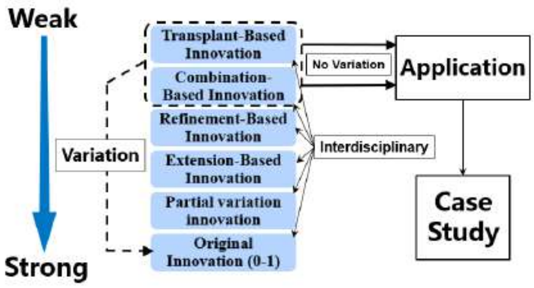

Fig. 1 Six Approaches to Innovative Thinking

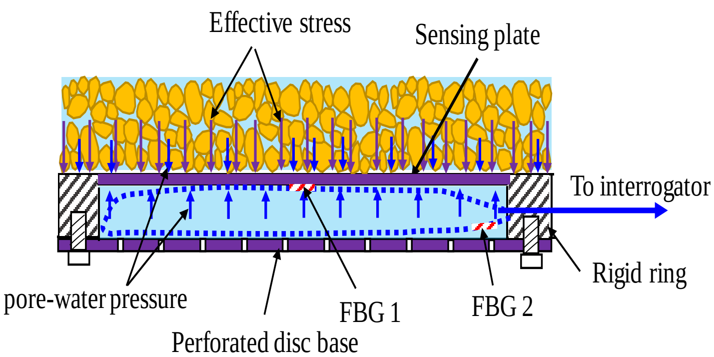

Fig. 2 Apparatus to measure effective stress directly (courtesy Prof. Jianhua Yin).

STABILITY CHARACTERISTICS OF PERMEABLE ARTIFICIAL BLOCK ARMOR STRUCTURE AND FOUNDATION OF SLOPING BREAKWATER UNDER WAVE ACTION

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

As a protective material for sloping breakwaters, permeable artificial block structures have po-rous water permeability that reduces the wave impact force. Meanwhile, the gaps facilitate the growth of animals and plants, which have positive ecological effects. Understanding the stability characteristics of permeable artificial block structures under wave action can aid deci-sion-making regarding their structural selection and application. In this study, we examined the stability characteristics of a guide-levee protective block structure with different numbers of openings using a wave flume cross-sectional test. Prior research has shown that the dynamic fac-tors that affect the instability of the armor block under wave action can be characterized by wave energy; hence, an instability-state function corresponding to the critical condition of the armor block structure failure was devised. After waves hit a block, they often break, and the position of the wave breaking is consistent with the position of the maximum wave pressure. A calculation formula for the maximum breaking wave pressure was established on the basis of experimental data. Our results show that laying an underlayer below the permeable protective block can ef-fectively improve the wave attenuation effect. Therefore, it is recommended to use an underlay-er for projects requiring high wave resistance.

Keywords: breakwater; wave; slope protection structures; physical model test

(a)

(b)

Figure 1. Equipment for the wave cross-sectional model test. (a) Multifunctional wave test flume. (b) Absorbing wave generator.

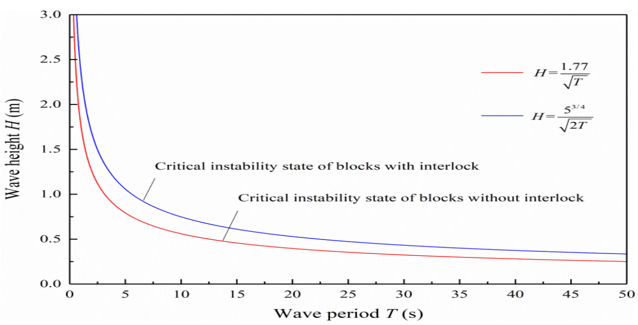

Figure 2. H–T function of critical instability state of four-sided interlocked blocks and non-interlocked blocks.

A COMPREHENSIVE RESILIENCE EVALUATION METHOD OF SHIELD TUNNEL STRUCTURES UNDER DISASTER DISTURBANCE

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ABSTRACT

Resilience evaluation of the whole process of disaster chain for shield tunnel structures is an urgent challenge to be solved. However, conventional evaluation do not adequately account for the impact of structural performance, restoration cost and affected time, which have an impact on comprehensive resilience. Unreliable evaluation outcomes are the result. In light of engineering disturbances, this research suggested a thorough resilience evaluation approach for shield tunnel. Firstly, the resilience connotation was discussed based on the adaptive cycling theory and structural performance characteristics throughout the life cycle. Structural performance analysis models and metrics were proposed according to their allowances, and indicators were suggested subsequently. Then, grading standards for resilience that took structural performance, restoration costs, and affected times into consideration were also presented. Additionally, a structural comprehensive resilience evaluation method for shield tunnels of the entire disaster chain was proposed, using the analytic hierarchy process and expert survey method to establish a comprehensive resilience index evaluation system and determine the weights of indexes. Finally, the reasonableness of this strategy was demonstrated using an engineering case. The research presented in this study will serve as a theoretical foundation for a thorough resilience assessment of shield tunnels and structural systems.

Keywords: Comprehensive resilience, Shiled tunnel structures, Adaptive cycling theory, Field study

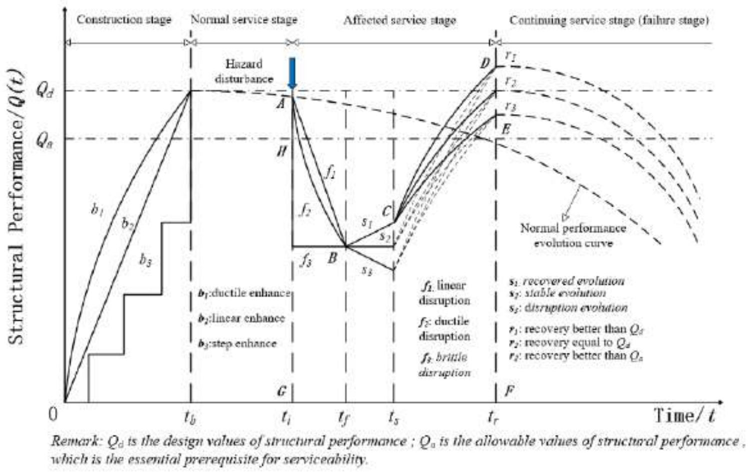

Fig. 1 Performance evolution throughout the life cycle of tunnel structures under disaster disturbances

ENHANCING METRO NETWORK FLOOD RESILIENCE THROUGH GENETIC ALGORITHM-BASED OPTIMIZATION: A CASE STUDY ON FLOOD BARRIER HEIGHT DESIGN FOR METRO NETWORK

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ABSTRACT

Global climate change has led to a marked increase in the intensity and frequency of extreme rainfall events, which pose significant challenges to the normal operation of urban metro systems. In recent years, metro networks in several cities worldwide have suffered disruptions due to such extreme rainfall events, notably in New York in 2012 and Zhengzhou in 2021. To enhance the resilience of metro systems when faced with extreme rainfall, it is crucial to optimize the design of flood prevention facilities. Metro stations, exit-entrance lines, and ventilation shafts represent key sources of flood risk during heavy rainfall. Flood barriers at these entry points are important for preventing water from inundating the metro network. Therefore, finding an optimal and cost-effective design for these barriers' height is a vital step in improving the resilience of metro systems. This study utilizes genetic algorithms and complex network theory, incorporating rainfall data, metro operation data, geographical information, and experiential data from metro operators. We have developed a metro network resilience model under extreme rainfall and optimization model for designing flood barriers' height at metro entry points on Jinan metro network.

Keywords: Genetic algorithms, metro flood prevention, extreme rainfall, network resilience, optimization design

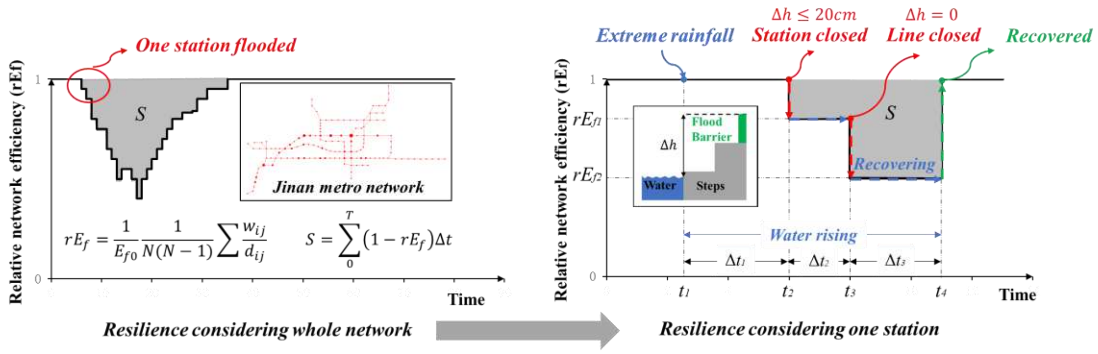

Fig. 1 Metro network resilience model under extreme rainfall

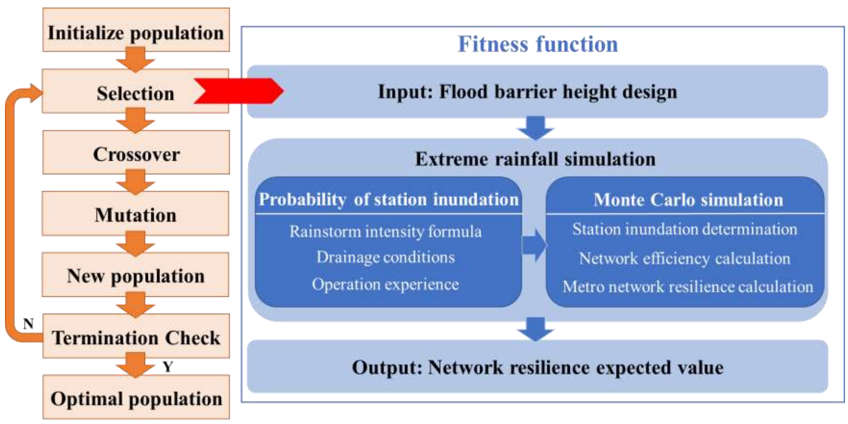

Fig. 2 Optimization model of metro network resilience based on genetic algorithms

Seismic Fragility Curve Development for Segmental Tunnels via Optimal IM and EDP Pairs

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ABSTRACT

Seismic fragility assessment for segmental tunnels is crucial in urban lifeline system disaster management. This process involves probabilistically connecting ground motion intensity measures (IMs) and engineering demand parameters (EDPs) through a probabilistic seismic demand model (PSDM). Despite its importance in refining seismic risk assessment, the appropriate pairing of IMs and EDPs for segmental tunnel fragility analysis remains uncertain. This study conducts a parametric numerical analysis to identify optimal IM-EDP pairs for segmental tunnels. Six hypothetical soil-segmental tunnel systems, varying in soil conditions and burial depths, are simulated using a validated numerical model. These models are subjected to 150 ground motions, resulting in 900 seismic response datasets. Utilizing these datasets, linear and bi-linear PSDMs are derived for each system through parametric statistical inference. Each type of these PSDMs combines four EDPs and two ground motion sets—outcrop-based and soil surface-based. Subsequently, the optimal IM-EDP pairs are selected based on four regression parameters: correlation; efficiency; practicality; and proficiency. The findings demonstrate the superior performance of the bilinear PSDM over the linear model, notably enhancing predictive ability across a wider intensity range. For each type of PSDM, velocity and acceleration-related IMs from both ground motion suites prove more effective than displacement, time, and frequency-related IMs for all EDPs. Moreover, this study generates seismic fragility curves using the identified optimal IM-EDP pairs, serving as a valuable reference for effective seismic risk assessment and management of segmental tunnels.

Keywords: Seismic fragility assessment; Probabilistic seismic demand model; Segmental tunnels; Intensity measures; Engineering demand parameters.

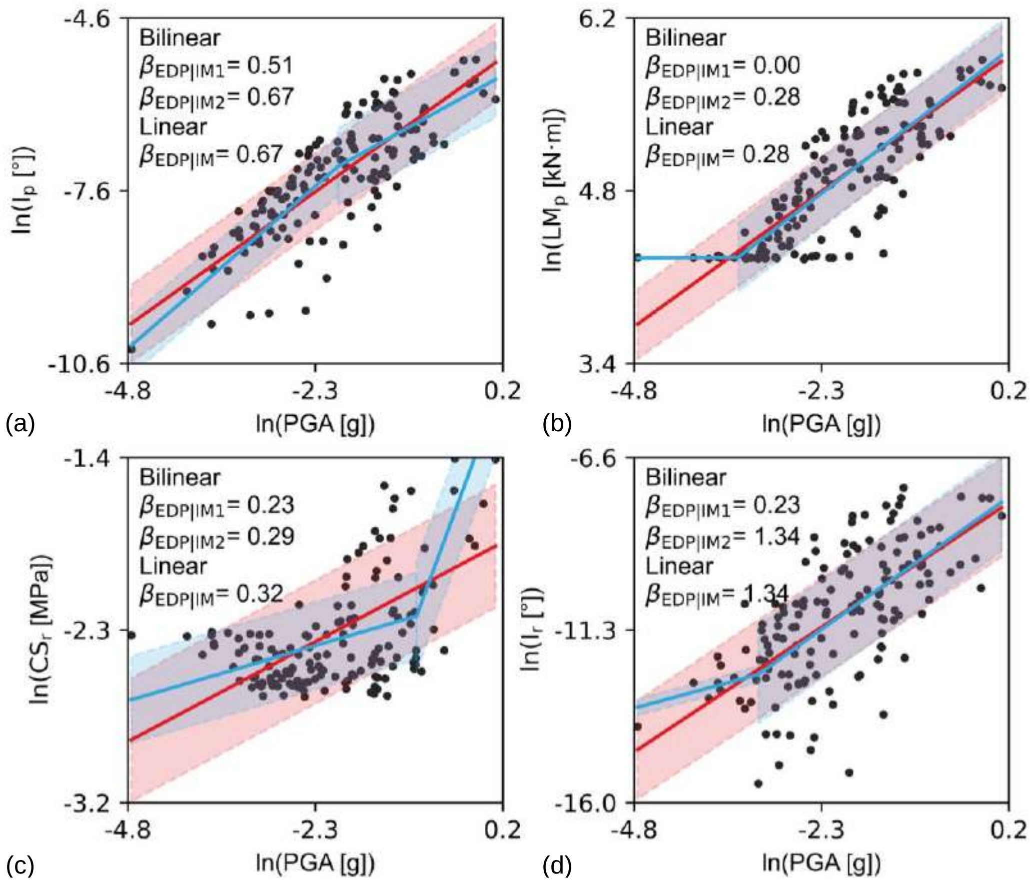

Fig. 1. Illustration of the linear and bilinear probabilistic seismic demand models.

SUATAINABILITY AND PERFORMANCE-BASED SEISMIC RISK ASSESSMENT OF PILE FOUNDATION USING STONE COLUMNS FOR LIQUEFACTION MITIGATION

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ABSTRACT

Sustainability has emerged as a paramount concern in the realm of construction and the development of built infrastructure. This study delves into systematic integration of environmental impact and cost metrics into performance-based engineering frameworks. For that purpose, a representative bridge pile foundation in potentially liquefiable sloping ground is considered, with stone columns as a ground improvement countermeasure to mitigate liquefaction-induced spreading damage. As such, a nonlinear 3D finite element framework (Fig. 1) is established with solid-fluid, fully coupled formulations, and the influences of stone columns on seismic vulnerability of the pile foundation and the earthquake risk are thoroughly explored. Based on this specific liquefaction-induced damage scenario, systematic assessment of cost and carbon emissions associated with stone columns in construction are performed (Fig. 2). In addition, three different life cycle assessment (LCA) approaches are employed to quantify carbon emissions: (i) process based (P-LCA), (ii) economic input output LCA, and (ii) a hybrid approach which uses P-LCA and economic input output LCA. Consequently, potential advantages and limitations concerning both costs and carbon emissions are highlighted, serving as an essential component within a major decision-support process.

Keywords: Sustainability; Stone columns; Life cycle assessment; Finite element; Liquefaction.

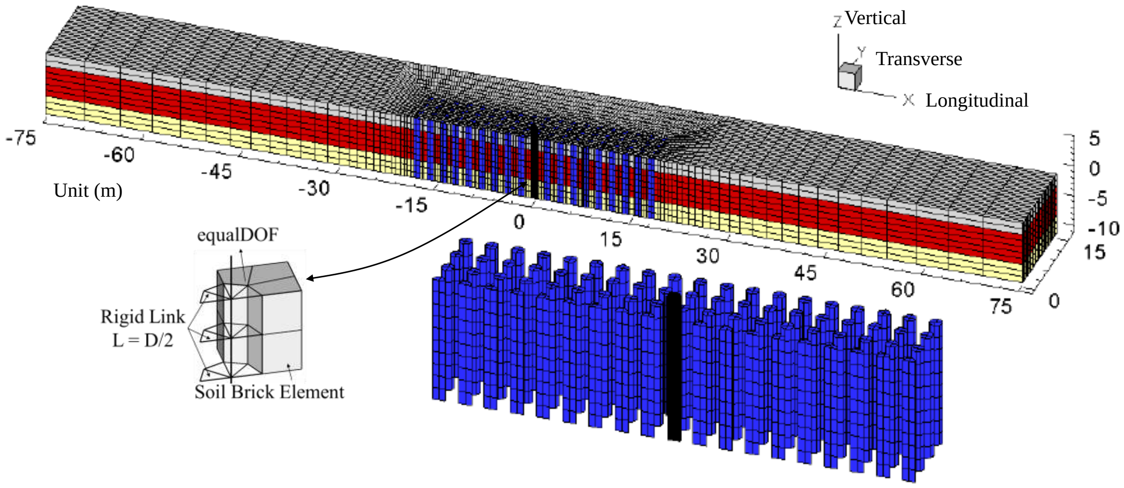

Fig. 1 Finite element model.

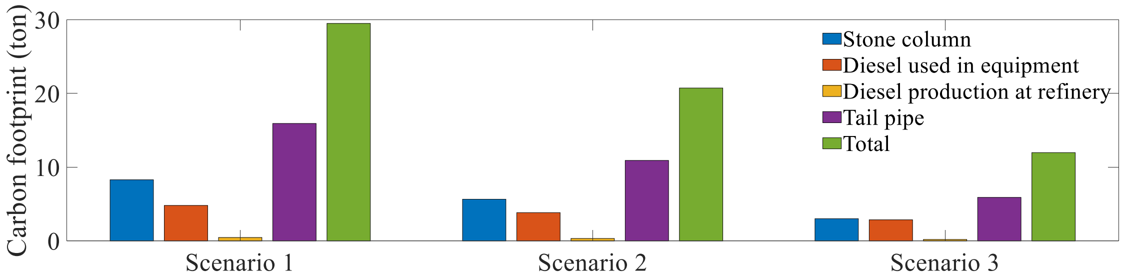

Fig. 2 Carbon footprint.

ENVIRONMENTAL IMPACT ASSESSMENT OF DCM UTILIZING WASTE MATERIALS IN LAND RECLAMATION IN HONG KONG

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ABSTRACT

The shortage of land resources and the accumulation of excessive industry waste have become two major issues restricting the development of coastal cities. As a sustainable solution, the Tung Chung East reclamation incorporated Ground Granulated Blast Furnace Slag (GGBS) as a partial replacement for Ordinary Portland Cement in the DCM binder, aiming at minimizing landfill waste, preserving natural resources, and reducing carbon emission during land reclamation. In this study, a comprehensive life cycle assessment of the GGBS-based DCM is conducted to provide a more realistic figure on the potential carbon footprint saving achieved in the Tung Chung East reclamation. A holistic consideration of the entire construction process, and the specific regional construction conditions of Hong Kong, including material preparations, transportation distances, and construction equipment, are taken into consideration. This study compares the carbon footprint of alternative DCM binders using waste materials like steel slag (SS) and waste concrete powder (WCP) at varying dosages. The results showed that the use of GGBS, SS, and WCP contributed to a 41.7%, 41.4%, and 42.0% reduction in carbon footprint per ton of DCM slurry compared to the use of traditional cement mixes. These findings serve as a valuable reference for future sustainable land reclamation endeavors in Hong Kong.

Keywords: Deep cement mixing, Environmental impact, Greenhouse gas, Carbon footprint analysis, Global warming potential.

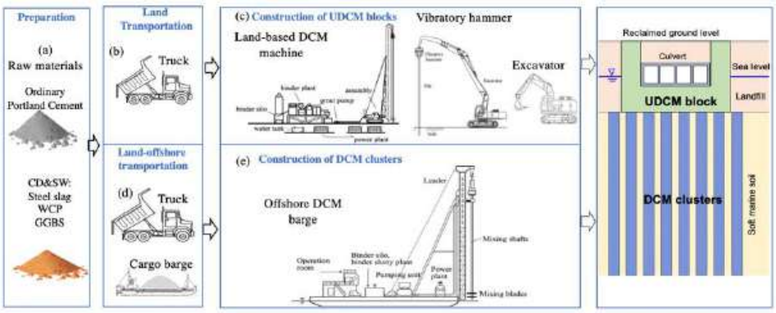

Fig. 1 Construction procedure of DCM clusters and UDCM blocks

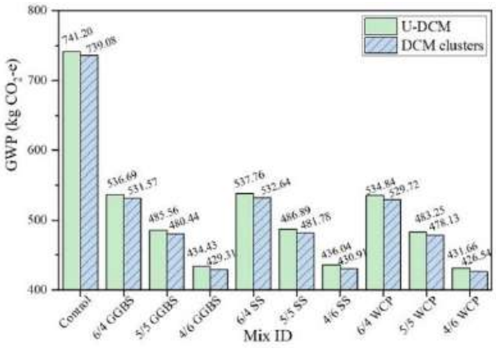

Fig. 2 Global warming potential for DCM projects

A FULL SCALE MODEL WITH CAUCHY-TYPE BOUNDARY CONDITIONS FOR SIMULATING NEAR SURFACE EFFECTS ON ENERGY PILES

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ABSTRACT

Energy piles are sustainable green technology utilizing shallow geothermal energy. Scholars have developed numerous heat transfer models for energy piles to establish more accurate design methods for energy piles. However, most heat transfer models for energy piles neglect the significant influence of the ground surface boundary and the heat capacity of energy piles, caused by the characteristics of energy piles with short pile depth and large pile diameter. In this paper, a full-scale model for energy piles is firstly developed under composite air-ground surface boundary condition (Cauchy-type boundary condition). The full-scale model is a composite expression consisting of a composite-medium line-source solution considering heat capacity of energy piles, a finite line-source solution considering air-ground surface boundary condition, and an infinite line-source solution. Secondly, the developed model will be verified by indoor modeling tests. Finally, based on the developed model, the influence of the air-ground surface boundary condition on energy piles of different lengths will be discussed, and the influencing factors on the thermal performance of energy piles, such as the indoor air temperature and the ground thermal properties, will be analyzed in detail. The research will provide theoretical support for future design criteria of energy piles.

Keywords: energy piles; air-ground surface boundary condition; full-scale model; thermal performance

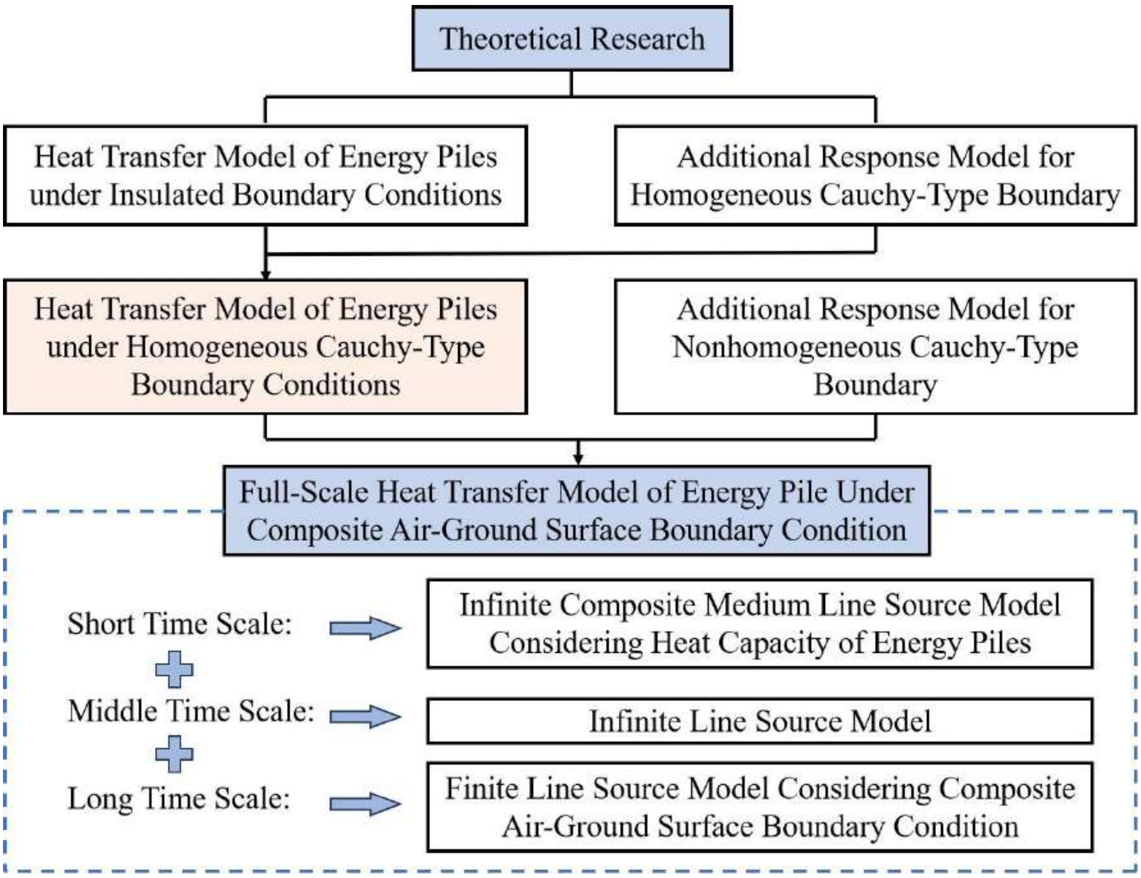

Fig. 1 Illustration of the proposed model

EVALUATION METHOD OF TRACK IRREGULARITIES BASED ON VEHICLE BODY ACCELERATION

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[#]Corresponding author; Underline denotes the presenter

ABSTRACT

Real-time evaluation of track conditions based on vehicle body acceleration parameters (VBAP) has emerged as a prominent area. Traditional methods for assessing track irregularities neglect the consideration of VBAP. This study addresses this gap by employing successive variational mode decomposition (SVMD) to analyze the trend terms present in track geometric irregularities (Fig.1(a)). Furthermore, successive multivariate variational mode decomposition (SMVMD) method is introduced to evaluate the correlation between different wavelengths of track geometric irregularities and VBAP (Fig.1(b)). The feasibility of utilizing VBAP to assess track status is validated. To further enhance the accuracy of evaluation, a novel local amplitude evaluation (LAE) method is proposed. By integrating VBAP information into geometric parameters, more precise fluctuation values for single-track parameters are obtained. Additionally, the track irregularities evaluation method based on SMVMD energy density (SMVMD-TQI) incorporates the interval mapping weighting method to quantify the degree of coupling between weights and parameters. Practical case applications validate the effectiveness of the proposed approach, showcasing its superior accuracy and real-time performance in identifying track irregularities (Fig.2). Consequently, this study establishes a strong theoretical foundation for the implementation of real-time track monitoring and provides valuable insights for track status evaluation.

Keywords: vehicle body acceleration, local amplitude evaluation, successive multivariate variational mode decomposition, interval mapping weighting method, real-time track monitoring.

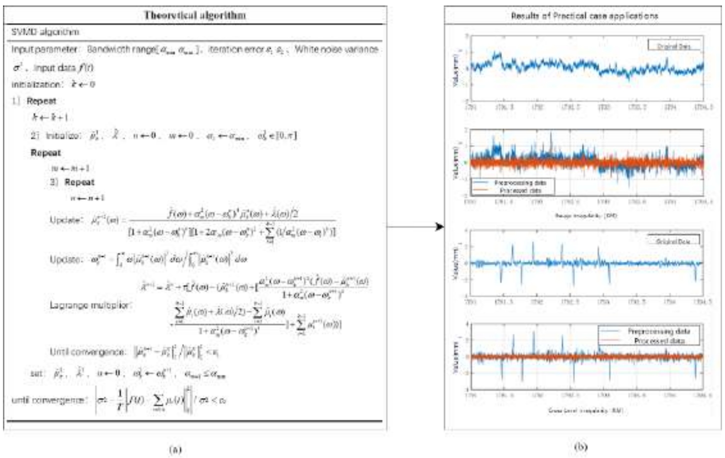

Fig. 1 Trend extraction (a) Theoretical algorithm (b) Results of Practical case applications

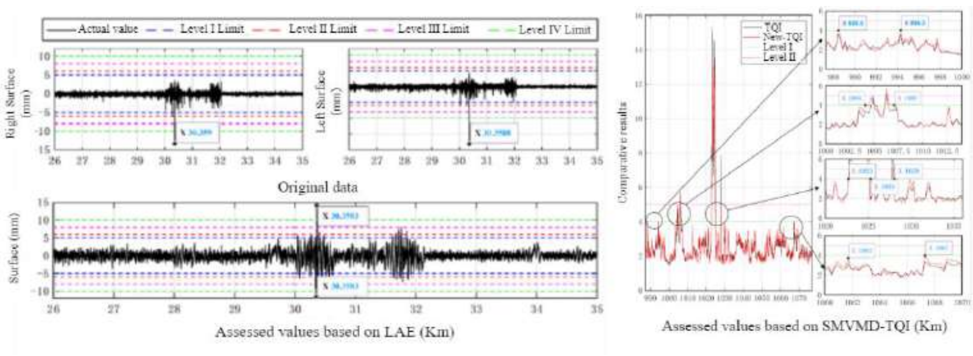

Fig. 2 Practical case applications

ENHANCED REAL-TIME EVALUATION OF TRACK IRREGULARITIES USING VEHICLE BODY ACCELERATION

Xiaohui Wang [1], Hai Liu[1#], and Jianwei Yang[2]
[1]*School of Civil Engineering, Guangzhou University, Guangzhou 510006, China, wxhnew2019@163.com, hliu@gzhu.edu.cn*
[2]*Beijing Key Laboratory of Performance Guarantee on Urban Rail Transit Vehicles, Beijing University of Civil Engineering and Architecture, Beijing 100044, China; yangjianwei@bucea.edu.cn*
[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

The evaluation of track irregularities in real-time, based on vehicle body acceleration parameters (VBAP), has gained significant prominence. Traditional methods for assessing track irregularities often overlook the consideration of VBAP. This study bridges this gap by employing successive variational mode decomposition (SVMD) to analyze the trend terms present in track geometric irregularities (Fig.1(a)). Furthermore, successive multivariate variational mode decomposition (SMVMD) method is introduced to evaluate the correlation between different wavelengths of track geometric irregularities and VBAP (Fig.1(b)). We validate the feasibility of utilizing VBAP to assess track irregularities. To enhance the evaluation accuracy further, we propose a novel local amplitude evaluation (LAE) method. By integrating VBAP information into geometric parameters, we obtain more precise fluctuation values for single-track parameters are obtained. Additionally, our track irregularities evaluation method, based on SMVMD energy density (SMVMD-TQI), incorporates the interval mapping weighting method to quantify the coupling degree between weights and parameters. Practical case applications validate the effectiveness of the proposed approach, showcasing its superior accuracy and real-time performance in identifying track irregularities (Fig.1(c)). As a result, this study establishes a robust theoretical foundation for the implementing real-time track monitoring and provides valuable insights for track status evaluation.

Keywords: vehicle body acceleration, local amplitude evaluation, successive multivariate variational mode decomposition, interval mapping weighting method, real-time track monitoring.

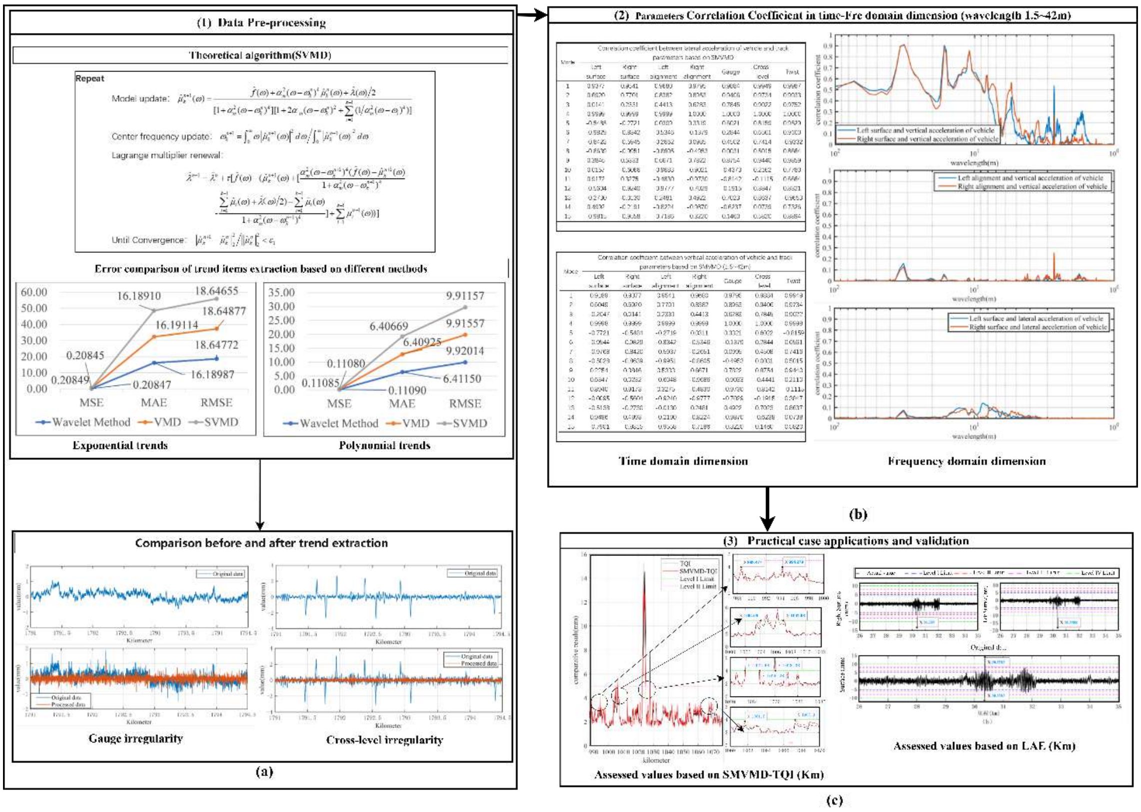

Fig. 1 Method and case study (a)Theoretical algorithm of trend extraction and Results of Practical case applications (b)Parameters time-frequency correlation (c)Practical case applications

ENHANCED REAL-TIME EVALUATION OF TRACK IRREGULARITIES USING VEHICLE BODY ACCELERATION

Xiaohui Wang [1], Hai Liu[1#], and Jianwei Yang[2]
[1]School of Civil Engineering, Guangzhou University, Guangzhou 510006, China, wxhnew2019@163.com, hliu@gzhu.edu.cn
[2]Beijing Key Laboratory of Performance Guarantee on Urban Rail Transit Vehicles, Beijing University of Civil Engineering and Architecture, Beijing 100044, China; yangjianwei@bucea.edu.cn
[#]Corresponding author; Underline denotes the presenter

ABSTRACT

The evaluation of track irregularities in real-time, based on vehicle body acceleration parameters (VBAP), has gained significant prominence. Traditional methods for assessing track irregularities often overlook the consideration of VBAP. This study bridges this gap by employing successive variational mode decomposition (SVMD) to analyze the trend terms present in track geometric irregularities (Fig.1(a)). Furthermore, successive multivariate variational mode decomposition (SMVMD) method is introduced to evaluate the correlation between different wavelengths of track geometric irregularities and VBAP (Fig.1(b)). We validate the feasibility of utilizing VBAP to assess track irregularities. To enhance the evaluation accuracy further, we propose a novel local amplitude evaluation (LAE) method. By integrating VBAP information into geometric parameters, we obtain more precise fluctuation values for single-track parameters are obtained. Additionally, our track irregularities evaluation method, based on SMVMD energy density (SMVMD-TQI), incorporates the interval mapping weighting method to quantify the coupling degree between weights and parameters. Practical case applications validate the effectiveness of the proposed approach, showcasing its superior accuracy and real-time performance in identifying track irregularities (Fig.1(c)). As a result, this study establishes a robust theoretical foundation for the implementing real-time track monitoring and provides valuable insights for track status evaluation.

Keywords: vehicle body acceleration, local amplitude evaluation, successive multivariate variational mode decomposition, interval mapping weighting method, real-time track monitoring.

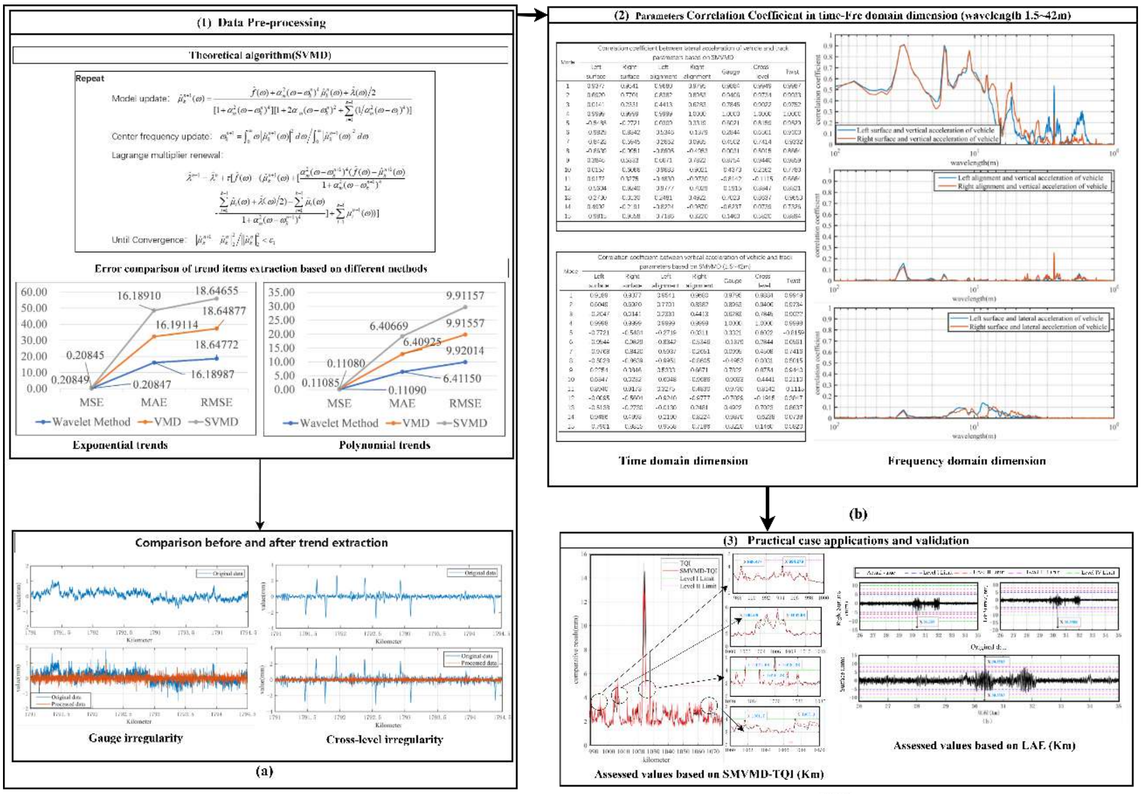

Fig. 1 Method and case study (a)Theoretical algorithm of trend extraction and Results of Practical case applications (b)Parameters time-frequency correlation (c)Practical case applications

RESEARCH ON RISK ASSESSMENT OF OFFSHORE WIND TURBINE FOUNDATIONS DURING LIFE-CYCLE

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ABSTRACT

The uncertainties in the process of onshore prefabrication, offshore construction and installation and service of offshore wind turbine (OWT) foundations pose a great threat to the safety of offshore wind farm projects. For instance, during the operation period of wind farms, the OWT foundations will be subjected to long-term cyclic loads, operational excitation and earthquakes, which will lead to the weakening of soil strength beside the OWT foundations and change the natural vibration frequency of the system. Given the complex and diverse risks at all stages of the life-cycle of OWT foundations, this paper focuses on the analysis of risk factors during the life-cycle of offshore wind turbine foundations. The risk matrix method is utilized to assess the risk factors of offshore wind turbine foundations. The research provides references for safety management and improves the emergency management ability of the life-cycle of offshore wind power projects.

Keywords: offshore wind turbine foundations; risk assessment; risk matrix method; life-cycle.

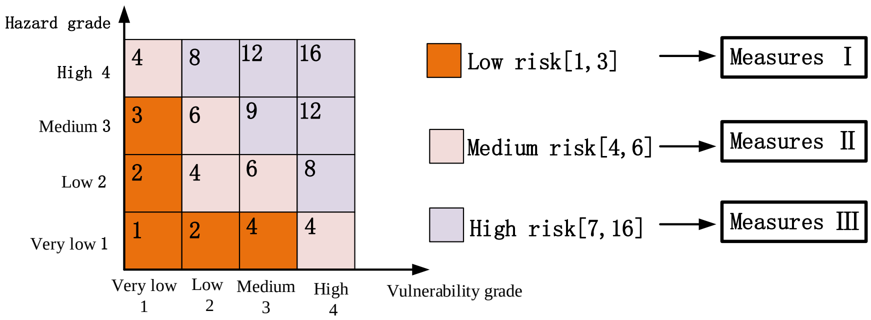

Fig. 1 Risk grade classification matrix

OPTIMIZATION STUDY OF CHIMNEY PARAMETERS FOR COAL MINE DUMP GRAVITY HEAT PIPE

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ABSTRACT

Coal mine spoil heaps have a severe impact on the ecological environment. Gravity heat pipes are an effective means of controlling the deep-seated temperature in coal mine spoil heaps. The magnitude of external airflow velocity in the heat dissipation section of the heat pipe is one of the key factors affecting its heat transfer efficiency. In this study, a chimney effect model for gravity heat pipes in coal mine spoil heaps is developed. The non-isothermal flow multi-physics transient solution method is employed to analyze the single-factor effects of the entrance radius, height of the outlet section, and radius of the outlet section on the average velocity at the chimney outlet. Subsequently, a comprehensive factorial response surface research method is used to fit the functional relationship between the average velocity at the chimney outlet and various chimney parameters. By introducing the height of the outlet section and the radius of the outlet section as constraint conditions based on field conditions, the optimal values for chimney parameter optimization are obtained. After comparative analysis, it is determined that the heat dissipation efficiency of the gravity heat pipe with the chimney has been improved by 2.6%.

Keywords: Spoil heaps; gravity heat pipes; chimney effect; parameter optimization; heat dissipation efficiency.

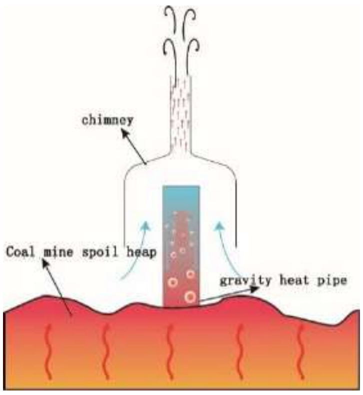

Fig. 1 Schematic diagram of chimney effect of gravity heat pipe in gangue hill

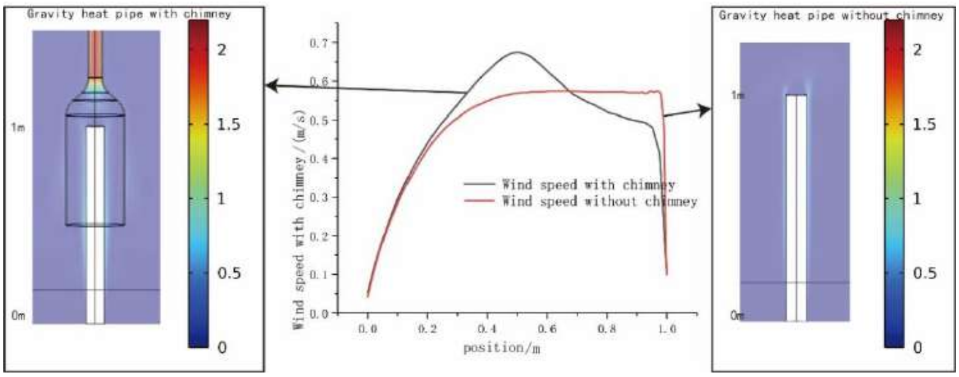

Fig. 2 The effect of chimney on the wind speed on the outer wall of gravity heat pipe

Experimental Study on Influence of Salt Content and Void Ratio on Soil Water Retention Characteristic

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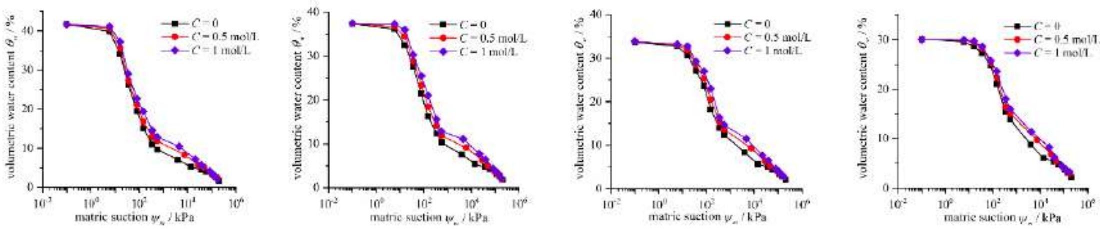
ABSTRACT

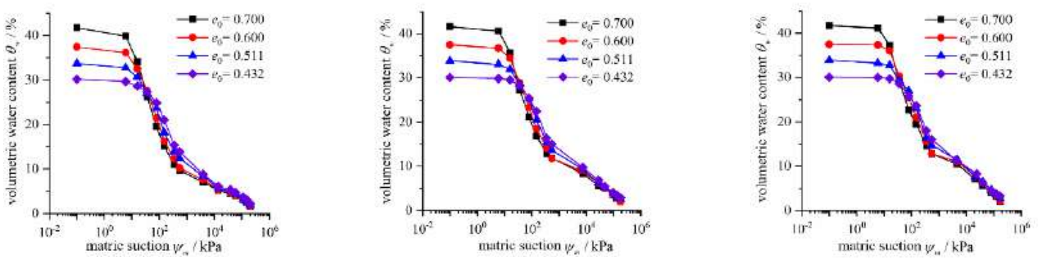
The groundwater environment in which geotechnical media are located is not pure water, which affects the water retention capacity of unsaturated soil. In this paper, the soil water characteristic curves of unsaturated clay were measured by pressure plate method and vapour equilibrium method in the full suction range during the drying path. The influences of salt content and initial void ratio on the soil water retention characteristic were revealed. The experimental results shown that in the low suction stage, the soil water retention capacity increases with the increasing of pore solution concentration. Besides, with the decreasing of initial pore ratio, the saturated volume water content decreases, and the air entry value increases. In the high suction stage, the soil water retention capacity increases with the increasing of salt content and the decreasing of initial void ratio. Besides, these influences decreases with the increasing of total suction.

Keywords: salt content; initial void ratio; pressure plate method; vapour equilibrium method; soil-water characteristic curve.



(a) e_0= 0.700 (b) e_0= 0.600 (c) e_0= 0.511 (d) e_0= 0.432

Fig. 1 SWCCs with different NaCl concentrations (full suction range)



(a) C = 0 mol/L (b) C = 0.5 mol/L (c) C = 1 mol/L

Fig. 2 SWCCs with different initial void ratio (full suction range)

STUDY ON THE STRUCTURAL PARAMETER OF LOESS: MAPPING ENERGY

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ABSTRACT

The soil structure has been broken, when the applying energy exceed the threshold of deformation energy of soil element. Thus, the structural parameter depended on the deformation energy can reflect the essential characteristic of soil structure directly and clearly. The confined compression tests were conducted on compacted remolded and undisturbed loess with different water content. We found that, the yield stress of remolded and undisturbed loess all decreased with the increase of water content; the yield stress of remolded loess with same water content increased with the dry density; the yield stress of undisturbed loess was greater than remolded loess with same water content. We also found the void ratio e was correlated piecewise linearly with the vertical pressure P in the dual logarithmic coordinate space of $\ln(1+e)$ -lg$P$. For this, a structural parameter called mapping energy, which was the area between the compression curve and the vertical axis in the dual logarithmic coordinate space of $\ln(1+e)/d$-lg$P$, by mapping the strain to natural logarithm axis, and mapping the stress to common logarithm axis, in strain energy density function, respectively. Where d is the intercept of the compression curve plastic section on the $\ln(1+e)$ axis.

Keywords: loess; structural parameter; strain energy density; confined compression tests.

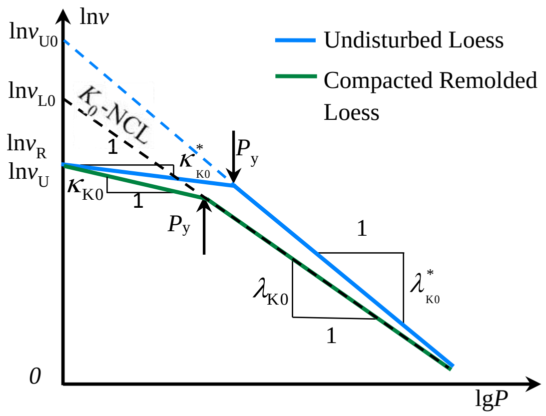

Fig.1 The relationship among K_0-NCLand compression curves of undisturbed soil and compacted remolded soil whose dry density equals to the undisturbed soil.

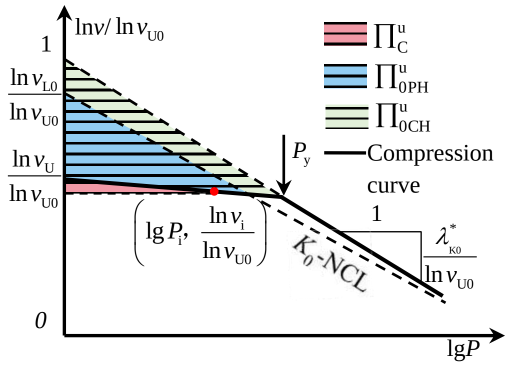

Fig. 2 The mapping energy in undisturbed soil elastic segment

A hydro-mechanical coupled model for wetting collapse of unsaturated soils: formulation, implementation, and application

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ABSTRACT

The engineering properties of unsaturated soils are significantly affected by the variaitons of hyraulic conditions due to the complex hydro-mechanical coupled behavior. Increase of water table, rainfall, and reservoir storage could result in wetting of unsaturated earthen structures, leading to potential damage or even failure. However, there is a lack of constitutive models for unsaturated soils implemented in computational codes to investigate this type of engineering problems and develop mitigation measures. In this study, a hydro-mechanical coupled constitutive model for unsaturated soils was proposed. The model adopts Bishop's effective stress, which considers the effect of hydraulic behavior on the stress-strain response through the influence of suction on the stiffness and hardening parameters. Meanwhile, the effect of mechanical behavior on the water retention response was accounted for by incorporating the influence of void ratio on the soil-water retention curves. The constitutive model was implemented in the finite difference program FLAC using the Two-Phase Flow option. The implemented constitutive model was verified using experimental data for wetting collapse of unsaturated soils. Simulation of rainfall-induced deformations for an example unsaturated embankment was illustrated, which demonstrates the applicability of this constitutive model for unsaturated soils subjected to wetting.

Keywords: Unsaturated soil; Hydro-mechanical behavior; Constitutive model; Wetting collapse; Rainfall-induced deformation

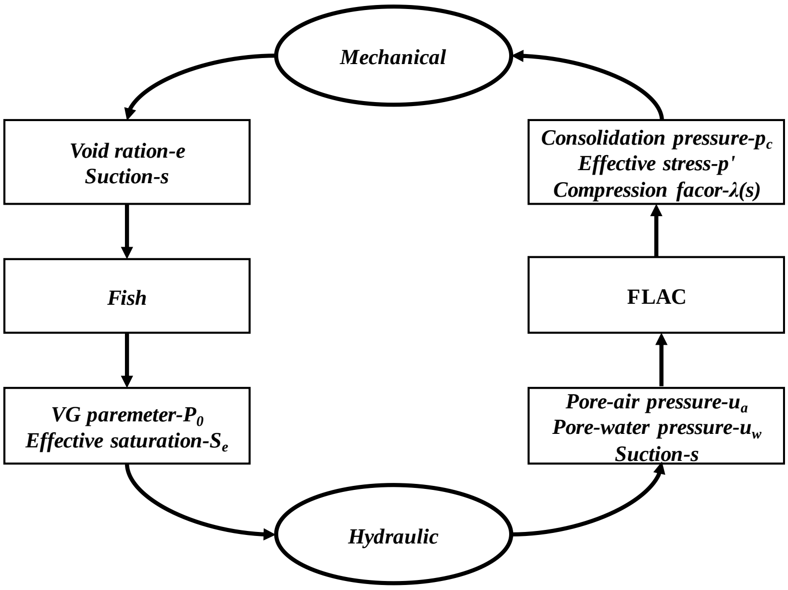

Fig. 1 Flow chart of implementation for the hydro-mechanical coupled model of unsaturated soils

REDUCING LATERAL EARTH PRESSURE ON RETAINING WALLS IN EXPANSIVE SOILS USING EPS GEOFOAM

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ABSTRACT

Expansive soil typically exerts significant lateral earth pressure on retaining walls upon wetting, which may lead to serious distress of retaining walls. Placing a layer of EPS geofoam between the retaining wall and expansive soil can effectively reduce the lateral earth pressure. This is due to the high compressibility of the EPS, which accommodates the lateral swelling strain of the expansive soils upon wetting. This presentation reports small-scale and model test studies on the retaining wall-EPS-expansive soil system. The experimental results demonstrate that (i) the cyclic swelling and shrinkage of the expansive soil during wetting-drying cycles do not affect the performance of the EPS in terms of reducing the lateral earth pressure; (ii) the 12 kg/m^3 EPS can reduce the lateral earth pressure by 50% when the expansive soil is fully saturated; (iii) without EPS, the lateral earth pressure increases with depth while the lateral earth pressure does not change significantly with depth when EPS is installed; (iv) the reduction in the lateral earth pressure increases with the increase in the thickness of EPS and the reduction in the density of the EPS. Based on the experimental observations, analytical approaches for determining lateral earth pressure are developed. The approaches are validated by in-situ monitoring data collected from a retaining wall project in expansive soil regions in Guangxi province, China.

Keywords: Lateral earth pressure, retaining wall, EPS geofoam.

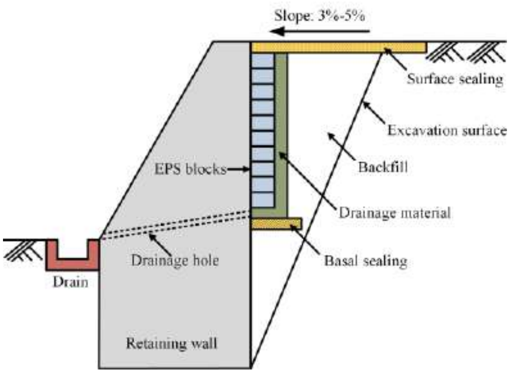

Fig. 1 The use of EPS in retaining wall structure

Fig. 2 Photo of the model tests

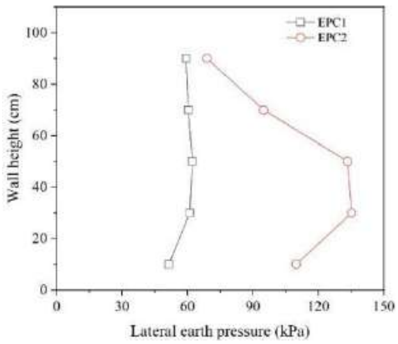

Fig. 3 Model test results

HYDRO-MECHANICAL BEHAVIOR OF COMPACTED EXPANSIVE STIFF CLAY SUBJECTED TO WETTING AND DRYING CYCLES

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ABSTRACT

Expansive stiff clays are inevitably subjected to wetting and drying cycles during earthwork, which can significantly threat the engineering safety. In this study, the hydro-mechanical properties of compacted Nanning stiff clay during wetting-drying cycles were investigated, focusing on a comprehensive analysis on swelling-shrinkage volumetric behavior, hydraulic conductivity and microstructure evolution. The results indicated that the evolution of total swelling or shrinkage strains was influenced by the combined effects of vertical stress and the number of wetting-drying cycles, which can be described by the definition of the size of swelling and shrinking domains. Furthermore, the swelling kinetics analysis showed that the normalized proportion of strain and duration time of the initial swelling phase escalated while the corresponding values in the primary swelling phase dwindled with increasing cycle numbers. These phenomena were predominantly ascribed to the evolution of microstructure, which was corroborated by microscopic test findings, evincing a significant reduction in cumulative pore volume and a transfer from an initial quasi-monomodal distribution to a fairly uniform one, characterized by a prominent peak pore size. Based on the results, the microscopic mechanisms of compacted stiff clay during wetting-drying cycles were proposed for better understanding the macroscopic volumetric behavior.

Keywords: stiff clay; volumetric behavior; wetting-drying cycle; microstructure

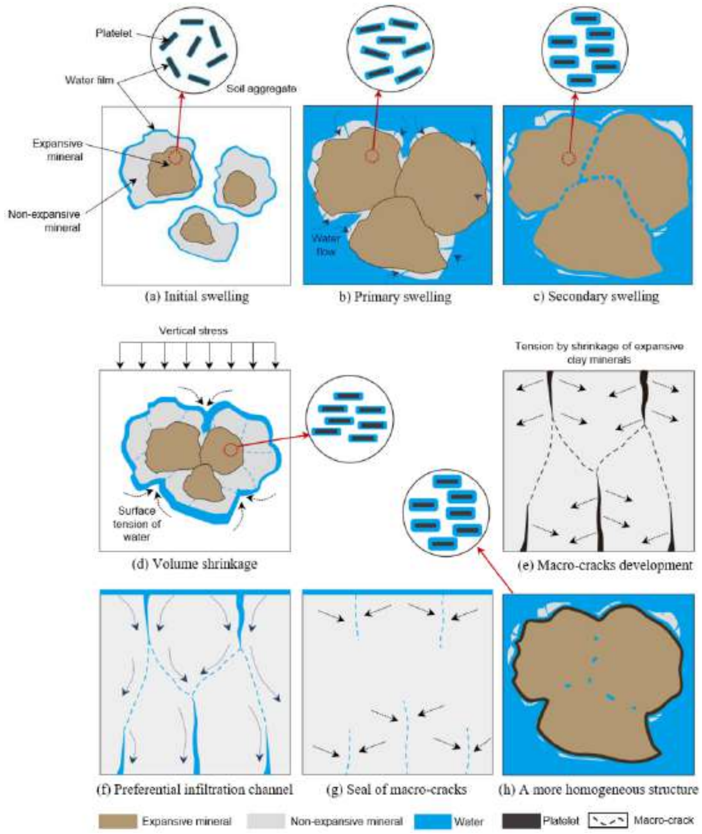

Fig. 1 Conceptual model of soil structure development during wetting-drying cycles

A THERMODYNAMIC FORMULATION OF WATER POTENTIAL IN SOIL

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ABSTRACT

In the mid-20th century, harnessing of thermodynamics in describing water movement in soil, viz the concept of water potential, marks the emergence of modern soil physics, unsaturated soil mechanics, and vadose zone hydrology. Yet to date, a seamless linkage between thermodynamics and water potential is still missing, leading to several long-lasting dilemmas regarding soil properties, e.g., abnormal soil water density, film water viscosity and relative permittivity. Here, a thermodynamic framework is established by synthesizing recent advancements in soil-water interaction. The classical thermodynamic concepts are revisited, highlighting the difference between macroscopic systems commonly treated in conventional theories and the intermolecular scale system subject to external fields. Soil water is conceived as an intermolecular scale open thermodynamic system subject to external fields of gravity, osmosis, and adsorption. The formulated thermodynamic framework is verified by reducing to the conventional definition of matric potential and a recently proposed unitary definition. The accuracy of the framework is further justified in terms of mechanical equilibrium criteria. The framework predicts the existence of spatially varied pore water pressure in soil pores and can serve as the theoretical basis for reconciling the physical origin of abnormal soil behavior such as water density, film water viscosity, and relative permittivity.

Keywords: Adsorption, Capillarity, Water potential, Free energy, Thermodynamics

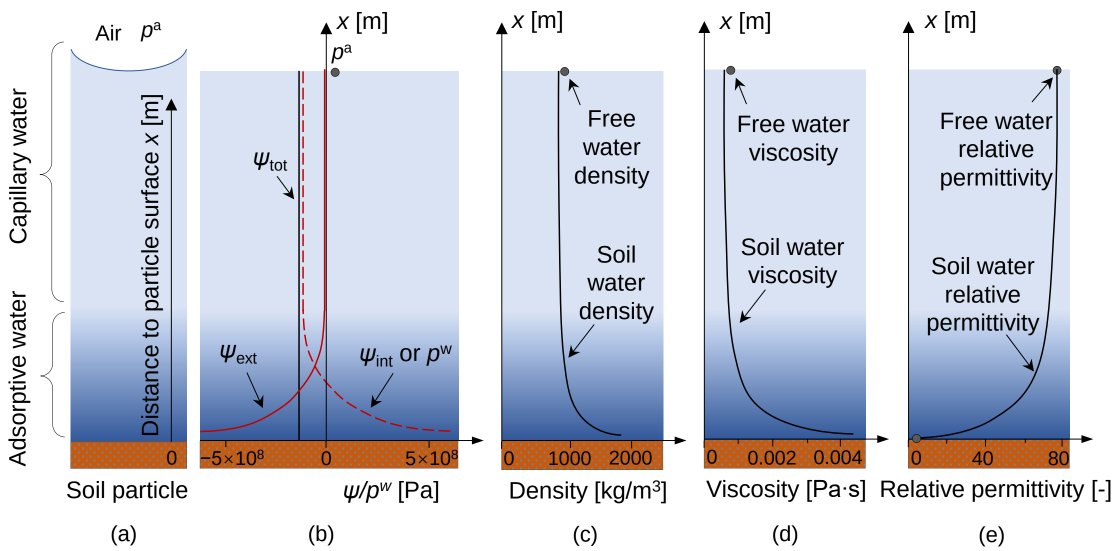

Fig. 1 Schematics for: (a) capillary and adsorptive water of soil; (b) soil water pressure, internal and external water potential profiles; (c) soil water density profile; (d) soil water viscosity profile; and (e) soil water relative permittivity profile.

A Poroelasticity Theory for Soil Incorporating Adsorption and Capillarity

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ABSTRACT

Adsorption and capillarity, in the order of high free energy to low, are the two soil-water interaction mechanisms controlling hydro-mechanical behavior of soils. Yet most of the poroelasticity theories of soil are based on capillarity only, leading to misrepresentations of hydro-mechanical behavior in the low free energy regime. This inability is reasoned to be caused by missing interparticle attraction energy and incomplete definition of adsorption-induced pore water pressure. A poroelasticity theory is formulated to incorporate the two soil-water interaction mechanisms by expanding the classical three-phase mixture system to a four-phase mixture system with adsorptive water as an additional phase. An interparticle attractive stress is identified as one of the key sources for deformation and strength of soils induced by adsorption and is implemented in the poroelasticity theory. The proposed poroelasticity theory can be reduced to several previous theories when interparticle attractive stress is ignored. The new theory is used to derive the effective stress equation for variably-saturated soil by identifying energy-conjugated pairs. The derived effective stress equation can be reduced to classical forms of Bishop and Terzaghi, and is experimentally validated for a variety of soil in the full matric suction range.

Keywords: Poroelasticity; effective stress; adsorption; capillarity.

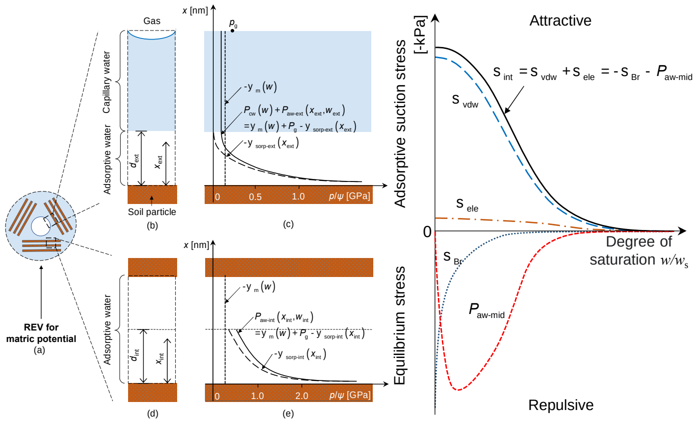

Fig. 1 Local mechanical equilibrium

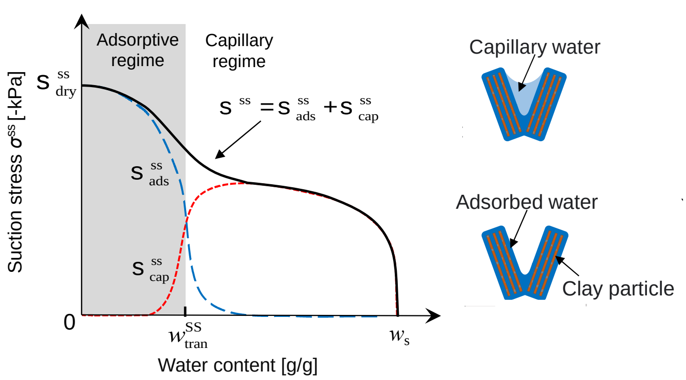

Fig. 2 Conceptual illustration of the derived effective stress equation

MODELLING TIME-DEPENDENT BEHAVIOUR OF UNSATURATED SOILS

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ABSTRACT

The study presents an advanced time-dependent constitutive model based on sub-loading surface plasticity for unsaturated soils, which combines viscous, mechanical, and hydraulic deformations using an overconsolidation parameter. Its extension to a triaxial stress state considers mean effective stress, suction, deviator stress and time variability. The hardening of yield surface and sub-loading surface is governed by viscoplastic volumetric strain and unified hardening parameter. The proposed model only involves 13 parameters, and it is validated against a variety of experimental data such as isotropic and triaxial tests. The constitutive framework can account for the mechanical, time-dependent and hydraulic behaviour of unsaturated soils, including the joint effects of mechanical/hydraulic loading and creep histories. For example, the response of unsaturated soils to different wetting rates is well assessed with the model under isotropic conditions and non-isotropic conditions.

Keywords: Unsaturated soils; Elasto-viscoplasticity; Over-consolidation; sub-loading surface, time-dependency.

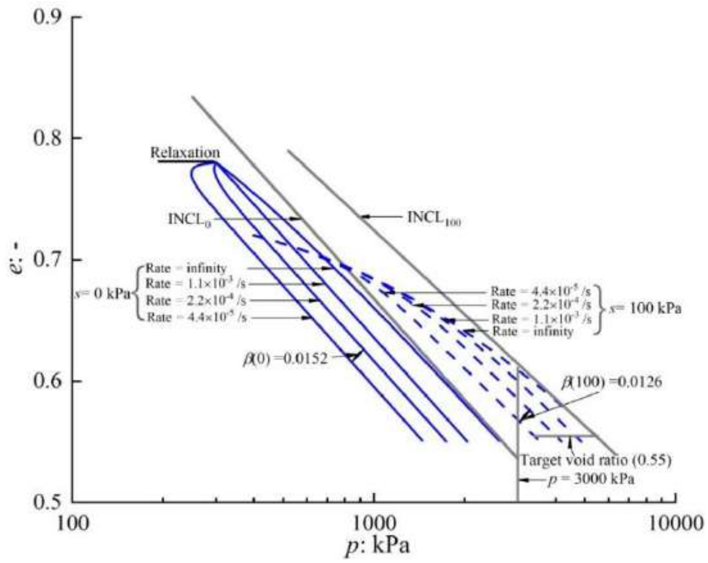

Fig. 1 Evolution of the proposed model under isotropic conditions and constant suction

BASIC THEORETICAL RESEARCH AND APPLICATION OF SEEPAGE EVOLUTION OF LOW PERMEABILITY MEDIUM

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ABSTRACT

The problem of seepage of low-permeability media is one of the key scientific problems in deep energy extraction and hazardous waste and storage. In deep environments, the corresponding hazardous waste barriers and energy storage caps will undergo an unsaturated-saturated evolution process. During this process, the characteristics of water and gas migration in the porous medium will also constantly change, especially the gas migration mechanism will gradually transition from the permeation in the unsaturated stage to the gas-water two-phase flow in the saturated stage.This article will focus on the basic theoretical research on unsaturated-saturated evolution of low permeability media in deep environments, as well as the corresponding equipment research and technological application.

Keywords: low-permeability media, gas migration, unsaturated-saturated evolution.

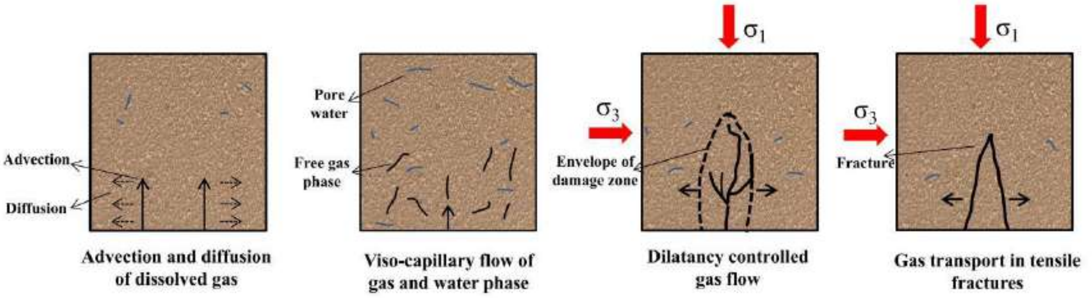
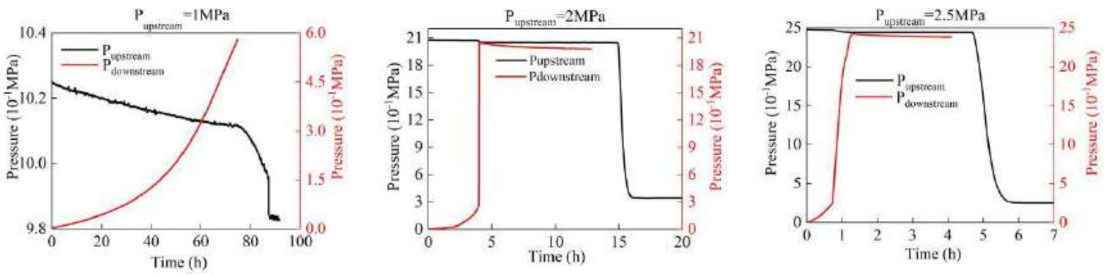


Fig. 1 Illustration of gas migranton porcess in low-permeability media



(a) (b) (c)

Fig. 2 Gas migration properties under different pressure

Investigating the shrinkage behaviour and microstructure changes of organic soils subjected to drying

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ABSTRACT

Soft soils frequently contain significant fractions of fines and organic matter with a high potential for shrinkage. To analyze the durability of infrastructures subjected to climatic stresses, it is essential to investigate the shrinkage behavior of soft soils. This paper examines the effect of soil fabric on shrinkage properties and compressibility on Shenzhen soft clay (SZ soft clay) and fibrous peat, supported by mercury intrusion porosimetry and scanning electron microscopy tests. As the water gradually drains from the multi-level pores, different drying stages were identified. Pore refinements occurred during the drying process, accompanied by a progressive reduction in the peak pore entrance. Contrary to SZ soft clay, intensive shrinkage occurred in the last stage of fibrous peats, due to the collapse of inter-pores and cracks created during drying. It suggests that fibres act as an unstable element in peat upon drying. A threshold void ratio discriminating between inter and inner porosity was found from the test data provided by this study. Above this threshold, the drying decreases the compressibility which dominated by the macrostructure response. Below this threshold, the inner-pores undergo structural modification, which substantially increases the apparent yield stress and reduces both the primary and secondary compressibility.

Keywords: fabric/structure of soil; drying; shrinkage curve; peats; fibres.

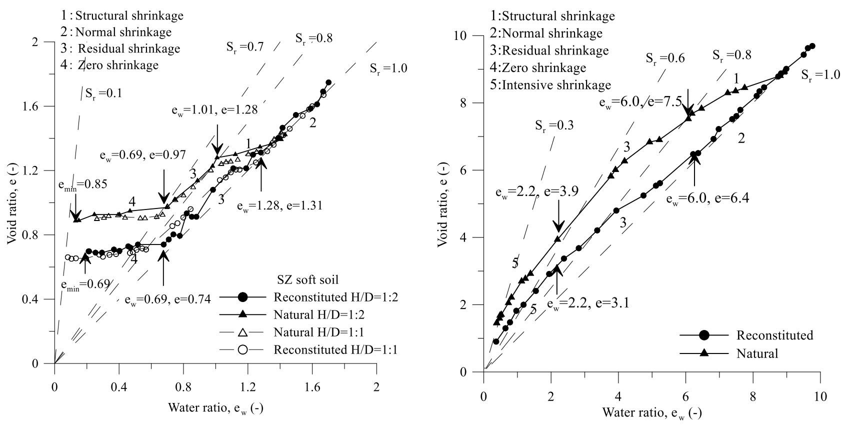

Fig. 1 Shrinkage curves: (a) soft soils; (b) peat samples

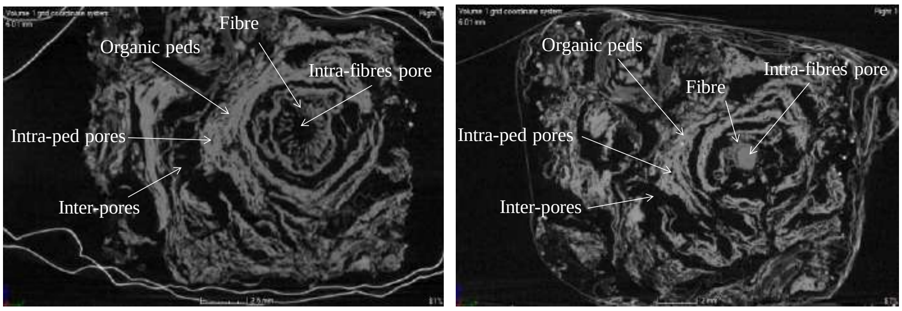

Fig. 2. Micro-CT scan of natural peat samples during desaturation: (a) e_w = 4.90; and (b) e_w = 2.16

Study of structural characteristics and deformation patterns of compacted Gaomiaozi bentonite during dry-wet cycles at micro-CT scale

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ABSTRACT: The sealing performance of the buffer layer for high-level nuclear waste in China is closely linked to the permeability features of Gaomiaozi bentonite (GMZ), which are directly related to the microscopic pore structure of GMZ during dry-wet cycles in the long-term geological storage process. The pore size distribution and pore structure characteristics of GMZ were determined using mercury intrusion porosimetry and nitrogen adsorption methods. Based on the micro-CT scanning data, an independent 3D digital image modelling program was developed. Adopting techniques such as image binarisation, digital image correlation (DIC), and volume digital image correlation (VDIC), the microscopic structural characteristics of GMZ were comprehensively investigated using Paraview as the visualisation platform. The structural features are examined, encompassing the mineral, pore, and fracture distributions within the 3D microspace and various cross-sections. In addition, the deformation of the 3D microstructure and the formation, expansion and closure of micro-fractures in the same cross-sections during dry-wet cycles are calculated. This experimental study explores the microstructural properties and deformation patterns of GMZ.

Keywords: Gaomiaozi bentonite(GMZ); micro-CT; pore structure; digital image correlation(DIC, VDIC).

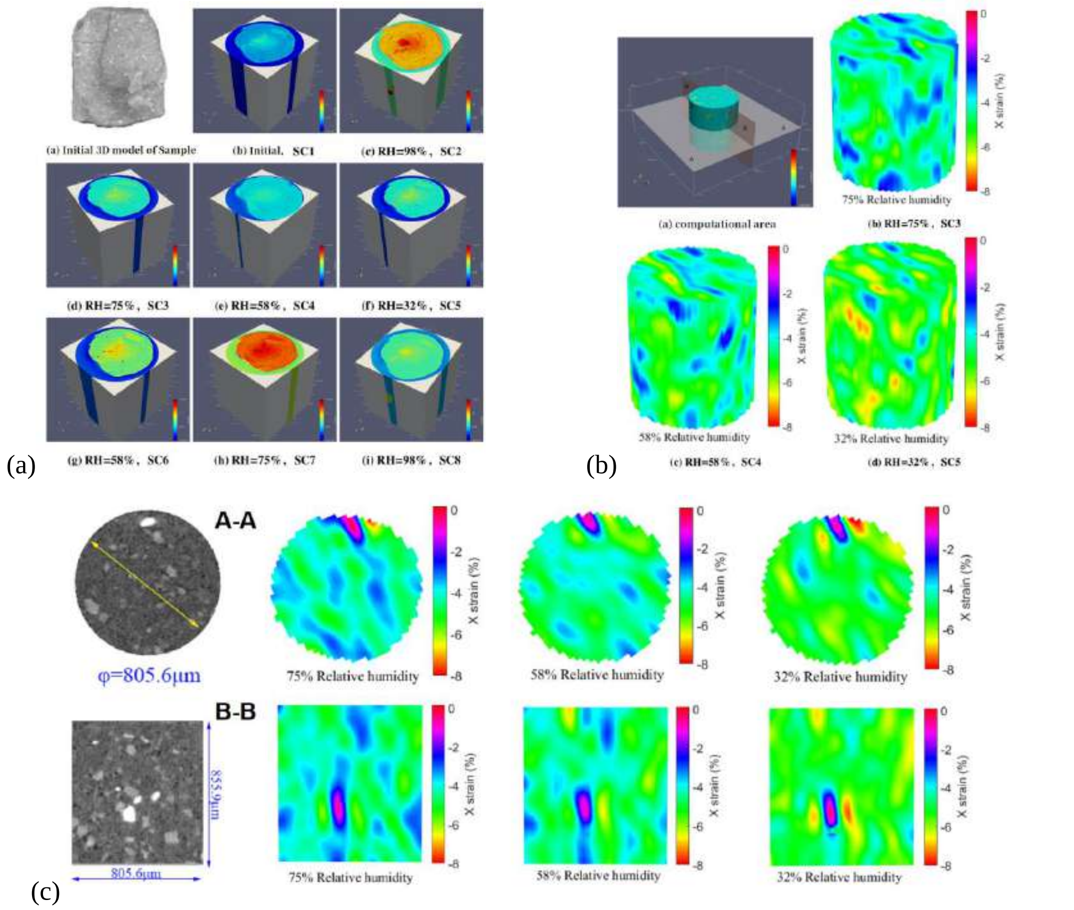

Fig. 1 Characterisation of GMZ microstructural deformation during dry-wet cycles using micro-CT (a), VDIC (b), DIC (c) techniques

CONSTITUTIVE MODEL FOR UNSATURATED SOILS IN A WIDE RANGE OF SUCTION BASED ON DISTURBED STATE CONCEPT

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ABSTRACT

The mechanical properties of unsaturated soil within a wide suction range will show significant differences. At low suction, the soil exhibits hardening and ductile failure characteristics. As the suction increases, its failure mode gradually exhibits softening characteristics, and at high suction, it exhibits brittle failure characteristics. In order to describe the shear characteristics of unsaturated soil in a wide range of suction, this paper establishes a constitutive model based on the disturbed state concept. The evolution law of disturbance function was analysed based on the shear test data over a wide range of suction, taking into account the structural changes caused by liquid phase redistribution under wetting. A saturation related disturbance function expression was proposed. Subsequently, the saturated state was adopted as the fully adjusted state, and the high suction state was adopted as the relatively complete state. A constitutive model based on the disturbed state concept for unsaturated soil was then established. The model was validated using existing experimental results, which showed that the model can predict both the hardening characteristics of soil under low suction conditions and the brittleness characteristics of soil under high suction conditions. The model can well describe the shear characteristics of soil within a wide range of suction.

Keywords: disturbed state concept; unsaturated soils; wide range of suction; constitutive model.

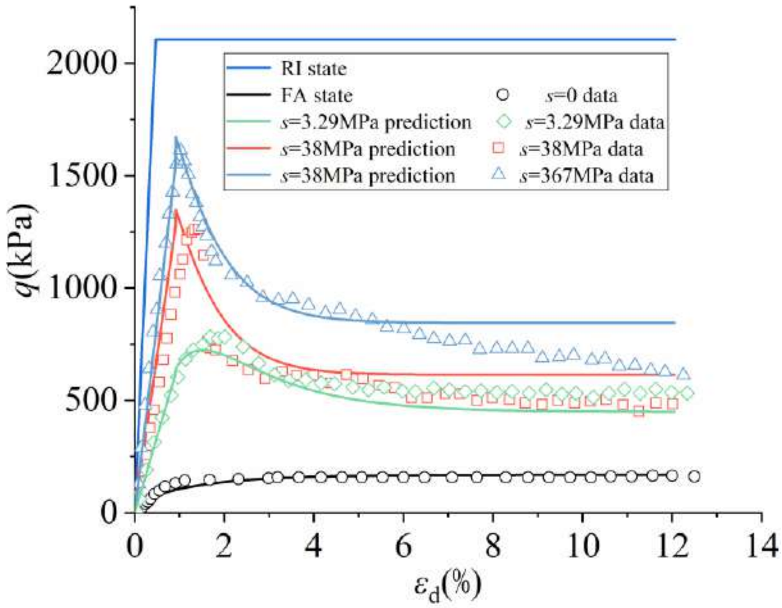

Fig. 1 Model predictions in a wide range of suction

COMPARISON OF HIGH-FREQUENCY COMPONENTS IN ACOUSTIC EMISSIONS FROM ROCK FRACTURE UNDER MODE I AND MODE II DOMINATED LOADING

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ABSTRACT

High-frequency components in acoustic emission (AE) or seismic radiation attract much attention as they are directly related to the fracture process. One of the main issues in our knowledge of high-frequency radiation is a lack of definition on the relationship between high-frequency content and source mechanisms. In this study, high-frequency emission waves due to rock fracture in tension and shear are studied experimentally and theoretically. Current data support that for each individual AE signal the later arriving waves contain lots of low-frequency components, while the high-frequency components are mostly carried by the direct arrivals. In comparison with tensile cracks, shear cracking generates more high-frequency components and tends to radiate energy in the form of waves with larger RA values. Combining the theories from dynamic fracture and acoustic radiation, the difference in high-frequency energy release from shear and tensile cracking can be attributed to the rate of stress drop at the tips. The present findings provide a framework for a new way to identify the tensile failure in rock. It will be helpful in solving the difficulty tracking seismic or micro-seismic events from tensile sources associated with karst collapsing, hydraulic fracturing and roof falling in mines.

Keywords: acoustic emission; high frequency components; Mode I loading; Mode II dominated loading; semi-circular bending test

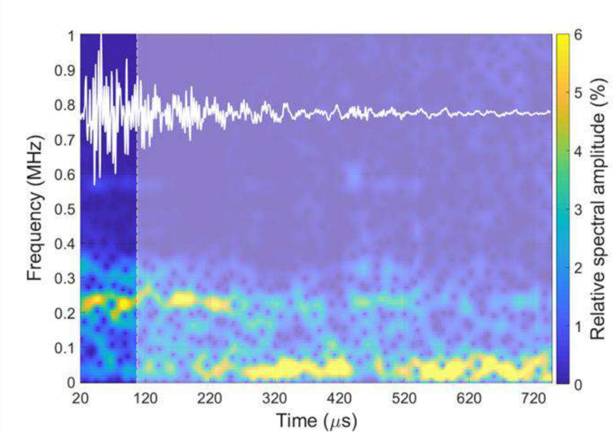

Fig. 1 The normalized spectrogram of an AE signal

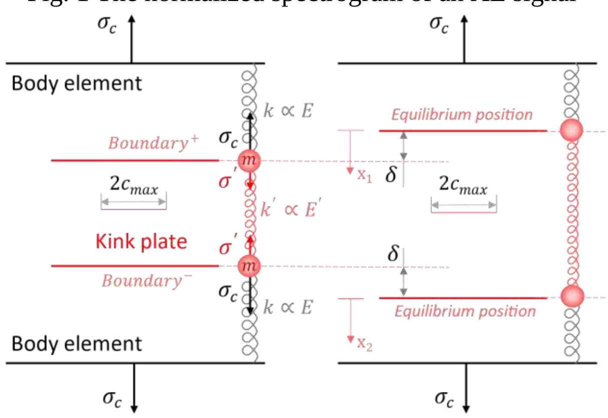

Fig. 2 Physical simplification for the boundary vibration from cracking

CHARACTERISTICS OF SOIL INTERNAL EROSION UNDER THE COUPLING EFFECT OF ANISOTROPIC STRESS AND CYCLIC HYDRAULIC LOADINGS

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ABSTRACT

Internal erosion, which involves the detachment and migration of soil particles from the soil matrix driven by seepage flow, occurs frequently in geotechnical and hydraulic structures. Previous studies primarily focused on soil internal erosion under the isotropic stress state and monotonic hydraulic loadings. However, the soil in engineering practices is under more complicated hydro-mechanical conditions, i.e. anisotropic stress states, and subjected to cyclic hydraulic loadings due to water level fluctuations. Under such conditions, the soil internal erosion process differs significantly from that under the monotonic seepage and isotropic stress states. Therefore, in this study, extensive laboratory tests were carried out to investigate the soil hydro-mechanical behaviour subjected to cyclic hydraulic loadings under various stress states. Detailed analysis was conducted on the soil internal erosion process, such as the eroded soil mass, seepage-induced soil deformations, post-erosion soil mechanical behaviours, etc. It was found that the soil experienced a gradually developed internal erosion process under an isotropic or low compressive shear stress, whereas it experienced rapid erosion followed by a complete failure when the stress ratio (η) was high. The cyclic hydrodynamic loadings played a negative role in the soil stability, which accelerated the occurrence of erosion due to stronger disturbance to the soil internal structure. Moreover, the peak and critical friction angles for all the post-erosion soils decreased considerably, particularly for the soils subjected to cyclic hydraulic gradients.

Keywords: internal erosion; anisotropic stress state; cyclic hydraulic gradient; post-erosion soil mechanical behaviour.

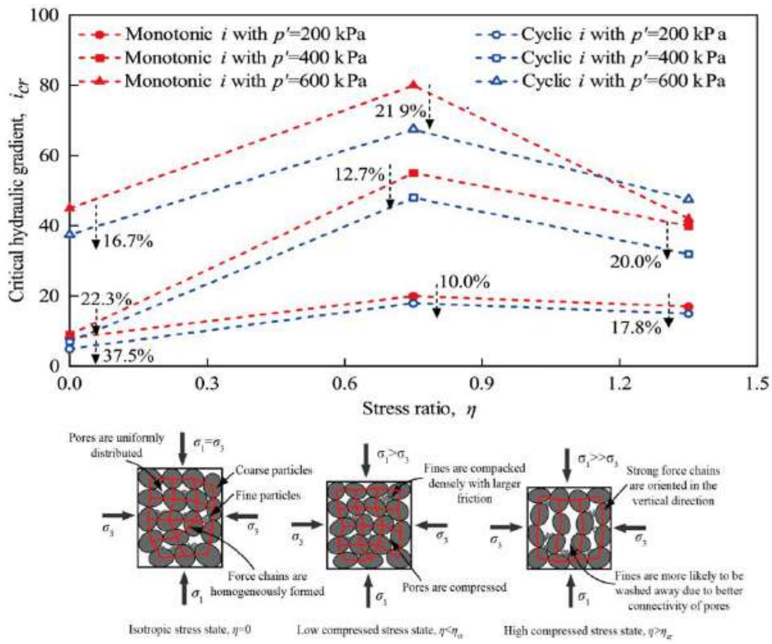

Fig. 1 Different soil critical hydraulic gradient under monotonic and cyclic hydraulic gradients

CROSS-SCALE CHARACTERIZATION OF MUDSTONE DETERIORATION AFTER WATER IMMERSION BASED ON NANOINDENTATION TECHNOLOGY AND SIMULATION

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ABSTRACT

Typical characteristics of mudstone include low strength, easy disintegration, gradual softening in water. Accurately characterizing the mechanical properties evolution of mudstone at the microscopic mineral scale after water immersion is very challenging. In this study, the mechanical degradation process of each microscopic mineral composition of mudstone was quantitatively analyzed by Nanoindentation technology combined with simulation research method. And the relationship between the Young's modulus of the micro minerals and the macro test results was accurately established. Test results indicate that the Young's moduli of quartz, feldspar minerals, and clay matrix in the original mudstone samples were 150.07, 65.37, and 14.91 GPa, respectively, which decreased to 148.28, 52.37, and 9.13 GPa after immersion. Micro - interfaces were formed after water immersion, because of the intrusion of clay minerals into the originally clastic mineral area. Based on nanoindentation results after deconvolution, the "three compositions - two interfaces" model of mudstone proposed in this study can accurately evaluate the macro - mechanical parameters, and realize the cross - scale characterization of the degradation mechanism of mudstone after water immersion.

Keywords: Mudstone, Deterioration, Cross-scale, Nanoindentation, Young's modulus

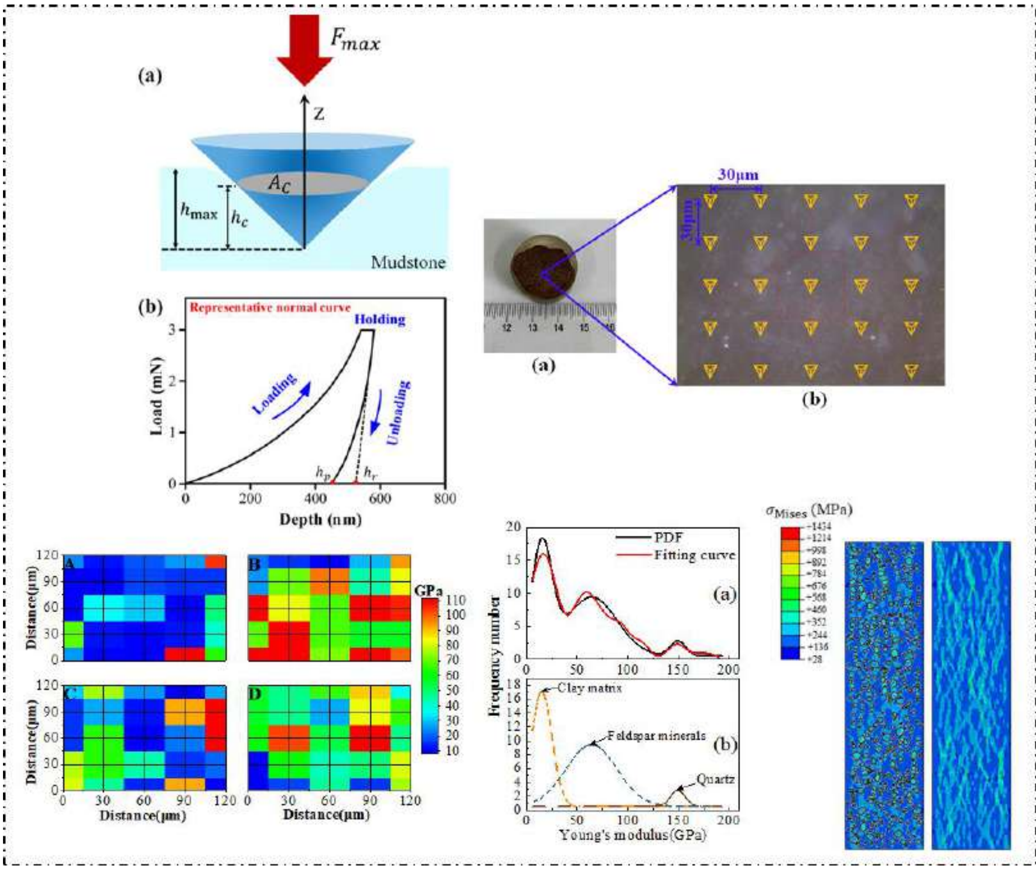

Fig. 1 Illustration of the proposed method.

FREEZING EFFECTIVENESS OF SINGLE FREEZING PIPE IN SAND-CLAY STRATUM UNDER DIFFERENT SEAWATER INFILTRATION VELOCITY

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ABSTRACT

The seepage velocity in the sandy clay stratum will affect the freezing range of the freezing pipe. The hydro-salt-thermal-mechanical model of the influence of seepage flow on the artificial freezing process in sand-clay stratum is derived. The influence of momentum conservation of fluid in seepage process is considered by Navier-Stokes equation. The good consistency between the results from the theoretical model and laboratory tests in the literature verified the accuracy of the proposed model. Parametric studies are conducted to investigate the influences of the seepage velocities on the spatial distributions. It is found that with the seepage velocity increases, in the sand layer and clay layer of the sand-clay stratum, the influence range of temperature is reduced by 58.1 % and 13.3 %, respectively, the influence range of the crystalline salt is reduced by 58 % and 30.6 %, respectively. In the upstream of the sand-clay stratum, the leading edge of salt crystallization in the sand layer and the clay layer decreased by 50.4 % and 26.2 %, respectively. When the seepage velocity is 15 m/d, in the sand-clay layer, the range of ice formation in the sand layer is 50.2 % lower than that in the clay layer.

Keywords: saturated frozen marine soil, frozen pipe, seepage flow, coupling of hydro-thermal-salt-mechanical, adsorption and desorption effect, sand-clay stratum

$$\frac{\partial(\phi^s\rho_s^s)}{\partial t}+\nabla\cdot(\phi^s\rho_s^s\boldsymbol{v}^s)=0 \tag{1}$$

$$\frac{\partial(nS^l\rho_w^l)}{\partial t}+\nabla\cdot\left[nS^l\rho_w^l\left(\frac{\boldsymbol{q}^l}{nS^l}+\boldsymbol{v}^s\right)\right]-\nabla\boldsymbol{j}_p^l=-\frac{\partial m_i}{\partial t}-\frac{\partial m_p^l}{\partial t} \tag{2}$$

$$S^i\rho^i\frac{\partial n}{\partial t}+n\rho^i\frac{\partial S^i}{\partial t}+nS^i\rho^i\nabla\cdot\boldsymbol{v}^s=\frac{\partial m_i}{\partial t} \tag{3}$$

$$\frac{\partial(nS^l\rho_p^l)}{\partial t}+\nabla\cdot(nS^l\rho_p^l\boldsymbol{v}^l)+\nabla\boldsymbol{j}_p^l=-\frac{\partial m_p}{\partial t}-\frac{\partial m_p^l}{\partial t} \tag{4}$$

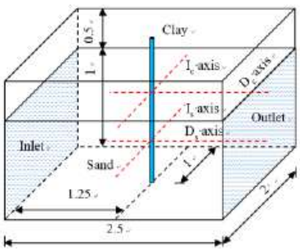
$$(1-n)\rho^s\frac{\partial w_p^s}{\partial t}=k_{ad}nS^l\rho^l w_p^l-k_{de}(1-n)\rho^s w_p^s \tag{5}$$

$$S^p\rho^p\frac{\partial n}{\partial t}+n\rho^p\frac{\partial S^p}{\partial t}+nS^p\rho^p\frac{\partial\varepsilon_v}{\partial t}=\frac{\partial m_p}{\partial t} \tag{6}$$

$$\frac{\partial\Phi_h}{\partial t}+\nabla\cdot q_h=L_{wi}\frac{\partial m_i}{\partial t}+L_{sc}\frac{\partial m_p}{\partial t}+L_{lp}\frac{\partial m_p^l}{\partial t} \tag{7}$$

$$\begin{aligned}&\nabla\left[\left[\boldsymbol{D}:(\boldsymbol{\varepsilon}-\boldsymbol{\varepsilon}_T-\boldsymbol{\varepsilon}_s-\boldsymbol{\varepsilon}_f-\boldsymbol{\varepsilon}_r)\right]+\alpha_B\left(S^lP_l+S^iP^i+S^pP^p\right)\boldsymbol{\delta}\right]\\&+\left[(1-n)\rho^s+nS^l\rho^l+nS^i\rho^i+nS^p\rho^p\right]\boldsymbol{g}=0\end{aligned} \tag{8}$$

(a)



(b)

Fig. 1 The (a) coupling model and (b) numerical diagram in this study

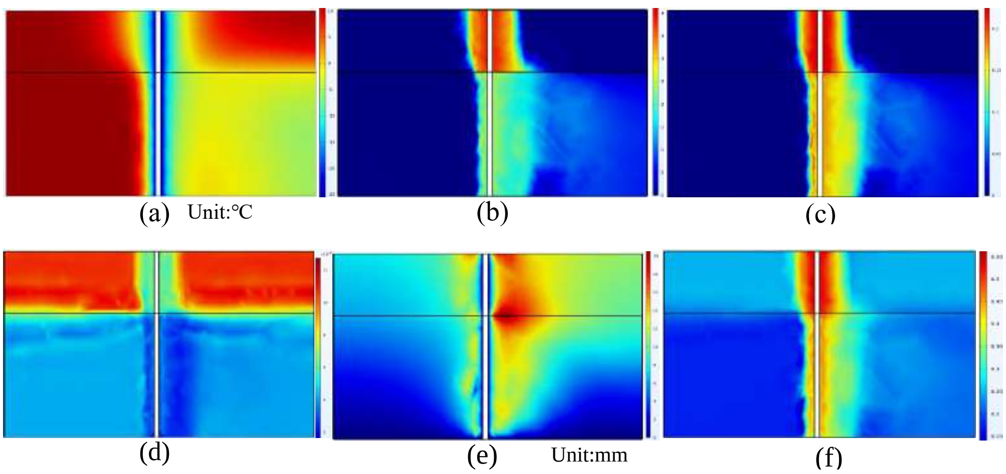


Fig. 2 The contour map of the (a) temperature, (b) ice content, (c) crystalline salt content, (d) adsorbed salt content, (e) soil displacement and (f) total salt content distribution profile in soil specimen after 70 h of freezing with seepage velocity of 10 m/d

COMPARISON OF THE SHADOW EFFECT OF AN EXISTING TUNNEL SHAPE ON THE EVOLUTION SOIL ARCHING

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ABSTRACT

This study evaluates the shadowing effect of existing tunnels on the evolution of soil arching, focusing on the shape of the tunnel (circular and rectangular) through trapdoor experiments. The displacement and shear strain distributions of ground soil resulting from trapdoor movement were estimated using a digital image correlation technique. The results showed that the shadowing effect of the rectangular tunnel was significantly greater than that of the circular tunnel of the same size. The sand above the tunnel was displaced in a double-groove pattern owing to the presence of the tunnel, and the maximum surface settlement occurred between the tunnel boundary and the trapdoor edge. The shear strain value of soil was lower for the rectangular tunnel case than that for the circular tunnel case. The rectangular tunnels required lesser trapdoor displacement than that of the circular tunnel to obtain the minimum soil arching ratio. The maximum stress ratio of the tunnel crown was consistently larger for the circular case than for the rectangular case.

Keywords: Soil arching; Circular tunnel; Rectangular tunnel; Trapdoor test; Digital image correlation

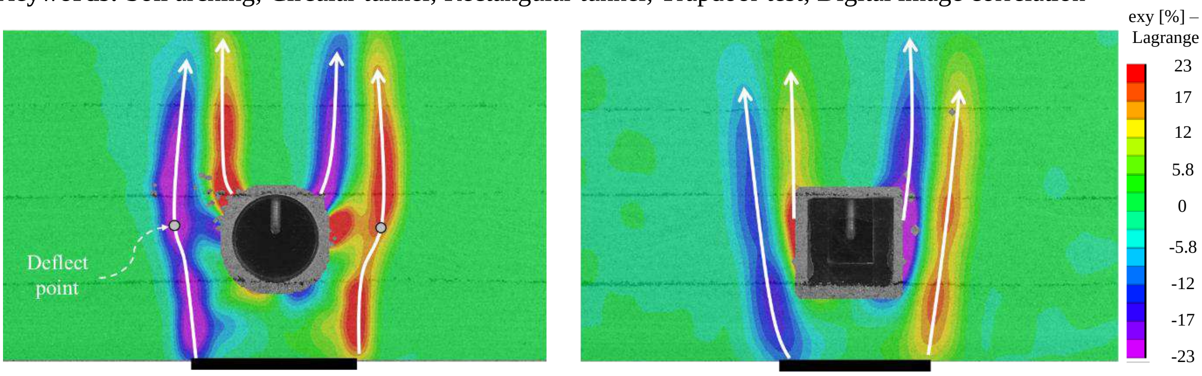

Fig. 1 Comparison of shear strain for different tunnel shape

REAL-TIME SETTLEMENT FIELD RECONSTRUCTION USING DEEP OPERATOR NETWORKS

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ABSTRACT

The assessment of surface settlements during mechanized tunneling is of importance and remains a challenging research topic. Generally, the surface settlement can be predicted using different paradigms: either a physics-driven approach utilizing computational models, or a data-driven approach employing machine learning techniques to establish mappings between influencing factors and ground settlement. In this work, we introduce a multi-fidelity deep operator network (DeepONet) framework to combine the advantages of both approaches and assimilate the data from different sources. The presented framework, which leverages the recently developed operator learning methods, comprises two components: a low-fidelity subnet that captures the fundamental ground settlement patterns obtained from finite element simulations, and a high-fidelity subnet that learns the nonlinear correlation between numerical models and real engineering monitoring data. The results show that the proposed method can capture not only the physical laws governed by numerical simulations, but also accurately fit measured data as well. Remarkably, even with limited noisy measurement data, our model can still provide rapid, precise, and robust reconstruction of the full-field surface settlement in real-time during mechanized tunneling.

Keywords: DeepONet, Multi-fidelity, Tunnel boring machine, Ground settlement prediction, Physics-informed machine learning.

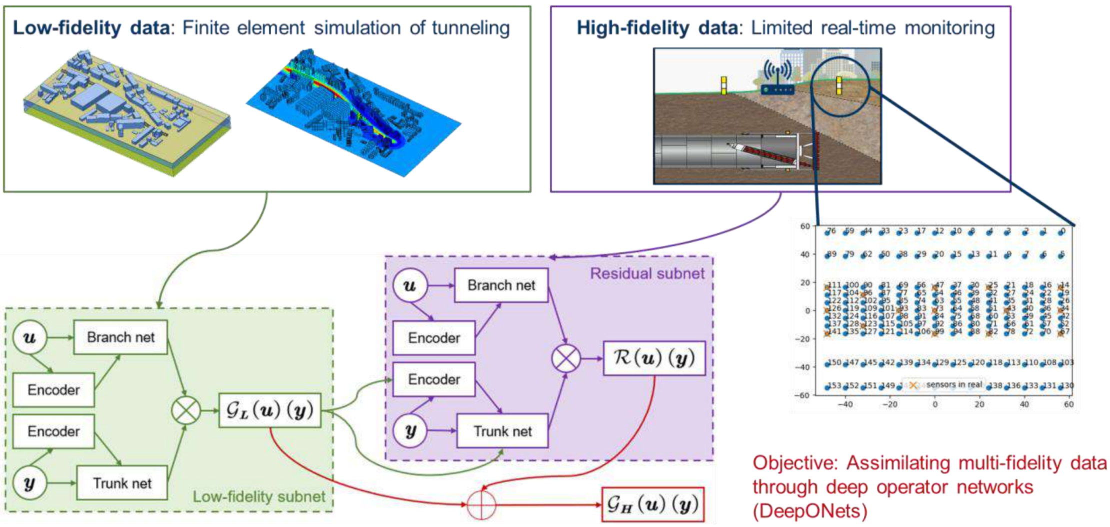

Fig. 1 Illustration of the proposed method

INTELLIGENT MODEL TO PREDICT DISC CUTTER WEAR IN REAL-TIME

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ABSTRACT

This paper proposed a new index for evaluation of disc cutter life during earth pressure balance (EPB) tunnelling. This new index was defined as the ratio of accumulated cutter radial wear to working time of the shield machine. With this new index, the measured disc cutter wear can be transformed into a time series data. To predict cutter wear with construction process, an ensemble intelligent model integrating one-dimensional convolutional neural network (1D-CNN) and gated recurrent unit (GRU) was developed via incorporating the proposed cutter wear index. A multi-step-forward prediction mode was adopted to train the ensemble model to predict cutter wear in advance. Field data collected from an EPB tunnelling section in Guangzhou-Foshan intercity railway, Guangzhou, China, was used for validation. Results showed that the proposed index and ensemble model can predict wear of a certain cutter with high accuracy. Three other sequential deep networks were employed for comparison to verify the applicability of the proposed index and ensemble model. The proposed index and ensemble model is convenient to be used on site and can predict wear of a certain cutter on cutterhead to help determine which cutter to be replaced during real-time construction.

Keywords: evaluation index; cutter life; prediction model; cutter wear; EPB tunnelling.

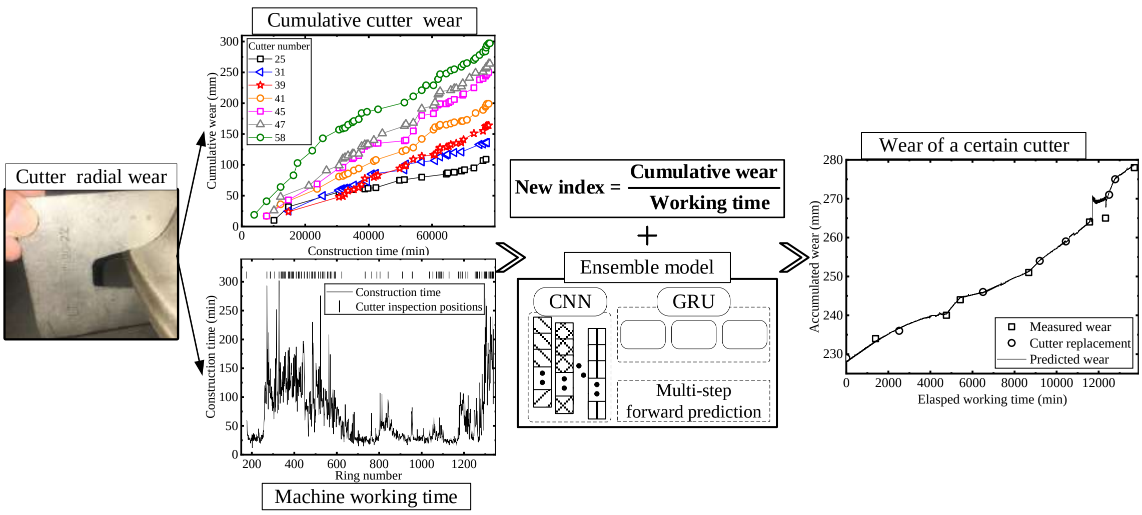

Fig. 1 Illustration of the proposed method

IDENTIFICATION OF SOIL-ROCK INTERFACES BASED ON DEEP LEARNING METHODS WITH VIBRATION DATA FOR SHIELD TUNNELING

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ABSTRACT

This study proposed a new approach for soil-rock interface detection based on deep learning methods and shield vibration data. The shield vibration signals were collected from the installed accelerometers on the cutterhead, which were generated by the disc cutters colliding with the soil-rock interfaces. The features of shield vibration (the acceleration peaks and cycles) coincided with the shield excavation process in various formations, which were analysed and presented by the time-frequency spectrum. Then, the time-series vibration data and time-frequency spectrum were considered as the input set for the deep learning algorithms (long short-term memory neural network and ResNet), which were trained and evaluated to select the best soil-rock interface detection model. The results showed that the soil-rock interface detection model could achieve high performance to provide more precise geological information for shield operators. A case study of the shield tunnel project in Guangzhou, China, was conducted to verify the high efficiency and effectiveness of the soil-rock interface detection model.

Keywords: Soil-rock interface; vibration data; deep learning; identification.

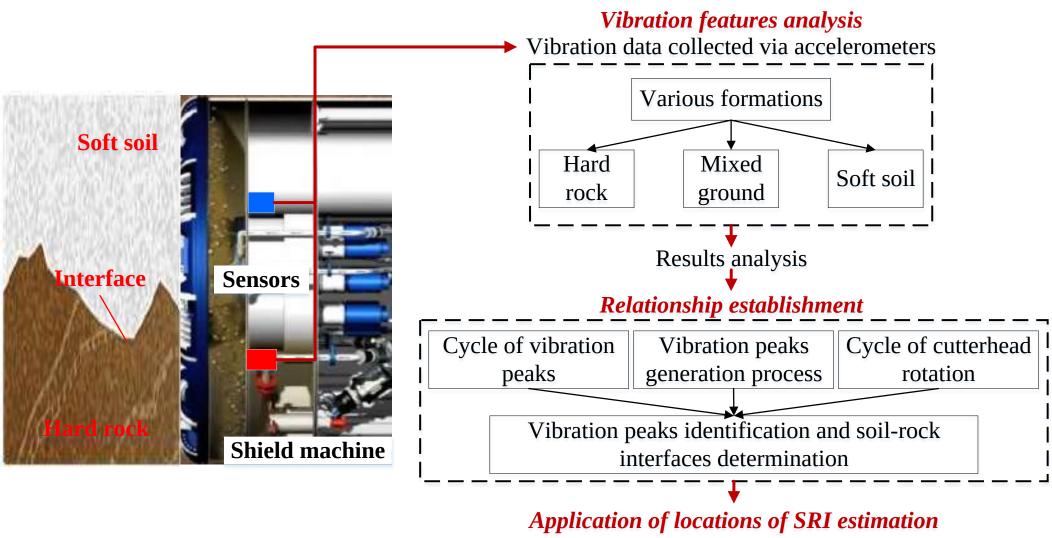

Fig. 1 Illustration of the proposed method (recreated from Shen et al., 2023).

STUDY ON DAMAGE CHARACTERISTICS OF SANDSTONE AFTER LONG-TERM FREEZING BASED ON NUCLEAR MAGNETIC RESONANCE TECHNOLOGY

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ABSTRACT

In order to study the damage characteristics of sandstone after long-term freezing, nuclear magnetic resonance technology was used to test the thawed sandstone after freezing for 0d, 5d, 10d, 20d, 30d, 40d, 50d and 60d under the saturation boundary, impermeable layer boundary and porous aquifer boundary. The corresponding T_2 spectrum distribution, T_2 spectral peak area, porosity and uniaxial compressive strength were obtained. The results show that, under the three boundary conditions, the internal pores of sandstone samples after long-term freezing are mainly micro pores, and small size pores and large pores is relatively small. The T_2 spectrum curve of sandstone moves to the left with the increase of freezing time, and the new pores are mainly micro and small size.The boundary conditions have a certain effect on the sequence and increase of internal pores of sandstone samples during long-term freezing, and the uniaxial compressive strength of sandstone samples decreases exponentially with the increase of porosity. The degree of sandstone damage was defined by the NMR porosity. The relationship between NMR porosity and damage variable was analyzed, and the functional relationship between freezing time and damage variable under three boundary conditions was established.

Keywords: nuclear magnetic resonance; long-term freezing; T_2 spectrum distribution; T_2 spectral peak area; porosity; damage variable

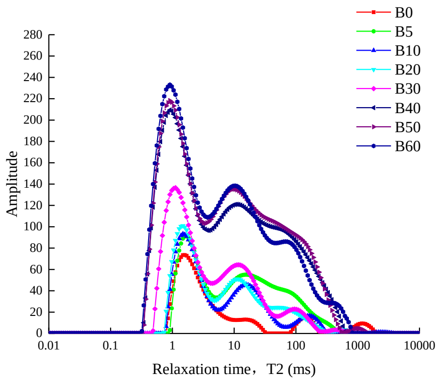

Fig. 1 Corresponding T_2 spectrum distribution of saturation boundary

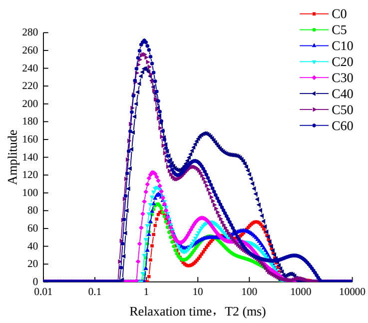

Fig. 2 Corresponding T_2 spectrum distribution of impermeable layer boundary

STUDY ON MECHANICAL PERFORMANCE MONITORING OF PREFABRICATED SUBWAY STATIONS USING DISTRIBUTED FIBER OPTIC SENSORS

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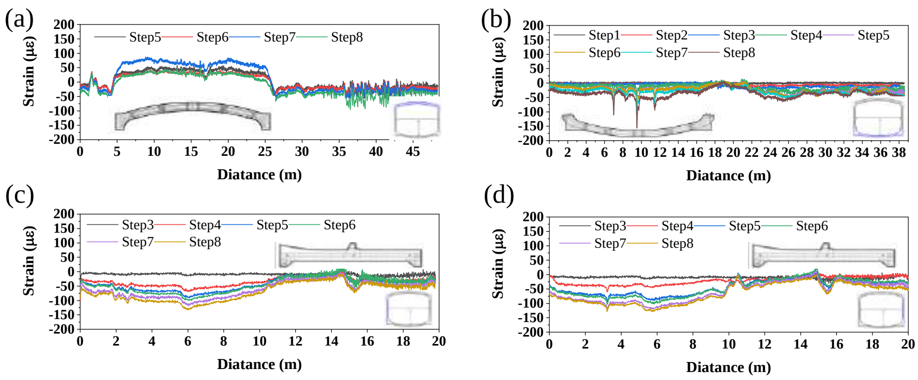
ABSTRACT

Mechanical performance of prefabricated structures is a key issue of construction safety for subway stations. In this study, distributed optical fiber sensors (DOFS) were adopted for monitoring stress/strain distribution in prefabricated structures in underground stations. DOFS were directly mounted inside prefabricated concrete structures. Strain fields of prefabricated components associated with assembling process were successfully obtained during construction phases. Monitored strain fields reveal that stress/strain concentration positions were mostly occurred at the middle position of both baseplates and side wall sections. Strain distribution were found continuously distributed inside prefabricated components and a maximum monitored strain were around -150 με in baseplate. Assembling of the two side walls led to an average strain change of -40με. After the assembly of the roof, slightly strain changes were observed in the both side walls, with a maximum value of -66 με at the mid-span, indicating that the assembly of adjacent components caused limited disturbance to the whole structure. Monitoring system based on DOFS was found to reflect the continuous strain distributions of prefabricated components during assembling process and can be used to indicate the potential high-risk positions in terms of continuous DOFS strain data.

Keywords: Prefabricated underground station; Assembly construction; Distributed optical fiber sensors; strain field; mechanical performance.

Fig. 1 Photos of the construction process for prefabricated underground station- Longxing station.



Note: Step1: Assembly of the left wall for Ring 20; Step2: Assembly of the left wall for Ring 20; Step3: Assembly of the middle plate for Ring 20; Step4: Assembly of the roof for Ring 20; Step5: Assembly of half-rings at Ring 19; Step6: Assembly of Ring 19; Step7: Assembly of half-rings at Ring 18; Step8: Assembly of Ring 18.

Fig. 2 Deformation evolution of the 20-ring components: (a) Roof strain; (b) Baseplate strain; (c) Left side wall strain; (d) Right side wall strain.

STUDY ON COUPLED TEMPERATURE AND PRESSURE CONDUCTION MECHANISM AND SENSOR VALIDATION IN IN-SITU DEEP ENVIRONMENT SIMULATION EXPERIMENTS OF ROCKS

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ABSTRACT

As the depth of deep engineering increases, a systematic exploration of deep-seated scientific principles becomes imperative. Existing simulations of deep in-situ environments, such as rock mechanics triaxial tests, coring experiments, and hydraulic fracturing, often rely on external sensor readings to reach predefined values. However, the internal temperature and pressure conduction within the rocks is not considered, which might lead to the initiation of destructive mechanical tests before the internal conditions reach the predefined values. This impacts the simulation of in-situ mechanical parameters and the exploration of deep Earth scientific principles, particularly pronounced in large-scale rock experiments. Based on in-situ high-temperature and high-pressure static hydrostatic environments in deep Earth, established a coupled model for internal pressure and temperature sensitivity conduction for large-scale simulated concrete rock samples (Φ450mmH1400mm). Through numerical simulations and tests, it preliminarily explored the time required for different rock samples to achieve uniform temperature and pressure under different in-situ environmental conditions. Utilizing a self-developed ultra-large triaxial testing instrument, the study designed a sensor structure and sealing method (150°C + 140MPa) for measuring internal temperature and pressure of concrete, enabling real-time measurement and data transmission of the temperature and pressure field during high-temperature and high-pressure triaxial tests. The measured data was used to validate and adjust the temperature and pressure conduction model, and an optimized triaxial test temperature and pressure application path was formed. This provided effective reference for in-situ high-temperature and high-pressure simulation experiments in deep Earth and laid the foundation for subsequent exploration of deep Earth scientific principles.

Key words: Deep earth science; Deep in-situ simulation experiment; Stress sensitivity; Temperature and pressure coupling; High-temperature and high-pressure sensor

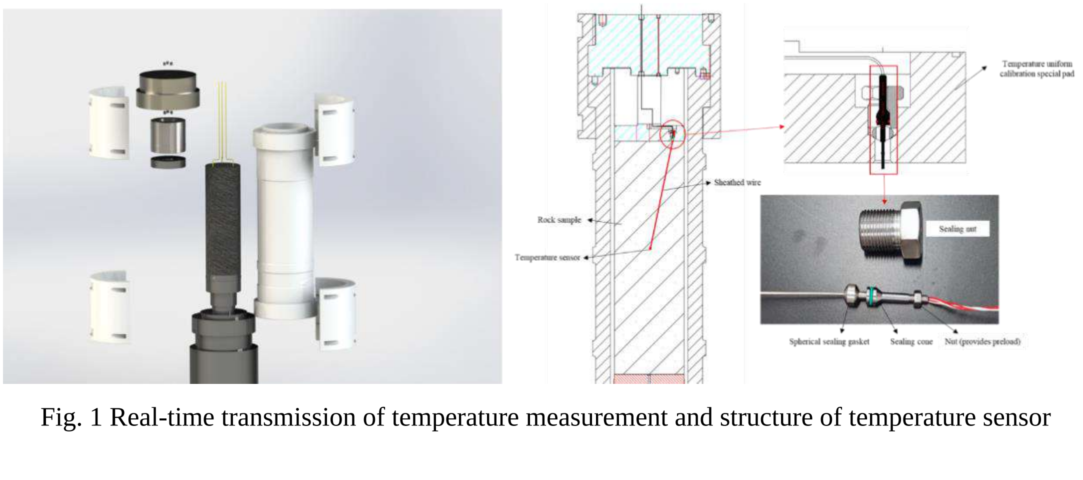

Fig. 1 Real-time transmission of temperature measurement and structure of temperature sensor

CONFINED AQUIFER DEWATERING OPTIMIZATION WITH A MODIFIED SIMULATION-OPTIMIZATION METHOD CONSIDERING THE LENGTH AND DEPTH OF WELL SCREEN

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ABSTRACT

The use of simulation-optimization method is widespread in dewatering optimization. However, traditional methods cannot compute the optimal well screen length and depth. A modified simulation-optimization method that considers screen length and depth for confined aquifer dewatering optimization is proposed, which is based on the linear programming method. The multivariate adaptive regression splines method is also introduced to develop the prediction model of the required parameters. A hypothetical dewatering case was optimized using the proposed method to demonstrate its feasibility, with the optimal pumping rates, screen lengths and depths of all activated wells computed. Additionally, parametric studies were performed to investigate the effects of some important factors on the optimization results, such as the number of considered pumping wells, required drawdown, insertion ratio of curtain, aquifer anisotropy coefficient, and prescribed length and depth of well screen. The results show that optimal total pumping rate and screen length generally increase with increasing required drawdown and aquifer anisotropy coefficient, and decrease with increasing considered well numbers and insertion ratio of curtain. Adjusting screen length is more critical since lower screen depth is always preferred. Optimizing well screen is more essential for higher well numbers, insertion ratio of curtain, and lower aquifer anisotropy coefficient.

Keywords: Confined aquifer dewatering; Simulation-optimization; Well screen length and depth; Linear programming; Multivariate adaptive regression splines.

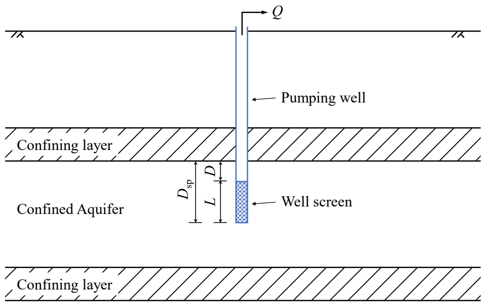

Fig. 1 Definition of the well screen length (L) and depth (D)

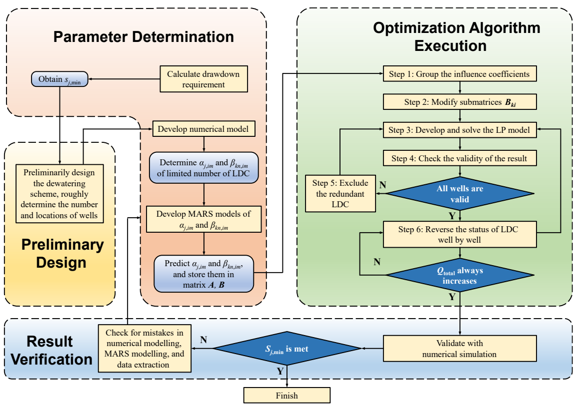

Fig. 2 Processes of the modified method

EXPERIMENTAL STUDY ON PORE STRUCTURE EVOLUTION AND AE RESPONSE CHARACTERISTICS OF DRY-WET CYCLE COAL SAMPLES

Hongxin Xie[1], Qiangling Yao[2#], Zetian Zhang[1], Changhao Shan[2], Ze Xia[2], Xuehua Li[2], Heng Gao[1], Yihang Li[1]

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ABSTRACT

Underground coal reservoir has become one of the main technologies to realize the co-exploitation of coal-water resources in ecologically fragile mining areas in western China. Revealing the internal mechanism of weakening coal strength under the action of dry-wet cycle is necessary for the sustainable operation of underground reservoirs. In this paper, through X-ray diffraction (XRD), nuclear magnetic resonance (NMR), uniaxial compression (UCT) and acoustic emission (AE) experiments, the pore structure parameters of coal samples under the influence of dry-wet cycles were quantitatively characterized, and the characteristics of AE response and crack propagation mechanism were analysed. The results show that the number of dry-wet cycles can promote the increase of pore expansion capacity, porosity and permeability. After seven dry-wet cycles, the effective porosity of coal samples increases from 4.67% to 6.18%, and the permeability increases from 0.0248mD to 0.0304mD. In the pore compaction stage, with the increase of dry-wet cycle times of coal samples, AE signals become more active, while in the unstable fracture development stage, it is the opposite. This study reveals the strength weakening mechanism of coal pillar dam body of underground reservoir from pore scale, which provides reference for long-term stability evaluation of underground reservoir.

Keywords: underground reservoir; coal pillar dam; dry-wet cycle; pore structure; AE response.

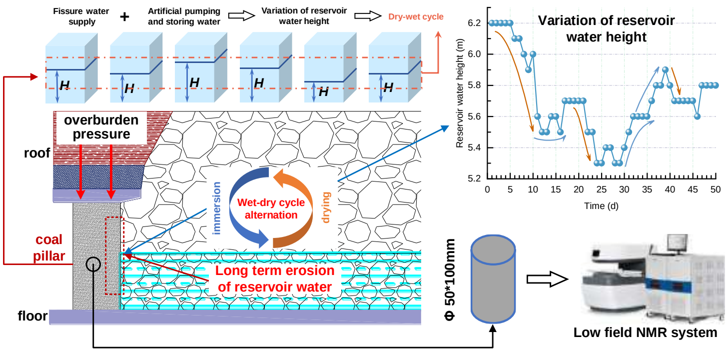

Fig. 1 Engineering environment and experimental schematic diagram of coal pillar dam of underground reservoir in coal mine

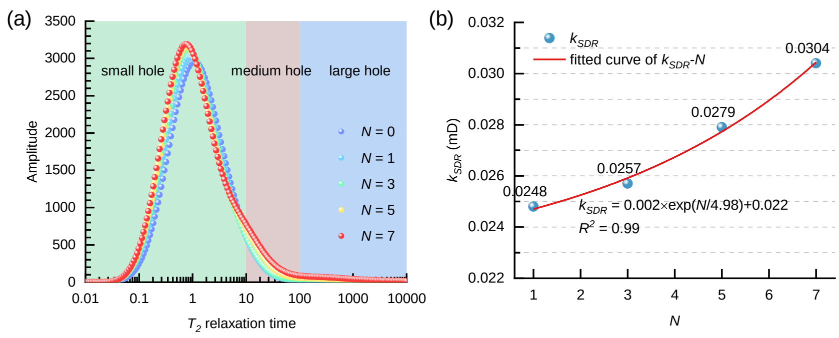

Fig. 2 Characteristics of T_2 spectrum curve (a) and permeability evolution (b) of dry-wet cycle coal samples

EXPERIMENTAL STUDY ON MECHANICAL RESPONSE OF DEEP ROCK AND CONSTITUTIVE MODEL BASED ON LARGE SIZE ROCK SAMPLES

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[2] *Institute of Deep Earth Science and Green Energy, College of Civil and Transportation Engineering, Shenzhen University, Shenzhen 518060, China*
[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

In-situ mechanical properties of deep rock serve as a seminal scientific and fundamental theoretical basis for deep drilling, exploitation of deep-seated resources, and deep rock engineering. The self-developed a deep rock in-situ condition preserved coring calibration platform was employed for testing, aiming to investigate the mechanical behavior of large-scale rock specimens (Φ200mm×400mm, Φ300mm×600mm, Φ450mm×1400mm) under deep conditions (high-temperature and high-pressure). In order to obtain the physical properties, mechanical properties, mining-induced disturbance, and time-dependent behavior of deep in-situ rocks, reveal the essential differences in the physical characteristics and mechanical behavior of rocks with different burial depth, and realize the exploration of scientific laws and quantitative description of the mechanical behaviors of the deep rocks. In addition, utilizing three-dimensional rock mechanics acoustic testing techniques, the damage and energy evolution characteristics of rock specimens are obtained with the aim of establishing a novel constitutive theory for deep in-situ rock mechanics. This study aims to gain novel insights into deep rock mechanics and deep rock engineering. The significance of this research extends to environmental, societal, and economic sustainability in engineering practices.

Keywords: Deep rock; Burial depth; Damage; Energy evolution; Constitutive theory.

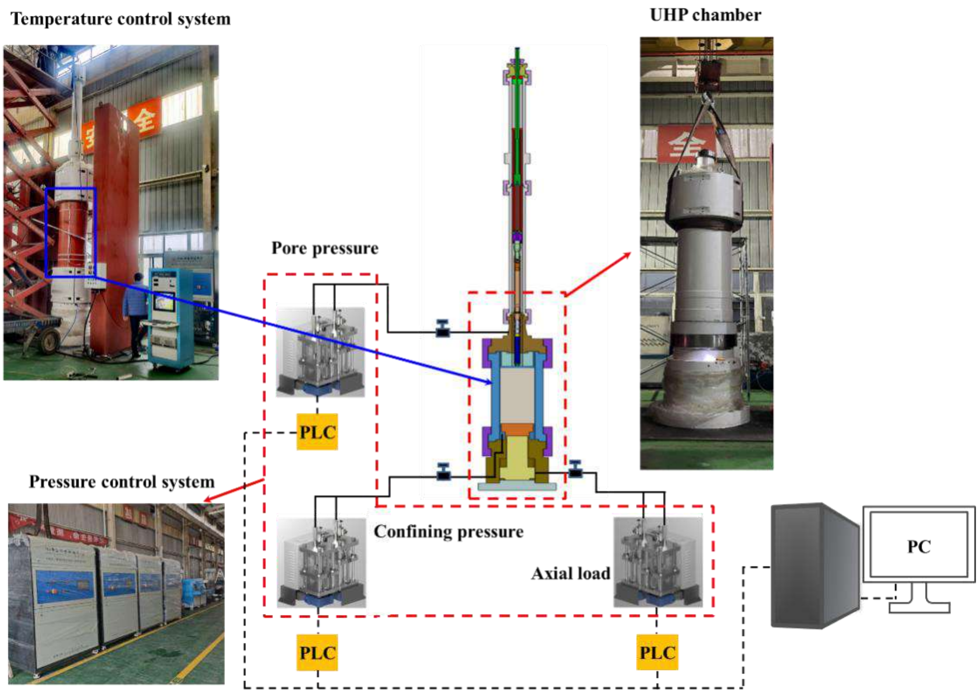

Fig. 1 Structural diagram of the deep rock in-situ condition preserved coring calibration platform

DEFORMATION CHARACTERISTICS AND GAS PERMEABILITY OF LOW-PERMEABILITY SANDSTONE AND ANISOTROPIC PHYLLITE UNDER TRIAXIAL CYCLIC LOADING STRESS PATH

Xuelei Duan[1], Wei Wang[1#], Yajun Cao[1], Chao Chen[1], Rubin Wang[1] and Qizhi Zhu[1]
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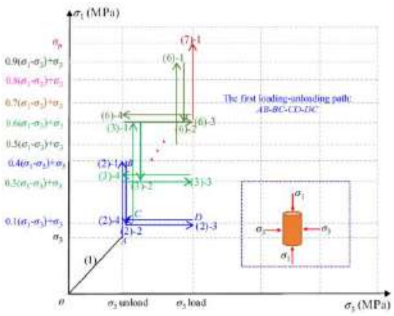
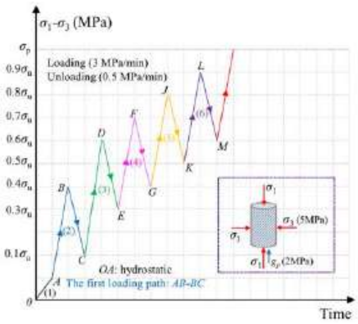
ABSTRACT

To guarantee the safety and stability of underground disposal and oil and gas resource extraction, deformation behavior and permeability evolution of host rock mass are studied in the present work, with a special attention to the influence of loading and unloading cycles of deviatoric stress and confining pressure. A series of triaxial compression tests with loading-unloading cycles and gas permeability measurements are performed on a low-porosity sandstone and anisotropic phyllite using a rock automatic servo-controlled triaxial testing system. The deformation parameters (Young's modulus E, deformation modulus E_{50}, Poisson's ratio μ), characteristic stress parameters (σ_{cc}, σ_{ci}, σ_{cd}), failure mechanism obtained under different levels of confining pressure and deviatoric stress are analyzed. Based on the steady-state method and Darcy's law, gas permeability of a low-porosity sandstone and anisotropic phyllite are discussed. With increasing cycle number, the permeability of low-porosity sandstone decreases firstly and then increases progressively, even a rapid increase after peak stress. These phenomena are related to the propagation and compaction of micro-cracks inside the sandstone specimens. Moreover, the relationships between the initial gas permeability of anisotropic phyllite and confining pressure, deviatoric stress show positive correlations.

Keywords: Rock mechanics, Deformation characteristics, Gas permeability, Triaxial cyclic loading.

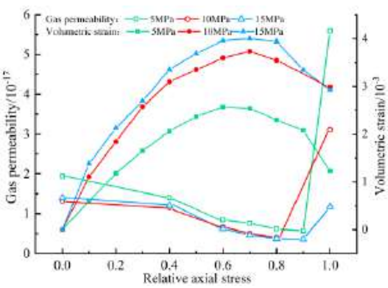


(a) Loading stress path of low-porosity sandstone

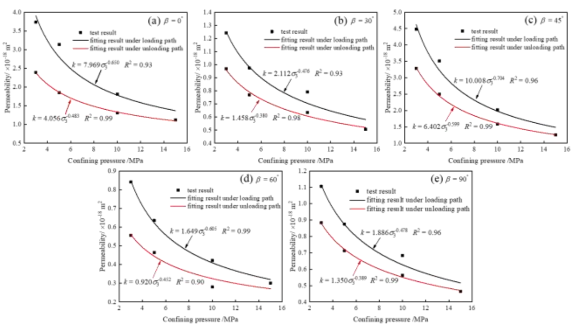


(b) Loading stress path of anisotropic phyllite

Fig.1 The triaxial cyclic loading stress path diagram



(a) gas permeability of low-porosity sandstone



(b) gas permeability of anisotropic phyllite

Fig. 2 Gas permeability of low-porosity sandstone and anisotropic phyllite under cyclic loading path

STUDY ON THE CAVING MECHANISM AND DEVELOPMENT PROCESS OF THE COMBINED ROOF BASED ON MICROSEISMIC MONITORING

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ABSTRACT

In the process of transferring the downward layered cemented filling mining method to the sublevel mining caving method in the West Mining Area of Longshou Mine, the natural caving of the combined roof is artificially induced to form the overburden. Studying the caving mechanism of the combined roof and mastering its development process are of great significance for the smooth formation of the overburden and the safety of the sublevel caving stope. In this paper, the microseismic monitoring technology is used to monitor the damage and caving process of the combined roof in the sublevel caving stope of the West Mining Area in real time. Monitoring results show that during the first mining level of the sublevel caving, the fracture microseismic events in the combined roof are mainly concentrated at 30 m to 45 m behind the mined-out area, within 5 m of the rear edge of the mined-out area, and the center of the mined-out area roof in sequence. On the basis of these results, the causes of microseismic events of combined roof fracture in different locations and the internal mechanism of combined roof failure are analyzed. Through theoretical calculation, the relationship between 1580 m level ore drawing and the development height of combined roof caving is discussed and is mutually confirmed with the microseismic monitoring results. Overall, this study reveals that the combined roof of the sublevel caving stope in the West Mining Area caved safely and timely as expected to form an overburden layer, which provides a good foundation for the overall success of the sublevel caving method in the mine.

Keywords: Sublevel caving mining method; Combined roof; Overburden formation; Caving mechanism; Microseismic monitoring

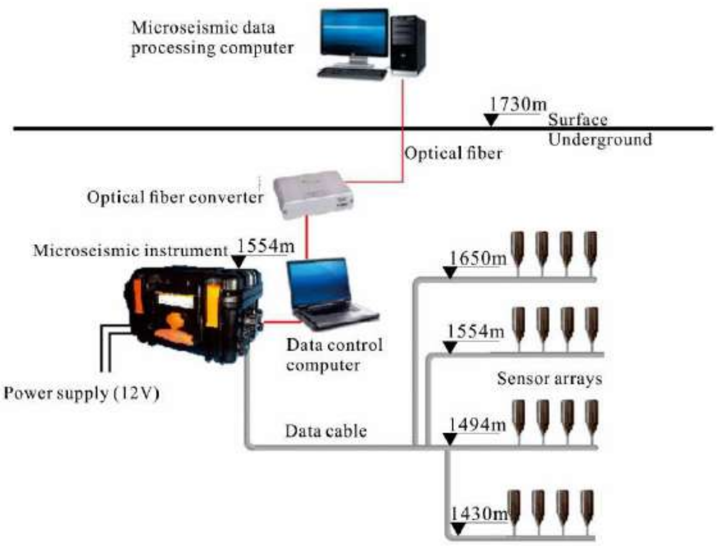

Fig. 1 Composition of the microseismic system in the West Mining Area

Optimal Sensor Placement for Wireless Sensing of Shield Tunnel Deformation in the Longitudinal Direction

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ABSTRACT

In order to enhance the sustainability and resilience of crucial infrastructure, structural health monitoring (SHM) is essential. Wireless sensor network (WSN) based monitoring technique has the advantages of easy deployment, low cost, high reliability, scalability and real time sensing. However, due to the limited budget for maintenance, wireless sensors cannot cover the whole range of large-scale infrastructure such as shield tunnels. Therefore, it is crucial to design an optimal sensor deployment scheme and maximize the efficiency of each wireless sensor. An optimal deployment criteria of minimizing measurement correlations is proposed for wireless sensors. The optimization of cross section deformation monitoring scheme is presented for shield tunnels in the longitudinal direction as an example. A numerical model of shield tunnels considering the ring joints is developed and validated. The vertical loads and lateral pressure coefficients are modelled with uncertainty. Monte Carlo simulation is conducted to obtain the probability distribution of tunnel cross section deformation. The correlation coefficient and mutual entropy are adopted to quantify the correlations between the measurements of any two sensors. Optimal inter-distance between monitoring cross section is determined. The influence of ring joint stiffness on these two indicators and optimal inter-distance is discussed.

Keywords: optimal sensor placement, wireless sensing, shield tunnel, mutual entropy

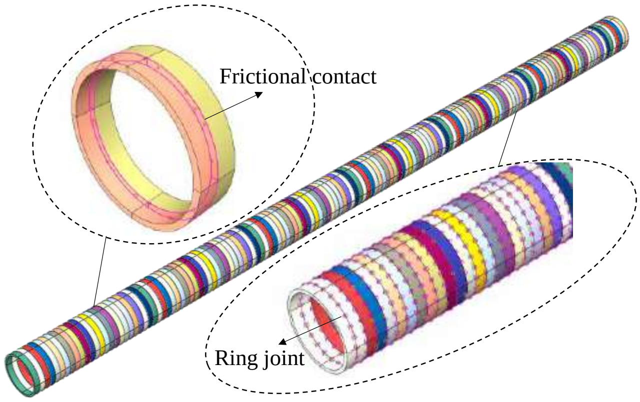

Fig. 1 Numerical model for shield tunnels in the longitudinal direction

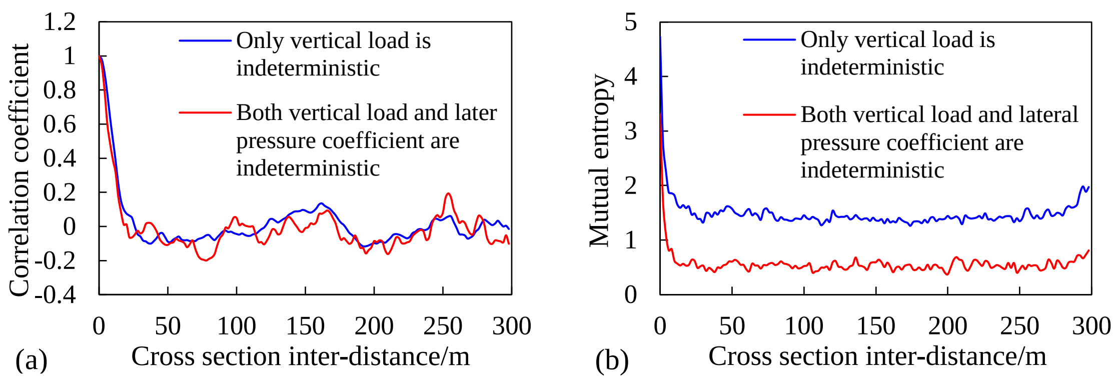

Fig. 2 Tunnel cross section deformation correlation coefficients and mutual entropy in the longitudinal direction: (a) correlation coefficients; (b) mutual entropy

A NEW VISCOELASTIC-PLASTIC SOLUTION OF SOFT ROCK DEFORMATION IN DEEP-BURIED TUNNEL CONSIDERING SUPPORTING

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ABSTRACT

To obtain the long term deformation of soft rock in the deep-buried tunnel, the viscoelastic-plastic model is applied to simulate time behavior of soft rock, a viscoelastic-plastic solution considering volumetric deformation of rock is proposed based on cavity expansion method, and it is verified with existing solutions and numerical results. Furtherly, an updated solution considering supporting stress and three-dimensional effect of excavation face is presented, and the influence of creeping parameters, supporting timing, initial stress on rock deformation and stresses is studied. Results show that the proposed new solution has good accuracy in predicting the long-term displacement of the tunnel wall, bulk modulus of the soft rock has a critical influence on rock deformation over the whole life cycle of the tunnel, earlier supporting timing will cause a smaller increment of rock deformation and smaller reduction of stresses.

Keywords: tunnel, soft rock, viscoelastic-plastic model, spatial effect, convergence confinement method.

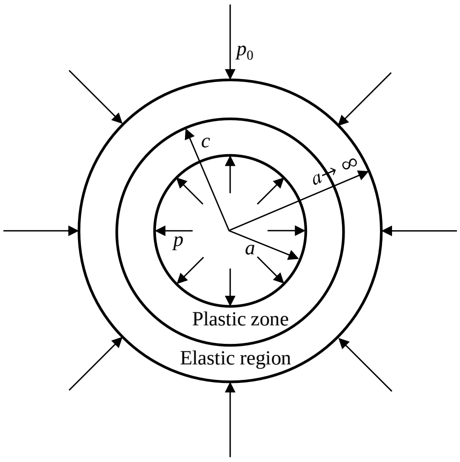

Fig. 1 Computation model

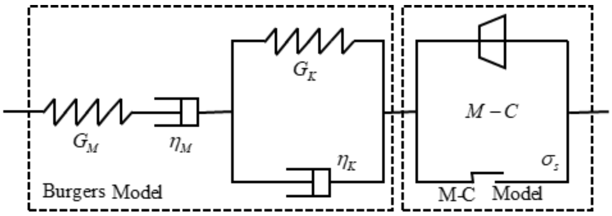

Fig. 2 CVISC constitutive model

APPLICATION OF GENERALIZED BLOCK THEORY FOR STABILITY ANALYSIS OF ROCK BLOCKS UNDER TIME-VARYING LOADS

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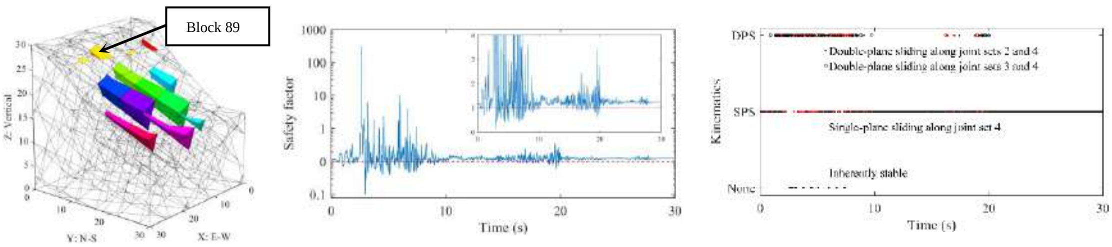
ABSTRACT

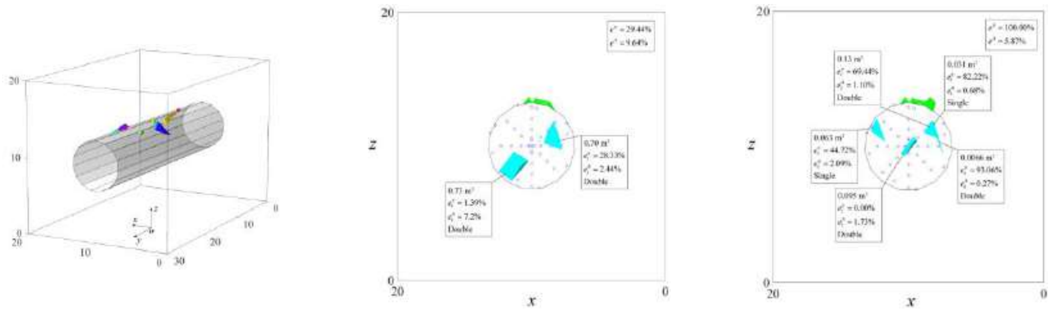
The stability analysis of rock blocks on man-made excavation faces (e.g., tunnel, cavern, and slope) subject to time-varying loads (e.g., seismic loads, machine-block interaction forces) is an important issue in the field of rock engineering in fractured rock masses. This paper proposes a generalized block theory (GBT) by combing a pseudo-static method and the traditional block theory to evaluate the stability of rock blocks under time-varying loads. The basic safety factors are derived considering time-varying loads to determine the stability of a rock block at each time step. We then use two parameters to evaluate the stability of a single block, denoted as instability probability and probabilistic instability volume. The stability of a blocky rock mass can be derived from the evaluation parameters of all the unstable blocks. Through the simulation of a generic slope excavation, we observe that seismic loads significantly affect the stability and kinematics of a rock block during an earthquake (Fig. 1). Another example is the rock blocks on the excavation face subject to the interactional forces between Tunnel Boring Machine (TBM) and blocks, i.e., TBM-block interaction forces, a special type of time-varying forces due to the advancement and rotation of TBM cutterhead; see Fig. 2.

Keywords: block theory, fractured rock mass, slope engineering, tunnel engineering



(a) (b) (c)

Fig. 1 Slope excavation under seismic loads: (a) removable blocks; (b) time-varying safety factor of Block 89; (c) time-varying kinematic mode of Block 89



(a) (b) (c)

Fig. 2 Tunnel excavation under TBM (Tunnel Boring Machine)-block interaction force: (a) unstable blocks without consideration of time-varying forces; (b) two unstable blocks considering time-varying forces at chainage K11+587; (c) five unstable blocks considering time-varying forces at chainage K11+588

Numerical investigation of end reinforcement technology for super-large diameter shield tunnels and online prediction using machine learning

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ABSTRACT

Shield tunneling has become a popular method in nowadays underground construction. In the process of shield initiation and reception, the end reinforcement of the connection between the shaft and the shield tunnel can avoid accidents such as excavation collapse or critical surface subsidence. However, the appropriate reinforcement method for super-large diameter tunnels in soft soil remains unclear. Based on a real tunneling project, the Zhuhai tunnel with a 15 m diameter, this paper investigates the effect of different end reinforcement methods on tunneling-induced ground movements via numerical simulation. The numerical model is validated on the field monitoring data and the most optimal reinforcement method is subsequently suggested. After that, a detailed parametric study is carried out to distinguish the key model factors that influence the ground movements during construction. Furthermore, to achieve online prediction of excavation-induced ground movements during construction, a modified multi-objective optimization procedure combined with acritical neuron network surrogate modeling is developed. The results show the proposed framework can efficiently and accurately predict tunneling-induced model responses, which can significantly benefit the engineering practice.

Keywords: end reinforcement, shield tunnel, online prediction, numerical simulation, field monitoring

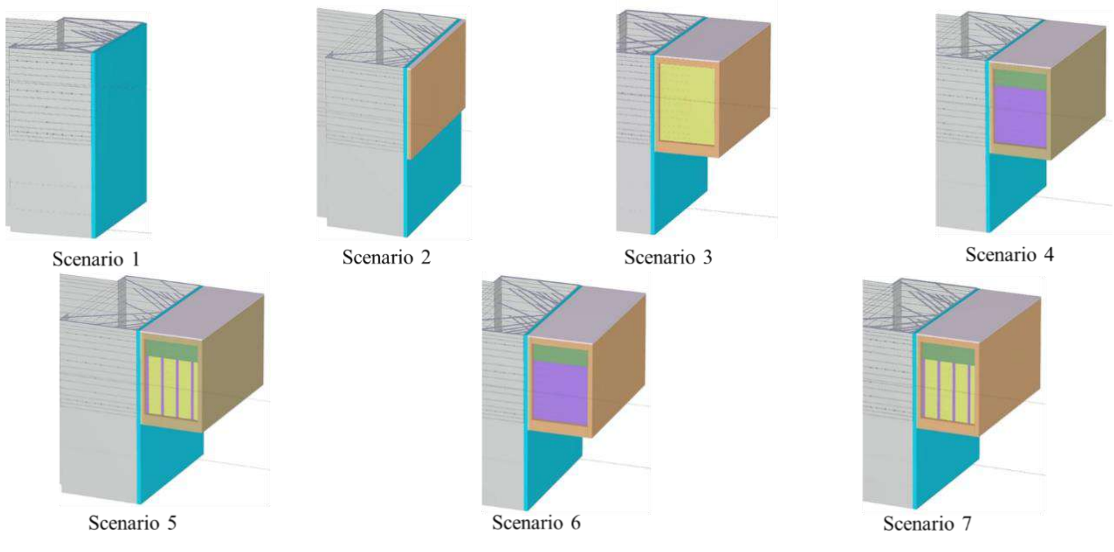

Fig. 1 Illustration of different end reinforcement methods

A FLEXIBLE AND GENERALIZABLE METHOD FOR PREDICTING SUBSEA IMMERSED TUNNEL SETTLEMENT

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ABSTRACT

Subsea immersed tunnel settlement prediction is challenging due to the complex marine and geotechnical environment. In this study, we propose a multi-beam model to simplify the immersed tunnel and introduce a physics-informed neural network (PINN) algorithm to predict the settlement of the Hong Kong-Zhuhai-Macau Bridge immersed tunnel. Our proposed method can integrate imperfect data and an incomplete physical model, making it highly flexible, generalizable, and requiring low data. The coefficient of determination (R2) for total settlement prediction can reach 0.88 with only five training datasets. However, the PINN algorithm's performance is poor when applied to predicting joint differential settlement. To further enhance prediction performance, we combine the PINN algorithm with the Bayesian probabilistic approach for model class selection and propose five criteria to guarantee the efficiency of model updating. Analysis using field data demonstrates that the updated model class can ensure that the R2 for both total settlement and joint differential settlement reaches 0.95.

Keywords: PINNs algorithm, settlement prediction, model class selection

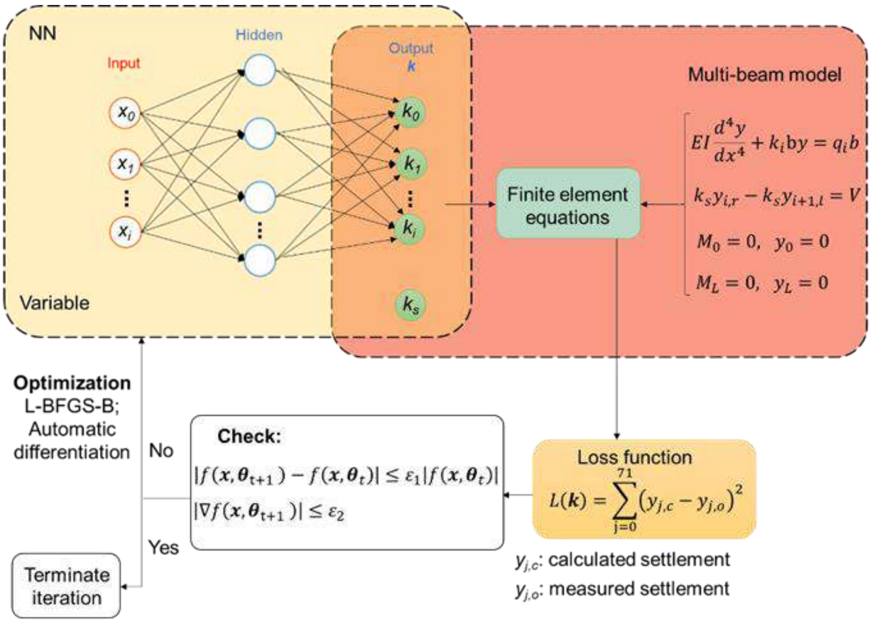

Fig. 1 Framework of the PINNs algorithm

A COMPUTATIONAL FLUID DYNAMICS-BASED INVESTIGATION OF SYNCHRONOUS GROUTING PERFORMANCE IN SHIELD TUNNELING

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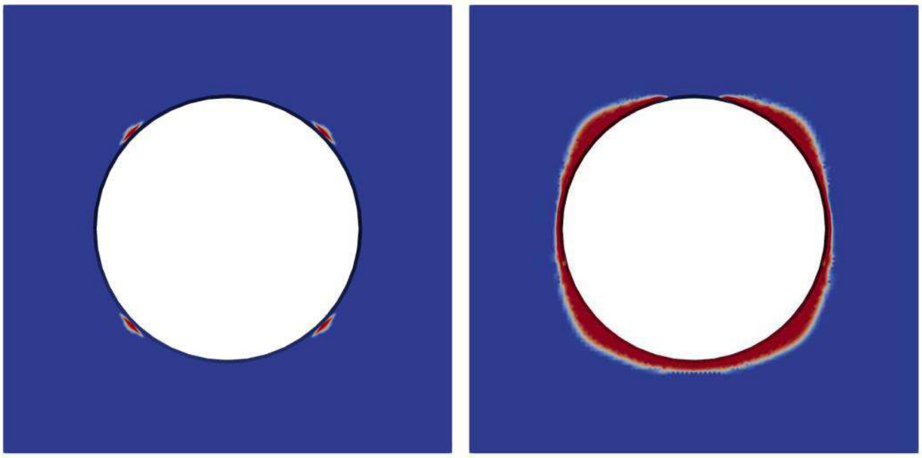
ABSTRACT

Synchronous grouting plays a pivotal role in shield tunnelling operations, with its performance intricately influenced by multifarious factors encompassing grout properties, surrounding soil characteristics, and the dynamics of fluid flow within porous soils. This study endeavours to establish a computational fluid dynamic (CFD)-based numerical simulation framework for a comprehensive analysis of grouting performance within shield tunnelling contexts. Within this framework, the Volume of Fraction approach will be harnessed to emulate the behaviour of multiphase fluids, including air and grout, while representing the surrounding soil as a porous medium. This approach enables precise tracking of the grout distribution within the tunnel. To ensure an accurate depiction of grout flow behaviour, we will first establish a constitutive model for grout, rigorously calibrated against data obtained from field and laboratory experiments. Subsequently, a permeability model will be developed to characterize grout flow through porous soils. Leveraging this advanced CFD numerical tool, we will simulate the grouting process in shield tunnelling, probing the influence of various grout and soil properties on grouting performance through meticulous model parameter analysis.

Keywords: Shield Tunnelling; Synchronous Grouting; Computational Fluid Dynamics; Multiphase Flow; Porous Media Modelling.



(a) beginning (b) end

Fig. 1 A snapshot showing the simulated grout profile in shield tunnelling.

A NUMERICAL STUDY ON THE TUNNELLING-INDUCED GROUND DEFORMATION CONSIDERING THE COMPRESSED PROPERTIES OF TAIL GROUTING MATERIALS

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ABSTRACT

Tail grouting is a significant process in shield tunnelling for controlling ground deformation, which fill the tail gap with prepared grouting materials. The grout will inevitably be compressed under earth pressure, of which the compressed deformation and strength of grouts could not be visualized and measured directly in construction. The ground deformation has no direct connection with grout ratio, and the grouting volume could not be accurately calculated. In this study, a novel lab device is designed to explore the compressed properties of tail grouts under different earth pressure in various soils. Based on lab tests results, he parameters of the displacement convergence method are calibrated to optimize numerical analysis. Compressed properties of the tail grouting materials including compressed deformation, compressed strength and permeability of compressed grouts are investigated using 3D Finite Element Method. The effect of each parameter variation on the tunnelling-induced deformation has been thoroughly investigated. According to the results, the compressed deformation is the factor that has a significant effect on the ground deformation. The increase proportion of cement in tail grouts will decrease the permeability of tail grouts, which is benefit for the longtime deformation control of shield tunnels.

Keywords: Tail grouting; Shield tunnel; Ground deformation; Numerical analysis.

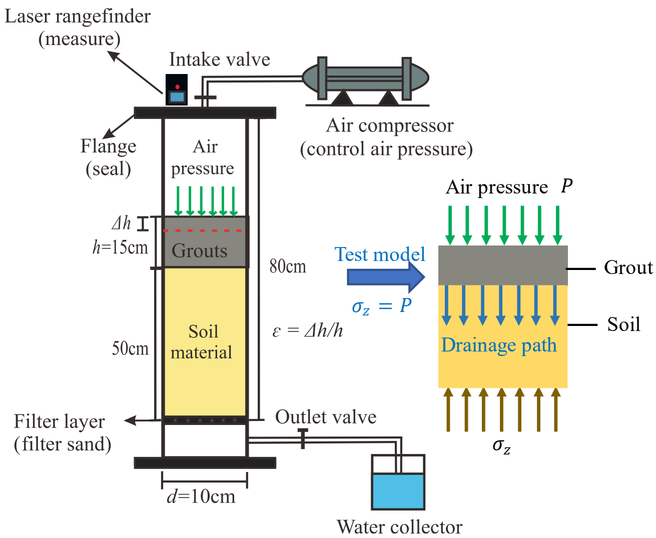

Fig. 2 Designed test device

SAFETY ASSESSMENT OF UNDERWATER TUNNEL WITH PROTECTIVE SHIELDING AGAINST BLAST LOADING

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ABSTRACT

Currently, the contribution of tunnels is of utmost significance. In recent years, damage analysis and safety assessment of tunnels against blast loading have become very vital due to the increase in terrorist attacks. This work investigates the performance of underwater tunnel against blast loading. A 3D Finite Element (FE) model has been formulated to carry out the damage analysis of the tunnel. The analysis has been performed in ABAQUS using the Coupled Eulerian Lagrangian (CEL) technique. A cladding layer of Glass Fiber Reinforced Polymer (GFRP) on the tunnel surface has been implemented for blast mitigation. Different constitutive models have been employed to model the behaviour of Lagrangian and Eulerian instances. Hashin damage criteria has been incorporated to simulate the behavior of GFRP. The influence of explosive charges and GFRP thickness on the behaviour of tunnels against blast is analysed using the validated model. The effectiveness of GFRP as a shield is investigated and found that the stress values at key points of the tunnel have been reduced significantly. Also, the optimum GFRP thickness required for strengthening against blast is achieved. The results obtained from this study could be helpful in designing blast resistant tunnels effectively.

Keywords: CEL, Cladding, Hashin damage, Blast resistant

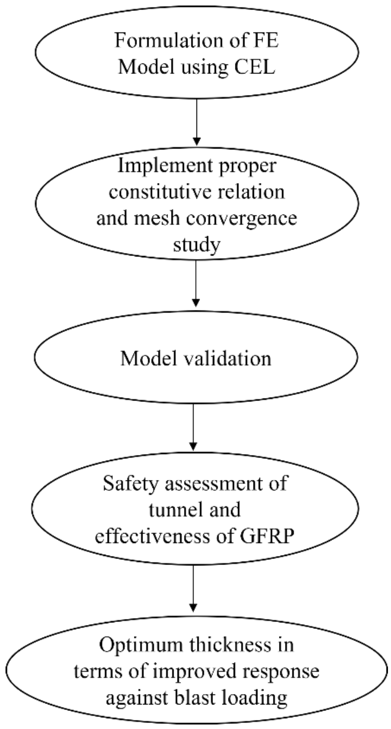

Fig. 1 Illustration of the proposed method

LARGE DEFORAMTION MODELLING ON TUNNEL FACE INSTABILITY DURING EPB SHIELD TUNNELLING CONSIDERING DYNAMIC EXCAVATION PROCESS

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ABSTRACT

Tunnels have been widely constructed to deal with the increasing demanding and development of cities. Face stability is a key issue during EPB shield tunnelling. Past research often ignored the impact of dynamic excavation process of tunnelling on the face stability. This study therefore proposed a large deformation finite element computational framework to model face instability, based on coupled Eulerian-Lagrangian approach. Specially, the dynamic excavation process of the cutterhead was realistically reproduced in the large-deformation model, as depicted in Fig. 1. The impacts of cutterhead opening ratio and tunnel buried depth on face stability were investigated in detail under dynamic excavation conditions. The results indicate that the dynamic excavation process destroys the stress arch ahead of tunnel face and forces the soil particles to rotate with the cutterhead, which greatly reduces face stability. The evolution process of stress arch from formation, development to failure was analysed under dynamic excavation in Fig. 2. This study provides an efficient approach for modelling face instability under dynamic excavation conditions.

Keywords: Face instability; Dynamic excavation process; Large-deformation modelling; Soil arching.

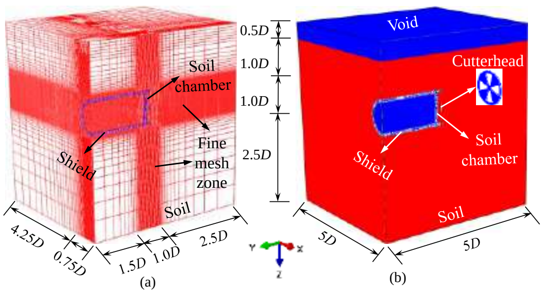

Fig. 1 Half finite element model of EPB tunneling: (a) model mesh; (b) soil and cutterhead details

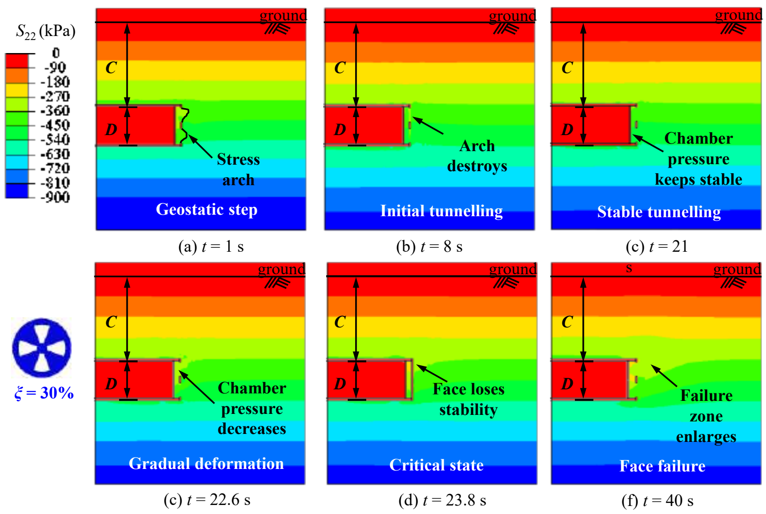

Fig. 2 Evolution process of soil arch during face instability

A MODIFIED HYDRO-THERMAL COUPLING METHOD CONSIDERING UNFROZEN WATER CONTENT IN ARTIFICIAL GROUND FREEZING

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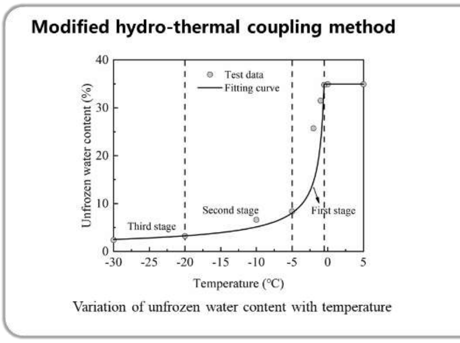
ABSTRACT

With the large-scale development of tunnels and underground spaces, artificial ground freezing as an environmentally friendly technology has been widely utilized in water-rich formations. However, groundwater seepage during the freezing process can influence the closing time of the frozen wall and cause construction accidents. This study proposed a modified hydro-thermal coupling method considering unfrozen water content of the soil to simulate temperature variations under seepage conditions. The calculation principle of the method is illustrated in Fig. 1. The main advantage of this method is that it takes into account the dynamic change of unfrozen water content during the freezing process, and it is more accurate in clay soils than the currently used apparent heat capacity method. The impact of different groundwater flow velocity on the temperature field and freezing wall closure time was investigated in detail. The temperature distribution of different flow conditions is shown in Fig. 2. The frozen zone gradually extended downstream and decreased with increasing seepage velocity, leading to the freezing wall closure time increased. This study can provide effective guidance for the design of artificial ground freezing schemes under seepage conditions.

Keywords: hydro-thermal coupling; artificial ground freezing; tunnel; seepage flow



$$\begin{cases}(\rho c_p)_{eff}\dfrac{\partial T}{\partial t}+\rho_w c_w u\nabla T=\lambda_{eff}\nabla^2 T+\rho_i L\dfrac{\partial \theta_i}{\partial t}\\ \dfrac{\partial(n\rho_w)}{\partial t}+\nabla(\rho_w u)=0\end{cases}$$

$$C(T)=\frac{\partial\theta_w}{\partial T}$$

$$\begin{cases}(\rho c_p)_{eff}\dfrac{\partial T}{\partial t}+\rho_w c_w u\nabla T=-\rho_w LC(T)\dfrac{\partial T}{\partial t}+\lambda_{eff}\nabla^2 T\\ \dfrac{\partial(n\rho_w)}{\partial t}+\nabla\left(\dfrac{k_w}{g}\nabla P_w\right)=0\end{cases}$$

Fig. 1 Principle of the proposed method

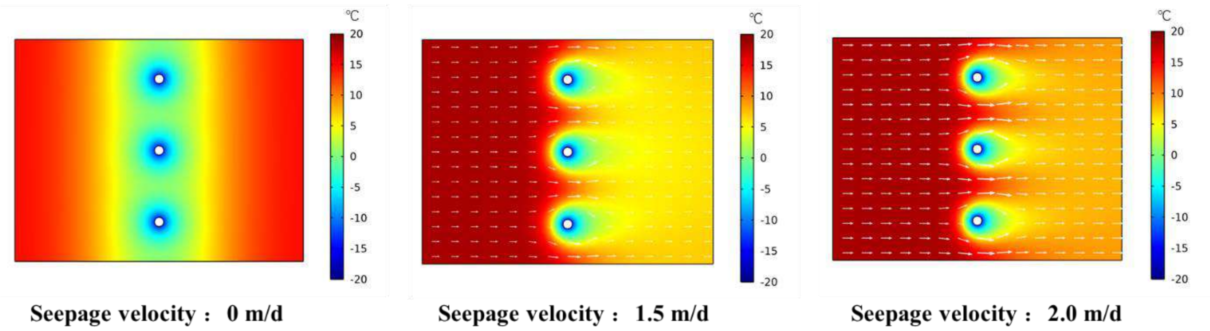


Fig. 2 Temperature distribution of freezing 40 h with different seepage velocity

EXPERIMENTAL STUDY ON TUNNELING-INDUCED DEFORMATION CHARACTERISTICS OF PILE-RAFT FOUNDATION OF HIGH-SPEED RAILWAY BASED ON PARTICLE IAMGE VELOCIMETRY

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Abstract: Tunneling beneath pile-raft foundation of high-speed railway may induce unexpected deformation of the pile foundation, which is directly threaten the safety of passing trains. Since the mechanism of tunneling-induced disturbance on pile-raft foundation is unclear, the tunneling beneath the earthwork of high-speed railways is still not allowed in China. An understanding of deformation characteristics of pile and soil is needed to evaluate the impact of tunneling beneath pile-raft foundation. Two dimensional tunneling model tests were carried out to study the problem of tunneling beneath pile-raft foundation. The pile-raft foundation was simulated by aluminum pile and plate with the subgrade weight. The tunneling process was simulated by moving the half-round trapdoor. Soil and pile displacement were measured by particle image velocimetry and displacement transducers. The develpment of pile settlement with distance between tunnel and pile, subgrade weight, tunnel volume loss to illustrate the main effects of tunnel-pile interaction. Results indicate that the affected area of tunneling beneath pile raft foundation is larger than that in greenfield. The maximum pile settlement reduces with the distance between tunnel and pile. There is little effect on the maximum pile settlement with the subgrade weight, but the tunneling-induced affected area expands with subgrade weight.

Keywords: Pile; Tunnelling; Deformation behavior; soil-pile interaction; Model test

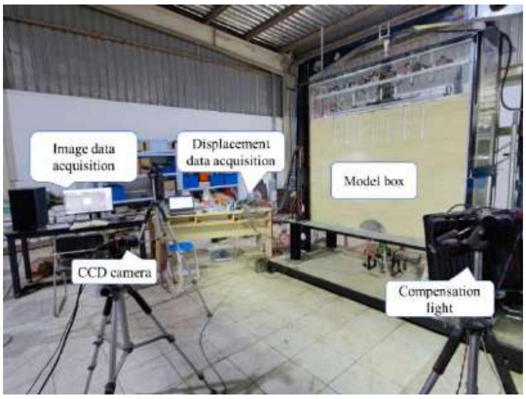

Fig. 1 Test layout

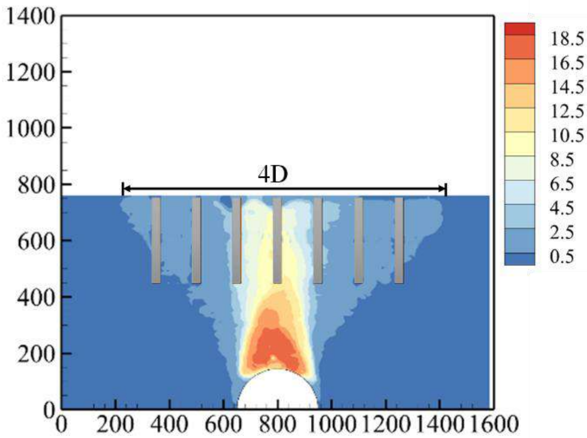

Fig. 2 Tunnelling-induced soil displacement field of pile-raft foundation

AN ANALYTICAL MODEL FOR THE CHANGEABLE TBM DISC CUTTER FORCE INDUCED BY CUTTING THE SOIL- ROCK INTERFACE

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ABSTRACT

Reasonably estimating the rock-breaking force of the TBM disc cutter is of vital importance for equipment maintenance and construction safety. When tunnelling in mixed-face ground conditions, the cutters that bounce on and off the hard layer and the soft layer will suffer a significant changeable cutting force, especially during the moving through the soil-rock interface. To represent this changeable cutting force, an analytical model is proposed based on the most popular practical model for calculating TBM cutter force, the CSM model, by introducing the concept of equivalent compressing strength $\bar{\sigma}_c$ and equivalent tension strength $\bar{\sigma}_t$ of the cutting area (Fig. 1). The proposed model has been validated by laboratory tests and numerical analysis. The advantage of this model is that it can reveal the time-variant characteristics of TBM cutter force (Fig. 2a) during cutting the mixed face changeable under different penetration rates p, rock strength σ_{cr}, cutter moving force v_c, and the strength ratio of the soft and hard layer R_{rs}. On the premise of the maximum cutting force limit $\dot{F}_{cv\_max}$ and cutting force changing rate limit $\dot{F}_{cv}$, the proposed model can be used to determine the allowable range of TBM construction parameters from the perspective of cutter protection (Fig. 2b).

Keywords: TBM; Changeable cutter force; Mixed face ground; Soil-rock interface; Analytical model.

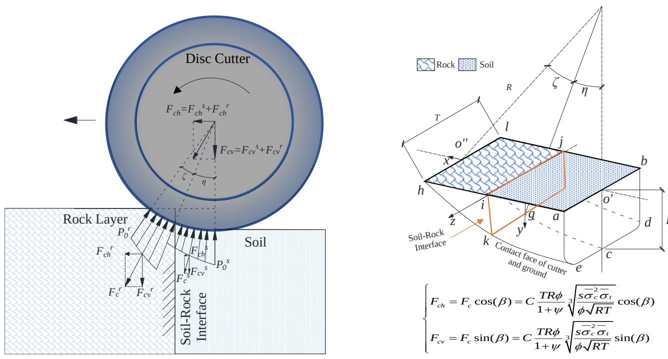
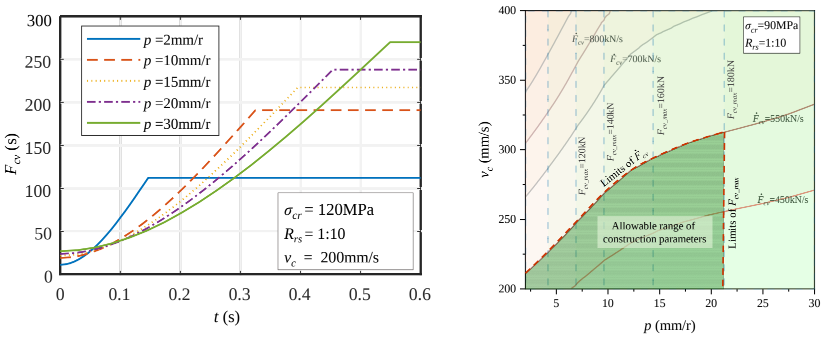


Fig. 1 Illustration of the proposed model for the changeable TBM cutter force.



(a) (b)

Fig. 2 Results analysis. (a) Cutting force variation under different ground conditions and construction parameters, and (b) the application for determining the allowable range of construction parameters.

UNDERGROUND SPACE EXPANSION UNDER EXISTING BUILDINGS: GEOTECHNICAL CHALLENGES AND SOLUTIONS

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ABSTRACT

Underground space expansion under existing building structure is one of the effective ways to combine old buildings with new buildings and meet the new functional requirements of old buildings (e.g., underground parking). This case study analyzes the geotechnical issues involved in a basement expansion project in China, including the deformation controlling and differential settlement controlling of superstructures, the underpinning of existing foundations, the load transfer principles of underpinning, etc. Firstly, a special underpinning technology with anchor jacked piles is introduced to analyze underpinning steps and the load transfer process in detail. Then, based on field simulation tests, static load tests and finite element analysis, the effect of new basement further excavation on underpinning pile bearing capacity is discussed, and a simplified calculation method of pile bearing capacity is proposed. Moreover, buckling stability of new underpinning piles is further analyzed to propose the recommended value of safe excavation depth. At last, the technical measurements are proposed to enhance the buckling stability of underpinning piles.

Keywords: Basement expansion; Anchor jacked pile; Deformation analysis; Finite element analysis; Field simulation test.

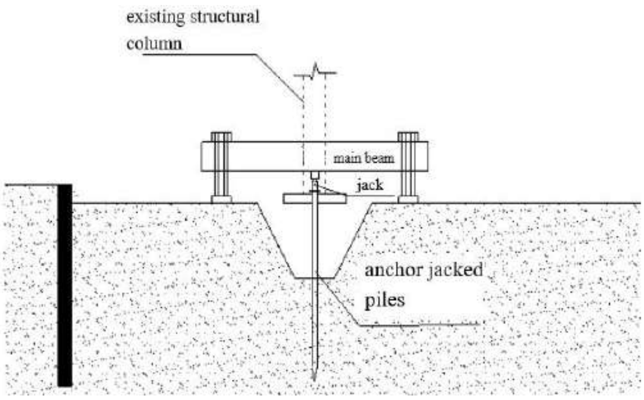

Fig. 1 The in-situ excavation simulation and the static load test of single pile.

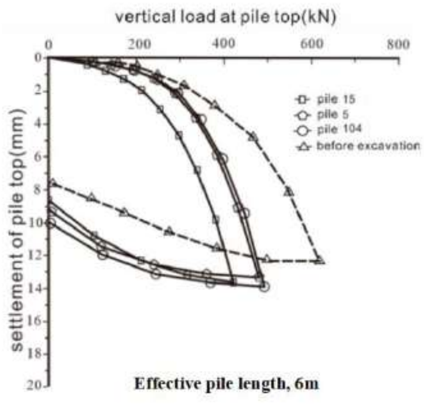

Fig. 2 Load test results of new anchor jacked piles before and after excavation.

THREE-DIMENSIONAL FACE STABILITY ANALYSIS OF CIRCULAR TUNNELS 249-283

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ABSTRACT

Predicting reasonable critical support pressure of the tunnel face is crucial for maintaining tunnel face stability. This study presents a new 3D limit equilibrium model including potential collapse geometries of a lower torus and an upper silo which can estimate the critical support pressure. A wedge-slice scheme was used to subdivide the torus geometry using a newly developed spatial discretization technique. The model adopted different lateral stress coefficients for the silo and the torus geometry under different arching levels. The distribution of shear force on the rotational surface which is the interface behaviour between the sliding torus and the surrounding soils was indicated at the state of limit equilibrium. Results from a large set of numerical tests based on safety factor nephogram analytical are validated with the proposed 3D model. Finally, the relationship between critical support pressure, failure mechanism, geotechnical and geometrical parameters of circular tunnels were established respectively. The proposed 3d model predicts the critical collapse state and the sliding failure range, and to provide reasonable support approaches for tunnel face with high accuracy.

Keywords: Tunnel face; Rotational failure; Soil arching; Limit equilibrium; Critical pressure.

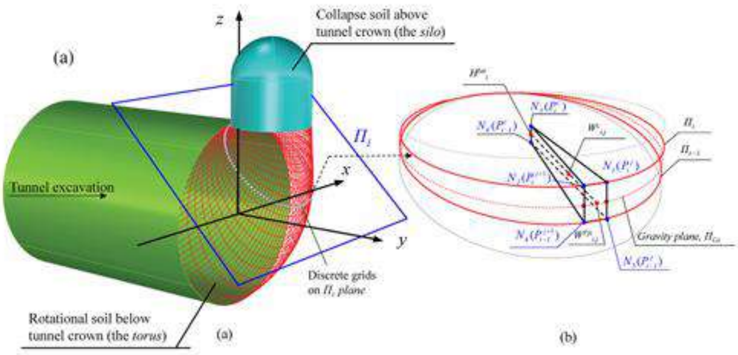

Fig. 1 Illustration of the proposed method(a) the potential collapse geometries of a silo cylinder, (b) the subdivided wedge elements from torus soild

STUDY ON THE CAVING MECHANISM AND DEVELOPMENT PROCESS OF THE COMBINED ROOF BASED ON MICROSEISMIC MONITORING

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ABSTRACT

In the process of transferring the downward layered cemented filling mining method to the sublevel mining caving method in the West Mining Area of Longshou Mine, the natural caving of the combined roof is artificially induced to form the overburden. Studying the caving mechanism of the combined roof and mastering its development process are of great significance for the smooth formation of the overburden and the safety of the sublevel caving stope. In this paper, the microseismic monitoring technology is used to monitor the damage and caving process of the combined roof in the sublevel caving stope of the West Mining Area in real time. Monitoring results show that during the first mining level of the sublevel caving, the fracture microseismic events in the combined roof are mainly concentrated at 30 m to 45 m behind the mined-out area, within 5 m of the rear edge of the mined-out area, and the center of the mined-out area roof in sequence. On the basis of these results, the causes of microseismic events of combined roof fracture in different locations and the internal mechanism of combined roof failure are analyzed. Through theoretical calculation, the relationship between 1580 m level ore drawing and the development height of combined roof caving is discussed and is mutually confirmed with the microseismic monitoring results. Overall, this study reveals that the combined roof of the sublevel caving stope in the West Mining Area caved safely and timely as expected to form an overburden layer, which provides a good foundation for the overall success of the sublevel caving method in the mine.

Keywords: Sublevel caving mining method; Combined roof; Overburden formation; Caving mechanism; Microseismic monitoring

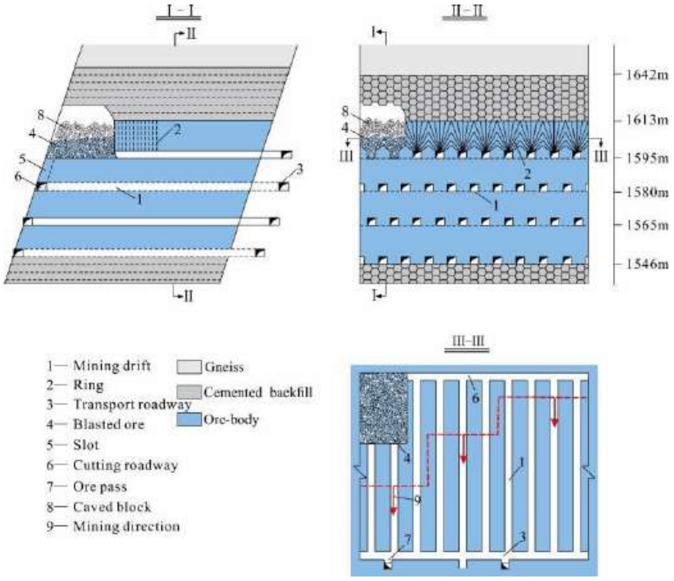

Fig. 1 Stope structure of the sublevel caving and overburden formation method in the West Mining Area of Longshou Mine

STUDY ON THE BRITTLE FAILURE IN DEEP TUNNEL AND BOLTING SUPPORT RESPONSE

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ABSTRACT

Underground engineering is developing increasingly deeper, and shallow intrinsic theories cannot be adapted to the actual deep rock response. Based on the field scale constitutive model, the supporting effect of bolt support on deep rock brittle fracture is studied. FLAC^{2D} is used to study the supporting time, supporting mode, and supporting effect of energy-absorbing bolt and ordinary bolt. The results show that the bolt support can effectively reduce the energy released when the underground chamber is broken, and the support effect is the best when the disaster is about to occur. Anchor rod can effectively inhibit the development of cracks in shallow surrounding rock, and PFC^{2D} was employed to validate this concept. The research results will provide a new theoretical perspective for the design of bolting support in deep surrounding rock.

Keywords: Bolt support; Cohesion-Weakening-Friction-Strengthening model; Scale effect; Field constitutive model.

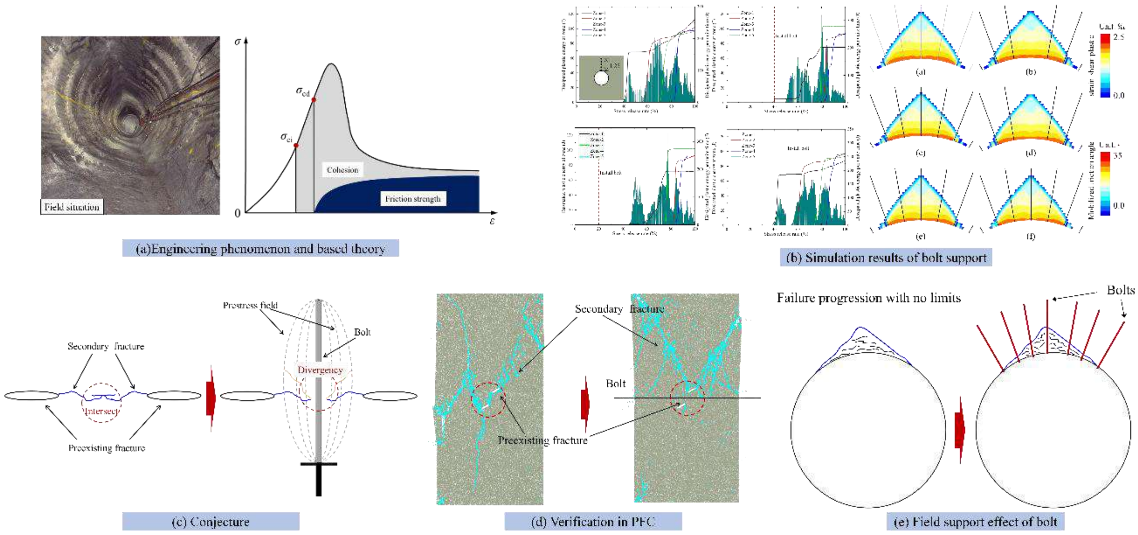

Fig. 1 Illustration of the proposed method

MULTIPLE COUPLING EFFECT OF SOIL SPATIAL VARIABILITY AND ADJACENT LOADING AND UNLOADING ON EXISTING TUNNEL

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ABSTRACT

Surcharge loading and excavation unloading are two common engineering disturbances affecting the adjacent tunnel in congested urban areas. Meanwhile, the spatial variability of soil parameters has been widely accepted. Therefore, this study aims to investigate the coupling effect of soil spatial variability and adjacent loading and unloading on the existing tunnel using random finite difference method (RFDM). The soil modulus is highlighted and simulated with horizontally stratified anisotropic random field that is discretized by the Karhunen-Loeve expansion. The tunnel was simulated by liner element in FLAC 3D software. An evaluation method of multiple coupling amplification effect between soil spatial variability and adjacent loading and unloading was proposed and the corresponding quantitative evaluation was carried out. The coupling effect index of tunnel stress and deformation is greater than 1 for different loading and unloading time series. This means that they are all in the category of adverse coupling effect. Meanwhile, the effect is more significant under the loading before unloading condition. Compared with the double coupling effect of adjacent overloading and adjacent unloading, the coupling effect index is larger and the adverse coupling degree is stronger under the triple coupling effect considering the soil spatial variability and adjacent loading and unloading.

Keywords: Multiple coupling effect; surcharge; excavation; soil spatial variability.

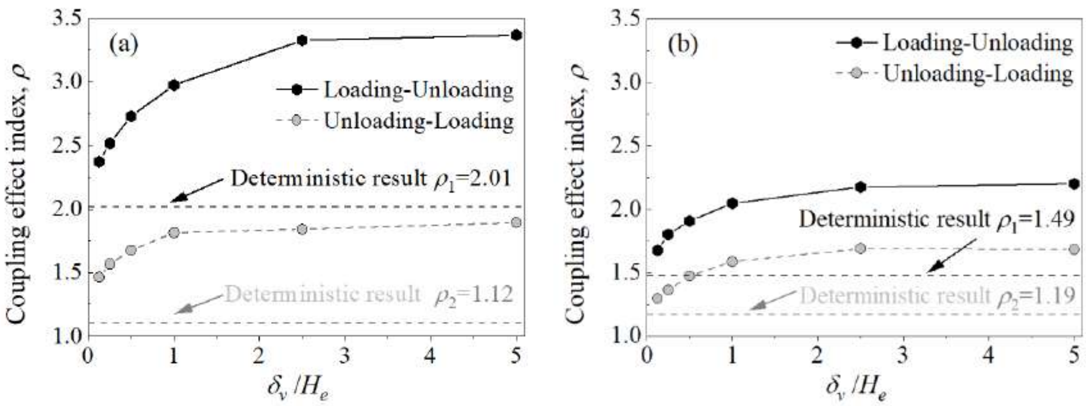

Fig. 1 Coupling effect index of tunnel horizontal movement and vertical movement under loading and unloading: (a) horizontal movement; (b) vertical movement

THE EFFECT OF BENTONITE CONTENT AND UREA CONCENTRATION ON THE STIMULATION EFFECT OF INDIGENOUS UREOLYTIC BACTERIA IN SANDY SOIL

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ABSTRACT

Biomineralization is an environmentally friendly and sustainable geotechnical improvement technology. At present, it mainly uses exogenous ureolytic bacteria to induce calcium carbonate precipitation to treat coarse grains such as sand or coarse-grained soils containing a small content of fine grains. For fine-grained soils, since the bacteria and soil pore size are comparable, when exogenous bacteria are injected into the soil by the grouting method, the calcium carbonate precipitates are easily concentrated near the injection port. The use of in bio-stimulation of indigenous ureolytic bacteria can improve the uniformity of bacterial distribution and thus the cementation effect of fine-grained soils. In this study, the effects of bentonite content in the sandy soil and urea concentration in the enrichment media on the enrichment efficiency were investigated by batch-type experiments, which clarified the evolution of ureolytic activity, pH and number of viable bacteria in the soil pore fluid with the changes of bentonite content and urea concentration at different stimulation times. It was found that the presence of low content of bentonite in sandy soils was favorable to the bio-stimulation of indigenous ureolytic bacteria, and the ureolytic activity and the number of viable bacteria were improved compared with that of pure sand. However, this improved efficiency will decrease with the increase of bentonite content in the soil, and the decrease of soil pore size will block the stimulation effect of indigenous ureolytic bacteria.

Keywords: Biomineralization, Sandy soil, Bentonite content, Ureolytic bacteria, Bio-stimulation

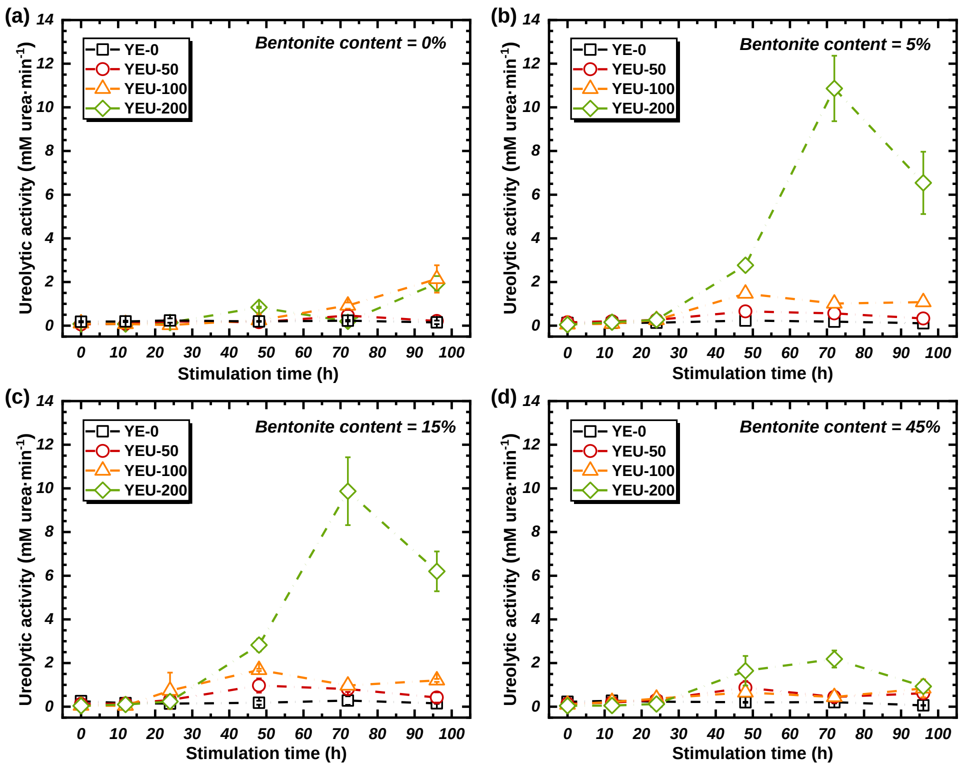

Fig. 1 Variations of ureolytic activity with stimulation time (a. Bentonite content=0%, b. Bentonite content=5%, c. Bentonite content=15%, d. Bentonite content=45%)

REMEDIATION OF NAPHTHALENE-CONTAMINATED SITES USING PAHS-DEGRADING BACTERIA

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) are persistent organic pollutants that pose a serious threat to surrounding environments and human health. In this study, three potential PAHs-degrading bacteria were isolated from petroleum-contaminated soil and identified as *Priestia sp., Microbacterium sp. and Rhodococcus sp.* respectively. After their growth for 30 h, the three bacteria were inoculated into a minimal salt medium containing naphthalene at 50 mg/L, 200 mg/L, and 500 mg/L respectively using 5% inoculation proportion. OD_{600} and pH were applied to characterize their growth and reproduction and evaluate the impact of metabolic processes on pH surrounding. Furthermore, gas chromatography-mass spectrometry (GC-MS) was applied to single-component quantitative of naphthalene and multi-component qualitative detection, reflecting the degradation efficiency and the metabolic pathways of naphthalene. The detected metabolites were evaluated using the Toxicity Estimation Software Tool (TEST). Results showed that the higher the concentration of naphthalene, the slower the growth and metabolism of bacteria. The *Microbacterium sp.* showed the highest degradation efficiency, although the metabolic pathways of naphthalene applied to different bacteria are of high similarity. Moreover, results also showed that the biomineralization process depressed the ecotoxicity of naphthalene. On the whole, the present work investigated metabolic pathways of naphthalene and explored the potential of applying *Microbacterium sp.* to the degradation of naphthalene.

Keywords: Polycyclic aromatic hydrocarbons; PAHs-degrading bacteria; naphthalene; metabolic pathways; metabolites evaluation

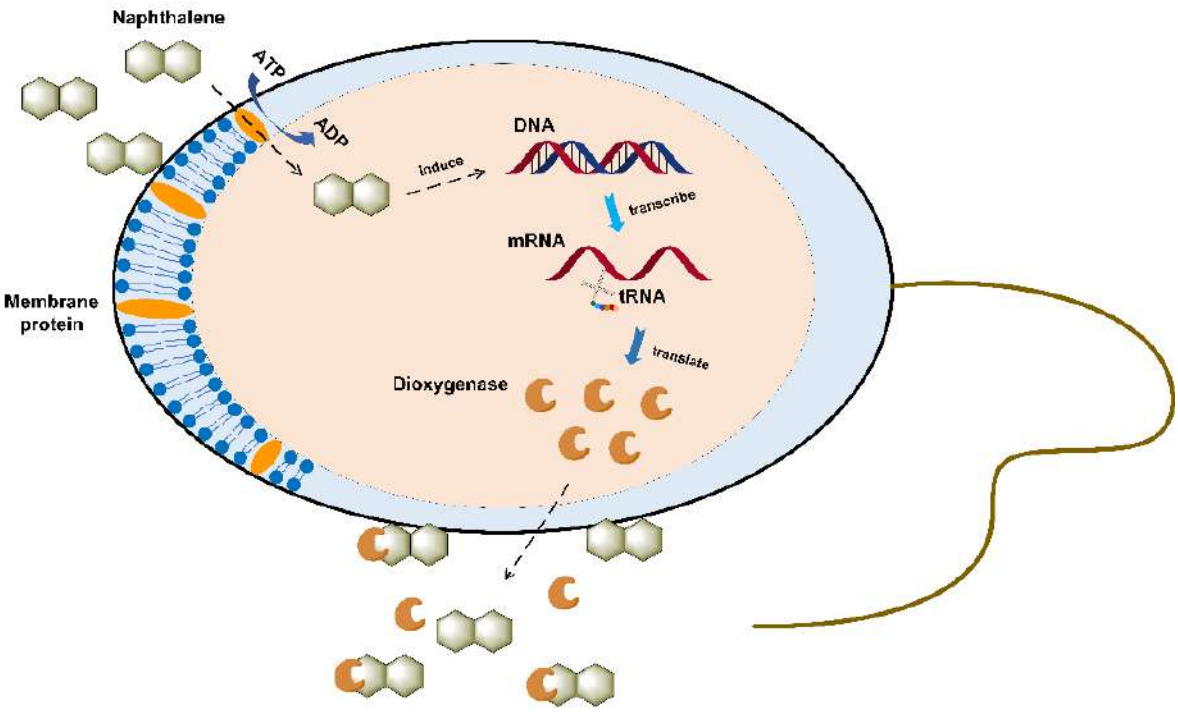

Fig. 1 Illustration of the degradation and metabolism of naphthalene

Experimental study of influence of plant roots on dynamic characteristics of clay

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ABSTRACT

The resonance column test of root-soil samples was carried out. the influence law of root soil dynamic characteristics and the soil dynamic model was proposed to reveal the mechanism of root system improving soil dynamic performance. The results showed that: The dynamic shear modulus and damping ratio were the largest when the roots were distributed in the upper part of the soil sample, which was beneficial to improve the dynamic characteristics of the soil; The dynamic shear modulus of soil increased first and then decreased with the increase of root mass density. The dynamic shear modulus could be increased up to 27.6 % and the damping ratio could be increased up to 5.39%. The hyperbolic model could well fit the variation of dynamic shear modulus and damping ratio with shear strain. The results could guide significance for the seismic/ vibration design of ecological slopes.

Keywords: root system of plant; resonant column test; dynamic shear modulus; damping ratio; root mass density.

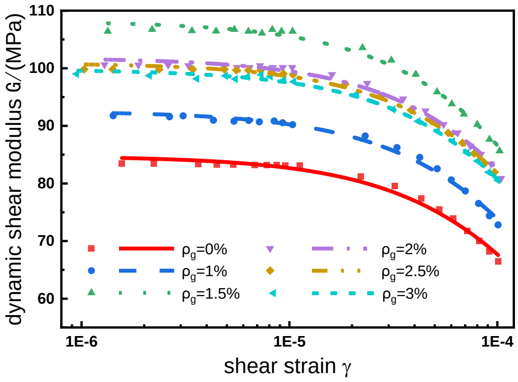

Fig. 1 $G \sim \gamma$ Relation Curves of Soil with $\omega = 12\%$ under Different ρ_g

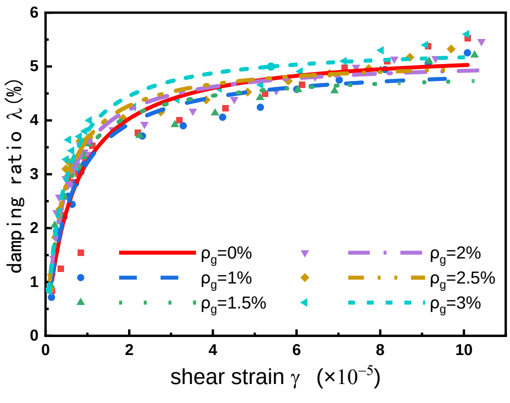

Fig. 2 $\lambda \sim \gamma$ Relation Curves of Soil with $\omega = 12\%$ under Different ρ_g

WATER-GAS FLOW IN UNSATURATED VEGETATED SOILS

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ABSTRACT

Effects of plant growth on water and gas permeability of soil need to be considered for long-term vegetation management of geotechnical infrastructure. This study quantifies the effects of plant growth on water and gas migration over time, through field monitoring and soil–plant–atmosphere interaction modelling. In order to find out the vegetation effects on soil hydrological properties, a full-scale flat landfill cover in China was monitored for more than a year. Multiple soil cores were sampled to determine the root length density (RLD) and saturated hydraulic conductivity (k_s) after various months of transplantation. In addition, effects of plant roots on the evolution of gas permeability (k_g) in the unsaturated landfill cover over a two-year period were also investigated. Results show that although closely spaced (0.5 m) shrubs preserved the most suction during the first 6 months of growth, the beneficial hydrological effects vanished after growing for 9 months because of the shrub growth-induced increase in k_s. k_g of grass-covered can be lower or higher than that of bare soil, depending on the plant age. The results of this study imply that vegetation has significant effects on water and gas migration in unsaturated soils.

Keywords: unsaturated cover; suction; vegetation; water flow; gas permeability.

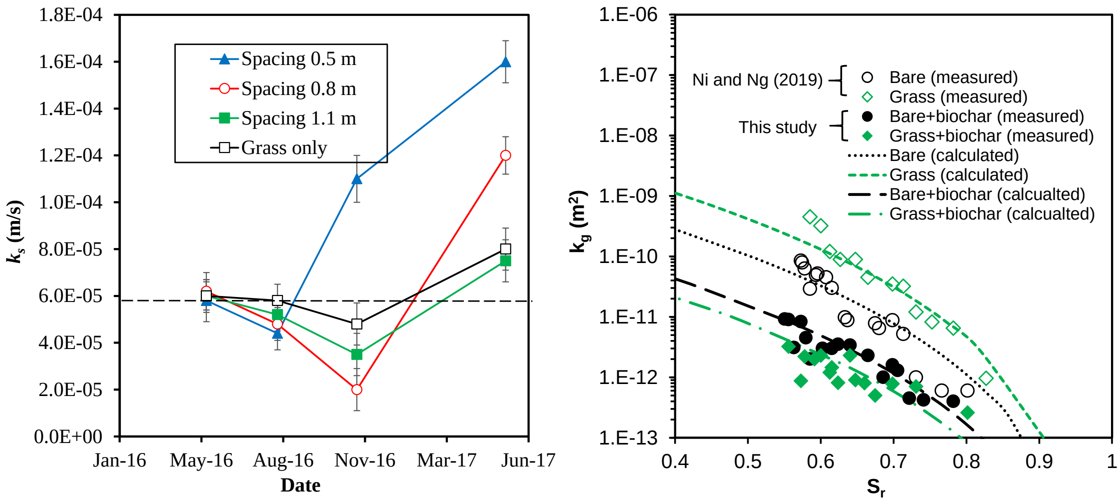

Fig. 1. Influence of vegetation on saturated water permeability and gas permeability in unsaturated soils (from Ng et al. 2020; Ni et al., 2023).

BIO-MEDIATED GEOTECHNOLOGY AND ITS APPLICATION IN GEOENGINEERING

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ABSTRACT

Bio-mediated geotechnology refers to the technology that utilizes various types of microbial processes to improve the hydro-mechanical behavior of soil and rock, aiming for the prevention and mitigation of geoengineering problems. Bio-mediated geotechnology has been identified as a hotspot research area in geoengineering in recent years, with the benefits of environmental friendliness, low energy consumption, and process controllability. Based on research progress on this topic, this paper systematically summarized the mechanisms of representative bio-mediated geotechnologies that can be well controlled and efficiently used, including biomineralization, biofilm and biogas. Among these geotechnologies, the most investigated and promising microbially induced carbonate precipitation (MICP) based on biomineralization was the focus of this review paper. Key influencing factors including bacteria species, bacteria concentration, temperature, pH, cementation solution, soil properties and treatment strategies that affect the improvement effect of biomineralization were discussed in depth. The engineering features (i.e., mechanical behavior, permeability, and erosion resistance) of the rock and soil improved by MICP were discussed, as well as the corresponding involved mechanisms. The application status of biomineralization in foundation treatment, liquefaction mitigation, islands and reefs construction, dust suppression, soil and water conservation, cracking remediation and seepage control, heavy metal remediation, cultural relics protection, geological disaster prevention and other fields were reviewed and summarized. Finally, current biomineralization challenges were discussed, with potential solutions proposed.

Keywords: bio-mediated geotechnology; microbially induced carbonate precipitation (MICP); biomineralization; geoengineering; rock and soil improvement; disaster prevention and mitigation

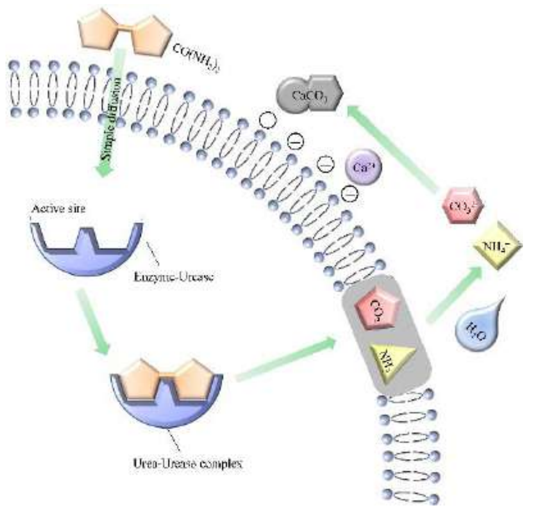

Fig. 1 Microbially induced carbonate precipitation (MICP) process

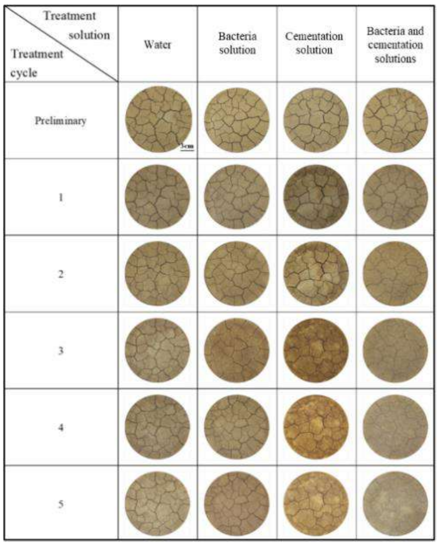

Fig. 2 MICP remediation for soil cracks

DEVELOPING A REACTIVE-TRANSPORT MODEL OF MICROBIALLY INDUCED CARBONATE PRECIPITATION (MICP) APPLIED TO HEAVY METAL-CONTAMINATED SITE REMEDIATION

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ABSTRACT

Microbially induced carbonate precipitation (MICP) has recently drawn great attention because of its good maneuverability regarding contaminated water bodies and sites remediation. Despite the power of numerical tools, they have not incorporated the interplay of bacteria with soil minerals under the effects of physical, electrical, and chemical fields yet, causing an inability of exploring the inherent mechanism affecting the immobilization efficiency. The current study proposed a novel reactive-transport model that considered the adsorption and desorption of bacteria, as well as the effect of Pb^{2+} toxicity on the ureolytic bacteria. In addition, the model also took the electrostatic adsorption and chemisorption (coordination complexation) between soil minerals and Pb^{2+} into account. Results revealed three phases of the ureolytic bacteria, including bacteria in suspension, adsorbed bacteria, and fixed bacteria. Bacterial adsorption and desorption behaviour caused differences in bacterial distribution, which in turn affected the spatial distribution of urease activity and prevented the alkaline front from reaching deep ground. The lead (Pb) immobilization efficiency decreased with increasing depth and that in shallow depths, the alkaline front promoted the chemisorption of Pb^{2+} with CO_3^{2-} reducing the depletion of quartz minerals. Quartz and albite minerals, when subjected to 16000 mg/kg Pb^{2+}, did not intervene in the chemisorption with Pb^{2+} where the combination between Pb^{2+} and CO_3^{2-} played a leading role in Pb immobilization. The findings revealed the inherent mechanism affecting the Pb immobilization efficiency.

Keywords: microbially induced calcite precipitation; lead metal; reactive-transport model; immobilization efficiency

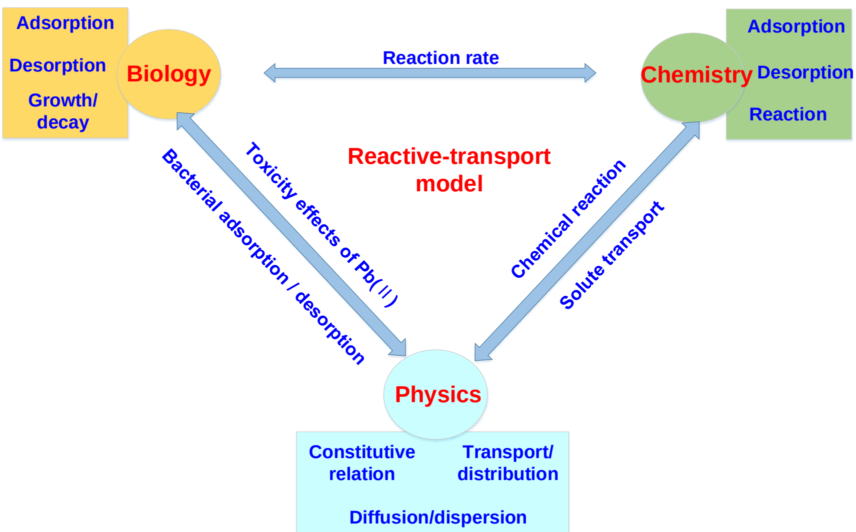

Fig. 1 Illustration of the reactive-transport model development

Effect of dilution on extraction efficiency and application of plant crude urease under equivalent feedstock concentration

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ABSTRACT

The extraction of crude urease from plants, such as soybean, to complete the Enzyme-induced Calcium Carbonate Precipitation (EICP) process reduces the cost. Since the extraction efficiency decreases with the increase of feedstock concentration, the method of extracting urease with high feedstock concentration and then diluting it will theoretically obtain worse application effect, even though this method will save the time and cost of extracting solution. In this study, the influence of dilution was explored by analyzing the conversion rate of calcium carbonate, crystal type and size of calcium carbonate and application effect. The results showed that the urease solution diluted to an equivalent final concentration for EICP treatment had little difference in urease activity, calcium carbonate conversion rate and strength of EICP-treated sand even though the initial concentration is different. The production cost of crude urease can be further reduced by this method.

Keywords: Enzyme induce calcium carbonate precipitation (EICP); Soybean; Urease; Dilution; Sand

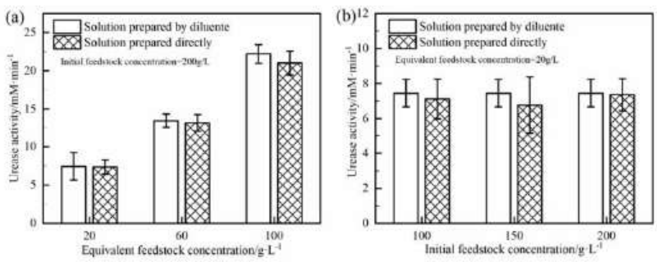

Fig. 1 Effect of dilution on urease activity under: (a) different equivalent feedstock concentration; (b) different initial feedstock concentration

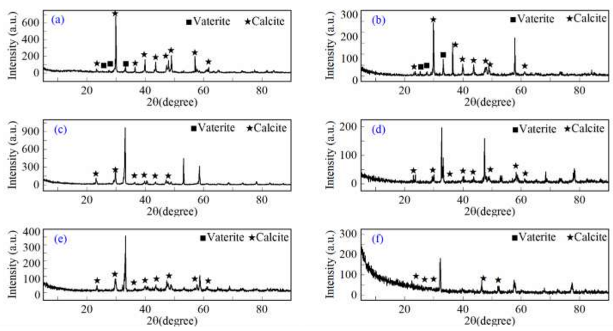

Fig. 2 XRD images of: (a) C_u^e=20 g/L, C_u^i=200 g/L; (b) C_u^e=20 g/L, C_u^i=20 g/L; (c) C_u^e=60 g/L, C_u^i=200 g/L; (d) C_u^e=60 g/L, C_u^i=60 g/L; (e) C_u^e=100 g/L, C_u^i=200 g/L; (f) C_u^e=100 g/L, C_u^i=100 g/L. (C_u^e: equivalent feedstock concentration; C_u^i: initial feedstock concentration)

ROLES OF GRASS ROOTS IN CRACK MITIGATION AND STRENGTH IMPROVEMENT OF LATERITIC SOIL

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ABSTRACT

Desiccation cracking is a major cause of shallow failure of lateritic soil slopes. Knowledge of soil tensile strength helps better understand the cracking behavior of lateritic soil. In most cases, lateritic soil is not bare but covered by vegetation. Because of the presence of plant roots, the behavior of surficial desiccation cracking and tensile strength of lateritic soil is more complicated. This study aims to examine the influence of grass roots on the desiccation cracking and tensile strength behavior of lateritic soil. To this end, three commonly used herbaceous plants in highway slope protection (i.e., Lolium perenne, Cynodon dactylon, and Trifolium repens) were selected, and desiccation cracking tests were conducted on lateritic soil covered by these plants in the laboratory considering the changes in drying duration, plant type, plant spacing, specimen size, transpiration, and season (Fig. 1). Afterward, desiccation cracking tests, root pullout tests and direct tensile tests were performed on remolded lateritic soil reinforced by grass roots considering different levels of porosity, degree of saturation, and root content. Finally, the mechanism underlying root reinforcements was analyzed by scanning electron microscopy (Fig. 2). The findings could provide references for vegetation-based protection design of cracked lateritic soil slopes.

Keywords: Lateritic soil; desiccation crack; tensile strength; root-soil interaction; vegetation

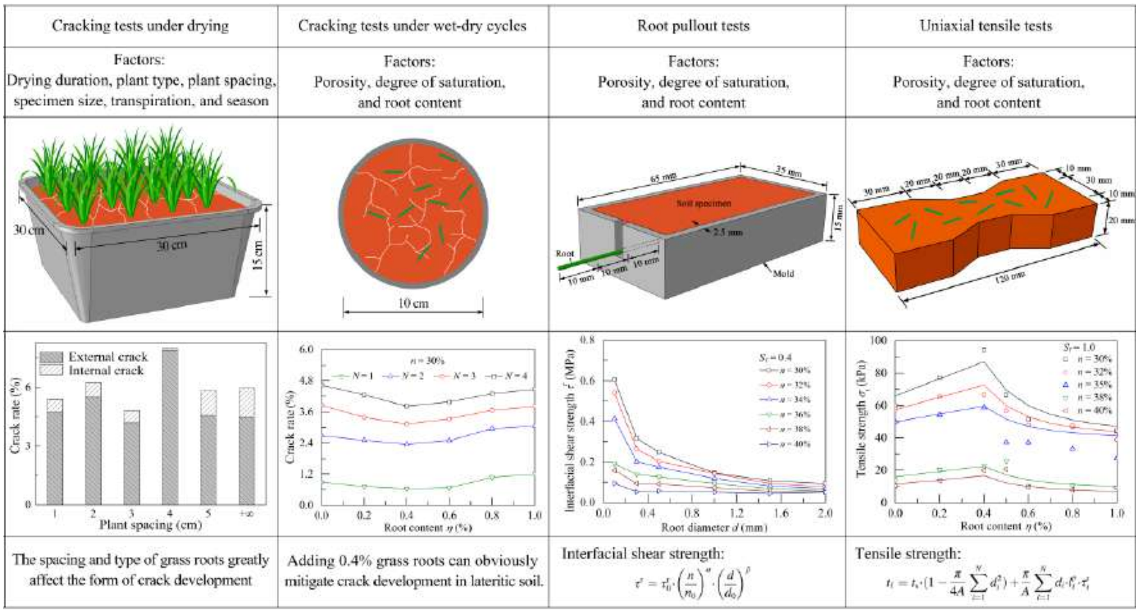

Fig. 1 Illustration of the macroscopic analysis methods

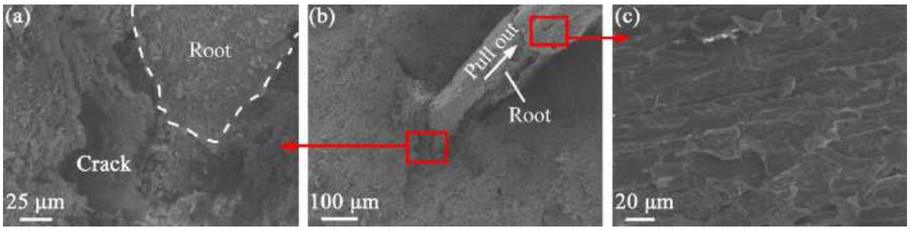

Fig. 2 Illustration of the microscopic analysis method

DISSOLUTION CHARACTERISTICS OF CORAL REEF LIMESTONE UNDER DIFFERENT SATURATED CO_2 CONDITIONSE

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ABSTRACT

The dissolution behaviours of coral reef limestone (CRL) in acidic environments significantly impacts its mechanical characteristics and the safety of coastal infrastructure. This study aims to explore the dissolution behaviours of CRL in saturated CO2 solutions under varying solution properties, temperatures, and pressures, to gain a deeper understanding of its dissolution characteristics. Experimental results indicate that the solubility of the CRL increases with decreasing temperature, increasing pressure, and higher solution salinity. Under identical dissolution conditions, CRL exhibits distinct dissolution characteristics based on variations in mineral composition and porosity. Specifically, compared to samples containing a small amount of magnesium calcite and calcite, samples with aragonite as the main mineral component exhibit higher solubility. In terms of pore structure, samples with independent pores and fractures gradually form channels during the dissolution process, resulting in significant surface etching. Conversely, for uniformly porous structures composed of different mineral constituents, selective mineral dissolution leads to uneven pore distribution. Meanwhile, samples with a single mineral composition and uniform porosity display a consistently uniform evolution of dissolved pore structures.

Keywords: Coral reef limestone, Mineral composition, Pore structure

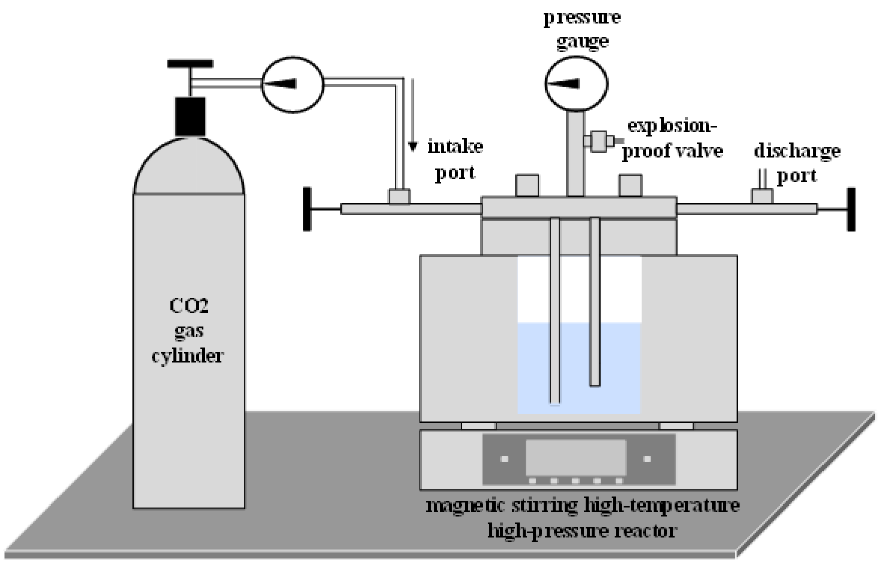

Fig. 1 Schematic of experimental setup.

THE ROLE OF BIO-GEOTECHNICS TO REACH NET ZERO COMMITMENT IN SLOPE ENGINEERING

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ABSTRACT

In the last few decades, the concepts of sustainable development and the net-zero commitment imposed by the United Nations have become the subject of various research and emerging eco-friendly technologies worldwide. The principles of two concepts have also expanded to geotechnical engineering, where innovative biological-based techniques were found promising in future development. For example, vegetation as a genuinely compatible element with the environment plays a crucial role in ecological restoration and rehabilitation efforts through offering numerous environmental benefits. Hence, it has been used extensively for flood and erosion reduction, level ground and slope stabilization, as well as urban greenery. Previous research proved that plant root system and its hydrological interactions with soil and atmosphere can effectively modify the engineering properties of soils. Therefore, this talk tries to compare the recently emerged bio-stabilization method in slope engineering with the two conventional construction methods of nailing and anchorage. In order to make a fair comparison as much as possible, a massive dataset from the current literature was retrieved in terms of the input variables for the process life cycle assessment (LCA) and the process life cycle cost (LCC) methods. Accordingly, the results are compared and discussed from the two perspectives of environmental and economic aspects (Fig. 1). According to a calibrated numerical model, slopes with certain geometries can be readily stabilized simply by planting compatible vegetation. Under these circumstances, even negative carbon emission can be achieved, attributed to the carbon-absorbing capacity of plants. Furthermore, design charts presented during this talk can help the practicing engineers to balance between environmental and economic aspects should conventional methods be the only possible solution to stabilize a slope. The talk will be ended by introducing some recent developments in the area of bio-geotechnics at Sharif University of Technology, thanks to the fine contribution of numerous research students.

Keywords: Green slope engineering; Life cycle assessment; Life cycle cost; Nailing; Anchorage.

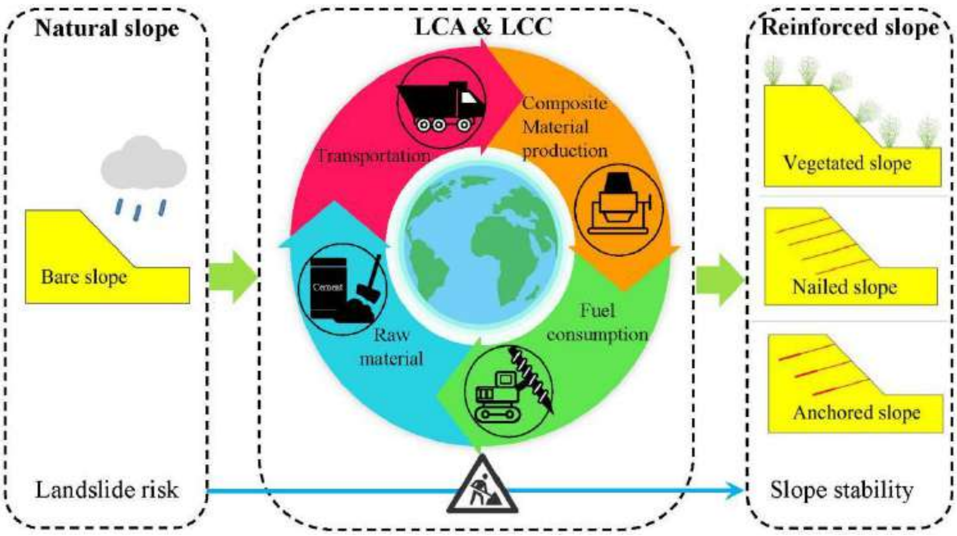

Fig. 1 Illustration of the proposed framework to compare different methods in terms of LCA and LCC

EFFECTS OF DIATOM MICROFOSSILS INCLUSION ON COMPRESSION BEHAVIORS OF SOFT CLAY

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ABSTRACT

Biogenous sediments containing diatom microfossils are widely distributed worldwide, mainly including lacustrine and marine types. Diatom microfossils, a special biogenic mineral different from general rock-forming minerals, endow the soil with unconventional engineering behaviors. This paper explored the influence of diatom content on soils by conducting a series of experiments on artificially mixed diatomaceous soil samples, from the perspective of consolidation characteristics. The influencing mechanism was revealed from the perspective of soil microstructure evolution through scanning electron microscopy tests and mercury intrusion porosimetry tests. The time- and stress-dependent consolidation characteristics of soils were extensively altered. The compression index of soil increases obviously, but the swelling index depends on specific circumstances. Alteration in microstructure of soils were deemed responsible and several microscopic tests have revealed this. In addition, the permeability and secondary consolidation characteristics of soils were also different from those of general soft soil. The application of some empirical concepts becomes rather limited for diatomaceous soils. Secondary consolidation of soil cannot be simply interpreted as the creep of soil skeleton, but the result of multiple mechanisms. These conclusions can clearly explain the various engineering problems arising from the use of classical concepts and methods to deal with diatomite in previous cases.

Keywords: Diatom microfossils; Compressibility; Artificial diatomaceous clays; Microstructure; Secondary consolidation.

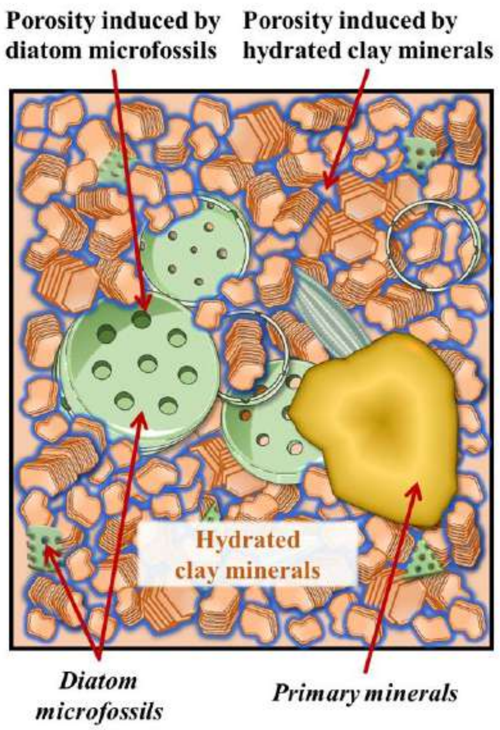

Fig. 1 Sketch conception of diatomaceous soil

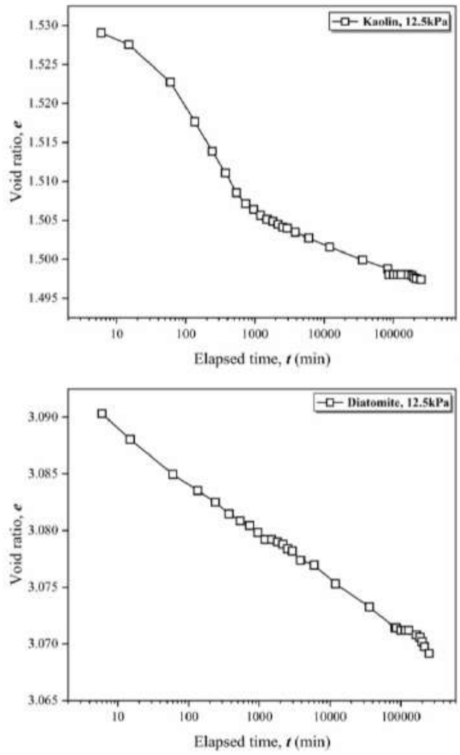

Fig. 2 *e*-log*t* curves of kaolin and diatomite

RESEARCH ON EROSION MITIGATION FOR SAND FORESHORE SLOPES BASED ON MICROBIOTA AND ENZYME MIX-INDUCED CARBONATE PRECIPITATION

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ABSTRACT

To mitigate foreshore erosion, it is necessary to find effective and environmentally friendly interventions to stabilize slopes. In this study, the microbiota and enzyme mix-induced carbonate precipitation (MEMCP) method was proposed to improve foreshore slopes' stability and mitigate erosion. The volume ratio of bacterial suspension (BS) and urease solution (US) varied to obtain the optimum condition. The angles of slopes, accumulative soil loss weights, surface strengths, and calcium carbonate ($CaCO_3$) contents were used to evaluate the treatment effect. The results showed that the slopes treated with microbially induced carbonate precipitation still experienced a drastic collapse. The slopes treated with enzyme induced carbonate precipitation had higher stability at the beginning; however, the slopes were still damaged in subsequent tidal cycles.With MEMCP treatment, the slopes' stability was significantly improved, especially for the slopes with the volume ratio of BS:US equaling 20:20. These slopes had higher surface strengths and $CaCO_3$ contents. In addition, the increase in $CaCO_3$ content resulted in an exponential increase in surface strength, regardless of the volume ratios of BS and US. The MEMCP method applied in this study for foreshore slope stabilization has shown success. The research lays a solid foundation for the application of foreshore surface erosion mitigation.

Keywords: MICP; EICP; Calcium carbonate; Erosion resistance; Foreshore slope

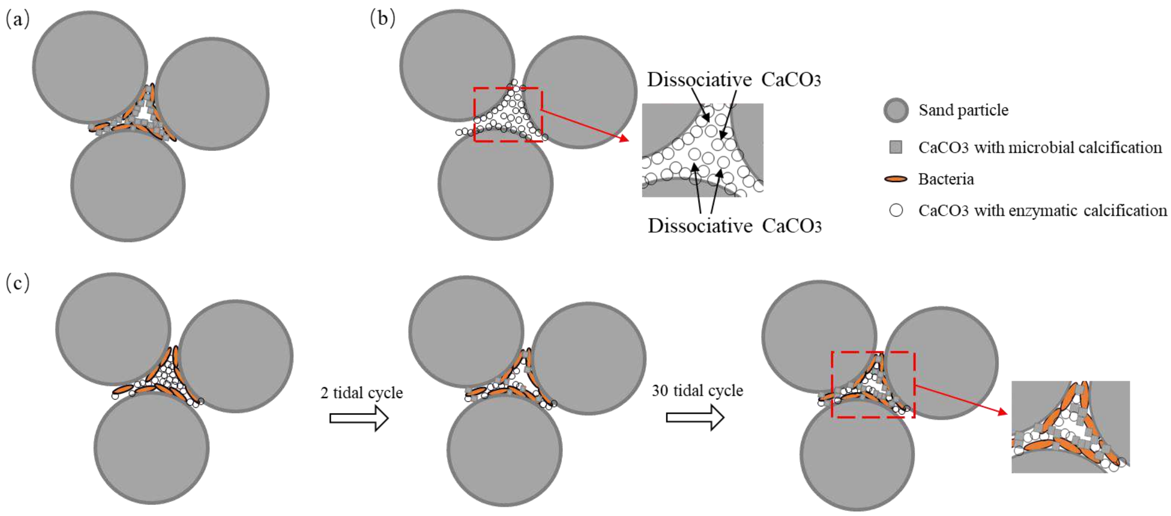

Fig.1. Schematic diagram of cementation between sand particles with: (a) microbially induced carbonate precipitation; (b) enzyme induced carbonate precipitation; (c) microbially and enzyme mixed induced carbonate precipitation.

EXPERIMENTAL STUDY ON THERMAL CONDUCTIVITY ENHANCEMENT OF CALCAREOUS SAND USING ENZYME-INDUCED CARBONATE PRECIPITATION (EICP)

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ABSTRACT

Geothermal energy is characterized as a clean, renewable and sustainable energy, however the thermal conductivity of backfill materials between energy geo-structure and stratum is the predominant factor affecting extraction efficiency of geothermal energy. Enzyme-induced calcite precipitation (EICP) has significant potential in improving the thermal conductivity of calcareous sand. The thermal conductivity and calcium carbonate content were identified to evaluate the enhancement effect. Moreover, the porosity of EICP-treated specimens was calculated according to the images of scanning electron microscope (SEM). Consequently, the thermal conductivity of EICP-treated calcareous sand increased as number of treatment cycles and calcium carbonate increased. The maximum values of thermal conductivity of EICP-treated calcareous sand was always obtained in finer sand (0-1mm). The optimal thermal conductivity of EICP-treated calcareous sand with finer particle was 4.5 times than its counterpart of untreated sand. Furthermore, the porosity of EICP-treated specimens gradually declined due to the formation of calcium carbonate, resulting in an increase in thermal conductivity of EICP-treated specimens. The enhancement of thermal conductivity of calcareous sand after treated by EICP may be caused by two aspects in the following: (a) calcium carbonate generation in the sand matrix; (b) the calcium carbonate precipitation on particle contact serving as "thermal bridge".

Key words: Enzyme induced calcite precipitation (EICP); Calcareous sand; Thermal conductivity; Micro-structure; Precipitation characterization

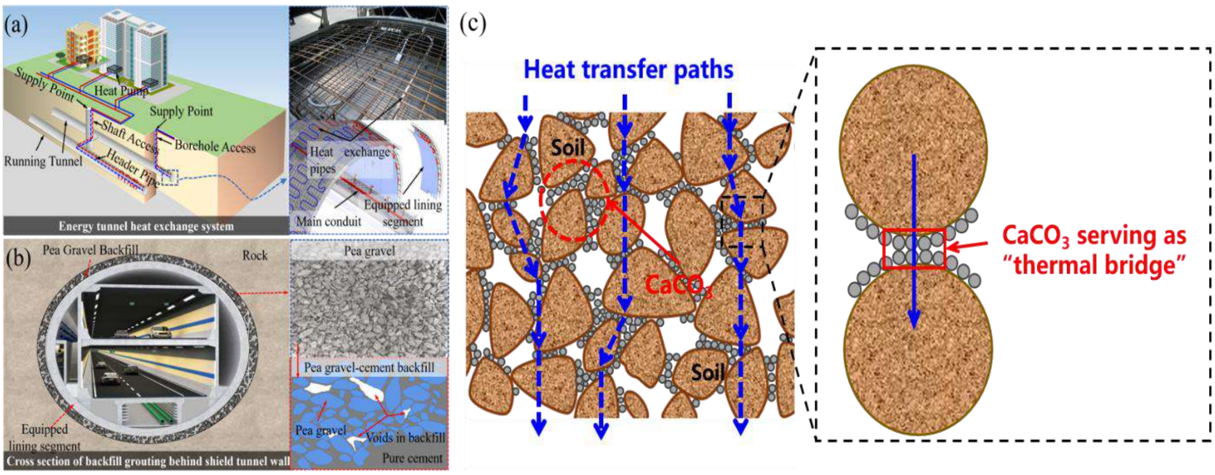

Fig. 1 Schematic diagram of energy tunnel heat exchange system (a); defects of pea gravel-cement backfill (b); CaCO3 generated by EICP serving as the thermal bridge for heat transfer in soil (c)

CONSIDERATIONS FOR IMPLEMENTING MICROBIALLY INDUCED CALCIUM CARBONATE PRECIPITATION (MICP) IN PRACTICAL APPLICATIONS

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ABSTRACT

Microbially Induced Calcium Carbonate Precipitation (MICP) has emerged as a promising biomineralization process with diverse applications across construction, environmental remediation, and soil improvement. As the transition from laboratory research to real-world applications progresses, it becomes paramount to address multifaceted considerations that impact the success and effectiveness of MICP implementations. This paper explores the array of critical considerations that guide the application of MICP in practical scenarios. Key factors encompass site-specific characteristics, microbial selection, nutrient delivery mechanisms, and strategies for real-time monitoring and control. The complex task of scaling up the MICP process to field scale while ensuring uniform distribution and engineering feasibility is deliberated. Regulatory compliance assumes significance in navigating the legal and environmental landscape, and thus, regulatory considerations become pivotal in securing approvals for MICP projects. Moreover, comprehensive performance testing, encompassing pilot studies and small-scale trials, is fundamental for evaluating the efficacy of MICP under site-specific conditions. Addressing the cost-benefit dynamics of MICP compared to alternative methodologies is imperative for demonstrating its economic viability. The assessment extends to long-term stability, accounting for factors such as erosion, microbial interactions, and potential alterations to the soil matrix over time. Emphasizing collaboration across multidisciplinary teams is advocated to integrate microbiological insights, engineering acumen, and environmental expertise. Furthermore, community engagement strategies play a role in fostering transparency and building rapport with stakeholders affected by the MICP application. In essence, this paper underscores that successful implementation of MICP hinges on a holistic approach encompassing scientific understanding, engineering precision, regulatory adherence, environmental responsibility, and adaptive learning. By navigating these considerations, researchers, engineers, and practitioners can pave the way for the judicious integration of MICP in practical applications, thereby addressing challenges and fulfilling the technology's transformative potential.

Keywords: Microbially Induced Calcium Carbonate Precipitation (MICP), Laboratory Research, Application of MICP, Small-scale Trials, Environmental Responsibility

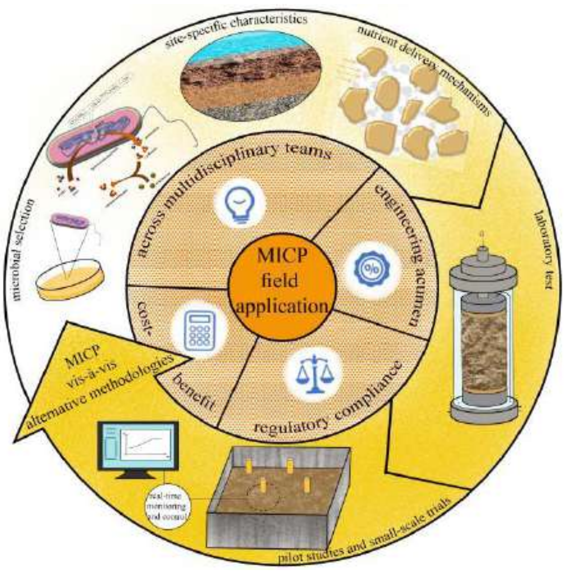

Fig. 1 Illustration of the critical considerations of MICP in practical applications.

NATURAL SYMBIOTIC FUNGI STRENGTHEN PLANT ROOTS

Xun Wen Chen[1], *Viroon* Kamchoom[2], *Jia Qi* Wu[3], *Guo Dong* Sun[4], *Qiang* Zhang[3], *Hui Shan* Li[3], *Ming Hung* Wong[5], *Hui* Li[1], *Jun-Jian* Wang[3#]
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[#]*Corresponding author; Underline denotes the presenter; XWC and VK contributed equally to this work*

ABSTRACT

Strong plant roots are desired during green slope engineering. The natural microorganisms, arbuscular mycorrhizal (AM) fungi, can increase root strength. They form "win-win" associations with many plants, aiding them in combating stressful conditions. How AM fungi alter essential root biomechanical properties remains unclear. We cultivated vetiver grass (*Chrysopogon zizanioides*) inoculated with three different fungal species and compared them with grass without fungi. Yield strain, yield stress, break strain, tensile strength, Young's modulus, plastic modulus, plastic strain, and toughness were determined for each root (388 in total). The results showed that AM fungi decreased Young's and plastic modulus by 23% and 17%, respectively, versus those without fungi (species-dependent). The yield stress was not significantly affected, but the tensile strength was increased by 7–17% due to the fungi. Together with the increases in break strain by 15–20%, the fungal roots exhibited a notably higher toughness than non-fungal roots by up to 36%. Greater root cohesion of the fungal roots suggests an enhanced (1.5-fold) factor of safety in the soil-root system. Our findings imply that AM fungi are of significant interest in studying plant biomechanics. AM fungi offer considerable potential for enhancing vegetation and stabilizing green slopes.

Keywords: Symbiosis, Tensile strength, Modulus, Toughness, Root cohesion

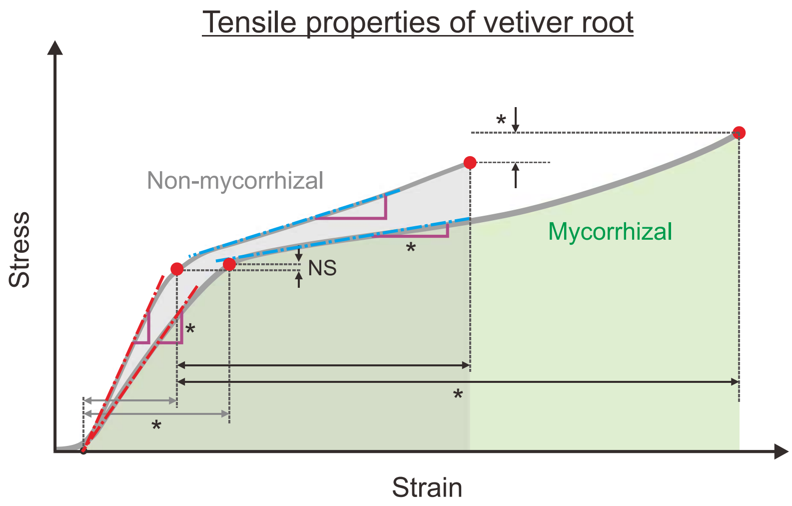

Fig. 1 Schematic illustration of the mycorrhizal fungal effects on the biomechanical properties. Asterisks: statistically significant differences (non-mycorrhizal vs mycorrhizal). NS: non-significant.

AN INVESTIGATION OF MICROSCOPIC INTERACTION BETWEEN TALL FESTUCA ROOT GROWTH AND SAND BY USING X-RAY MICROTOMOGRAPHY

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ABSTRACT

This study aimed to enhance the understanding of root-soil interaction at a microscale level and its implications for vegetated slopes. Specifically, the interaction between tall fescue root growth and sand was investigated using four-dimensional (4D) CT scanning. The growth process of tall fescue roots in the sand was tracked on the 2nd, 4th, 6th, and 8th days after seed transplantation. To accurately segment root/soil CT images and overcome challenges such as the partial volume effect (PVE) and the similarity of root water grayscale in CT images, a semi-automatic segmentation process was developed. This study clarified the three-dimensional spatial distribution of soil porosity and saturation during the grwoth of tall fescue roots and revealed the gradual increase of shallow soil porosity under the influence of roots, as well as the evolution process of overall saturation reduction of sand columns. The results show that a higher initial soil porosity leads to a longer and thinner root system, and a lower initial soil porosity results in a shorter and thicker root system. The “short and thick” roots loosen the pore network near the roots as they grow, causing an increase in soil porosity near the roots, which slightly reduced the water retention capacity. The “long and thin” roots fill the pores as the roots become thicker, causing a slight decrease in soil porosity near the roots. The soil saturation decreases globally with root growth. The study also revealed that the root system's influence on saturation, on the eighth day after transplantation, extended up to 800 pixels (8 mm) from the root surface.

Keywords: Root-soil interaction; X-ray computed tomography; Image segmentation; Representative volume element.

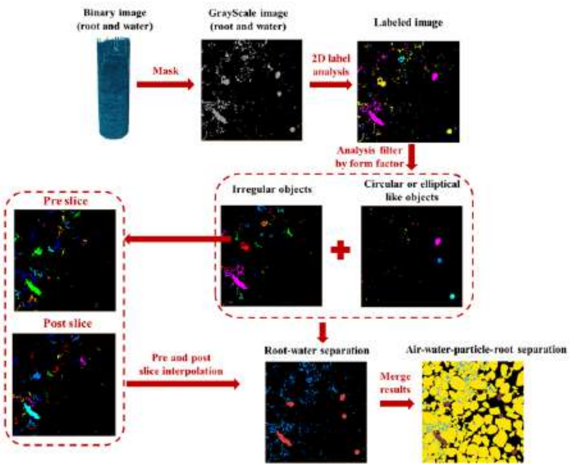

Fig. 1 Flow chart of root-water phase segmentation in the root-soil image

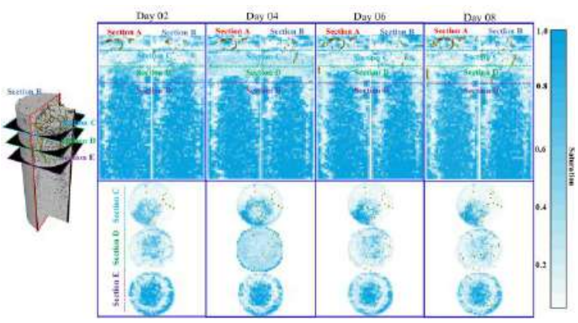

Fig. 2 Saturation analysis based on RVE grid

INVESTIGATION ON CANOPY INTERCEPTION PERFORMANCE OF TYPICAL SLOPE PROTECTION GRASSES

Xu-Guang Gao[1], and *Ji-Peng Wang*[2#]

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ABSTRACT

The redistribution of precipitation by vegetation canopy can significantly change the spatial distribution pattern of surface precipitation, thus affecting a series of hydrological processes such as infiltration, runoff and evapotranspiration. This study conducted experimental investigations on the canopy interception characteristics of five typical slope protection grass species using the water-balance method (WBM), the water-wiping method (WWM) and the water-immersion method (WIM), respectively. The results showed that the variation process of canopy interception over time can be divided into three stages: rapid period, slow period, and saturation period. The contact angle of leaves may be an important canopy variable that explains the differences in canopy interception between different grass species, and the canopy interception per unit leaf area decreases as the contact angle increases. Leaf area, dry mass, rainfall intensity, canopy projection area and precipitation were the five most influential factors affecting canopy interception, with gray correlation coefficients of 0.8552, 0.8090, 0.7882, 0.7723 and 0.7559, respectively. There is a significant positive correlation between canopy interception and canopy structural parameters such as leaf area, dry mass, and canopy projection area. Canopy interception tended to increase and then decrease with increasing rainfall intensity, while the relationship between canopy interception ratio and precipitation satisfied a negative power function.

Keywords: Rainfall interception; Grass; Leaf hydrophobicity; Influencing factor; Test methods

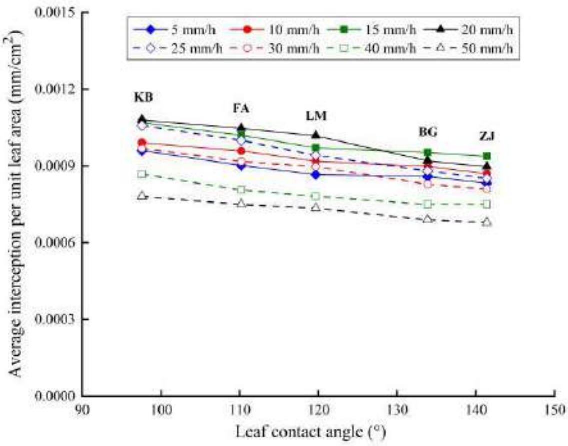

Fig. 1 The relationship between leaf contact angle and canopy interception per unit leaf area.

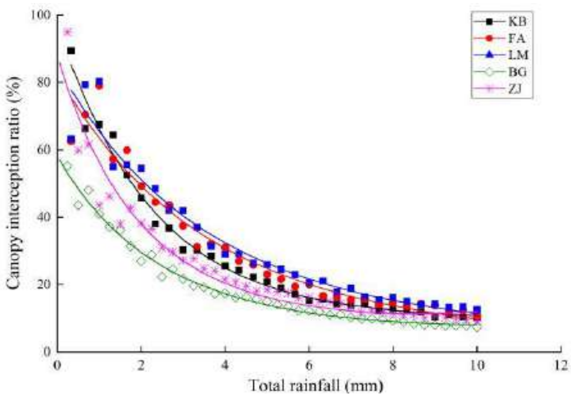

Fig. 2 The relationship between canopy interception and precipitation.

PORE-BASED MODELLING OF RELATIVE HYDRAULIC CONDUCTIVITY FUNCTION OF UNSATURATED ROOTED SOILS

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ABSTRACT

Mualem's approach has been widely used to predict relative hydraulic conductivity (K_r) functions of soils if a soil water retention curve (SWRC) model was available. The assumption that the Mualem's approach holds is that the distribution of soil pores is spatially completely random. Under this assumption, K_r is determined by the continuance probability of water-filled pores. However, this assumption is not valid for rooted soils since root growth causes soil particle and thus soil pore rearrangement, which reduces the degree of randomness of pore distribution to certain extent. Without considering the root effect on pore distribution, predictions of K_r of rooted soils by Mualem's approach are far from the measurements. This study aims to develop a new approach for predicting K_r of rooted soils by considering the soil pore rearrangement induced by roots, and the resultant change in continuance probability of water-filled pores in rooted soils. The new model was verified against experimental data from literature. Prediction is compared with that by the Mualem's approach and it is found that the proposed new model demonstrates its ability to predict K_r of rooted soils reasonably well within all range of suction investigated.

Keywords: Mualem's approach, hydraulic conductivity function, soil water retention curve, rooted soil, unsaturated soil.

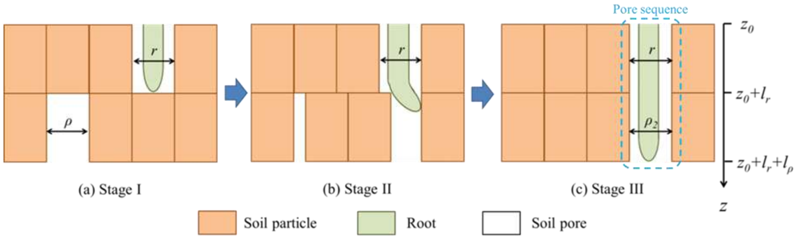

Fig. 1 The process by which the single root changes the spatial distribution of soil pores

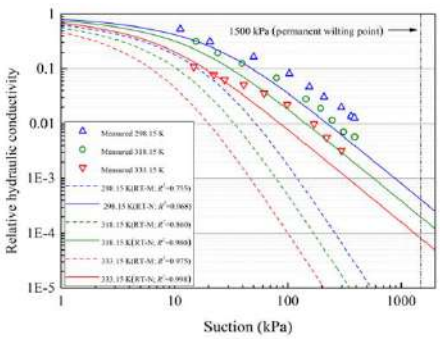

Fig. 2 The comparison among experimental data, the prediction by the Mualem's approach and the prediction by the new model

HYDROGEN SULPHIDE IN LANDFILL GAS AFFECTS GRASS GROWTH AND SOIL HYDROLOGICAL RESPONSE IN GRASS-PLANTED UNSATURATED SOIL.

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ABSTRACT

Vegetation has been found to improve the performance of landfill cover. However, effects of hydrogen sulphide (H_2S) remain unclear, which is a toxic odour generated in landfills but very recently appears as a potential signalling molecule in plant metabolism, such as stomatal aperture. The present study aimed to investigate effects of H_2S on Bermuda grass growth and hydrological response of soil. Four series of soil columns were conducted, including three series with vegetation fumigated with different H_2S concentrations, and a series for bare soil as reference. Drying-wetting cycle was applied. It was found that leaves almost withered in the vegetated soil without H_2S fumigation, likely due to the Pythium diseases caused by antecedent waterlogged conditions. In contrast, higher H_2S fumigation promoted the survival of grasses, probably due to the fungicidal effects of H_2S. During drying, the vegetated soil fumigated without H_2S had the largest suction, while vegetated soils with H_2S fumigation had similar suction to bare soil. It may be due to the closure of stoma induced by H_2S. During wetting, a lower infiltration rate but a higher suction were observed in the bare soil than that in vegetated cases, as a result of decay roots in the later cases.

Keywords: Plant transpiration; water flow; Landfill gas; Plant-soil interaction.

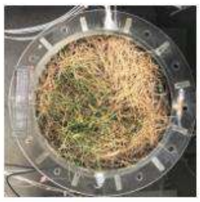
Ventilated with air containing 50 ppm H_2S	Ventilated with air	Ventilated with air containing 50 ppm H_2S	Ventilated with air containing 100 ppm H_2S
			

Fig. 1 Overhead view of bare and vegetated soil columns ventilated with different concentrations of H_2S at the end of drying test

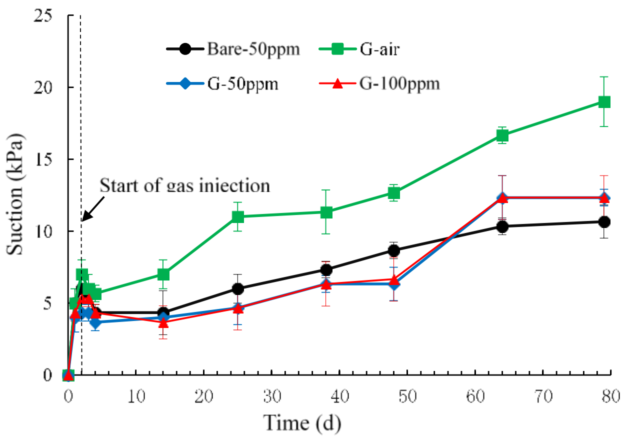


Fig. 2 Temporary variations of measured suction at depth of 0.3 m in bare and vegetated soil columns during drying period (G present grass-planted soil; the error bar represents standard deviation)

EFFECTS OF SINGLE AND MIXED PLANT SPECIES ON METHANE EMISSION REDUCTION IN EARTHEN LANDFILL COVER UNDER DRYING AND WETTING CYCLES TITLE

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ABSTRACT

The effects of single and mixed plant species on methane emission reduction in earthen landfill cover were investigated. The landfill cover consist of a machine-made sand tailing mixed with bentonite layer, a gravel layer, and a silt layer. A total of four drying-wetting cycles tests were conducted. During experiment, plant characteristics, soil moisture content, gas pressure, and gas concentration was monitored. Tests results show that landfill gas has a coercive effect on plant growth. The methane oxidation of the mixed plant species group is larger than that of single plant species group, and the methane emission reduction rate of single species group is approximately 69-89% of that of the mixed species group. Differences in methane oxidation between the mixed and single species group increase with the increase of drying-wetting cycles. After four drying-wetting cycles, the methane oxidation rate of both mixed and single species groups rapidly decreased. This study reveal that under drying-wetting conditions, the combination of plant affects methane oxidation in landfill final cover. This research provide a theoretical basis for methane emission reduction treatment in landfill.

Keywords: Drying-wetting cycles; Single and mixed plant species; Methane emission reduction

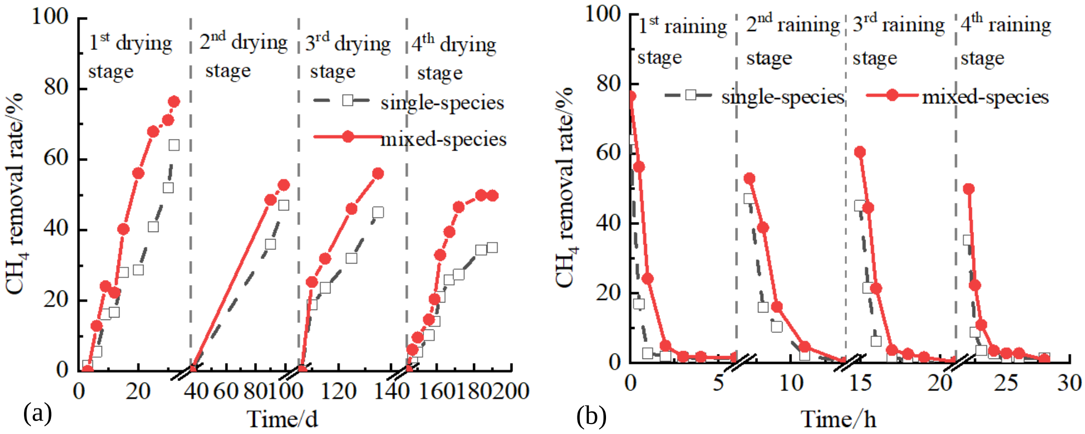

Fig. 1 Methane removal rate of single and mixed plant species group during (a) drying and (b) wetting.

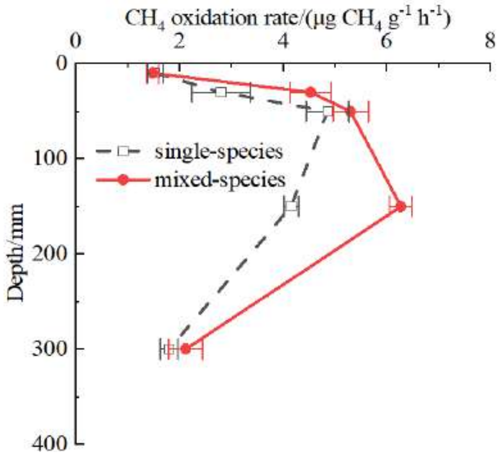

Fig. 2. Methane oxidation rate at different depth

ROLE OF BIOCHAR IN IMPROVING BIOSTIMULATED MICP: SHEAR STRENGTH ENHANCEMENT AND AMMONIUM REMOVAL

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ABSTRACT

Biostimulation via the amplification of indigenous ureolytic bacteria has been established as a practical strategy for executing microbially induced carbonate precipitation (MICP). To adapt this methodology to real-world engineering contexts, current research is focused on: (1) augmenting the cementation content to bolster the mechanical attributes of biocemented sand; and (2) mitigating the detrimental impact of ammonium, a harmful byproduct. In the present study, biochars of varying morphologies were deployed as additives in calcareous sand. The influence of biochar on shear/stress-dilatancy behaviors, alongside ammonium removal, was scrutinized through isotropically consolidated drained (CD) triaxial shear tests and corresponding ammonium adsorption and leaching tests. Experimental outcomes revealed that biochar exerted a positive impact on cementation content, especially in the case of powdered biochar possessing smaller particle sizes, which increased peak shear strength in CD tests. Microscopic analysis of biochar-supplemented biocemented sand suggested that biochar could operate as supplementary nucleation sites for precipitation. Moreover, biochar demonstrated remarkable ammonium removal in both aqueous and sand column conditions. A schematic diagram depicting different ammonium removal processes is presented in Fig. 1. These discoveries bear substantial practical implications for the stabilization of local calcareous sand, as well as for global coastal cities.

Keywords: Biostimulation; Biochar; Triaxial consolidated drained shear test; Ammonium removal.

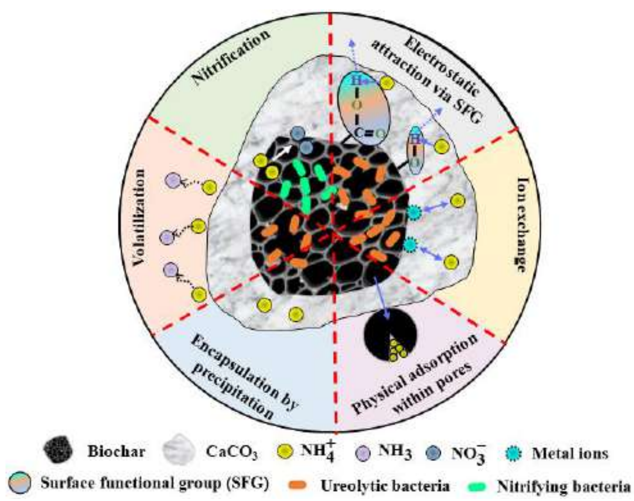

Fig. 1. Potential mechanisms for ammonium removal during biostimulated MICP process

MULTISCALE EXPERIMENTS AND DEM MODELING OF BIOTREATED SAND

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ABSTRACT

The Microbially Induced Calcium Carbonate Precipitation (MICP) technique is a promising green reinforcement technique, which utilizes the metabolic activities of microorganisms to form calcium carbonate ($CaCO_3$) within the pore space of soils to improve their physical and mechanical characteristics. Biotreated sand presents clear multiscale nature, namely the grain-scale structural and mechanical features can significantly affect the meso- and macro-scale properties. A systematic study will be presented herein from the perspectives of multiscale experimental study and DEM modelling. Microfluidic experiments will be presented to illustrate the evolution of calcium carbonate precipitation under the MICP conditions; grain-scale experiments for the particle scale mechanical features of MICP bonds; meso- and macro-scale experiments for the engineering performance of biotreated sand. DEM model of biotreated sand has been established to build bridge between the lower scale mechanical features of MICP bonds and the upper scale engineering properties of biotreated sand. Cementing fines have been adopted in the DEM model to consider the various precipitation patterns and the inhomogeneous distribution of within the space. Hopefully, this work will provide a brief multiscale picture of biotreated sand to the geotechnical community.

Keywords: MICP; biotreated sand; microstructure; cementing fines

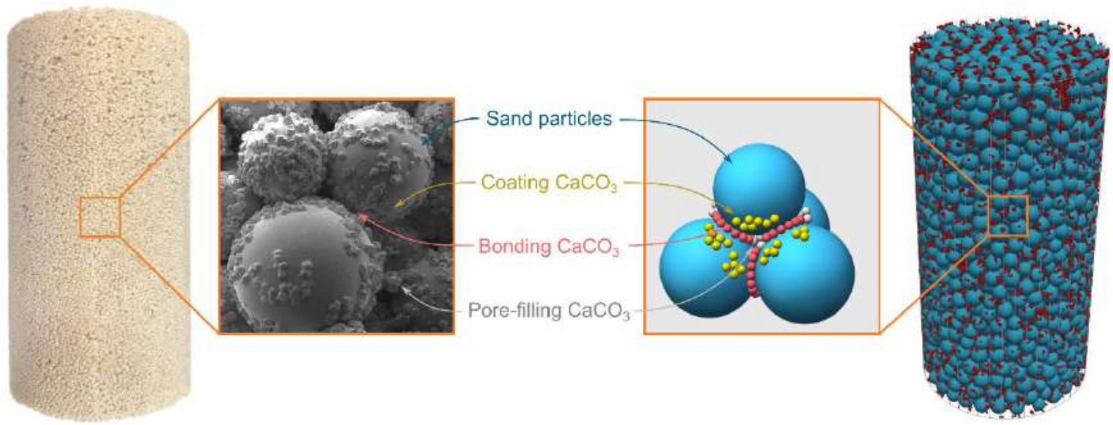

Fig. 1 Illustration of the research strategy (adapted from [1])

ANISOTROPIC BEHAVIOUR OF OVERCONSOLIDATED ROOTED SOILS

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ABSTRACT

The use of vegetation as a sustainable nature-based solution to reinforce shallow soil slopes is an ecologically and environmentally friendly approach. The rooted soil could be consolidated due to different natural processes such as drying-wetting cycles, traffic loadings and compaction. However, the effect of roots on soil reinforcement in over consolidated (OC) conditions has not been addressed in the literature. To examine the anisotropic behaviour of OC rooted soils, two sets of drained monotonic triaxial tests were carried out. Decomposed soil samples were cultivated with vetiver grass (*Chrysopogon zizanioides L.*) and were subjected to compression and extension stress paths at two different over consolidation ratios (OCR) of 1 and 3 and three effective confining pressures (i.e. 50, 100, and 150 kPa). With the increase in OCR, the shear strength of rooted soil was increased (Fig. 1), yet the contractive volumetric behaviour of the soil samples reduced. As a result, there was a shift of the centre of the Mohr's circle of strain towards the extensive side of the strain increment (Fig. 2). This means that OC rooted soil samples displayed a higher shear strength compared with normal consolidated case, attributed to more root tensile stress mobislisation under the OC condition.

Keywords: Rooted soil, Anisotropy, Over consolidation, Shear strength

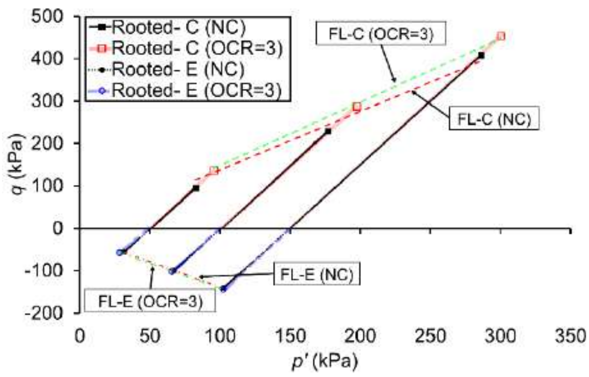
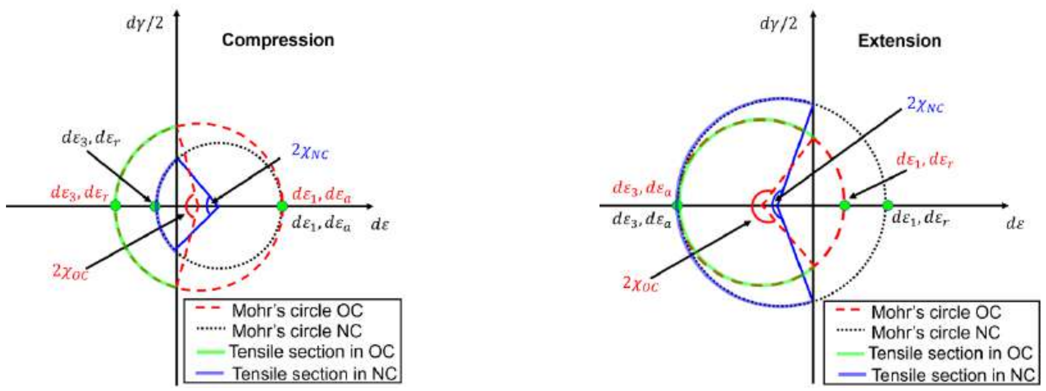


Fig. 1 Stress paths and failure envelopes derived for rooted samples at *p'* = 50, 100, 150 kPa under NC and OC conditions.



(a) **(b)**

Fig. 2 Shechmatics of the Mohr's circles of strain for the triaxial tests of NC and OC rooted samples: (a) compression path and (b) extension path.

PRELIMINARY OBSERVATIONS OF FINE ROOT EFFECTS ON SOIL HYDRAULIC PROPERTIES

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ABSTRACT

Fine roots of plants are generally known to exhibit more significant physical interactions with soil pore structures compared with coarse roots, inducing different effects on the hydraulic properties of unsaturated soils. However, the fine root impact on soil hydraulic properties (SHPs) based on direct experimental observations is not straightforward due to the inability to quantify pore-level root-soil interactions. This study aims to measure the effects of fine root on SHPs, specifically the saturated hydraulic conductivity and water retention curves, aiding with a multiscale X-ray computed tomography image-based analysis workflow. Element-scale experiments showed a clear relationship between the water retention (**Fig. 1a**) and the pore diameter (**Fig. 1b**) of rooted soils. A root system with more fine roots could fill the micropores (pore size comparable to root radius) to reduce the conductivity due to pore clogging, whereas that with coarser roots could increase the inter-aggregate pore size by particle reorganisation. Therefore, the fine root effects on the SHPs can be clearly observed by the proposed experimental methods and the multiscale workflow.

Keywords: Fine roots, rooted soils; soil water retention curve; saturated permeability; X-ray computed tomography

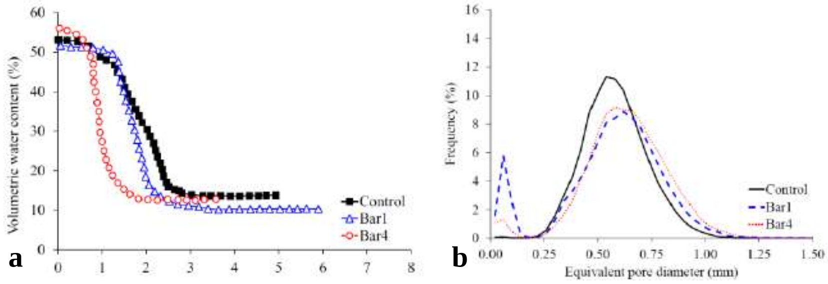

Fig. 1 Root-induced changes in (a) soil water retention curves and (b) equivalent pore diameter of rooted soils. Control, Bar1, and Bar4 denote the specimens without a plant, one seed, and four seeds, respectively.

NEW COLLABORATIVE TECHNOLOGY SYSTEMS FOR MOUNTAIN DISASTER PREVENTION BASED ON NBS CONCEPT

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ABSTRACT

Mitigating mountain disaster (e.g., debris flows and landslides) risks, should consider both timely control and long-acting effect, focusing on ecological restoration and sustainable development. Conventional, one-dimensional approaches—ecological or geotechnical—fall short. A comprehensive, nature-based solution integrating eco-geotechnical methods is imperative and necessitates novel technologies and improved mitigation standards. Yet, understanding and effectively applying eco-geotechnical concepts and models in hazard management remain partial. Consequently, this study provides a comprehensive summary and extension of the evolution of treatment measures for mountain hazard mitigation by the bibliometric visualization review. The results reveal that the evolution of mountain disaster management has shifted from pure geotechnical measures to ecological measures to synergistic measures based on natural solutions. This emphasizes the importance of ecosystem restoration and sustainable development in addition to immediate prevention and control. Meanwhile, we define the concept and connotation of eco-geotechnical synergistic measures in debris flow mitigation, list the corresponding collaborative measures and functions based on different conditions and scales, point out the remained scientific issues, and use a case study to validate the benefits of comprehensive measures. Overall, this study has the potential to break through existing disaster prevention concepts and models, promote scientific and technological innovation in disaster reduction, and guide the development of eco-geotechnical measures for coordinated prevention and control of mountain disasters.

Keywords: nature-based solution; mountain hazards mitigation; eco-geotechnical synergistic measure; debris flow; mountain area

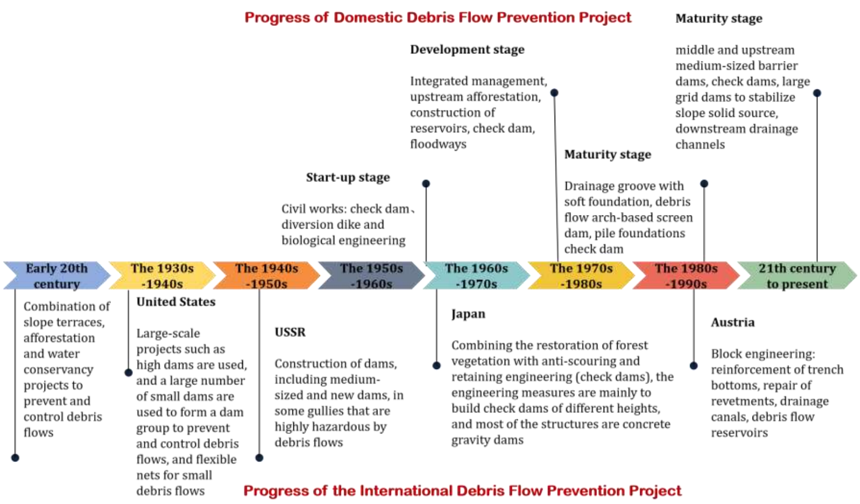

Fig.1 The progress of mountain disaster prevention methods

HERBACEOUS SPECIES AND MYCORRHIZAL FUNGI INTERACTION ON SOIL AGGREGATE STABILIZATION AND DISINTEGRATION IN COMPACTED SOIL

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ABSTRACT

Soil aggregate is a crucial structural unit that reflects and affects near soil surface physical, chemical, and microbial characteristics. Soil erosion process is influenced by water-stable aggregates, which can decrease the detachment capacity and increase the potential for deposition. While the abrasion of aggregates during transport can generate finer and more transportable particles, leading to a substantial impact on sediment transport capacity and erosion rate. Aggregate stability is therefore an essential property in establishing soil erosion models and evaluating the success of revegetation on geotechnical structures. In this study, we investigate the effects of soil compaction, herbaceous species (e.g., *Cynodon dactylon* and *Chrysopogen zizanioides*), and soil arbuscular mycorrhizal fungi on aggregate properties of completely decomposed granite using a pot-culture experiment (Fig. 1). We conducted measurements of plant growth characteristics and various chemical and microbial agents related to soil aggregation, including plant biomass, root and hyphae length density, soil total organic carbon, polysaccharides, and glomalin-related soil protein. The dry-sieving method was employed to determine soil aggregate formation, and the Le Bissonais method and a particle size analyzer were utilized to assess the stability and fractionation of soil macro-aggregates. Our research findings will be discussed during the conference.

Keywords: soil aggregate stability, aggregate breakdown mechanisms, vegetated slope

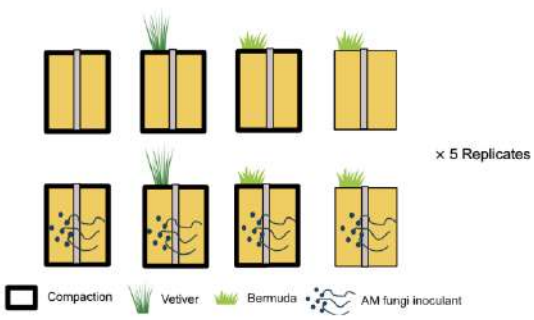

Fig. 1 Experiment setup

NUMERICAL MODELLING OF RAINFALL-INDUCED INTERNAL EROSION PROCESS WITHIN VEGETATED DEPOSITED SLOPES

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ABSTRACT

The hydro-mechanical responses of vegetated deposited slopes are complicated and far from clear. On one hand, the soils in those deposited slopes are usually widely graded and weakly consolidated, which are susceptible to internal erosion upon rainfall infiltration; on the other hand, vegetation can affect the soils' hydro-mechanical characteristics significantly on the slope surface. This paper investigates the influence of roots at different ages on the rainfall infiltration process as well as the associated internal erosion process via a seepage-erosion coupled finite element method. The numerical results indicate that the roots at different ages will exhibit totally different effects on the rainfall infiltration and internal erosion processes of deposited soils, hence leads to complicated and even opposite results on the stability of vegetated deposited slopes.

Keywords: vegetated deposited slopes; internal erosion; slope stability; finite element method

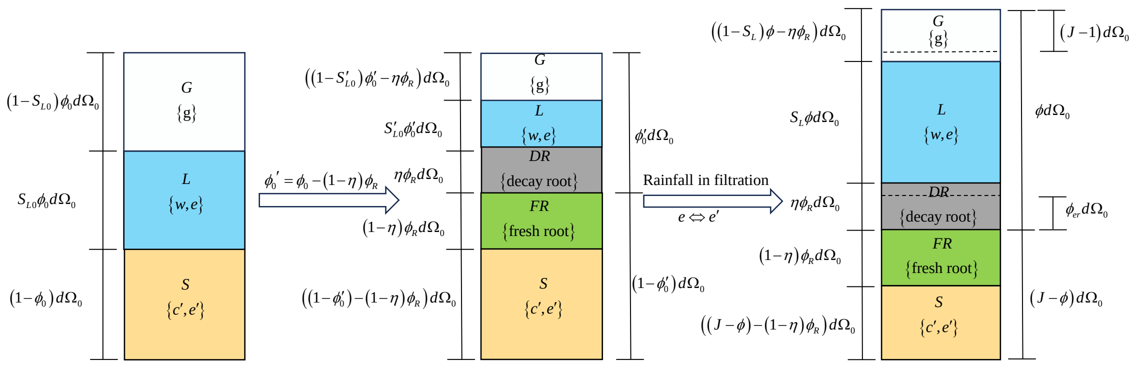

Fig. 1 Schematic illustration of initial and current volume fractions after infiltration.

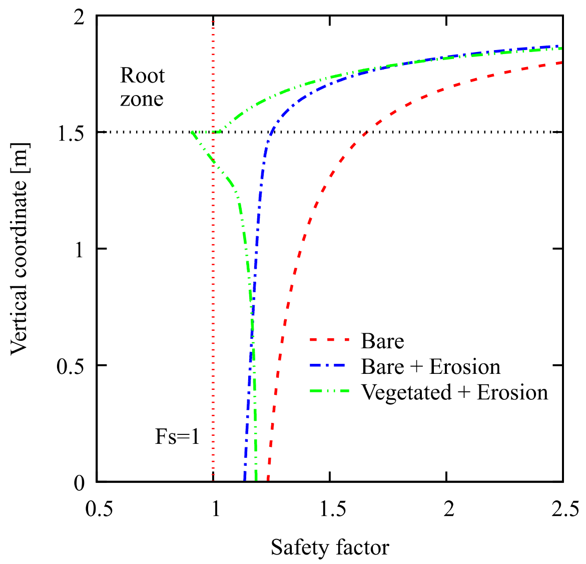

Fig. 2 Safety factor of mix root group on deposited slopes

FAILURE BEHAVIOR AND SURROUNDING SOIL STRESS RESPONSES OF SUCTION ANCHOR IN LOW STRENGTH MUDDY CLAY

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ABSTRACT

Anchorage failure of suction anchor is more likely to occur in low strength muddy clay. This paper focuses on the failure behaviors of suction anchors and muddy clay stress responses. The centrifugal model test was used to study the loading processes of suction anchors with various pulling angles. Firstly, the multi-stage developing process of anchoring force was analyzed according to the test results. The numerical modeling was used to validate the test results. The displacement of the suction anchor and muddy clay soil were analyzed according to the numerical results. Then, the mechanical responses of horizontal soil stress around the inclined pulling suction anchors were analyzed. The change in loading direction affected the distribution and development of soil stress. The horizontal soil resistance was helpful in improving the bearing capacity. The soil stress variation indicated that the suction anchors showed multi-attitude coupling movement during the inclined pulling. The vertical pulling suction anchor showed shear—slip failure behaviors, and the inclined pulling suction anchors showed compression—shear—slip coupling failure behaviors. The results of this paper reveal the interaction mechanism between the suction anchor and muddy clay, which can provide references for the design and application of suction anchors.

Keywords: centrifugal model test, suction anchor, failure behavior, muddy clay.

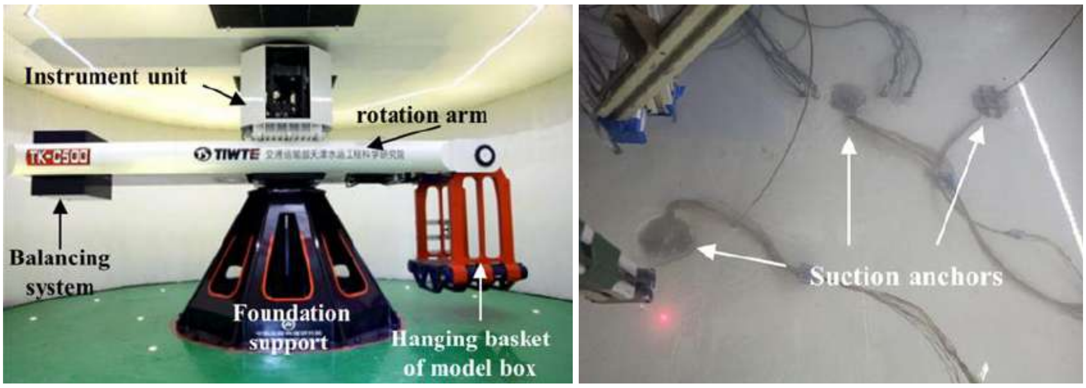

Fig. 1 The geotechnical centrifuge and model suction anchors

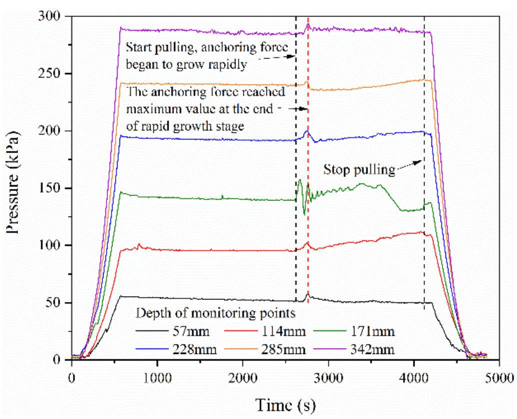

Fig. 2 Soil pressures development around the suction anchor

FEASIBILITY OF BARE FBG SENSING TECHNOLOGY IN THE MEASUREMENT OF INNER WALL AXIAL STRESS ALONG OPEN-ENDED PIPE PILE IN SAND

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ABSTRACT

Larger-diameter open-ended pipe piles are widely used as foundation for offshore structures. The lack of high-quality inner wall axial stress measurement results in difficulties in loading analysis of open-ended pipe piles during penetration and service period due to the effect of soil plugging. In this paper, two groups of model tests to assess the feasibility of bare FBG sensing technology in monitoring the inner wall axial stress profile of open-ended aluminous pipe piles during penetration and horizontal loading are presented. One open-ended aluminous pipe pile was instrumented with bare FBG sensors and then penetrated into the sand bed with penetration rate of 20 mm/min and 30 mm/min, respectively. Two horizontal static loading tests were also conducted after 24 hours penetration. Model test results indicated that the bare FBG sensing technology was feasible to measure the axial stress of inner wall along open-ended pipe piles during penetration and horizontal loading in sand. The axial stress difference of inner wall and outer wall along model pile in penetration and horizontal loading is the result of a combination of the inside and outside soil friction as well as of the pipe in-wall shear stiffness.

Keywords: Bare FBG sensing technology; Open-ended pipe pile; Inner wall axial stress; Outer wall axial stress; Sand bed

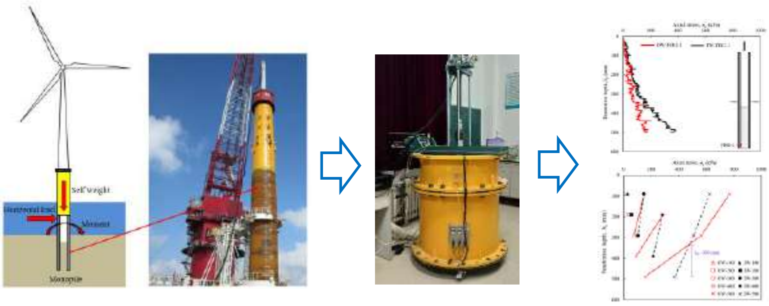

Fig. 1 Model test of offshore wind turbine foundation

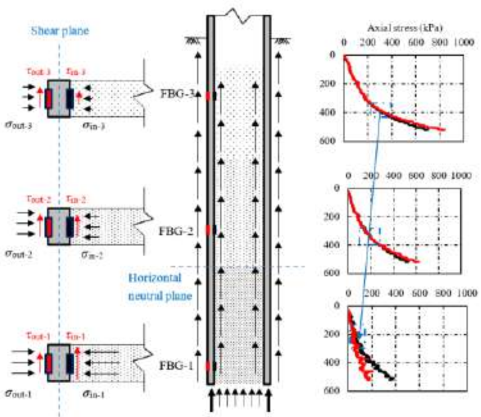

Fig. 2 Schematic diagram of soil stresses action on IW and OW of model pile during installation

STABILITY CHARACTERISTICS OF PERMEABLE ARTIFICIAL BLOCK ARMOR STRUCTURE AND FOUNDATION OF SLOPING BREAKWATER UNDER WAVE ACTION

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[#]Corresponding author; Underline denotes the presenter

ABSTRACT

As a protective material for sloping breakwaters, permeable artificial block structures have po-rous water permeability that reduces the wave impact force. Meanwhile, the gaps facilitate the growth of animals and plants, which have positive ecological effects. Understanding the stability characteristics of permeable artificial block structures under wave action can aid deci-sion-making regarding their structural selection and application. In this study, we examined the stability characteristics of a guide-levee protective block structure with different numbers of openings using a wave flume cross-sectional test. Prior research has shown that the dynamic fac-tors that affect the instability of the armor block under wave action can be characterized by wave energy; hence, an instability-state function corresponding to the critical condition of the armor block structure failure was devised. After waves hit a block, they often break, and the position of the wave breaking is consistent with the position of the maximum wave pressure. A calculation formula for the maximum breaking wave pressure was established on the basis of experimental data. Our results show that laying an underlayer below the permeable protective block can ef-fectively improve the wave attenuation effect. Therefore, it is recommended to use an underlay-er for projects requiring high wave resistance.

Keywords: breakwater; wave; slope protection structures; physical model test

(a) (b)

Figure 1. Equipment for the wave cross-sectional model test. (a) Multifunctional wave test flume. (b) Absorbing wave generator.

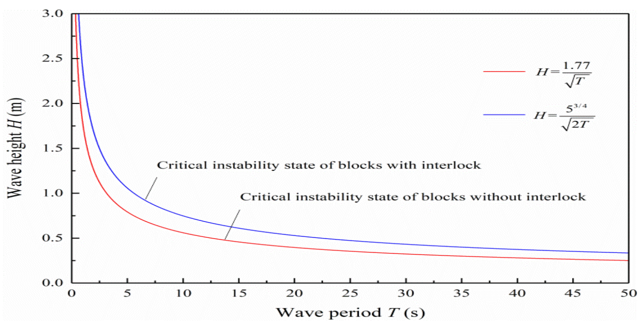

Figure 2. *H*–*T* function of critical instability state of four-sided interlocked blocks and non-interlocked blocks.

THE BEHAVIOUR OF FRP-CONFINED SAND AND CEMENTED SAND UNDER FOUR-POINT FLEXURAL TESTS

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ABSTRACT

The use of fibre-reinforced polymer (FRP) composites is on the rise due to their excellent corrosion resistance, making them a viable alternative to traditional piling materials in harsh environments. This paper presents a novel glass fibre-reinforced polymer (GFRP) pile that includes an outer GFRP tube filled with sand or cemented sand. Four-point flexural tests were conducted to evaluate the flexural behaviour of the new pile system, and the Optical Frequency Domain Reflectometry (OFDR) technique was utilized to capture the longitudinal strain distributions during the tests. The effects of the type of infill material (sand or cemented sand) and the wall thickness of the GFRP outer tube (3 mm or 5 mm) were investigated. The test results showed a significant improvement in the flexural bearing capacity and deformation ability of the novel pile structures compared to the hollow FRP pile, which could be attributed to the presence of the infill materials. The composite action of the ductile GFRP tube and the high-ductile infill materials provides an enhanced structural performance. A theoretical model was adopted to rationally predicted the load-strain behaviour of FRP-confined cemented sand piles.

Keywords: Fiber-reinforced polymer; Sand and Cemented sand; Circular pile; Flexural strength; Optical frequency domain reflectometry.

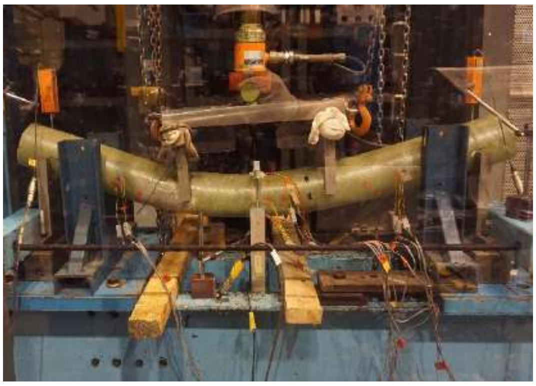

Fig. 1 Failure mode of the GFRP pile.

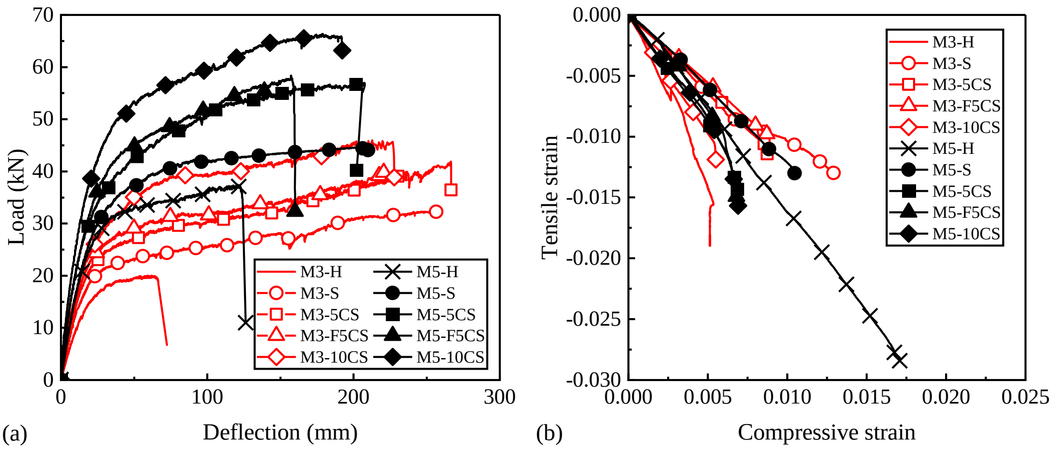

Fig. 2. (a) Load-deflection and (b) tensile-compressive strain relationships for all tested piles.

ARTIFICIAL PREPARATION OF NATURAL STRUCTURED SOFT CLAY PRODUCING HIGH LIQUID LIMIT AND MACROPOROUS CHARACTERISTIC

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ABSTRACT

To solve the difficulty of collecting in-situ soft clay samples from deep water areas such as oceans or lakes and overcome the influence of sampling disturbance on laboratory units or model experiments of natural soft clay, this paper proposes an artificial preparation method that can controllably produce the high liquid limit, large porosity, high compressibility and structure of soft clay samples. Taking the natural marine soft soil in Osaka Bay, Japan, as the primary reference target, the optimal ratio scheme of artificially making structured soft clay was given by using silt clay, diatomite, kaolin, calcium bentonite, cement, and urea as the preparation materials. The strength, deformation, and liquid-plastic limit of artificially prepared structural soft clay were measured by needle penetration, one-dimensional compression, triaxial compression, and triaxial tension tests. The results showed that: (1) The optimal ratio of artificial structured soft clay was silt clay of 35%, calcium bentonite of 5%, kaolin of 20%, diatomite of 25%, urea of 10%, and cement of 5%. (2) The pore ratio e is 1.7, and the liquid and plastic limits are ω_L=75.9% and ω_P =31.7%. (3) The M values of triaxial compression and tensile strength are 1.34 and 0.87, respectively. (4) Its compression index C_c and swelling index C_s are 0.672 and 0.092, respectively. (5) The porosity ratio, liquid-plastic limit, strength index, and deformation index are close to the target natural soft clay, which verifies the controllability and stability of the preparation method for artificial structured soft clay.

Keywords: structured soft clay; high liquid limit; macroporous; high compressibility; artificial preparation method.

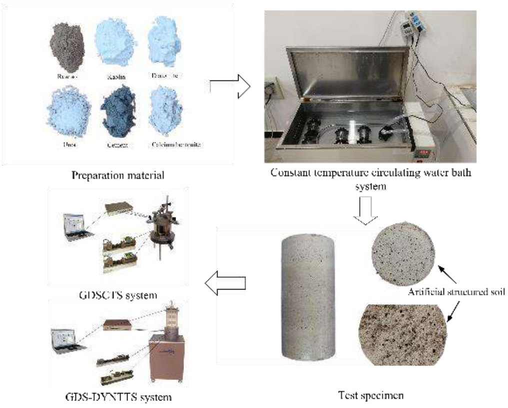

Fig. 1 Illustration of the proposed method

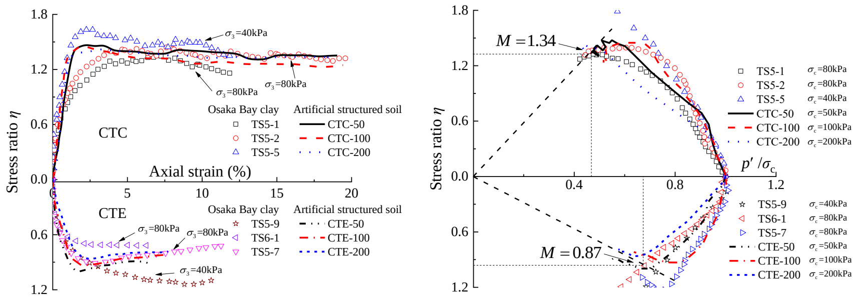

Fig. 2 Strength comparison between artificial structured soil and Osaka Bay clay

NUMERICAL MODELLING OF A PILE-LEG MAT FOUNDATION ON CLAY SEABED UNDER COMBINED LOADING

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ABSTRACT

The pile leg-mat foundation is a new type of jack-up platform foundation suitable for clay seabed, avoiding the problems of excessive insertion and extraction difficulties of spudcan foundation. Mat foundation mainly provides vertical and moment bearing capacity and increase horizontal bearing capacity by inserting pile legs into the soil. The combined bearing capacity of the foundation was numerically studied in this research. The effects of pile leg insertion depth and soil undrained shear strength on the bearing capacity of the foundation were investigated. Numerical results indicate that both an increase in the depth of pile leg insertion depth and the soil shear strength heterogeneity ratio contribute to the improvement of the vertical, horizontal, and moment bearing capacity of the foundation. As the pile leg insertion depth increases, the horizontal load distribution of the foundation gradually transitions from the mat to the pile legs. Nevertheless, the vertical and moment bearing capacity of the foundation primarily stem from the mat. In comparison to the vertical and moment bearing capacity, the enhancement in the horizontal bearing capacity is more significant. The failure envelope equations of *VHM* bearing capacity of the pile leg-mat foundation in clay were proposed.

Keywords: Pile leg-mat foundation, bearing capacity, clay seabed.

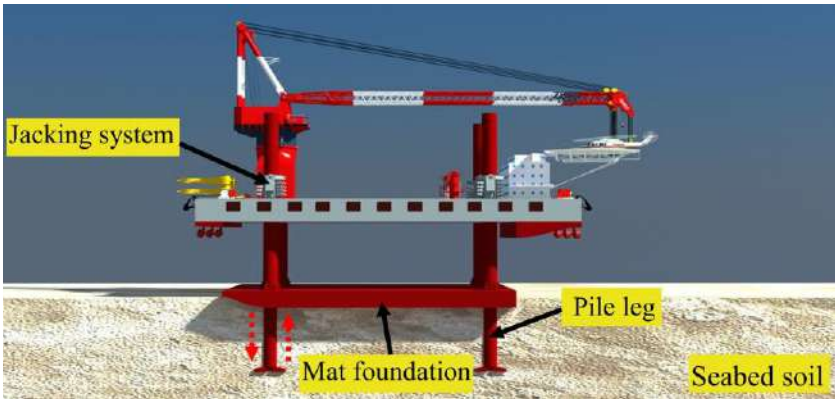

Fig. 1 The pile leg-mat foundation for jack-up platform

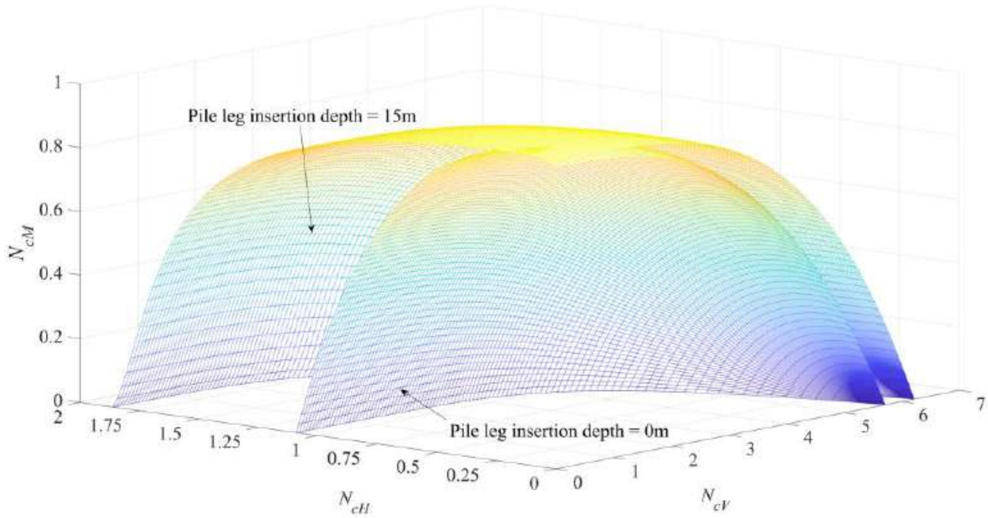

Fig. 2 *VHM* failure envelopes of the foundation with various pile leg insertion depth

Experimental Investigation of Keying Flap Motion and Embedment Loss of SEPLA during Keying in Transparent soil

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ABSTRACT

In order to reduce the loss of embedment of the suction embedded plate anchors(SEPLAs), the keying flap is often attached to the top of the anchor. There are two types of keying flaps: outwardly rotating keying flap and inwardly rotating keying flap. In this paper Laponite RD transparent soil with mechanical properties similar to marine clay was prepared. Model tests were conducted to observe keying flap motion and embedment loss of SEPLA with different keying flaps during keying. The mechanism of keying flap to reduce the loss of embedment are investigated, and our main conclusions are: the SEPLAs with inwardly rotating keying flap rotate faster compared to the SEPLAs with outwardly rotating keying flap, which helps the SEPLAs with inwardly rotating keying flap to reach more quickly the working bearing state. The SEPLAs with inwardly rotating keying flap reduces the loss of embedment by 53.62% and increases the bearing capacity by 8.73% compared to the SEPLAs with outwardly rotating keying flap.

Keywords: suction embedded plate anchor, keying flap, transparent soil, model test

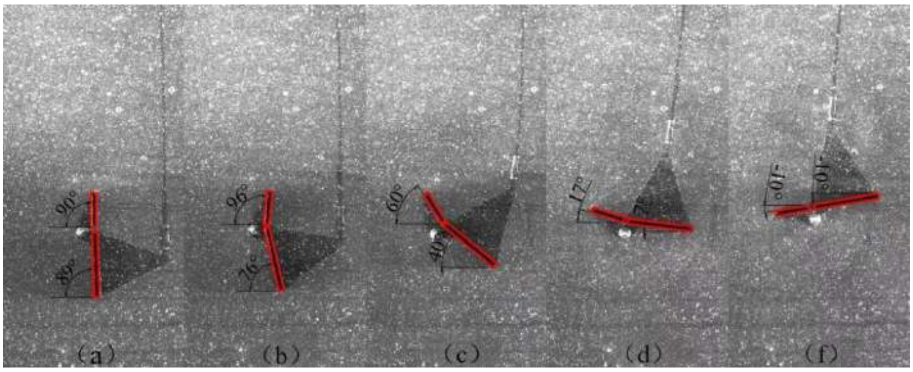

Fig. 1 The motion morphology of the SEPLAs with inwardly rotating keying flap during the keying

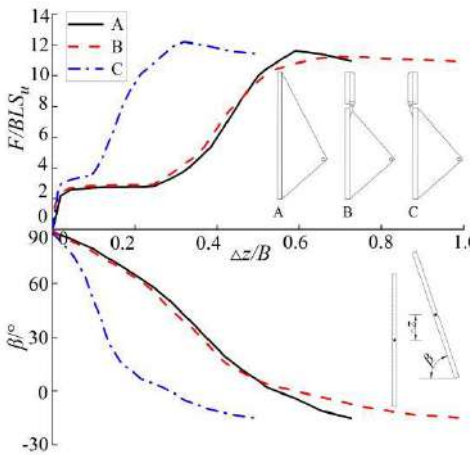

Fig. 2 Load-displacement curves and anchor rotation during keying for the anchors with no flap, an inwardly rotating keying flap and an outwardly rotating keying flap

EVOLUTION LAW OF PARTICLE BREAKAGE DURING ONE-DIMENSIONAL COMPRESSION OF CALCAREOUS SAND

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ABSTRACT

In the context of ocean engineering development, the utilization of calcareous sand as a natural foundation has become indispensable. Therefore, in this paper, one-dimensional compression tests were conducted on three different grain size groups of calcareous sands to analyze the progressive evolution and effect of particle breakage. The findings of the tests reveal intriguing patterns. An inflection point is identified in the e-log(p) curve, indicating the onset of grain fragmentation, leading to a steeper curve slope. Notably, larger-grain calcareous sands exhibit heightened susceptibility to breakage compared to their smaller-grain counterparts. This vulnerability can be attributed to their higher internal porosity and inherent defects. Among calcareous sands of identical grain groups, increasing vertical stress induces a gradual shift in the Particle Size Distribution (PSD) curve. This shift may even generate particles smaller than 0.075 mm, causing an increase in the B_r^*(Einav) value. Furthermore, as B_r^* value rises, the e-log(p) curve gradually descends. Leveraging these test outcomes, we establish a hyperbolic function linking B_r^* and plastic work W_p, and propose a critical state equation that accounts for particle breakage. This equation offers insights relevant to ocean engineering geology.

Keywords: calcareous sand; particle crushing; critical state; particle size; plastic work

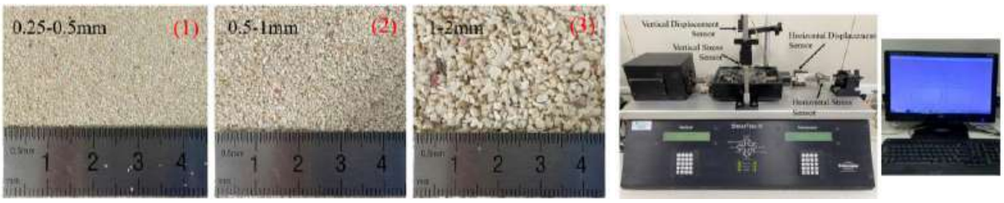


Fig. 1 Test materials and equipment

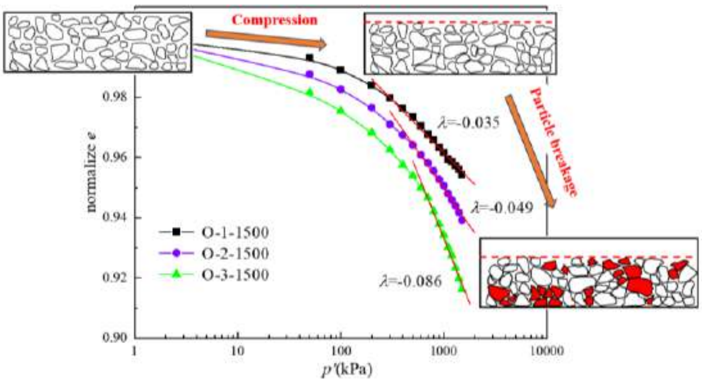
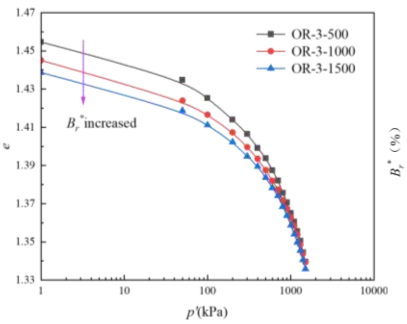
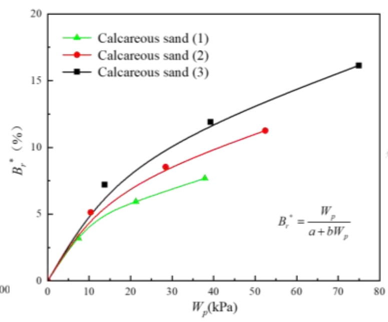


Fig. 2 Effect of particle size on particle breakage





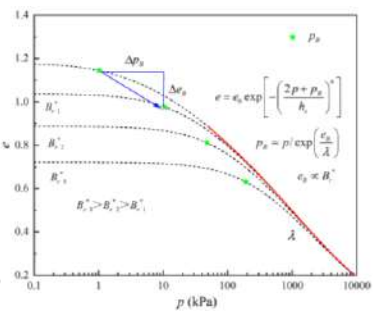


Fig. 3 Effect of particle breakage　Fig. 4 Relation between B_r^* and W_p　Fig. 5 Modified critical state

DEVELOPING AN INTEGRATED MOORING SYSTEM MODELLING PROGRAM

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

Offshore floating facilities in deep water require a reliable mooring system to keep them on station in harsh offshore environments. For mooring system analysis, the current practice focuses on the floating facility and the suspended mooring line segments in water while the embedded anchors and chains are simplified as fixed anchoring points at the seabed, which brings uncertainty into mooring design. On the other hand, the geotechnical analysis of embedded chains has commonly been simplified as cylindrical bars in two-dimensional space. This paper develops a modelling program based on a finite element framework for integrated analysis of the mooring system in time-domain. The chain-soil and anchor-soil interaction are modelled by force-resultant models that consider the coupling of soil resistances. To implement the force-resultant models into the integrated modelling program, an explicit integration algorithm is employed and transformations between local and global coordinate systems are described for the large-displacement analysis of chains and anchor. The integrated modelling program is validated by comparing the results with two existing analytical solutions. Calculation examples are carried out to demonstrate the applicability of the integrated modelling program.

Keywords: Mooring system; Integrated analysis; Force-resultant model; Embedded chains

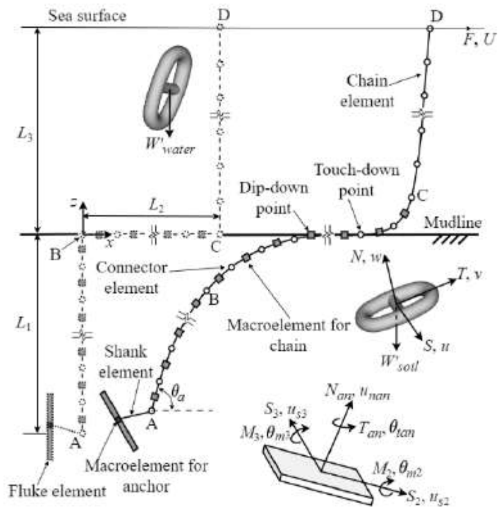

Fig. 1 Illustration of the integrated model

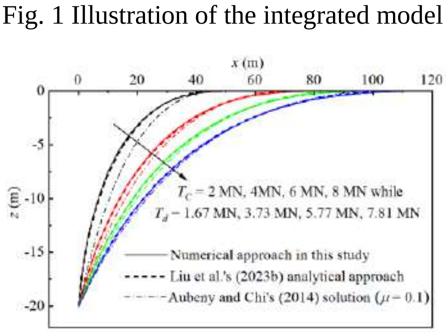

Fig. 2 Comparison of embedded chain profiles

EXPERIMENTAL ANALYSIS OF STATIC AND DYNAMIC CHARACTERISTICS OF SAND-CLAY MIXTURES FOR OFFSHORE FLOATING WIND TURBINES

Liheng Tang[1], *Chencong Liao*[1,#], *Yuanxi Li*[2], *Diyang Zhu*[3]
[1] *Shanghai Jiao Tong University, Department of Civil Engineering, Shanghai 200240, tangliheng2022@sjtu.edu.cn (Liheng Tang); billaday@sjtu.edu.cn (Chencong Liao);*
[2] *Guangdong Electric Power Design Institute, Guangzhou 510663, 277837597@qq.com;*
[3] *City University of Hong Kong, Hong Kong 999077, diyangzhu2-c@my.cityu.edu.hk (Diyang Zhu);*

ABSTRACT

The future utilization of deep-sea wind energy relies heavily on the offshore floating wind turbines, which are anchored to seabed through mooring systems. These structures are particularly susceptible to dynamic loads such as wind, waves and currents. In offshore geo-engineering, it is quite common to encounter sandy seabed mixed with clay particles. These sand-clay mixtures often lead to accidents like pile running during the installation of mooring systems. Therefore, studying the static and dynamic characteristics of sand-clay mixtures is crucial in ensuring the stability and safety of floating wind turbines during operational service. In this study, the characteristics of sand-clay mixtures collected from wind farm in Guangdong province are analysed based on dynamic simple shear test (DSS). The results are as follows: 1) Since such sand-clay mixture easily produces considerable volume change due to hygroscopic shrinkage of plastic fines during saturation, a method of sample preparation and evaluation (Fig. 1) based on optimum moisture content is proposed. 2) The resistance of sand-clay mixtures against cyclic load after applying average shear stress under drained condition is significantly higher than that under undrained condition (Fig. 2). The results can provide a reference for the calculation of bearing capacity in foundation design.

Keywords: sand-clay mixture; sample preparation; dynamic simple shear; cyclic resistance;

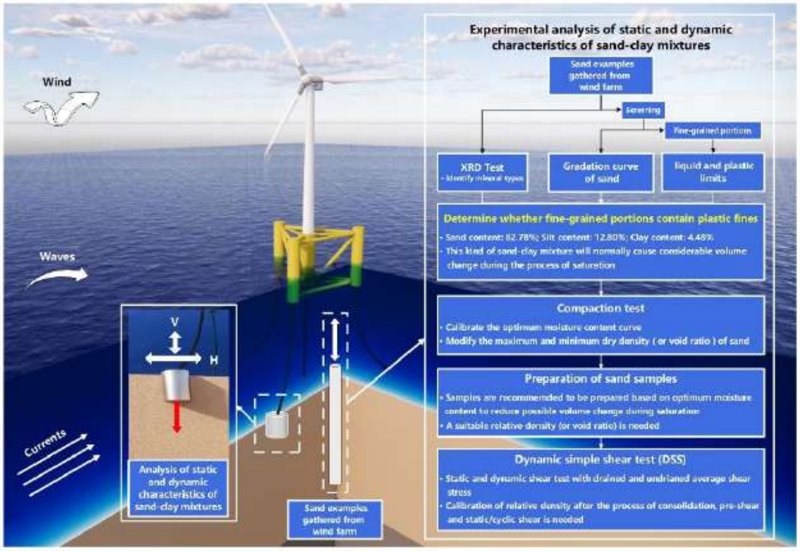

Fig. 1 Illustration of the proposed method

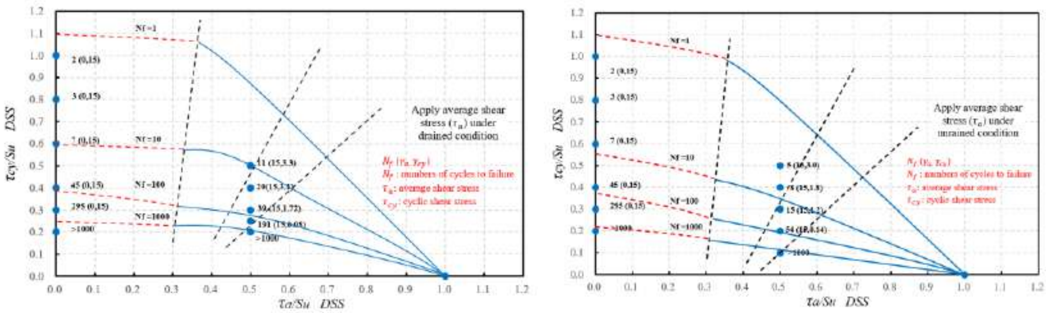

Fig. 2 Comparison of resistance against cyclic loading with drained and undrained average shear stress

EXPERIMENTAL ANALYSIS OF STATIC AND DYNAMIC CHARACTERISTICS OF SAND-CLAY MIXTURES FOR OFFSHORE FLOATING WIND TURBINES

Liheng Tang[1], *Chencong Liao*[1,#], *Yuanxi Li*[2], *Diyang Zhu*[3]

[1] *Shanghai Jiao Tong University, Department of Civil Engineering, Shanghai 200240, tangliheng2022@sjtu.edu.cn (Liheng Tang); billaday@sjtu.edu.cn (Chencong Liao);*

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[3] *City University of Hong Kong, Hong Kong 999077, diyangzhu2-c@my.cityu.edu.hk (Diyang Zhu);*

ABSTRACT

The future utilization of deep-sea wind energy relies heavily on the offshore floating wind turbines, which are anchored to seabed through mooring systems. These structures are particularly susceptible to dynamic loads such as wind, waves and currents. In offshore geo-engineering, it is quite common to encounter sandy seabed mixed with clay particles. These sand-clay mixtures often lead to accidents like pile running during the installation of mooring systems. Therefore, studying the static and dynamic characteristics of sand-clay mixtures is crucial in ensuring the stability and safety of floating wind turbines during operational service. In this study, the characteristics of sand-clay mixtures collected from wind farm in Guangdong province are analysed based on dynamic simple shear test (DSS). The results are as follows: 1) Since such sand-clay mixture easily produces considerable volume change due to hygroscopic shrinkage of plastic fines during saturation, a method of sample preparation and evaluation (Fig. 1) based on optimum moisture content is proposed. 2) The resistance of sand-clay mixtures against cyclic load after applying average shear stress under drained condition is significantly higher than that under undrained condition (Fig. 2). The results can provide a reference for the calculation of bearing capacity in foundation design.

Keywords: sand-clay mixture; sample preparation; dynamic simple shear; cyclic resistance;

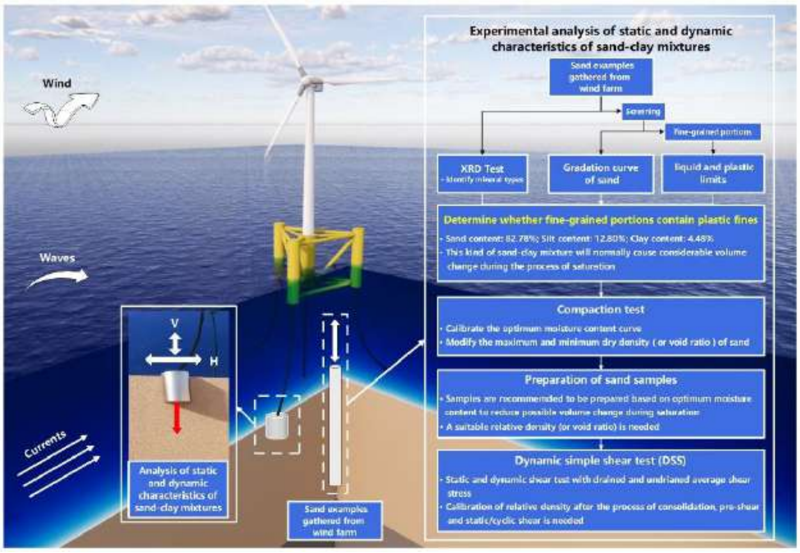

Fig. 1 Illustration of the proposed method

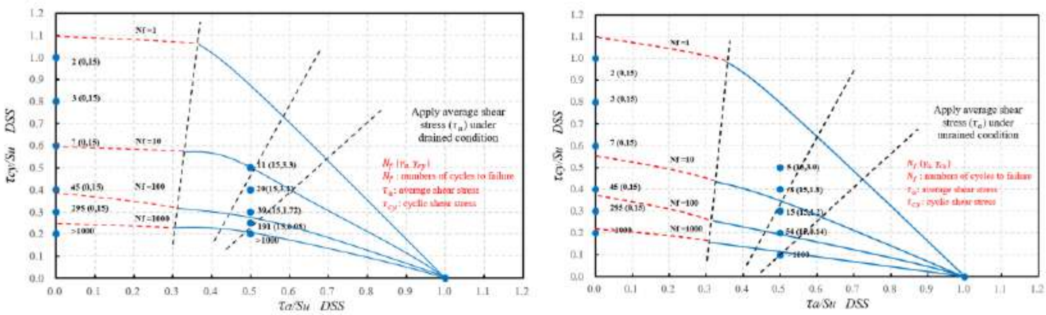

Fig. 2 Comparison of resistance against cyclic loading with drained and undrained average shear stress

A STABILIZED NODE-BASED PARTICLE FINITE ELEMENT FOR DEBRIS FLOW AND MULTIPHASE ANALYSIS

Lu-Jia YU[23], Xi-Wen ZHOU[2], *Yin-Fu JIN*[1#], *Zhen-Yu YIN*[2] and *Jian-Fei CHEN*[3]
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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

In offshore geotechnical engineering, the submarine landslides and the generated tsunamis can cause impact on offshore facilities. It is a great challenge to correctly simulate the submarine landslides and their consequences in a unified system that concerns free-surface flow, phase-changing soil and flexible structures. In this paper, a stabilized node-based particle finite element method (PFEM) with unified Lagrangian formulation is proposed. The multi-phase debris flow is simulated by incompressible non-Newtonian fluid and Mohr-Columb model, and the nodal integration method can naturally corporate different fluid phases in a monolithic way. The generalized-alpha method is adopted for time integration, and the PSPG stabilization is included in the continuity equation. Several validation tests were conducted and compared to numerical or experimental references, demonstrating ability of the proposed algorithm in solving incompressible free-surface-related debris flow and multiphase problems.

Keywords: Free-surface flow, Multiphase flow, Node-based PFEM, PSPG stabilization, Generalized-alpha method.

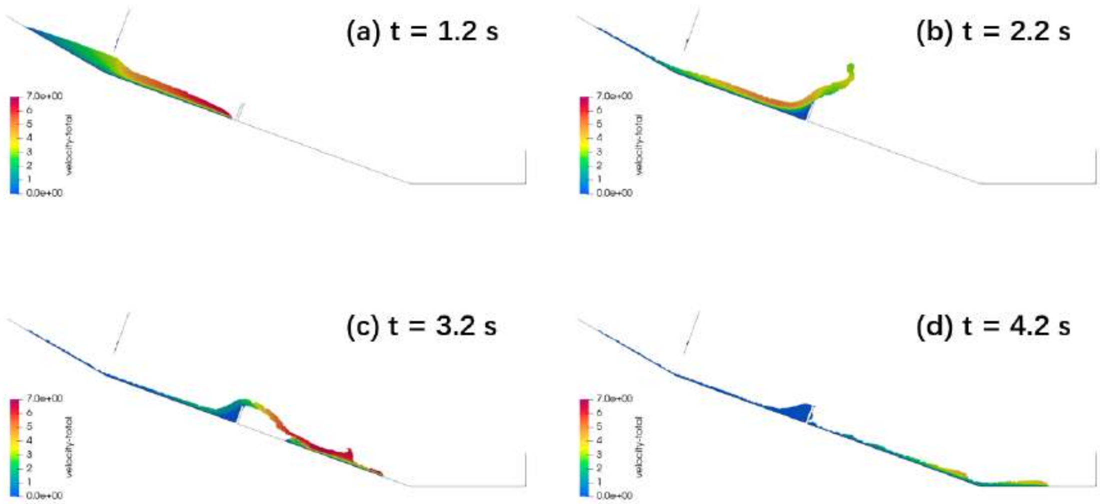

Fig. 1 Debris flow at different time instants

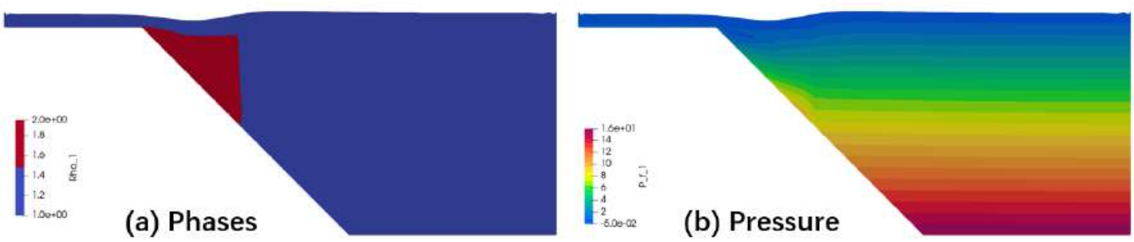

Fig. 2 Submarine landslide (a) Phase contour, (b) Pressure contour

PHASE FIELD MODELING FOR HYDRAULIC FRACTURING IN HBS

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[2] *State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan 430071, China,* xsun@whrsm.ac.cn
[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

Marine natural gas hydrate, as a kind of clean energy with huge reserves in subsea sediments, has been successfully tested. However, poor gas production rate due to low reservoir permeability is an essential factor limiting its commercial exploitation. Hydraulic fracturing technology has been proposed to improve the hydrate bearing sediments (HBS) permeability by injecting high pressure fluid to create cracks. This study proposed a coupled mathematical framework for fracturing in low permeable unsaturated porous HBS based on phase-field method (PFM). The diffusion-type cracks propagation is driven by the strain energy, and the damage state of HBS is described by introducing a continuous phase field function. The thermal, two-phase flow, phase change and poroelastic deformation are all considered with the cracks growth and solved in finite element method. The proposed model is verified by Sneddon's analytical solution. The multiphysics behaviours are studied with fracturing in HBS under the hot water injection. The results shown that the crack propagation occurs when the pore pressure is greater than the critical value. The hydrate dissociation is found in the crack due to the temperature rise caused by the hot water. Overall, this study provides an effective tool for predicting the hydraulic fracturing in HBS.

Keywords: Marine gas hydrate, Hydraulic fracturing, Coupled multiphysics, Crack propagation

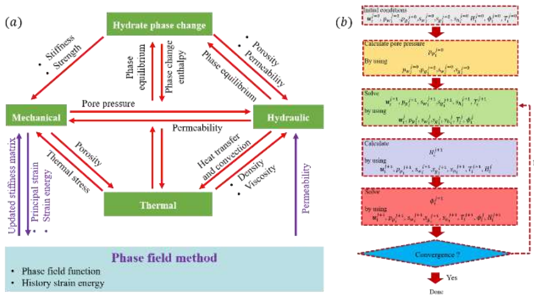

Fig.1 Relationship/Algorithm of the fully coupled multiphysics based on phase field model of hydraulic fracturing

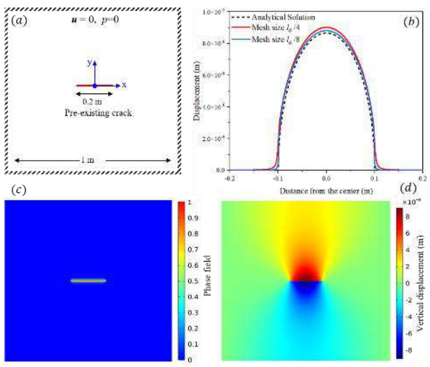

Fig. 2 Benchmark of the Sneddon analytical solution. (a) Model setup and boundary conditions; (b) crack displacement for the analytical solution and numerical results; (c) map of phase field ϕ for mesh size $l_0/8$; (d) simulated vertical displacements for mesh size $l_0/8$

AN EXTENDED HILL SOLUTION FOR THE UNDRAINED BEARING CAPACITY OF STRIP FOUNDATIONS ON SOIL MODELED BY NON-STATIONARY RANDOM FIELD

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[1]*Tianjin University, School of Civil engineering, China, chen_hz@tju.edu.cn*
[2]*South China University of Technology,School of Marine Science and Engineering, China, shenzhichao@scut.edu.cn*
[3]*Harbin Institute of Technology, School of Ocean Engineering, China, xuanxuan.chu@nottingham.ac.uk*
[4]*Tianjin University, School of Civil engineering, China, lewang_1895@tju.edu.cn*
[5]*University of Melbourne, Department of Infrastructure Engineering, The University of Melbourne, Australia, yinghui.tian@unimelb.edu.au*

ABSTRACT

Classical upper bound solutions were proposed for the bearing capacity of shallow foundation on spatially uniform soil and mainly based on symmetrical failure mechanism, without considering the influence of soil spatial variability. This study aims to establish a theoretical model using upper bound solutions for the undrained bearing capacity of shallow foundations on spatially variable soils modeled by non-stationary random fields. By enabling the variation of one controlled point and four controlled angles of Hill's mechanism, an extended Hill solution was proposed to represent the asymmetrical failure mechanism of strip foundations on spatially variable soils with increasing shear strength with depth. The theoretical model along with the search program developed were verified for spatially uniform and variable soils by published solutions and random finite element results, respectively. The results show that the proposed model can reasonably capture the failure mechanism and normalized bearing capacity of strip foundations on soils modeled by non-stationary random fields. The proposed model has advantages in computation efficiency and convergence, which is suitable for rapid quantification of bearing capacity of strip foundations in spatially variable soils. A parametric study shows the influence of the soil spatial variability on bearing capacity.

Keywords: bearing capacity; footings/foundations; soil spatial variability; upper bound; Hill solution

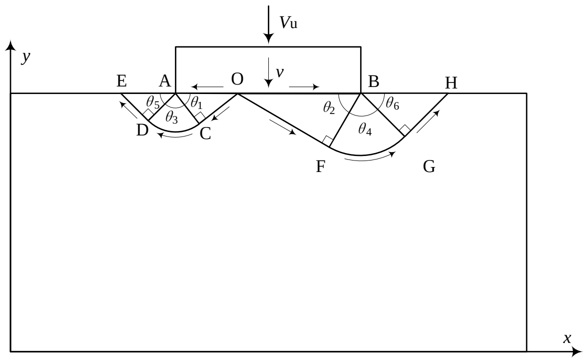

Fig. 1 A potential shear failure mechanism in spatially variable soil

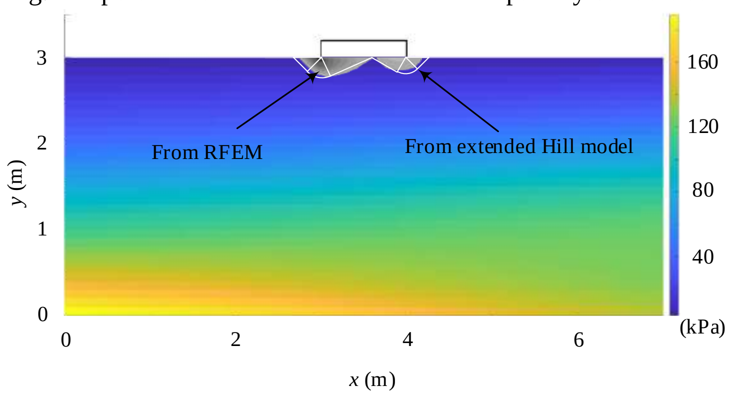

Fig. 2 Failure mechanisms obtained from the extended Hill model and RFEM

SEABED LIQUEFACTION UNDER DIVERSIFORM WAVES: FROM REGULAR, RANDOM, TO BREAKING WAVE

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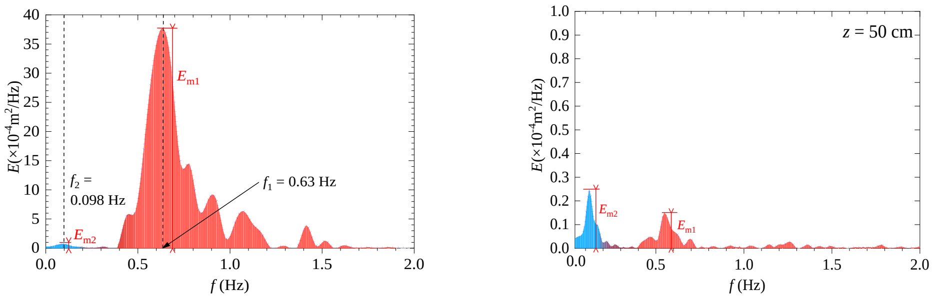
ABSTRACT

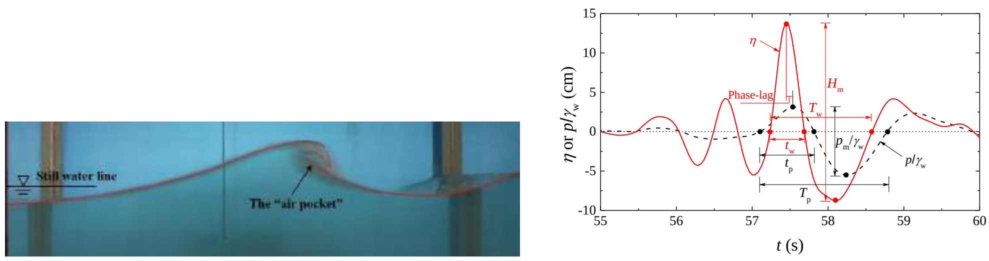
In offshore environments, wave-induced pore pressures in a porous seabed may weaken the soil strength, or even lead to seabed liquefaction. Previous studies on wave-induced pore pressure in a porous seabed mainly focused on non-breaking regular waves, e.g., Airy linear waves or Stokes waves. Nevertheless, the real state of ocean waves is random in nature with various monochromatic components. And the progressive waves may break while propagating towards shallow waters or in the mid-ocean as long as the wave amplitude is sufficient. Recent advances on the pore-pressure and liquefaction of the porous seabed under the action of diversiform waves are presented, i.e., from regular, random, to breaking waves. Flume observations on random wave-sandbed interactions indicated that the profiles of the transient pore pressures are featured with conspicuous irregularity, which can be described with a series of response spectra for various soil depths. Similarly, Fourier spectra can also be obtained for breaking waves and the corresponding pore-pressures; but the peak frequency of the surface waves was found to be generally larger than that of the pore-pressures. Beyond the phenomenological analyses, some analytical progresses are further presented, including the criteria for wave-induced instantaneous liquefaction, and the solutions for the instantaneously-liquefied soil depth, etc.

Keywords: Seabed liquefaction, Pore pressure, Ocean waves, Random waves, Breaking waves.



(a) (b)

Fig. 1 (a) Frequency spectrum of the JONSWAP random-waves; (b) Response spectrum for random-wave induced pore pressures in the bed at z = 50 cm (water depth d = 0.6 m, significant wave height H_s = 15 cm, and significant wave period T_s = 1.5 s; adapted from Yu et al., 2023).



(a) (b)

Fig. 2 (a) Generation of breaking waves in a wave flume; (b) Characterization for the free surface elevation (η) of breaking-waves and the corresponding pore-pressures (p) (Li et al., 2021).

DYNAMIC RESPONSE OF LARGE DIAMETER PILE FOUNDATION IN GASSY SEABED

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ABSTRACT

Many of offshore wind power projects around the world are being implemented in the sea area where gassy soils are widely distributed. These gassy soils contain a large amount of unconnected gas, which brings challenges to the design of the large diameter monopile foundation for the wind turbine. It is necessary to conduct a series of finite element simulations for the large diameter monopile foundation of wind turbines installed in the gassy seabed and investigate the dynamic strain and pore pressure responses of the soil around piles under cyclic wind and wave loading. The cumulative deformation of the mud surface is obtained to determine whether the design of the pile foundation meets the requirements of the foundation design code. Meanwhile, it is found that with the accumulation of deformation, the fluctuated increase in the excess pore pressure around the pile induced by the cyclic loading determines the strength of the foundation soil. This study will provide an innovative coupled soil-fluid dynamic analysis method that will contribute to the emerging application of large diameter monopile foundation in the offshore wind power projects.

Keywords: Gassy soil; Large diameter monopile; Pile-soil interaction; Dynamic response analysis.

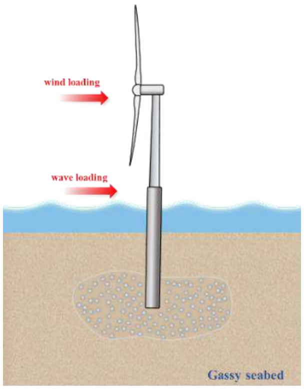

Fig. 1 The large diameter monopile foundation located in the gassy seabed is deformed by wind and wave loading

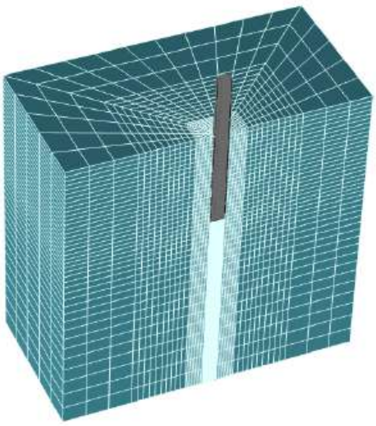

Fig. 2 The hexahedral grid is used to divide the grid and encrypt the grid near the pile

PARTICLE BREAKAGE OF CORAL SAND DURING CYCLIC SHEAR LOADING

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ABSTRACT

Coral sand is prevalent in offshore oil and gas basins, as well as the foundation of offshore wind turbines, which are exposed to persistent cyclic loads, including wind, ocean waves and seismic activity. Due to these loads, coral sand easily occurs particle breakage resulting in unexpected differential settlements which potentially threaten the security of offshore structures. A series of dynamic cyclic simple shear tests were conducted in this study to investigate the process of coral sand particle breakage during cyclic loading. The findings reveal that particle breakage becomes severe when cyclic shear strain amplitude, vertical stress, and the number of cycles increase. There exists a critical cyclic shear rate that causes serious particle breakage in coral sand. Moreover, serious particle breakage results in a more regular particle shape of coral sand. The “mechanical debonding” and “mechanical grinding” models are proposed to analyze the mechanism of coral sand particle breakage. Energy input is introduced to describe the relationship between particle breakage and energy transformation in coral sand. It is found that a robust power function can be used to describe the relationship between the relative breakage rate and energy input of coral sand at the energy input level of this test.

Keywords: coral sand; dynamic cyclic simple shear test; particle breakage; particle morphology; energy input

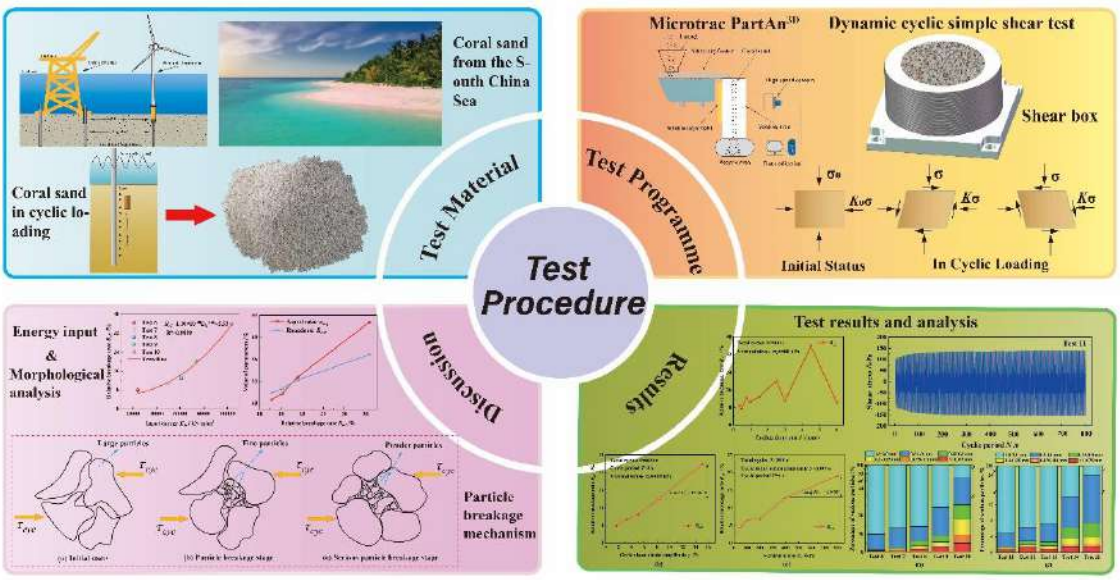

Fig. 1 Illustration of the test procedure

THE PREDICTION OF CIRCULAR CYLINDER FLOW OF SUBMARINE PIPELINE USING PHYSICS-INFORMED NEURAL NETWORKS

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ABSTRACT

Submarine pipelines often experience suspension due to seabed irregularities, resulting in circular cylinder flow as ocean currents pass through. Although numerous computational fluid dynamics (CFD) simulations have predicted this phenomenon, real-time long-term flow field predictions remain challenging due to the limitations of computational resources. The emerging Physics-Informed Neural Networks (PINN) provides a fusion method of data-driven and knowledge-driven to quickly obtain the flow field distribution related to the phenomenon. In this study, a PINN neural network is established, which is a fully connected neural network that writes the residual term as loss functions according to the Navier–Stokes equation, boundary conditions and initial conditions. Subsequently, Galerkin finite element method (GFEM) is employed to perform CFD simulations of the flow around the cylinder to obtain training data as supervision data and complete the training of PINN. Upon convergence of the neural network's loss function, the model is employed to prognosticate the flow fields at a specific temporal instant and compared with the results of GFEM to verify the accuracy of PINN. This research establishes an efficient and rapid surrogate model for the real-time long-term prediction of flow phenomena around submarine pipeline and the in-place stability of submarine pipeline.

Keywords: Submarine pipeline; Circular cylinder flow; Physics-Informed Neural Networks; Surrogate model

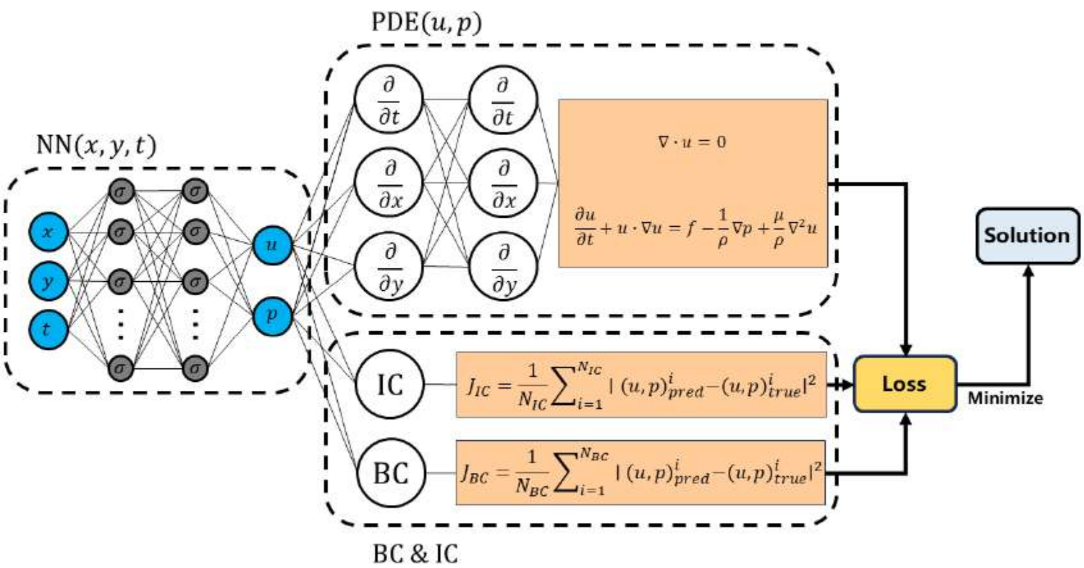

Fig. 1 Illustration of the Physics-Informed Neural Networks (PINN)

A NVOLE APPROACH FOR STOCHASTIC RECONSTRUCTION OF CALCAREOUS SAND PARTICLES BASED ON PARTICLE SHAPE AND INTERNAL POROSITY

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ABSTRACT

Calcareous sand has garnered substantial scholarly interest due to its intricate morphology and abundant internal porosity. However, there are almost no studies on the correlation between the shape of calcareous sand particles and the distribution of internal voids, and on the random reconstruction of calcareous sand particles. This study employs computed tomography (CT) scans of calcareous sand to comprehensively investigate various aspects, including analysis of particle morphology, internal void porosity distribution and correlations, and exploration of the relationship between particle shape parameters and spherical harmonic coefficients (SH). The study further examines the interrelation between pore structures and parameters derived from the quasi-stochastic generation system (QSGS). Novel theories are developed based on established correlations, enabling the generation of spherical harmonic coefficients from particle shape and QSGS parameters from pore distribution. Through a three-dimensional spatial differencing approach, the study achieves random generation of calcareous sand particles with irregular shapes and internal voids. This research facilitates advances in numerical simulations at the particle scale and macroscopic-scale internal stress transmission in calcareous sand.

Keywords: Calcareous sand, spherical harmonic, quartet structure generation set.

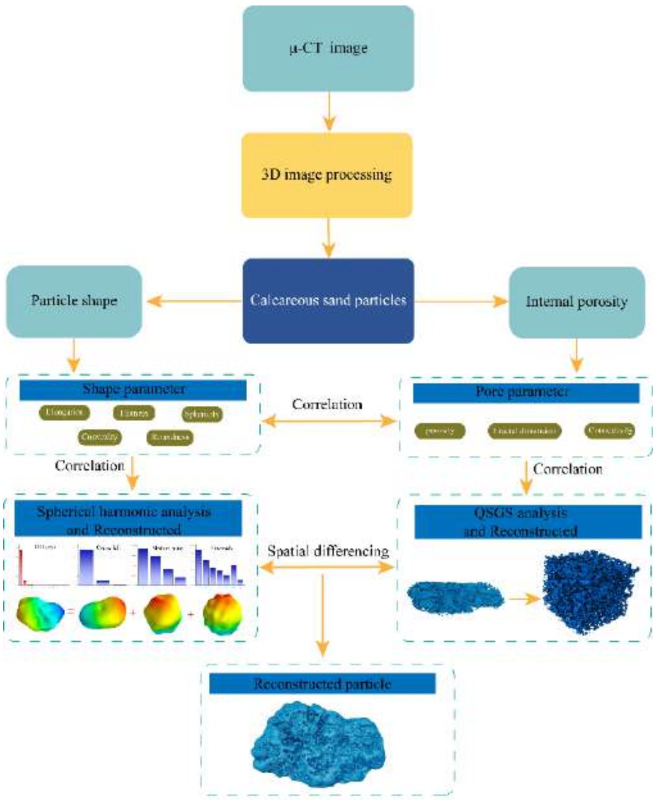

Fig. 1 Flowchart of the Stochastic Reconstruction method

SENSITIVITY ANALYSIS AND COUPLING MECHANISM OF HYDRATE-BEARING CLAYEY-SILTY SEDIMENTS UNDER MULTI-INFLUENCE FACTORS

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ABSTRACT

The vast majority of global gas hydrate resource exist in clay and silty fine-grained reservoirs, so it is important to fully grasp the mechanical properties of fine-grained hydrate resources. In order to investigate the effect of different factors on the shear strength of hydrate-bearing clayey-silty sediments (HBCSS), multi-factor and multi-level orthogonal triaxial tests were conducted, and the sensitivity of different factors to the effect of HBCSS strength was investigated. The study results show that the sensitivity order of the effect on the strength index is effective confining pressure, saturation, pore pressure, fines content and clay content; the sensitive factors on the effect of secant modulus are mainly clay content, saturation, and effective confining pressure. Compared to the effective confining pressure, pore pressure and saturation have a smaller effect on the strength, but their sensitivity to strength is similar. The factors with higher sensitivity can dominate the change of stress-strain relationship and have a decisive effect on the strength. Some of the results indicate that the coupling of influencing factors can cover the role of factors with higher sensitivities, thus affecting the strength of HBCSS.

Keywords: HBCSS; orthogonal triaxial tests; strength; effective confining pressure; sensitivity analysis.

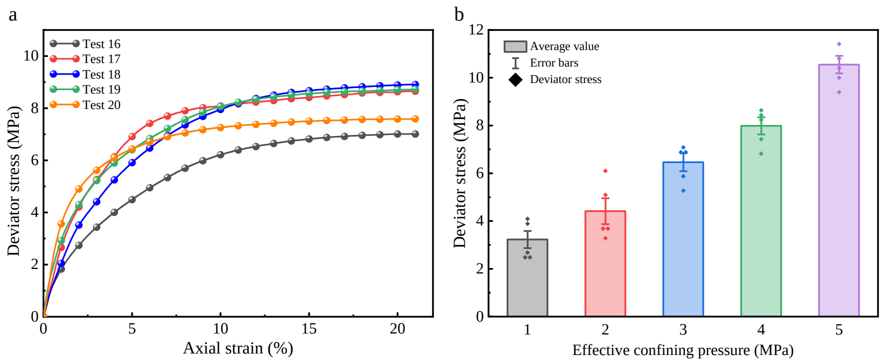

Fig. 1 The effect of effective confining pressure on HBCSS

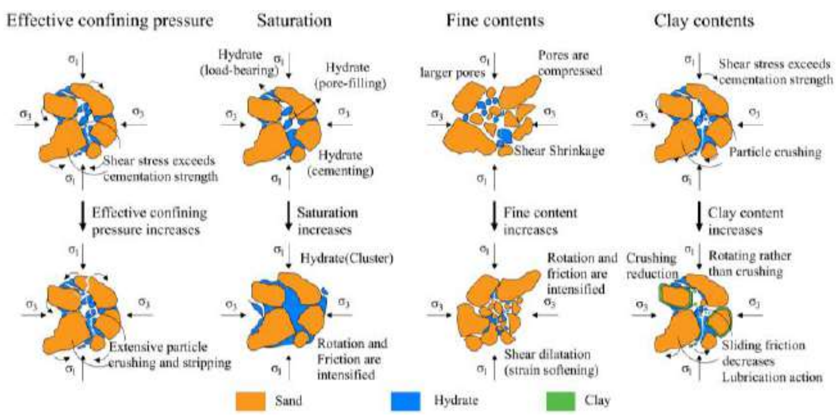

Fig. 2 Particle-scale mechanisms of different factors during the shearing process

NUMERICAL ANALYSIS ON THE EMBEDMENT LOSS OF PLATE ANCHORS IN DOUBLE-LAYER CLAY

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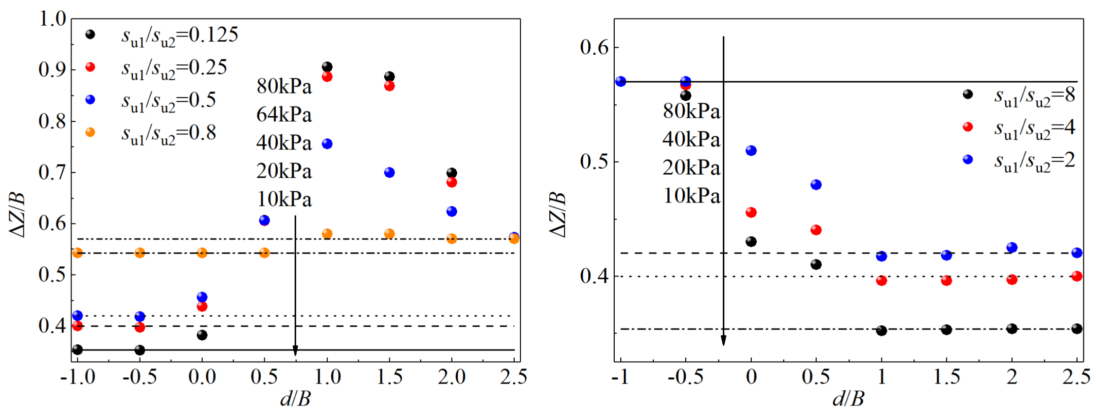
ABSTRACT

Based on the coupled Eulerian-Lagrangian (CEL) method, a numerical analysis is conducted for analyzing the embedment loss of plate anchors in double-layer clay. With the same embedment depth, the embedment loss of plate anchors is analyzed at different values of the distance between the shackle and the soil boundary (d) and the ratio between the strengths of the top and the bottom soil (s_{u1}/s_{u2}). By analyzing the soil flow mechanism around plate anchors, the reason for the increasing of anchor loss embedment is identified. In addition, the empirical formula is established for the embedment loss of plate anchors. It concludes that for the double-layer clay of $s_{u1}/s_{u2}<1$, the embedment of the anchor increasing and then decreasing as the value of d increases, and there exists a maximum value of ΔZ_{max}, which is 74.2%~81.1% larger than the embedment loss of the anchor in the uniform soil at the bottom and is dangerous in the engineering practice. For the double-layer clay of $s_{u1}/s_{u2}>1$, the embedment of the anchor decreasing as the value of d increases. For $d \leq -0.5B$ and $d \geq 1B$, the keying of plate anchors is only affected by the top and bottom soil, respectively.

Keywords: Embedment loss, plate anchor, double-layer clay, numerical



(a) $s_{u1}/s_{u2}<1$ (b) $s_{u1}/s_{u2}>1$

Fig. 1 Embedment loss at different values of d (h=3B)

BEHAVIOR OF FRP CONFINED SEAWATER SEA-SAND CONCRETE PILES

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ABSTRACT

Fiber-reinforced polymer (FRP) composites coupled with seawater sea-sand concrete (SSC) provide an innovative and sustainable solution by replacing the conventional piling materials. This study investigates the axial behavior of FRP composite SSC model piles subjected to static and cyclic loadings. The strain along the depth of piles is measured by an advanced distributed optic sensing technique called optical frequency domain reflectometry (OFDR) having a spatial resolution of 1 mm and ±1με sensing accuracy. Three structural configurations; FRP tube confined and FRP rebars cage reinforced and centered FRP rebar SSC piles ended in rock-socket are investigated in physical models to examine the performance of FRP composites and SSC in pile foundations. It is found that the accumulation of permanent cyclic displacement increases markedly initially till 30 cycles and then follows a constant trend with increasing cycles passing. Under the same cyclic loading conditions, the FRP tube confined model piles exhibited lower cyclic degradation leading to stable behavior. The FRP tube confined model piles showed higher confinement and axial cyclic capacities compared to those reinforced with FRP rebars. The OFDR sensing technique monitored the localized effects efficiently and how the load is distributed along the length of model piles.
Keywords: Rock-socketed piles, FRP composites, SSC, and fiber optic sensing

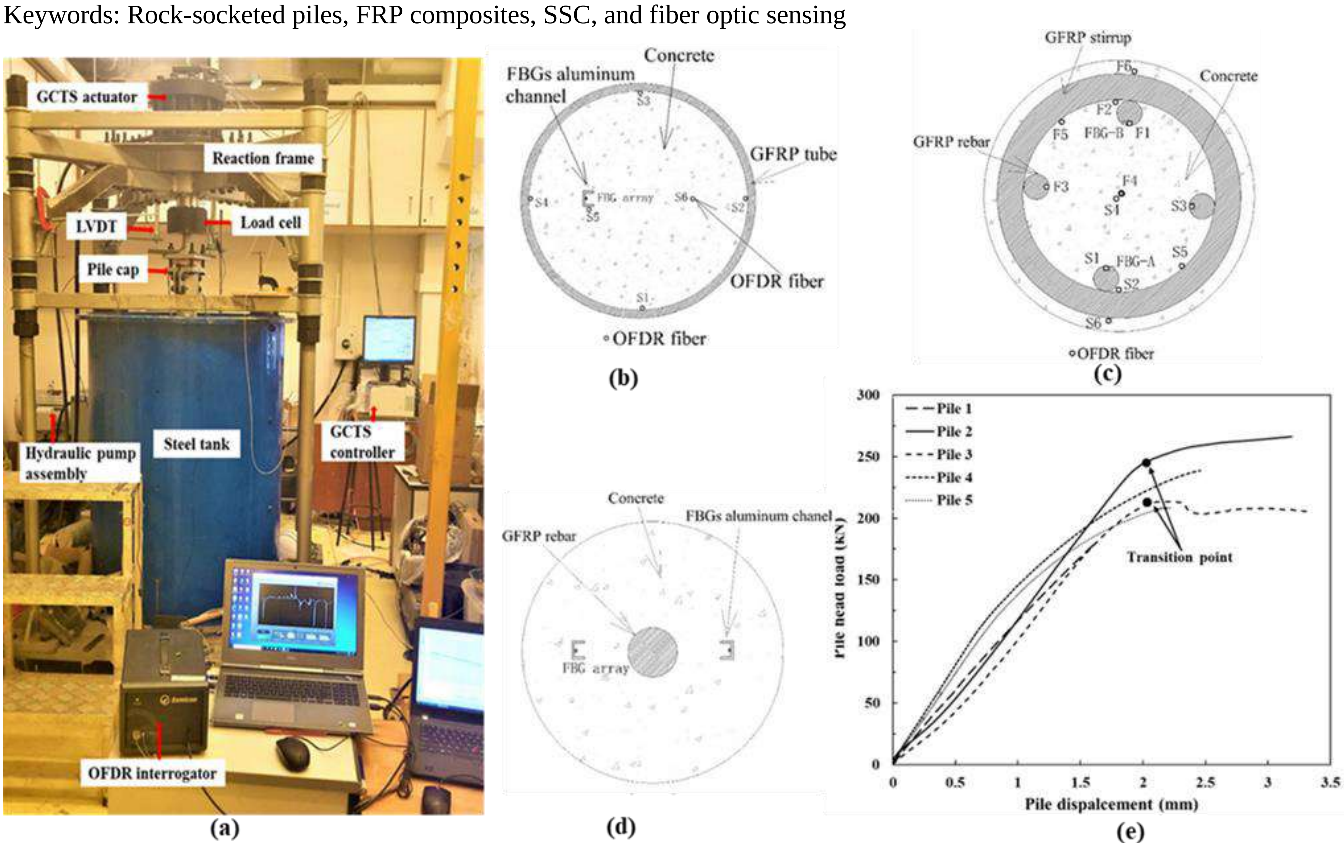

Fig.1 (a) setup of physical model system; (b) Pile 2; (c) Pile 3; (d) Pile 4 and (e) Load-displacement response

INVESTIGATION ON THE INSTALLATION BEHAVIOUR OF DRAG ANCHORS IN SAND

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ABSTRACT

Drag anchors are appealing anchoring solutions for floating offshore wind turbines due to their high holding capacity ratios and relative low cost for installation. In clayey soils, the installation behaviour and in-place holding capacity of drag anchors are relatively well understood and they are normally designed using codified methods. However, in sandy soils, there exists no widely accepted design method for predicting the installation trajectory and in-place holding capacity of drag anchors. This creates considerable difficulty in design of such foundations in sandy seabed. In this talk, we will present a comprehensive study on the behaviour of drags anchors in sand, comprising large deformation finite element simulations, analytical analyses and scaled model tests. Results of the numerical and physical simulations as well as analytical analyses will be compared and insights will be discussed.

Keywords: drag anchor; large deformation finite element analysis; model test; offshore wind

Fig. 1 Illustration of numerical and physical drag anchor models

(For any further information, please contact the Secretariat: iges.2023dec@polyu.edu.hk)

EXPERIMENTAL STUDY ON BEARING CAPACITY OF THE CONSOLIDATED UNDER-REAMED PILE

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ABSTRACT

In order to select the optimized scheme of the pile foundation design and construction for the pier of a highway bridge, the static load test and sound wave transmission test between the consolidated under-reamed pile and the conventional cast-in-situ bored pile with the same length in sandy soil layer at the construction site have been carried and the results have shown and proved that the consolidated foundation can strengthen the compressive capacity of soil and the consolidated under-reamed pile has a significant advantage in increasing the bearing capacity of pile foundation.

Key words: consolidated under-reamed pile, consolidated foundation, bearing capacity of pile foundation

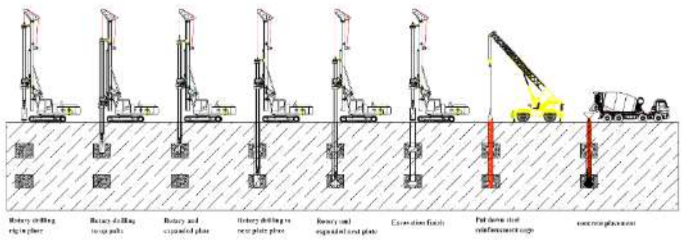

Fig. 1 Construction process

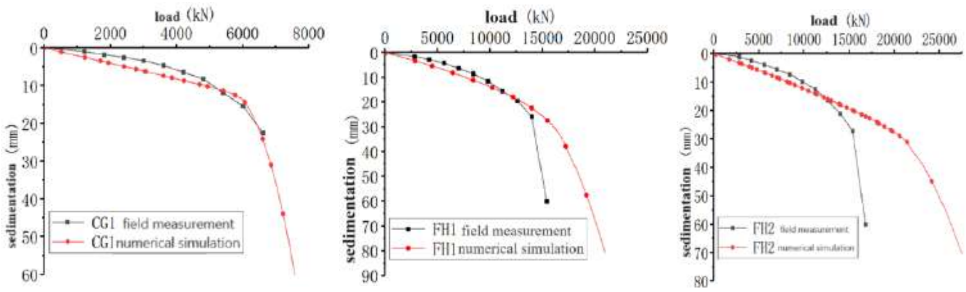

Fig. 2 Comparison between numerical simulation and field measurement

DYNAMIC RESPONSE OF MOORING SYSTEM FOR FLOATING WIND TURBINE CONSIDERING THE CYCLIC DEGRADATION OF CLAY

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ABSTRACT

The assessment of the mooring line tension of the fairlead and anchor point of the floating wind turbine is crucial to the safety of the dynamic system. The behaviour of embedded offshore structures like suction caissons or the vertically loaded anchors would be influenced significantly by the degradation of surrounding soil under cyclic loading. In the present study, the detailed effects of cyclic degradation of clay on the mooring analysis of a floating wind turbine i.e. OC4 semisubmersible floating wind turbine are investigated. The aerodynamic response of the wind turbine is performed based on blade element momentum method, the hydrodynamic response of the supporting structures is carried out based on potential flow method. The mooring line is modelled by analytical catenary equation in which the inertial and drag force on the line is neglected. The anchor part is taken into account as an anchor zone instead of a single anchor point. The concept of equivalent cycle and UDCAM-S model are employed in the analysis. A detailed procedure on considering cyclic degradation of clay on the line tension response is proposed and the effect of the anchor zone on the mooring analysis is discussed thoroughly.

Keywords: Cyclic degradation, mooring, anchor zone.

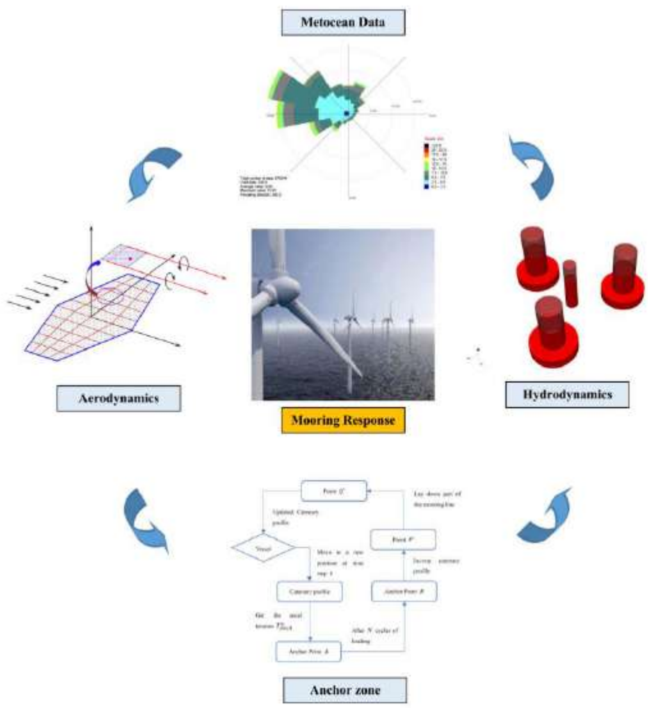

Fig. 1 Mooring analysis for semisubmersible wind turbine

TITLE

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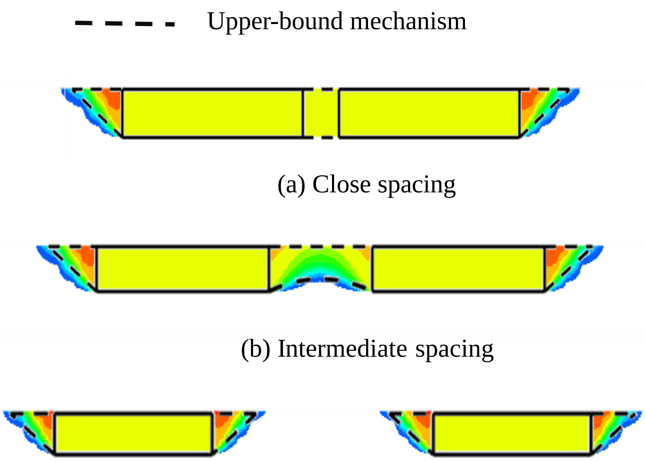
ABSTRACT

Offshore oil and gas development is increasingly shifting towards deep water, leading to the emergence of new infrastructure such as the foldable mudmats. The foldable mudmats address the issue of high transportation and installation costs associated with the large size of traditional single isolated mudmats. The complex underwater conditions such as thermal expansion and contraction of the connecting pipelines lead to the foldable mudmats being subjected to significant horizontal (H) and torsional (T) loading during its service life. This paper focuses on evaluating the undrained capacity of the foldable mudmats under combined H-T loading. The H-T capacity of the foldable mudmats is influenced by several factors, including embedding depth, foundation spacing, and soil strength distribution. This paper proposes a kinematically admissible mechanism and uses the plastic limit analysis method to calculate the ultimate bearing capacity of the foldable mudmats under pure horizontal, torsional loading and combined H-T loading. The results of the upper bound analysis are compared with the finite element analysis results, allowing for a systematical analysis of the different failure mechanisms under various conditions. Additionally, the failure envelopes under the combined H-T loading are established, with the results showing a good agreement between the two methods.

Keywords: Bearing capacity; foldable mudmats; torsion; upper-bound analysis; failure; foundation spacing.



(a) Close spacing

(b) Intermediate spacing

(c) Wide spacing

Fig. 1 Soil failure mechanisms for foldable mudmats under horizontal load

AN EXPERIMENTAL INVESTIGATION OF PIGGY-BACKED ANCHORS IN COHESIVE SOIL

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ABSTRACT

This research focused on examining four factors that influence the motion patterns of drag embedment anchors (DEAs). These factors include the spacing between anchors, the angle between the fluke and shank, the attachment point, and the fluke's aspect ratio. To track the movement and orientation of the attached anchors, a magnetometer system equipped with a magnetic sensor, allowing for six degrees of freedom, was used. The experiments involved embedding the anchors in clay with shear strength gradually increasing. The study comprehensively compared and analyzed the paths taken by the anchors, their pitch angles, and the force required for installation. Through this analysis, the research enhances our understanding of how to enhance anchor efficiency by properly utilizing two separate DEAs. This approach ensures the necessary capacity while also promoting energy conservation and emission reduction, all without necessitating the creation of a new, larger anchor.

Keywords: Piggy-backed anchors; Trajectory; Capacity; Yield Surface; Plate anchor.

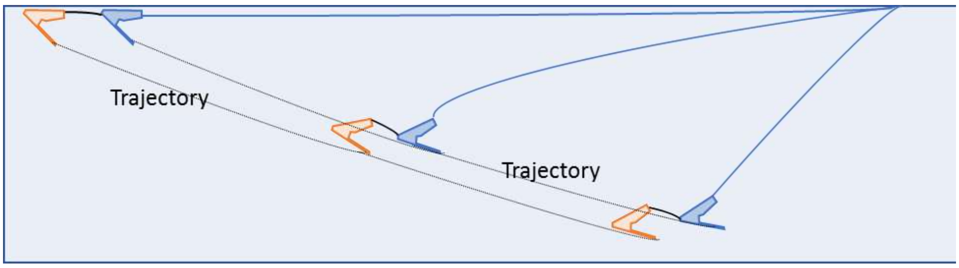

Fig. 1. Example of tandem anchor and trajectory

FULL-SCALE NUMERICAL SIMULATION ON LOCAL SCOUR UNDER COMBINED CURRENT AND WAVE BASED ON FIELD DATA

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

Monopile is the most common used foundation to support the offshore wind turbine. In the marine environment, local scour due to combined current and wave is a significant issue that must be considered in design of wind turbine foundation. In this paper, a full-scale numerical model was developed and validated based on the field data in Rudong, China. Scour developments around monopile are investigated and effects of wave and Reynolds number Re are analyzed. Several formulas to predict the scour depth in the literatures are evaluated. It is found that wave can accelerate the scour development even if KC number is small (0.78<KC<1.57). And the effect of wave depends on the water depth. The formula obtained from small-scale model tests may be unsafe or wasteful when it is applied in practical design due to the scale effect. A new equation to predict the scour depth based on average pile Reynolds number (Rea) is proposed and is validated with field data. The equilibrium scour depth predicted using the proposed equation is evaluated and compared with those from the 9 equations in the literatures. It is shown that the predicted value from the proposed equation and that from the S/M (Sheppard/Melville) equation are closer to the field data.

Keywords: full-scale numerical simulation, field data, scale effect, Reynolds number effects, local scour

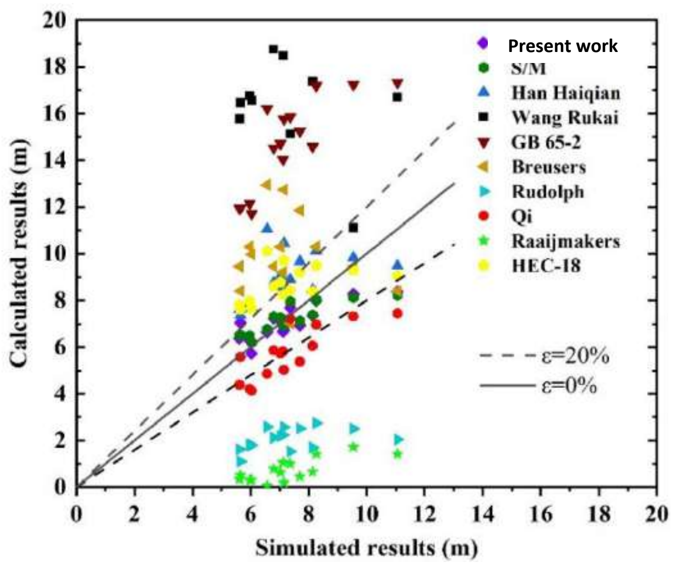

Fig. 1 Comparison results with 10 formulas

Multiple-GPU parallelization of three-dimensional material point method based on single-root complex

Youkou Dong

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ABSTRACT

As one of the arbitrary Lagrangian–Eulerian methods, the material point method (MPM) owns intrinsic advantages in simulation of large deformation problems by combining the merits of the Lagrangian and Eulerian approaches. Significant computational intensity is involved in the calculations of the MPM due to its very fine mesh needed to achieve a sufficiently high accuracy. A new multiple-GPU parallel strategy is developed based on a single-root complex architecture of the computer purely within a CUDA environment. Peer-to-Peer (P2P) communication between the GPUs is performed to exchange the information of the crossing particles and ghost element nodes, which is faster than the heavy send/receive operations between different computers through the infiniBand network. Domain decomposition is performed to split the whole computational task over the GPUs with a number of subdomains. The computations within each subdomain are allocated on a corresponding GPU using an enhanced "Particle-List" scheme to tackle the data race during the interpolation from associated particles to common nodes. The acceleration effect of the parallelization is evaluated with two benchmarks cases, mini-slump test after a dam break and cone penetration test in clay, where the maximum speedups with 1 and 8 GPUs are 88 and 604, respectively.

Keywords: cone penetration test, material point method, mini slump test, parallel computation

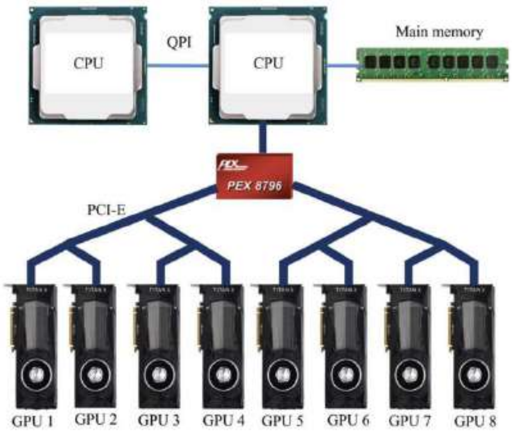

Fig. 1 Configuration of a multiple-GPU system with a single root complex (Reference: https://www.servethehome.com/singleroot-or-dual-root-for-deep-learning-gpu-to-gpu-systems/)

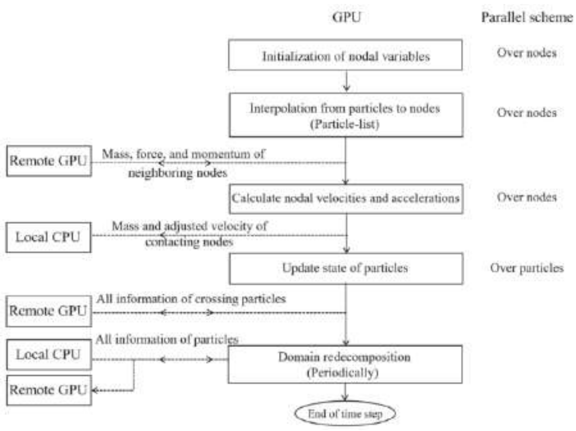

Fig. 2 Essential operations in multiple-GPU parallelization of MPM

The formation mechanism of post-penetration cavity of torpedo anchor

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ABSTRACT

Torpedo anchor is a promising novel offshore anchor foundation for deep-water floating facilities due to its efficient and economical installation. During installation, torpedo anchor is dropped at a preassigned height above seabed and penetrates into seabed with a penetration depth of 2-3 times anchor length under self-weight. The formation of a cavity above the shaft of the installed anchor was observed both in centrifuge test and numerical simulations. However, there is a lack of understanding on the formation mechanism of the cavity. This work focuses on the effect of installation condition on the formation mechanisms of post-penetration cavity of torpedo anchor. Three dimension large deformation finite element (LDFE) analyses using Coupled Eulerian-Lagrangian(CEL） method in ABAQUS were used with modifying the elastic-plastic Tresca model to allow strain softening and incorporate the strain-rate dependency of shear strength using Herschel-Bulkley model. The formation and evolution of the cavity mechanism were studied extensively, exploring a large range of normalized undrained shear strength of soil for uniform clay and surface roughness of torpedo anchor. This work provided a good insight into the formation mechanisms of post-penetration cavity of torpedo anchor.

Keywords: Torpedo anchor; installation effect; cavity; clay; large deformation finite element

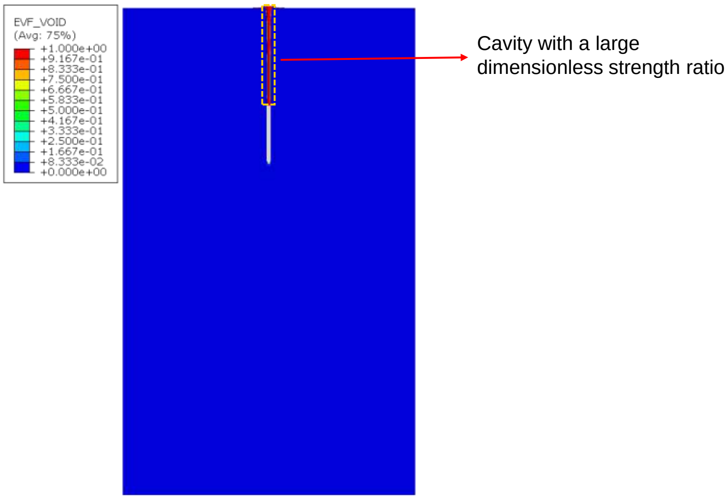

Figure 1 The formation of cavity after anchor installation

Numerical study on the behaviour of horizontal anchor using Upgraded SANISAND-MS

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ABSTRACT

Horizontal plate anchors are widely used to secure tension leg platforms via mooring lines. A thorough understanding of the monotonic, cyclic and post-cyclic behaviour of plate anchors is essential to accurately estimate plate anchors' capacity. The objective of this paper is to investigate the horizontal rectangular plate anchors subjected to vertical monotonic and cyclic loads in quartz sand under drained conditions using three-dimensional finite-element simulations. For the purpose to accurately capture sand's ratcheting behaviour, the existing elastoplastic bounding surface model SANISAND-MS has been upgraded with a hyperelastic formulation. The influence of embedded depth ratio, aspect ratio, relative density, cyclic amplitude ratio, cyclic asymmetric ratio, and contact types used between the soil-anchor interface is investigated. The local soil response is also investigated. The structure of the paper is as follows: First, to accurately predict sand's strain accumulation, the SANISAND-MS model is upgraded with a hyperelastic formulation which is proposed by Houlsby et al. (2019). Then, calibration for quartz sand is conducted, and the performance of the upgraded model under cyclic loading is presented. Finally, 3D finite element models of soil-anchor interaction are constructed using the open source platform OpenSees. The study supports the development of long term analysis for anchoring systems subjected to cyclic loading in offshore applications.

Keywords: constitutive model; sand's ratcheting; hyperelasticity; plate anchor; cyclic loading

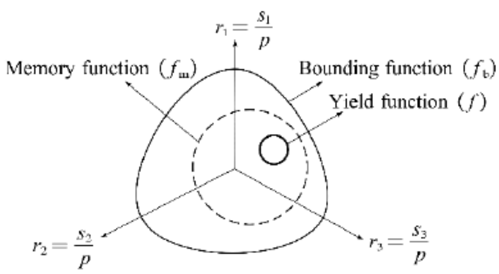

Fig. 1. Relevant loci in the deviatoric stress ratio plane (modified after Liu et al., 2019).

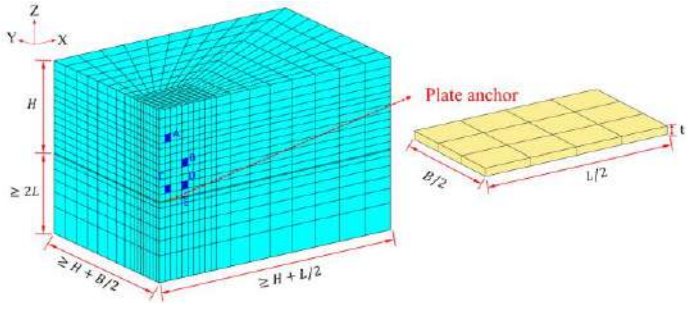

Fig. 2. 3D finite element model and the geometry of the plate anchor

FIN CONFIGURATION EFFECT ON THE PENETRATION AND PULLOUT BEHAVIORS OF DEEP-SEA DYNAMICALLY INSTALLED ANCHOR

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ABSTRACT

Deep-sea dynamically installed anchor is an innovative and cost-effective anchoring technology in offshore engineering. However, the current research on the dynamically installed anchors is mainly focuses on their penetration and pullout loading mechanisms, and relatively few studies have been carried out on the geometrical configuration of finned dynamically installed anchors, especially the anchor fin configuration. Therefore, this study is intended to investigate the influence of different fin configuration related factors (i.e., anchor fin area, anchor fin aspect ratio, anchor fin position, anchor fin shape) on the performance of dynamically installed anchor penetration installation in water and soil, and pullout bearing performance after penetration into the seabed (i.e., the stability of penetration direction in water, penetration speed, depth of penetration in seabed, and holding capacity), and to put forward a set of design and calculation methods, which may provide references and scientific guidance for the test, engineering design, and installation construction of dynamically installed anchor in practice.

Keywords: deep-sea dynamically installed anchor; fin configuration effect; directional stability; penetration depth; pullout capacity.

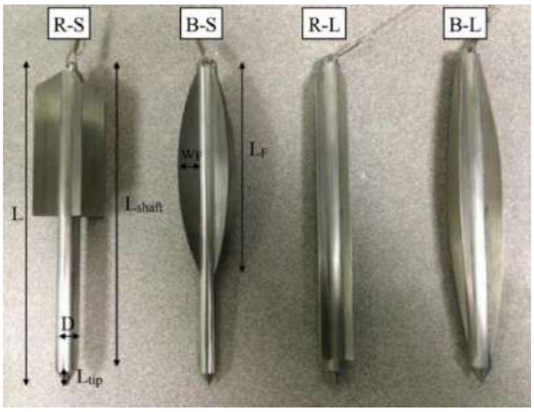

Fig. 1 DIA models with different fin configurations, but identical fin surface area in centrifuge tests

EXPERIMENTAL STUDY ON TEMPERATURE EFFECT ON THE CONSOLIDATION OF SEABED AND PENETRATION RESISTANCE OF SUBSEA PIPELINE INTO SEABED CLAY

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ABSTRACT

The subsea pipeline is normally utilized to connect wells to offshore platforms transporting crude oil or natural gas. The interaction between the seabed soil and the pipeline-soil interface is related to its fatigue life, which is of great importance for practical application. Pipelines lying on the seabed usually experience varying temperatures when functioning, which would affect the mechanical behaviour of saturated clay and in turn, lead to variations in the pipeline-soil interaction. Therefore, understanding the penetration resistance of the risers into soft clay under varying temperatures are critical. This study includes a series of laboratory penetration experiments on the soft kaolin clay as the seabed obtained via vacuum consolidation. Three full-scale pipeline parts with same length of 85 mm and different outer diameters of 80 mm, 129 mm and 200 mm penetrate into the seabed at a constant rate of 0.01 mm/s under temperatures of 15º, 25º, 40º. Constant temperatures are achieved by water/oil circulation in thin plastic pipes wrapping the risers. The results demonstrate that the penetration resistance increases as the decrease of temperature. Also, as the diameter increases, the failure modes of the underlying seabed soil change from punching shear failure to general shear failure.

Keywords: Subsea pipeline; Kaolin clay; Temperature effect; Penetration resistance

Fig. 1 Pipeline penetration

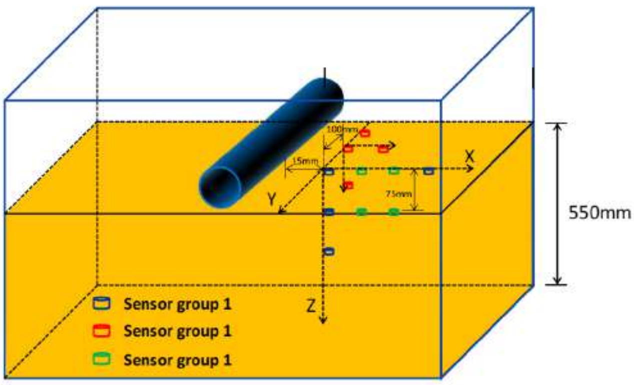

Fig. 2 Temperature sensor placement

EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF TOLERABLY MOBILE SUBSEA FOUNDATIONS WITH VARIED INTERFACE CONDITIONS

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ABSTRACT

Tolerably mobile subsea foundations obey the 'compliant' design guidelines rather than the traditional approaches which require adequate geotechnical capacity to fix the foundations. When the connecting pipeline is heated up for operation or cooled in 'shut-down', the foundation is allowed to cyclically slide on the seabed to release the axial expansion or contraction force in the pipeline. It is necessary to determine the sliding resistance, vertical settlement and rotation of the foundation in order to derive optimised design solutions. The sliding resistance and the shear-induced settlement are greatly affected by the foundation-soil interface condition. This study conducted a series of model tests to investigate the effect of interface roughness on the performance of the sliding foundation. Test results indicate that the underneath soil softens significantly for a rough interface, resulting in soil ploughing and berm accumulation at the leading edge of the foundation. After 40 cycles, the accumulative settlement of the foundation with rough interface is approximately four times of that with smooth interface, which emphasises the remarkable effect of interface roughness condition on the performance of the tolerably mobile foundation during the whole-life operation.

Keywords: Sliding foundation; tolerably mobile foundation; settlement; sliding resistance; offshore geotechnical engineering.

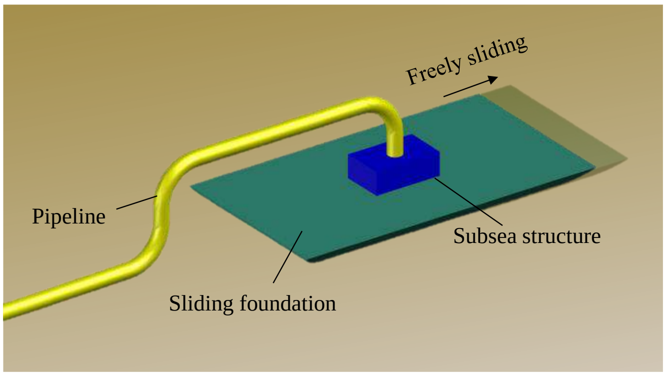

Fig. 1 Tolerably mobile sliding foundation

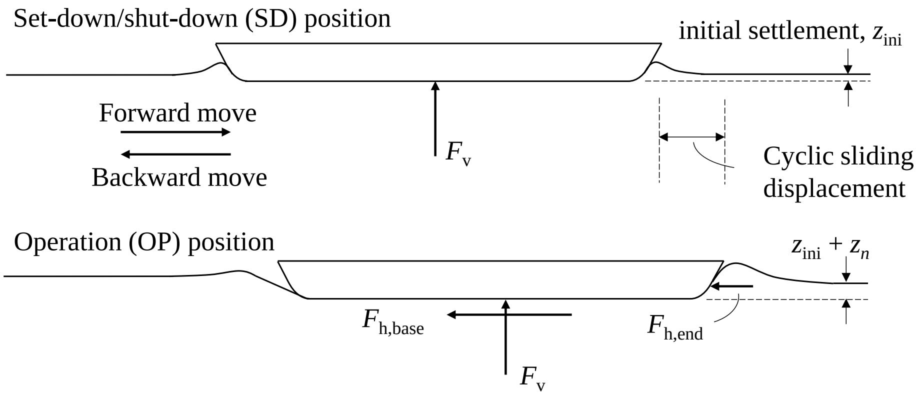

Fig. 2 Sketch shown the cyclic movement of the sliding foundation

Elucidating Dewatering Behaviour of Soft Ground: A Two-Stage Combined Filtration-Consolidation Model (249-242)

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ABSTRACT

The vacuum preloading technique is frequently employed to enhance soft terrain, including reclaimed land from dredged slurry which is characterised by very high water content and very low strength, and exhibits spectacular pore water pressure (PWP) dissipation phenomenon when treated with prefabricated vertical drains. Specifically, the PWP dissipation initially slows down, speeds up only by the end of the treatment period. Aiming to elucidate this behaviour, a two-stage combined dewatering model was proposed with encapsulating both filtration and consolidation processes. Initially, an axisymmetric filtration model was adopted to illustrate the growth of the soil column which is formed due to the migration and compaction of the slurry particles. The radial distributions of void ratio, permeability coefficient, and pressure, ascertained at the culmination of filtration, were used as initial conditions for the analysis of the consolidation stage. This stage was portrayed by a large-strain consolidation model operating under free strain assumption. Results show that the inclusion of the filtration stage is imperative for accurately depicting the high-water content slurry consolidation. Furthermore, the proposed filtration-consolidation model can successfully describe the observed dewatering behaviour of the dredged slurry undergoing vacuum pressure.

Keywords: Filtration; Consolidation; Pore pressure; Dewatering; Land reclamation

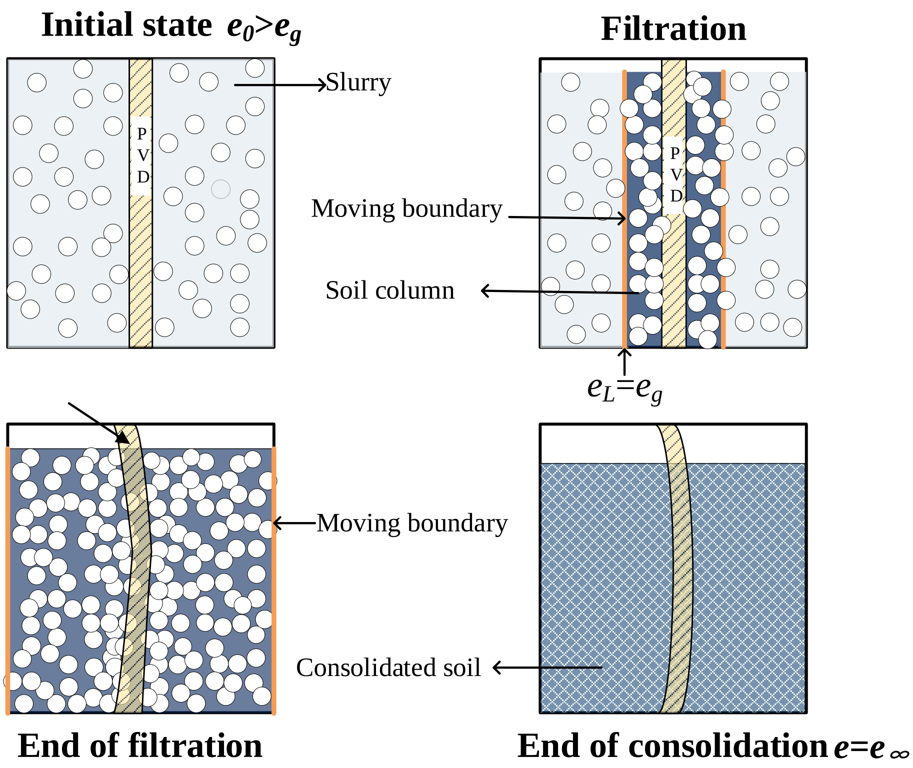

Fig. 1 Conceptual model of filtration and consolidation stages of dredged slurry under vacuum pressure

A novel gravity installed anchor with ring fins and soft shanks and its dynamic performance in water and clay

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ABSTRACT

A novel gravity installed anchor (GIA) is introduced in the present work, which combines features of the conventional GIA and the drag embedment plate anchor, with a ring fin attached to the anchor tail and two soft shanks. A systematic numerical investigation on the dynamic performance of the novel GIA in water and clay which involves the performance analyses and improvements and structure optimizations is performed. The CFD approach and the CEL technique are used in study of the behaviors in water and clay, respectively. Key technique of simulating the soft shanks is presented.The research focuses on the effects of the anchor body and ring fin on the hydrodynamic characteristics. Besides, its dynamic performance in clay are thoroughly investigated, focusing on initial penetration, the behaviors of keying, diving and pulling out, the optimization of the shackle point, and the effect of loading rates on the maximum embedment loss.The numerical investigation confirms that, compared with the OMNI-Max anchor, the novel GIA possesses better directional stability and higher terminal velocity, achieves deeper initial penetration depth during installation, requires shallower initial penetration depth that ensures subsequent keying and diving, and possesses stronger ability of resisting dynamic loading with high loading rates.

Keywords: Gravity installed anchor; Ring fin; Soft shank; Hydrodynamic characteristic; Comprehensive behavior

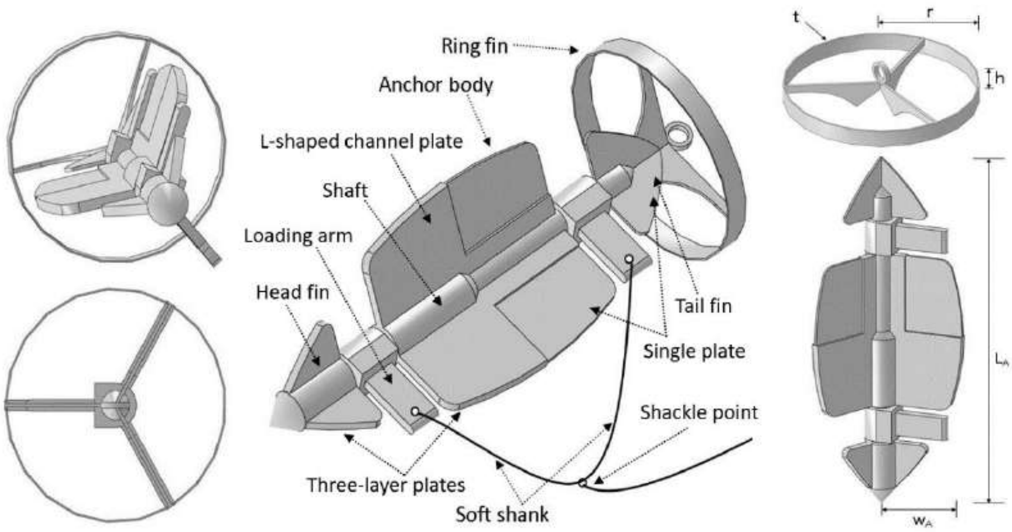

Fig. 1 Schematic diagram of the novel GIA

AN INNOVATIVE MGO-CARBONATED COMPOSITE PILE IN GROUND IMPROVEMENT

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ABSTRACT

To satisfy global carbon reduction strategies, an innovative low-carbon/CO_2-fixation pile is developed for the improvement of soft soils. The MgO-carbonated composite pile (MCP) is formed by inserting a gas-permeable concrete pile (inner core) into the center of an MgO-mixing column (outer core) subjected to forced CO_2 carbonation. The performance of carbonated MgO-mixed soils and the interface between the inner and outer cores dominate the load transfer of the MCP. In this investigation, after clarifying the engineering performance of carbonated MgO-mixed soils, the interface behavior is discussed based on interfacial shear tests. Subsequently, MCPs are used in an engineering pilot project to ascertain their practical feasibility and reliability. The laboratory results indicate that the strength of the carbonated MgO-mixed soil and its interface with the concrete are similar to those of cement-based stabilized soil. For the pilot project, the MgO-mixing column shows integrity and a high hardness, and the average N_{SPT} and unconfined compressive strength are 39 and 1.02 MPa, respectively. The ultimate bearing capacity of the MCP is 1920 kN, which is approximately 37.1% higher than that of a prestressed high-strength concrete (PHC) pipe pile. The maximum settlement and lateral displacement of the ground under the embankment are very small and fall within the specification range. This confirms the applicability of MCP and its effectiveness in engineering practice.

Keywords: MgO-carbonated composite pile; carbonate fixation by magnesia; strength and interface performance; pilot project; embankment engineering.

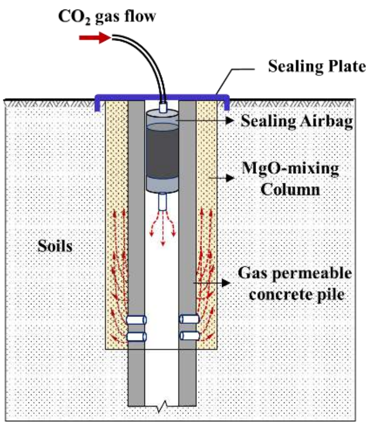

Fig. 1 Schematic of the MgO-carbonated composite pile

Laboratory experimental study on electrokinetic geosynthetics encased stone columns combined with electroosmosis for soft ground reinforcement

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ABSTRACT

To verify the effect of electrokinetic geosynthetics-encased stone columns combined with electroosmosis on soft soil foundation reinforcement, laboratory model experiments were conducted using non-encased stone columns (NSC), geosynthetics-encased stone columns (GSC) with/without electroosmosis. The changes in the energy consumption coefficient and drainage rate of electroosmosis were analyzed, and the shear strength, water content distribution and deformation law of the gravel pile section at different depths were studied. Experimental results show that the strength of the soil around the pile increases under the action of electroosmosis, and the pile-soil stress ratio of the gravel pile is reduced and the side friction resistance is effectively exerted. The ultimate bearing capacity of the composite foundation formed by the electroosmosis with geosynthetics encased stone columns (E-GSC) method is 6.6 times that of the NSC and 3.8 times that of the GSC. Moreover, the expansion deformation distribution of the gravel pile in the E-GSC and GSC is basically the same, and the maximum radial deformation is less than that in the NSC. Most of the deformation exists in the range of 2 times the pile diameter below the boundary line of the wrapped section.

Keywords: electroosmosis; pile-soil stress ratio; joint construction method; composite foundation; ultimate bearing capacity

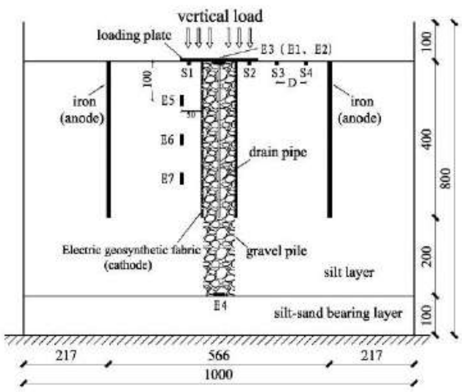

Fig. 1 Layout of the laboratory experiment

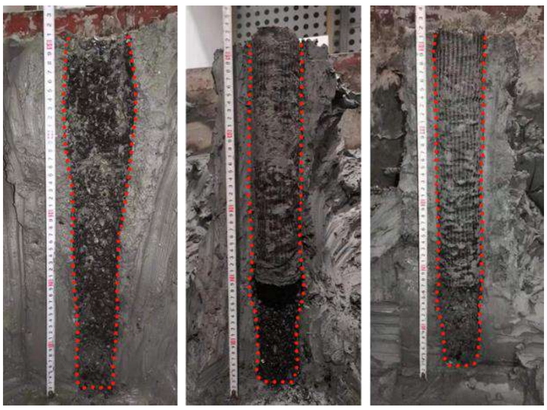

Fig. 2 Cross sections of the NSC, GSC, and E-GSC piles (after the experiment)

DURABILITY AND HYDRATION MECHANISM OF A PHOSPHOGYPSUM-BASED SOLID WASTE BINDER FOR SOIL SOLIDIFICATION

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ABSTRACT

The resource utilization of phosphogypsum, slag, and carbide slag remains limited. In this study, these waste materials are combined with Shanghai's silty clay to develop a composite solidified soil (PSCS). The objective is to evaluate the feasibility of substituting conventional fill materials with solid waste in road construction. The mechanical properties of PSCS are assessed through compaction, compressive strength, and water stability tests. Durability is investigated through dry-wet and freeze-thaw cycling tests. Environmental performance and economic benefits are studied through leaching concentration tests and cost analysis. The formation of hydration products during the strength development of PSCS was analyzed using SEM, XRD, FTIR, and TGA. The results indicated that the 28d strength of PSCS with 15% dosage reached 1.6 MPa, and the water stability coefficient of PSCS reaching 62.58%. Following 5 cycles of dry-wet conditions and 10 cycles of freeze-thaw conditions, the strength retention rate of PSCS was 79.37% and 138.7%, respectively. Leaching of phosphorus and fluoride met standards. The performance of PSCS outperformed that of control group. The result of XRD, SEM, TGA and FTIR indicating hydration products included ettringite and hydrated calcium silicate, this product bonded with soil particles to increase the strength of PSCS.

Keywords: Industrial solid waste; binder; Solidified soil; Durability; Hydration mechanism.

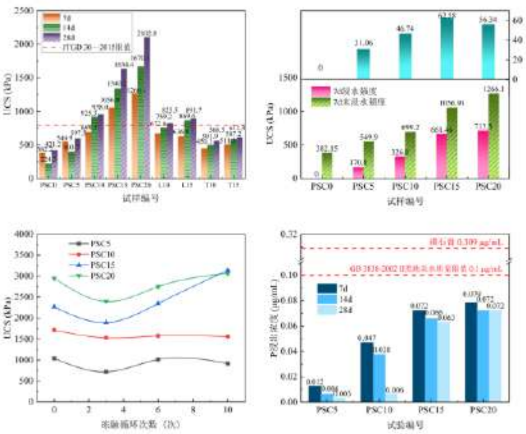

Fig. 1 Performance test results of PSCS

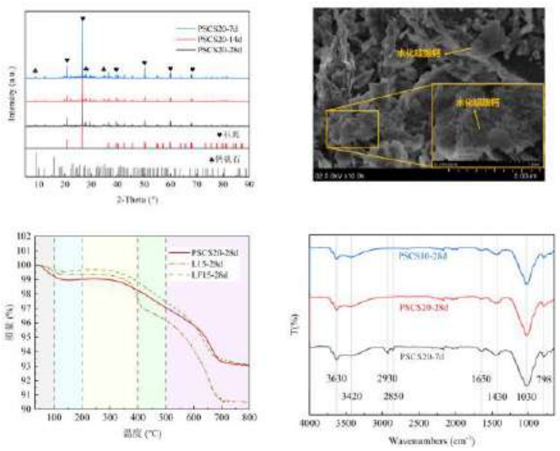

Fig. 2 Results of microscopic characterization of PSCS

A NOVEL BALLAST ROUGHNESS INDEX AND ITS ASSIGNMENT METHOD BASED ON ROUGHNESS RANDOM FIELD

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ABSTRACT

The ballast roughness has a significant impact on the performance and mechanical behavior of ballast beds. However, there is no appropriate index and reconstruction method for ballast surface roughness. In this study, a ballast roughness index which comprehensively characterized the surface undulations and its anisotropy was proposed based on the surface apparent dip angle. By using 3D point cloud data obtained from the laser scanning for 584 ballast particles, a probability density function for ballast surface roughness was established. Subsequently, a method was proposed to assign the roughness to the polyhedral ballast particle. This method built the roughness random field and then assigned the roughness based on particle positions. The method was applied to assign roughness to 600 and 3000 reconstructed ballast particles. The results showed that the roughness probability distribution of the reconstructed ballast samples was consistent with that of the real ballast samples. This means that the proposed method can be used to replicate the particle roughness in reconstructions.

Keywords: Ballast, Surface Roughness, Reconstruction method

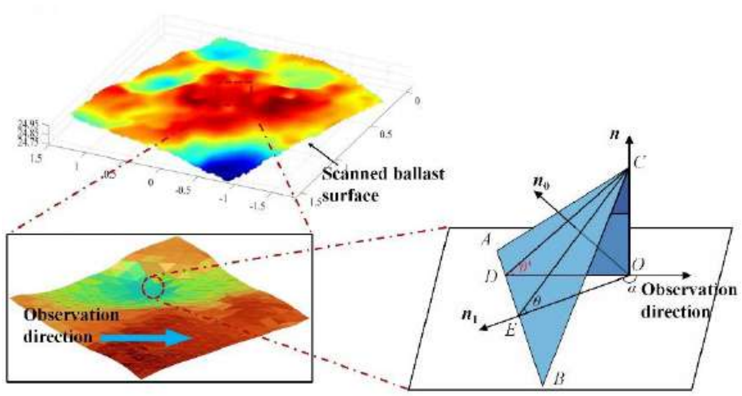
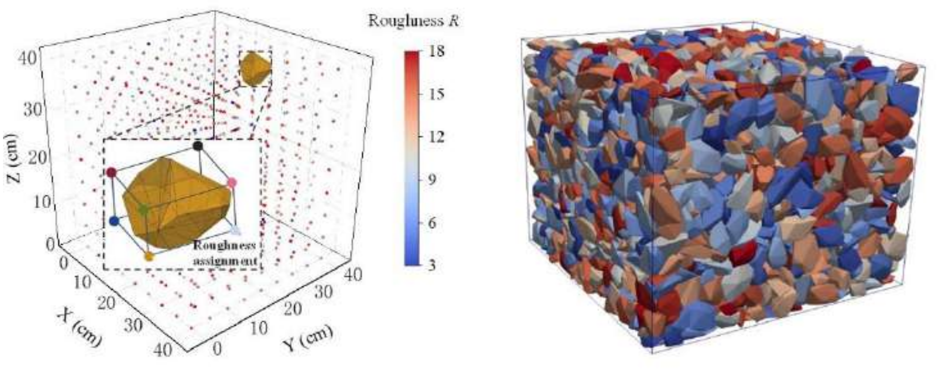


Fig. 1 Apparent dip angle of ballast surface mesh



(a) Roughness random field (b) Ballast particle after roughness assignment

Fig. 2 Roughness random field and particle assignment

Quantifying Geogrid-Aggregate Interface Shear Resistance Components Using 3-D Discrete Element Method

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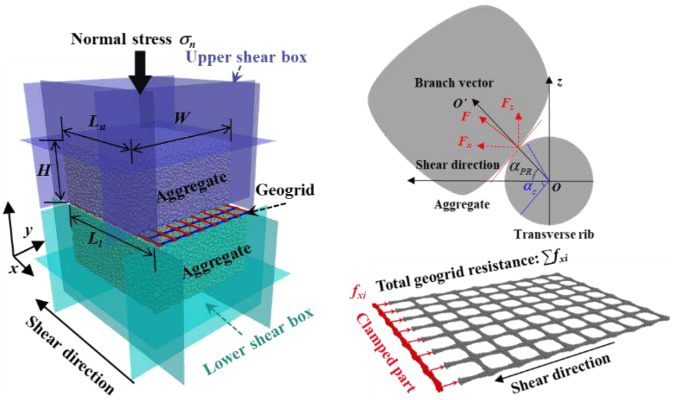
ABSTRACT

The shear behavior of the geogrid-soil interface significantly impacts the performance and stability of geogrid-reinforced soil (GRS) structures. This study developed a well-calibrated three-dimensional discrete element method (DEM) model, based on experimental test results, to systematically evaluate the geogrid-aggregate interaction mechanism and evolution of interfacial shear resistance components under direct shear loading. The tensile behavior and deformation response of geogrids were simulated through a series of calibration tests. Realistic aggregate particles with complex shapes were modelled to precisely capture interlocking effects between aggregates using actual particle surface geometries. Individual shear resistance components at the geogrid-aggregate interface were quantified from particle displacement distributions and identified special contacts in the DEM simulations. Results indicate the frictional resistance of aggregates exceeds both the transverse rib passive resistance and geogrid surface friction. Optimizing the aperture-particle size ratio (A_s/D_{50}) can increase rib passive resistance. Relatively stiff geogrids can optimize total shear resistance. In summary, the DEM model provided new insights into the shear behavior of geogrid-aggregate interface and methods to improve shear resistance for design of GRS structures.

Keywords: DEM; Geogrid; Aggregates; Interaction mechanism; Direct shear



(a) (b)

Fig. 1 DEM simulation: (a) Direct shear tests; (b) Identification of contacts

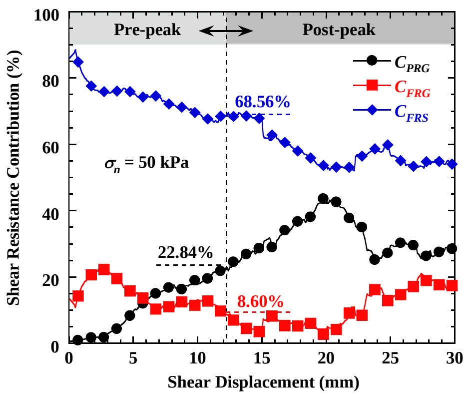


Fig. 2 Shear resistance contribution

INVESTIGATING PARTICLE BREAKAGE IN SAND UNDER TRIAXIAL SHEARING: A NOVEL APPROACH COMBINING X-RAY TOMOGRAPHY AND PARTICLE TRACKING

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ABSTRACT

In this study, we present a unique approach to analyze the particle breakage behavior of sands in the field of transportation geotechnical engineering. We employ a combination of X-ray micro-computed tomography (μCT) and sand particle tracking techniques to investigate the morphology and movement of sand particles. To begin, we conduct an in-situ μCT triaxial test on a miniature sand specimen, which allows us to visually observe the particle-scale characteristics and behavior. Subsequently, we develop a two-step particle tracking method that enables us to track individual sand particles that undergo minimal or no breakage. Notably, we successfully employ this method to track intact particles within a sheared sand specimen, which consists of a mixture of crushed and uncrushed particles. This marks the first time such tracking has been accomplished. Our findings indicate that the degree of particle breakage during the consolidation stage is negligible. However, during the pre-peak stress phase, more than half of the particles experience initial crushing, with significant breakage occurring at the center of the specimen during the post-peak stage. Additionally, our analyses of particle shape and gradation demonstrate that larger grains with lower sphericity and convexity values are more susceptible to breakage. Moreover, the crushed particles exhibit angularity characteristics that are closely linked to their respective parent particles. This research provides valuable insights into the particle breakage behavior of sands in the field of transportation geotechnical engineering. The methodologies and findings presented here can inform the design and analysis of transportation infrastructure projects involving sand materials.

Keywords: Particle breakage; Particle shape; Particle tracking; Sands; In-situ x-ray micro-tomography

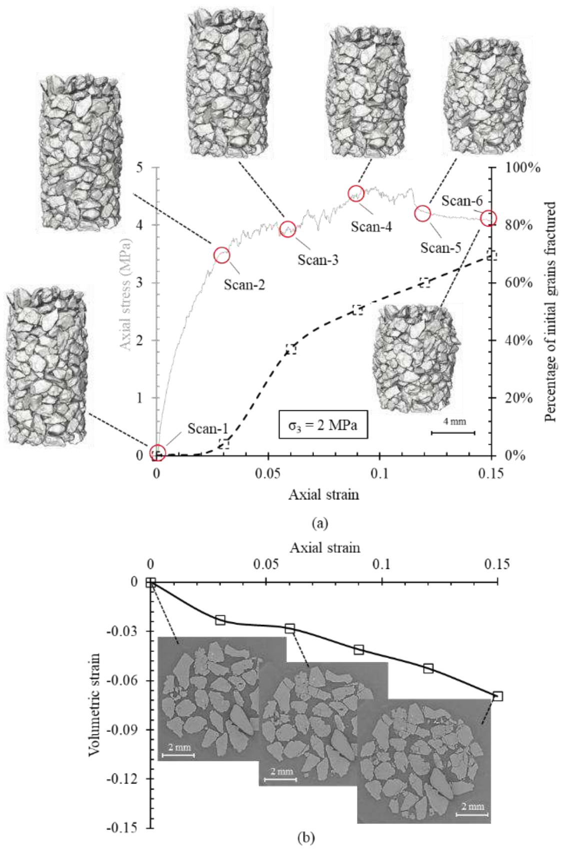

Fig. 1 The stress-strain curve and volumetric strain curve of the sample

Recycled Utilization of Dredged Sludge as a Subgrade Material and Field Application Study

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ABSTRACT

Dredged sludge has arisen wide concerns of its pollution to water environment requiring urgent treatment. However, the shortage of land resources owing to development of urbanization posed a formidable hurdle to conventional landfill mode. In this study, dredged sludge was solidified by solid wastes and utilized as a subgrade material. Calciu0m carbide slag, gypsum, and cementing agent were selected as three compositions of a novel curing agent and were added into dredged sludge. A series laboratory tests, including unconfined compressive strength, scanning electron microscopy, and X-ray diffraction were carried out to investigate strength performance and microstructure of solidified dredged sludge. The optimal ratio of three compositions was obtained of 20:1:1 and optimal dosage of curing agent was determined as 18%. In a field application, the novel curing agent was added into a channel and mixed with dredged sludge, which was then dug out and filled as a subgrade material for the riverbank. In situ CBR tests were conducted on the compacted subgrade and results showed that bearing capacity of solidified dredged sludge satisfied the requirement of III degree highway with regard of technical specifications for construction of highway subgrades of China. This study will provide a reference for the recycled utilization of dredged sludge.

Keywords: dredged sludge;solid wastes;subgrade;field application

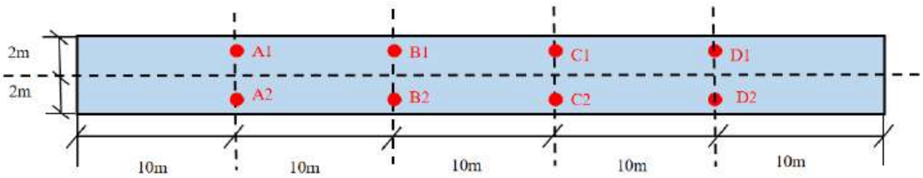

Fig. 1 Field application site

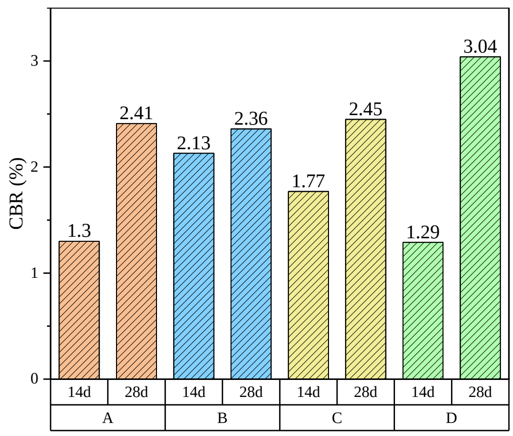

Fig. 1 the CBR values at different locations

In-Situ X-Ray CT Investigation of Internal Erosion Using A Mini-Triaxial Apparatus

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ABSTRACT

Soils with a gap-graded grain-size distribution tend to exhibit internal instability under seepage flow when the fine particles can migrate within the interstices of coarse particles. The removal of fine particles can alter the internal structure and hydraulic properties of the soil, resulting in increased permeability and reduced soil strength. To conduct a microscopic investigation of the internal erosion behaviour under the triaxial stress state, A mini-triaxial apparatus for in-situ X-ray CT investigation of internal erosion is developed. Then, the progression of internal erosion during triaxial shearing with X-ray micro-tomography (μCT) is investigated. Experimental results reveal that this apparatus can help to obtain clear particle images by cooperating with the X-ray CT machine. The progressive internal erosion due to mechanical disturbance leads to the formation of a flow channel from the upstream loading platen throughout the sample, resulting in a dramatic increase in permeability.

Keywords: Mini-triaxial apparatus; internal erosion; triaxial shearing; X-ray CT; permeability.

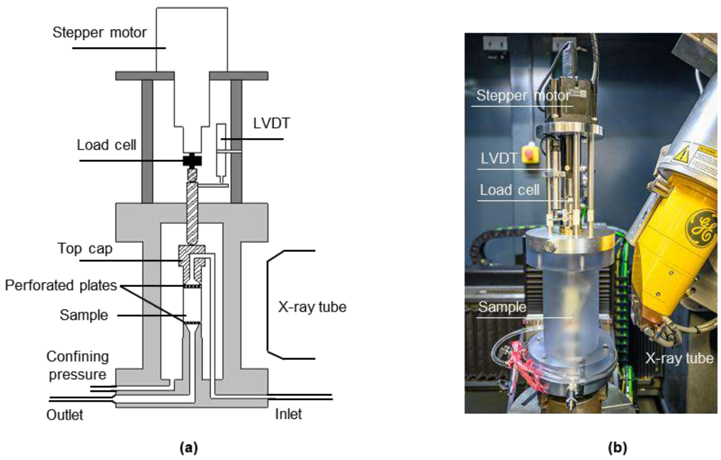

Fig. 1 Mini-triaxial apparatus: (a) schematic diagram; (b) photo of the apparatus during scan in an X-ray CT scanner

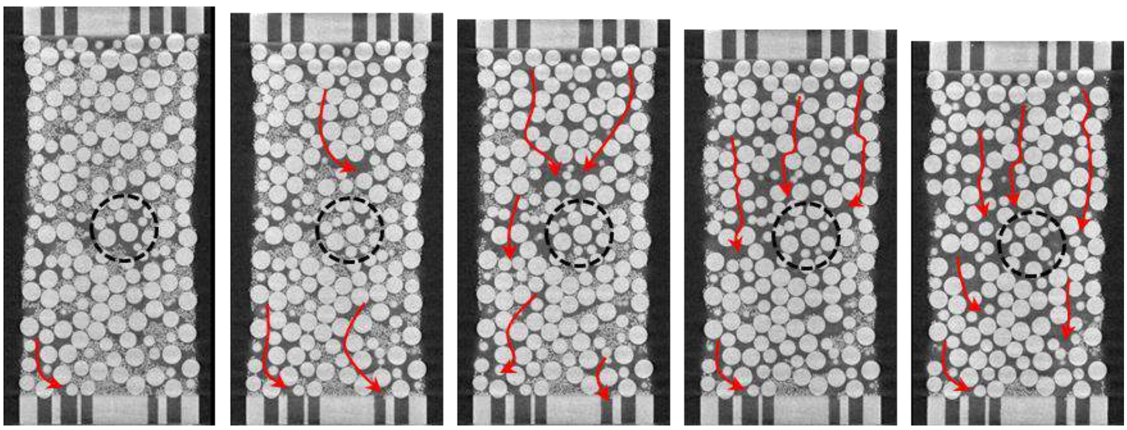

Fig. 2 Vertical slices of CT images on the middle plane of the sample.

THE REACTIVATION MECHANISM OF ANCIENT LANDSLIDES UNDER THE COUPLED EFFECTS OF RAINFALL AND TRAIN VIBRATION

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ABSTRACT

With the improvement of the railway network in Northwestern China, recently, loess railway ancient landslides (LRALs) are often restarted due to the coupled effect of rainfall and train vibration (CERV), threatening lives, railway operations, and safety. To explore the restart mechanism of LRALs under the action of CERV, a physical similarity model was established based on an LRAL in Qingjian County, China along the Baotou–Xi'an railway. Based on the pore pressure growth and pore structure evolution when an LRAL restarts, it is found that, before the LRAL restarts, under the action of dry-wet cycling, the number of macropores gradually increases, the pore roughness decreases, and the efficiency of water transport in soil is improved. After applying vibration loads, the pore water pressure gradually increases until the effective stress dissipates, and the LRAL restarts after the soil structure is damaged and rendered unstable. A formula for the sliding distance of the LRAL based on the number of vibration load loading events i was derived, and used to explain the restart mechanism of the LRAL under the action of CERV from micro, micro, and macro-perspectives. After the development of cracks under vibration, water infiltration forms a pore-crack-seepage network. Under the action of CERV, the pore-crack-seepage network continues to develop and expand. After the soil structure is destroyed and rendered unstable, the LRAL restarts. After restarting, the LRAL will start to creep and slide under the cumulative effect of dynamic load. Due to the degradation associated therewith, when the sliding range reaches the threshold, the LRAL stops creeping and sliding, and the LRAL disaster ends.

Keywords: Loess train ancient slope · Comb-ining effect · Train vibration · Rainfall · Sha-king table test.

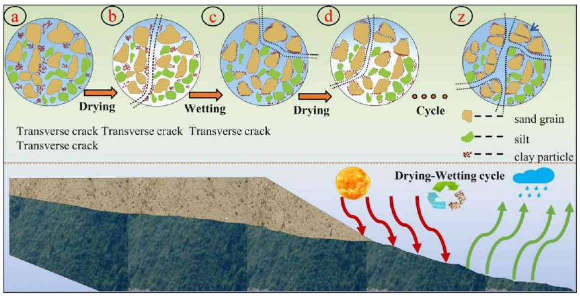

Fig. 1 Schematic diagram of shaking table model.

EXPERIMENTAL STUDY ON FROST HEAVE CHARACTERISTICS OF RED-BED MUDSTONE FOR HIGH-SPEED RAILWAY SUBGRADE IN SEASONAL FROZEN REGIONS

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ABSTRACT

Severe freezing problems have been observed in high-speed railway subgrade in seasonal frozen regions, but fewer experimental studies have been conducted on the frost heave characteristics of red-bed mudstone subgrade fill. A unidirectional freezing test device was designed to carry out orthogonal tests of frost heave characteristics with different cooling paths, water content (6%,7%, and 8%), and dry density (2.06,2.13, and 2.20g/m^3). The test results show that the frost heave ratio is less than 1% when the water content is less than or equal to 7% and greater than 1% when the water content is 8%. The moisture in the specimen migrated to the direction of lower temperature. With water supply, the weights of influence on the frost heave ratio are water content (0.38), dry density (0.32), and cooling path (0.09), and the weights of influence on the frost depth are cooling path (0.66), dry density (0.15) and water content (0.12). Without water supply, the weights of influence on frost heave ratio are dry density (0.45), water content (0.34), and cooling path (0.17), and the weights of influence on frost depth are cooling path (0.64), water content (0.16) and dry density (0.14). The most favorable combination for frost heave was proposed.

Keywords: Frost heave; Red-bed mudstone; Orthogonal design test; Analytic hierarchy process

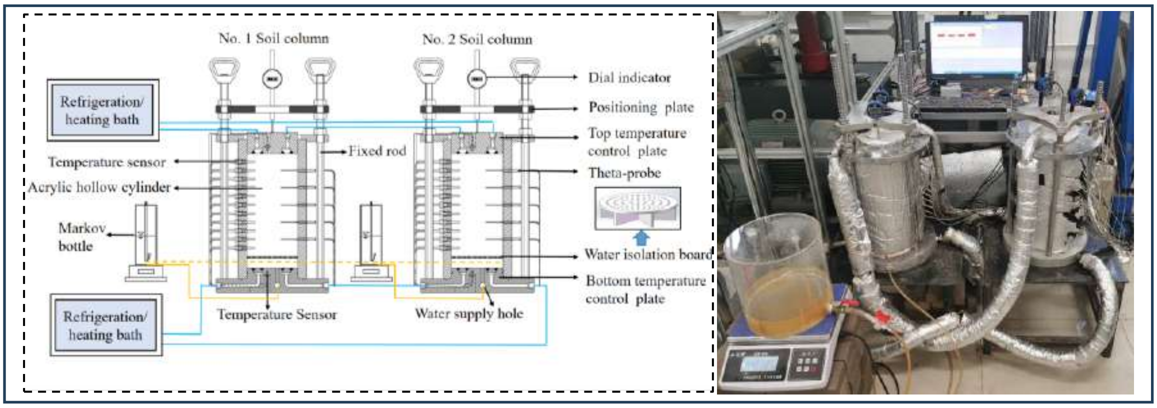

Fig. 1 Unidirectional freezing test device

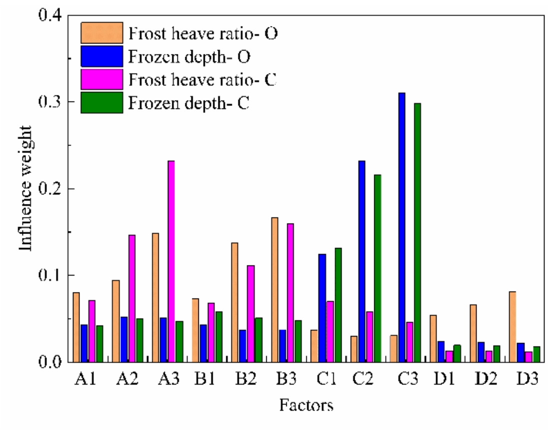

Fig. 2 The weight of the level on the test

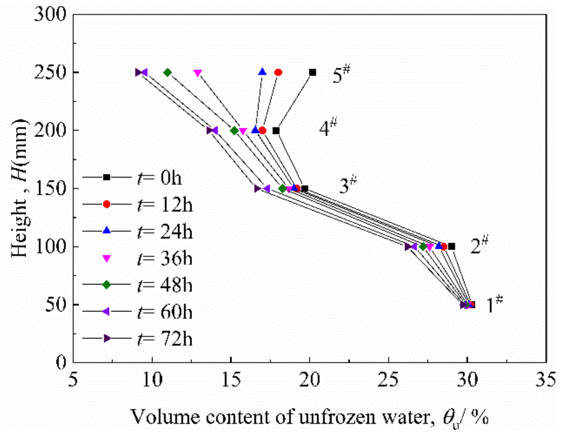

Fig. 3 Variation of unfrozen water distribution with time

A MULTI-SCALE STUDY ON THE STRENGTH CHARACTERISTICS OF THE LIME STABILISED RED MUDSTONE FILL MATERIAL

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ABSTRACT

The lime stabilised red mudstone could be used as the fill material of the high- speed railway subgrade to ease the problem of the shortage of the high- quality fill material in Southwest China. However, the mechanism of the lime stabilised red mudstone is unclear. Therefore, direct shear test, mercury intrusion test and scanning electron microscope test were operated to study the influence of the lime modification on the strength of the red mudstone fill material. Consequently, the results show that: when the red mudstone reaches to the saturated state, the edges and corners of the particles disappear, the pores between the particles collapse, and the pore size distribution changes from a bimodal structure to a unimodal structure. This reflects that the red mudstone fill material has a strong trend on water sensitivity. Besides, under the saturated state, the shear strength of the lime stabilised one would be larger than the plain soil. In terms of the microstructure, the bimodal structure just shows a slight change with the change of saturated state. Besides, with the increase of the curing age, the number of micropores of the lime stabilised fill material gradually decrease and the number of nanopores gradually increase.

Keywords: High-speed railway, Red mudstone, Subgrade fill material, Lime modification, Microstructure

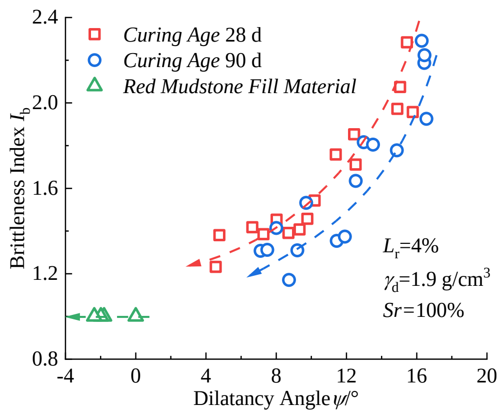

Fig. 1 Change of brittleness index with dilatancy angle of the lime stabilised red mudstone fill material

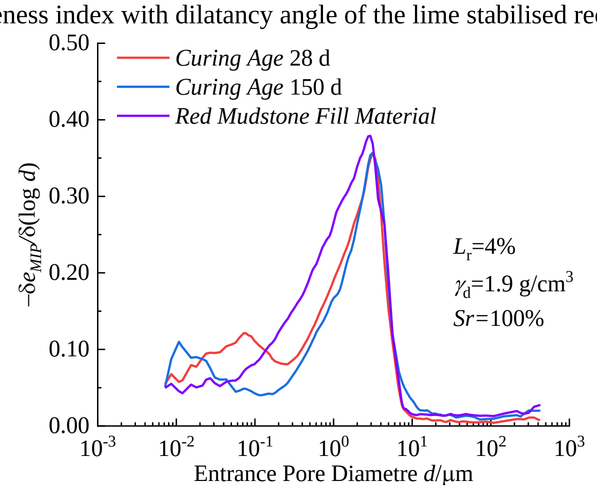

Fig. 2 PSD curve of the lime stabilised red mudstone fill material with different curing ages

RESEARCH ON THE MECHANISM OF PRESTRESSING ANCHOR SUPPORT BASED ON THE PRINCIPLE OF ENERGY MIGRATION

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ABSTRACT

As the only component in the tunnel support system that improves the surrounding rock from the inside, the active support technology centered on prestressed anchors can fully mobilize the self-bearing capacity of the surrounding rock. Despite their widespread use, the design of tunnel construction anchors is still predominantly governed by empirical and analogical methods. The active support mechanism of prestressed anchors is studied from an energy migration perspective using the finite difference method combined with elastic strain energy density theory. By comparing energy redistribution maps between the bare tunnel and the tunnel with prestressing anchors, it is observed that the surrounding rock is actively influenced by the prestressing force applied by the anchors. This causes energy in the arch's energy reduction zone, following tunnel excavation, to rebound, thereby enhancing the load-carrying capacity. Additionally, this process reduces the degree of energy aggregation in the side wall, consequently lowering the risk of shear damage in that area. Changes in the plastic zone and displacement field also reflect this phenomenon. This paper proposes prestressed anchor support principles for the energy reduction zone under various horizontal stress ratio conditions, offering valuable construction insights for future projects.

Keywords: tunnel engineering, prestressing anchor, energy migration, support recommendation

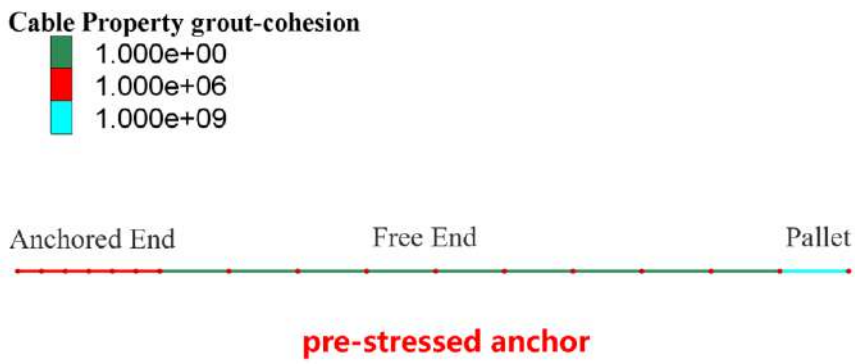

Fig. 1 Simulation of prestressing anchors

INVESTIGATION ON THE RESILIENT MODULUS OF SOIL MIXTURE AT VARIOUS WATER CONTENTS AND COARSE GRAIN CONTENTS UNDER THE TRAIN MOVING LOADS (249-91)

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ABSTRACT

An interlayer soil in railway substructure was characterized by a fine/coarse soil mixture. As the resilient modulus M_r of mixture can be influenced by the microstructure of fine soil, this aspect was investigated in depth. The microstructure of fines was explored by mercury intrusion porosimetry, and its influence on the M_r of mixture was studied by dynamic triaxial tests with varying deviator stress amplitudes σ_d. Results showed a fine matrix fabric obtained at water contents of fine soil w_f =17.6% and 13.7% (> the plastic limit of fine soil w_p = 12%), and a fine aggregate fabric identified at w_f =10.6% (< w_p =12%). Interestingly, the combined effects of w_f and σ_d on M_r of the mixture were found - increasing σ_d led to a decrease of M_r when $w_f > w_p$, but an increase of M_r when $w_f < w_p$. This led to the conclusion that, for the fine matrix fabric ($w_f > w_p$), increasing σ_d induced a reduction of M_r, while for the fine aggregate fabric ($w_f < w_p$) increasing σ_d gave rise to the growth of M_r. This distinct M_r–σ_d behaviors were explained by the competing effects between soil hardening upon loading and soil rebounding upon unloading.

Keywords: resilient modulus; soil mixture; cyclic triaxial test; mercury intrusion porosimetry

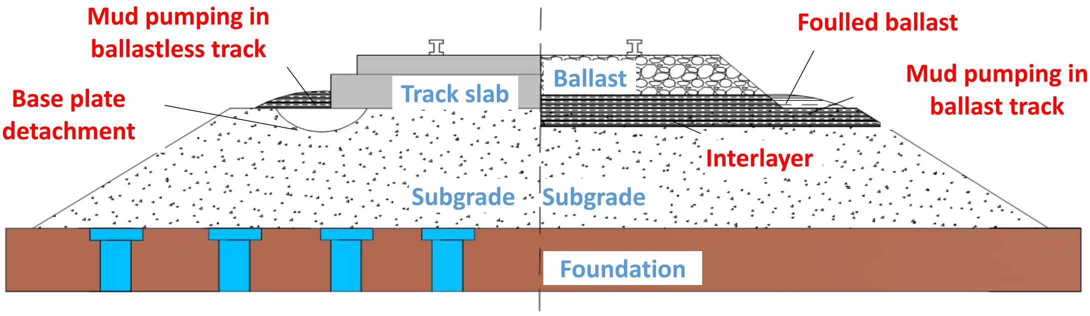

Fig.1. Schematical view of the formation of interlayer in the ballast railway track

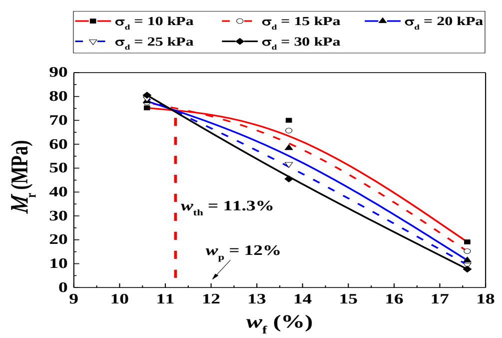

Fig. 2. Plots of end-stage resilient modulus M_r versus water content of fine soil w_f for f_v=0%

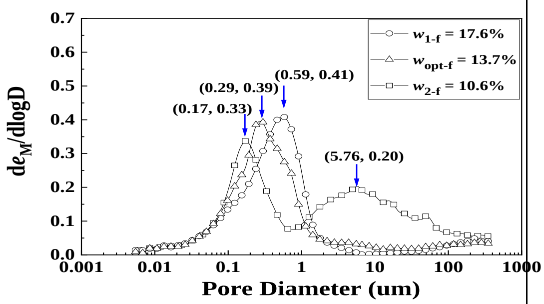

Fig. 3. Density function curves of pore size distribution of fine soil at f_v=0% and varying water contents

A NOVEL THEORETICAL MODEL TO PREDICT THAWING SETTLEMENT COEFFICIENT OF MULTIPLE-CATEGORIES PERMAFROST(249-208)

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[3]*Kunming University of Science and Technology, Faculty of Electric Power Engineering, Kunming, hit_mdr@163.com*
[4]*Harbin Institute of Technology, Civil Engineering School, Harbin, hit_wangzy@163.com*
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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

With extensive on-site monitoring and rich construction experience on the subgrade building in cold regions, the settlement of the subgrade is mainly attributed to thawing settlement and creep of the soil foundation beneath the embankment. With a better understanding of the mechanism of thawing settlement, prevention measures can be performed to ensure the safety of railway operations and reduce the fluent maintenance work. Scholars and engineers attempted to foresee the thawing settlement of frozen soil prior to design, but there was no universally accepted and satisfactory theoretical model for the prediction. Based on the four-phase charting of frozen soil towards a generalized frozen soil system that experiences thawing settlement, an original theoretical model is developed. The model induces four physical-meaning-clear factors that describe the thermal-hydraulic-structural characteristics of soil and attempts to take specimen scale into account. The innovative model adopts initial water content and dry density to forecast the coefficient which is widely used to describe thawing settlement. Thawing settlement test results of clayey, silty and gravelly sandy permafrost from various regions of Northeast China were substituted to verify the model. The model explains some thawing settlement characteristics and provides a happening probability list of various thawing settlement coefficients.

Keywords: Thawing settlement, permafrost, frozen soil, cold region, subgrade.

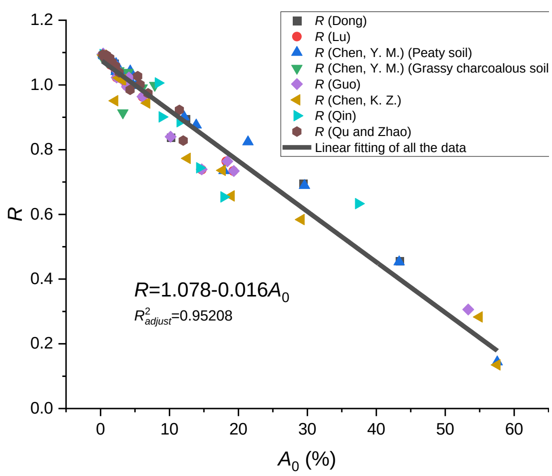

Fig. 1 R (Water retention capacity) - A_0 (Thawing settlement coefficient) of clayey permafrost (for example) from all the cited regions which presents an unified linear relationship.

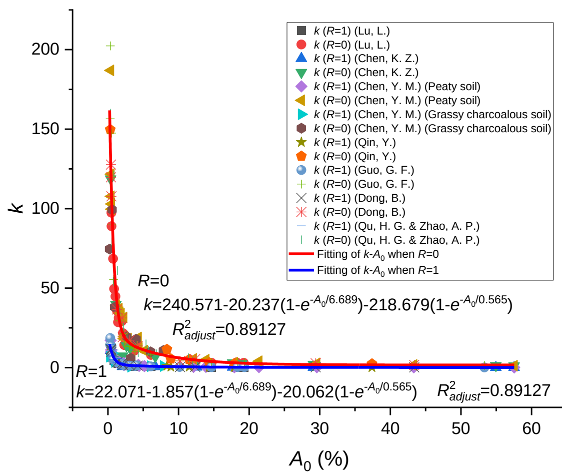

Fig. 2 k (Skeleton structural property) - A_0 (Thawing settlement coefficient) of clayey permafrost (for example) from all the cited regions when $R = 0$ and 1.

REACTIVATION MECHANISM OF ANCIENT LANDSLIDES UNDER THE COUPLED EFFECTS OF RAINFALL AND TRAIN VIBRATION

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ABSTRACT

In Northwestern China, the expanding railway network raises concerns about reactivating loess railway ancient landslides (LRALs) due to combined rainfall and train vibrations (CERV). This poses risks to lives and railway safety. This study focuses on an LRAL site in Qingjian County along the Baotou–Xi'an railway, aiming to comprehend the reactivation mechanism under CERV. The methodology uses a physical similarity model to understand pore pressure, structure, and water transport changes pre-reactivation during wetting and drying cycles. Vibration loads gradually increase pore water pressure, leading to LRAL reactivation through structural degradation. A derived formula predicts LRAL sliding distance accurately based on vibration events. The study details LRAL reactivation from microscopic to macroscopic scales, emphasizing pore, crack, and seepage network development under CERV. Post-reactivation, LRALs creep and slide until reaching a critical threshold, concluding the LRAL disaster.

Keywords: Loess train ancient slope · Comb-ining effect · Train vibration · Rainfall · Sha-king table test.

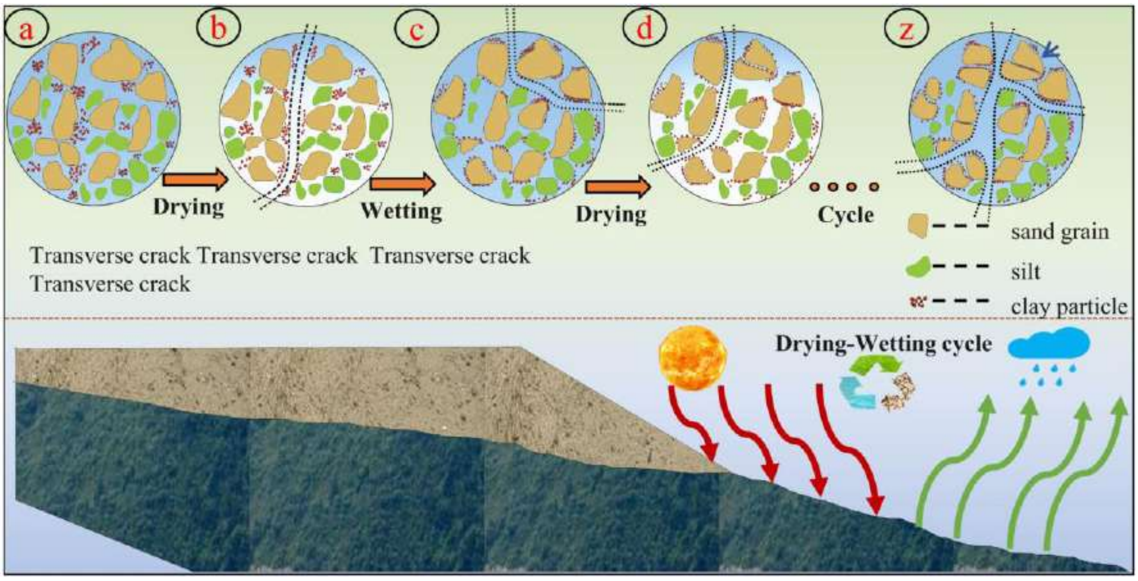

Fig. 1 Schematic diagram of shaking table model.

PERFORMANCE EVALUATION OF LIGHT-WEIGHTED CEMENT-STABILIZED-CLAY COLUMNS FOR SOFT GROUND IMPROVEMENT USING THE CENTRIFUGE MODEL TEST

Zhenping Zhao[1,2], *Zi* Ying[1#], *Wei* Yuan[1], *Yongfeng* Deng[1], *Xiaoqiang* Liu[2], *Chengfu* Chu[3], and *Xingwen* Gu[4]

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ABSTRACT

The thick soft clay (> 20 m) is difficult to be treated by the deep mixing method for financial reasons; accordingly, the light-weighted cement-stabilized soil (LWCS, 1.0 Mg/m3) columns produced by casting are proposed as an alternative. To investigate the performance of the LWCS columns, a centrifuge model test with an acceleration of 100 g was conducted on a composite ground with LWCS columns and traditional deep mixing columns (1.7 Mg/m3). The results indicate that the ground with traditional columns exhibits a significantly larger deformation than that with LWCS columns. The axial force increases and then decreases with respect to the traditional column depth, and decreases with respect to the LWCS column depth. The stress concentration ratio and column efficacy of LWCS columns is significantly lower than that of traditional columns, suggesting that the LWCS columns and soil could share the loading together, thus realizing a better coordination between the column and soil.

Keywords: centrifuge model test, foamed light-weighted column, performance of composite ground, load transfer

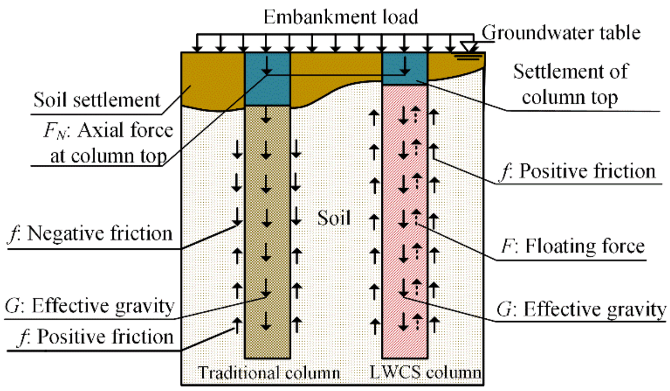

Fig. 1. Conceptual model for column axial force analysis

TRACKING UNFRAGMENTED AND SLIGHTLY FRAGMENTED PARTICLES IN A MINI-TRIAXIAL SAMPLE USING THE NEURAL NETWORKS

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[#]*Corresponding author: jefwang@cityu.edu.hk (J. Wang); Underline denotes the presenter*

ABSTRACT

In this paper, a novel particle tracking method is proposed to investigate the kinematics of particles exhibiting zero or low-level fragmentation by combining PointConv and PointNetLK networks. Firstly, a series of image processing algorithms were employed on the 2D slices to facilitate reproduction of particle morphology and motion. Subsequently, all particles were represented as point sets, downsampled and grouped, yielding substantial datasets for neural network training and testing. Additionally, Gaussian noise was generated and introduced into the particle point sets to enhance the network robustness. Then, the PointConv network was implemented to efficiently track unfragmented and slightly fragmented particles under different strains. This success was attributed to the good preservation of morphological features of these particles and the excellent capacity of PointConv to capture morphological features. Next, the PointNetLK network was trained and integrated with the particle correspondence obtained by PointConv, aiming to determine the optimal transformation matrix for the corresponding particles. The predictive results are evaluated based on the visualization of the transformed point cloud, followed by a discussion of the influence of different parameters on the predictions. Finally, a comprehensive comparison with several existing particle tracking methods highlights the advantages of the proposed method.

Keywords: Particle breakage; Particle identification and tracking; Image processing; Sands; Machine learning

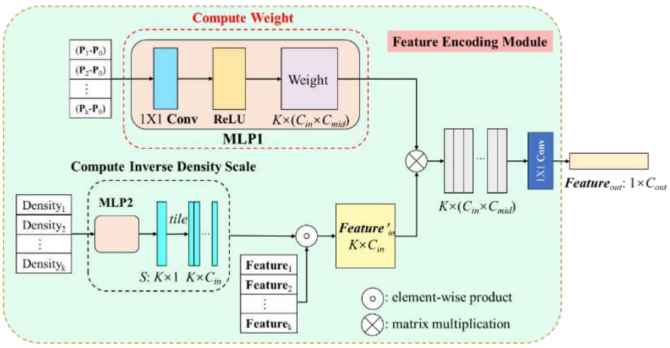

Fig. 1 The architecture of the PointConv network.

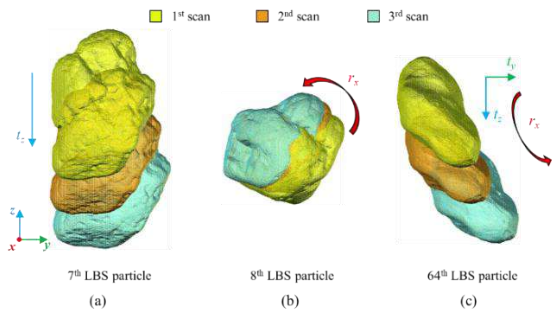

Fig. 2 Position of particles in different scans: (a) 1st scan; (a) 2nd scan; (a) 3rd scan.

TENSILE STRENGTH OF REMOULDED CLAYEY SOIL — INSIGHTS FROM THE INITIATION MECHANISM OF EARTHQUAKE-INDUCED LANDSLIDES

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ABSTRACT

Earthquake-induced landslides constitute a critical component of seismic hazard in mountainous regions. Due to the complexity of propagation of seismic waves in the mountain topography, especially for the superposition of reflected waves and incoming waves on the slope surface, the stress state of soil in the slope is dominated by tension. Therefore, it is important to investigate the tensile strength of soil in order to find the deep mechanism of earthquake induced slope failure. This paper presents a new apparatus which is suitable for the soil tensile tests. In the tensile test of soil, the most important thing is to realize the tensile of soil. As we all know, soil belongs to fragmentary materials, which cement by minerals and water. Consequently, it is particularly important to realize the direct tensile of soil. In this paper, a device is designed and developed to prepare the soil samples. When the soil is remoulded and compacted in the device, the soil sample can be established. The shape of the soil sample is like "dog bone" which considered the stress concentration on the both ends of the samples. The displacement and the stress can be recorded by the relevant sensor. The results show that the tensile break of clayey soil is not the brittle failure but the plastic failure. The stress-strain curves show that the residual strength of clayey soil is still existed. The cracks on the clayey soil caused by the tensile force are gradually generated. The peak tensile strength should not completely determine the damage of clayey soil.

Keywords: tensile strength; uniaxial tensile test; clayey soil

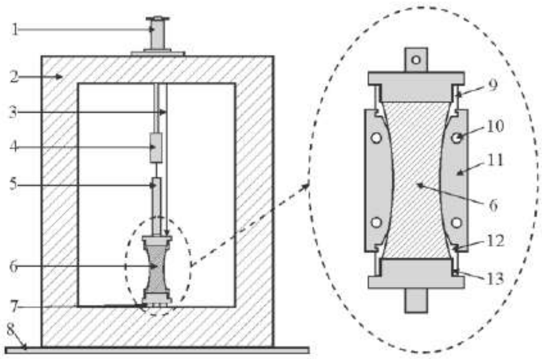

Fig. 1 Test mould and device of uniaxial tensile test

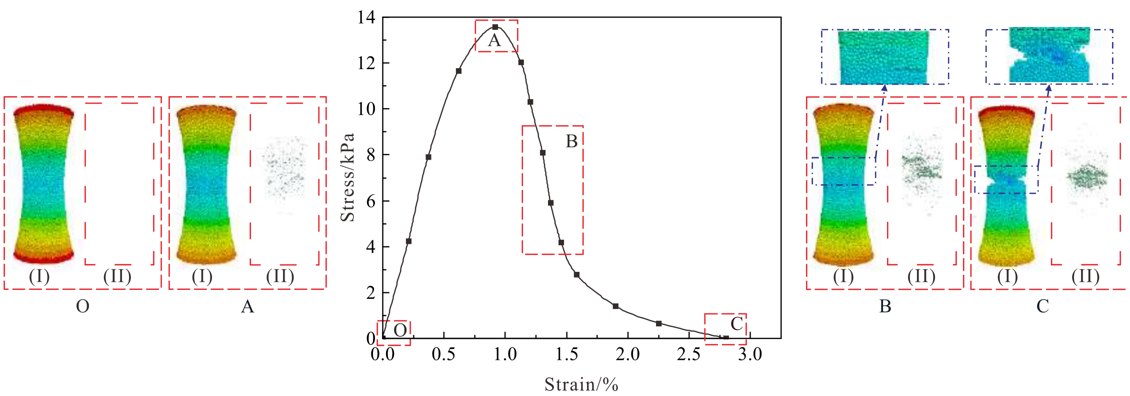

Fig. 2 Sample failure process and stress-strain curve

THE LIQUEFACTION AND RELIQUEFACTION BEHAVIOR OF SAND CONSIDERING RECONSOLIDATION EFFECT UNDER UNDRAINED CYCLIC SIMPLE SHEAR BY DEM

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ABSTRACT

It has been recognized that sand that experienced liquefaction in the mainshock may liquefy again (reliquefaction) when suffered an aftershock. Although the pore pressure is dissipated and the density of the reconsolidated sand increases prior to the aftershock, the reliquefaction may cause more severe damage to the infrastructure supported by sandy soil. To gain more micromechanical insights into the reliquefaction behaviours of sand, a series of undrained cyclic simple shear tests are carried out on granular specimens with different reconsolidation ratios and liquefaction history, using an advanced discrete element servomechanism that avoids stress concentration and strain non-uniformity. The evolutions of load-bearing structure of the granular specimens are quantified through a contact-normal-based fabric tensor. The interplay between the external loading and internal structure evolutions is analysed in detail. The simulation results show that under otherwise identical conditions, the granular specimen exhibits more significant non-coaxiality between the loading direction and major principal direction of fabric during the aftershock than that of the mainshock. The degree of non-coaxiality between the loading direction and the major principal direction of fabric may serve as a proper indicator of liquefaction/reliquefaction of sandy soils under earthquake shakings.

Keywords: Reliquefaction; reconsolidation; granular soils; cyclic simple shear; Fabric evolution

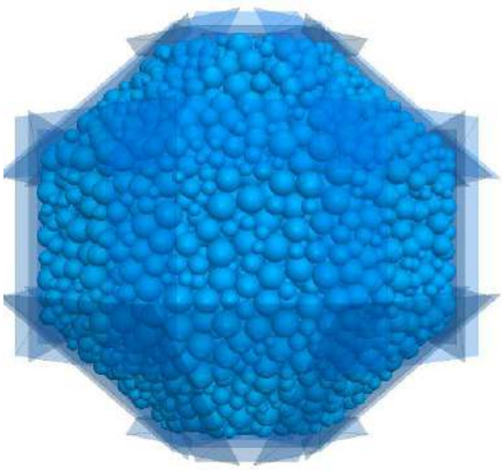

Fig. 1 Numerical specimen based on polyhedral configuration

FREEZING EFFECTIVENESS OF SINGLE FREEZING PIPE IN SAND-CLAY STRATUM UNDER DIFFERENT SEAWATER INFILTRATION VELOCITY

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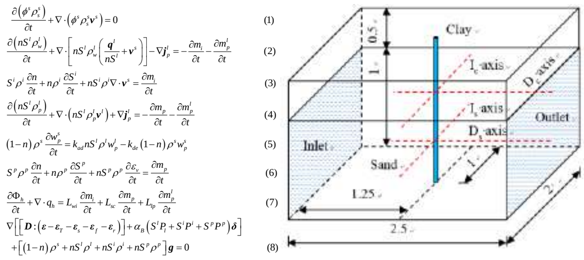
ABSTRACT

The seepage velocity in the sandy clay stratum will affect the freezing range of the freezing pipe. The hydro-salt-thermal-mechanical model of the influence of seepage flow on the artificial freezing process in sand-clay stratum is derived. The influence of momentum conservation of fluid in seepage process is considered by Navier-Stokes equation. The good consistency between the results from the theoretical model and laboratory tests in the literature verified the accuracy of the proposed model. Parametric studies are conducted to investigate the influences of the seepage velocities on the spatial distributions. It is found that with the seepage velocity increases, in the sand layer and clay layer of the sand-clay stratum, the influence range of temperature is reduced by 58.1 % and 13.3 %, respectively, the influence range of the crystalline salt is reduced by 58 % and 30.6 %, respectively. In the upstream of the sand-clay stratum, the leading edge of salt crystallization in the sand layer and the clay layer decreased by 50.4 % and 26.2 %, respectively. When the seepage velocity is 15 m/d, in the sand-clay layer, the range of ice formation in the sand layer is 50.2 % lower than that in the clay layer.

Keywords: saturated frozen marine soil, frozen pipe, seepage flow, coupling of hydro-thermal-salt-mechanical, adsorption and desorption effect, sand-clay stratum



(a) (b)

Fig. 1 The (a) coupling model and (b) numerical diagram in this study

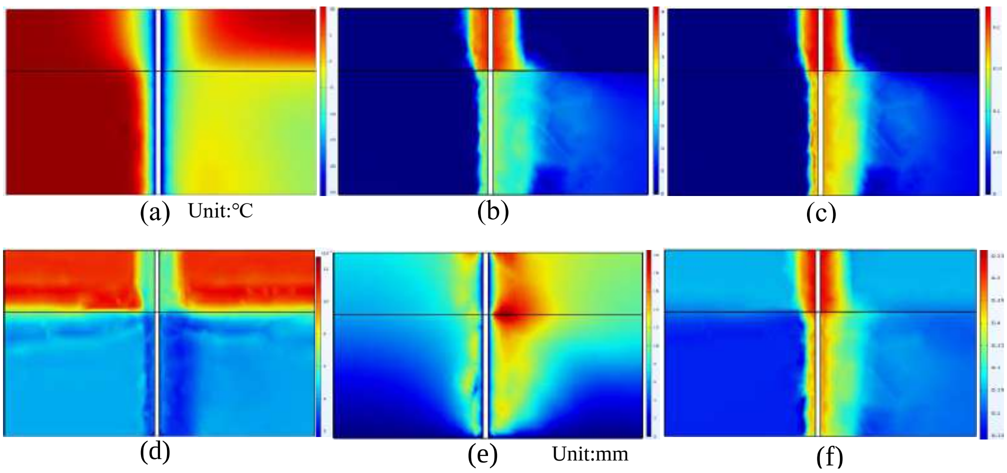


Fig. 2 The contour map of the (a) temperature, (b) ice content, (c) crystalline salt content, (d) adsorbed salt content, (e) soil displacement and (f) total salt content distribution profile in soil specimen after 70 h of freezing with seepage velocity of 10 m/d

NUMERICAL MODELING OF DRAG ANCHOR PENETRATION AND CAPACITY

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ABSTRACT

The advancement in modeling anchoring systems for floating offshore wind turbines (FOWTs) is a rapidly-evolving field of study. This research focuses on the anchoring process and the subsequent interaction with the seabed, which are crucial for both the installation phase and operational state of the anchoring system. However, these interactions are barely considered in existing standards. Applying the CEL method, first models effectively simulate large displacements and extensive soil deformations characteristic of these applications. Investigations include the simulation of installing drag embedment anchors (DEAs) and the effect of anchor structural modifications on the structure-soil interaction, revealing that fine-grained soils demand complex models for accurate simulation, see Fig. 1. Further analyses also investigate different anchor modeling techniques for the already embedded anchoring systems, reflecting their influence on soil's load-deformation behavior, see Fig. 2. Emphasis is placed on understanding complex dynamics in anchoring systems and the impact of anchor movement, highlighting the importance of precise modeling strategies. The study offers significant insights into the optimization of anchoring structures, thus contributing to the sustainability and reliability of floating offshore applications.

Keywords: Drag Embedment Anchor (DEA), CEL, Structure-Soil Interaction, Anchor Installation, Floating Renewables.

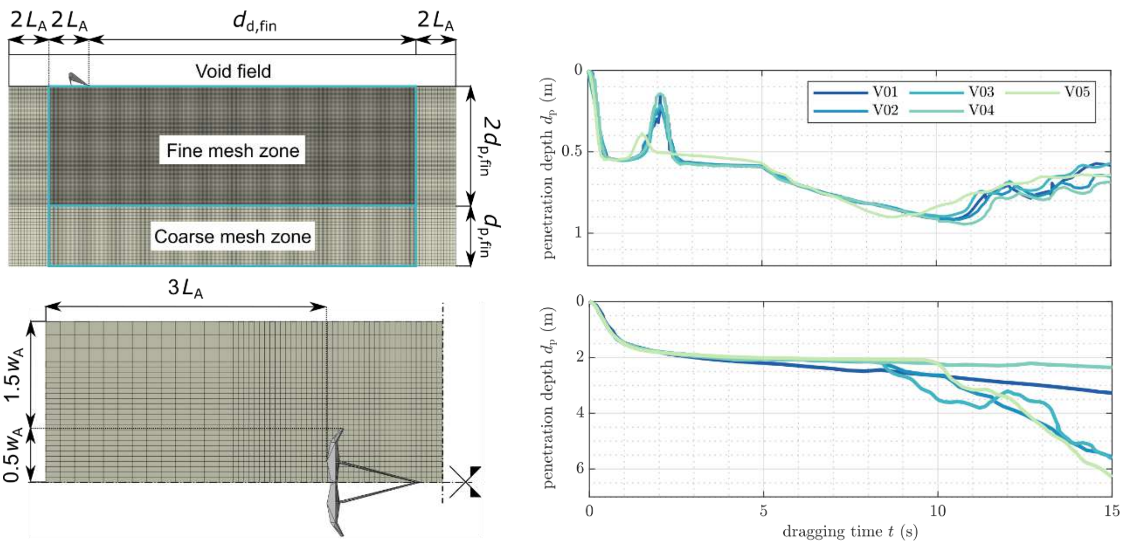

Figure 1: Side view and selected top section view of the discretized simulation domain and numerically calculated penetration depth of different anchor versions over time for sand (top) and clay (bottom)

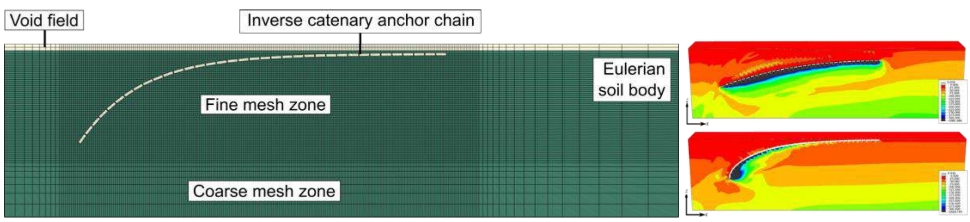

Figure 2: Anchor chain model and stress state of the soil (in kPa) for a fixed anchor point (top) and a free support (bottom) after pulling.

A NOVEL NUDCT RESONATOR BASED WPT-MRC SYSTEM WITH ANTI-MISALIGNMENT FUNCTION

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ABSTRACT

In WPT-MRC (Wireless Power Transfer via Magnetic Resonance Coupling) systems, the resonator coils need to be aligned for maximum efficiency, and any misalignment between resonator coils can result in a significant drop in output efficiency. Therefore, improving the anti-misalignment capability of WPT systems is an important consideration for practical applications. The paper has proposed a NUDCT (Non-Uniformly Distributed Coil Turns) coupler with uneven turns that generates a uniform magnetic field to improve anti-misalignment capability of WPT-MRC systems. The proposed NUDCT resonator has been optimized using GA (Genetic Algorithm), and the theoretical analysis of the magnetic field in case of misalignment has been presented. The paper has also validated the WPT-MRC system's transmission performance using the optimized coil. The results indicate that the magnetic field generated by NUDCT provides better uniformity under misalignment and higher system efficiency.

Keywords: Wireless power transfer, Magnetic Resonance Coupling, Misalignment.

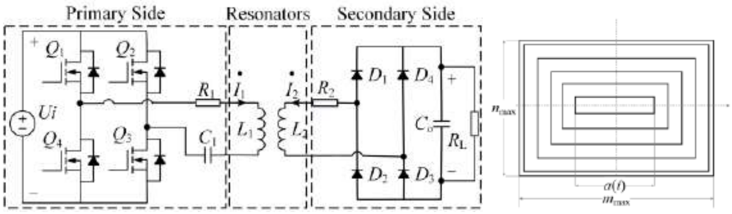

Figure 1. WPT-MRC system diagram(a)System topology; (b)NUDCT coil.

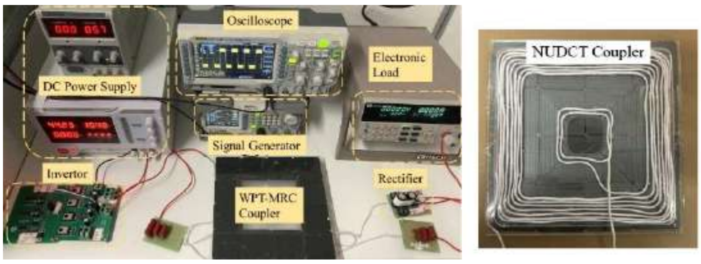

Figure 2. WPT-MRC system experimental equipment:(a)Overall system; (b)NUDCT coil.

AUTOMATIC DETECTION OF TUNNEL DEFECTS BASED ON POINT CLOUD DATA

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ABSTRACT

Deformation monitoring and quality inspection of tunnels are important aspects of tunnel construction and post-operation maintenance. With the innovation of optical measurement technology, 3D laser scanning technology can work well without any external illumination and is particularly suitable for measurement in underground tunnels. Using a 3D laser scanner for point cloud data acquisition to identify defects, various techniques, and methods need to be combined for data collection, pre-processing, feature extraction, classification and recognition, defect analysis, and location. Among them, feature extraction is a critical step as it determines whether defects can be accurately identified. Previous studies have mostly focused on point cloud geometric information for feature extraction, identifying structural damage through mutations in point cloud geometric features. However, this study identifies damaged areas by combining point cloud geometric information with reflection intensity and texture information, which can further improve the accuracy of identifying defects in tunnel lining.

Keywords: point cloud, tunnel defects, feature extraction, machine learning.

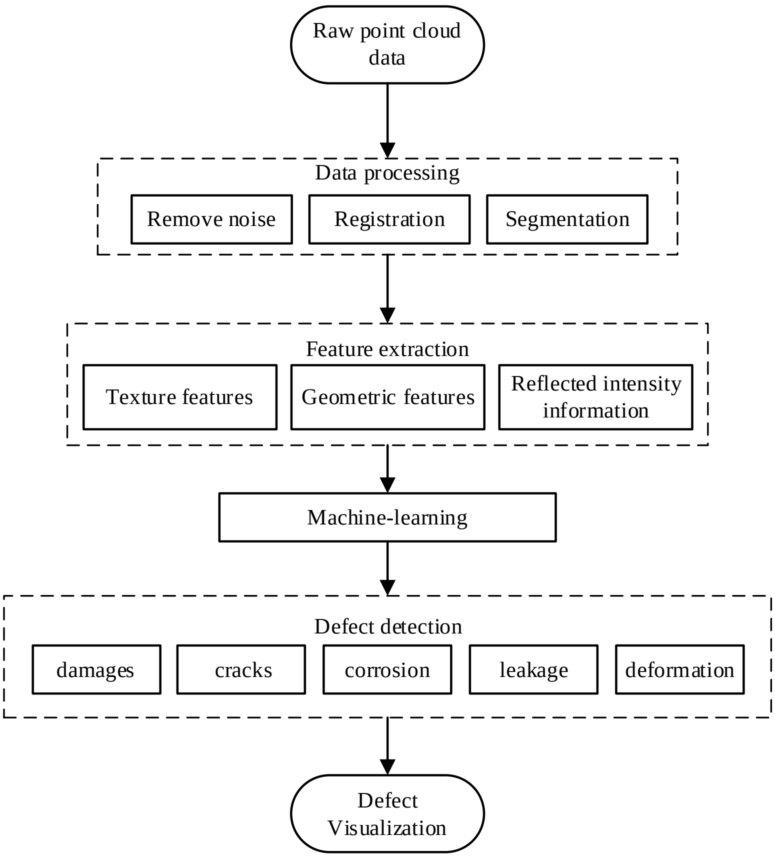

Fig. 1 Illustration of the research procedures.

DEM ANALYSIS OF MESO-MECHANISM FOR STRESS TRANSITION WITHIN GRANULAR ASSEMBLIES

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ABSTRACT

Granular assemblies are an illustrative example of complex material where unexpected macroscopic properties may emerge when they are subjected to a given loading. The microstructural rearrangement within granular assemblies leads to the nonuniform transition of shear stress. Based on a discrete element method (DEM), the numerical simulations of biaxial loading for granular assemblies with different initial densities were carried out to analyze the transition of deviatoric stress from the perspective of meso-loop. The meso-structures are divided into strong/weak loop assemblies according to the global mean stress. In topology network, the strong loops form the slender and continuous structure chain to bear and transfer the principal stress, while the weak loops fill in the space to support the extension of strong structure chain. The strong loop assemblies hold a larger fabric anisotropy and a stronger stress level for the transition of deviatoric stress during shearing. Particularly, during the critical state regime, the deviatoric stress level of specimens with different densities is governed by the unique strong and weak loop assemblies, i.e., the same level of number proportion, fabric anisotropy degree and stress level for both strong and weak loops with the same loop order.

Keywords: Granular assemblies, meso-loops, strong/weak structure, stress transition, DEM.

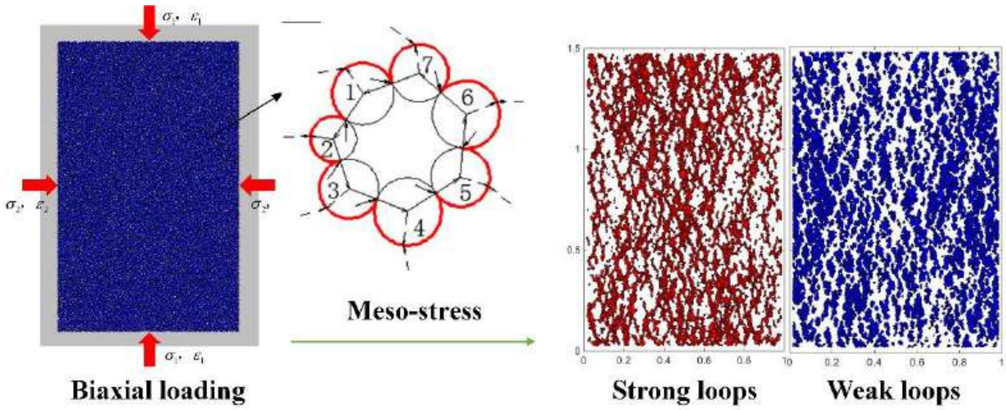
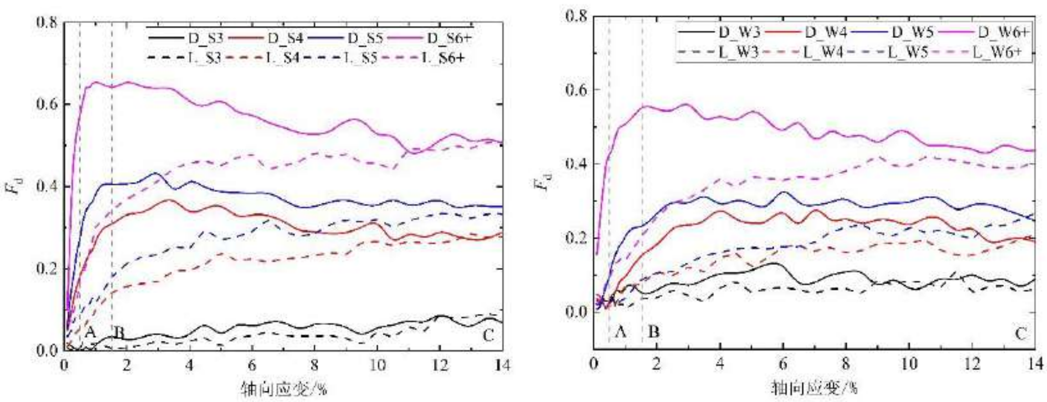


Fig. 1 Strong/weak loop assemblies within granular assemblies under biaxial loading.



(a) (b)

Fig. 2 Evolution of deviatoric fabric for different loops in strong (a) and weak (b) structural assemblies

EVALUATING LIQUEFACTION RESISTANCE OF NEARLY SATURATED SOILS BY COMPRESSIONAL WAVE VELOCITY

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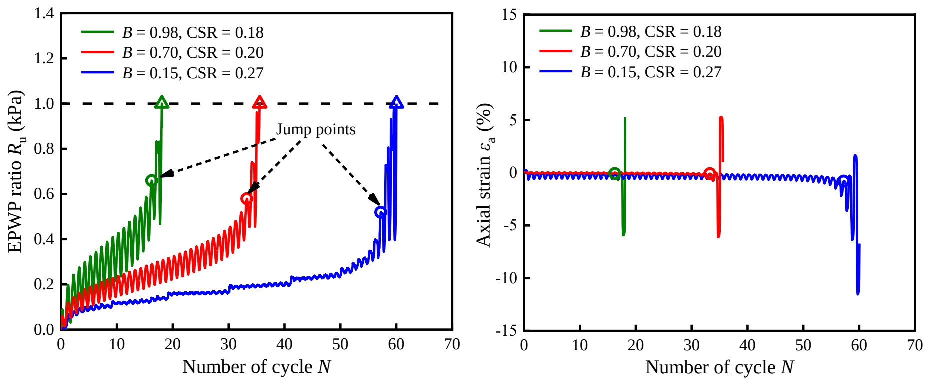
ABSTRACT

Nearly saturated soils below groundwater table usually exist due to the water level fluctuations or soil desaturation technologies. Therefore, it is necessary to investigate the cyclic responses of nearly saturated soils and establish a practical method to quantify the improvement of liquefaction resistance due to the decrease of saturation. For this purpose, an experimental programme comprising undrained cyclic triaxial and bender elements tests was performed on nearly saturated soils under various conditions. Results show that the cyclic shear behaviors of nearly saturated sands are significantly different from those of fully saturated sands. As excess pore water pressure (EPWP) accumulates to a certain proportion of effective confining pressure, it suddenly develops with a significant increase followed by the occur of more than 5% of axial strain. The values of EPWP at the change-points named “jump points” decrease as the *B*-value decreases. Based on the test results including test data from independent literature, a unique experimental relation between the liquefaction resistance improvement K_{20} and the compressional wave velocity V_p is proposed regardless of relative density, sample preparation method, effective confining pressure, and fines content.

Keywords: Cyclic triaxial; nearly saturated soils; liquefaction resistance; compressional wave velocity; fines content.



(a) (b)

Fig. 1 Typical dynamic responses of clean sands with different *B*-values: (a) EPWP ratio against number of cycles; (b) axial strain against number of cycles

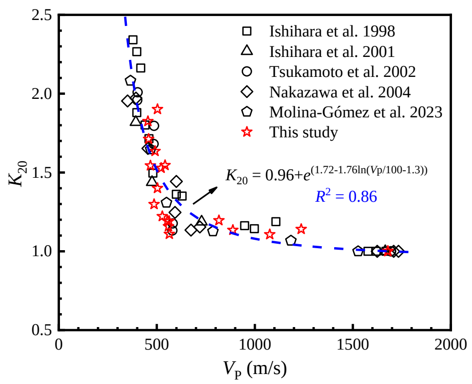


Fig. 2 Universal K_{20}-V_p relationship

EVALUATION OF FABRIC FORMATION OF SAND USING ANISOTROPY OF MAGNETIC SUSCEPTIBILITY

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ABSTRACT

It is well known that fabric of sand may significantly affect mechanical behaviors and liquefaction resistance of sand. Various optical techniques are currently utilized to visualize the fabric, especially the distribution of the long axis of soil particles. However, none of these methods provides an ideal solution in laboratory tests and in situ observation. In this study, anisotropy of magnetic susceptibility (AMS) was first proposed as a convenient and efficient way to evaluate the liquefaction of clean sand. At first, investigations with scanning electron microscopy (SEM) and AMS were simultaneously conducted on two groups of soil specimens with different initial fabrics to verify the feasibility of the AMS technique. Then, 80 in situ samples were collected to analyze the feature of liquefied and non-liquefied sand layers through AMS tests. It is clearly known from the test results that the natural sedimentary fabric was destroyed during liquefaction and the fabric anisotropy was greatly changed after liquefaction. The feasibility of evaluating soil fabric using the AMS survey was verified by the laboratory tests. Furthermore, the applicability of AMS in detecting liquefied layer in situ was confirmed for the first time.

Keywords: sand liquefaction; soil fabric; anisotropy of magnetic susceptibility; geotechnical seismic engineering

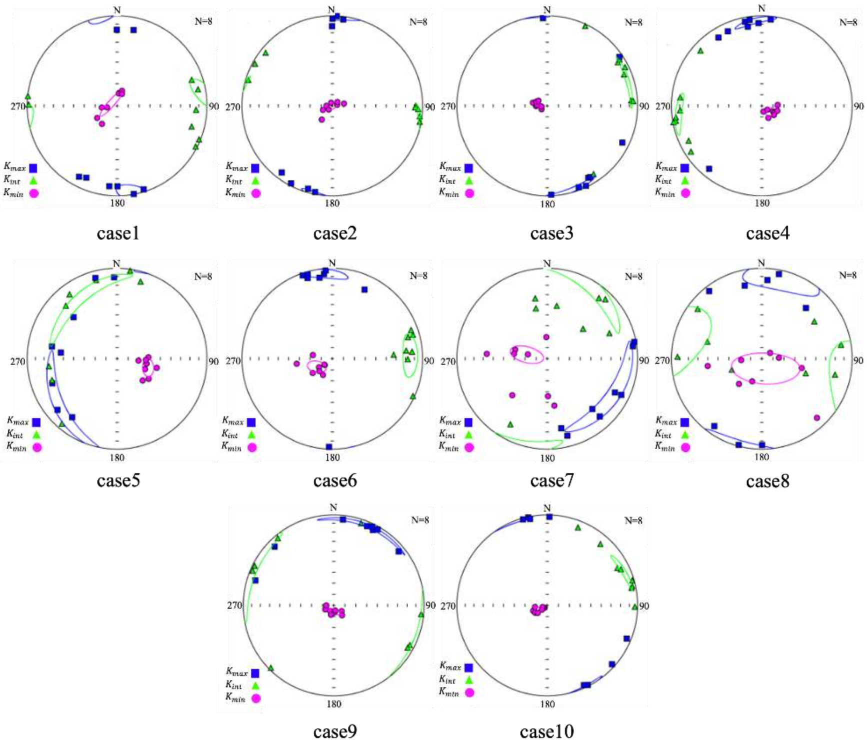

Fig. 1 Equal area lower hemisphere projections of the principal eigenvectors of in situ specimens by AMS survey

MONOTONIC AND CYCLIC BEHAVIOR OF SILTY SAND WITH A CONSTANT STATE PARAMETER: A DEM INVESTIGATION

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ABSTRACT

Field observations in sedimentation and erosion-prone areas indicate that most natural sand deposits may contain a certain amount of non-plastic fines and are often under anisotropic stress conditions. A series of constant-volume triaxial tests were simulated using the particle flow program PFC3D to understand the impact of anisotropic consolidation on undrained shear behavior of clean and silty sand. The simulation results indicate that the state parameter ψ is a superior predictor for characterizing the responses of sand-fines mixtures compared to the global void ratio and relative density. A comparison of the behavior of clean and silty sand with a constant value of ψ (=-0.025) confirms that the sample with 10% fines content exhibits comparably higher monotonic and cyclic shear resistance, irrespective of the consolidation conditions. The evolution of two microscopic quantities, i.e., the fabric norm (F) and coordination number (Z_m), were also explored. It is shown that the critical state locus in the Z_m plane is non-unique, which exhibits a declining tendency as the fines content increases up to 10%. Furthermore, under identical cyclic shear conditions, the anisotropic consolidation typically leads to a larger Z_m variatation and also an increase in the cyclic liquefaction resistance.

Keywords: silty sand; state parameter; anisotropic consolidation; shear resistance; coordination number

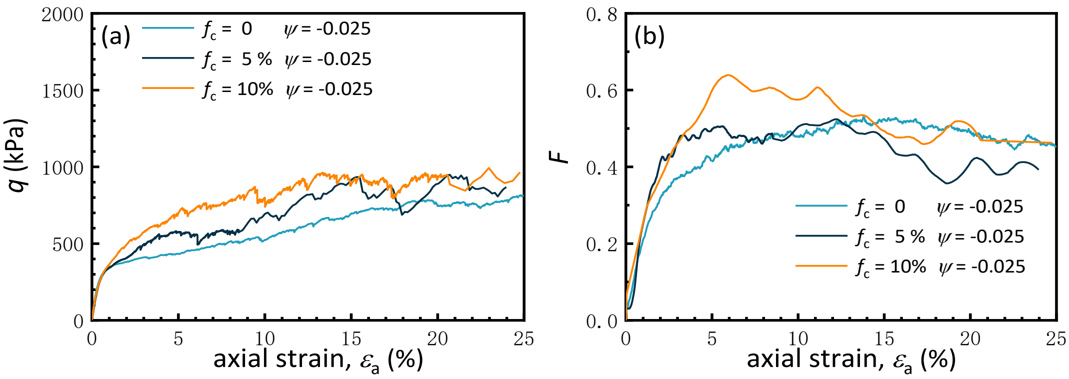

Fig. 1 Monotonic response of samples with a constant ψ: (a) stress-strain curve; (b) fabric evolution

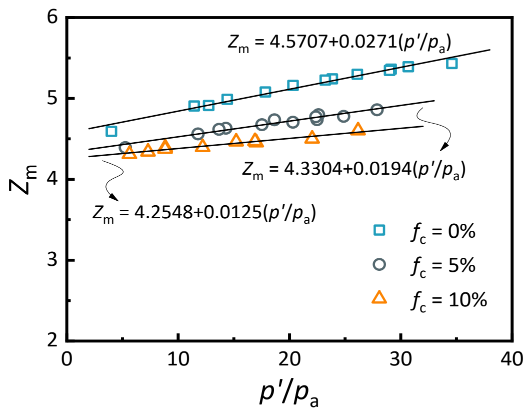

Fig. 2 Critical state locus in Z_m-p'/p_a space

COMPRESSION BEHAVIOR OF CLAYEY SOILS WITH INITIAL HIGH WATER CONTENTS

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ABSTRACT

The compression behavior of very soft soils is of great importance for finite strain consolidation analysis. However, limited investigations of the compression features were reported. In this study, a modified apparatus based on the standard oedometer cell is designed firstly by incorporating a slight plexiglass cap, adding a fixed pulley and the weight tray, and replacing the traditional displacement measurement device using the non-contact laser displacement sensor. The enhanced oedometer apparatus was utilized to perform oedometer tests on two kinds of clayey soils. A minimum vertical stress of 0.025 kPa is applied on the soils, with a maximum initial water content of over eight times the liquid limit. The compression curve features and the effect of initial water content on the compression indexes were then discussed. The test results show that initial water content has great influence on the compression and creep parameters, e.g., C_c, Cs, and C_α. The compression curves of kaolinite clay with high initial water contents indicate that the C_c is changing with the effective stress increasing. Finally, a non-linear compression function with a compression limit that can capture the compression characteristics of soft soils better than the function with a constant compression index was proposed and verified.

Keywords: very soft soils; compression behaviour; improved oedometer apparatus; small stress; compression limit

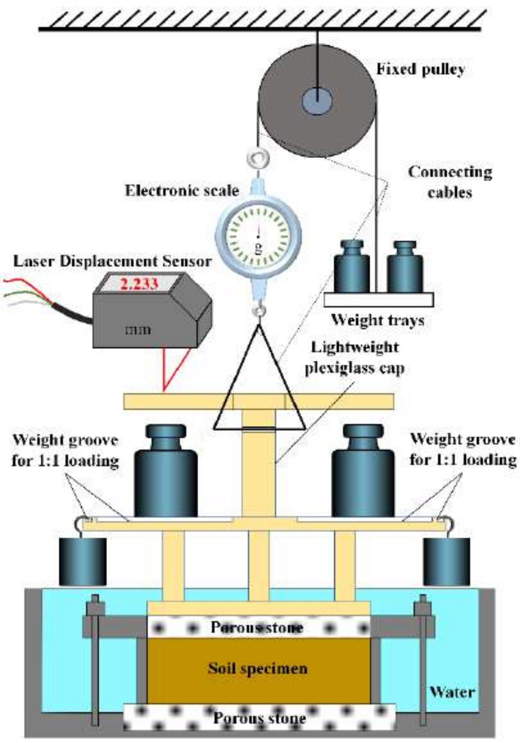

Fig. 1 Modified small stress oedometer system

DEFORMATION TRANSFER MECHANISM BETWEEN OVERLYING SOIL LAYER AND TUNNELS UNDER REVERSE FAULT ACTION

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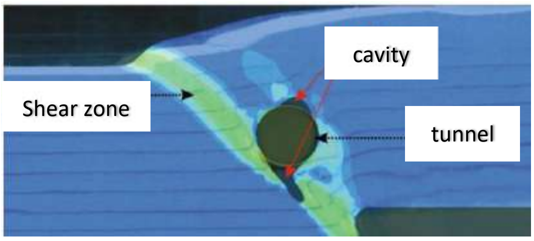
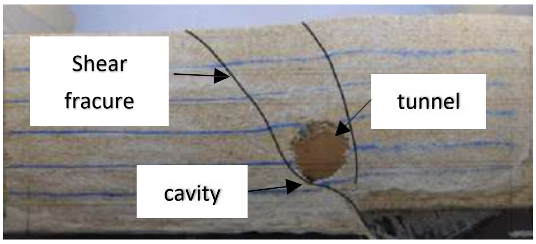
ABSTRACT

An overlying soil tunnel model experiment with the ratio of 1:80 was carried out under the action of reverse fault displacement. The whole process of shear fracture of overlying soil caused by the action of 60°r everse fault is measured by non-contact whole-field measurement of DIC technology. From the aspect of the interaction between the overlying soil layer and the tunnel, shear fracture propagation of overlying soil, the deformation of the overlying soil and the surface deformation are analyzed, respectively. The deformation transfer mechanism is investigated between the overlying soil layer and the tunnel. Compared with the free field test results, it is shown that, the shear fracture path of the overlying soil is offset around the tunnel when the overburden meets the rigid tunnel during shear fracture from the bottom to the top. The tunnel cannot only produce bifurcation of the overburden and affect the fracture path, but also can spread the shear deformation to a wider area and produce a wider range of scarps on the ground surface. In addition, due to the difference of mechanical properties between the overlying soil layer and the tunnel, the two cannot deform synchronously under the action of reverse fault. During the fault dislocation, the soil around the tunnel will appear void, which is unfavorable to the seismic resistance of the tunnel, especially when seismic vibration occurs simultaneously.

Keywords: Tunnel in fault area; Fault dislocation; Soil-structure interaction; DIC technique.





(a) Numerical simulation (b) model test

Fig. 1 Comparison and verification of model test and numerical simulation

ISOLATION MECHANISM OF A SUBWAY STATION STRUCTURE WITH FLEXIBLE DEVICES: AN EXPERIMENTAL RESEARCH

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[#]*Corresponding author; Underline denotes the presenter*

ABSTRACT

Good robustness and recoverability under earthquake are the basic requirements for earthquake-resilient underground structures. The installation of flexible isolation devices at the end of columns is considered an effective means to improve the resilience of underground space structures due to its ability to centralize deformation during seismic action and its easy and fast replacement after seismic action. However, current research only focuses on theoretical and numerical aspects, lacking experimental research. In view of this, we conducted a series of large-scale shaking-table model tests for subway station structures with flexible isolation devices installed at the column ends (Fig. 1). By comparing the dynamic response of structural models with or without mini natural rubber bearings (Mini-NRBs) (Fig. 2), the isolation mechanism and effectiveness of Mini-NRB on the station model were studied. Experimental data, real-time monitoring images, and ultimate structural seismic damage all indicate that Mini-NRB shares most of the lateral deformation of the column under a series of near-field strong ground motions, so that the column is no longer a vulnerable spot in the subway station structure. This series of tests confirms that installing flexible isolation devices at the column end significantly improves the structural robustness of the subway station structure.

Keywords: Earthquake-resilient underground structures, Shaking-table test, Isolation mechanism.

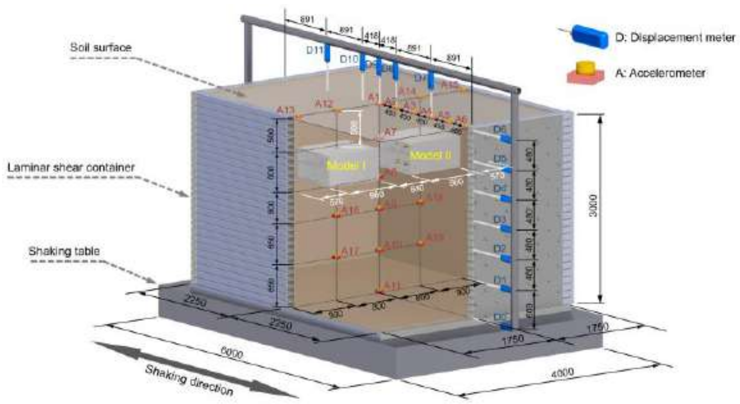

Fig. 1 Illustration of the proposed method

(a) Physical diagram of two model structures (b) Inside scene of Model II

Fig. 2 Deviatoric stress evolution

STUDY OF THE TOPOGRAPHIC EFFECTS OF CIRCULAR ARC VALLEY: 1-G SHAKING TABLE TESTS

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ABSTRACT

As a typical local irregular topographic, valley can change the seismic properties within the local site, which has been confirmed by numerous ground shaking observations and earthquake damage records. However, current knowledge on the site effects of the valley is focused on analytical or numerical methods, and lack of the experimental data from physical models. In this paper, a physical model test method based on 1-g shaking table for arc-shaped valley topography is proposed, and a series of shaking table test were carried out. Three sets of circular valley topography with depth-to-width ratios of 1/8, 1/4, and 1/3 were designed for the experiment, the free-field test under the flat field was used as a benchmark to compare the topographic effects of the valley site, and the effects of different topographic conditions on the valley effect were investigated. Results show that the dynamic response on the surface of model soil exhibits strong spatial variability due to the impact of the local valley topography. The acceleration response and the Arias intensity amplification factor within the valley gradually increases from the valley bottom to the valley top, and the amplification effect of the valley topography gradually increases with the increase of depth-to-width ratio.

Keywords: shaking table test; valley topography; site effect; acceleration response； arias intensity.

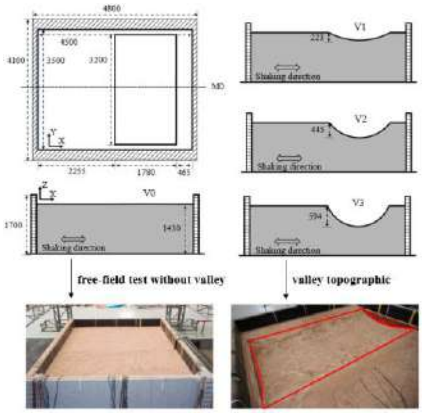

Fig. 1 Model site configuration.

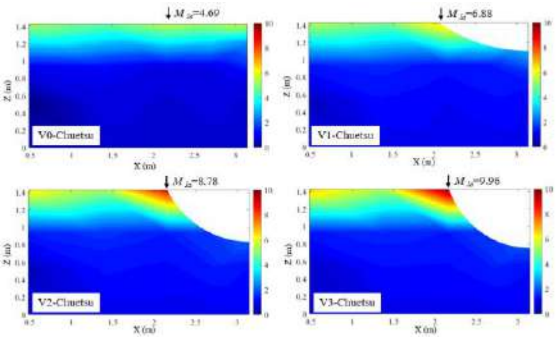

Fig. 2 Distribution of Arias intensity amplification factor for the valley with different depth-to-width ratios under the Chuetsu record

SEISMIC DAMAGE OBSERVATION AND INVESTIGATION OF DALIANG TUNNEL UNDER THE 2022 MENYUAN EARTHQUAKE

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ABSTRACT

This study investigated the seismic damage of the Daliang tunnel suffered from the M6.9 2022 Menyuan Earthquake, which crosses the active fault , Lenglongling Fault, in Qinghai Province, China. We conducted a field investigation, assessed the seismic damage of the Daliang tunnel and summarized the damage patterns. The main findings are: (1) The earthquake damage of Daliang tunnel can be classified into four categories: dislocation and collapse of lining, cracks, spalling, and track bed uplift. The damage is mainly concentrated in the fault fracture zone and its affected area. (2) The earthquake damage is mainly caused by the combination of ground shaking and fault dislocation, with the latter being the dominant affected factor. (3) The earthquake damage degrees of different tunnel segments vary greatly depending on their distance from fault or their earthquake intensity region. (4) Different design methods should be used for different tunnel segments according to their seismic risk level. This study provides new insights into the characteristics and mechanism of tunnel damage crossing active fault, and suggests new seismic fortification measures for tunnel design.

Keywords: the 2022 Menyuan Earthquake, the Daliang tunnel, active fault, seismic damage observation, aseismic design.

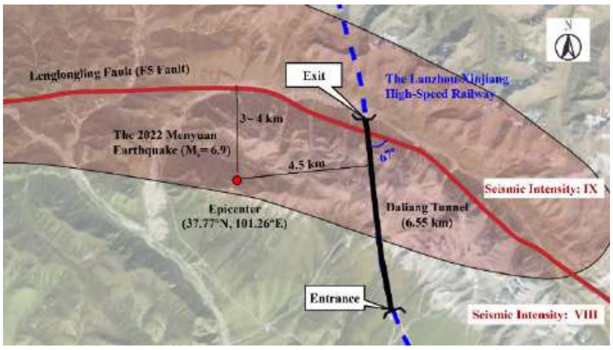

Fig. 1 Location of Daliang tunnel and epicenter.

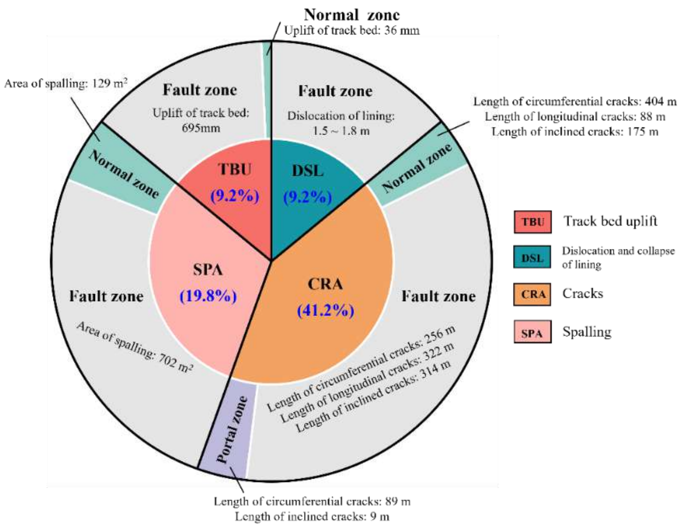

Fig. 2 Distribution of seismic damage in different zones.

Seismic effects on reinforcement load of geosynthetic-reinforced soil walls in multitiered configuration

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ABSTRACT

Current design guidelines for the stability design of tiered geosynthetic-reinforced soil (GRS) walls are empirical and are constrained to static conditions. A modified limit equilibrium (LE)-based top-down procedure is employed to conduct pseudo-static analyses on multitiered GRS walls with battered facings. For the given wall specifications and horizontal seismic acceleration coefficient, the distribution of required tensile force along each reinforcement layer is computed, while considering the limitation posed by the rear end pullout resistance. By adjusting the front end pullout, the required connection load at the facing for each reinforcement layer is established. Parametric studies are carried out to explore the impacts of wall geometry (wall batter, tier height and offset distance), reinforcement layout (length and spacing), internal friction angle of soil and horizontal seismic acceleration coefficient on the maximum required tensile force and the connection load. Results show that the difference in maximum required tensile force between upper and lower tiers escalates with higher seismic forces. Increased seismic activity leads to higher connection loads, particularly when the tier height ratio deviates from 1.0. Assuming sufficiently long reinforcements, the critical offset distance is determined for various design parameters and seismic coefficients.

Keywords: Geosynthetic-reinforced soil wall; Earthquakes; Multitiered configuration; Limit equilibrium.

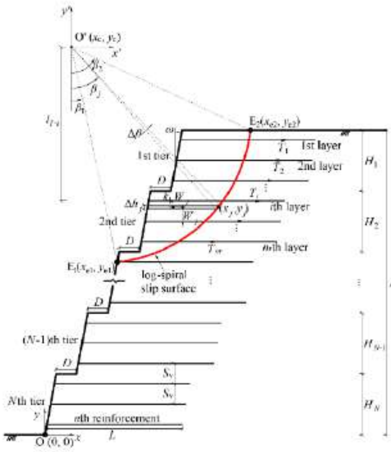

Fig. 1 Notation and convention for seismic stability analysis of multitiered GRS walls.

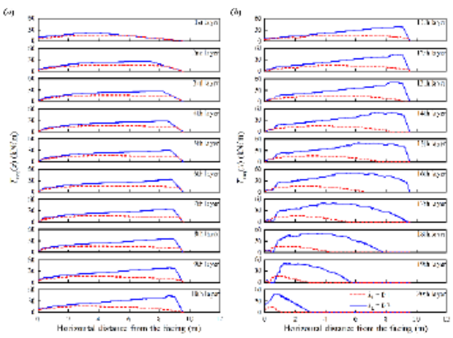

Fig. 2 Distribution of required tensile force along each reinforcement layer.

THE LIQUEFACTION POTENTIAL OF SILTY SANDS EVALUATED USING AN ENERGY-BASED PERSPECTIVE

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ABSTRACT

Evaluation of the liquefaction resistance of soils is one of the fundamental steps in geotechnical earthquake engineering. The energy-based liquefaction evaluation procedure is based on the correlation between the pore pressure generation and the strain energy dissipated into the soil. It does not need to convert the irregular seismic loading to uniform cyclic stress compared with the conventional simplified procedure of liquefaction evaluation. This study presents typical experimental results of silty sands, and the liquefaction potential, together with the pore pressure generation characteristics, are evaluated using the energy-based approach.

Keywords: Liquefaction, silty sand, pore pressure, energy-based approach

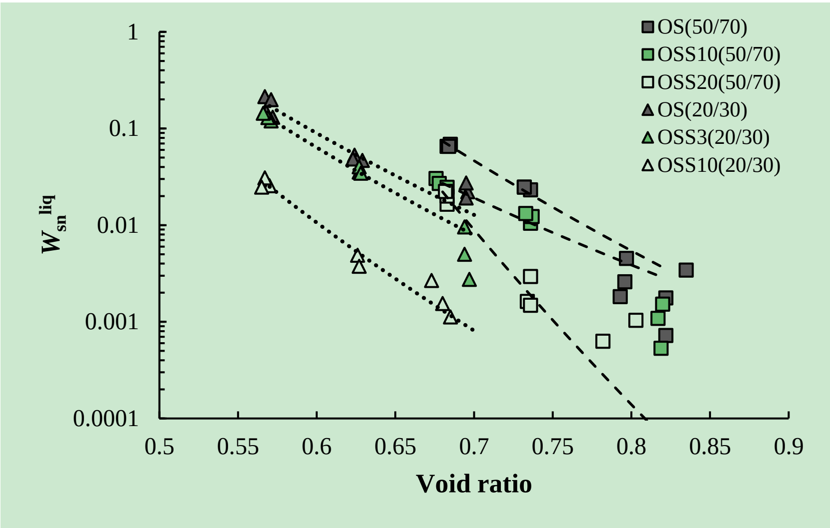

Fig. 1 Liquefaction potential of the tested materials

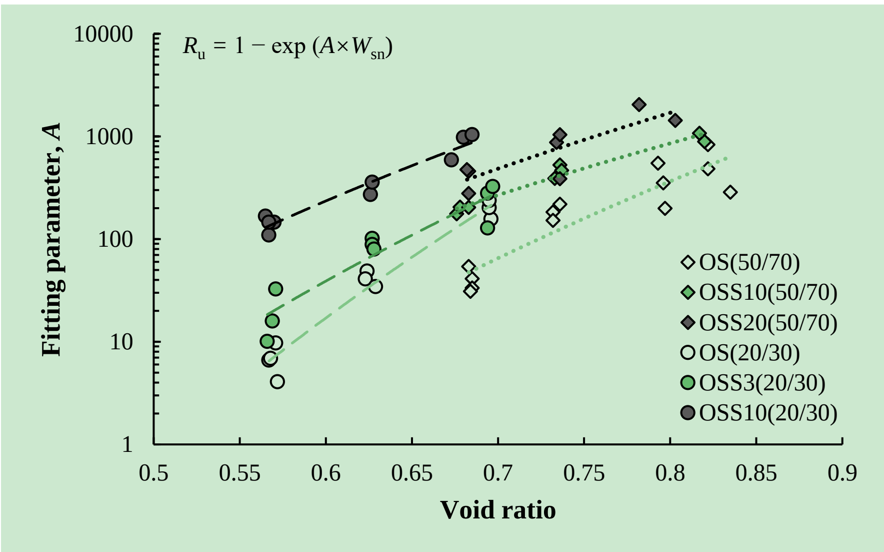

Fig. 2 Pore pressure generation parameter

USE OF WICKING GEOTEXTILE TO DEHYDRATE ROAD EMBANKMENT UNDER UNSATURATED CONDITIONS

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ABSTRACT

When an infrastructure is built, for example, a pavement structure, it is often built with soils compacted at their optimum moisture contents. The surface soils are exposed to the surrounding atmospheric environment with relative humidity of less than 90%. Such a relative humidity corresponds to a suction value of 14 MPa. All soils become air-dry under such high suction and have very low permeability (nearly impermeable) to transport water from inside to outside. In the meantime, the soils inside the pavement structure tend to reach equilibrium with the ground water table through capillary rise. When surface soils are air-dry and have cracks, they have high permeability for water infiltration. As a result, the soils inside the pavement structure are often wet or have tendency to become wet with time. Increase in soil moisture content often means deteriorating performance. Research indicates when moisture contents of the soil increase from 3.3% to 6%, the resilient moduli for Alaska D-1 materials are at least reduced 50%. Therefore keeping moisture content low in the pavement structure is very important for pavement performance.Conventional drainage system relies on gravity to drain water out of soils, which cannot help prevent the above scenarios from happening. A new type of wicking geotextile is recently developed to drain the water under unsaturated conditions and potentially maintain good performance. By installing a layer of wicking fabric in the pavement, the water in the pavement structure can be transported along the wicking fabric to the shoulder and vaporized to the surrounding atmosphere which has much higher suction. It is likely to generate a relatively dry zone in the pavement structure which not only can help improve pavement structure, but also help prevent the frost heave and subsequent thaw-weakening in cold regions. This presentation discusses the applications of the wicking fabric to prevent the frost heave and thaw-weakening (as shown in Figure 1) as well as pumping in concrete pavements (as shown in Figure 2) by dehydrating the water in the pavement structure under unsaturated conditions. The results indicated that by removing the capillary water inside the pavement structure, the performance of the road has been significantly improved.

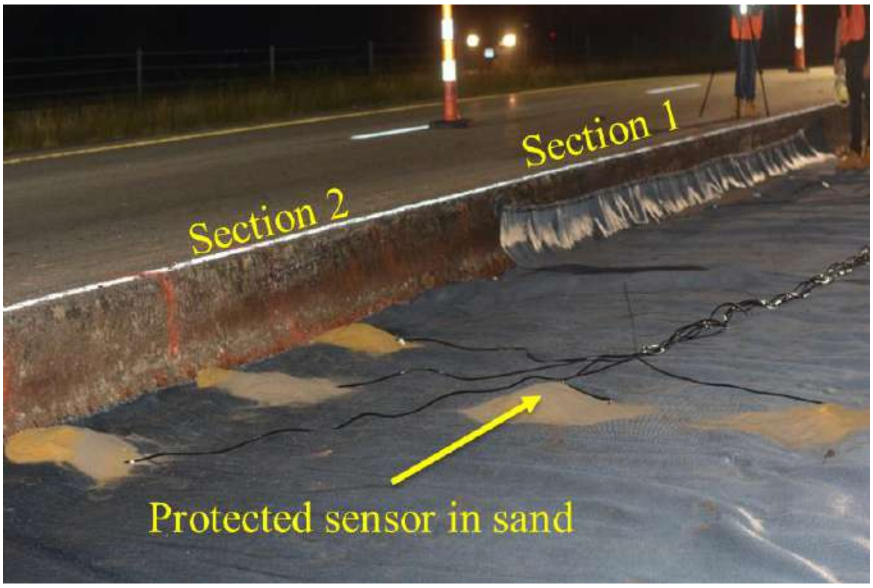

Fig. 1 Installation of Wicking Geotextile to Mitigate Pumping at I44 in Missouri

A STUDY OF THE 2022 MENYUAN 6.9 MAGNITUDE EARTHQUAKE'S DYNAMIC RUPTURE CHARACTERISTICS AND THE CAUSES OF SIGNIFICANT SURFACE FAULTING

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ABSTRACT

In 2022, a magnitude 6.9 earthquake occurred in Menyuan, Qinghai Province, China, with a maximum surface fault displacement of up to 3.7 meters. One of the primary explanations for this event is that the earthquake's source rupture occurred at a relatively shallow depth. However, the physical mechanisms responsible for the significant surface faulting remain unclear. To uncover the seismic rupture dynamics of this earthquake, a numerical analysis model of strong near-fault ground motion was constructed by integrating data on surface fault displacement and records from nearby strong earthquakes. The validity of the model was confirmed through a comparison between the numerical simulation results and observed data. The research findings indicate that the presence of fault damage zones favors the occurrence of surface faulting and facilitates the propagation of seismic rupture, resulting in larger fault displacements at the surface. This promoting effect primarily arises from the interaction between the free surface or low-velocity layer interfaces and the seismic rupture. Faults with lower roughness are more prone to causing surface faulting, featuring larger rupture areas and reduced stress drop. The study also discusses the potential occurrence of different types of mechanisms, offering possible physical explanations for the surface faulting observed in the Menyuan earthquake.

Keywords: earthquake dynamic rupture; surface breaking earthquake; fault displacement; earthquake hazard analysis; numerical modelling

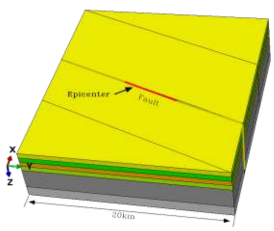

Fig. 1 geometric model

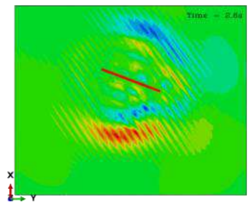

Fig. 2 Seismic wave field snapshot