Proceedings of

The 25th Annual Conference of HKSTAM 2022
The 17th Jiangsu – Hong Kong Forum on Mechanics and Its Application

April 23, 2022

Hong Kong University of Science and Technology, Hong Kong

Editors

Hui TANG and Gang WANG

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PREFACE

The 25th Annual Conference of HKSTAM 2022 in conjunction with the 17th Jiangsu–Hong Kong Forum on Mechanics and Its Application is held online on April 23, 2022. This conference is co-organized by The Hong Kong Society of Theoretical and Applied Mechanics (HKSTAM), The Jiangsu Society of Theoretical and Applied Mechanics (JSTAM), The Hong Kong University of Science and Technology (HKUST), The Hong Kong Polytechnic University (PolyU). The conference aims to provide a platform for all scientists, engineers, and mathematicians working on mechanics and related areas to share, communicate and exchange ideas, and to enhance co-operations within relevant parties. This proceeding consists of 5 Distinguish Lectures by Prof. Jidong ZHAO from The Hong Kong University of Science and Technology, Prof. Maosen CAO from Hohai University, Prof. Yuan LIN from The University of Hong Kong, Prof. Yulong HAN from Nanjing University of Aeronautics and Astronautics, and Prof. Hui TANG from The Hong Kong Polytechnic University. The conference also contains 51 extended abstracts in 10 parallel sessions. These presentations are delivered by nine students and faculty from JSTAM; one from overseas; six research students from University of Macau; thirty-two by research students, and three by faculty and research staff from universities in Hong Kong. These student presenters enter into the completion of "Best Presentation Student Award".

The Society appreciates all the speakers and contributors for their efforts to make this event a successful one. Special thanks go to Ms. Xuan Wu of JSTAM for her great help in organizing conference; Dr. Zhaokun Wang of PolyU for his help in communicating with various parties. The Society also wishes to thank the generous support from Institution Members of HKSTAM.

On behalf of and for the Executive Committee

Gang WANG
President of HKSTAM
Professor and Associate Head
Department of Civil and Environmental Engineering
Hong Kong University of Science and Technology

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Conference Program

April 23, 2022 Saturday, Morning

Plenary	https://hkust.zoom.us/j/93465497313?pwd=YmlvSko0V3ZoenBydElXNHdEMEhxQT09 Zoom Meeting ID: 934 6549 7313 Passcode: HKSTAM2022
9:00 – 9:15am	**Opening address** **MC: Prof. Hui Tang, Secretary of HKSTAM** **Prof. Gang WANG (王剛)** **President of HKSTAM 香港力學學會理事長** **Prof. Qinsheng BI (畢勤勝)** **Vice President of JSTAM 江蘇省力學學會副理事長**
9:15 – 9:45am	**Distinguished Lecture I** **Chair: Prof. Qinsheng Bi, Vice President of JSTAM** **Prof. Jidong Zhao (趙吉東)** Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology (HKUST) “Multiscale, Multiphysics Modeling of Granular Materials”
9:45 – 10:15am	**Distinguished Lecture II** **Chair: Gang Wang, President of HKSTAM** **Prof. Maosen Cao (曹茂森)** Department of Engineering Mechanics, Hohai University “Mechanics-activated Data Processing for Structural Health Monitoring”

10:15 – 10:30am	**Online photo taking and break**
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	Department of Mechanical Engineering, The University of Hong Kong "Plastic Response of Cells: From Embryo Development to Disease Detection"
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11:30am – 12:00pm	**Distinguished Lecture V** **Chair: Prof. Jun Yang, Vice President of HKSTAM** **Prof. Hui Tang (唐輝)** Department of Mechanical Engineering, The Hong Kong Polytechnic University "Machine Learning Guided Active Flow Control"
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4:35 – 4:50pm	**Closing Ceremony and Award Presentation**	Meeting ID: 915 7745 8847 Passcode: HKSTAM2022
5:00 – 5:30pm	**HKSTAM Annual General Meeting**	Attendees: Representatives of all Institution Members and all Full HKSTAM members

~ Closure of the conference ~

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Session B1, B2 https://hkust.zoom.us/j/93596903128?pwd=UGtOR1FyRHBqazBPaEQrN2RQNnNudz09	Meeting ID: 935 9690 3128 Passcode: HKSTAM2022
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Session E1, E2 https://polyu.zoom.us/j/93520853974?pwd=MnlDZURQYkF5NUhoNEVBSVlOTThoQT09	Meeting ID: 935 2085 3974 Passcode: HKSTAM2022
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Distinguished Lectures

Distinguished Lecture I

Prof. Jidong ZHAO (趙吉東)

The Hong Kong University of Science and Technology

Dr. Jidong Zhao is Professor in Computational Geomechanics of Department of Civil and Environmental Engineering at HKUST and Chang Jiang Scholar Chair Professor of Ministry of Education, China (2021-2024). He earned both is bachelor’s degree and Ph.D. from Tsinghua University, China. He serves as co-editor for Computers and Geotechnics (Elsevier), editor for Granular Matter (Springer Nature), and associate editor for Journal of Engineering Mechanics (ASCE). Dr. Zhao’s research has been focused on developing advanced computational methodologies to capture and understand the multiscale, multiphysics nature of granular media relevant to their engineering and industrial performance in civil, geotechnical, mining, chemical engineering, energy extraction and carbon sequestration, pharmaceutical industry, and powder technology.

Multiscale, multiphysics modeling of granular materials

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Granular media are ubiquitous on the earth and closely related to our daily life. They are the second most processed materials (next to water) in the world. Granular media are typical porous, discrete media and exhibit intricate behaviours of both solids and fluids across multiple temporal and length scales depending on the loading conditions and specific applications. Understanding of the multiscale mechanics and multiphysics of granular media plays a pivotal role for a wide range engineering and industrial applications. This talk introduces the latest advances in computational multiscale modelling of granular media that potentially push for a paradigm shift on the modeling and understanding of granular media as an engineering science. We demonstrate that a granular material in a typical engineering setting can be rigorously and effectively simulated by a general-purpose continuum-discrete coupling framework which combines the advantages and strengths of both conventional continuum modelling approaches and purely discrete-based numerical methods (Guo & Zhao, 2014, 2016; Liang & Zhao, 2019; Zhao et al., 2020). It helps avoid the necessity of assuming continuum phenomenological constitutive models in conventional continuum analysis, while providing straightforward cross-scale links of key granular responses and phenomena in an engineering scale, including strain localization, liquefaction, large deformation, and failure. The framework is highly adaptable to include latest developments in both continuum and discrete modelling approaches for enrichments, including consideration of complex grain shape, grain crushing, particle-fluid interactions which can find wide, important engineering relevance in civil, mining, chemical, coastal and offshore engineering, agriculture and pharmaceutical industry. The talk will cover developments of prevailing computational methods such as finite element method (FEM), material point method (MPM), discrete element method (DEM), nonlinear contact dynamics (NLCD) and physics engine (PE).

Acknowledgements

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Zhao, S. W., Zhao, J. D. & Lai, Y. M. (2020), "Multiscale Modeling of Thermo-mechanical Responses of Granular Materials: A Hierarchical Continuum-discrete Coupling Approach," *Computer Methods in Applied Mechanics and Engineering*. **367**, 113100.

Distinguished Lecture II

Prof. Maosen CAO (曹茂森)

Hohai University

Dr Maosen Cao is a full professor at Hohai University, PRC. His specific areas of interest relate to structural integrity assessment, health monitoring, damage modeling and identification, and multiscale vibration and dynamics. He is currently director of the Institute of Engineering Vibration and Dynamics of the University; deputy dean of the Co-Innovation Centre of Safety and Health S&T on Civil Infrastructures of Jiangsu Province; principal of Jiangsu provincial outstanding S&T Innovation Team in Structural Integrity and Safety; standing director of the Chinese Society of Health Monitoring and Risk Warning of Equipment & Structure. He has conducted research for six years at Washington State University, the Hong Kong Polytechnic University, and the Polish Academy of Sciences. He is the author/co-author of 150 papers, including over 120 papers in international journals such as SHM, JSV, MSSP, SMS, IJSS, and APL, with 1500+ citations in Web of Science. He has successfully secured research grants in the capacity of principal investigator from various government agencies, e.g., 4 NSF projects from the National Science Foundation Committee in China and 16 International Cooperative Research Projects. He is Deputy Secretary General and Director of Academic Work Committee of Jiangsu Society of Theoretical and Applied Mechanics, and Editor-in-Chief of the journal of Structural Durability & Health Monitoring.

Mechanics-activated data processing for structural health monitoring

Maosen CAO[1, #] and Huaxin ZHU[2]
[1]Department of Engineering Mechanics, Hohai University, Nanjing, China
[2]Jiangsu Zhongji Engineering Technology Research Co., Ltd., Nantong, 226001, China
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Abstract: Structural health monitoring (SHM) is an emerging interdisciplinary that integrates material, structure, mechanics, sensors, and information, etc., and it is of great practical significance to ensure the normal operation, avoid failure, and prolong the service life of the structure. In general, the SHM involves four components: operational evaluation, data acquisition and cleaning, damage feature extraction, and damage pattern recognition. Currently, it is feasible to acquire structural responses such as deformation, strain, acceleration, displacement, temperature, and humidity, etc., forming a set of monitoring data warehouse. Noticeably, the scientific explanation of measured data is the acknowledged bottleneck that hinders the advance of the SHM. Most existing methods remain in the traditional signal analysis category, not originate from the damage mechanism. These methods cannot effectively reveal the damage information underlying the monitoring data. To address this problem, this study proposes a new perspective: mechanics is the tool to activate the data, mechanics tells us how to extract damage characteristics based on damage mechanism; the combination of data and mechanics is the path to impel the progress of SHM. From this perspective, a group of monitoring algorithms with successful cases of damage monitoring are provided, especially for fatigue and corrosion damage. The results of this study show that the mechanics-activated data processing methods break through the signal analysis category, providing an effective way for developing viable SHM technologies.

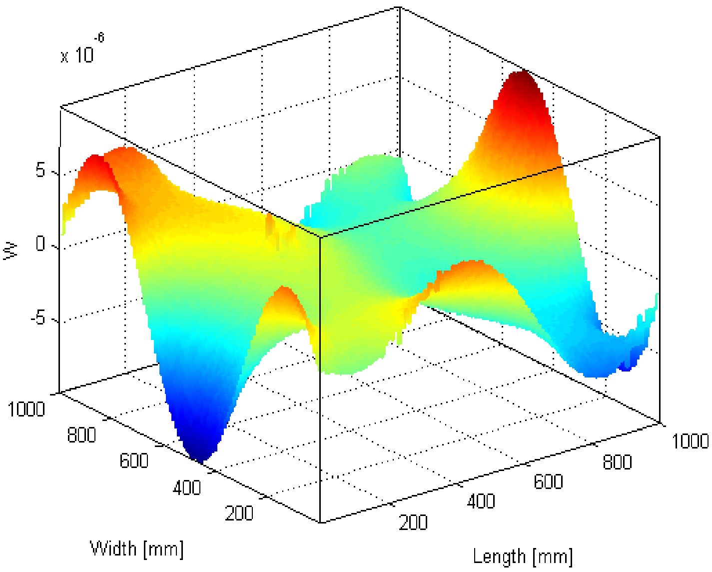

Figure 1. Damage identification using multiscale curvature of the 6th mode of a plate.

Acknowledgements

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Distinguished Lecture III

Prof. Yuan LIN (林原)

The University of Hong Kong

Dr. Yuan Lin received the BS and MS degrees in Engineering Mechanics from Tsinghua University. After that, he obtained a MS degree in Applied Mathematics from Brown University, followed by a Ph.D. degree in Solid Mechanics. Dr. Lin's research interests include cellular and molecular biomechanics, tissue development and morphogenesis, and mechanics of biological materials. His works have been published in places like Science Advances, PNAS and PRL, as well as being selected as journal cover and highlighted articles by Advanced Healthcare Materials, Biophysical Journal and Soft Matter.

Plastic response of cells: from embryo development to disease detection

C. FANG, Z. YAN, X. XIA and Y. LIN*

Department of Mechanical Engineering, The University of Hong Kong, Hong Kong, China

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Living cells need to undergo significant shape changes during processes such as cell division, migration and tissue formation. Therefore, it is commonly believed that the deformability of cells is intimately related to their capability in executing different biological duties as well as the progression of diseases. In this talk, I will discuss how irreversible deformation of cells ensures proper axial extension of embryos during their development and how the plastic response of tumor cells can be used in monitoring the progression of cancer. Specifically, I will show that the presence of active intracellular/intercellular contraction will trigger the severing and re-bundling of actin filaments in cells (leading to cellular anisotropy and plasticity), elevate the internal hydrostatic pressure of embryo and eventually drive its elongation. In particular, the gradual re-alignment of F-actins must be synchronized with the development of intracellular forces for the embryo to elongate, which is then further sustained by muscle contraction-triggered plastic deformation of cells. In addition, I will also introduce a microfluidic setup developed in our lab allowing us to impose precisely controlled cyclic deformation on cells and therefore probe their plastic characteristics. Interestingly, we found that significant plastic strain can accumulate rapidly in highly invasive cancer cell lines and circulating tumor cells (CTCs) from late-stage lung cancer patients with a characteristic time of a few seconds. In comparison, very little irreversible deformation was observed in the less invasive cell lines and CTCs from early-stage lung cancer patients, highlighting the potential of using the plastic response of cells as a novel marker in future cancer prognosis and monitoring.

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Yan, Z., X. Xia, W.C. Cho, D.W. Au, X. Shao, C. Fang, Y. Tian, and Y. Lin (2022), "Rapid Plastic Deformation of Cancer Cells Correlates with High Metastatic Potential," *Advanced Healthcare Materials*. 2101657.

Distinguished Lecture IV

Prof. Yulong HAN (韓玉龍)

Nanjing University of Aeronautics and Astronautics

Prof. Yulong Han received his B.S. (2011) and Ph.D. (2017) in Biomedical Engineering from Xi'an Jiaotong University, followed by a postdoctoral experience in the Department of Mechanical Engineering at MIT until 2022. He is presently a professor in the Department of Mechanics at Nanjing University of Aeronautics and Astronautics; his main focus is on how mechanical properties and biological functions regulate each other in multicellular systems.

Biomechanical imaging of cells, extracellular matrix, and cancer invasion in 3D

Yulong HAN

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Abstract: Control of the structure and function of three-dimensional multicellular tissues depends critically on the spatial and temporal coordination of cellular physical properties, yet the organizational principles that govern these events and their disruption in disease remain poorly understood. Using a multicellular mammary cancer organoid model, we map here the spatial and temporal evolution of positions, motions and physical characteristics of individual cells in three dimensions. Compared with cells in the organoid core, cells at the organoid periphery and the invasive front are found to be systematically softer, larger and more dynamic. These mechanical changes are shown to arise from supracellular fluid flow through gap junctions, the suppression of which delays the transition to an invasive phenotype. These findings highlight the role of spatiotemporal coordination of cellular physical properties in tissue organization and disease progression.

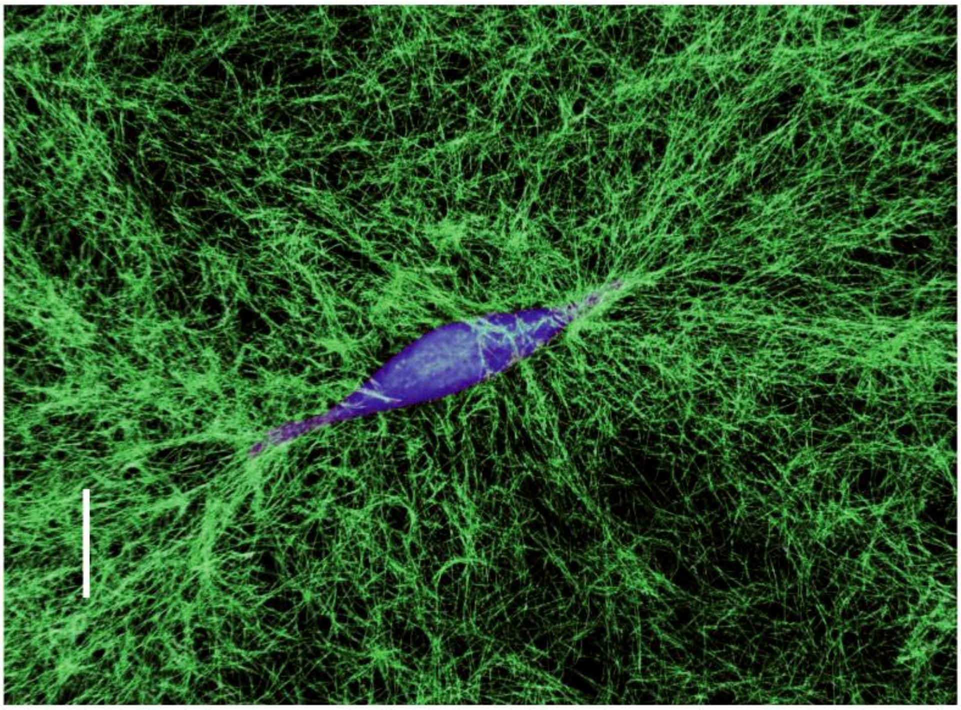

Figure 1. Cell contraction causing stiffness in an extracellular matrix. In blue, the cell; in green, the collagen matrix.

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Distinguished Lecture V

Prof. Hui TANG (唐輝)

The Hong Kong Polytechnic University

Dr. Hui Tang is Associate Professor in Department of Mechanical Engineering, The Hong Kong Polytechnic University (PolyU). He also serves as Associate Head of Department and Director of Research Center for Fluid-Structure Interactions in PolyU. He received his PhD degree in Aeronautical Engineering from University of Manchester, UK. Prior to joining HK PolyU, he worked in Nanyang Technological University, Singapore, and University of Michigan - Ann Arbor, USA. His research interests include aerodynamics/hydrodynamics, active flow control, fluid-structure interaction, and heat and mass transfer. He served as editorial board member and guest editor for several journals including Frontiers in Bioengineering and Biotechnology, Journal of Hydrodynamics, and Actuators. He also served as member of scientific or organizing committees for a number of international conferences/symposiums. He is now the Secretary and Executing Committee Member of Hong Kong Society of Theoretical and Applied Mechanics (HKSTAM).

Machine learning guided active flow control

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Abstract: Active flow control (AFC) is a vibrant branch in fluid mechanics research, which, through injecting a small amount of energy into a flow system, changes the flow behaviour so as to significantly enhance the system's aerodynamic/hydrodynamic performance. Compared to its counterpart, i.e., passive flow control, AFC is adaptive and on-demand, and hence has a much wider operation range. Classical AFC is usually model-based, which requires sufficient knowledge of the dynamics of flow system. However, for complex flow control problems such as turbulence control, there are serious challenges associated with equation-based fluid-dynamics analysis, including high dimensionality, strong nonlinearity and multi temporal-spatial scales, which limit real-time control efforts. To address these challenges, data-driven model-free control may be a vital solution, since fluid dynamics is intrinsically a data-rich field thanks to rapid advances in simulation capability and experimental techniques. To this end, it is believed that the booming machine-learning (ML) techniques can play an important role. In this talk, some recent applications of ML in AFC will be introduced. These applications include the use of generic-programming selected explicit control laws for the blowing/suction enabled control of vortex-induced vibration of a circular cylinder, the use of deep reinforcement learning (DRL) for eliminating the hydrodynamic traces of a circular cylinder using a group of windward-suction-leeward-blowing (WSLB) actuators, and the use of DRL for finding best drag reduction strategies for a fixed circular cylinder. Through these studies, some new and unexpected control strategies have been revealed.

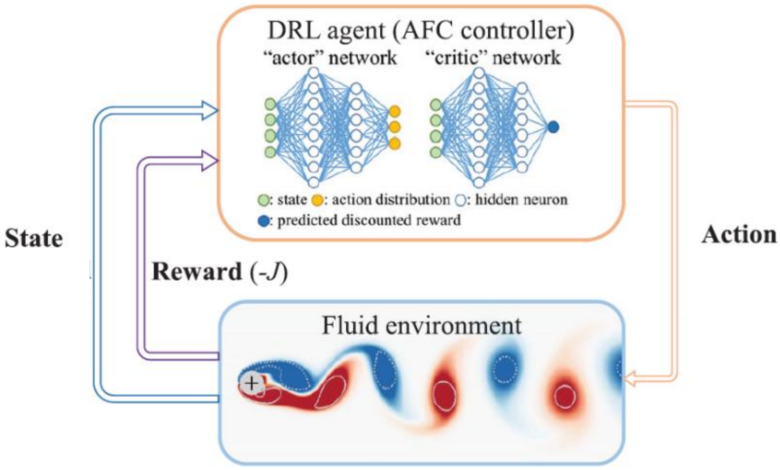

Figure 1. Schematic showing the loop of a typical DRL based AFC (Ren et al. 2021a, 2021b).

Acknowledgements

The author wishes to acknowledge the financial support from the Research Grants Council of Hong Kong under General Research Fund (Project No. 15218421).

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Technical Papers

A nodal fractional step method for incompressible free-surface flow modelling in PFEM

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Abstract: The modelling of free-surface flow and its interaction with structure is a challenge in offshore engineering. On the basis of the Finite Increment Calculus (FIC) for solving incompressible N-S equations, a stabilized fractional step algorithm has been developed by introducing pressure gradient projection. The Particle Finite Element Method (PFEM) with nodal integration is applied on simulation to track the evolving fluid domain. Accuracy and stability of the proposed nodal fractional step method are proved by several benchmark tests involving complex motions via impact on boundaries. The numerical results show the strong ability of this algorithm in solving incompressible free-surface flow and the good application prospects.

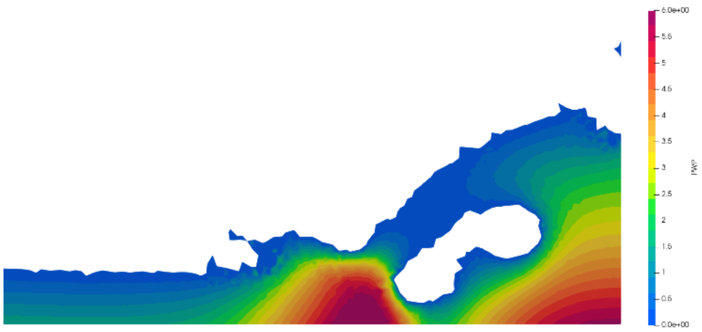

Figure 1. Pressure contour of water dam break after impact.

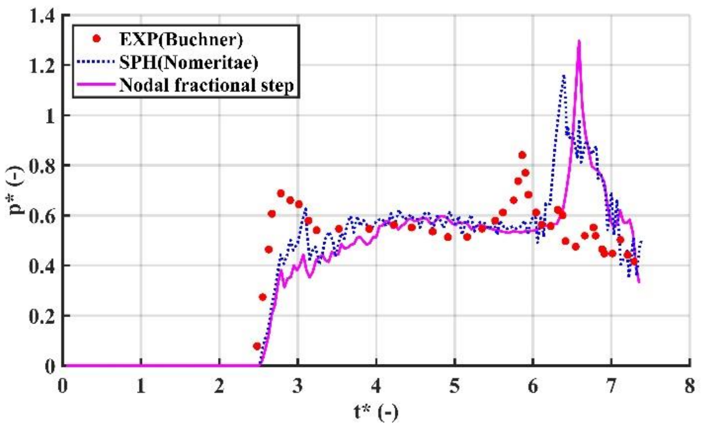

Figure 2. Normalized pressure with time of record point.

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Flow induced vibration of a circular cylinder with an attached splitter plate

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Abstract: In this study, a circular cylinder attached by a rigid splitter plate was tested to study the effects of splitter plate length on the resulting FIV. As schematically illustrated in Fig.1, the tests were conducted in a closed-loop water tunnel with a cylinder model being fixed on an air-bearing system from the top. The cylinder of diameter D=20 mm and length H=430 mm, made of aluminum, can oscillate in the transverse direction, and, if required, can also rotate along its own axis. The total mass of the cylinder and its supporting moving rods over the air bearings is around 9.0 kg, corresponding to a mass ratio m*≈50. A six-component load cell and a time-resolved PIV system were used to measure the relevant kinematics, hydrodynamic forces and flow patterns. A wide range of splitter length was considered, i.e., L/D= 0~3.5, and a range of freestream velocity was applied, corresponding to a range of reduced velocity Ur=1~25 and the Reynolds number ranging in Re = 800~10000. It was revealed from Fig. 2(a) that, as the cylinder only undergoes heaving motion, the peak value of cylinder oscillation amplitude increases and appears at higher reduced velocities with the increase of the splitter length from L/D= 0 to 0.25. When the splitter length further increases, galloping-type oscillations appear. The oscillation is then greatly suppressed when the splitter length approaches L/D=1.0. Once the rotation is allowed for the cylinder, i.e., the system has both the heaving and pitching motions, the FIV amplitude obviously changes, as shown in Fig. 2(b) and 2(c). The amplitude Arms is significantly reduced at L/D = 0, 0.125 and 0.25 compared with the heaving only cases, almost completely suppressed at L/D = 0.5, 0.75 and 1.0, and has a sharp increase at L/D = 2.0 and 2.5 when Ur > 11.5. These results indicate that the splitter length plays an important role in the system dynamics and is associated with rich physics. More details will be revealed and discussed in our talk, including the time-, phase-averaged information and simulation results to explain the Arms variations.

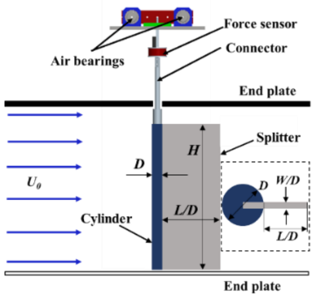

Figure 1 Schematic of the test rig installed in a closed-loop water tunnel.

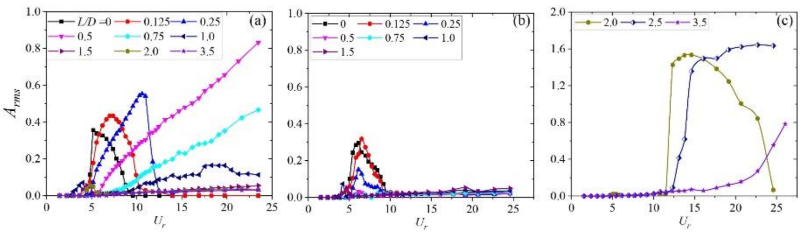

Figure 2 rms of the amplitude A_{rms} of a circular cylinder with an attached splitter plate versus reduced velocity U_r: (a) heaving motion only; (b)&(c) coupled heaving and pitching motions.

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Influence on oil characteristic of hydro-viscous drive with consideration of inlet velocity

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Abstract: During the process of hydro-viscous drive, a large amount of frictional heat is generated due to viscous dissipation and also as a result of interaction of surfaces. Then elastic or even plastic deformation, and the viscosity of the oil film between the deformed disks will eventually lead to the failure of hydro-viscous drive. In this paper, the dynamic elastoplastic deformation of the disks and the viscosity-temperature characteristics of the oil film are comprehensively considered. Numerical simulation model was established by using computational fluid dynamics (CFD). The influence of inlet velocity on the oil characteristics of hydro-viscous drive is analyzed. The results show that large amount of frictional heat due to velocity difference leads to thermal elastoplastic deformation of the disks, which then results in complicated evolution about the fluid field. Furthermore, different forms of source-shaped warping deformation occur when either the inner radius or the outer radius is constrainted. And the influences of inlet velocity on dynamic parameters, such as pressure, temperature, velocity and hydrodynamic torque are considered. Finally as the oil film between the disks becomes thinner, the decrease of frictional heat leads to the reduction of the rotational angle. So the influences of the inlet velocity can be ignored.

Keywords: hydro-viscous drive; inlet velocity; oil film dynamics; deformed disk.

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Numerical investigation of the coastal macro-vortices dynamics in Hong Kong waters

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Abstract: Hong Kong (HK) is located downstream of the Pearl River Estuary (PRE), acting as a bridge between the PRE and the South China Sea (SCS). Pearl river discharge, tidal currents from the SCS, and Ekman currents generated by monsoon wind are mixing in the PRE and HK waters, resulting in complex flow patterns and estuarine circulation. The Finite-Volume Coastal Ocean Model (FVCOM) (Chen et al., 2003) was used to simulate the coastal circulation and the interaction of oceanic currents with coastlines around the HK waters. The role of tidal currents and monsoon wind were analyzed by comparing with simulations without wind or tide forcing. Macro-vortices were identified using vorticity and the Okubo-Weiss parameter. Results showed that monsoon wind dominated the southeast area of HK and generated vortex streets in the wind direction, whereas the tidal currents dominated in the north part where massive tidal vortices were periodically developed, transferred, and dispersed around narrow channels, islands, and headlands.

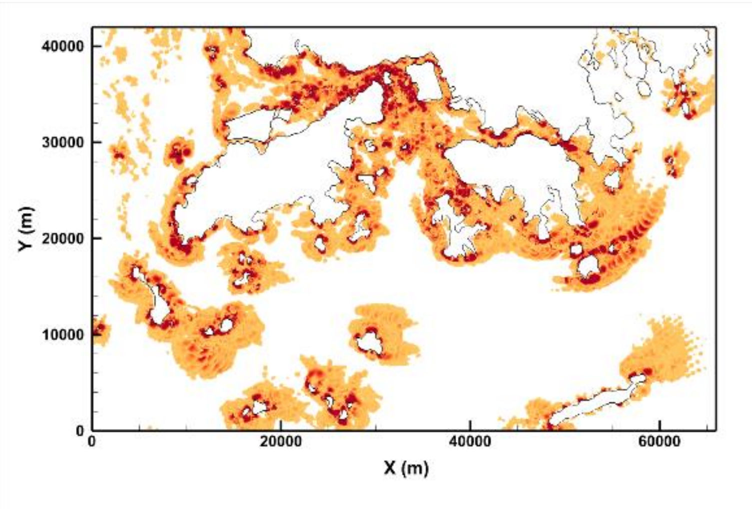

Figure 1. The density map of the coastal macro-vortices in Hong Kong waters.

Acknowledgments

This work is supported by the Research Impact Fund of the Research Grants Council of Hong Kong (RGC R5037-18). The Finite-Volume Coastal Ocean Model (FVCOM) source code was obtained from the Marine Ecosystem Dynamics Modeling Laboratory (http://fvcom.smast.umassd.edu/).

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Three-dimensionality of supersonic laminar flow over a hollow cylinder-flare

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Abstract: Supersonic laminar flow over a hollow cylinder-flare with a Mach number of 2.25 is investigated for a wide range of cylinder radii and deflection angles using computational fluid dynamics (CFD) and global stability analysis (GSA).

The CFD results show that the critical angles of both incipient and secondary separation increase as the cylinder radius is decreased. GSA is performed to explore the global stability in terms of azimuthally periodic perturbations. The GSA results demonstrate that the flow becomes globally unstable with the increase of the deflection angle. Furthermore, the GSA results reveal that the global instability emerges prior to secondary separation.

The triple-deck theory is then applied to the supersonic hollow cylinder-flare flow to correlate the CFD and GSA results. A scaled critical deflection angle in terms of the incipient separation, secondary separation and global instability, is introduced from the triple-deck theory. The criterion to predict the emergence of global instability for supersonic compression corner flows with respect to a scaled deflection angle (Hao et al., J. Fluid Mech., vol. 919, 2021, A4) is extended to supersonic hollow cylinder-flare flows.

Direct numerical simulations (DNS) are performed for a representative unstable supersonic hollow cylinder-flare flow to verify the GSA results without introducing any external or internal disturbances. The DNS results show that the three-dimensional hollow cylinder-flare flow firstly experiences an exponential increase in the azimuthal velocity and then a nonlinear saturation before it becomes quasi-steady. The mode shape, growth rate and spanwise wavelength of the three-dimensional perturbations in the exponential growth stage correspond well with the GSA predictions. It is indicated that the unsteadiness of the investigated supersonic hollow cylinder-flare flow is associated with the intrinsic instabilities of the dynamic system.

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Probabilistic-based contact modeling of sand particles

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Abstract: Granular materials though very common in everyday experience are poorly understood from a theoretical perspective. This may be attributed to the fact that they exhibit surprisingly complex behavior even in the simplest of the situations. The discrete-based numerical tools have been proven to provide interesting insights into the complex behavior of granular materials, however, their accuracy depends primarily on the chosen contact parameters. Recent literature on particle scale experiments reveals that there are significant discrepancies of the contact parameters of granular systems, adding significant uncertainties in contact mechanics modeling and the selection of input parameters. Hence, a probabilistic-based approach in the analysis of grain-scale experimental data provides an invaluable solution to address these high discrepancies. In this study, we present a new probabilistic-based approach illustrated in Figure 1 in the analysis and identification of the best-suited models to fit the tangential stiffness reduction-displacement curves of granular contacts (after Reddy et al., 2022). For this purpose, three different hyperbolic models and the Mindlin and Deresiewicz model were accordingly adjusted with respect to their original versions to be suitable for analysis of non-conforming contacts employing the concept of secant stiffness rather than tangent stiffness. Bayesian probabilistic optimization and model selection was employed for each individual experimental curve analysed in the present study. Through this study, we demonstrate that the new approach outperforms that of traditional methods used in contact mechanics modeling.

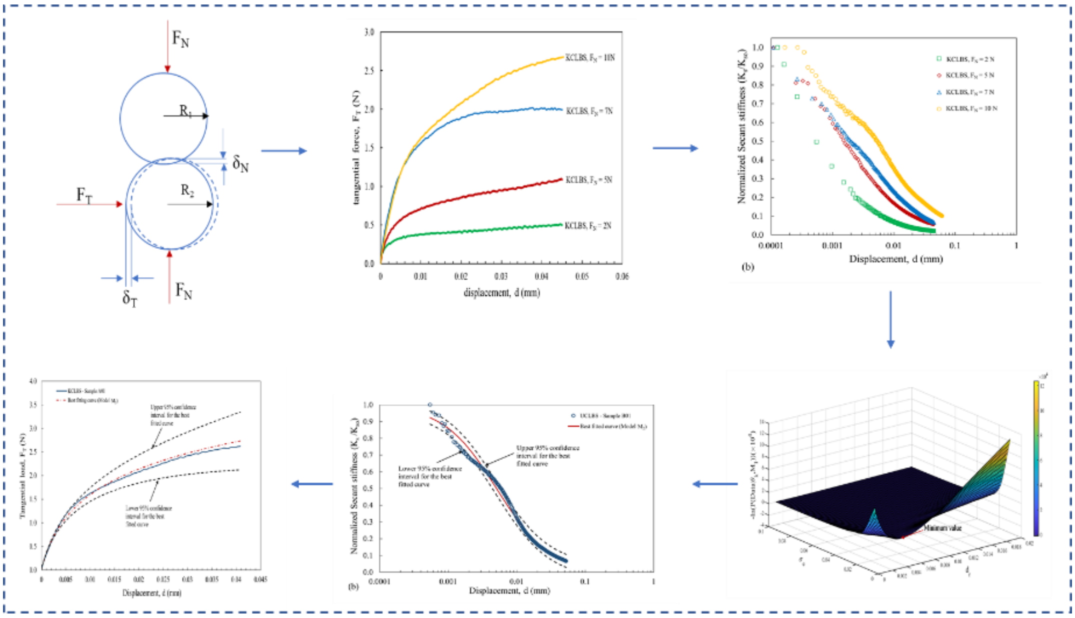

Figure 1. Schematic representation of the proposed Bayesian probabilistic approach for curve-fitting

Acknowledgements

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Experimental study on mechanical behaviors of FRP-confined sand and cemented sand

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Abstract: Extensive studies have been conducted on the use of fibre-reinforced polymer (FRP) as a confining material in hybrid tubular columns for civil construction. This work introduces a novel pile incorporating fibre-reinforced polymer (FRP). The exterior container of the pile is FRP jacket, while the infill is sand or cemented sand. This novel structure has the advantage of rapid construction with high bearing capacity. The variables included the type of infill (i.e. sand and cemented sand), the thickness of FRP jacket (i.e. 3.5 mm, 4.5 mm, and 5.5 mm), and load type (i.e. pure vertical load on infill material and load on the tube). Test results showed that the loading capacity and deformability of the pile structure has been significantly enhanced attributed to the confinement provided by the exterior FRP container. The existing stress-strain model for FRP-confined normal concrete can be used to provide reasonable predictions of the behaviour of the confined infill material in the new column.

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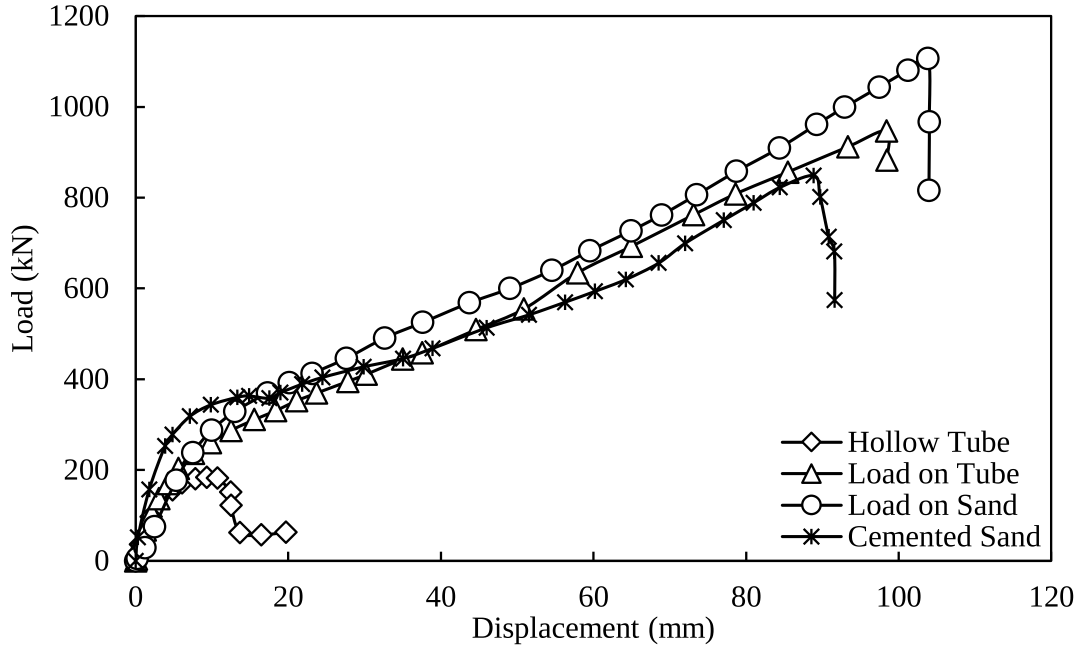

Figure 1. Load-displacement relationships

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A new stacked ring torsional shear apparatus for multiple liquefaction tests of sands

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Abstract: In this study, we develop a new stacked-ring torsional shear device to investigate multiple liquefaction behaviors of saturated sands. A series of inner and outer staked rings, fabricated using 5 mm thick stainless steel supported by specially designed bearings, provide lateral restraint to the sample, preventing large changes in sample shape during loading, consolidation, and reloading in multiple liquefaction tests. Four to six restraining poles are installed to guide the torsional shear movement only in the horizontal plane. The circumferential friction between the rings is negligible due to the bearing system. We use pressure compensation technique to reduce vertical friction between the sample and the rings, such that the stress in the sand sample can be much more uniformly distributed. The new device facilitates the investigation of multiple liquefaction behavior of saturated sands.

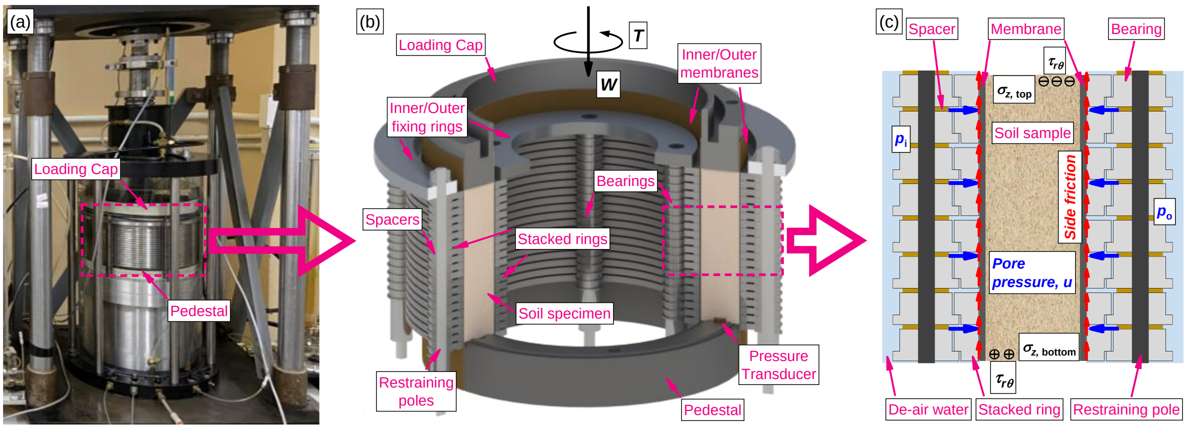

Figure 1. (a) The loading system of the apparatus; (b) Schematic diagram of a new stacked-ring device, and (c) stress state of the sand sample under pressure compensation.

Acknowledgements

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Sealing behaviour and morphological features of filter cake from sand-modified bentonite slurry

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Abstract: Modification to water-bentonite slurry is critical for slurry shield tunnelling in highly permeable stratum. In practice, various additives (e.g., sand, polymer and vermiculite) have been added to water-bentonite slurry, but the infiltration behaviour and mechanism of filter cake formation for the modified slurry have not been well understood. In this study, the infiltration behaviour and forming mechanism of filter cake by water-bentonite slurry (Series 1) and water-bentonite-sand slurry (Series 2) in different sand beds were investigated, respectively. Morphological features of the filter cake were captured from the scanning electron microscope (SEM) tests. Results demonstrated that, for Series 1, the thin filter cake (~1 mm) with extremely low permeability (~10^{-8} m/s) could only be formed for the fine sand, which is consist of layers of oriented bentonite platelets with dense structure. For Series 2, the combination of the sand cake and the filter cake is found on the sand bed surface when the sand content is controlled within a certain range. However, more fine sand in the slurry prevents the bentonite platelets from achieving a horizontally oriented arrangement.

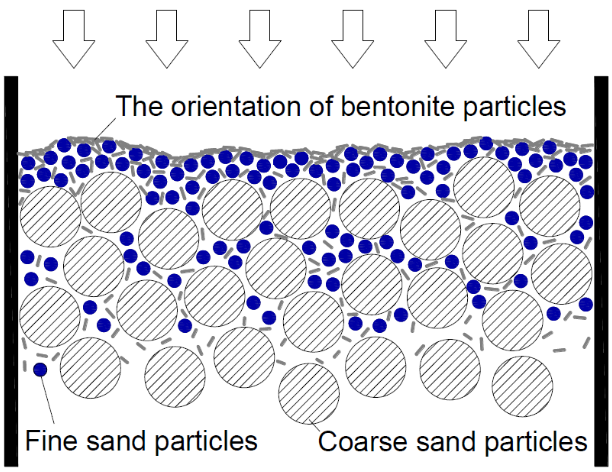

Figure 1. Water-bentonite-sand slurry infiltrating into coarse sand with filter cake formation

Acknowledgements

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Numerical investigation of inclined pull-out capacity of suction anchors in sand

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Abstract: Suction anchor is a novel type of anchor foundation used in offshore engineering. This paper focuses on the pull-out capacity of suction anchors under inclined loading using numerical modelling. The critical state elastoplastic constitutive model SIMSAND is adopted. The finite element model with model parameters is first validated via two centrifuge tests. After full numerical validations, simulations concerning different padeye positions and pull-out inclination angles are carried out, based on which the pure vertical and horizontal pull-out, the optimal padeye position and three related soil failure modes are identified. Finally, an analytical formula of the *V-H* failure envelope is calibrated.

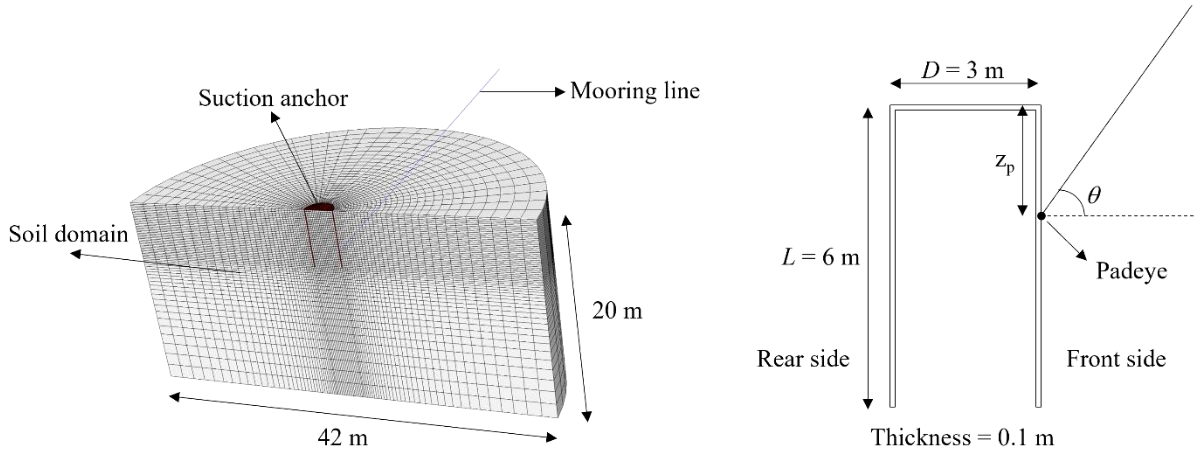

Figure 1. Assembly and dimension of the whole numerical model.

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Behaviour of granular soils under constant shear drained loading from a critical state perspective

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Abstract: Slope failures have been frequently observed in the field under storm rainfall, for which the constant shear drained (CSD) stress path is more pertinent to the soil element. To evaluate the stability of a slope under the CSD stress path requires a fundamental understanding of the corresponding shear behaviour of granular soils. This study explores soil response through the discrete element method in the context of the critical state soil theory. The constant shear stress path is rigorously achieved. A notable finding is that the development of shear strength in CSD tests is similar to that under conventional drained tests, and no run-away instability behaviour is observed. Based on Hill's stability criterion, a granular assembly remains stable under the CSD loading if the second-order work is positive. The vanishing of second-order work can be used to delineate the boundary of a potential unstable zone. Such a boundary can be the instability line for loose soil inside the critical state line or the transition from strain hardening to strain softening for dense soil outside the critical state line.

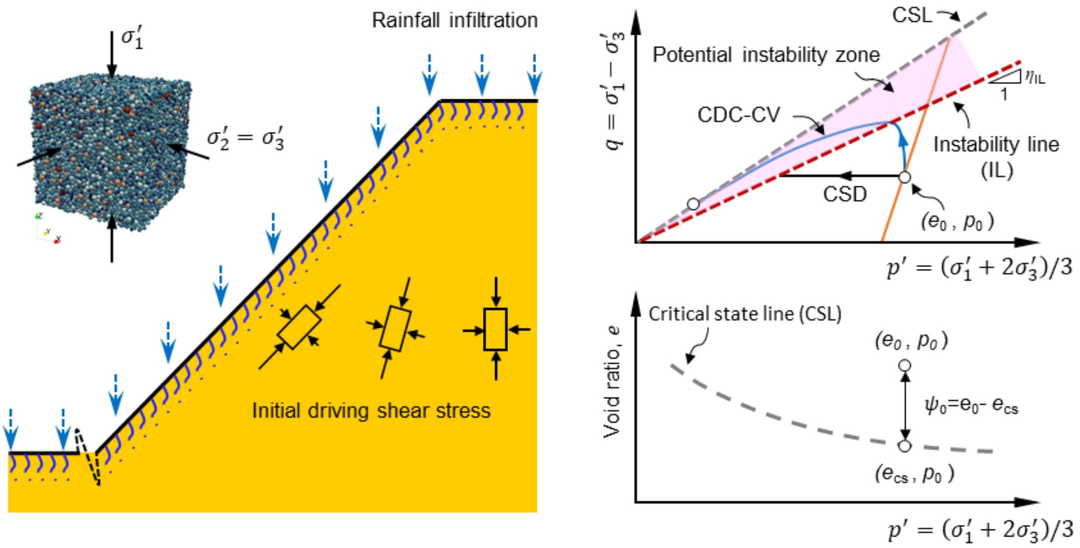

Figure 1. Illustration of CSD stress path of the soil element within a slope induced by rainfall infiltration.

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A Mask R-CNN based particle identification for quantitative shape evaluation of granular materials

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Abstract: Particle identification and shape evaluation of granular materials from their realistic packing images are challenging and of great interest to many engineers and researchers. In this study, a systematic tool is developed based on computing techniques, including deep learning and computational geometry. First, image datasets of the target granular particles with well-labeled masks are established. The Mask Region Convolutional Neural Network (Mask R-CNN) is employed to implement the end-to-end instance segmentation and contour extraction of particles on different realistic images. Since Mask R-CNN models have several different feature extraction backbones, the optimal model is selected and then trained on the established datasets using transfer learning technique. After the particles are successfully identified from images of cobble and ballast, the elongation, angularity, and roughness are evaluated and the statistical shape analysis are conducted. The proposed method has strong generalization ability, especially for densely-packed particles.

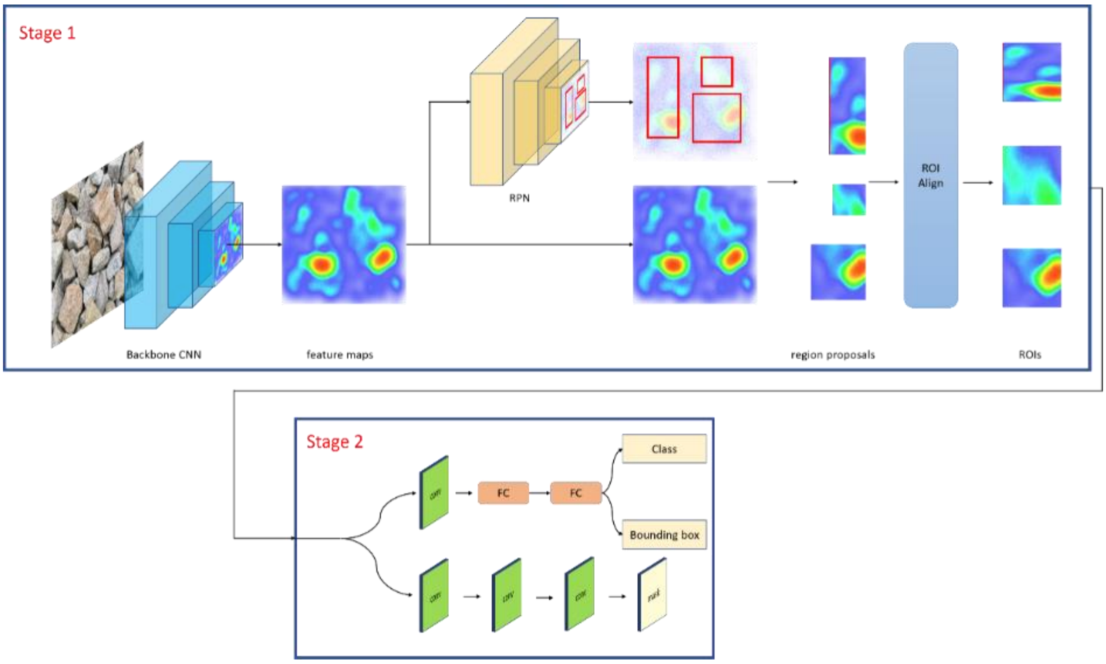

Figure 1.The framework of Mask R-CNN.

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Numerical simulation of compaction of elasto-plastic adhesive granular powders

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Abstract: Powder compaction is widely used in the pharmaceutical, metallurgical and food industries. Reduction in porosity of the compacted powders may be due to the rearrangement, deformation and crushing of powder particles (Gethin et al., 2001). Multi-particle finite element method is employed in this study to investigate the compaction process of highly deformable powders. Each individual powder grain is simulated by FEM with an elastoplastic material point to account for the plastic deformation of particle due to compaction. A cohesive contact model is proposed to describe the occurrence of cohesive bonds and formation of solid bridge over the contact surface between two powder grains. The cohesive contact model is first validated by analytical solutions on contact between two identical spherical particles (Gonzalez, 2019). A packing of initial spherical powder particles is then simulated by the MPFEM to examine the deformation and damage responses of the assembly. Our simulation results show that the elastic properties of individual sphere, the relative density of the sample and the fracture strength of the formed solid bridge at contact are major influencing factors for the deformation, yielding and energy dissipation of the assembly. We further establish a relationship between the deviator stress, confining pressure, and the fracture energy for compacted powders in triaxial stress conditions. The consideration of cohesive contact is found to significantly affect the cyclic loading behaviour of the sample.

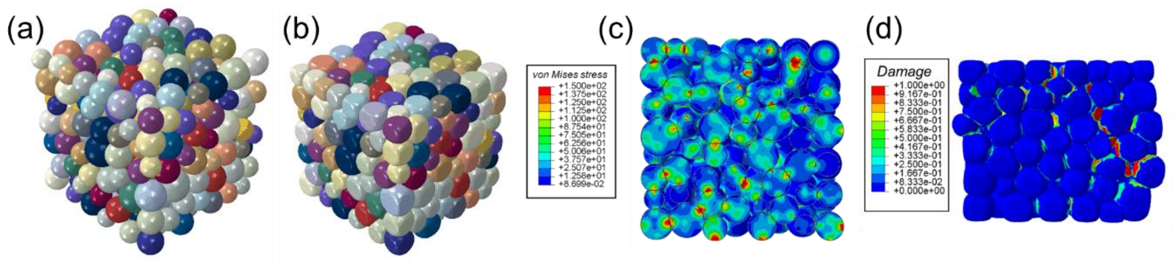

Figure 1. MPFEM simulation of powder compaction: (a) initial and (b) deformation packing after isotropic compression, (c) von Mises stress distribution during the loading stage, and (d) damage distribution induced in the compacted sample.

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The authors wish to acknowledge the financial support of Research Grants Council of Hong Kong via GRF # 16208720.

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Mesoscale discrete element modelling of cemented granular materials

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Abstract: Cemented granular materials have been widely used in engineering construction. In this study, we developed a meso-scale discrete element model to study the mechanical behaviours of cemented granular particles, considering irregularly shaped particles, void structure and cement distribution. The mesoscale model predicts the strength of the cemented granular materials as well as the fracture and breakage patterns of the material. A series of uniaxial compression tests with cement ratios ranging from 5% to 40% were conducted, which is used to validate the numerical simulations, showing that the mesoscale model can be well used to simulate the behaviours of cemented granular materials with a wide range of cement ratios.

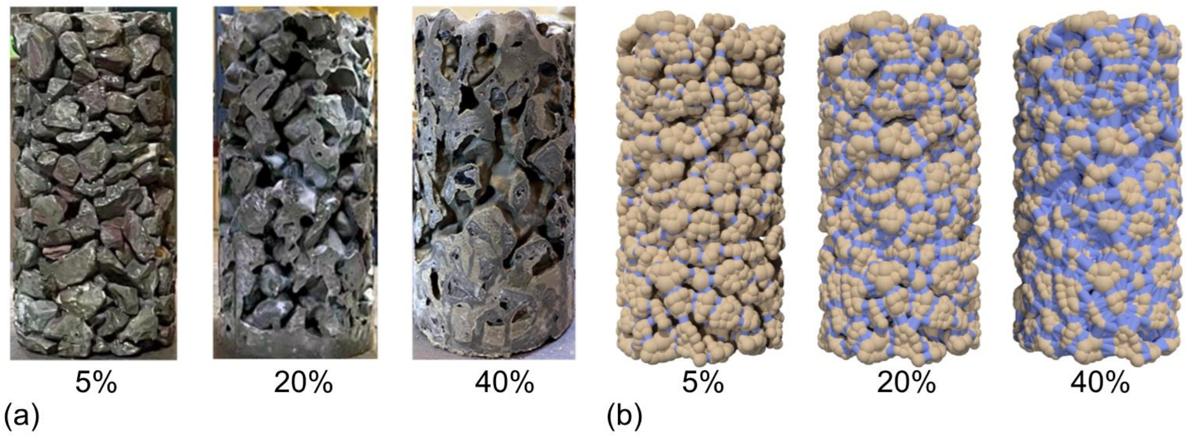

Figure 1. (a) The cemented granular packings and (b) DEM samples with cement ratios of 5%, 20%, 40%

Acknowledgements

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Micromechanical modelling of hollow cylinder tests on granular material

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Abstract: A series of three-dimensional discrete element method (DEM) simulations on hollow cylinder specimen is presented. Based on the calibrated micro-parameters, numerical hollow cylindrical torsional shear tests were carried out under different loading paths, i.e., different intermediate principal stress parameter b and principal stress direction α. The results show that the mechanical behaviour of granular material can be significantly affected by b and α: the strength of material increases with the decrease of α. It is captured that b and α also affect the non-coaxial behaviour of granular material. Besides, the fabric of granular material (i.e., the distribution of normal contact force F_n, shear contact force F_t and the contact normal N_c) are also significantly affected by b and α.

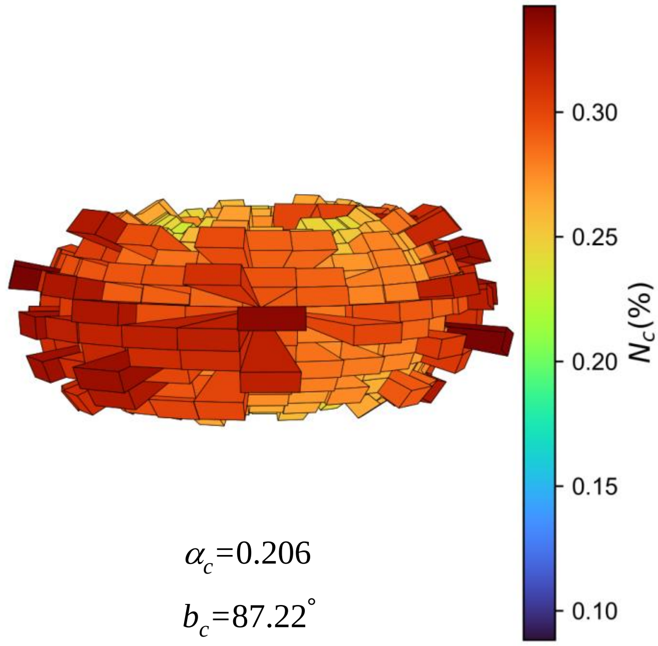

Figure 1. Distribution of the contact normal N_c (b = 0.5, α = 60°).

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Examination of the micromechanical contact behavior of iron tailing particles in various submersion states

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Abstract: The stability of tailing dams, where the disposed mining residuals are stored, is critical, as their failure poses threats to public safety and causes adverse impacts on the environment. The application of biopolymer-based stabilizers can provide an alternative solution in the enhancement of the mechanical properties of soils and the stability of geo-systems. Although a number of works in the geotechnical engineering filed have evaluated different types of polymer-based fluids, less attention has been given to the fundamental study in this type of ground improvement/soil-environment interaction at the level of grain-to-grain contacts. In this study, a laboratory investigation is performed on the frictional behavior of tailing grains through a set of monotonic and cyclic shearing tests by considering various influences including abrasion, saturation condition and the presence of biopolymer-based coating. These experiments are achieved using a micromechanical apparatus which allows precise measurements of force and displacement, and a technique is developed to coat in-situ tailing grains with a biopolymer fluid at various concentrations. The results show that abrasion significantly affects the frictional response of the tailing grains; this implies that a constitutive model might need to incorporate this important influence for realistic simulations of materials such as tailing sands. Besides, the data suggest promising application of the biopolymer-based fluid as a stabilizing agent for the tailing grains.

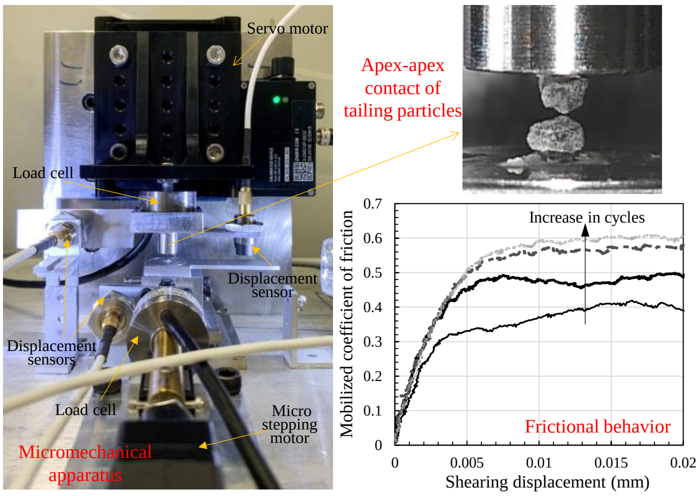

Figure 1. An image of the micromechanical apparatus with a representative plot of shearing behavior of tailing grains (Ren et al., 2021)

Acknowledgements

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Experimental study of the grid type prefabricated horizontal drains with vacuum preloading in Hong Kong marine deposit

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Abstract: Prefabricated vertical drains (PVD) with vacuum preloading have been widely studied and applied in practice, but it is time-consuming, and the bending phenomenon often occurs with a large settlement. Therefore, the prefabricated horizontal drains (PHD) with vacuum preloading have been proposed in recent years to improve the drainage efficiency and avoid the problem of bending, but the construction technique is immature. A novel ground improvement method with a grid-type PHD with vacuum preloading to speed up consolidation and protect drains is proposed in this study. A large-scale model test in Hong Kong marine deposit (HKMD) with PHDs installed and activated with staged vacuum pressure is carried out. In the meanwhile, the water content, pore water pressure, vacuum pressure, undrained shear strength, and the weight of deranged water are monitored. It is found that the average water content reduced from 200% to 76% during the consolidation process, the undrained shear strength of HKMD increased to around 30 kPa and the PHD kept its initial shape after the treatment. The test results show that the grid type PHD with vacuum preloading is an effective way to shorten the consolidation time of HKMD in reclamation projects.

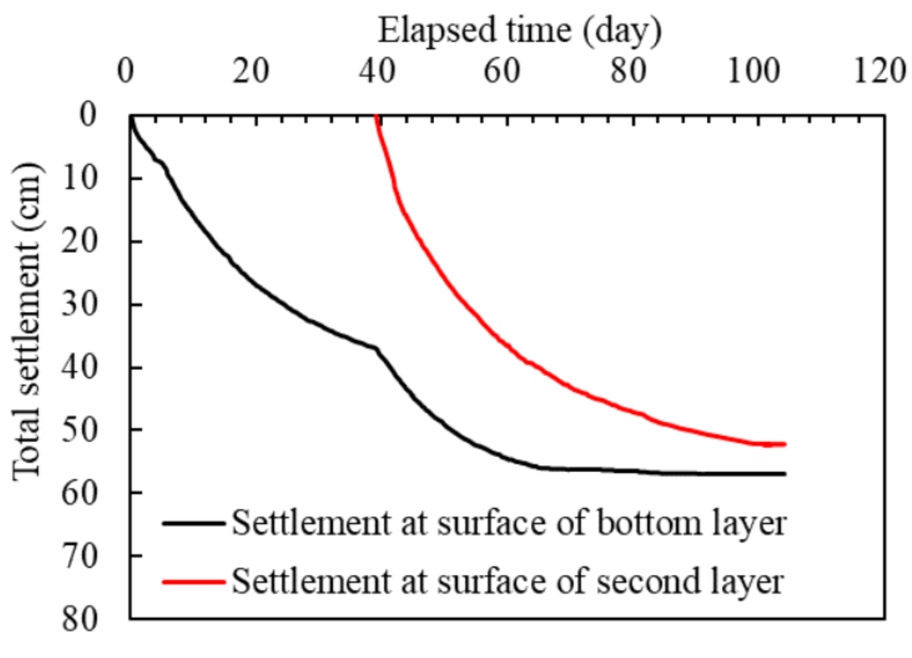

Figure 1. Settlement of two layers of HKMD with time after treated by PHD with vacuum preloading

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Experimental characterization of ITZ in concrete by SEM-DIC method

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Abstract: Due to the limitation of current experimental methods, measuring mechanical properties of interfacial transition zone (ITZ) in concrete is almost an unsurpassed challenge. For experimentally characterizing mechanical behaviour of ITZ at micro scale, a combined strategy between scanning electron microscope (SEM) and digital image correlation (DIC) is presented. A bi-material sample composed of aggregate and mortar is designed for convenience to conduct uniaxial compressive and tensile tests in SEM. By the proposed SEM-DIC method, stress-strain relation of ITZ can be measured, and mechanical properties including strength, nominal fracture energy and nominal elastic modulus are evaluated. Also, micro-damage distribution in ITZ area is further evaluated by wavelet packet analysis. Besides, the effects of aggregate type and water-cement ratio on the mechanical properties and thickness of ITZ are investigated. Results reveals that a region with apparently lower elastic modulus can be characterized as the ITZ area. In addition, the degree of micro-damage could be well characterized by energy change rate through wavelet packet analysis. It is also indicated that ITZ areas with limestone aggregates and high water-cement ratio is much easier deformed under load.

Acknowledgements

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Modelling and stability assessment of slurry shield tunnel excavation surface

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Abstract: Stability assessment of slurry shield tunnel excavation surfaces is crucial for safe excavation of underground tunnels, and it can reduce the occurrence of unsafe tunnel construction accidents. Considering the special way in which support is provided in slurry shield tunnels, it can also have an impact on the seepage in front of the excavation surface. In this study, based on limit theory, the stability of the tunnel face is analysed by establishing an analytical solution to describe the flow field with an upper limit method based on a multi-block rupture body model. The safety factor is obtained by the proposed method, and a parametric analysis of the relevant influencing parameters including excess slurry pressure transfer rate, internal friction angle, cohesion force, etc., was carried out.

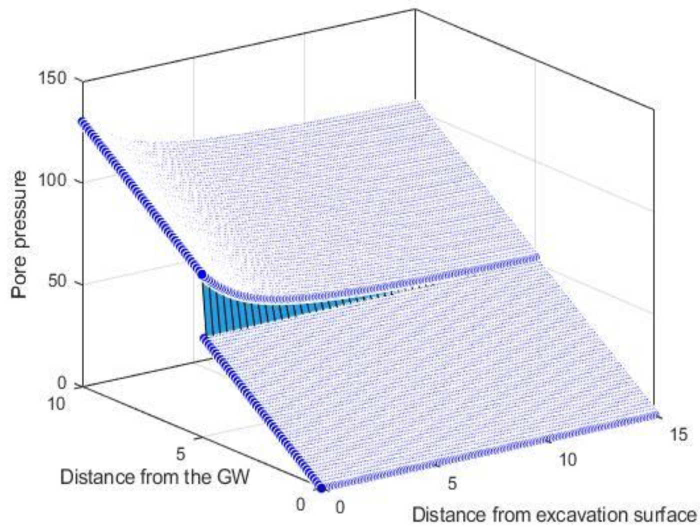

Figure 1. Analytical solution of the pore pressure distribution in front of shield tunnel

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Experimental study on the monotonic mechanical behavior of completely decomposed granite soil reinforced by disposable face-mask chips

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Abstract: In response to the global outbreak of the coronavirus pandemic (COVID-19), a staggering amount of disposable face masks have been used, leading to an urgent environmental issue. This study evaluates the feasibility of mask chips for the soil reinforcement through triaxial tests on samples mixed with complete decomposed granite (CDG) and mask chips. The experimental results show that adding a moderate volumetric amount of mask chips (0.3%-1% by volume) improves the soil strength, especially under high confining pressure. When the volumetric content of mask chips exceeds the optimum value, the peak shear strength decreases accordingly. A limited amount of mask chips also increases the elastic modulus and makes the volumetric response more dilative. By contrast, excessive mask chips create additional voids and shift the strong soil-mask contacts to weak mask-mask contacts. The typical samples' scanning electron microscope (SEM) images demonstrate the microstructure of mask fibers interlocking with soil particles, highly supporting the macro-scale mechanical behavior.

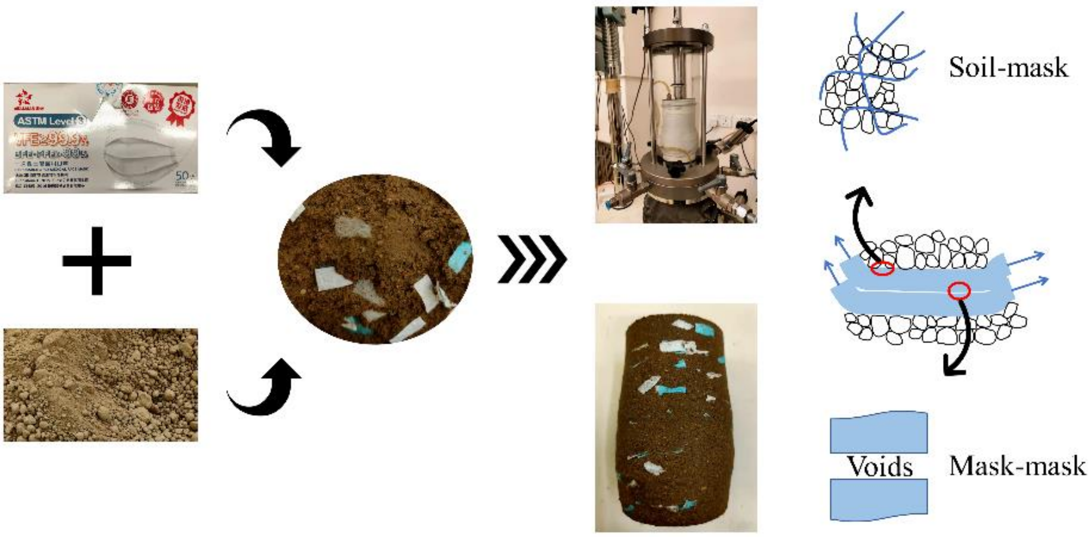

Figure 1. Experimental scheme and proposed reinforcement mechanism

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Macrotransport theory for chemotactic microorganisms and diffusiophoretic colloids in hydrodynamic flows

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Abstract: Deterministic motion of a colloidal-scale species can be induced by the concentration gradient of a surrounding solute. Diffusiophoresis refers to such motion due to the electrokinetic interactions between charged colloids and electrolyte solutions. Chemotaxis refers to microorganisms utilizing their transmembrane chemoreceptors to detect the surrounding solute gradient, along which they preform deterministic motion. Linking these two seemingly disparate phenomena is the "log-sensing" response, where the induced velocity of the colloid is related to the gradient of the logarithm of the solute concentration. Predicting the transport of chemotactic or diffusiophoretic colloids in hydrodynamic flows has been an ongoing challenge due to the multiple mechanisms as well as the separation of time and length sales involved. In this talk, we present our recently-developed macrotransport theory for efficiently predicting the long-time transport of a chemotactic/diffusiophoretic colloidal species in a uniform circular tube under a steady pressure-driven flow and transient solute gradient. We demonstrate excellent agreement between the one-dimensional macrotransport equation and direct numerical solution of the original, two-dimensional advection-diffusion equation for the colloidal species transport. In addition to its accuracy, the macrotransport equation requires $O(10^3)$ times less computational runtime than direct numerical solution of the advection-diffusion equation. In closing, we discuss generalization of the macrotransport equation to channels of arbitrary cross-section and to incorporate more sophisticated chemotactic flow models. This macrotransport framework could be employed to tailor chemotactic/diffusiophoretic colloids transport using hydrodynamic flows, which is central to applications such as enhanced oil recovery, drug delivery, and bioremediation of aquifers.

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Modeling the adhesion and spreading of cells regulated by ligand diffusivity

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Abstract: Cells live in a highly dynamic environment where their physical connection and communication with outside are achieved through receptor-ligands binding. Therefore, a precise knowledge of the interaction between receptors and ligands is critical for our understanding of how cells execute different biological duties. Interestingly, recent evidence has shown that the mobility of ligands at the cell-extracellular matrix (ECM) interface significantly affects the adhesion and spreading of cells, while the underlying mechanism remains unclear. Here, we present a modeling investigation to address this critical issue. Specifically, by adopting the Langevin dynamics, the random movement of ligands was captured by assigning a stochastic force along with a viscous drag on them. After that, the evolution of adhesion and subsequent spreading of cells were analyzed by considering the force-regulated binding/breakage of individual molecular bonds connecting polymerizing actin bundles inside the cell to the ECM. Interestingly, a biphasic relationship between adhesion and ligand diffusivity was predicted, resulting in maximized cell spreading at intermediate mobility of ligand molecules. In addition, this peak position was found to be dictated by the aggregation of ligands, effectively reducing their diffusivity, and how fast bond association/dissociation can occur. These predictions are in excellent agreement with our experimental observations where distinct ligand mobility was introduced by tuning the interactions between the self-assembly polymer coating and the surface.

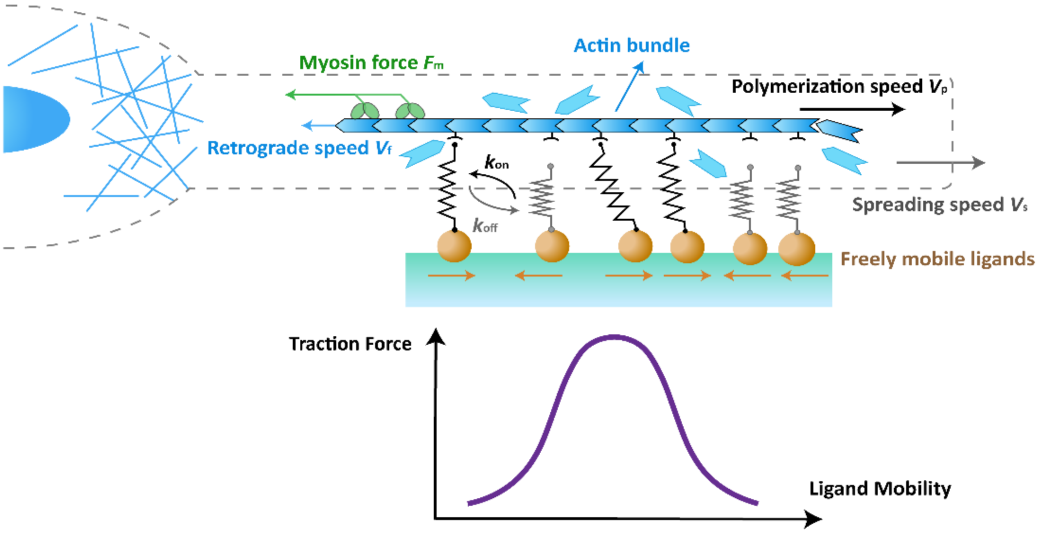

Figure 1. The motor-clutch model was modified for examining the influence of ligand mobility on cell adhesion and spreading. And a biphasic relationship between adhesion and ligand diffusivity was predicted.

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Characterization of the living plant cell wall modulus and turgor pressure using nanoindentation and mechanical modeling

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Abstract: The plant leaf epidermis is a single layer of cells that cover the leaf. They have a clear color allowing the sunlight into the leaf for photosynthesis. The morphogenesis of the epidermal cells influences the development of the leaf, and therefore, it has a primary role on the photosynthesis. During growth, the epidermal cells will grow to an interdigitated pattern under internal hydrostatic pressure from the initial regular brick paving pattern. This phenomenon attracts many efforts to develop a reasonable understanding and most of them are quite often explained in the mechanical point of view. For example, the mechanical properties across a single cell wall are not distributed uniformly so that the growth rate within a cell wall is not homogeneous (Elsner, Lipowczan et al. 2018, Li, Keynia et al. 2021). Even though this kind of concept has been widely investigated, the direct evidence is never enough because the cellular and sub-cellular scale of the epidermal cell size limit most mechanical measurements. In the presentation, we took Arabidopsis thaliana plant as an example, and presented an approach to characterize the pavement cell wall elastic modulus and its distribution across a single cell using nanoindentation and mechanical modeling. It is the first time to reasonably measure the plant cell wall modulus and design an experiment to validate the approach. The results show that Young's modulus of the cell walls is in the scale of 100-800 MPa, and the internal hydrostatic pressure is around 1 MPa.

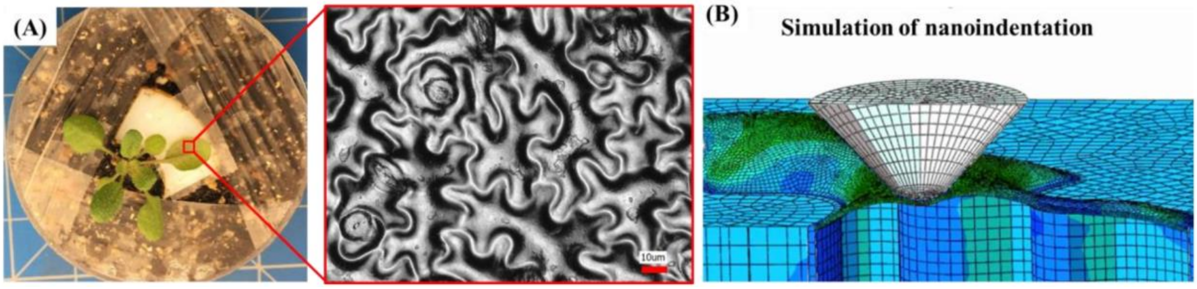

Figure 1. Characterization of living plant cell wall modulus and turgor pressure. (A) Interdigitated pattern of the Arabidopsis epidermal cells, which were measured using a laser scanning confocal microscope. (B) Finite element simulation of the nanoindentation, as is shown the cut-view of the probe and a single cell wall.

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Defect size controlled rupture of biopolymer networks

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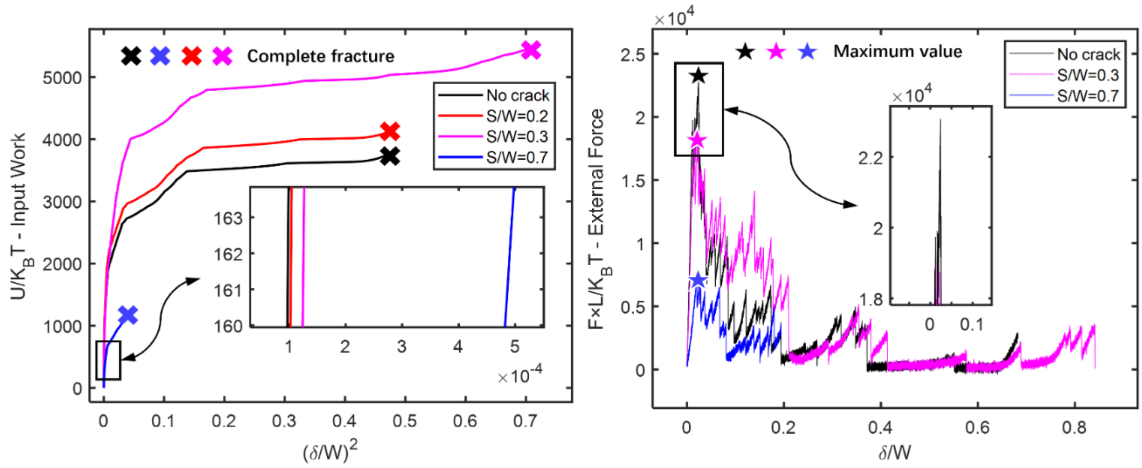
Abstract: Damage in cytoskeleton can occur frequently during processes like cell migration and division. However, the question of how the presence of micro-cracks affects the deformation and fracture response of such bio-filament networks remains unclear. Here, we report a computational study to address this unsettling issue where large deformation and thermal fluctuations of individual biopolymers, as well as the forced breaking of crosslinks between them, have all been taken into account. It was found that the introduction of micro-cracks could alter the fracture path inside the network, change its ductility and actually result in an increased fracture energy of the material. More interestingly, we showed that on average the maximum fracture resistance will be achieved when the crack length is a few times of the network pore size, highlighting the flaw insensitive nature of such materials. Finally, the network fracture energy was observed to increase with the linear stiffness of crosslinking molecules monotonically but reach its minimum at an intermediate rotational stiffness value. In addition to enhancing our understanding of how cytoskeleton performs different cellular duties, findings here could also provide useful information for the development of high performance biological materials in the future.



(A) (B)

Figure 1. (A) Work done by the external load as a function of the imposed deformation under different introduced crack sizes; (B) Force-displacement curves for the same network with or without introduced cracks.

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Simulation of tumor ablation in hyperthermia based cancer treatment

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Abstract: Magnetic hyperthermia is a cancer therapeutic procedure, in which magnetic nanoparticles (MNPs) are injected into tumor tissues, and then exposed to an alternating magnetic field (AMF), to ablate malignant cells.[1, 2] In this study, a numerical framework using the Lattice Boltzmann method (LBM) is developed to study the process of magnetic hyperthermia treatment. Governed by the momentum equation, energy equation, and concentration equation, the heat generation and transfer, tissue fluid flow, and MNPs diffusion in porous media were numerically simulated. To evaluate the ablation performance, the CEM43[3], i.e., the cumulative equivalent exposure time in minutes at 43℃, was employed. Figure 1 shows the schematic of the numerical model. A tumor is surrounded by a block of healthy tissue, both being modelled as porous media containing interior tissue fluid but with different permeability. Simulation results indicated that, without the gravity, a perfect treatment time can be determined to completely ablating the tumor while protecting the healthy tissue; with the gravity, however, the MNPs gathered near the lower side of the tumor, thereby leading to overheating on some healthy tissue. The effects of several key parameters were also explored, including the Lewis number, heat source number, buoyancy ratio, Darcy ratio. More detailed results will be presented and discussed in our talk.

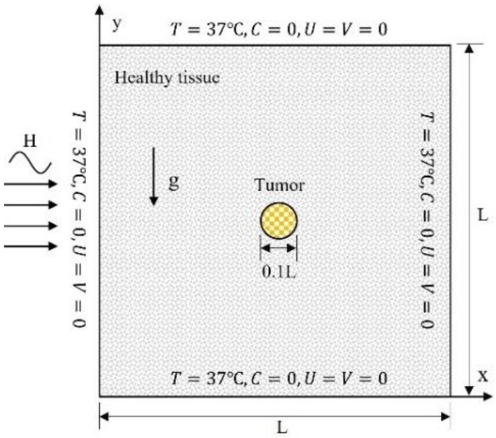

Figure 1: Schematic of the numerical model for magnetic hyperthermia.

Acknowledgements

This study was financially supported by the Research Grants Council of Hong Kong under General Research Fund (Project No. 15214418).

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Hydrodynamic flows in driven and active, nematic liquid crystals

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Abstract: Liquid crystals (LCs) are an anisotropic liquid exhibiting long-range orientational ordering, which is sensitive to external stimuli, making it a promising material for applications in display technology, sensing, photonic devices, etc. There is a recent interest in active liquid crystals thanks to its potential in autonomous materials. However, the fluid dynamics of liquid crystals under driven and active stresses are difficult to elucidate, hindering its applications in areas including microfluidics. Here, we develop a hydrodynamic model to simulate driven and active nematic LCs. We investigate two types of nematic LCs. In one, the nematic is tumbling under a constant shear. Our method is validated by a favorable comparison to a pressure-driven flow of tumbling nematic in experiments. We further study how the interplay of driven field and active stress can give rise to tunable spontaneous flows and periodically evolving stripe patterns in different flow conditions. The other type of nematic LCs exhibit spontaneous chirality. In such system, we probe the self-propulsion dynamics of topological defects in flat and curved boundary. Specifically, we find that the intrinsic twist can break the mirror symmetry of the +1/2 defects, giving rise to their circular motion on a curved surface. Taken together, our results pave the way towards microfluidic applications of tumbling active nematics.

Acknowledgements
The author wishes to thank Research Grants Council of Hong Kong via Grant no. 26302320.

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Intermittent locomotion of two self-propelled flexible plates in a side-by-side configuration

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Abstract: Intermittent locomotion is usually adopted by natural swimmers. Previous studies have shown that the locomotion of this type can effectively improve the propulsion performance of an isolated individual(1-2), whereas the influences of such locomotion strategy on the collective hydrodynamics of multiple swimmers remain largely elusive. This work aims at filling this gap through a series of numerical investigations. In particular, two swimmers are considered, and they are modelled as two self-propelled flexible plates in a side-by-side arrangement with a lateral distance of *S* (see Fig. 1(a)). The plates both adopt the half-tail-beat (HT) intermittent swimming mode(1) with a duty cycle of *DC* (see Fig. 1(b)) and undergo heaving motions in an in-phase or anti-phase manner. The influences of *S* and *DC* are explored systematically using an in-house solver based on the immersed boundary-lattice Boltzmann method (IBLBM) and the finite element method (FEM). Preliminary results show that depending on the aforementioned factors various self-organized collective behaviours can emerge spontaneously, including the staggered-following (SF) behaviour and alternate-leading (AL) behaviour in the in-phase scenario as well as the moving abreast (MA) behaviour in the anti-phase scenario. When exhibiting the SF and MA behaviours, the cruising speed (U_C) and efficiency (η) of the plates are usually higher than those of the isolated counterpart, while it is not the case when the AL behaviour presents. If the AL behaviour does not emerge, U_C and η generally increase with *DC* but decrease with *S*, as shown in Figs. 1(c) and (d).

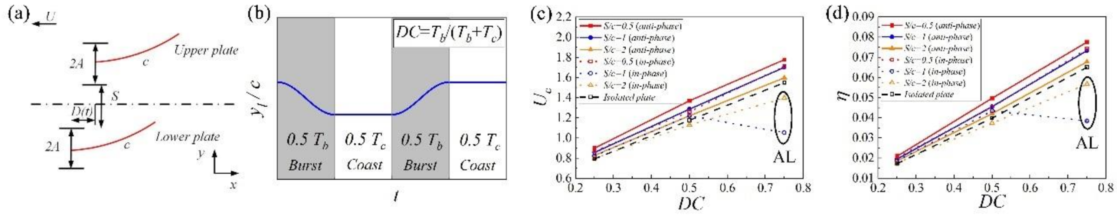

Figure 1. (a) Schematic diagram of two self-propelled plates undergoing heaving motions in a side-by-side configuration, where *A* is the heaving amplitude, *S* is the lateral distance, *c* is the plate length, and *D* is the instantaneous distance between the plates; (b) Time histories of the leading-edge location of one plate over one cycle period (T_b+T_c), where T_b and T_c are the burst and coast periods, respectively, and the duty cycle *DC* is defined as $T_b/(T_b+T_c)$; (c) Variations of the mean cruising speed (U_c) and (d) efficiency (η) of the two plates with A/c=0.5 against *DC* in the anti-phase (solid-symbol solid lines) and in-phase (open-symbol dotted lines) cases with S/c=0.5, 1 and 2 as well as in the isolated-plate cases (open-symbol dashed lines).

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Hydro-mechanical coupled NS-PFEM with nodal integration stabilization and polynomial pressure projection

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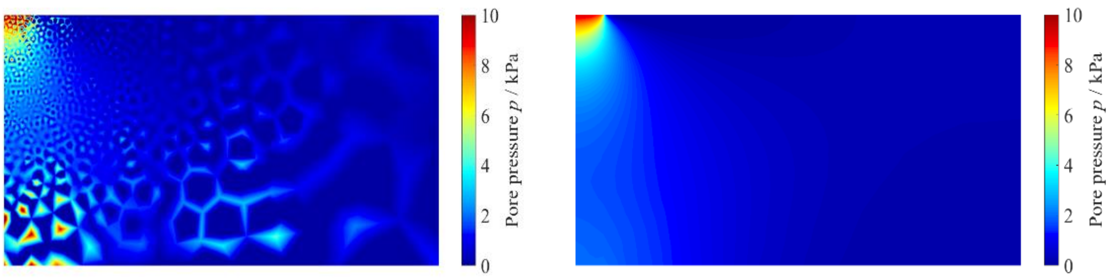
Abstract: The node-based smoothed particle finite element method (NS-PFEM) offers high computational efficiency but is numerically unstable due to possible spurious low-energy mode in direct nodal integration. Moreover, the NS-PFEM has not been applied to hydromechanical coupled analysis. This study proposes an implicit stabilized T3 element-based NS-PFEM (SNS-PFEM) for solving fully hydromechanical coupled geotechnical problems that (1) adopts the stable nodal integration based on multiple stress points over the smooth domain to resolve the nodal integration instability of NS-PFEM, (2) implements the polynomial pressure projection (PPP) technique in the nodal integration framework to cure possible spurious pore pressure oscillation in the undrained or incompressible limit and (3) expresses the nodal integration for assembling coefficient matrices and calculating internal force in SNS-PFEM with PPP as closed analytical expressions, guaranteeing computational accuracy and efficiency. Five benchmark tests are simulated and compared with analytical solutions or results from other numerical methods to validate the correctness and efficiency of the proposed approach.



(a) (b)

Fig. 1 Contour of pore pressure in the undrained incompressible limit using (a) SNS-PFEM without PPP; (b) SNS-PFEM with PPP

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Effects by prefabricated drains and vacuum preloading on consolidation of Hong Kong marine deposits

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Abstract: Hong Kong faces the scarcity of construction land, and reclamation is the common way to this problem. How to accelerate the consolidation is a key issue in reclamation projects. Prefabricated vertical drains with fill surcharge is an effective approach to speed up the consolidation of soft clays and is widely used in Hong Kong. However, the filling materials as the surcharge loading are very scarce nowadays. Vacuum preloading is regarded as an effective alternative to overcome the scarcity of filling materials.

A series of small-scale physical model tests to improve dredged slurry of HKMD by prefabricated drain and vacuum preloading was carried out. The effects of different layout of prefabricated drains such as prefabricated vertical drain (PVD) and prefabricated horizontal drain (PHD) were studied. The vacuum pressure, weight of dissipated water, settlement, pore-water pressure, and water content were monitored during all tests. After testing, the shear strength and permeability were measured for consolidated soils along the depth. In addition, particle size distribution analysis test, oedometer test and scanning electron microscopy test were conducted for further exploration. All results indicated that the combined PHD and PVD method reaches the best improvement compared with the PHD or PVD only.

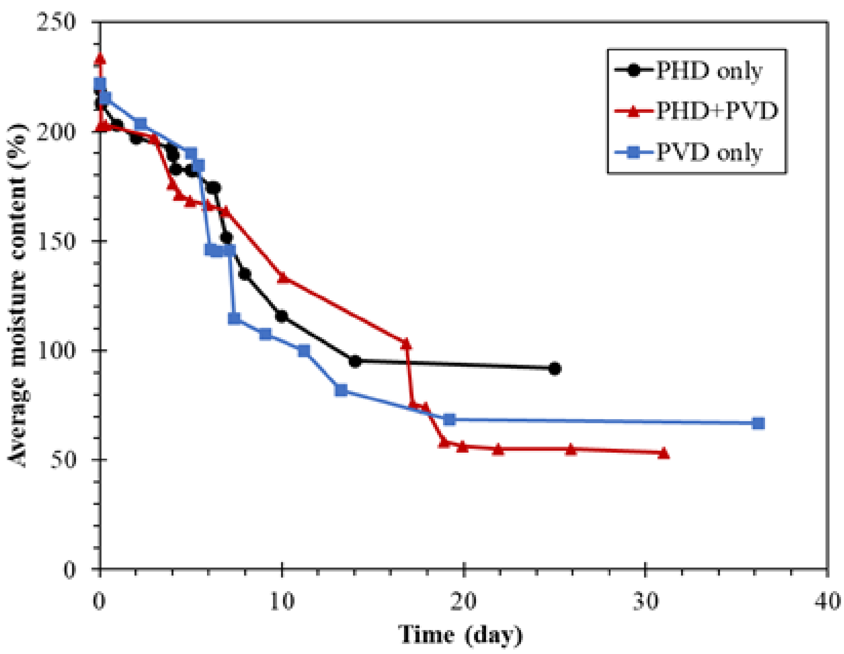

Figure 1. Evolutions of average water content with time using different improvement methods

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Effect of fabric anisotropy on suffusion for gap-graded soils by coupled CFD-DEM method

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Abstract: The natural deposition of soils results in significant fabric anisotropy, which influences the strength and seepage properties of granular sand. For gap-graded soils, groundwater scours fine particles from the matrix of the coarse particles and internal erosion (suffusion) occurs. This paper presents a coupled computational fluid dynamics and discrete element method (CFD–DEM) analysis of suffusion considering different bending angles of particles in gap-graded granular soils. Both the macroscopic and microscopic characteristics during suffusion and triaxial loading tests are analyzed. The fabric anisotropy is found to play a significant role affecting the erosion process and the mechanical consequence of soils. Results show that the smaller the bending angle is, the harder it is for suffusion to occur and continue. Three erosion mode of fine particles can be identified based on the particle trajectory for different bending angles.

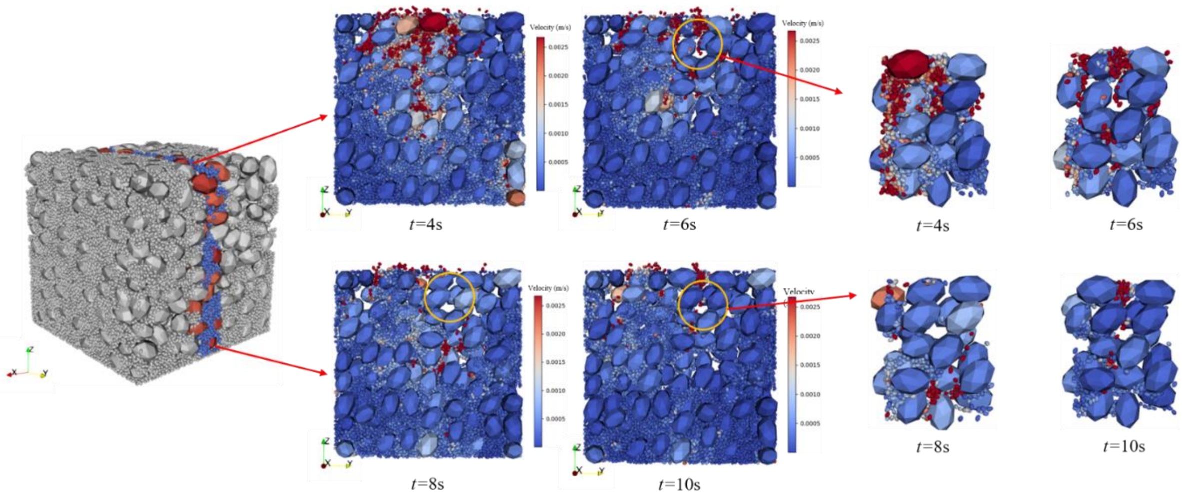

Figure 1. Particle erosion in gap-graded soils with fabric anisotropy.

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Thermal transport spectroscopy in atomistic simulations

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Abstract: When the scale of materials goes down to a tiny scale, i.e., nanometer scale which is a billionth of a meter, the thermal properties of the materials become quite unusual due to the quantum and size effects. As a result, nanotechnologies have often served as tools for design of highly functional engineered materials & structures with potential applications in energy and thermal related area. In this seminar, I will firstly introduce a new methodology to handle the thermal transport process in magnetic semiconductors & insulators, propose a strategy based on nonequilibrium molecular dynamics to quantify the scattering process in nanostructures and across interfaces, and modelling the transport properties of heterostructures at multiscale. Specifically, I will discuss a number of nanoengineering examples showcasing our recent technologies innovations including the active control of heat conduction using magnetic controllable thermal conductivity, enhancing the interfacial thermal transport via inelastic phonon scattering process, reaching high-efficiency heat conduction medium using nanostructures.

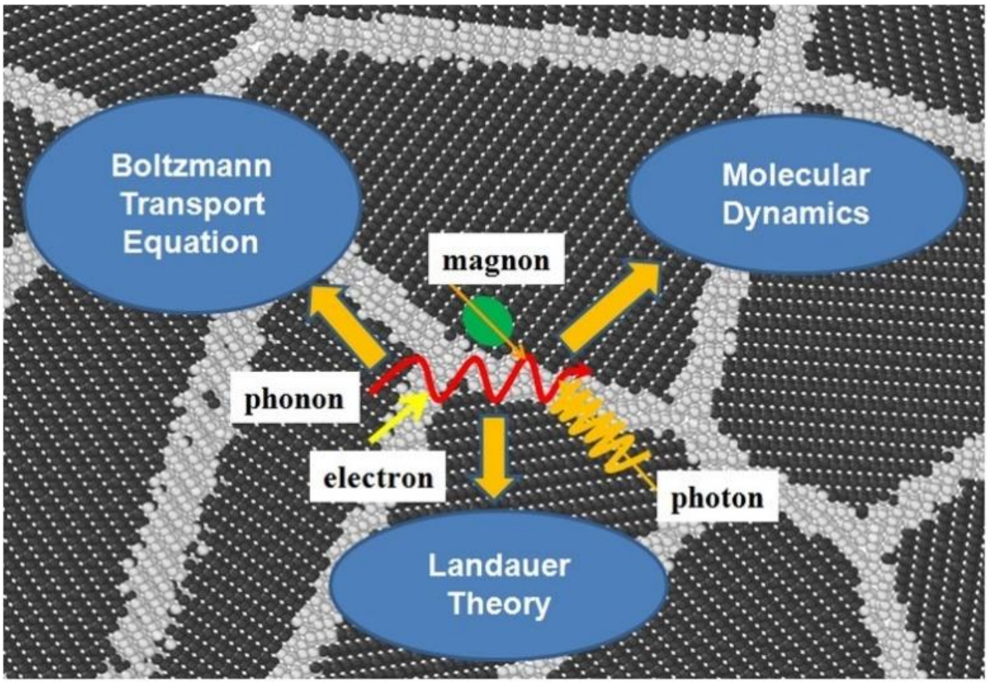

Figure 1. Heat carriers in materials and the corresponding methodologies that capture their behaviours.

Acknowledgements

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The finite element simulation of heat transfer in continuum

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Abstract: The finite element method was used to calculate heat transfer in continuum. First, the governing equation of heat transfer based on conservation of energy was used to deduce the Galerkin weak form equation and discretized FEM equation. Two modes of heat transfer including thermal conduction and convection were taken into consideration, while the thermal radiation mode is neglected for its slight influence in submarine geotechnical engineering. Three kinds of boundary conditions including Dirichlet, Neumann, and Robin boundaries were considered. The backward difference method was used for time domain discretization. Both the steady and transient heat transfer problems were conducted using the FEM code in Matlab. The results were compared with analytical solution for validation.

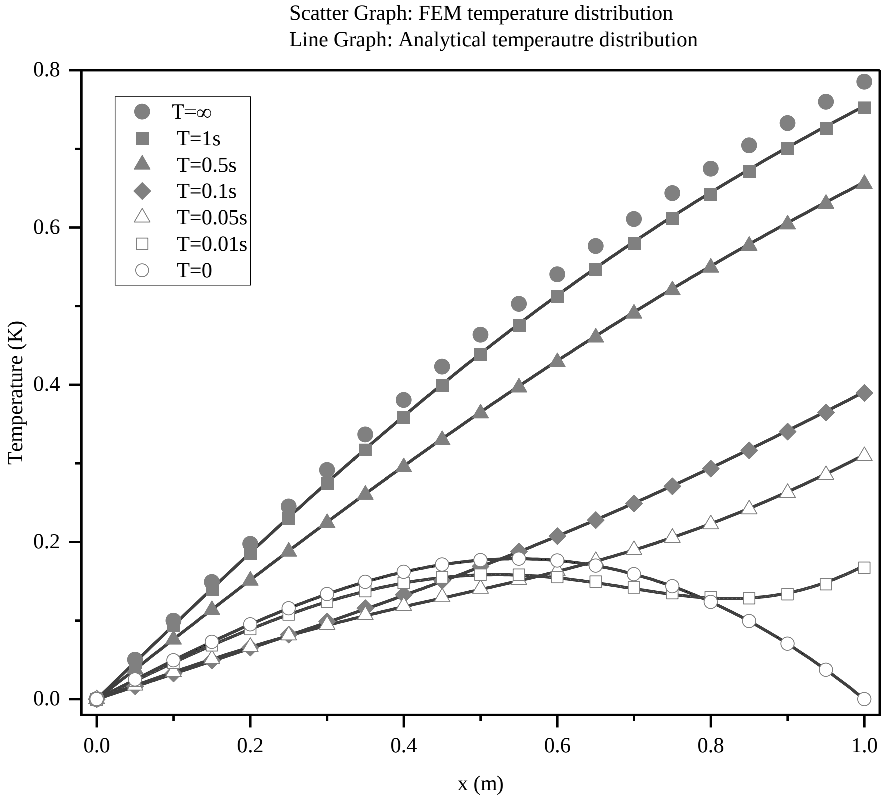

Figure 1. Temperature distribution of the 1D heat transfer problem.

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Large deformations of hyperelastic curved beams based on the absolute nodal coordinate formulation

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Abstract: Compared with traditional linear elastic materials, the soft structure composed of incompressible hyperelastic materials has not only geometrical nonlinearity but also material nonlinearity during deformation. In this paper, the absolute nodal coordinate formulation (ANCF) is used to study the large deformations and large overall motions of incompressible hyperelastic curved beams. A novel large deformation dynamic modeling method for curved beams made of hyperelastic materials is proposed, in which a simplified Neo-Hookean model is combined with the one-dimensional ANCF beam element. The elastic force matrix is calculated according to the exact expression of curvature. The dynamic equations are derived by using the virtual work principle. The dynamic responses of a cantilever silica gel beam under gravity are calculated based on the present method and compared with those of the improved low-order beam element (ILOBE), high-order beam element (HOBE), and commercial finite element analysis software (ANSYS). Simulation results show that the proposed method can accurately describe the large deformation and large overall motion of the beam, and has better computational efficiency. Research in this paper provides an efficient dynamic model for soft robot arm dynamics analysis.

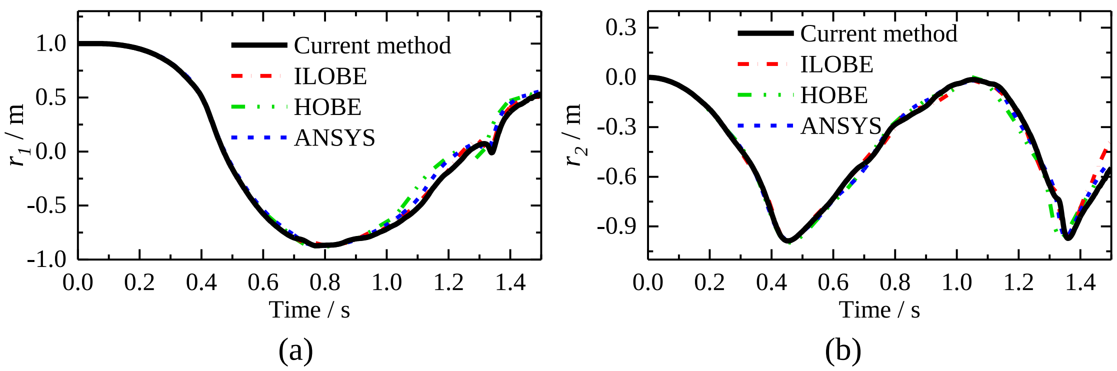

Figure 1. Variations of (a) the tip horizontal and (b) the vertical displacements of the hyperelastic beam calculated by the current method and other methods.

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Novel modelling method for 3D stratigraphic uncertainty

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Abstract: As one of the advanced stochastic simulation methods, random field has been widely applied to estimate 1D and 2D geo-data. However, the poor interpretability of Scale of Fluctuation (SoFs) that are the essential characteristics to determine the performance of the outcomes brings challenges to uncertainty modelling. The determination of SoFs proposed in previous research has been no longer applicable since there is no numerical meaning for discretized data points in space. To address this problem, in the study, the flexibility of a random field in 3D stratigraphic uncertainty modelling with a variety of inputs for horizontal SoFs was examined. The vertical SoFs are determined by the thickness distribution of the stratum. The Gaussian autocorrelation function assigns a probability distribution to each point in the space, and the information entropy is applied to quantify the uncertainty. The proposed method is verified in an in-situ hypothetical case, which can be illustrated by the solid voxel-based model. The results are presented in terms of several SoFs, and the underground stratigraphic uncertainty is well characterized.

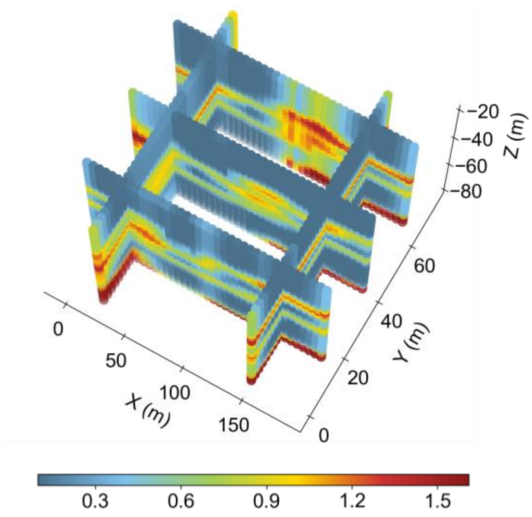

Figure 1. A voxel-based entropy model developed by boreholes

Acknowledgements

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Modelling of monotonic and cyclic behaviors of soil-structure interface using nonlinear incremental model

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Abstract: The soil-structure interface is critically important for the geotechnical engineering structures, such as pile foundation, dam, retaining wall, and tunnel. The behavior of the soil-structure interface, known as a shear zone between the soil and the structure, has attached many scholars' research interests. By now, there are many different models to characterize the behaviour, in general, the models can be separated to two different types of models. This research adopts the exponential function to simulate the shearing behaviors of the soil-structure interface, considering several concepts of soil mechanics (i.e., hardening, softening, dilatancy, nonlinear elasticity, critical state concept, breakage effect, etc.). Good agreement between simulations and experimental results demonstrates that the model is able to reproduce the hardening/softening, critical state, breakage behaviors of the soil-structure interface.

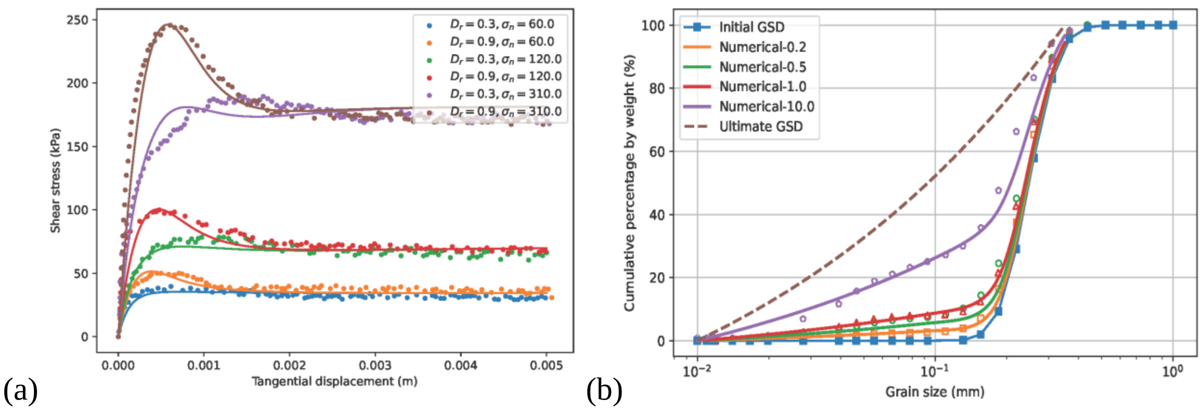

Figure 1. Comparison between test results and model simulations based on exponential-equation-based model: (a): Shear Stress, (b) Grain Size Distribution (GSD)

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Settlement prediction of immersed tunnels by a Bayesian framework

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Abstract: Many immersed tunnels have been reported to suffer a considerable amount of settlement during their long-term service period. Various problems, such as leakage, and concrete cracking are likely to arise as significant settlement develops, which may significantly affect the serviceability performance of an immersed tunnel. Accordingly, accurate prediction of settlement is beneficial to prevent potential damage in an immersed tunnel. In this study, a Bayesian back analysis framework is proposed for predicting the settlement of immersed tunnels based on a beam on elastic foundation model (BEFM) and using knowledge gathered from field observations to promote prediction accuracy. The procedure combines the differential evolution transitional Markov chain Monte Carlo (DE-TMCMC) algorithm with finite element solving algorithm to perform effective sampling and settlement calculation. Field application in the Hong Kong-Zhuhai-Macao (HZM) immersed tunnel is performed to demonstrate the effectiveness of the proposed framework.

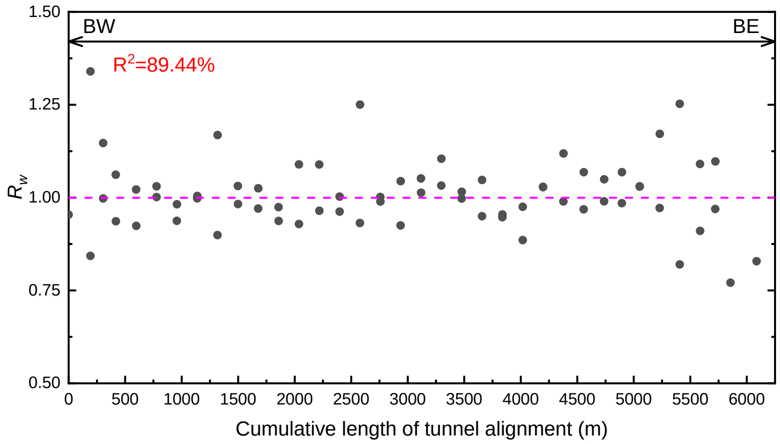

Figure 1. Ratios of predicted settlement to observed settlement along the cumulative length of the tunnel alignment

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Orientation dependent large plasticity of single crystalline gallium selenide

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Abstract: Unlike metals and alloys with high ductility, inorganic semiconductors are mostly ceramics with brittle nature due to covalent/ionic bonding. Recent studies showed that some layered/van der Waals semiconductors could exhibit substantial room-temperature ductility, despite that the underlying mechanisms remain to be understood. Here we report that van der Waals semiconductor GaSe can have crystal orientation-dependent large plasticity at room temperature. Through in situ tensile and compressive experiments inside electron microscopes, we demonstrate that microfabricated GaSe can have substantial ductility loaded along and slanted with the intralayer direction, while showing predominantly elastic deformation perpendicular to the intralayer direction until brittle fracture. We further reveal that, despite the interlayer gliding as the main mechanism, cross-layer slips induced by buckling associated with stacking faults also contribute to the plasticity. This study offers insights to understand the ductility and plasticity of van der Waals semiconductors and shows promising flexible/deformable electronics and energy device applications.

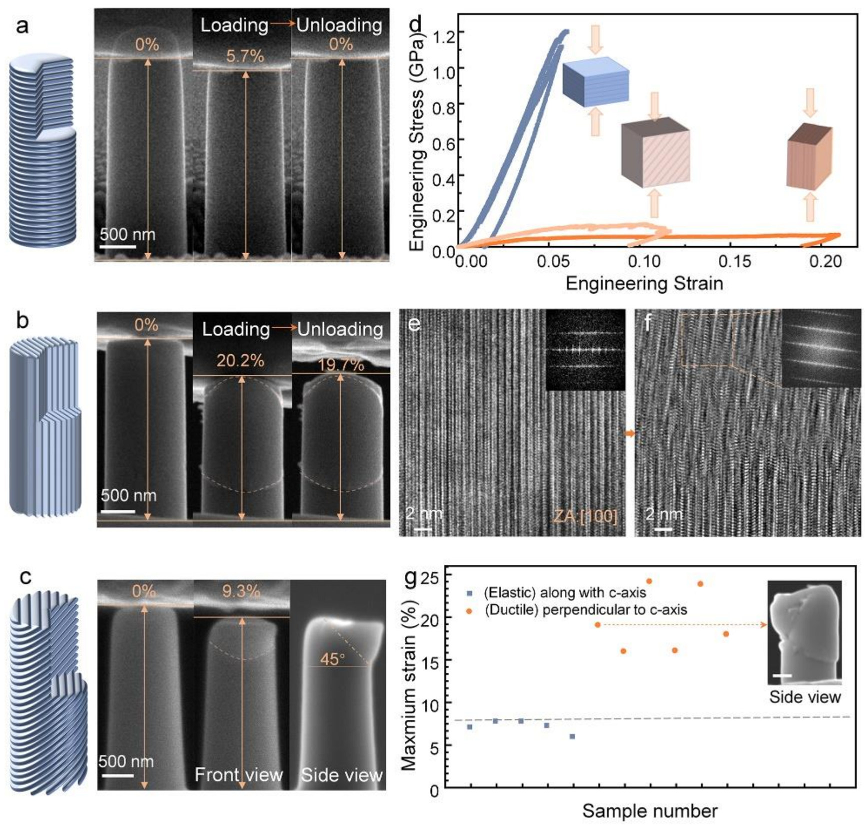

Figure 1. in situ Compression tests on GaSe samples along, perpendicular, and slanted with the c-axis

Acknowledgements

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Simulation on vibration suppression of flexible manipulator with segmented constrained layer damping treatment

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Abstract: In response to the problem that the flexible robot arm in space is prone to vibration, the flexible hollow shell robot arm is covered with segmented constrained layer damping treatment, fully covered active constrained layer damping treatment, and fully covered passive constrained layer damping treatment respectively for better vibration suppressions. The dynamic simulation analysis of the three structural models is carried out by using finite element software, and the vibration suppression effect and damping characteristics of the three models are studied and compared. Due to the segmentation method forms a cut in the constrained layer damping patch, which makes the shear deformation of the viscoelastic material in the vibration suppression process increase, and can effectively improve the damping characteristics of the structure compared with the other two structures. Moreover, it is found that the applicability of segmentation is related to the level of shear strain of the damping layer.

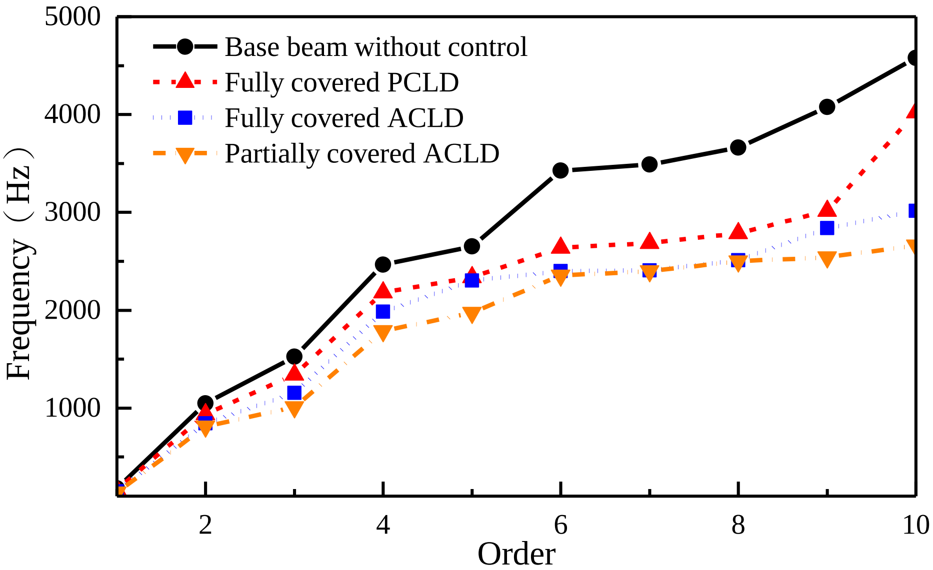

Figure 1. The first ten natural frequencies of the base beam and the three models

Acknowledgements

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Flood risk assessment for vehicles on artificial islands during extreme weather

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Abstract: Heavy rainfall, high tides, and strong wind speeds induce serious inundation and immeasurable losses in coastal areas, posing serious threats to vehicles and people during extreme weather. The west artificial island of the Hong Kong-Zhuhai-Macao Bridge is a vital link between the immersed tunnel and the bridge. In this study, flooding caused by the compound effects of rain and wave overtopping on the artificial island was analyzed, and the risk of vehicles in flood was assessed during extreme weather. The hydrodynamic model for the artificial island was created to evaluate flood disasters with various levels of rainfall and wave overtopping. The flooding process and maximum flood depth distribution for different scenarios were presented. The vehicle damage caused by the flood was evaluated, and the probability-vehicle loss curve was analysed for flood risk assessment. The method described in this study provides technical support for artificial island flood prevention by evaluating the risk of flood.

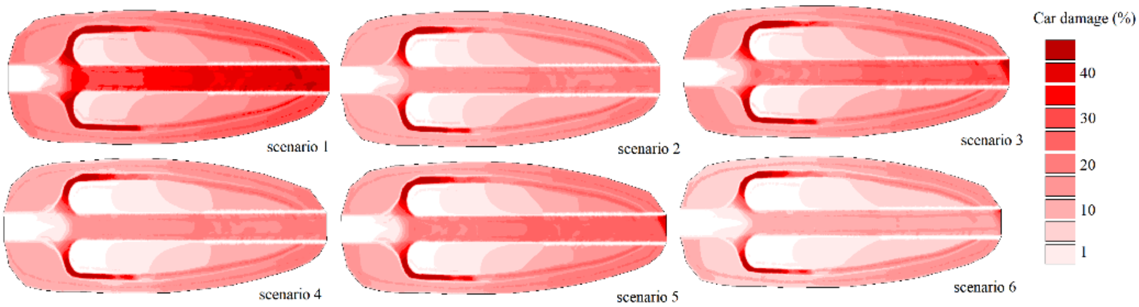

Figure 1. The maximum car damage of the artificial island for different tropical cyclone scenarios.

Acknowledgements

The authors greatly acknowledge the financial support from Ministry of Science and Technology of the People's Republic of China (No. 2019YFB1600700), the Science and Technology Development Fund, Macau SAR (File nos. 0026/2020/AFJ and SKL-IOTSC(UM)-2021-2023), and Research Committee of University of Macau (No. MYRG2018-00173-FST). The authors acknowledge the financial support from the Center for Ocean Research in Hong Kong and Macau (CORE), which is a joint ocean research center established by the Qingdao National Laboratory for Marine Science and Technology and the Hong Kong University of Science and Technology. The authors also acknowledge the Hong Kong-Zhuhai-Macao Bridge National Field Scientific Observation and Research Station for Material Corrosion and Structural Safety.

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Experimental and numerical investigation on the ballistic resistance of 2024+7075 double layers plates impacted by blunt projectiles

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Abstract: Due to the characteristics of high strength, light weight and corrosion resistance, 2024-T351 and 7075-T651 aluminum alloys are widely used to build passive defense structures for military or civilians. This paper studies the ballistic resistance of 2024-T351 (front layer)+7075-T651 (rear layer) aluminum alloy target struck by blunt projectiles by means of experiments and numerical simulation. Ballistic impact tests were performed by using a one-stage gas gun. Experimental results show that the ballistic limit of the double layer target is 155.2 m/s. The front target is failed by shear plugging while the rear target is failed by membrane stretching and global bending. The global deformation of the second plate is larger than that of the first plate. In parallel with experiments, numerical simulations were carried out by ABAQUS/Explicit. The deformation behavior of the 2024-T351 plates was described by a modified Johnson-Cook (MJC) plasticity model accompanied with either the Lode-dependent modified Mohr-Coulomb (MMC) fracture criterion or the Lode-independent Johnson-Cook (MJC) fracture criterion (JC). The deformation behavior of the 7075-T651 plates was described by a Johnson-Cook (MJC) plasticity model accompanied with either the Lode-dependent modified VM fracture criterion or the Lode-independent Johnson-Cook fracture criterion(JC). FE simulation results were compared with the experimental ones and the results showed that the simulation results using the Lode-dependent fracture criterion are closer to the experimental results. Finally, the stress state of the target failure element was analyzed, and the influence of Lode parameters on the simulation results was revealed.

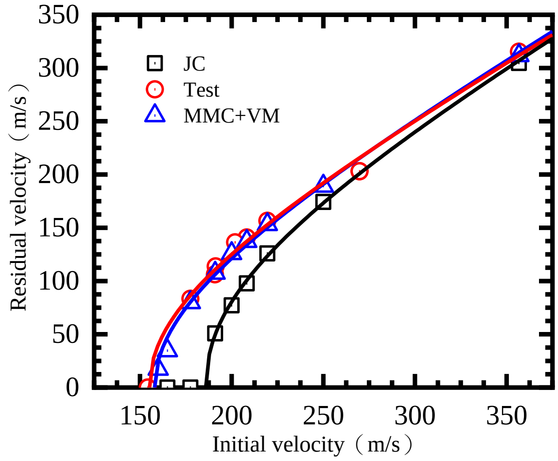

Figure 1. Relationship between initial velocity and residual velocity.

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Energy harvesting using two fully passive flapping foils in tandem

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Abstract: Following our previous works on single fully passive flapping foils[1-2], the present study further investigated the energy harvesting performance of a two-foil system. A pair of new test rigs was designed and manufactured. The energy harvesting performance of single foil deployed was tested by experiment at a freestream velocity 0.62 m/s, corresponding a Reynolds number 8.7×10^4. The efficiency is around 15.1% with total power coefficients 0.20 and heaving power coefficient 0.15. To reveal more flow details, a CFD study was also conducted in accord with the experimental arrangement. The dynamics and energy extraction performance of the tandem flapping foils were studied with various initial conditions as well as streamwise distances. Both the experimental and numerical results indicated that the terminal phase difference between the two foils is independent of the initial releasing conditions within the tested range in their streamwise distance (from *c* to 6*c*, where *c* is chord length). Furthermore, the phase difference is positively correlated with the streamwise distance. As the streamwise distance is less than 2.5*c*, the upstream foil is significantly influenced by the downstream foil due to the blockage effect. When the distance is further extended to beyond 2.5*c*, it behaves like the single foil. As for the downstream foil, it was found that its energy harvesting performance is always enhanced, caused by the wake shed from the upstream foil. The maximum efficiency of 19.7% was achieved by the downstream foil with the streamwise distance *c*, significantly increased from 16.7% for the single foil. Thus, if only considering the power output, the smallest streamwise distance, i.e., *c*, can help the system gain the overall best efficiency, i.e., 37%. Nevertheless, when taking the structural integrity into consideration, a streamwise distance of no less than 2.5*c* is recommended.

Acknowledgements

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3D printing of hierarchically strengthened medium-entropy alloy microlattices via structure-material-process integration

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Lightweighting and complex geometries manufacturing have been two of the greatest yet longstanding challenges for any structural applications. Combining the additive manufacturing (AM) techniques and cellular structure design, AM-ed microlattices provide us new opportunities for developing advanced structure materials with exceptional mechanical performance. In this paper, from nanoscale to macroscale, we designed and fabricated hierarchically strengthened medium-entropy alloy microlattice via micro-selective laser melting technology. The microlattices shows excellent high energy absorption and specific strength.

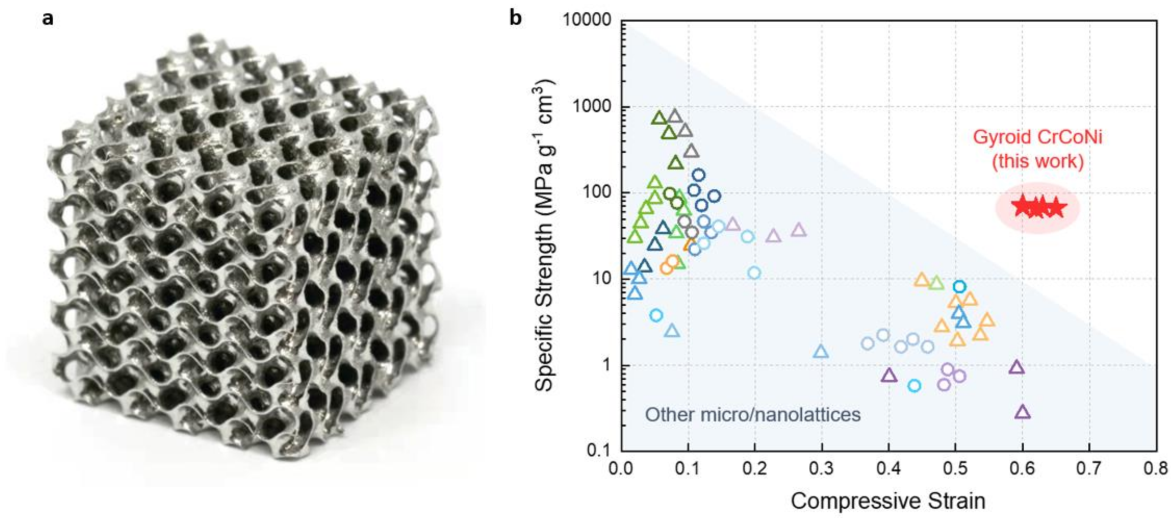

Figure 1. Fabrication and mechanical performance of CoCrNi medium-entropy alloy microlattice. a) CoCrNi gyroid microlattice fabricated via micro selective laser melting (uSLM). b) Plot of specific compressive strength against compressive strain showing the mechanical properties of uSLM CoCrNi microlattice compared to previously reported micro and nanolattices.

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Three-dimensional meta lattice structures for broad band vibration suppression and sound absorption

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Abstract: Phononic crystals (PCs) and acoustic metamaterials (AMs) have been studied due to their unique performance in generating elastic wave bandgaps. However, for vibration isolation structures with load bearing requirements, the conflict between stiffness and vibration control of the periodic structures is still a major concern. This work presents a new type of three dimensional (3D) single-phase meta-plate lattice (MPL) structure consisting of chiral microstructures. When the elastic wave propagates through the lattice structure, the energy is absorbed by the multiple vibration modes of the chiral surface, thus achieving the effect of broadband vibration reduction. In order to illustrate the isolation effect and the cause of bandgap formation, the propagation characteristics of elastic waves in a meta-plate beam are studied numerically and the isolation effect of the proposed lattice structures are validated by the vibration transmission tests. The sound absorption experiment is also carried out to evaluate the sound absorption performance of the new structure. This work offers an innovative method to develop new multi-functional lattice structures with both load bearing, vibration attenuation and sound reduction requirements.

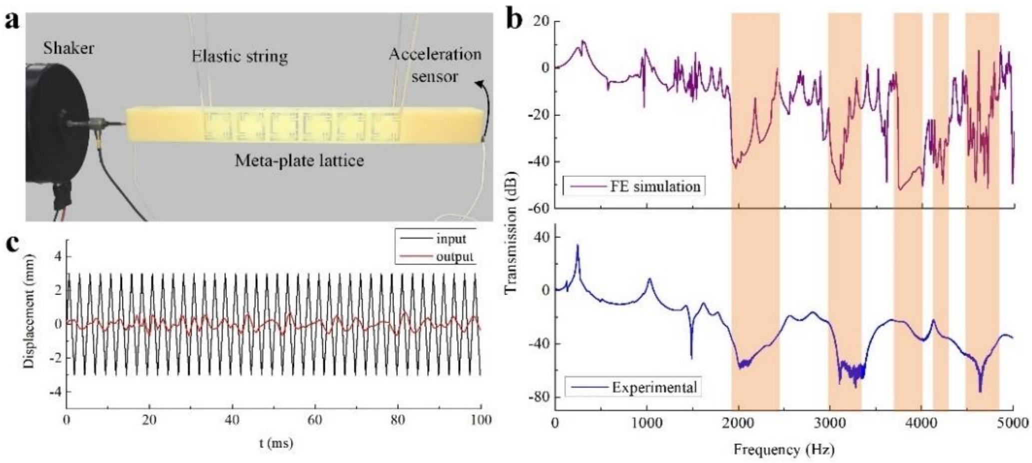

Figure 1. Verification of vibration isolation effectiveness of the meta-plate lattice structure.

Acknowledgements

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On the generalized Snell's law for the design of elastic metasurfaces

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Abstract: Various metasurfaces have been designed based on the generalized Snell's law (GSL), but their performances are undermined by extra propagating waves that do not follow the GSL, especially when the phase gradient is large [1]. Although a modified version of GSL has been proposed for acoustic metasurfaces to describe the extra waves [2], the underlying mechanism of extra wave generation remains unclear. For elastic metasurfaces, such extra waves also exist as shown in Figure 1, indicating that the GSL might be invalid under some circumstances. In light of this, a systematic numerical study on the GSL for elastic waves is performed. It is found that mismatched impedance, material discontinuity, and phase discontinuity are the sources of the extra waves. The generation mechanisms of the extra waves from these sources are identified and theoretically justified. Based on these results, a guideline on metasurface design for improved performance is devised.

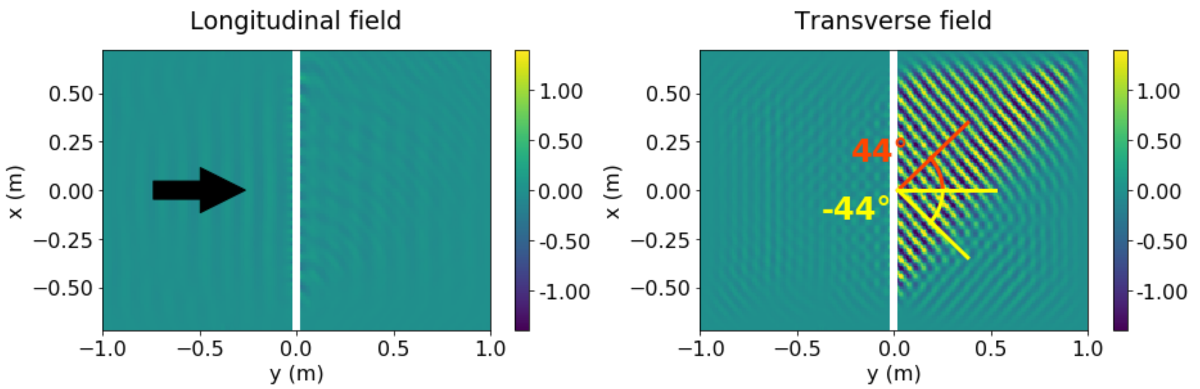

Figure 1: The scatter longitudinal field and transverse field after a longitudinal wave incident normally on the metasurface at y = 0 from the left. According to the GSL, the transmitted wave should be a transverse wave that travels at 44°. However, weaker wave components that travel at -44° and 0° can also be observed in the transmitted transverse field.

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A time-domain structural response reconstruction method based on mode synthesis

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Abstract: Response reconstruction of large-scale civil structures by traditional methods will result in heavy computational burden and low efficiency. To improve the efficiency, a novel time-domain response reconstruction method based on mode synthesis is proposed in this paper. According to mode synthesis, the target structure is divided into several substructures and the finite element model of each substructure is condensed to a super-element. The super-elements of all substructures are then coupled to represent the target structure. The dimensions of model matrices of the condensed structure can be sharply reduced. Thus, the computational efficiency of time-domain response reconstruction using the condensed structure can be greatly improved. The procedure of this novel response reconstruction method is shown in the flowchart below. The accuracy and efficiency of the proposed response reconstruction method were verified using a numerical example of a frame structure.

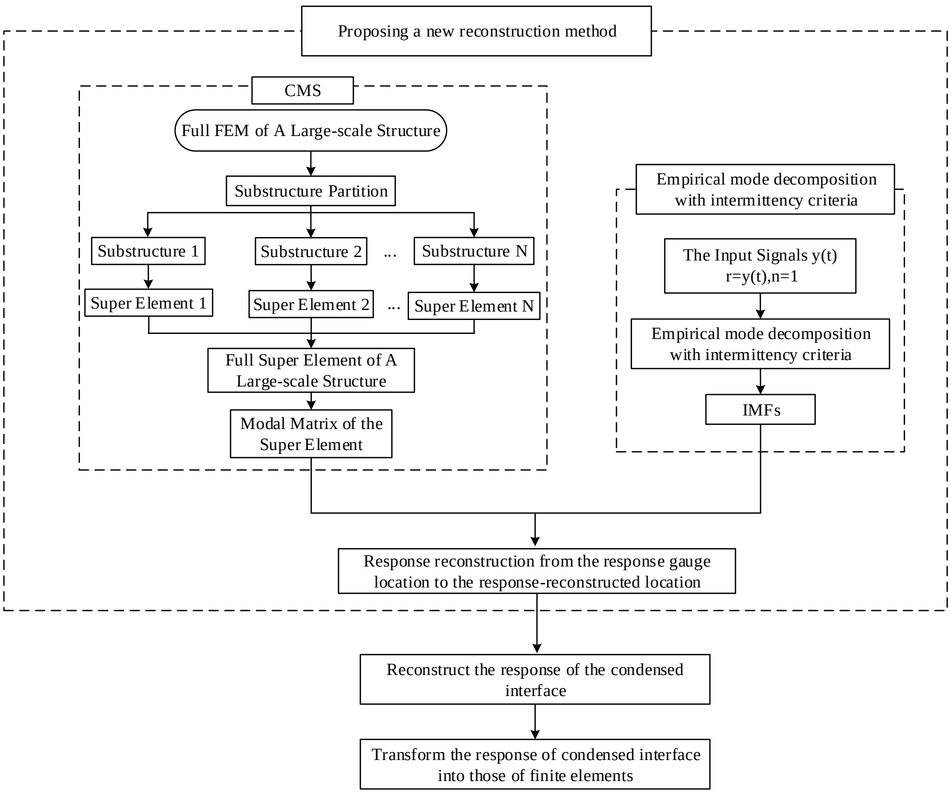

Figure 1. The flow chart of this new response reconstruction method

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A finite strain consolidation model considering creep and non-Darcy's flow for vertical drains-improved clay under surcharge and vacuum preloading

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Abstract: Vertical drains with vacuum combining surcharge preloading is an effective method for speeding the consolidation and enhancing the stability of soft clay ground. When the soil is in a state that has a large void ratio or high water content, a large surface settlement compared with the thickness will occur and the flow law may deviate from Darcy's law. The creep is also non-negligible in the prediction of consolidation process especially for soft clays. Therefore, it is of significance to develop a finite consolidation model considering above factors to predict the consolidation process accurately. In this study, a finite strain consolidation model based on Barron's free-strain theory incorporating creep model, radial and vertical flows, non-Darcian flow law, the weight of the soil, changing hydraulic conductivity and compressibility is presented. The proposed model is compared with existing radial consolidation model and finite element simulation for the validation. It is then applied to predict the settlement of a long-term monitoring embarkment with good performance.

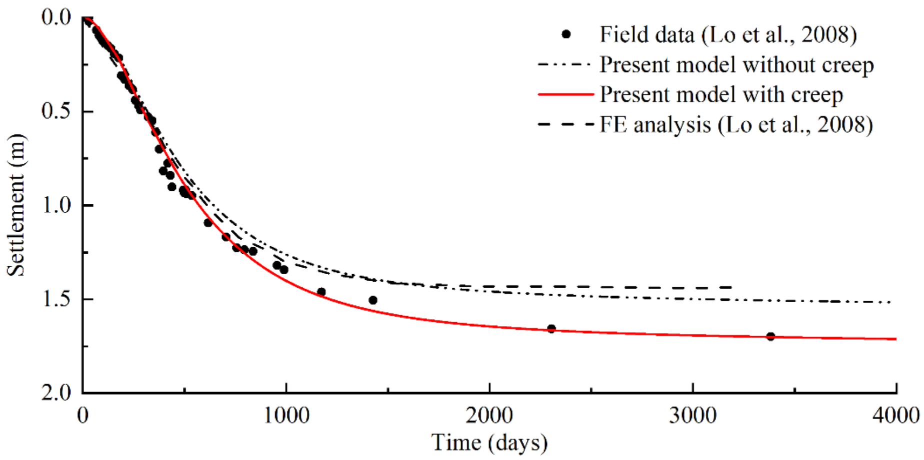

Figure 1. Comparison between the predicted results using the proposed model and the observed and simulated results by Lo et al. (2008)

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Application of deep learning techniques in type classification, geometry evaluation, 3D reconstruction and strength prediction of rock particles

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Abstract: Rock assemblies, such as ballasts and cobbles, are typically composed of granular particles of various types and shapes that significantly affect their mechanical behaviour such as the compressive strength of rock assemblies. In this study, a systematic framework is proposed to identify the types and to estimate the compressive strength, and to reconstruct the 3-dimensional shapes of rocks particles. Firstly, a dynamic particle scanning system was proposed to capture the images of particles through a series of vibration so that each particle can generate multiple images with different angles. Then a rock dataset was obtained by a dynamic particle scanning system, and the types and compressive strength were tested and labelled for each rock particle. Then a DenseNet model was trained for the rock type classification and compressive strength prediction. Finally, a video instance segmentation algorithm was applied to track the trajectory of each particle, and the 3-dimensional reconstruction results can be obtained based on the images in the trajectory. The results demonstrated that the proposed approach is robust and efficient in type classification, strength estimation, and 3D reconstruction of rock particles and offers a rapid and low-cost practical solution for dealing with rock assemblies.

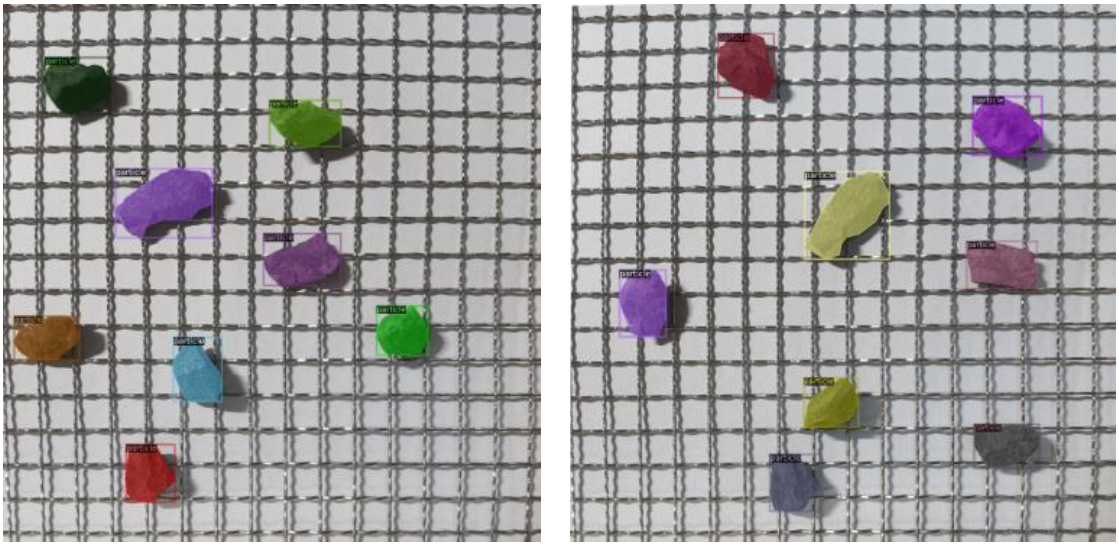

Figure 1. The tracking results of the particles.

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Research on the settlement prediction of immersed tunnel based on the physics-informed machine learning

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Abstract: In the service period of an immersed tunnel, large differential settlement may lead to serious safety problems. The settlement prediction of an immersed tunnel faces several uncertainties, including the complex stratigraphic distribution problem, errors of measurement, back-silting and dredging, etc. In this study, based on the simplification of taking a tunnel as a multi-beam model, a physics-informed machine learning method was proposed to analyse the foundation modulus distribution of the tunnel and predict its settlement. A case study with the designed parameters showed that the proposed method can overcome 20% of noise while using at least three groups of settlement data as training set. Furthermore, with seven to ten groups of training data, accurate and stable results can be obtained. For the uncertainties in the problem, the Markov Chain Monte Carlo algorithm and Bayesian theory were introduced to calculate the credible interval of the prediction, which further improves the accuracy of the analysis. The data analysis on the immersed tunnel of the Hong Kong–Zhuhai–Macao Bridge proved that the proposed method is applicable to practical engineering.

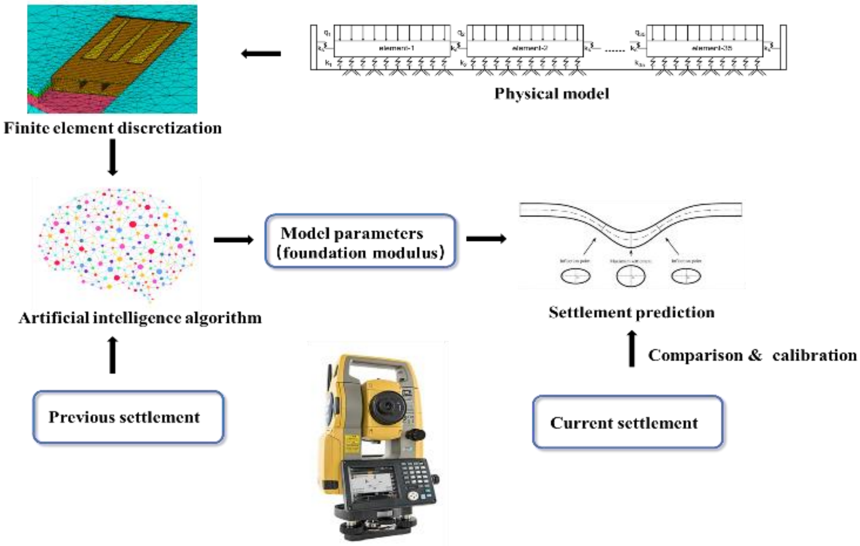

Figure 1. Framework of the settlement analysis of immersed tunnel with physics-informed machine learning method

Acknowledgements

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A novel method for automatic identification of concrete micro-damage: artificial intelligence-improved DIC

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Abstract: In this paper, a three-point bending experiment of concrete was done to investigate the identification and early warning of micro-damage of concrete. DIC was utilized to acquire physical quantities such as strain and displacement on the surface of concrete specimens during the experiment. A back propagation artificial neural network (BP-ANN) containing three hidden layers with seven neurons per layer and micro-damage indicator (MDI) of concrete was proposed. Then different combinations of physical quantities obtained by DIC were adopted as the input vector to train and calculate by the BP-ANN. By comparing the MDI of different combinations and the load-displacement curves in the experiment, it is verified that the BP-ANN method can effectively identify micro-damage and give early warning. Comparing the results of the BP-ANN method with those of the DIC strain nephogram, it is found that the BP-ANN method with appropriate warning thresholds can make earlier warning and identification of micro-damage of concrete. T Using the BP-ANN improved DIC technique, automatic identification of concrete micro-damage can be achieved by setting appropriate indicator parameters and avoiding the subjectivity of human judgment.

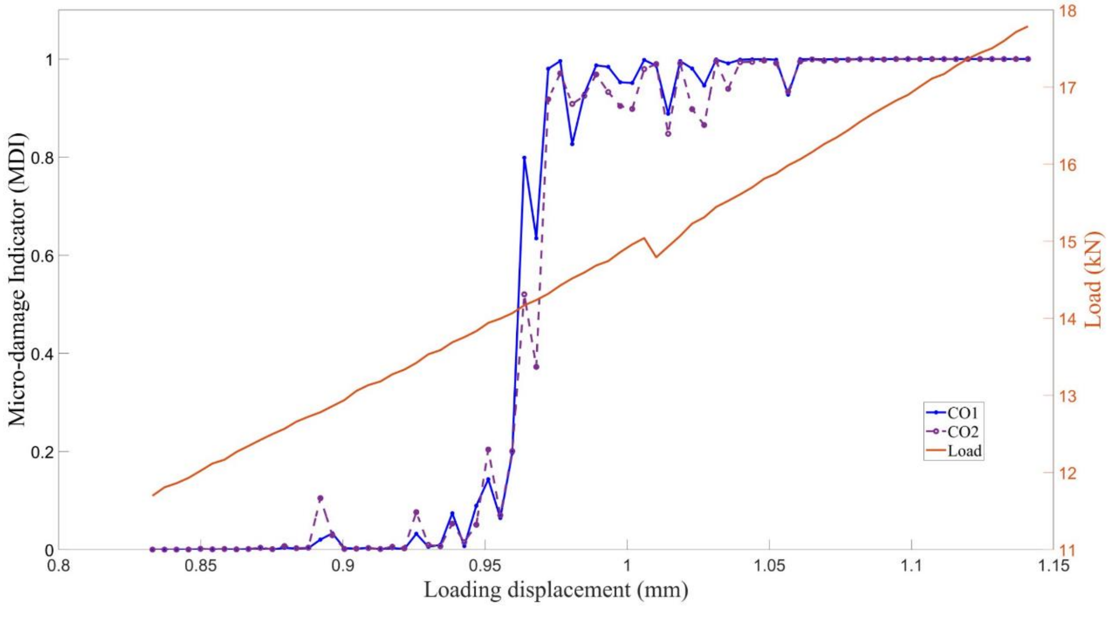

Fig. 1. Calculation results of sample data under CO1 and CO2

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Data-driven modelling of rate-dependent behaviour of soft clays

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Abstract: Soft clays exhibit complex rate-dependent and path-dependent behaviours. Conventional phenomenological elastic-viscoplastic models include myriad parameters that need to be calibrated by case-specific experiments. The data-driven modelling method has recently emerged and provided an alternative to constitutive modelling. This study uses a multi-fidelity residual neural network (MR-NN) to model elastic-viscoplastic behaviours of clays, and reduce the demand for experimental data. A low-fidelity (LF) model trained using LF data generated by a phenomenological model is employed to capture a general trend of stress-strain relationship. A high-fidelity (HF) model trained using HF data generated by experimental tests is used to calibrate the predictions of the LF model for enforcing the agreement with the actual results. Long short-term memory and feedforward neural networks are used as the fundamental algorithms for constructing LF and HF models, respectively. MR-NN is employed for constitutive modelling of various clays. Besides, the effect of LF data on the performance of the multi-fidelity model is also discussed to verify the generalization ability of MR-NN. The results demonstrate that undrained shear strength and pore-water pressure can be accurately simulated by the proposed MR-NN. The MR-NN modelling approach can leverage both LF and HF data, achieving accurate simulations with fewer costs and is robust to the change of LF data, thus showing a large potential in constitutive modelling of complex soil behaviours.

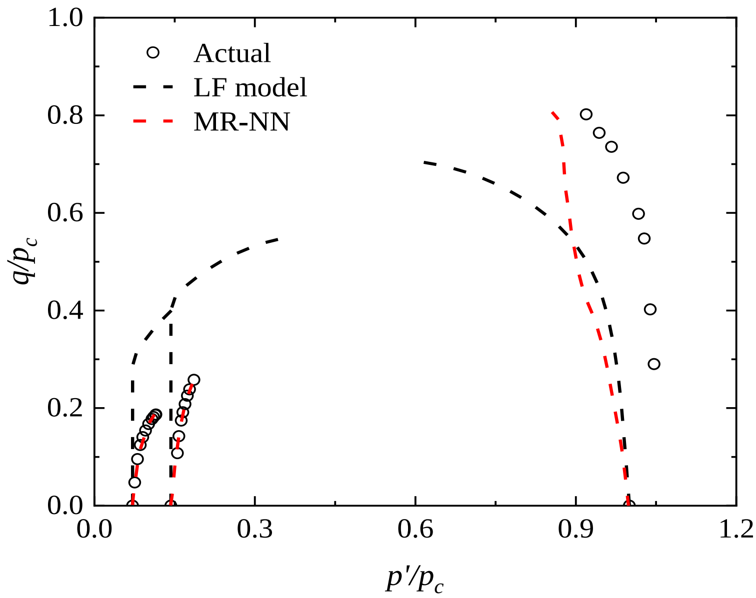

Fig. 1 Predicted and actual stress paths based on various models

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基于 Wavelet-Gramian 的故障特征数据重构方法

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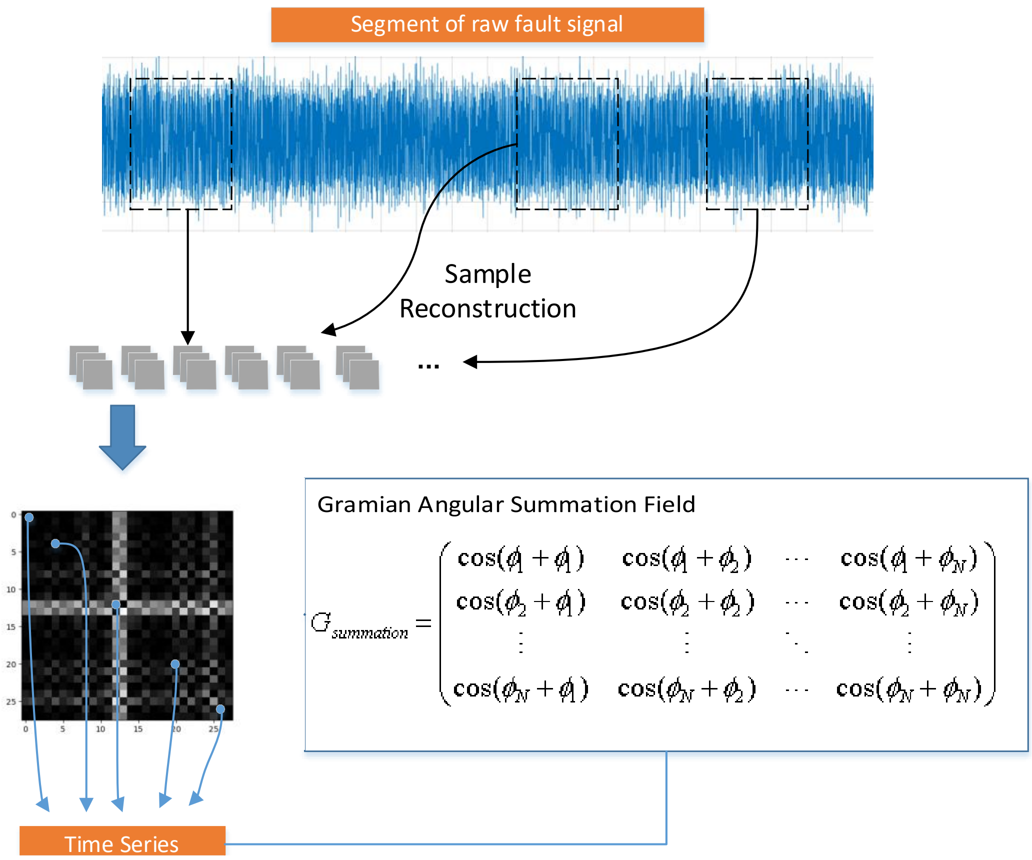
摘要：一维时间序列数据是常见的用于故障诊断特征提取的原始数据形式，通过对应传感器和数电信号转换器可以轻易获取，堪称工业设备故障诊断的璞玉。然而，高性能的智能诊断网络模型往往具有个体复杂性，对于工业计算机不具有普适性，且过于原始的故障数据使得具有简单结构的网络的性能变得捉襟见肘。为提高少量特征工程在基于深度学习的故障网络模型的应用，本文提出一种基于 Wavelet-Gramian 的故障特征数据重构方法，该方法的核心是通过小波变换将原始数据信号进行滤波处理，细化故障数据时频细节，在通过格拉姆角场将经小波处理的时序信号进行升维重构，形成的二维时序图可以通过像素值量化故障特征重要程度，最后通过 VGGNet 进行验证，实验结果表明，该方法在降低网络训练难度的同时提高了诊断的精确度，使轻量级网络在复杂设备故障诊断工作中具备竞争力。
关键词：数据重构；深度学习；小波变换；格拉姆角场；工业设备；故障诊断



$$G_{summation}=\begin{pmatrix}\cos(\phi_1+\phi_1) & \cos(\phi_1+\phi_2) & \cdots & \cos(\phi_1+\phi_N)\\ \cos(\phi_2+\phi_1) & \cos(\phi_2+\phi_2) & \cdots & \cos(\phi_2+\phi_N)\\ \vdots & \vdots & \ddots & \vdots\\ \cos(\phi_N+\phi_1) & \cos(\phi_N+\phi_2) & \cdots & \cos(\phi_N+\phi_N)\end{pmatrix}$$

图 1. 原始信号升维重构示意图

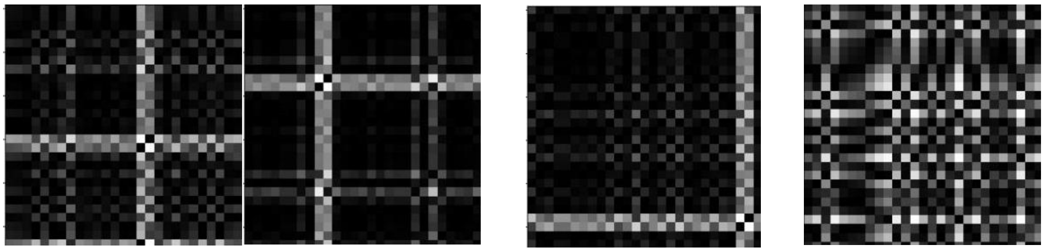


图 2. 利用格拉曼角从一维振动信号中得到的二维故障时序图

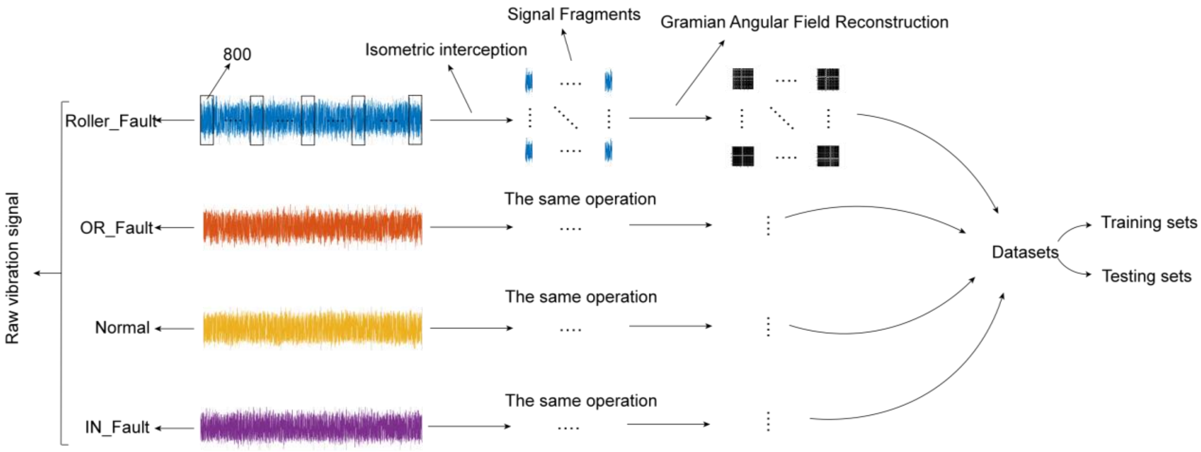


图 3. 数据集形成

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