# The Thirty-Second KKHTCNN Symposium on Civil Engineering


**October 24-26, 2019**

**KAIST Mun-Ji Campus, Daejeon, Korea**

## Organized by

Korea Advanced Institute of Science and Technology (KAIST)

## Coordinators

Tomomi Yagi, **K**yoto University

Gye-Chun Cho, **K**orea Advanced Institute of Science and Technology

Xueqing Zhang, **H**ong Kong University of Science and Technology

Huanjun Jiang, **T**ongji University

Tirawat Boonyatee, **C**hulalongkorn University

Louis Ge, **N**ational Taiwan University

Sze Dai Pang, **N**ational University of Singapore

# FOREWORD

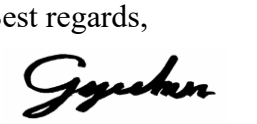
On behalf of the organizing committee members of KAIST, we welcome all the participants to the Thirty-Second KKHTCNN Symposium on Civil Engineering who come from Korea Advanced Institute of Science and Technology (KAIST), Kyoto University (KU), Hong Kong University of Science and Technology (HKUST), Tongji University (TU), Chulalongkorn University (CU), National Taiwan University (NTU) and National University of Singapore (NUS).

For the last thirty-one years, we have held this symposium successfully and enriched the participating members continuously. Through this symposium, we have demonstrated our growing strength and influence in the international communities of Civil Engineering, and this symposium will play a greater role in the future as a platform for students and faculty members to contribute to the development of Civil Engineering technologies. This year, we have sought to organize a special session on smart city, a global new trend for demonstrating the present and future of smart cities.

It is our great honor to host the Thirty-Second KKHTCNN symposium at KAIST, Daejeon, Korea, October 24-26 in 2019. We truly believe that this symposium is a wonderful opportunity for all the participants to foster and advance our professional knowledge and visions in the Civil Engineering.

I wish that the Thirty-Second KKHTCNN symposium becomes a very meaningful and fruitful event for every participant and hope you enjoy the stay in Daejeon, Korea during the symposium.

Best regards,



Gye-Chun Cho
Chair of Thirty-Second KKHTCNN Symposium Committee
Professor, Dept. of Civil and Env. Eng., KAIST

# ORGANIZATION

## Coordinators

Tomomi Yagi, Kyoto University (KU)

Gye-Chun Cho, Korea Advanced Institute of Science and Technology (KAIST)

Xueqing Zhang, Hong Kong University of Science and Technology (HKUST)

Huanjun Jiang, Tongji University (TU)

Tirawat Boonyatee, Chulalongkorn University (CU)

Louis Ge, National Taiwan University (NTU)

Sze Dai Pang, National University of Singapore (NUS)

## Local Organizing Committee

**Chair**

Gye-Chun Cho (KAIST)

**Member**

Jung-Wuk Hong (KAIST)
Hyung-Jo Jung (KAIST)
Youngchul Kim (KAIST)
Tae-Hyuk Kwon (KAIST)
Yoonjin Yoon (KAIST)

**Staff**

Sung Ae Je (KAIST)
Moon-Sook Jung (KAIST)
Joo-Young Im (KAIST)
Hyung-Soo Kim (KAIST)

## Sponsoring Organizations

Korea Advanced Institute of Science and Technology (KAIST)
Daejeon International Marketing Enterprise (DIME)

# Contents

# Symposium Program

**Day 1: Thursday, October 24, 2019** **Venue: KAIST Mun-Ji Campus**

| Time | Event | | | | | |
|---|---|---|---|---|---|---|
| **08:30 – 12:00** | **Registration** (1st Floor of Lecture Wing) | | | | | |
| **09:00 – 09:20** | **Opening Ceremony** (Supex Hall) | | | | | |
| **09:20 - 10:00** | **Keynote I** (Prof. C.B. Yun, KAIST & ZJU) | | | | | |
| **10:00 – 10:40** | **Keynote II** (Prof. C.F. Leung, NUS) | | | | | |
| **10:40 – 11:00** | **Group Photo** (Lobby) | | | | | |
| **11:00 – 11:20** | Coffee Break | | | | | |
| **11:20 – 12:50** | **Parallel Session 1** | | | | | |
| | Structural Engineering 1 (Rm 401) | Structural Engineering 2 (Rm 403) | Geotechnical Engineering 1 (Rm 405) | Geotechnical Engineering 2 (Rm 409) | Construction Engineering 1 (Rm 202) | Civil Engineering 1 (Rm 204) |
| **12:50 – 13:50** | Lunch (The lunch box will be provided.) | | | | | |
| **13:50 – 15:40** | **Parallel Session 2** | | | | | |
| | Structural Engineering 3 (Rm 401) | Structural Engineering 4 (Rm 403) | Geotechnical Engineering 3 (Rm 405) | Geotechnical Engineering 4 (Rm 409) | Construction Engineering 2 (Rm 202) | Transportation Engineering 1 (Rm 204) |
| **15:40 – 16:10** | Coffee Break | | | | | |
| **16:10 – 18:00** | **Parallel Session 3** | | | | | |
| | Structural Engineering 5 (Rm 401) | Structural Engineering 6 (Rm 403) | Geotechnical Engineering 5 (Rm 405) | Geotechnical Engineering 6 (Rm 409) | Construction Engineering 3 (Rm 202) | Transportation Engineering 2 (Rm 204) |
| **18:00 – 18:20** | Free Time | | | | | |
| **18:20 – 20:20** | Welcome Dinner (Lobby) | | | | | |

**Day 2: Friday, October 25, 2019** **Venue: KAIST Mun-Ji Campus**

| Time | Event | | | | | |
|---|---|---|---|---|---|---|
| **09:00 – 10:30** | **Parallel Session 4** | | | | | |
| | Structural Engineering 7 (Rm 403) | Structural Engineering 8 (Rm 405) | Geotechnical Engineering 7 (Rm 409) | Materials (Rm 202) | Smart City Session 1 (Rm 401) | |
| **10:30 – 11:00** | Coffee Break | | | | | |
| **11:00 – 12:30** | **Parallel Session 5** | | | | | |
| | Structural Engineering 9 (Rm 403) | Structural Engineering 10 (Rm 405) | Geotechnical Engineering 8 (Rm 409) | Construction Engineering 4 (Rm 202) | Smart City Session 2 (Rm 401) | |
| **12:30 – 13:30** | Lunch (The lunch box will be provided.) | | | | | |
| **13:30 – 15:00** | **Parallel Session 6** | | | | | |
| | Structural Engineering 11 (Rm 401) | Structural Engineering 12 (Rm 403) | Structural Engineering 13 (Rm 405) | Geotechnical Engineering 9 (Rm 409) | Civil Engineering 2 (Rm 202) | Transportation Engineering 3 (Rm 204) |
| **15:00 – 15:30** | Coffee Break | | | | | |
| **15:30 – 17:00** | **Parallel Session 7** | | | | | |
| | Structural Engineering 14 (Rm 401) | Structural Engineering 15 (Rm 403) | Structural Engineering 16 (Rm 405) | Geotechnical Engineering 10 (Rm 409) | Civil Engineering 3 (Rm 202) | Water Resource Engineering (Rm 204) |
| **17:00 – 17:30** | Move to Main Campus | | | | | |
| **17:30 – 18:00** | Free Time | | | | | |
| **18:00 – 20:30** | Symposium Banquet (Sky Lounge of Academic Cultural Complex)<br>1. Closing Address<br>2. Best Presenter Award | | | | | |

**Day 3: Technical Tour**

**Tour Sites:**

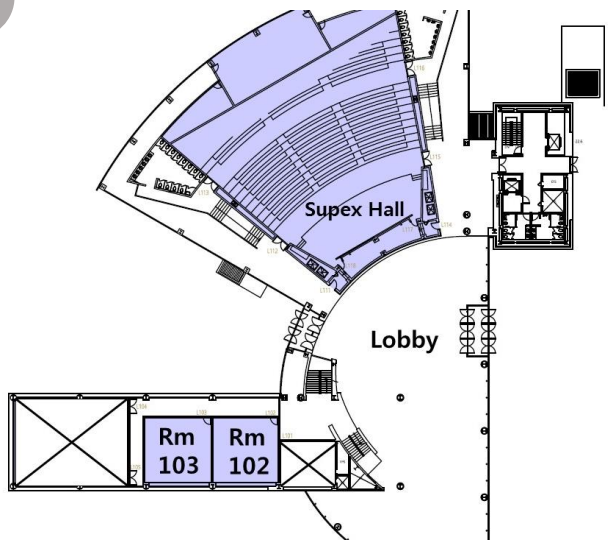
- **Sejong Smart City**
  Center for Smart City

- **Buyeo, a Historical City of Ancient Baek-je Kingdom**
  Goransa Temple
  Buso-san Forest
  Buyeo National Museum
  Gungnam-ji Pond

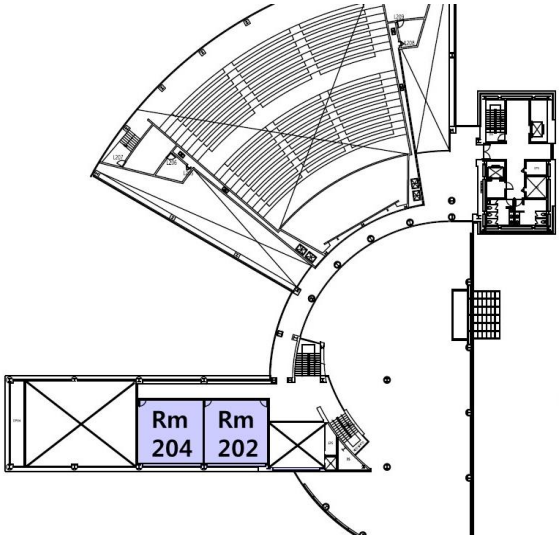

# Floor Plan

The conference will take place on 1st, 2nd and 4th floors of Lecture Wing, KAIST Mun-Ji Campus

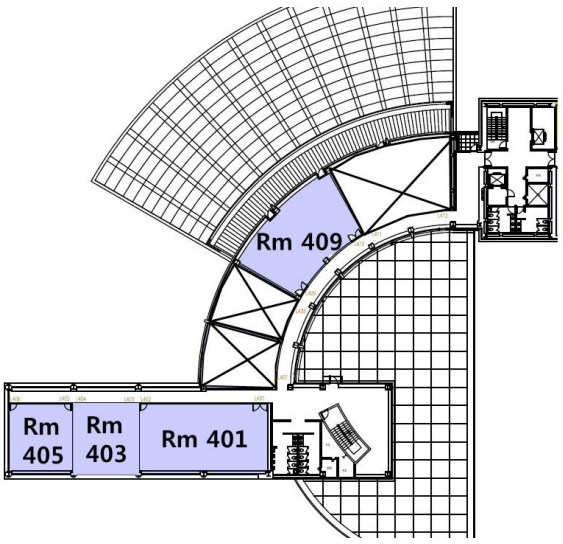
1F




2F




4F



# *Keynote Lectures*

# Professor Chung Bang Yun

Department of Civil Engineering
College of Civil Engineering and Architecture, in Zhejiang University

Professor Chung Bang Yun is currently a fulltime adjunct professor at Department of Civil Engineering, College of Civil Engineering and Architecture, in Zhejiang University. He is also a professor emeritus both at Korean Advanced Institute of Science & Technology (KAIST) and Ulsan National Institute of Science & Technology (UNIST) in Korea. He received his B.S. degree in civil engineering at Seoul National University, Korea in 1969, and his Ph.D. degree in civil engineering at Columbia University in 1978. He worked at KAIST as a professor in 1982-2012, and at UNIST as a chaired professor in 2012-2015. He was the director of Smart Infrastructure Technology Center at KAIST in 2002-2011. His primary research areas are structural dynamics, stochastic mechanics, smart sensors, structural monitoring, damage assessment, earthquake, wind, and offshore engineering. He served as an editor-in-chief of Smart Structures & Systems, *an International Journal*. He is a member of the Korean Academy of Science and Technology, and a member of the National Academy of Engineering of Korea.

# Recent R&D on Guided Waves and Impedance-based SHM

C. B. Yun[1*], Y. F. Duan[1], X. Xu[1], J. Q. Tu[2], and X. D. Sui[2]

*[1, 2]Department of Civil Engineering, Zhejiang University, China,*
**Corresponding Author: ycb@zju.edu.cn*

**Abstract**

Recent R&D activities on guided waves and electro-mechanical impedance methods are presented for effective assessments of small local damages in the structural health monitoring (SHM) of steel structural members, such as beam, cable, and anchorage of steel tendons. Piezo-electric and magneto-strictive sensors are used as actuators and receivers. Semi-analytical finite element (SAFE) method is employed for analyzing the wave dispersion characteristics regarding the wave modes, exciting frequencies, and propagation speeds in slender structural members. Damage detections are carried out based on the residuals between the current measurements and the reference signals. Time of flight information is used for damage localizations. Advanced pattern recognition techniques are introduced for effective damage detection and localization. Wavelet analysis are employed for construction of damage indices, principal component analyses (PCA) are for compensation of the temperature effect, and independent component analyses (ICA) are for effective damage localization in the guided waves methods. On the other hand, artificial neural network (ANN) technique is used for autonomous frequency range selection for the impedance-based method. Wireless impedance nodes are also introduced for SHM of multiple locations spread in a wide range. Experimental validations were carried out successfully for wire breakage and corrosion damages in a cable, small damages on the weldment of a beam, loose bolts in a bridge girder, and tension losses in steel tendons.

**Keywords:** Guided Waves; Impedance; SHM; Steel Members; Cables; Piezo-electric Sensors; Magneto-strictive Sensor; Temperature Compensation; Wavelet; SAFE; PCA; ICA; ANN

# Professor Chun Fai Leung

Department of Civil Engineering
National University of Singapore

Professor LEUNG Chun Fai is a professor in the Department of Civil Engineering at the National University of Singapore. Professor Leung has taught courses in geotechnical engineering, pile foundations, rock mechanics and foundation analysis. He has published many technical papers in international journals and conferences covering topics such as centrifuge modelling of geotechnical problems, pile foundations, land reclamation and excavation in jointed rocks. Professor Leung has delivered keynote/invited lectures at many international geotechnical and offshore engineering conferences. He is on the ISO Jack-up foundation panel P4.

Professor Leung is a registered professional engineer (geotechnical specialist) in Singapore and a chartered civil engineer in UK. He has served as a geotechnical consultant for many government and private organisations involving projects in Singapore and the region on pile foundations, land reclamation, seafront wharf structures, anchored retaining wall, centrifuge model testing, slope stability, soil settlement and erosion studies.

# Centrifuge model study on onshore, marine and offshore geotechnical problems

C. F. Leung

*Department of Civil and Environmental Engineering, National University of Singapore, Singapore*
*ceelcf@nus.edu.sg*

**Abstract**

Centrifuge modelling is a powerful and versatile tool to investigate geotechnical problems. This lecture will first highlight the advantages of centrifuge model testing and briefly cover the centrifuge model scaling laws. This is followed by the applications of centrifuge model testing on sample onshore, marine and offshore geotechnical problems. An example of onshore problem examines the effect of rising ground water table on the bearing capacity and settlement of shallow foundation on loess soil. This is followed by a marine geotechnical problem concerning the movement of gravity caisson wharf front structures under container port service loading and the effects of breaking waves on gravity caisson breakwater structures. The example of offshore geotechnical problem investigates the effects of jack-up spudcan installation on adjacent piled foundation supporting the permanent jacket platform. Through these sample problems, the advantages and possible pitfalls of centrifuge modelling technique are illustrated.

**Keywords:** Centrifuge model, onshore, marine, offshore

# *Special Session on Smart City*
# *"Present and Future of Smart City"*

Sponsored by **KAIST International Office**

# Organizers

- **Prof. Yoonjin Yoon**

  Department of Civil and Environmental Engineering, KAIST

- **Prof. Hyun Myung**

  School of Electrical Engineering, KAIST

# Co-organizer & Session Chair

- **Prof. Youngchul KIM**

  Department of Civil and Environmental Engineering, KAIST

## Invited Speakers:

**Prof. Jun CHEN**
College of Civil Engineering, Tongji University

Dr. Jun Chen is currently a full professor of structural dynamics at Department of Structural Engineering, College of Civil Engineering, Tongji University. Dr. Chen received his PhD degree in Structural Engineering from Tongji University. His research interests include human-induced loads, structural vibration serviceability, big data in civil engineering, structural health monitoring and vibration control. He has held more than twenty research projects including one major research project and four general projects from National Science Foundation China. Dr. Chen has published more than 140 articles in peer-reviewed scientific journal and one book. He is the third recipient of the Second Class Prizes of the State Scientific and Technological Progress Award and recipient of four Shanghai Scientific and Technological Progress Awards. He has been awarded several academic titles as: Shanghai Outstanding Academic Leaders, New Century Excellent Talents in University, and Shanghai Pujiang Talents.

**Prof. Sorawit NARUPITI**
Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University

Dr. Sorawit Narupiti is an Associate Professor at Department of Civil Engineering, Chulalongkorn University, where he served as Head of Department from 2012 to 2015. He specializes in transportation and traffic engineering especially Intelligent Transportation Systems (ITS), sustainable mobility, and transport policy. He has been conducting research and development on Intelligent Transportation Systems (ITS) for more than 20 years. He has numerous academic papers and made presentations on topics at regional conference levels. He is currently an editor/reviewer in some ITS-related journals/conferences and a coordinator of the ITS group at Chulalongkorn University. He has taught classes on Highway Engineering, Traffic Engineering, Transport Policy and Planning, Intelligent Transport System, Simulation and Modeling and more. Professionally, he served as the President of Thai ITS Association from 2008-2012, the secretary of Intelligent traffic information center (iTIC) foundation which promotes better transport through the use of intelligent transport system data in Thailand. Moreover, he joins many transportation engineering professional associations.

**Prof. Nak Young CHONG**

Japan Advanced Institute of Science and Technology (JAIST)

Nak Young Chong is a Professor in Intelligent Robotics at the Japan Advanced Institute of Science and Technology (JAIST), Japan. He received the B.S., M.S., and Ph.D. degrees in mechanical engineering from Hanyang University, Seoul, Korea, in 1987, 1989, and 1994, respectively. From 1994 to 2007, he was a member of research staff at Daewoo Heavy Industries and KIST in Korea, and MEL and AIST in Japan. In 2003, he joined the faculty of JAIST, where he currently is a Professor of Information Science. He also served as Vice Dean for Research and Director of the Center for Intelligent Robotics at JAIST. He was a Visiting Scholar at Northwestern University, Georgia Institute of Technology, University of Genoa, and Carnegie Mellon University, and also served as an Associate Graduate Faculty at the University of Nevada, Las Vegas, International Scholar at Kyung Hee University, and Distinguished Invited Research Professor at Hanyang University. He serves as Senior Editor of the IEEE Robotics and Automation Letters and Springer Intelligent Service Robotics, Topic Editor-in-Chief of International Journal of Advanced Robotic Systems, and served as Senior Editor of IEEE ICRA CEB, and IEEE CASE CEB, and Associate Editor of the IEEE Transactions on Robotics and many other journals.

**Prof. Albert CHEN**

Civil Engineering, National Taiwan University


Albert Y. Chen received the Bachelor's Degree from NTU in Civil Engineering, Master of Science Degree in Structural Mechanics from the University of California, Los Angeles (UCLA) in Civil and Environmental Engineering (CEE), Master of Computer Science Degree from University of Illinois at Urbana-Champaign (UIUC), and his Ph.D. in CEE at UIUC. He conducted his PhD thesis under the supervision of Prof. Feniosky Pena-Mora. Dr. Chen's research focuses and interests are in Civil Infrastructure Systems, Information Technology in Construction, and Intelligent Transportation Systems. Dr. Chen is interested in artificial intelligence and utilizes methodologies such as mathematical programming and combinatorial optimization, image processing and computer vision, and machine learning and pattern recognition. Dr. Chen has received numerous international and domestic awards for research, teaching and service. He received the Best Paper Award in ICCCBE 2018, Best Paper Honorable Mention in ICCBEI 2015, and the Excellent Paper Award in ICCEPM 2011. He's also received 4 Excellent Teaching Awards at NTU, the 2013 ASCE Best Reviewer Award for the Journal of Computing in Civil Engineering, and his supervising team won the Golden Prize in the National Competition on Engineering Innovation, Institute of Engineering Education Taiwan.

**Prof. Kevin Sze-Chiang KUANG**
Department of Civil and Environmental Engineering, National University of Singapore

Dr. Kevin Kuang is presently a Senior Lecturer in the Department of Civil and Environmental Engineering, National University of Singapore. Dr. Kuang was awarded the PhD in 2002 from the University of Liverpool, United Kingdom in the area of structural health monitoring of advanced composite materials. He obtained his first degree in Mechanical Engineering (Hons. 1st Class) from the University of Leeds, United Kingdom. Dr. Kuang's area of specialty is in the use of optical fibres for sensing in civil engineering and is one of the pioneers in the application of plastic optical fibre sensors for structural health monitoring in civil engineering. His research focus is in the design, development and application of sensor technologies and smart materials, in particular optical fibre-based sensors SHM of civil structures.

**Prof. Ayoung KIM**
Department of Civil and Environmental Engineering, KAIST

Ayoung Kim is the assistant professor in the department of civil and environmental engineering with joint affiliation at KI robotics and school of computing, KAIST. She received the B.S. and M.S. degrees in mechanical engineering from Seoul National University, Seoul, Korea, in 2005 and 2007, respectively, and the M.S. degree in electrical engineering and the Ph.D. degree in mechanical engineering from the University of Michigan (UM), Ann Arbor, in 2011 and 2012, respectively. She also worked as a post-doctoral researcher in naval architecture and marine engineering, UM in 2013 before works at ETRI as a senior researcher. Her research interests include visual simultaneous localization and mapping, navigation.

## Room 401 (09:00-12:30, October 25)

*Special Session on "Smart City"*

Session Chair: Prof. Youngchul KIM

| Paper ID | Paper Title | Presenter |
|---|---|---|
| SMART-01 | Vibration Comfortability of a City: a Smartphone-based Survey Approach | Jun Chen |
| SMART-02 | Smart City and Smart Mobility in Thailand | Sorawit Narupiti |
| SMART-03 | Culturally Competent Elderly Care Robots in a Smart ICT Environment | Nak Young Chong |
| SMART-04 | Image sensing for Transportation and Construction | Albert Y. Chen |
| SMART-05 | Heart-of-the-Matter: Making Concrete Feel and Heal – a smart concrete based on smart paint and hollow tunnels | K.S.C. Kuang |
| SMART-06 | Robotic sensing for Digital Twin | Ayoung Kim |

**SMART-01**

# Vibration Comfortability of a City: a Smartphone-based Survey Approach

J. Chen, H. Du and L. Cao

*College of Civil Engineering, Tongji University, Shanghai, China*
*cejchen@tongji.edu.cn, beyond060716@163.com*

## Abstract

Rapid form of urbanization has led to millions of migrant workers moving and living in giant cities. As a result, with in the city, the population density, the number of buildings, the density of public transportation network and logistic chains has increased dramatically. Taking Shanghai City as an example, in 2018, the population is estimated to be 22 million (about 3800 people per square kilometre) and the length of subway line is 705 km. Heavy daily public transportation and other dynamic sources as machines in factories, construction activities can cause severe vibration serviceability problems to citizens. A measure thus is necessary to assess the vibration comfortability of a city. To this end, we suggest in this study a smartphone-based approach to survey the vibration issues in a city. The measurement accuracy of various kinds of smartphones available in the marker was first checked by shaking table tests. Then, an application (App) has developed to record acceleration of the smartphone using its embedded sensors. When people in a city feels vibration during their daily life in a city, they can download and open this App to record the vibration, take pictures, make videos and finish a vibration questionnaire form. They can then submit all the information to a cloud server, under the principle of voluntariness, which will be analysed to study the city's vibration comfortability. We have collected about 10,000 records so far. Preliminary statistical analysis on these records are reported in this paper with focuses on data cleaning, vibration source, vibration sites and vibration sensitivity thresholds for male and female. It is found that the proposed survey approach is applicable and a large number of records is important for a reasonable assessment.

**Keywords:** vibration comfortability, smartphone, smart city, big data

**SMART-02**

# Smart City and Smart Mobility in Thailand

Sorawit Narupiti[1]

[1] *Department of Civil and Engineering, Chulalongkorn University*
*kong@chula.ac.th*

## Abstract

Smart city is a striking word to governments and public agencies at all levels, where they wish to foster their city development, economic growth and quality of life of their citizens with a new set of smartness strategic directions and programs. In Thailand, smart city is a big initiative by several stakeholders including ministries, local governments, private sectors, and others. The smart city is not only the use of technologies for urban development, but citizens should receive the quality of livings from a new lifestyles, environments, and convenience. This presentation will describe the smart city activities in Thailand. Government organizations has initiated several smart city programs targeting at areas, towns, or cities to enhance their areas into the smarter ones. Smart Mobility is one of the pillars of the Smart city. Several developments and pilots are underway. The presentation will show the smart mobility pilots and initiatives in Thailand.

**Keywords:** Smart City, Smart Mobility, Thailand

**SMART-03**

# Culturally Competent Elderly Care Robots in a Smart ICT Environment

Nak Young Chong

*School of Information Science, JAIST, Japan*
*nakyoung@jaist.ac.jp*

## Abstract

Rapid demographic change constitutes an unprecedented societal challenge for Japan. I will shed light on the issues of Japan's super-aging society and introduce the human-robot interaction work package of our ongoing EC Horizon 2020 project "CARESSES", aiming at developing culturally competent elderly care robots, jointly commissioned by the Ministry of Internal Affairs and Communications of Japan. We envision a future where socially assistive robots are able to interact with the elderly with different cultural and personality traits through personalized emotion generation and facial/vocal/body expression. Specifically, robots are able to autonomously re-configure their way of acting and speaking, when offering a service, to match the culture, customs, and etiquette of the person they are assisting. By designing robots that are more sensitive to the user's needs, our innovative solution will offer elderly clients a safe, reliable, and intuitive system to foster their independence and autonomy, with a greater impact on quality of life, a reduced caregiver burden, and an improved efficiency and efficacy. I will share some of our preliminary results of multi-modal human-robot interaction and explore opportunities for future collaboration with people from diverse social and cultural groups. Furthermore, I will introduce a smart ICT environment testbed iHouse, and a user speech activated interface to enable an off-the-shelf robot to gain control over the iHouse devices and functions and provide data through verbal interaction with the user. I am hoping to discuss the technical feasibility of a robotic smart care home interface toward supporting independent living of the elderly.

**Keywords:** Socially assistive robots; Human-robot interaction; Cultural competence; ICT smart environment

**SMART-04**

# Image sensing for Transportation and Construction

Albert Y. Chen[1]

[1] *Department of Civil Engineering, NTU, Taiwan*
*albertchen@ntu.edu.tw*

## Abstract

Image sensing provides many opportunities for the observation and data collection of daily operations in the domain of civil engineering, transportation, and the architectural, engineering, construction, and facilities management (AEC/FM). In this work, directions to improve decision making for a smarter city through traditional and state of the art image sensing are investigated. Case studies on the construction jobsite, and also at signalized intersections are presented to show the potential of a smarter city. Although there are rapid developments of innovative and emerging technologies that enable better quality of life, there are still many potential directions for technology adaptation for the general civil engineering domain which is critical for a smarter and intellectual city.

**Keywords:** Smart City; Image Sensing; Deep Learning; Artificial Intelligence

**SMART-05**

# Heart-of-the-Matter: Making Concrete Feel and Heal – a smart concrete based on smart paint and hollow tunnels

K.S.C. Kuang

*Department of Civil and Environmental Engineering, National University of Singapore 117576, Singapore*
*kevinkuang@nus.edu.sg*

## Abstract

Cracks in concrete structures could developed over time and should be detected and repaired as early as possible to prevent possible ingress of corrosive elements which could lead to corrosion of the reinforced bars. In this paper, a system comprising the use of a smart paint as the crack sensor and an automatic integrated self-healing system comprising a set of internal hollow tunnels within the concrete beams and a peristaltic pump and reservoir system working together to supply the healing agent to seal and heal the cracks. In addition to the automatic response of the system in the event of cracks, an SMS-alert message will be immediately sent out by the system controller. The results showed that a crack as small as 0.1mm width could be detected while the sealing or healing effectiveness was found to be promising in that water-tightness was achieved implying proper sealing and a regain in strength following post-failure post-curing loading tests.

**Keywords:** cracks; sensors; smart paint; self-healing, smart structures

**SMART-06**

# Robotic sensing for Digital Twin

Ayoung Kim[1]

[1] *Department of Civil and Environmental Engineering, KAIST, Korea*
*ayoungk@kaist.ac.kr*

## Abstract

Robot navigation exploits both extrovert and introvert sensors to perceive the environment. The extrovert sensors including cameras and LiDARs have been widely utilized, dominantly leading recent autonomous navigation research. Unfortunately, these sensors are strongly depending on the environment that encompasses both structural and temporal variance (e.g., illumination and structural variance). This talk will introduce robust sensor fusion and control and its application to robot perception for digital twin.

**Keywords:** Robot, Sensors, Digital Twin

# *Parallel Technical Sessions*

## Room 401 (11:20-12:50, October 24)

***Structural Engineering 1***

Session Chair: Prof. Huanjun Jiang

Session Co-chair: Prof. Kyohei Noguchi

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-22 | Methodology of Seismic Risk Analysis of Deteriorated Structures with High-Fidelity FEM model | Dawon Park |
| TU-8 | Seismic Inputs of a Shaking Table Test for a Granite Façade System | Y. Fan |
| KAIST-28 | The Effect of Soil-Structure Interaction on Seismic response of Nuclear Power Plant Structures | Yuree Choi |
| HKUST-1 | 3D Topographic Amplification of Ground Motions considering the shaking direction of seismic waves | Z.W. Chen |
| KAIST-27 | Numerical simulation for seismic risk assessment of urban water transmission network | Gi-Hun Gwon |
| TU-30 | Method for assessment of building function loss in an earthquake based on fuzzy logic | Haifeng Bu |

## Room 403 (11:20-12:50, October 24)

***Structural Engineering 2***

Session Chair: Prof. Tomomi Yagi

Session Co-chair: Prof. Jung-Wuk Hong

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-19 | Operational strategy of Multi-functional Electromagnetic damper for Cable Structure | Hyung-Soo Kim |
| NTU-36 | Development of Nano-Fluid Viscous Damper | S.K. Peng |
| KU-12 | Tracking of Airborne Sea Salt Particles around a Rectangular Prism in Smooth Flow by LES | Y. Tsuda |
| NTU-41 | Piezoelectric Tuned Mass Damper Designed for Footbridges | Y.F. Deng |
| NTU-37 | Design and Analysis of Piezoelectric Tuned Mass Damper for Taipei 101 | Y.W. Ho |

## Room 401 (13:50-15:40, October 24)

***Structural Engineering 3***

Session Chair: Prof. Wen-Cheng Liao

Session Co-chair: Prof. Yasuo Kitane

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-40 | Development of Shrinkage and Creep Formula in Taiwan Based on Database Analysis | W.Y Chin |
| TU-17 | Meso-scale Simulation of Bond Behavior Between Retarded-bonded Prestressed tendon and concrete | Q.S. Xiao |
| KU-26 | A statistical response of GFRP channel member performance considering material variability | G. Hayashi |
| TU-41 | Flexural behavior of reinforced ultra-high performance engineered cementitious composites (UHP-ECC) beams：Experiment and analytical model | Z.W. Cai |
| NTU-38 | Experimental Investigation on Isolated Strut Behavior of High Strength Steel Fiber Reinforced Concrete Panels | C.C. Kuo |
| TU-9 | Analysis of durability prediction models of FRP and adhesive subjected to harsh environment | Q.Q. Yu |
| NTU-44 | Influence of Deep Steel Columns on Seismic Collapse Response of Steel Special Moment Frames | T.Y. Wu |

## Room 403 (13:50-15:40, October 24)

***Structural Engineering 4***

Session Chair: Prof. Yin-Nan Huang

Session Co-chair: Prof. Hyung-Jo Jung

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-49 | Estimation of Response Distribution Considering Structural Nonlinearity | Heekun Ju |
| TU-23 | Seismic Response Characteristics of Steel Frames Coupled with Dual-Rocking Energy-Dissipated Structures | W.J. Zhang |
| NTU-42 | Performance of Friction-Pendulum Bearing Systems Subjected to Near-Fault Ground Motions | Ya-Heng Yang |
| TU-40 | Seismic Resilience-Based Rating of Energy Dissipation Building Structures | Guangchun Zhong |
| NTU-50 | Characteristics of Correlation Coefficient and Duration of Near-Fault Pulse-Like Ground Motion | S.H. Chiu |
| TU-37 | Seismic fragility analysis of ultra-high ductility cementitious composite frame structure without steel reinforcement using incremental dynamic analysis | F.Y. Dong |
| KU-4 | Collisions of Vehicles Running on Highway during an Earthquake | K. Fukunaga |

## Room 401 (16:10-18:00, October 24)

***Structural Engineering 5***

Session Chair: Prof. Shu-Wei Chang

Session Co-chair: Prof. Yoshinao Goi

| Paper ID | Paper Title | Presenter |
|---|---|---|
| HKUST-3 | Investigation on Savonius Turbine Interactions by Cluster Layout Optimization | H. Chan |
| NTU-35 | A Study on Hysteresis Modeling of Reinforced Concrete Columns | Y.C. Ling |
| TU-12 | Simplified Models of Steel Moment Connections under a Column Removal Scenario | Jinwei Li |
| KU-27 | Study on Improvement of WRF Accuracy for the Evaluation of Dew Condensation on Steel Bridges | Zabihullah Rasoli |
| TU-19 | An Integrated Method Based on the Probability Density Evolution Method for Structural Optimization Considering Dynamical Reliability | Jiashu Yang |
| TU-20 | A Study on The Constitutive Model of Structural Steel Plasticity with Lode Angle Dependence | Zucheng Yao |
| KU-16 | Vibration test and system identification of Gerber-type steel plate girder bridge | Xin Zhou |

## Room 403 (16:10-18:00, October 24)

***Structural Engineering 6***

Session Chair: Prof. Qian-Qian Yu

Session Co-chair: Prof. Kai-Chun Chang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KU-6 | Fessibility Study on Monitoring System with Micro Energy Harvester for Bridge Pier Scouring | Kawabata Kohei |
| KU-3 | Development of Tension Estimation Method for a Cable with a Damper using Natural Frequencies | K. Hirose |
| KAIST-39 | FIR Filter Based Bridge Displacement Estimation Using Strain and Acceleration Measurements | Zhanxiong Ma |
| KU-13 | Improving accuracy of acceleration-based drive-by road profile identification by correcting sensor inclinations | N. Toshi |
| TU-27 | A mesoscale modeling method of concrete material with refined aggregate shapes based on image recognition | Yue Li |
| KU-18 | A feasibility study of sound-based inspection in hammer test | Yiran. YU |
| KU-23 | Fundamental study on health monitoring of steel girder bridge using displacement and slope at girder end | Thant Yin Tun |

## Room 403 (09:00-10:30, October 25)

***Structural Engineering 7***

Session Chair: Prof. Akira Igarashi

Session Co-chair: Prof. Wen-Cheng Liao

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KU-32 | A Method of Bi-directional Displacement Demand Assessment for Bridge Bearings Subjected to Ground Motions with Directionality Effects | Xinhao He |
| KU-33 | Finite Element Modeling and Performance Evaluation of Strip Scrape Tire Rubber Pad Base Isolator | M.B. Zisan |
| NTU-46 | Development and experimental verification of Dual-length nonlinear pendulum for seismic protection of buildings | X. Wang |
| NTU-48 | The displacement restraint mechanism of seismic isolation buildings | Yu-Jen Lai |
| TU-25 | High Damping Rubber Bearings: A Review with Emphasis on Deformation-history Integral Type Model | X.R. Hu |
| TU-34 | Analysis of Vibration Isolation Performance of Bridge Basin Rubber Bearing and Spherical Steel Bearing | B. Wang |

## Room 405 (09:00-10:30, October 25)

***Structural Engineering 8***

Session Chair: Prof. Yasuo Kitane

Session Co-chair: Prof. Huanjun Jiang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| TU-42 | Sensitivity Analysis for Bridge Effect based on Vehicle Mass Flow Parameter Information | X.J. Wang |
| KU-24 | Assessment of a Bridge Structure subjected to Flood Loadings “Case Study of Licungo Bridge” | C.S. Mafuiane |
| TU-14 | Experimental Investigation and Design Method Research on Full-scaled Concrete Spread Foundation Slab with Large Width-to-height Ratio | Xiaoliang Qin |
| KU-29 | Development of Plastic Hinge Replaceable Bridge Piers under Gravity Load based on Metabolism Concept | Maeda Hiroto |
| TU-35 | Numerical simulation of interfacial bond behavior in steel reinforced concrete composite bridge | Xianlin Wang |
| KU-22 | Experimental and Analytical Study of Temperature Effect on Different Colored Steel Bridges caused by Solar Radiation | Ruobing SUN |

## Room 403 (11:00-12:30, October 25)

***Structural Engineering 9***

Session Chair: Prof. Sze Dai Pang

Session Co-chair: Prof. Tomomi Yagi

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-26 | Improved Shear Stud Spacing in Steel-concrete-steel Sandwich Structures | WonHo Lee |
| KU-19 | Influence of Repair Plate Shape in GFRP Repairing | A. Sato |
| NUS-5 | Capturing the Size Effect in Quasi-Brittle Fracture with Localizing Gradient Damage Enhancement | Y. Zhang |
| TU-29 | Application Study on the Rubber-Sleeved Stud Connectors in the Cable-tower Composite Anchorage | Bozhou Zhuang |
| NUS-4 | Slot and Grout Connection for Steel and Composite Modular Construction | T.Y. Cheong |
| KU-20 | Study on shear deformation performance of rubber bearing with steel plate | Kosuke Mine |

## Room 405 (11:00-12:30, October 25)

***Structural Engineering 10***

Session Chair: Prof. Kai-Chun Chang

Session Co-chair: Prof. Qian-Qian Yu

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KU-2 | Study on Earthquake Resistance Improvement Effect for Masonry Buildings using Interlocking Blocks | K. Asano |
| KU-21 | Pounding Effect of Skew Bridge and Method of Mitigation | Jing Yixiong |
| NTU-49 | Global Stability of BRBs using Truss Restrainer | Chun Chen |
| TU-43 | Effects of Center Column Enhancement on Seismic Performance Improvement for Underground Structures | C.Z. Yue |
| TU-44 | Experimental Investigation on transverse steel damper seismic system for cable-stayed bridges under earthquake sequences | Lianxu Zhou |
| KU-28 | Consideration on Response of Seismic Isolated Elevated Bridges due to Slightly Strong Earthquakes | Yin Xiang |

## Room 401 (13:30-15:00, October 25)

***Structural Engineering 11***

Session Chair: Prof. Kyohei Noguchi

Session Co-chair: Prof. Sawekchai Tangaramvong

| Paper ID | Paper Title | Presenter |
|---|---|---|
| CU-16 | Wind load Analysis of a high-rise building by Computation Fluid Dynamics | Canh Thiet Phung |
| KU-9 | Investigation of Wake-induced Vibration of Parallel Cables Based on Unsteady Aerodynamic Forces | H. Fukushima |
| TU-45 | Multi-Mode Cable Vibration Control using MR Damper based on Nonlinear Modeling | Fangdian Di |
| KU-11 | Comprehending Large Amplitude Aerodynamic Vibrations of Rectangular Cylinder in terms of the Time Derivative of Relative Angle of Attack | T. Okunishi |
| TU-6 | Study on Uniaxial Compression Bearing Capacity of Bolted Ball-Cylinder Joint | Qiang Zeng |
| KU-10 | Effects of Side Openings on Galloping Instability of Rectangular Cylinder | S. Yamamoto |

## Room 403 (13:30-15:00, October 25)

***Structural Engineering 12***

Session Chair: Prof. Atsushi Hattori

Session Co-chair: Prof. Shu-Wei Chang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-46 | Application of deep learning techniques for determination of crack signals in structural damage monitoring | Gyeol Han |
| KU-5 | Detection of Crack and Delamination of Concrete by Optical Imaging of Surface Acoustic Wave | Takuya Watanabe |
| KU-7 | Optical Imaging of Surface Acoustic Wave for Fatigue Crack Detection at Trough Rib on a Steel Box Girder Viaduct in Service | Takuya Muneoka |
| CU-11 | Photo Inspection of Crack in Reinforced Concrete | T.T. Nguyen |
| NTU-45 | Application of Convolutional Neural Networks for Structural Damage Detection | P.H. Chiu |
| NTU-47 | Crack Detection Based on Deep Learning and Computer Vision Algorithms | J.W. Yu |

## Room 405 (13:30-15:00, October 25)

***Structural Engineering 13***

Session Chair: Prof. Yoshinao Goi

Session Co-chair: Prof. Yin-Nan Huang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| TU-38 | Localized Corrosion Induced Damage Detection of Large-scale Reinforced Concrete Piles Using Acoustic Emission Technique | Y.J Zhou |
| NTU-39 | Experimental Investigation for Corrosion Current Density of Corroded Steel Rebars with Different Corrosion Degrees in Different Media | K.C. Lin |
| KU-8 | Impacts of Cable Corrosion on Cable-stayed Bridge Structure | M.T. Dao |
| KU-17 | Remaining Capacity of Damaged Weathering Steel Bridge by Long-Term Atmospheric Corrosion | Wint Thandar |
| TU-33 | Experimental Study and 3D Cellular Automata Simulation of Corrosion Pits in Q345 Steel | Cui Chuanjie |
| TU-28 | Experimental Study on Grout Defects Identification in Precast Column Based on Wavelet Packet Analysis | X. Zhang |

## Room 401 (15:30-17:00, October 25)

***Structural Engineering 14***

Session Chair: Prof. Yoshikazu Takahashi

Session Co-chair: Prof. Hyung-Jo Jung

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-25 | Evaluation of the response of RC members subjected to blast loading | SeokJun Ju |
| HKUST-2 | Peridynamics simulation of contact behavior in granular particles | S. Mohajerani |
| KU-30 | Nonlinear Dynamic Response of Structures with negative stiffness in Skeleton Curves | Watanabe Kousuke |
| KU-31 | Experimental/Numerical Investigation on Mechanism of Vertical Crack Generation on Mesnager Hinge | K. Uemura |
| CU-20 | An Efficient ES-FEM Complementarity Approach for Post-Collapse Responses of Concrete Gravity Dam | Sawekchai Tangaramvong |
| KU-1 | Dynamic 2D Finite Element Analysis of Interlocking Brick Wall | J.J. Prasetyo |

## Room 403 (15:30-17:00, October 25)

***Structural Engineering 15***

Session Chair: Prof. Jung-Wuk Hong

Session Co-chair: Prof. Kevin Kuang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-20 | Low-velocity Impact Resistance of Nacre-like Composites | Kwonhwan Ko |
| NUS-1 | A field implementation of a remote crack detection system based on plastic optical fiber sensors to monitor cracks in concrete pedestrian pavements | V. Ramani |
| KAIST-24 | Nonlinear Analysis of Reinforced Concrete Slab Subjected to Extreme Loading | Minjoo Lee |
| KU-25 | Early stage detection method of vehicle loads induced fatigue cracking under the coating film in steel bridges | M. Mboup |
| KAIST-23 | Measurement of Residual Material Properties of Fire-damaged Concrete using a Nonlinear Ultrasonic Technique | GyuJin Kim |
| TU-26 | Fatigue Evaluation of UHPC-Orthotropic Steel Composite Deck | Y. Huang |

## Room 405 (15:30-17:00, October 25)

***Structural Engineering 16***

Session Chair: Prof. Chul-Woo Kim

Session Co-chair: Prof. Jae Hong Kim

| Paper ID | Paper Title | Presenter |
|---|---|---|
| TU-16 | Application of Wireless Sensing in Shanghai Utility Tunnel | Y.Q. Wu |
| NTU-43 | 3D Modal Feature Extraction Based on Video Measurement | J.Y. Chou |
| KU-14 | Changes in Modal Frequencies and Structural Behavior at Supports on a steel plate girder bridge Caused by Local Damage and Varying Temperature | T. Hirooka |
| TU-21 | A Safety Management System Based on Faster-R-CNN and BIM | Binghan Zhang |
| KU-15 | Benefits of Implementation of Building Information Modeling (BIM) in Bridge Projects | Ahmed Mohamed Waheed |

## Room 405 (11:20-12:50, October 24)

***Geotechnical Engineering 1***

Session Chair: Prof. Seung-Rae Lee

Session Co-chair: Prof. Suched Likitlersuang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-14 | A Framework to Compute the Width and Area of Debris-FlowBased on DAN3D | E. Cheon |
| KAIST-43 | Advanced geomorphological survey method using UAV-LiDAR system for landslide analysis | Shin-Kyu Choi |
| CU-3 | Development of 3D vegetated soil slope model based on Unmanned Aerial Vehicle (UAV) photograph | P. Ongpaporn |
| NTU-10 | Stability Analysis of Unsaturated Slope Using Random Finite Element and Monte-Carlo Methods | C.H. Hsiao |
| NTU-11 | Large Deformation Analysis for The Failure Process and Post-Failure Behavior of Slopes Subjected to Rainfall | Y.K. Wu |
| KU-44 | Behaviors of an undercut slope with a plane of discontinuity observed in centrifugal acceleration field | K. Aroonwattanaskul |

## Room 409 (11:20-12:50, October 24)

***Geotechnical Engineering 2***

Session Chair: Prof. Christina Tsai

Session Co-chair: Prof. Tirawat Boonyatee

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-18 | Predicting Natural Frequency of Piled Raft Foundation by Finite Element Method | M.Y. Yang |
| NTU-22 | Raft Foundation Structural Deformation Characteristics Induced by the Normal Fault: Investigations Based on Numerical Model | Ru-ya Fang |
| KU-41 | Dynamic Centrifuge Tests on Three-hinge Type of Precast Arch Culvert under Asymmetrical Overburden | K. Ambai |
| KU-35 | Deep learning model to predict time series of real-time ground motions | Ryota Otake |
| CU-21 | Multimodal inversion of surface waves for determining Vs profiles | Tirawat Simlemkin |
| NTU-25 | Site Response at the Vertical Arrays in the Taiwan Surface-Downhole Monitoring Network | Chun-Chieh Yao |

## Room 405 (13:50-15:40, October 24)

***Geotechnical Engineering 3***

Session Chair: Prof. Louis Ge

Session Co-chair: Prof. Tae-Hyuk Kwon

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-14 | Seismic Damage Analysis of Pile Foundations Considering Ground Movement | Y.W. Fu |
| NTU-15 | Determination of nonlinear dynamic properties of sand from centrifuge shaking table testing | C.L. Chen |
| KAIST-48 | InSAR-based Detection and Mapping of Seismically-induced Ground Deformation in Pohang City using Sentinel-1 | Ryan Ramirez |
| CU-6 | Liquefaction potential evaluation of Chiang Mai subsoils due to strong earthquakes | W. Tanapalungkorn |
| TU-1 | Liquefaction-induced settlement of existing structures: experimental and numerical investigations | Wuwei Mao |
| KU-34 | Systematic Understanding of the Ground Motion Amplification on Three-dimensional Basin Structure | Yuki Tanaka |
| KU-45 | Dynamic model tests on beam action and arch action in embankments subject to subsidence of foundation | T. Gondai |

## Room 409 (13:50-15:40, October 24)

***Geotechnical Engineering 4***

Session Chair: Prof. Yasuo Sawamura

Session Co-chair: Prof. Wuwei Mao

| Paper ID | Paper Title | Presenter |
|---|---|---|
| TU-22 | Investigation of longitudinal performance of tunnel due to surface surcharge considering soil spatial variability | J.Z. Zhang |
| KAIST-44 | Real-scale TBM excavation test with rock-like concrete samples | Gi-Jun Lee |
| KU-42 | Application of Hoek-Brown Criterion on tunnel excavation simulation under high overburden condition with fault zone | Ryota Kashima |
| KU-43 | Single Rock Fracture Modeling through CT data and Its Application for Grouting Injection Flow | Kyosuke Iseki |
| KAIST-32 | Numerical study on ground behavior at connection of submerged floating tunnel to land | Seok-Jun Kang |
| TU-10 | Single-channel blowing-in longitudinal ventilation theory and its applicability analysis in road tunnel | C. Guo |
| NTU-21 | Stability Analysis of Jointed Rock Masses Influenced by Rock Joint Geometrical Properties | Yu-Hsuan Chang |

## Room 405 (16:10-18:00, October 24)

***Geotechnical Engineering 5***

Session Chair: Prof. Yusuke Miyazaki

Session Co-chair: Prof. Jiunn-Shyang Chiou

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-16 | Representative Elements Volume of Hydraulic Conductivity of Fractured Rock Mass | Chia-Min Tsao |
| TU-7 | Probabilistic performance assessment of shield tunnels due to chloride-induced corrosion | X. R. Duan |
| KU-40 | Discussion on the frictional healing of single rock fracture in consideration of the rock weathered condition | J.T. Zhang |
| NTU-17 | Lining Crack Patterns Corresponding with 3D Displacements for Rock Tunnels in Operation Revealed by Numerical Simulation | Yi-Chen Li |
| KAIST-2 | Characteristics of the momentum transfer efficiency depends on the abrasive flow rate considering focus geometry | Yohan Cha |
| KU-38 | Effect of contact-area variation within a single granite fracture on hydraulic properties | C.L. Song |
| KAIST-3 | Effect of abrasive flow rate on rock drilling volume of abrasive waterjet | Hyun-Joong Hwang |

## Room 409 (16:10-18:00, October 24)

***Geotechnical Engineering 6***

Session Chair: Prof. Gye-Chun Cho

Session Co-chair: Prof. Tirawat Boonyatee

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-42 | Coupled CFD-DEM modeling of soil erosion at particle level | Soo-Min Ham |
| TU-24 | DEM simulations of drained and undrained behaviors of sand | Jiachen Zhang |
| KAIST-47 | Development of hydro-mechanically coupled pore network model | Min-Kyung Jeon |
| HKUST-6 | Numerical Simulation on the Shear Behavior of Crushable Granular Material under Various Intermediate Stress Ratio | K. Shi |
| TU-4 | Destabilization modes of upper continental slopes undergoing hydrate dissociation induced by climate warming | Fang Liu |
| KU-36 | Application of arbitrary particle domain interpolation to soil-water coupled consolidation analysis using Material Point Method | Goto Yoshikazu |
| KAIST-34 | Image-based Crack Detection and Quantification of Crack properties | Jin Kim |

## Room 409 (09:00-10:30, October 25)

***Geotechnical Engineering 7***

Session Chair: Prof. Suched Likitlersuang

Session Co-chair: Prof. Yasuo Sawamura

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-33 | Evaluation of backfill soils for underground power cable | Jun-Beom An |
| KU-39 | Soil-water coupled analysis of excavation process in deep cylindrical shaft | T. Tangjarusritaratorn |
| NTU-12 | Effects of Sand Cushions on the Performances of GRS Wall Subjected to Rainfall | T. L. Tseng |
| NTU-24 | A Global Database for Deep Excavation and Wall Deformation | Shih-Hsiang Yuan |
| CU-4 | Numerical study of plane strain ratio for deep excavation in Bangkok clay | P. Pisitsopon |
| TU-15 | Continuous Mechanism for Slurry Trench Stability Analysis in Layered Soils | H.Y. Wang |

## Room 409 (11:00-12:30, October 25)

***Geotechnical Engineering 8***

Session Chair: Prof. Tae-Hyuk Kwon

Session Co-chair: Prof. Christina Tsai

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-1 | Evaluation of Suction Anchor Adaptability for the Submerged Floating Tunnel Foundation in Silty-Sand | J.S. Bae |
| TU-5 | Influence analysis of excavation under the existing building to pile dynamic impedance | Ping Cao |
| CU-7 | Analysis of double rod auger pile load test results from a Bangkok clay site | K. Kounyou |
| NTU-26 | Pile analysis based on cone penetration tests considering spatial variability and model uncertainty | Mohammad Tabarroki |
| NUS-2 | Spudcan-pile interaction in two-layered soils: stiff overlying soft clay | Kencana E. Y. |
| NTU-13 | Numerical Simulation of Geosynthetic-Reinforced Soil Foundation Subjected to Faulting | Y.H. Chan |

## Room 409 (13:30-15:00, October 25)

***Geotechnical Engineering 9***

Session Chair: Prof. Wuwei Mao

Session Co-chair: Prof. Louis Ge

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-45 | Feasibility study of using enzyme-induced biopolymer formation for bioclogging | Yong-Min Kim |
| KAIST-35 | Experimental study on undrained shear strength of biopolymer treated soils | Yeong-Man Kwon |
| CU-5 | Preliminary investigations on performance of bioengineering solutions for enhancing slope and river bank stability | K. Ngamcharoen |
| NTU-23 | Experimental Investigation of Soil Behavior of Partially Saturated Penghu Calcareous Sand | Jia-Ren Liu |
| KAIST-50 | Dynamic Centrifuge Testing to investigate the dynamic behavior of gravity-type quay wall | Y.S. Kim |
| NTU-19 | Investigation of Post Cyclic Behavior of Sands under the Framework of Binary Packing | Y.H. Yang |

## Room 409 (15:30-17:00, October 25)

***Geotechnical Engineering 10***

Session Chair: Prof. Jiunn-Shyang Chiou

Session Co-chair: Prof. Yusuke Miyazaki

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-41 | Simplified resonant column testing appratus for small-strain stiffness and dampling coefficient | Dong-Hwa Noh |
| TU-18 | Tri-axial experiment on the influence of stress paths on clay in deep excavation | N. Xu |
| KAIST-36 | Biopolymer applications to form hydraulic barriers in clay matrices | Minhyeong Lee |
| NTU-20 | Effects of Fines Content on the Mechanical Properties of Binary Mixtures | Y. H. Lin |
| KAIST-40 | Influence of temperature on swelling pressure of Korean domestic bentonite | Minseop Kim |
| NUS-3 | Size Effect of Laboratory Samples on Consolidation and Creep Behaviour in Oedometer | N.G.L.H. Lee |

## Room 202 (11:20-12:50, October 24)

***Construction Engineering 1***

Session Chair: Prof. Po-Han Chen

| Paper ID | Paper Title | Presenter |
|---|---|---|
| CU-9 | An Information Transfer Framework for Facility Management in BIM Projects | S. Thadaeng |
| NTU-6 | Automatic BIM Dimension Adjustment for Feng Shui Using the "Luban Ruler" Standard | Bo-Lun Lin |
| HKUST-4 | Optimization of Occupant Thermal Comfort and Energy Consumption in MVAC Systems Using a BIM-Supported Computational Approach | H.H.L. Kwok |
| NTU-2 | Promoting Urban Renewal through the Application of Security Token Offering and Building Information Modeling (BIM) | Hao-Yang Cheng |
| CU-10 | A BIM-Enabled Dashboard System for Construction Project Monitoring and Control | P. Nantapanuwat |
| CU-13 | Collaborative Forms for Different Ecosystems of Building Information Modeling (BIM) Projects | S. Ummarin |

## Room 202 (13:50-15:40, October 24)

***Construction Engineering 2***

Session Chair: Prof. Xueqing Zhang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| CU-15 | Factors Influencing Entry Mode Decisions into Myanmar Construction Market | Naw Ruth Po Gay |
| CU-19 | Construction Bidding Behaviors and The Impact on Public Project Performance | Kittitee Kaewmanee |
| NTU-1 | The Focus on Promoting CSR and Issuing CSR Reports for Construction Firms | C.Y. You |
| HKUST-8 | Key Issues in Public-Private Partnerships Insurance | G. Shi |
| NTU-3 | Application of blockchain in construction industry loans | Hong-Lin Ko |
| NTU-7 | The Correlation between Job Stress and Heart Rate Variability of Engineers in Engineering Consultant Companies | Tsai-Ning Yang |
| NTU-62 | A Study of Improving Geoid Model by Hybrid Method - A Case Study of Taiwan Area | C.J. Huang |

## Room 202 (16:10-18:00, October 24)

***Construction Engineering 3***

Session Chair: Prof. Sze Dai Pang

| Paper ID | Paper Title | Presenter |
|---|---|---|
| CU-17 | Quantification of Construction Waste using Digital Image and 3D Model | Kanjanapot Srisuksai |
| CU-18 | Augmented Reality for Progress Tracking in Infrastructure Construction | Sittinut Srinoi |
| NUS-7 | Grouted Sleeve Connection for Modular Construction | S.D. Pang |
| NTU-8 | Development on Monitoring and Alarm System of Scaffold Collapse | Jing-Xian Lin |
| NTU-9 | Application of PPG Bracelet on Fatigue and Stress Evaluation of Tunnel Construction Using Heart Rate Variability | K.Y.Chen |
| KAIST-51 | Reviews on recent advancements of sensing and heating cementitious nanocomposites | D.I. Jang |
| KAIST-52 | Effect of Electrode Geometries on Electrical Resistivity Measurement in Limited Space | C.H. Hong |

## Room 202 (11:00-12:30, October 25)

***Construction Engineering 4***

Session Chair: Prof. Xueqing Zhang

Session Co-chair: Prof. Po-Han Chen

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-4 | Assessing Ridership Forecast Risk by Delphi Technique and Polynomial Tree for HSR under PPP | Teh-Ping Wang |
| NTU-5 | IRENO-ARCHITECTURE A Possible Adaptation of Architecture for Peace in Honduras | Moisés D. Osorto Carrasco |
| HKUST-5 | Logistics Management of Construction Waste Material: Exploration of Future Research Directions | Rana Rabnawaz Ahmed |
| HKUST-7 | Some Asian green roof standards and guidelines through the lens of biodiversity | Xiran Hui |
| CU-14 | Change Management for BIM Adoption in AEC Organizations | R. Prapornpen |
| NTU-61 | Using System Identification and Interpolation Method to Develop Optimal Sensor Placement with High-Rise Building without Numerical Model | Yen-Yu Yang |

## Room 204 (11:20-12:50, October 24)

***Civil Engineering 1***

Session Chair: Prof. S. Ping Ho

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-6 | Crack Width Measurement with an Adaptive Kernel | Suyeong Jin |
| NUS-6 | Near-surface Monitoring in Urban Environments based on Extremely Short Period of DAS Recordings | Y. Zhao |
| NTU-27 | A Re-identification System for Multi-Target, Multi-Camera Tracking of Building Occupants | S.H. Hsu |
| NTU-28 | Numerical Modeling of Surface Waves Triggered by Bottom Disturbances | H.-E. Wang |
| KAIST-53 | Performance of an Equivalent Shear Beam (ESB) Model Container for Dynamic Centrifuge Tests using Partially Saturated Soil | H.I. Lee |
| NTU-34 | A low-cost freeway data collection system based on photogrammetric and positioning techniques | Y.T. Lin |

## Room 202 (13:30-15:00, October 25)

***Civil Engineering 2***

Session Chair: Prof. Yoonjin Yoon

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-29 | Influence of Group Composition on Group Dynamics in a Transdisciplinary Project-based Course | Y. H. Pan |
| KAIST-12 | Visual pollution on public sites affecting public sights | Jinha Kim |
| KAIST-31 | The impact of air quality on flating population by age group in Yeouido, Seoul | Yeji Kim |
| NTU-31 | Crossing the Line: Interdisciplinary Learning for Engineering Students | M.M. Song |
| KAIST-9 | Development of a Digging Robot that Fuses the Behavior of Moles and Mole-rats | Christian Tirtawardhana |
| TU-46 | Vibration Comfortability of a City: a Smartphone-based Survey Approach | J. Chen |

## Room 202 (15:30-17:00, October 25)

***Civil Engineering 3***

Session Chair: Prof. Ying-Chieh Chan

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-37 | Anomaly Detection of Hydro Turbine using Autoencoder | Jun Lee |
| KAIST-38 | Mask R-CNN Based Loosened Bolt Detection and Quantification Using RGB-depth Sensor | Junyeon Chung |
| NTU-60 | Seismic Evaluation of Reinforced Concrete Bridges Using Capacity-Based Inelastic Displacement Spectra | W.C. Cheng |
| NTU-30 | Consumer Behaviors in Certified Green Buildings -An Empirical Study | W.C. Hsu |
| KAIST-5 | Particle-Based Numerical Analyses for Water Wave Generation | Sangmin Lee |
| NTU-33 | A Framework for Integrated Energy-Efficient Building Design | T.A. Phan |

## Room 204 (13:50-15:40, October 24)

***Transportation Engineering 1***

Session Chair: Prof. Yoonjin Yoon

Session Co-chair: Prof. Yu-Ting Hsu

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-10 | Urban Street Changes using a Deep Learning Method | Gi Young Byun |
| NTU-52 | Comparison of solution methods of dial-a-ride problems for rural areas | Yu-An Xiao |
| KAIST-29 | A Review on Pedestrian Evacuation Network Analysis in Earthquake Disasters and Its Applications | Sangjoon Park |
| NTU-55 | Dynamic Traffic Assignment upon Short-Duration Intense Rainfall Events | Chi Chang |
| KAIST-30 | Review of pedestrian sensing technologies and their applications in response to disasters | Jae Hong Lee |
| NTU-56 | Stochastic Dynamic Dispatch Model for Freeway Incident Response | Hong-Yi Li |
| KAIST-21 | Experimental and Numerical Investigations for Collision Risk Assessment of Unmanned Aerial Vehicle | Youngjun Choi |

## Room 204 (16:10-18:00, October 24)

***Transportation Engineering 2***

Session Chair: Prof. Youngchul Kim

| Paper ID | Paper Title | Presenter |
|---|---|---|
| NTU-51 | Optimization of Deployment and Repositioning in Dock-less Electric Scooter Sharing Systems | F.Y. Liao |
| KAIST-11 | How do Luxury Fashion Brands Build a Global Urban Network? Cases in Cities of East Asia | Ha Kyeong Lee |
| NTU-53 | VRP-based Model for Lane Marking Assessment with MRU Vehicle | Si-Ting Liao |
| CU-8 | Relationship Between Driver's Compensation Satisfaction and Passenger's Service Quality Satisfaction of Public Buses in Bangkok | Sucharee Rawithornthada |
| NTU-57 | Scheduling and Charging Optimization of Electric Buses | Jou-Chun Yeh |
| CU-12 | Heavy Traffic Performance Study of Smoked Natural Rubber under Sleeper Pad for Ballasted Track Railway using Box Tests | Supakorn Rodkrantuk |
| NTU-58 | A mesoscopic model for large-scale pedestrian simulation | Yu-Ting Wei |

## Room 204 (13:30-15:00, October 25)

***Transportation Engineering 3***

Session Chair: Prof. Yu-Ting Hsu

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-16 | Weighted Complex Network Analysis of the Northeast Asian Air Route Network | Seyun Kim |
| CU-1 | Possibility of Drone Delivery in Thailand: Technical & Legal Perspectives | Jittichai Rudjanakanoknad |
| KAIST-15 | A study on the urban airspace for sUAV operation | Nam Woo Kim |
| NTU-54 | Exploring Urban Trip-Activity Patterns Based on Smart Card Data and Land-Use Characterization | Kuan-Chieh Lee |
| KAIST-17 | Assessing the impact of restricting airspace in populated areas on airspace availability for UAV Operation | Soo Hwan Oh |
| KAIST-18 | Reflecting Structural Dynamicity of Traffic Networks to Graph Convolution Modules: A Deep Learning Approach to Traffic Forecasting | Yu Yol Shin |

## Room 202 (09:00-10:30, October 25)

***Material Engineering***

Session Chair: Prof. Jae Hong Kim

| Paper ID | Paper Title | Presenter |
|---|---|---|
| KAIST-4 | An overview on the binder chemistry of aluminosilicates activated by carbon negative minerals | Sang Jin Bae |
| TU-36 | Nonlinear Self-excited Force Characteristics and Mathematical Model of Coupled Flutter of Flat-Box-Girder Bridge Deck | Yi-Wen Cui |
| KAIST-8 | In Situ Measurements of Yield Stress for Freshly Mixed Mortar | Tae Yong Shin |
| CU-2 | Development of Mathematical Models for Predicting the Compressive Strength of Fly Ash Blended Cement Pastes from Different Sources | T.T. Win |
| KAIST-7 | Prediction of adiabatic temperature rise of concrete using isothermal microcalorimetry | Dong Jin Jeong |
| TU-11 | Basic properties of recycled powders made from different sources of construction and demolition materials | S.D. Hou |

## Room 204 (15:30-17:00, October 25)

***Water Resource Engineering***

Session Chair: Prof. Sha Lou

| Paper ID | Paper Title | Presenter |
|---|---|---|
| TU-31 | Hydrodynamic Characteristic of A Porous Cube Artificial Reef: An Experimental Study | Y.H. Zheng |
| TU-3 | Hydrodynamics and sediment suspension affected by rigid cylinder | Sha Lou |
| NTU-59 | Stochastic Sediment Transport with Memories | Serena Y. Hung |
| TU-32 | Return period of low tide level in the Yangtze Estuary based on nonstationarity analysis | Y.C. Zhou |
| TU-39 | Experimental Research on Hydrodynamic and Morphological Responses of the Submerged Artificial Sandbar to Irregular Waves | X.J. Han |

# *Abstracts from Chulalongkorn University*

**CU-01**

# Possibility of Drone Delivery in Thailand: Technical & Legal Perspectives

Natapadh Taechanuruk[1] and Jittichai Rudjanakanoknad[2(*)]

*[1]Aerospace Engineering, International School of Engineering, [2]Department of Civil Engineering, Chulalongkorn University, Bangkok, 10330, Thailand*
*Natapadh.T@student.chula.ac.th, jittichai@hotmail.com*

## Abstract

This manuscript documents the study of drone delivery possibilities in Thailand, particularly focused on technical and legal Perspectives. As Unmanned Aerial Vehicles (UAVs), or drones, have been proved to boost the aerial supports in diversified implementations including goods delivery and have been tested by many leading technological companies across the world for a few years. Nonetheless, utilizing drones for delivery have been concerned by government regulatory and general public since it could jeopardize lives or properties and might violate individual privacy and national security. This research analyses the possibilities in establishing commercial drone delivery services in Thailand. The compiled data were analyzed in accordance with precedent countries' methodologies. We also get insights obtained from many local specialists via in-depth interviews and consolidated the data to propose the most eligible approach towards the suitability in Thailand context. Key recommendations include underlying infrastructures and legislative modifications to successfully establish the service in Thailand.
**Keywords**: Unmanned Aerial Vehicle (UAV); Drone Delivery; Transportation Policy

**CU-02**

# Development of Mathematical Models for Predicting the Compressive Strength of Fly Ash Blended Cement Pastes from Different Sources

T.T. Win[1], R. Wattanapornprom[2] and W. Pansuk[3]

[1,2,3] *Innovative Construction Materials Research Unit, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*
*6171439321@student.chula.ac.th, rungrawee.w@gmail.com, withit.p@chula.ac.th*

## Abstract

Recently, to maintain the durability of the infrastructure, the pozzolan materials are used in the concrete mixture in each country. However, with the different properties of the materials, the hardened concrete properties become differ. Among the Southeast Asia countries, fly ash is the mostly used pozzolan in this area. However, the proper guideline in using fly ash across the country is limited. Thus, a further experiment about fly ash from different sources is necessary. In this study, fly ash from Myanmar, Thailand and Indonesia were collected and used as the pozzolan in the mix proportions. Each type of fly ash was used to replace the OPC in the mixture in a percentage of 0%, 10%, 20%, and 30% with the water to binder ratio 0.44, 0.54 and 0.64. After curing 28 days and 91-days, blended-cement paste's compressive strength following ASTM standard, was evaluated. Since the chemical composition of each country's fly ash is slightly different, the chemical reaction with cement is expected to be slightly different. Thus, the mechanical properties of blended-cement paste were differed. A mathematical analysis and second-degree polynomial equation were applied to predict the compressive strength of fly ash blended cement paste. Finally, the proper mix proportion of the fly ashes were suggested in the paper.
**Keywords:** Fly ash; Blended-cement paste; Compressive strength.

**CU-03**

# Development of 3D vegetated soil slope model based on Unmanned Aerial Vehicle (UAV) photograph

P. Ongpaporn[1], W. Tanapalungkorn[2], S. Likitlersuang[3] and A. Jotisankasa[4]

*[1,2,3]Center of Excellence in Geotechnical and Geoenvironmental Engineering, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*
*[4] Department of Civil Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand*
*n_pchaya@hotmail.com, weeradetch1@hotmail.com, fceslk@eng.chula.ac.th, apiniti.j@gmail.com*

## Abstract

In recent years, a considerably increase of landslides happens worldwide due to climate changes. Landslides are frequently responsible for considerable losses of both money and lives. In Thailand, one of the greatest landslides occurred at Ban Na Tum, Tha Uthae Subdistrict, Kanchanadit District, Surat Thani Province in 2011. After disaster, the area was improved by a soil-bioengineering method cooperated with simple structures. The solution included a cropping to help runoff slowdown and to increase strength of the soil slope by the roots of plants as well as using erosion control blankets and logs for slope reinforcement. Over time, some structures were decomposed by lifetime; however, plants still grow and spread consecutively which is sustainable restoration of ecosystem. This paper presents a geological survey of the vegetated soil slope using aerial photographs taken from an Unmanned Aerial Vehicle (UAV) or called Drone. A structure form Motion technique is employed to build a 3D geological model from slope surface and ground elevation. The geological model can be enhanced with the boring log data and subsurface information for slope stability analysis in the future.
**Keywords:** Landslide; Aerial Photograph; Structure from Motion; Vegetated Soil Slope.

**CU-04**

# Numerical study of plane strain ratio for deep excavation in Bangkok clay

P. Pisitsopon[1] and S. Likitlersuang[2]

*[1,2]Center of Excellence in Geotechnical and Geoenvironmental Engineering, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*
*piroon.pis@gmail.com, fceslk@eng.chula.ac.th*

## Abstract

In recent years, a 2D finite element analysis (FEA) has been widely used for design and analysis of deep excavation in practice. However, simplified assumptions of 2D FEA could be reasonably applied for some cases (i.e., a case of large length-to-width ratio). A plane strain ratio (PSR) was introduced to take into account of complex geometry and corner effect of deep excavation. In this study, a 3D FEA of deep excavation in Bangkok was performed to determine the PSR values. The results from numerical study were compared with the monitoring data from a construction site. Advanced constitutive soil models considering small strain stiffness were also employed in this study. Finally, the PSR values calculated from the case study of Bangkok can be comparable to the results from previous studies.
**Keywords:** Deep Excavation; Plain Strain Ratio; Bangkok subsoil; Finite element modelling.

**CU-05**

# Preliminary investigations on performance of bioengineering solutions for enhancing slope and river bank stability

K. Ngamcharoen[1], S. Likitlersuang[2] and A. Jotisankasa[3]

*[1,2]Center of Excellence in Geotechnical and Geoenvironmental Engineering, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*
*[3] Department of Civil Engineering, Faculty of Engineering, Kasetsart University, Bangkok, Thailand*
*kamonrat.nga@gmail.com, fceslk@eng.chula.ca.th, apiniti.j@gmail.com*

## Abstract

Soil-bioengineering method using vegetation has been considered as an environmentally-friendly alternative to improve earth infrastructure safety. Vegetation can potentially be a new construction material that can promote sustainable infrastructure and provide better built environment. In recent year, vetiver and other vegetation with some simple construction material were locally employed in Thailand to enhance the stability of hill slopes and river banks as well as to protect the nearshore erosion under supports from a corporate social responsibility project. The project has encouraged the leaders of community to use bioengineering solutions for constructing simple structures to protect their houses and properties from natural disasters. This study reports the sustainability, successfulness, problems and limitations of using bioengineering methods through the project. Preliminary investigations were performed based on desk study, site investigation and interviewing of the community leaders. The study can provide valuable resources for users to deploy the bioengineering method in practice.

**Keywords:** Soil erosion; Slope stability; Soil-bioengineering; Vegetation.

**CU-06**

# Liquefaction potential evaluation of Chiang Mai subsoils due to strong earthquakes

W. Tanapalungkorn[1], L.Z. Mase[2], S. Techavorasinskul[3] and S. Likitlersuang[4]

*[1,3,4] Center of Excellence in Geotechnical and Geoenvironmental Engineering, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*
*[2]Department of Civil Engineering, Faculty of Engineering, University of Bengkulu, Bengkulu, Indonesia*
*weeradetch1@hotmail.com, lmase@unib.ac.id, fceslk@eng.chula.ac.th, tsupot@chula.ac.th*

## Abstract

In last decade, the 6.8 Mw Tarlay Earthquake in 2011 and the 6.2 Mw Mae Lao Earthquake in 2014 attacked and damaged many building structures in the northern Thailand. Liquefaction phenomena were also observed in Chiang Rai province due to these two strong earthquakes. After the earthquakes, site investigations of subsoil condition have been carried out in many provinces in the northern Thailand. The investigations including soil boring and shear wave velocity measurements can be used to preliminarily assess liquefaction potential. Therefore, this study presents an evaluation of liquefaction using both empirical method and numerical analysis. The studied area are sites in Chiang Mai province, which is the tourist and business hub of the north of Thailand. In numerical analysis, the ground motion records measured during the earthquakes were employed. Next generation ground attenuation models were adopted for simulating input ground motions for each site. One-dimensional nonlinear site response analysis was conducted to observe liquefaction potential of subsoils due to the earthquakes. It is expected that the results can provide the information to establish the proper countermeasures to mitigate the liquefaction hazards in the northern Thailand.

**Keywords:** Liquefaction; Earthquake; Ground motion; One-dimensional nonlinear analysis; Northern Thailand

**CU-07**

# Analysis of double rod auger pile load test results from a Bangkok clay site

K. Kounyou[1]and S. Likitlersuang[2]

*[1,2]Center of Excellence in Geotechnical and Geoenvironmental Engineering, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*
*kittikhun.koun@gmail.com, fceslk@eng.chula.ac.th*

## Abstract

Double rods auger method (DRA) is pre-bored and precast pile systems with pouring cement milk into the borehole for improving mobilised skin friction. DRA piles have been using in Korea and Japan. Recently, the first project in Bangkok using DRA method has been launched. The Bangkok subsoils generally contain a thick soft clay layer having low shear strength and high compressibility. The project included static and dynamic pile load tests which can be used to study the capacity of DRA pile in clay. This paper studies end bearing capacity and skin friction behaviour of DRA pile using finite element analysis. The results from numerical analysis were compared with the pile load test results. It is expected that the results from this study can provide a guideline for DRA pile design in Bangkok clay site.

**Keywords:** Double rods auger pile; Pile load test; Finite element analysis; Bangkok subsoil

**CU-08**

# RELATIONSHIP BETWEEN DRIVER'S COMPENSATION SATISFACTION AND PASSENGER'S SERVICE QUALITY SATISFACTION OF PUBLIC BUSES IN BANGKOK

Sucharee Rawithornthada

*Research Advisor: Associate Professor Saksith Chalermpong Department of Civil Engineering, Chulalongkorn University,Thailand E-mail: sucharee.r.thada@gmail.com*

## Abstract

According to the BMTA's complaints database, reveals one of the significant unsatisfactions on the Bangkok bus service is a driver's behavior. The interesting variable is a certainty of the driver's compensation which seems not only the main factor to encourage the driver to work overtime but also to have detrimental driving behavior, which increasing negative complaints and risks of accident. Especially in private operators, the most drivers unstably gain daily income from ticket sales, without basic welfares, while the BMTAs have the monthly guarantee and living welfares as permanent staff. The sufficient remuneration management is expecting to have a strong potential to improve quality of the service accordingly, contributes more reliability of passenger to Bangkok bus system and opportunity to reduce traffic congestion and road accident involving the function.

**Keywords:** BMTA; Bangkok bus service; bus driver; remuneration; compensation; a level of service quality

**CU-09**

# An Information Transfer Framework for Facility Management in BIM Projects

V. Likhitruangsilp[1] and S. Thadaeng[2]

[1,2] *Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Thailand*
*Veerasak.L@chula.ac.th, sutasinee.thd@gmail.com,*

## Abstract

Facility management (FM) is an essential task in the operation and maintenance (O&M) phase of the building life-cycle. In present, building information modeling (BIM) technology is widely used to facilitate various aspects of building design and construction. Yet, the applications of BIM in FM have been comparatively limited. This is because the information accumulated during the design and construction phases cannot be efficiently transferred for FM. This paper proposes a new framework for extracting information from as-built BIM models and transferring it for FM. The framework encompasses the workflow and information exchange among project participants of such process. In addition, an application software in the form of graphic user interface (GUI) is developed to facilitate the implementation of the proposed framework. The information transfer structure is created based on the data compiled from in-depth interviews with BIM and FM experts. The Python programming language is chosen to develop the application software. An office building on the Chulalongkorn University campus is chosen to illustrate the implementation of the proposed framework.

**Keywords:** Building information modeling (BIM); Facility management (FM); Construction information management; As-built BIM model

**CU-10**

# A BIM-Enabled Dashboard System for Construction Project Monitoring and Control

V. Likhitruangsilp [1] and P. Nantapanuwat [2]

[1,2]*Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Thailand*

*Veerasakl@gmail.com, Pimpisut.nt@gmail.com*

## Abstract

Typical construction project monitoring and control primarily depends upon paper-based documents, which are prone to mistakes and human errors as well as cannot conveniently organize and retrieve relevant data and information. This is because the conventional process mainly focuses on producing documents, rather than managing information efficiently. Building information modeling (BIM) is a modern concept, which is extensively used for information management of construction projects. BIM can benefit every mission throughout project life cycle, including project monitoring and control during construction. This paper presents a BIM-based system, which is developed to support construction project monitoring and control. Relevant data and information from BIM models are organized, analyzed, and presented via dashboard software. The proposed system focuses on compiling and managing project data from various sources, as well as reporting project progress to project executives in the form of visualized and interactive dashboard. *Autodesk Revit* is used to author BIM models for storing project data and update the models to reflect actual work progress. *Microsoft Excel* and *Tableau* are integrated to manage project data and present project progress.

**Keywords:** Building information modeling (BIM); Construction project monitoring and control; Construction progress report; Dashboard

**CU-11**

# Photo Inspection of Crack in Reinforced Concrete

T.T. Nguyen[1], C. Jarroonnarm[2] and W. Pansuk[3]

[1,2,3] *Innovative Construction Materials Research Unit, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*
*thanhtung48c@gmail.com, mindchanamon@gmail.com, withit.p@chula.ac.th*

## Abstract

Cracks in reinforced concrete structures are the very popular problem which do not only deteriorate the appearance of structural components but also decrease the strength capacity of whole structures. The existing methods for cracks inspection are primarily based on the manual visual observation of the structural surface and the inspection results are completely depended on the experience of inspectors. Additionally, it is very time-consuming, expensive, and often unsafe when inaccessible structural members are to be assessed. Unmanned Aerial Vehicle (UAV) technologies have recently been applied for inspecting of reinforced concrete infrastructures to overcome the restrictions of physical investigation. This paper introduces photo inspection of crack in reinforced concrete by discovering a distance and angel of the appropriate shooting. This paper purposes are also finding the involved features to get a better crack images, then, bringing the results to determine cracks width and directions. More importantly, the outcomes of photo inspection are not only to categorize structural deficient, but also this technology can be applied to have faster external inspection in a safer way, decrease manpower, time and costs.

**Keywords:** Photo inspection; Crack inspection; Cracks width.

**CU-12**

# HEAVY TRAFFIC PERFORMANCE STUDY OF SMOKED NATURAL RUBBER UNDER SLEEPER PAD FOR BALLASTED TRACK RAILWAY USING BOX TESTS

Supakorn Rodkrantuk[1], Boonchai Sangpetngam[2]

*[1,2]Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand. E-mail: supakorn_38@hotmail.com[1],*
*[2]Center of Excellence in Infrastructure Management, Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand. E-mail: boonchai.sa@chula.ac.th[2]*

## Abstract

Most railway networks in the world are built with a ballasted track structure. As traffic tonnage accumulates, ballast rocks will get degraded increasingly due to aggregate breakage and abrasion. So, attempts to reduce ballast degradation to lower maintenance cost have been a major topic for many railways and researchers. A successfully proven alternative is to apply elastic under-sleeper pads (USP) between sleeper and ballast particles. Synthetic polymeric materials have been used in many USP suppliers and able to decrease ballast deterioration and track vibration. A recent study has found that natural rubber can serve a similar function as USP as well. Since natural para rubber is abundant in South East Asia countries, it is interesting to investigate deeper on its performance as the USP. In this study, natural rubber USP is vigorously simulated under heavy traffic loads using a cyclic box test under rigid foundation condition. The results indicate that natural rubber USP can reduce amount of ballast particle breakage significantly comparing to the case without USP.

**Keywords**: Ballast degradation; Natural rubber; Cyclic load; Maintenance Construction progress report; Dashboard

**CU-13**

# Collaborative Forms for Different Ecosystems of Building Information Modeling (BIM) Projects

V. Likhitruangsilp [1] and S. Ummarin [2]

[1,2] *Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Thailand*

*Veerasak.L@chula.ac.th, Sutthiluk.g@gmail.com*

## Abstract

Building information modeling (BIM) is widely adopted for facilitating various tasks of construction management. The ecosystem of a BIM project encompasses people with diverse specialties from different organizations such as the project owner, designer, construction contractor, construction management professional (CM), and material supplies. These people must work together by sharing the common vision and objective of the project. Yet, the relations between any two parties are unique and are characterized by different perspectives and requirements. Hence, the collaboration among the project stakeholders is considered a challenging factor in managing BIM projects. In this paper, we thoroughly examine the collaborative forms for different ecosystems of BIM projects. We identify crucial obstacles in communication and collaboration among the key stakeholders of BIM projects by interviewing the BIM personnel of project owners, designers, and contractors. The findings reveal several obstacles and issues that directly affect the project collaboration. The research also characterizes important features of existing collaboration forms for major BIM projects in Thailand. The results can greatly benefit all stakeholders to design collaborative forms that are suitable for their BIM projects.

**Keywords:** Building Information Modeling (BIM); BIM collaboration; BIM collaborative forms; BIM collaboration obstacles; BIM projects

**CU-14**

# Change Management for BIM Adoption in AEC Organizations

V. Likhitruangsilp[1], R. Prapornpen [2]

[1,2]*Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Thailand*

*Veerasak.L@chula.ac.th, Runganan.Prapornpen@gmail.com*

## Abstract

Digital disruption has had a major role in changing various aspects of organizational management in every industry, especially the Architecture, Engineering, and Construction (AEC) industry. Among numerous digital technologies, building information modeling (BIM) is the most dominant disruptive technology that is widely embraced by the AEC industry worldwide. BIM is a modern concept that transforms traditional construction work processes to digital paradigms, which can maximize organizational efficacy, minimize resource consumption, and exploit construction information. BIM adoption requires organization change, which is extremely challenging and complex. Such change is characterized by various factors such as organizational culture, resource, and policy. Inappropriate change management may result in undesirable results or failure. This paper proposes a framework for transforming AEC organizations adopting BIM based on the concept of change management. The preliminary framework is created based on the change management principle and is then modified to the context of the AEC industry by conducing in-depth interviews with project owners, contractors, designers, and consultants adopting BIM. The preliminary results reveal that the life cycle of BIM in AEC organizations consists of three major phases: (1) the beginning phase, (2) the transformation phases, and (3) the operation phases. In each phase, the AEC organizations have to make several major decisions according to their own attributes, including their objectives of using BIM, the selection of BIM team and change agent, and change readiness.

**Keywords:** Building information modeling (BIM), BIM adoption; Change management; Construction digital transformation; Architecture, Engineering, and Construction (AEC)

**CU-15**

# Factors Influencing Entry Mode Decisions into Myanmar Construction Market

Naw Ruth Po Gay[1], Vachara Peansupap[2] and Tanit Tongthong[3]

[1,2,3] *Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*
*vachara.p@chula.ac.th, th_tanit@yahoo.com, 6070495121@student.chula.ac.th*

## Abstract

This study draws upon entry modes (EM), a critical decision for market expansion as it determines the successful implementation. Despite the existence of several studies, not much attention was being given on developing Asian countries and little is known about entry modes adopted in Myanmar. Therefore, the purpose of this study was to identify the factors that influence the choice of entry modes by international construction companies. The influencing factors were identified by using ranking order, analysis of variance to analyze the differences between entry modes and Spearman's rank correlation was for finding the relationship between factors. The result indicates the predominantly adopted type of entry modes' common decisions influencing factors were political stability, demand and potential growth of construction market. The findings will help improving the knowledge of the Host Country for strategic entry planning.

**Keywords:** Influencing factors; Entry modes; International expansion; Myanmar

**CU-16**

# Wind load Analysis of a high-rise building by Computation Fluid Dynamics

Canh Thiet Phung[1] and Chatpan Chintanapakdee[2]

[1,2]*Department of Civil and Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand*
*phungthietcanh@gmail.com, chatpan.c@chula.ac.th*

## Abstract

Wind load is a critical load that governs the design of the primary lateral force resisting system of a tall building. As new buildings become taller due to limited land area and often irregular in shapes for esthetics and some design constraints, wind load formula provided in design codes and standards cannot be applied because of the limitations in using basic wind load formulas being violated. Wind tunnel test (WTT) is thus the suggested approach to obtain the appropriate wind load for design of such buildings. However, WTT is costly and time-consuming as it often requires much preparation of the small-scale model of the principal building being considered with instrumentation and numerous realistic blocks of surrounding buildings. In past decades, Computational Fluid Dynamics (CFD) has been studied and proposed as an alternative method to WTT in various applications, e.g., aerospace and automobiles, but it requires highly powerful computers to be able to obtain adequate accuracy of results. Nowadays both computer hardware and software are ready for the application of CFD in computing wind loads for irregular tall buildings. In this study, the accuracy of wind loads on a 150m-tall irregular-shaped building in Bangkok is evaluated by comparing the results from CFD to those from the WTT of the same building at 1:400 scale with 400m radius of the neighboring area. CFD was implemented in ANSYS Fluent for the conditions as close as possible to the WTT setup, which was tested at Thammasat University, Pathum Thani, Thailand. Two most effective turbulence models, steady-state *k-ω-SST* (shear stress transport) and transient state *LES* (large eddy simulation), were used in the simulation as two alternatives and evaluated to identify the more promising method. Preliminary results showed that the LES turbulence model provides slightly better accuracy, but the *k-ω-SST* turbulence model still provides reasonably acceptable accuracy when compared to WTT results, but *k-ω-SST* turbulence model requires significantly less computational time. In addition, comparison of CFD results from the case with and without surrounding neighboring buildings reveals that neighboring buildings played an important role regarding turbulence development at low elevation and significantly influences wind pressure on the principal building.

**Keywords:** Computational Fluid Dynamics (CFD); Wind loads; Tall buildings; Turbulence models; Large eddy simulation (LES).

**CU-17**

# Quantification of Construction Waste using Digital Image and 3D Model

Kanjanapot Srisuksai[1], Tanit Thongtong[2]

*[1,2] Department of Civil Engineering,*
*Chulalongkorn University, Bangkok, Thailand*
*6070119221@student.chula.ac.th, tanit.t@chula.ac.th*

## Abstract

The quantification of construction waste requires budget and resources. Waste generated from construction is a significant factor impacting the cost and time. Knowing the amount of waste significantly benefits management of waste construction. This research establishes a system for determining the volume of construction waste by applying photogrammetry technique and buidling information modeling (BIM). A building construction project in Thailand is selected as a case study to demonstrate the proposed system. The result of case study shows that the system is capable of supporting green construction and environmental impact assessment.
**Keywords:** Photogrammetry; Construction Waste; Point Cloud; Green Construction

**CU-18**

# Augmented Reality for Progress Tracking in Infrastructure Construction

Sittinut Srinoi[1] and Tanit Tongthong[2]

[1,2] *Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, Thailand*

*6070335421@student.chula.ac.th, Tanit.t@chula.ac.th*

## Abstract

This study aimed at a development of a new approach to improve progress tracking in infrastructure construction. Instead of dealing with conventional paper-based documents, this study presented a system that generated an Augmented Reality (AR) model combining information of work plans from Microsoft Project and 3D model from Building Information Modeling (BIM). The AR model represented the state of the project according to the day by day work plan. Then, it is superimposed on the video of the actual work conditions of the infrastructure project that was collected by using Unmanned Aerial Vehicles (UAVs). The result improved the tracking processes by comparing the similarities or differences between images of Augmented Reality of the work plan and the actual work conditions. This allowed project managers to see a more comprehensive overview of the project's progress.
**Keywords:** Infrastructure; Progress Tracking; Augmented Reality; Building information modeling (BIM)

**CU-19**

# Construction Bidding Behaviors and The Impact on Public Project Performance

Kittitee Kaewmanee[1], Tanit Thongtong[2] and Vachara Peansupap[3]

[1,2,3] *Department of Civil Engineering,*
*Chulalongkorn University, Bangkok, Thailand*
*6070109021@student.chula.ac.th, tanit.t@chula.ac.th, vachara.p@chula.ac.th*

## Abstract

In public construction, government agencies sometimes faced the problems that their projects were delayed or abandoned. These problems may due to very low bids by the contractors who tried to increase their chances to win the auction. This research aimed to use the historical procurement data and project performance information to create a model that could predict the project success or failure before signing the construction contract. This model was developed with a modified statistical graph and also the decision tree, regression analysis and neural networks. The result showed the bidding behaviors and the chance of the impact on project performance.
**Keywords:** Bidding behavior; Abnormal bid; Project performance

**CU-20**

# An Efficient ES-FEM Complementarity Approach for Post-Collapse Responses of Concrete Gravity Dam

Sawekchai Tangaramvong[1] and Le Hoang Vu[2]

[1,2] *Applied Mechanics and Structures Research Unit, Department of Civil Engineering,*
*Chulalongkorn University, THAILAND*
*sawekchai.t@chula.ac.th, lehoangvu.chula.11793@gmail.com*

## Abstract

The paper presents a novel complementarity mathematical programming-based technique modeled within an edge-based smoothed finite element method or ES-FEM framework to map out the complete responses of a concrete gravity dam under hydraulic pressures. The physically instabilizing failure underpinning the damaged interface between concrete dam and solid rock foundation is considered by the so-called cohesive fracture processes. The concrete structure is assumed elastic or undamaged during the whole loading regime. The mode-I tensile fracture incorporating nonlinear softening traction is formulated as a mixed complementarity problem or MCP in a rate form that can be solved using the stepwise holonomic algorithm run directly within a generic mathematical programming framework. What is also important is that the efficient ES-FEM modeling platform automatically and nonuniformly refines (merges) some specific discrete meshes involving the high (low) values of stress intensity developed at concrete body and interface points. Such model construction presents a major computational advantage, namely coarse mesh accuracy even under stress singularity and incompressibility ill-conditions at crack tips, and is hence suitable for the broad applications in engineering fracture mechanics, such as one (namely failure analyses of concrete gravity dam) presented in this work. The analysis results showed the strength deterioration given by the concrete dam leading to softening equilibrium responses as when an upstream hydraulic uplifting pressure penetrated through the cracked interface.
**Keywords:** Cohesive fracture; Complementarity problem; Smoothed finite element; Automatic mesh refinement; Softening equilibrium path.

**CU-21**

# Multimodal inversion of surface waves for determining Vs profiles

Tirawat Simlemkin[1] and Tirawat Boonyatee[2]

*Department of Civil Engineering, Chulalongkorn University, Thailand*

*tirawat.scu97@gmail.com*[1], *dr.tirawat.gmail.com*[2]

## Abstract

A surface wave inversion is a numerical technique for estimating the shear wave velocity profile of a ground from the dispersion characteristic of surface waves. For a normally dispersive ground where the ground stiffness increases monotonically with depth, the dispersion characteristic is mainly influenced by the fundamental mode of vibration. Unfortunately, actual geological conditions and their dispersion characteristics are more complex and involve with higher modes of vibration. In this study, an inversion code which considers higher vibration modes is developed in MATLAB. By performing predictions on synthesis signals generated by FEA and on field measurements in locations where the ground conditions are known, the estimated shear wave velocity profiles and validation data are found to be in good agreements.

**Keywords:** Inversion, Surface waves, Multimode

# *Abstracts from Hong Kong University of Science and Technology*

**HKUST-01**

# 3D Topographic Amplification of Ground Motions considering the shaking direction of seismic waves

Z.W. Chen[1], G. Wang[2] and D. Huang[3]

[1,2]*Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China*

[3]*Department of Hydraulic Engineering, Tsinghua University, Beijing, China*

*zchendq@connect.ust.hk, gwang@ust.hk, huangduruo@tsinghua.edu.cn*

## Abstract

It is necessary to consider the topographic amplification of ground motions in the seismic design of infrastructure. This study uses a 3D regional-scale Spectral Element model to investigate the topographic effect, using sites in Hong Kong as testbeds. Firstly, the Ricker wavelets with different frequencies are adopted as input motions to study the effect of wave frequency and shaking direction. The amplification pattern is frequency dependent and can be well correlated with a characteristic smoothed topographic curvature. A parametric model based on the combination of smoothed curvatures along and perpendicular to the shaking direction is proposed, and it can quantify the notable difference in ground-motion amplification along different directions. Finally, simulations are conducted using a real recorded earthquake motion as the seismic input, and it shows that the proposed model has a good prediction of the amplification of both PGA and SA.

**Keywords:** Topographic amplification; Spectral element method; Shaking direction; Smoothed curvature.

**HKUST-02**

# Peridynamics simulation of contact behavior in granular particles

S. Mohajerani[1], G. Wang[2]

[1,2] *Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong*

*smohajerani@connect.ust.hk, gwang@ust.hk*

## Abstract

The knowledge of the behavior of solids touching each other is known as contact mechanics (CM). The principle of CM is the foundation of a tremendous number of contributions in various disciplines such as particle crushing, coupling devices, tires, bearings, combustion engines, ultrasonic welding, electrical contacts and many others. Conspicuous challenges dealt in the literatures may encompass stress analysis of contacts and mating parts. In this research, the behavior of coupled grains between loading plates is simulated using Peridynamics. Peridynamics is a novel theory of none-local solid mechanics which formulates the physics in terms of integral equations instead of local partial differential equations. This research is aimed to demonstrate the capabilities of Peridynamics to model the normal and frictional contacts in grain scale. The simulations are performed such that the grains are subjected to normal and tangential loadings and the behavior of the contact is analyzed. The numerical results are validated using analytical and experimental evidences with a satisfactory correlation.

**Keywords:** Peridynamics, Contact Mechanics, Numerical Simulation, Frictional Contact.

**HKUST-03**

# Investigation on Savonius Turbine Interactions by Cluster Layout Optimization

H. Chan[1], K.M Li[2], C.M. Chan[3]

*Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong*
*cecmchan@ust.hk, kmliac@connect.ust.hk, hchanai@connect.ust.hk*

## Abstract

Savonius-type wind turbines show great potential in urban wind harvesting. While their coefficient of performance ($C_p$) is lower than that of the propeller-type wind turbines used in utility-scale wind farms, they are preferred in urban areas because of their self-starting abilities, lower cut-in wind speeds and omni-directionality. Recent research discovered potential beneficial near-field interactions among Savonius-type wind turbines. This feature is uncommon because near-field interactions among most other types of wind turbines, including propeller-type wind turbines and Darrieus-type wind turbines, are usually destructive. The beneficial near-field interactions do not only improve power generation but also significantly reduce the floor space taken up by wind turbines. Since urban land is scarce, these synergetic interactions make urban wind farm development more economically viable. However, the interaction mechanisms of these effects have not been fully explored and identified, making utilization of such interactions not practically possible.

To fully exploit the potential of the beneficial interactions, a rigorous inspection on the interaction mechanisms is carried out. The locations of Savonius-type wind turbines within a wind turbine cluster are optimized with genetic algorithm (GA) optimization and two-dimensional computational fluid dynamics (CFD) simulations to maximize the $C_p$ at a fixed tip-speed ratio of 0.8 and a steady incident wind velocity at 4 m/s. The beneficial cluster interactions are then deduced from the flow structures of the optimized layouts. In our study, the $C_p$'s of the optimized clusters are improved by at least 40% over standalone wind turbines. By understanding the near-field interaction mechanisms, we may be able to generalize these effects and exploit these mechanisms under different wind conditions. Efficient and compact urban wind farms with closely spaced Savonius-type wind turbines can be thus developed and help us tap into the energy potential of urban wind.

**Keywords:** Wind energy, vertical-axis wind turbine, urban wind farm.

**HKUST-04**

# Optimization of Occupant Thermal Comfort and Energy Consumption in MVAC Systems Using a BIM-Supported Computational Approach

H.H.L. Kwok[1] and J.C.P. Cheng[2]

[1,2]*Department of Civil and Environmental Engineering, HKUST, Clear Water Bay, Kowloon, Hong Kong*
*hlkwokab@connect.ust.hk, cejcheng@ust.hk*

## Abstract

As people spend most of their time indoor, occupant thermal comfort is important in both health and productivity aspects. Thermal comfort is usually controlled by a Mechanical Ventilation and Air Conditioning (MVAC) system, which is the main contributor to the electricity consumption of buildings in Hong Kong. Many previous studies have developed simulation approaches for optimizing occupant thermal comfort and energy consumption in an indoor environment. However, few of them validated their simulated results against experimental data. This paper proposed a methodology to optimize occupant thermal comfort and energy consumption of a typical lecture theatre using building information modeling (BIM) technology. A BIM model of the lecture theatre was created to provide both geometry and semantic information to conduct CFD and energy simulations. The CFD simulation was validated using measured temperature data. To minimizing electricity consumption while maintaining satisfactory thermal comfort, CFD and energy simulations were conducted in different occupancy scenarios to determine optimal diffuser placement and MVAC control setting.

**Keywords:** BIM; CFD; Energy simulation; MVAC; Thermal comfort

**HKUST-05**

# Logistics Management of Construction Waste Material: Exploration of Future Research Directions

Rana Rabnawaz Ahmed[1] and Xueqing Zhang[2]

[12] *Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China*
*rrnahmed@connect.ust.hk, zhangxq@ust.hk*

**Abstract**

Globally, construction waste (CW) generation and its effective management are two longstanding issues in the field of CW management. Although, waste management (WM) hierarchy has been used worldwide for improved WM but, dealing with growing problems & achieving sustainability is still a challenging thing. Subsequently, a saturation of the limited capacity waste infrastructure facilities e.g., landfills are understandable and obvious. Therefore, it is significant to deal with waste material using methods that provide maximum value recovery and minimum disposals to landfill in a cost-effective and environmentally friendly manner i.e., by ensuring effective implementation of best practices in logistics management (LM). For this, possible integration of these two topics i.e., CW & LM needs to be investigated i.e., exploration of future research directions. The systematic literature review (SLR) approach is used as a methodology to explore the frequently used key-words in the last 2 decades i.e., 1998-2018 as well as across different continents i.e., from a geographical perspective. In the end, identified keywords were used for suggesting possible research directions for future researchers as the contribution of the study.

**Keywords:** Construction waste; Logistics management; Systematic literature review; Research directions

**HKUST-06**

# Numerical Simulation on the Shear Behavior of Crushable Granular Material under Various Intermediate Stress Ratio

K. Shi[1] and J.D. Zhao[2]

[1,2]*Department of Civil and Environmental Engineering, HKUST, Hong Kong SAR, P.R. China*
*kshiad@ust.hk, jzhao@ust.hk*

## Abstract

Particle crushing is universally observed in various engineering fields and in civil engineering, it changes the most important properties of granular materials including stress-strain relationship, permeability and internal friction angle, posing a threat to the stability of structures it supports. Several experimental and numerical methods studying particle crushing behavior have been developed over the past few decades. However, most laboratory tests and numerical simulations were conducted under uniaxial or triaxial loadings conditions and the influence of intermediate principal stress was not considered. In this paper, an impulse-based physics engine coupled with peridynamics method was used to simulate the stress and dilatancy behavior of crushable dense sand with different intermediate stress ratio. Results show that the stress ratio of dense sand is reduced, and particle breakage increases with increasing intermediate stress ratio.

**Keywords:** particle crushing; intermediate stress ratio; physics engine.

**HKUST-07**

# Some Asian green roof standards and guidelines through the lens of biodiversity

Xiran Hui[1] and Xueqing Zhang [2]

[1,2]*Department of Civil and Environmental Engineering, The Hong Kong University of Science & Technology, Hong Kong, China*

*xhui@ust.hk,zhangxq@ust.hk*

## Abstract

In the last few decades, green roofs, with their benefits for cities' sustainable development, have become a feature of buildings around the world. This has required countries and regions to establish standards and guidelines for standardizing green roofs, including design, requirements and maintenance of roof greening. This paper compared and analyzed the green roof standards in Hong Kong, Singapore, and Beijing Different, with reference to local climate conditions, the intensity of rainfall, need for irrigation, type of green roof and type of building in order to evaluate the effectiveness of green roof standards and guidelines in supporting biodiversity in different countries and regions. Some recommendations were made for developing better standards and guidelines for enhanced green roof performance.

**Keywords:** Green roof; biodiversity; standards; guidelines.

**HKUST-08**

# Key Issues in Public-Private Partnerships Insurance

G. Shi[1] and Xueqing Zhang[2]

[1,2]*Department of Civil and Environmental Engineering, The Hong Kong University of Science & Technology, Hong Kong, China*

*gshi@ust.hk, zhangxq@ust.hk*

## Abstract

Natural disasters such as the earthquakes, floods and other risks happened worldwide and bring significant impacts to individuals and communities. It is important for the government to manage these risks and maintain a good social development. However, for countries, especially those developing countries, the government have heavy financial burden to provide efficient fund for good disaster management. Although insurance is a good tool to provide financial support, insurance companies are reluctant to cover the risks which are hard to address. Moreover, these countries' financial market is not mature to provide suitable financial products. In this paper, we expand the domain of public-private partnerships (PPPs) to include other kinds of interactions between the government and the insurance company which can effectively address response and recovery issues in disaster management. We identified and analyzed four cases and proposed useful points for successful implementation of PPPs in insurance. The framework of procedures is also designed based on the lessons learnt from the cases, which is expected to improve the disaster management in practice.

**Keywords:** Public-private partnerships; insurance; risk management; case study.

# *Abstracts from Korea Advanced Institute of Science and Technology*

**KAIST-01**

# Evaluation of Suction Anchor Adaptability for the Submerged Floating Tunnel Foundation in Silty-Sand

J.S. Bae[1], Y.J. Jeong[2] and D.S. Kim[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*Baejunsik2@kaist.ac.kr, yeonghoon@kaist.ac.kr, dongsookim@kaist.ac.kr*

## Abstract

The concepts of Submerged Floating Tunnel (SFT) are considered as an optimal method to cross the ocean. Since the characteristics of the SFT (i.e., failure on the body, psychology issues, and unsuspected loading), selecting the appropriate foundation system is important. Therefore, a suction anchor with advantages in utility and capacity was regarded as the based concept for the SFT foundation system in KAIST SFT project. To understand the suction anchor, a series of centrifuge tests are conducted and compared with prior researches. In this study, the effects of the loading inclinations and the anchor dimension on the anchor behavior (i.e., capacity and rotation) are presented. Furthermore, the expected anchor sizes are suggested based on the results of researches. Finally, the causes of the difficult to apply the suction anchor are discussed.

**Keywords:** Submerged Floating Tunnel, Suction anchor, Rotation behavior, Pullout capacity, Inclined loaded, Centrifuge.

**KAIST-02**

# Characteristics of the momentum transfer efficiency depends on the abrasive flow rate considering focus geometry

Yohan Cha[1], Tae-Min Oh[2], Hyun-Joong Hwang[3], and Gye-Chun Cho[4*]

[1,3,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

[2]*Department of Civil Engineering, PNU, Korea*

*ground@kaist.ac.kr, geotaemin@pusan.ac.kr, hyunjoong@kaist.ac.kr, gyechun@kaist.ac.kr*

## Abstract

Abrasive waterjet is emerging technical tools for civil engineering purpose such as for concrete demolition and rock cutting. Since it can remove concrete mass without damaging the embedded steel bar in reinforced concrete, it can be applied for old structure demolition or repair. The high velocity water accelerated abrasives are the main energy of abrasive waterjet. The acceleration of the abrasive is affected by the momentum transfer efficiency and results in different cutting energy. In this study, the effect of abrasive flow rate on the momentum transfer efficiency was evaluated by rock cutting experiments. The momentum transfer efficiency was theoretically estimated from the relationship between the abrasive kinetic energy and cutting depth depends on the abrasive flow rate, and the influence of the water flow rate and the focus geometry on the efficiency was evaluated. The results of this study are expected to be used for the characteristics of optimum abrasive flow rate for rock cutting.

**Keywords:** Waterjet; acceleration efficiency; momentum transfer; rock cutting

**KAIST-03**

# Effect of abrasive flow rate on rock drilling volume of abrasive waterjet

Hyun-Joong Hwang[1], Yohan Cha[2], Tae-Min Oh[3] and Gye-Chun Cho[4*]

[1,2,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

[3] *Department of Civil Engineering, Pusan National University, Korea*

*hyunjoong@kaist.ac.kr, ground@kaist.ac.kr, geotaemin@pusan.ac.kr, gyechun@kaist.edu*

## Abstract

Abrasive waterjet has been used in various fields of milling and cutting. In civil engineering, it is recently applied to rock excavation and tunneling. For rock drilling, under certain standoff distance conditions, it is inefficient due to interference effects such as collision between abrasives. So we analyzed the characteristics of removal volume with abrasive flow rate and standoff distance at the same exposure time. Additionally, we evaluated applicability by comparing abrasive flow rate with rock drilling rate in terms of cost. This analysis demonstrates the possibility of abrasive waterjet drilling for field application.

**Keywords:** Abrasive waterjet; Rock drilling; Abrasive flow rate; Standoff distance

**KAIST-04**

# An overview on the binder chemistry of aluminosilicates activated by carbon negative minerals

S.J. Bae[1], J.H. Seo[2], S.H. Kim[3], S.M. Park[4] and H.K. Lee[5,*]

[1,2,3,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

*bsj921008@kaist.ac.kr, junhoo11@kaist.ac.kr, kimsh1187@kaist.ac.kr, solmoi.park@kaist.ac.kr, haengki@kaist.ac.kr*

[*] *Corresponding author*

## Abstract

Alkali-activated materials have been extensively investigated in an effort to develop alternative cementing systems. Alkali-activated materials can be typically synthesized by the alkaline activation of aluminosilicates obtained from industrial by-products such as fly ash and slag. Past studies preferred utilizing highly alkaline agents (e.g., sodium hydroxides and water glass) to make the alkali-activated materials exhibiting mechanical performances comparable to and/or superior than those of Portland cement-based materials. Recent works, however, are focusing on searching price-competitiveness and naturally obtainable activators, namely carbon negative minerals. In this regard, this paper revisits previous studies of aluminosilicates activated by carbon negative minerals and summarizes their binder chemistry. In addition, a preliminary study pertaining to the microstructural evolution of lime-activated slag carried out by the authors will be presented.

**Keywords:** Alkali-activated material; Aluminosilicate; Carbon negative mineral; Binder; Chemistry

**KAIST-05**

# Particle-Based Numerical Analyses for Water Wave Generation

S. Lee[1], K. Ko[2], and J.W. Hong[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*lesami89@kaist.ac.kr, kwonhwan0911@kaist.ac.kr, j.hong@kaist.ac.kr*

## Abstract

In this research, waves with various wave steepnesses are generated by the use of the smoothed particle hydrodynamics (SPH), and the numerical results are compared with the experiments. The experiment was carried out in a 50 m long tank, and the numerical wave tank (NWT) is modeled to 11 m in length for computational efficiency. A piston-type wavemaker is installed at the left end of the NWT, and a particle-based damping zone is applied to the right end to suppress the reflected waves. Compared with the results from the linear wave theory, the accuracy of the wave heights in the experiment and numerical wave heights decrease with increasing relative depth and wave steepness. When the target wave height exceeds more than 10% of the wavelength, waves break in both the experiment and simulation. As a result of numerical analyses, the regular and breaking waves can be simulated accurately.

**Keywords:** Smoothed particle hydrodynamics (SPH); Numerical wave tank (NWT); Wave generation

**KAIST-06**

# Crack Width Measurement with an Adaptive Kernel

S. Jin[1], S. E. Lee[2], and J. W. Hong[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*jinso77@kaist.ac.kr, sangeon1@kaist.ac.kr, j.hong@kaist.ac.kr*

## Abstract

The boundaries of cracks are irregular, and the measurements of the crack widths are generally subjective and challenging due to the irregular boundaries as well as image resolution. In this research, a crack width measurement is proposed using an adaptive kernel changing the size to calculate the direction of the crack propagation. The main skeleton of cracks is extracted using a pruning algorithm. The size of the adaptive kernel is determined by the distance between the main skeleton and the boundaries of the cracks. An eigenvalue problem of the adaptive kernel is solved to obtain the direction of the crack propagation. The crack widths measured by the proposed measurement are investigated, and the distributions of the crack widths are calculated. As a result, the crack widths by the proposed method are in good agreement with the crack widths measured manually.

**Keywords:** Crack width; Pruning method; Adaptive kernel

**KAIST-07**

# Prediction of adiabatic temperature rise of concrete using isothermal microcalorimetry

D.J. Jeong[1], and J.H. Kim[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*dj.jeong@kaist.ac.kr, jae.kim@kaist.ac.kr*

## Abstract

Hydration heat of concrete has an influence on the dimensional stability of early-age concrete. Analysis of the thermal expansion and followed shrinkage of concrete requires its adiabatic temperature rise, which depends on the mix proportion and the chemical compositions of raw materials. However, the measurement of the adiabatic temperature rise is cumbersome and highly costs. In this study, a model is proposed to predict the adiabatic temperature rise of concrete using isothermal microcalorimetry of its binder. Isothermal microcalorimetry analysis was conducted for cement pasting proportioned by the water-to-cement cement ratio of 0.45 to 0.55. The predicted adiabatic temperature rise is the verified by comparing it with the measurement using a conventional equipment.
**Keywords:** Adiabatic temperature; Concrete; Isothermal microcalorimetry; Degree of hydration

**KAIST-08**

# In Situ Measurements of Yield Stress for Freshly Mixed Mortar

T.Y. Shin[1] and J.H. Kim[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*tyshin@kaist.ac.kr, jae.kim@kaist.ac.kr*

## Abstract

The rheological properties of fresh mortar are directly related to concrete workability. The flowability or filling ability of concrete can be evaluated by measuring rheological properties of mortar with considering size and fraction of coarse aggregates. The previous researches proposed correlation between rheological parameters and flow test results such as mini-slump or channel flow tests. This research aims to establish yield stress equation of freshly mixed mortar based on flow table test results, which is flow test for mortar having relatively poor workability. In this study, a number of flow table test, numerical simulations and rheological measurements using concentric vane rheometer were conducted, and Sisko and Bingham model can generalize the flow behavior of fresh mortars.
**Keywords:** Mortar; Rheology; Flow table; Yield stress

**KAIST-09**

# Development of a Digging Robot that Fuses the Behavior of Moles and Mole-rats

C. Tirtawardhana[1], J.S. Lee[2] and H. Myung[3]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

[3] *School of Electrical Engineering, KAIST, Korea*

*christiant@kaist.ac.kr, ljs630@kaist.ac.kr, hmyung@kaist.ac.kr*

## Abstract

In recent years, space exploration has become one of the most flourishing fields that are substantial for the future of the earth inhabitants. Many researches have been performed in order to expedite this need, yet the aggravating problems such as the depth of excavation, roughness of the terrain, range of exploration and soil-waste treatment, are still challenging. To overcome those drawbacks, the digging principles of two of the most proficient burrowing animals, i.e., moles and mole-rats, are investigated, combined, and applied to designing a novel digging robot. In this paper, the excavation mechanism of a digging robot using an expandable drill-bit and forelimbs system, along with the soil-waste removal mechanism, which are inspired by moles and mole-rats, are proposed.

**Keywords:** Digging robot; Bio-inspired; Mole; Mole-rat

**KAIST-10**

# Urban Street Changes using a Deep Learning Method

Giyoung Byun[1] and Youngchul Kim[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*rain8496@kaist.ac.kr, youngchulkim@kaist.ac.kr*

## Abstract

This paper seeks to capture urban street changes using a deep learning method. Although previous studies normally used satellite images and census data to capture changes, this paper adopts an image recognition approach on a street level. The Woodward Avenue in the Midtown of Detroit, Michigan, USA is chosen to investigate street changes by a deep learning method. By analyzing panoramic images on streets, this paper identifies changes on streets and visualizes its affect on their neighborhood. Additionally, this paper develops a figure to trace whether those change affect growth or decline on a street. As a result, this paper effectively illustrates urban growth and decline on a street level. Urban growth areas are captured in the southern part of the Woodward Avenue in the Midtown of Detroit. It is expected to be helpful to identify streetscapes and perception in an urban area.

**Keywords:** Urban Change Detection; Streetscape; Deep Learning; Image Recognition

**KAIST-11**

# How do Luxury Fashion Brands Build a Global Urban Network? Cases in Cities of East Asia

Ha Kyeong Lee[1] and Youngchul Kim[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*lhkny96@kaist.ac.kr, youngchulkim@kaist.ac.kr*

## Abstract

Global luxury fashion brands have developed a network between cities in a domestic and international scale, by building a global distribution system with their flagship stores and boutiques. Global networks usually focus on global industrial, law, financial services firms and air passengers, which represent actual links of services and movements respectively. Because of the global luxury fashion brand's inherent sensitivity to trend, their network has potential as an index evaluating cultural competitiveness of cities. Thus, this paper seeks to develop a new global urban network with luxury fashion brands to capture cultural competitiveness between cities. This paper establishes a method to develop a global network between cities in East Asia with three luxury brands boutiques. As a result, this study demonstrates a hierarchical tendency between cities to investigate city characteristics as a trendsetter and powerful cultural influence.

**Keywords:** Urban Network; Globalization; Luxury Fashion Brand; Network Analysis

**KAIST-12**

# Visual pollution on public sites affecting public sights

Jinha Kim[1] and Youngchul Kim[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*jinhakim@kaist.ac.kr, youngchulkim@kaist.ac.kr*

## Abstract

This paper explores the factors influencing visual perception and cognition which enable people to form aesthetic judgements in urban areas. In particular, visual pollution is an important element that affect visual perception and cognition in the streetscape. To assess the measures of visual pollution in public sites, we systematically reviewed literatures on people's perception on visual pollution. As a result, visual pollution is commonly referred as main factor of unconscious suffer from mental distress. Visual pollution includes aged architecture, idle public space, outdoor advertisement, media façade, night lights, etc. It is also found that topics in investigating visual pollution has changed from understanding people's perception with a survey method to developing a method to measure intensity and proposing detailed cityscape planning guidelines that give identity in the public sites.

**Keywords:** Visual pollution; Detailed Cityscape Plan; Outdoor Advertisement

**KAIST-14**

# A Framework to Compute the Width and Area of Debris-Flow Based on DAN3D

E. Cheon[1], S.R. Lee[2], S.M. Lee[3], D.H. Lee[4], M.S. Kim[5], and H.H. Lim[6],

[1,2,3,4,5,6] *Department of Civil and Environmental Engineering, KAIST, Korea*

*enokjun@kaist.ac.kr, srlee@kaist.ac.kr, lsmgrrr3@kaist.ac.kr,*

*deukhwan@kaist.ac.kr, hellopdlms@kaist.ac.kr, hwanhui@kaist.ac.kr*

## Abstract

This study describes an algorithmic framework developed to compute the width and area of debris-flow using the results from DAN3D program that simulates debris-flow hazards. Currently, DAN3D program discretizes debris-flow into particles and analyzes each particle individually. However, this presents some limitation to calculate the width and area of debris-flow, as it requires analyzing the debris-flow as a continuous mass, rather than individual particles. Therefore, the developed framework considers the collection of particles as a continuous mass of debris-flow to compute the width and area of debris-flow by using the established algorithms, such as Shoelace formula and Convex Hull. The width and area of the debris-flow are expected to function as effective and reliable data for estimating the damaged basin caused by the debris-flow and designing structures to mitigate debris-flow hazards.

**Keywords:** Debris-Flow, DAN3D, Convex Hull, Shoelace formula

**KAIST-15**

# A study on the urban airspace for sUAV operation

N. Kim[1], J. Cho[2] and Y. Yoon[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*ih736x@kaist.ac.kr, jjw9171@kaist.ac.kr, yoonjin@kaist.ac.kr*

## Abstract

The recent growth in small Unmanned Aerial Vehicle (sUAV) applications in public and private sectors has generated great interest in developing robust airspace management to operate sUAVs in urban airspace. However, the urban drone use is particularly challenging since a good amount of the airspace is already occupied with manmade structures. In order to operate sUAV in urban airspace, the building footprint and height data should be considered. In this study, we adopt the airspace availability assessment framework to identify available airspaces for the Greater Gangnam area and the Manhattan area. This study is not only capable of identifying airspace availability but also has the potentials to design path planning of sUAV and to assess capacity in urban airspace.

**Keywords:** Urban Airspace, sUAV, Geofence, UTM

**KAIST-16**

# Weighted Complex Network Analysis of the Northeast Asian Air Route Network

Seyun Kim[1] and Yoonjin Yoon[1]

[1] *Department of Civil and Environmental Engineering, KAIST, Korea*

*whataud@kaist.ac.kr, yoonjin@kaist.ac.kr*

## Abstract

Studying the properties of airport network of various countries based on complex network theory has been well researched over the past decade. However, there were only a few attempts made to utilize air route network with waypoints and air traffic service routes, and even most of which were unweighted networks. Since unweighted air route network may not suffice to fully describe the air traffic service, distance-weighted and demand-weighted air route networks are modeled in this study. Weighted air route networks of the rapidly growing Northeast Asian region are considered, and their topological characteristics and network robustness are analyzed. As a result, it is found that targeted attacks on waypoints with high weighted betweenness showed the most severe outcome. Findings on the set of important waypoints and corresponding air routes provide key insights for effective disaster mitigation and airspace design.

**Keywords:** Air transport network; Northeast Asia; Network robustness; Complex network; Weighted network

**KAIST-17**

# Assessing the impact of restricting airspace in populated areas on airspace availability for UAV Operation

S.O. Oh[1] and Y.J. Yoon[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*suhwan@kaist.ac.kr, yoonjin@kaist.ac.kr*

## Abstract

In several countries, small Unmanned Aerial System (sUAS) operations are not allowed in populated areas to minimize risks to population on the ground. Such conservative approach is expected to eventually be relaxed when sUAS demand grows exponentially. Particularly in urban areas, sUAS demand is expected to be concentrated. Thus, appropriate mitigation measures are needed to address risk of collision between unmanned aircraft and non-involved person in urban environments for sUAS operations. This study aims to evaluate the impact of restricting airspace in populated areas on airspace availability, by measuring risks to population on the ground. The risk is quantified through a probabilistic approach based on high-resolution people flow data, to assess the actual number of people who are in direct exposure to sUAS operations. We then set no-fly zones (NFZ) based on the level of risk. In the study area of Seoul, South Korea, the effect of designating NFZs by considering spatiotemporal dynamics of people flow is examined and discussed.

**Keywords:** Drone safety; Urban air mobility; Geospatial analysis; People flow data

**KAIST-18**

# Reflecting Structural Dynamicity of Traffic Networks to Graph Convolution Modules: A Deep Learning Approach to Traffic Forecasting

Y.Y. Shin[1], and Y. Yoon[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*yuyol.shin@kaist.ac.kr, yoonjin@kaist.ac.kr*

## Abstract

Traffic forecasting is a research area in transportation engineering for its role as a crucial component of urban traffic management. The key challenge to accurate traffic forecast is that the traffic data possesses both spatial and temporal non-linearity. With emergence of Graph Convolutional Networks (GCN), the structure of traffic networks has been modeled into deep learning architectures. However, in many current researches, the importance of graph edge weights is frequently overlooked and use of simple distance weight may not be enough to capture structural dynamicity of traffic networks and model spatial non-linearity. In our work, we applied various types of graph weights to adjacency matrix of traffic network graph, and applied graph convolution network to traffic forecasting problem with the different weighted adjacencies. Analyzing the experiment conducted on real-world 5min average speed data, we show different types weights needs to be implemented in different locations. For locations with more homogeneous roads characteristics, the distance weight may be appropriate, but for locations with more heterogeneous characteristics, the speed limit weight may yield more accurate prediction.

**Keywords:** Graph Convolution Networks; Transportation Network; Deep Learning; Traffic Forecasting

**KAIST-19**

# Operational strategy of Multi-functional Electromagnetic damper for Cable Structure

H.S. Kim[1], H.Y. Jung[2], S.K. Kye[3] and H.J. Jung[4]

[1,3,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

[2] *Hyundai Construction Equipment, Korea*

*rlagudtn0934@kaist.ac.kr, hyjung89@gmail.com, skkye@kaist.ac.kr, hjung@kaist.ac.kr*

## Abstract

Vibration control and monitoring of cables, the main structural component of cable-stayed bridges, are becoming more important as their span length increases. Especially, stay cables are susceptible to vibrations because of their relatively small damping ratio and flexibility. In this paper, the multi-functional electromagnetic (EM) damper that can estimate the cable tension and harvest the electrical energy enough to operate low-power electronics as well as can effectively control excessive vibration of the stay cable was proposed. The proposed system normally operates in the energy harvesting mode to perform energy harvesting and tension estimation. However, it operates in the vibration control mode that can generate maximum control force when excessive cable vibration occurs. An operation strategy for applying the proposed system to the actual cable was evaluated by numerical simulation under actual wind loads condition.

**Keywords:** Electromagnetic Damper; Cable Vibration Control; Numerical Simulation; Energy Harvesting

**KAIST-20**

# Low-velocity Impact Resistance of Nacre-like Composites

K. Ko[1], S. Jin[2], S.E. Lee[3] and J.W. Hong[4]

[1,2,3,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

*kwonhwan0911@kaist.ac.kr, jinso77@kaist.ac.kr, sangeon1@kaist.ac.kr, j.hong@kaist.ac.kr*

## Abstract

Significant efforts have been made in order to demonstrate the key mechanisms and develop a new generation of material system with improved mechanical properties by replicating the nacre. In this study, we utilize a drop weight impact loading to investigate the performance and key failure mechanisms of a nacre-like composite. By employing a Voronoi diagram, a 3D model of the nacre-like composite is designed, and a corresponding 3D bimaterial specimen is fabricated with a dual-extrusion FDM 3D printer. Impact performance of the nacre-like specimen is determined and compared with a single stiff material by applying drop weight impact loading. Additionally, it is simulated with a finite element model of the nacre-like specimen, and the experiment and numerical results agree well. From both the experiment and numerical results, it is validated that the nacre-like specimen outperform the single stiff material under the impact.

**Keywords:** 3D printing; Nacre; Drop weight impact test; FEA

**KAIST-21**

# Experimental and Numerical Investigations for Collision Risk Assessment of Unmanned Aerial Vehicle

Y. Choi[1], J.W. Jung[2], S.E. Lee[3] and J.W. Hong[4]

[1,2,3,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

*youngjunc@kaist.ac.kr, jaewook1987@kaist.ac.kr, sangeon1@kaist.ac.kr, j.hong@kaist.ac.kr*

## Abstract

Collision tests of a small unmanned aerial vehicle (UAV) are performed on heat-strengthened glass commonly used for building exterior. A high-speed camera and dynamic load sensors are used in obtaining the collision behaviors and impact forces, respectively. Controlling the collision velocities, ranging from 5 m/s to 18 m/s, we can observe the tendency of the collision behaviors and impact forces. To convince the experimental results, a numerical modeling technique is also developed using the finite element method.

**Keywords:** UAV; Collision; Heat-strengthened glass; Force measurement

**KAIST-22**

# Seismic Risk Analysis of Deteriorated Structures with High-Fidelity FEM model

H.W. Jang[1], Y. Choi[2], D. Park[3] and J.W. Hong[4]

[1,2,3,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

*hwjang90@kaist.ac.kr, youngjunc@kaist.ac.kr, brianpark@kaist.ac.kr, j.hong@kaist.ac.kr*

## Abstract

In this study, we develop a methodology for the seismic risk analysis with high-fidelity finite element (FE) model to consider the cracks of deteriorated structures. Most of the existing seismic analyses have been performed by using simplified 2D or 3D models of structures. However, the simplified model cannot describe the decrease in durability due to the cracking of the deteriorated structures. Therefore, we construct high-fidelity FE models of the structures to consider the cracks. Numerical analyses are conducted by using the high-fidelity FE model of RC and piloti structures and 27 artificial earthquakes considering the design response spectrum for several recurrence intervals. In results, damages are concentrated in the pillars of the piloti structures. Each analysis of an earthquake takes about 72 hours. The model and methodology developed through the study would be used for the accurate seismic analyses of deteriorated structures.

**Keywords:** Deteriorated structures; Seismic analysis; Earthquake; High-fidelity

**KAIST-23**

# Measurement of Residual Material Properties of Fire-damaged Concrete using a Nonlinear Ultrasonic Technique

*G.J. Kim[1] and H.G. Kwak[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*kkjin1@kaist.ac.kr, khg@kaist.ac.kr*

## Abstract

In this study, fire-damaged concrete was investigated by a nonlinear resonance vibration (NRV) technique, in order to evaluate its residual material properties. For the experiments, five cubic concrete specimens were prepared and four of them were damaged at different temperatures using a furnace. With a thermal insulator wrapped at the sides of specimen, thermal gradation was applied to the samples. According to the peak temperatures and depths of the samples, nonlinearity parameters were calculated with the NRV technique before the tendency of the parameters was evaluated. In addition, compressive strength and dynamic elastic modulus were measured for each sample and a comparison with the nonlinearity parameter was carried out. Through the experimental results, the possibility of the NRV technique as a method for evaluating residual material properties was evaluated.

**Keywords:** fire-damaged concrete; nonlinear resonance vibration (NRV); thermal gradation; residual material property

**KAIST-24**

# Nonlinear Analysis of Reinforced Concrete Slab Subjected to Extreme Loading

M.J. Lee[1] and H.G. Kwak[2]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*ttl1114@kaist.ac.kr, kwakhg@kaist.ac.kr*

## Abstract

This study aimed to improve a numerical model to accurately predict the structural behaviour of reinforced concrete (RC) slab subjected to extreme loading. The proposed model is based on the strain rate dependent biaxial strength envelope. To minimize size dependency in a finite element, the improved failure strain describing the post-peak behavior of concrete is introduced on the basis of fracture energy concept. In this equation, the increase in fracture energy due to strain rate as well as the increase in strength due to strain rate are reflected through a regression analysis of experimental data. In particular, the tensile failure strain is related to tension stiffening effect, and this study confirmed the difference of numerical results depending on consideration of tension stiffening effect. Moreover, the bond-slip effect between concrete and reinforcing steel is considered by changing the bending stiffness of elements because the bond-slip has a dominant influence on the nonlinear behavior of RC structures after yielding of main reinforcement. The proposed model is verified through the correlation with the experimental data in terms of the mid-span deflection and time histories. The results show that the accuracy of simulation results is improved by the proposed numerical model.

**Keywords:** Concrete biaxial strength envelope; Tension stiffening effect; Strain rate effect; Bond-slip effect

**KAIST-25**

# Evaluation of the response of RC members subjected to blast loading

*S.J. Ju[1] and H.G. Kwak[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*zoon1400@kaist.ac.kr, khg@kaist.ac.kr*

## Abstract

A numerical model for RC members subjected to blast loading based on the moment-curvature relationship is introduced. A dynamic increase factor, which can be directly applicable to the moment-curvature relationship, is newly defined as a function of the curvature rate. In addition, the equivalent flexural stiffness is calculated and introduced to account for the reduction of flexural stiffness due to bond-slip effect. The hysteretic moment-curvature relationship of RC sections governed by the hysteretic behavior of the reinforcing steel is introduced to evaluate the maximum response as well as the residual response of the RC member under blast loading. Correlation studies between analytical results and experiment are conducted to verify the validity of proposed numerical model.

**Keywords:** Blast loading; Monotonic and hysteretic moment-curvature relationship; Dynamic increase factor; Bond-slip effect

**KAIST-26**

# Improved Shear Stud Spacing in Steel-concrete-steel Sandwich Structures

*W.H. Lee[1] and H.G. Kwak[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*wonho.lee@kaist.ac.kr, khg@kaist.ac.kr*

## Abstract

The application of steel-concrete-steel sandwich composite structure (SCP) for the modular construction of LNG storage tanks installed at polar or coastal regions is being studied because of their short construction time and cost. However, the design of SCP must be based on the application of existing design guidelines which require very close arrangement of shear studs. Densely arranged studs cause difficulty in placing of concrete during the manufacturing process and increase of production costs. This paper proposes an improved ratio of the stud spacing to the thickness of steel plate on the basis of numerous parametric studies to evaluate the relative influence of the stud spacing on the stability of the SCP.

**Keywords:** Sandwich structure; Headed shear stud; Local buckling; Design guidance

**KAIST-27**

# Numerical simulation for seismic risk assessment of urban water transmission network

G.H. Gwon[1], S.S. Yoon[2] and H.J. Jung[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*irlgns@kaist.ac.kr, yss3366@kaist.ac.kr, hjung@kaist.ac.kr*

## Abstract

The water transmission network is responsible for supplying water from the sources to the local residents through various facilities. When earthquakes occur, pipelines or facilities may be destroyed, causing direct or indirect damage to the network, which makes difficult to mitigate the secondary damage. In this study, a numerical simulation is conducted to evaluate the effect on the connectivity of water transmission networks considering the uncertainties of ground motion, pipeline deterioration, and interdependencies of lifelines. The ground motion is estimated by employing spatially correlated seismic attenuation law. Next, the modified failure probability of buried pipelines is determined considering pipe deterioration. Finally, network performance is estimated with different earthquake magnitudes by considering the failure probability of network components.

**Keywords:** Water transmission network; Buried pipeline deterioration; Lifeline interdependency; Connetivity analysis; Seismic risk assessment

**KAIST-28**

# The Effect of Soil-Structure Interaction on Seismic response of Nuclear Power Plant Structures

Yuree Choi[1], Heekun Ju[2] and Hyung-Jo Jung[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*choiyuree@kaist.ac.kr, heekun.ju@kaist.ac.kr, hjung@kaist.ac.kr*

## Abstract

Seismic response of nuclear power plant (NPP) structure is largely affected by soil-structure interaction, when it is constructed on a soft soil site. In this paper, comparison between two model with different soil profiles is investigated. A simplified beam-stick model with a rigid basemat is adopted for numerical analysis, which can reduce a computing time. For numerical analysis, SSI analysis is done by ACS SASSI, which is widely used SSI analysis software. The SSI analysis by ACS SASSI is using flexible volume substructure method in frequency domain. For the comparison, the FRS of the structure is developed, which shows that the SSI has a significant effect on seismic response of the structure. As a result, the SSI effect reduces peak acceleration frequencies and changes the amplitudes of FRS.

**Keywords:** Soil-Structure Interaction, Seismic Analysis, Floor Response Spectrum

**KAIST-29**

# A Review on Pedestrian Evacuation Network Analysis in Earthquake Disasters and Its Applications

Sangjoon Park[1], Wonjun No[2] and David Lee[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*psj1866@kaist.ac.kr, jn0704@kaist.ac.kr, david733@kaist.ac.kr*

## Abstract

During a natural disaster, when people must evacuate quickly from urban hazard zones but vehicle use is unfeasible, pedestrian networks become vital for evacuation. Earthquakes can significantly alter these networks by causing or increasing the chance of building collapses, which make certain roads and open spaces impossible or too risky to cross; preventing pedestrians from finding the shortest path to nearby shelters. Using GIS and network analysis, we can adapt evacuation route planning in such unpredictable disaster scenarios. In this paper, we developed a pedestrian network analysis approach that identifies vulnerable areas in earthquake disasters, and alternate evacuation routes. After reviewing the relevant literature, we apply the concepts and methodologies to a potential earthquake scenario in Kyeongju, South Korea, site of a recent actual earthquake in 2016. Future work will build on this by applying network weighting and considering the real-time location of floating populations on the actual sites, as estimated from mobile phone network usage.

**Keywords:** Earthquake disaster; Pedestrian evacuation network analysis; Geographic Information System (GIS)

**KAIST-30**

# Review of Pedestrian Sensing Technologies and Their Applications in Response to Disasters

Jae Hong Lee[1], David Lee[2]

[1,2]*Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*

*vaink@kaist.ac.kr, david733@kaist.ac.kr*

## Abstract

For the past couple of decades, pedestrian detection and tracking technologies have gained growing interest among science communities and research fields, thanks to development of their application industries who make tracking techniques useful. The application area spans largely from classic video surveillance to motion capture and clinical diagnosis systems in a variety of industries. This paper reviews current state-of-the-art techniques to detect pedestrians and their applications in response to disasters. First, as the paper reviews type of sensors and sensing techniques, it deliberates how computer vision has now dominated the field and also talks about its limitations. Then, the paper presents case studies of vision-based detection technologies as well as mobile crowd sensing in response to different phases of disasters, focusing on pedestrian behaviours and evacuation dynamics.

**Keywords:** name; affiliation; civil engineering; Symposium

**KAIST-31**

# The Impact of Air Quality on Floating Population by Age Group in Yeouido, Seoul

Yeji Kim[1], Junyong Choi[2] and David Lee[3]

[1] *Department of Earth Science and Environmental Engineering, GIST, Gwangju 61005, Korea*

[2,3]*Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*

*yejikim93@gist.ac.kr, wnsdyd@kaist.ac.kr, david733@kaist.ac.kr*

## Abstract

Air quality plays a significant role in people's respiratory health. In this paper, we use Air Quality Index (AQI) defined by the United States Environmental Protection Agency (USEPA) using 6 major air pollutants (PM10, PM2.5, CO, NO2, O3, SO2) for quantifying air quality. First, we calculated population-weighted exposure to air pollution for 9,123 neighborhoods in Seoul over four months, based on hourly floating population data derived from mobile network usage. We visualized these patterns using GIS software to identify areas with the highest active population exposure, separated by age group. Then, we analyzed air quality impacts on working age and elderly populations in the Yeouido district of Seoul, where both groups were highly exposed during this period. We found that the elderly population remained similar or even increased on highly polluted days (high AQI) compared to high reduction of population among working age groups. This response pattern suggests that elderly populations may not adjusting their behavior to avoid exposure to air pollution. For further research, a smaller scale of floating population is needed to distinguish whether people stay in buildings or not. In addition, Statistical tests would be conducted to verify AQI and human response among different age groups.

**Keywords:** Air quality index (AQI); Air pollution; Human exposure; Human response pattern

**KAIST-32**

# Numerical Study on Ground Behavior at Connection of Submerged Floating Tunnel to Land

S.J. Kang[1] and G.C. Cho[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*incheon@kaist.ac.kr, gyechun@kaist.ac.kr*

## Abstract

In this paper, numerical analysis was conducted for evaluating ground behavior at the connection between submerged floating tunnel and subsea bored tunnel. Although the subsea bored tunnel had little displacement due to surrounding ground, the submerged floating tunnel allowed displacement. The imbalance of displacement made the stress concentration at the ground around the connection between the submerged floating tunnel and land. The external load applied on the submerged floating tunnel and the type of grouting material surrounding the subsea bored tunnel were considered as the main factors affecting the ground stability at the connection, and they were controlled in the numerical simulation for obtain their effects. As the results, two factors affected the position and magnitude of stress concentration.

**Keywords:** Submerged floating tunnel; Subsea bored tunnel; Stability at connection; numerical analysis

**KAIST-33**

# Evaluation of backfill sands for underground power cable

Jun-Beom An[a], Song-Hun Chong[b] and Gye-Chun Cho[a]

[a]*Department of Civil & Environmental Engineering, KAIST, Republic of Korea*

[b]*Department of Civil Engineering, Sunchon National University, Republic of Korea*

*E-mail: anssi6@kaist.ac.kr, shchong@scnu.ac.kr and gyechun@kaist.ac.kr*

## Abstract

Thermal and mechanical properties of backfill sands carry out an important role in using the underground power cable effectively. The power cable should be in stable condition not to be in failure by settlement, and also the cable should emit their heat for preventing insulation melting and for setting higher allowable current. In this study, it was experimentally investigated that the correlations between relative density of backfill sands, thermal conductivity and cone tip resistance using $k_0$ chamber. The experimental results concluded that the contact condition of sands controlled by relative density and overburden pressure directly effects on thermal conductivity. And the cone tip resistance, which can be indicator of backfill sands' contact condition also has strong correlation with thermal conductivity. From those correlations, it is possible to control and maintenance for underground power cable in an integrated manner.

**Keywords:** Relative density; Overburden pressure; Thermal conductivity; CPT; Cone tip resistance

**KAIST-34**

# Image-based Crack Detection and Quantification of Crack properties

*Jin. Kim[1] and Gye-Chun. Cho[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*

*kjgood413@kaist.ac.kr, gyechun@kaist.ac.kr*

## Abstract

These days, the issue of the importance of safety as well as the lifespan of structure itself has been an issue. The crack cause severe problems for tunnel safety and, if the cracks were detected early and accurately, the lifespan of structures would be increased. The aim of this study was that by using convolution neural network, the objectivity of detection was increased and from detected images, to be quantified the properties of crack such as length and width. By repeating the whole process and scoring in each iteration, the accuracy that model predict accurately was increased, and the optimized number of repetitions was fluctuated depending on the actual image. Also, the properties of crack such as length, width in pixel could be obtained using characteristics of pixel images in simple crack case. Finally, we applied the detection method using actual crack image and obtaining the properties in pixels in a specific case.

**Keywords:** Image-Based; Neural Network; Crack Detection;

**KAIST-35**

# Experimental study on undrained shear strength of xanthan gum treated soils

Yeong-Man Kwon[1], Ilhan Chang[2] and Gye-Chun Cho[3]

[1,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

[2] *School of Engineering and Information Technology, University of New South Wales (UNSW), Canberra, ACT 2600, Australia*

*yeongman.kwon@kaist.ac.kr, ilhan.chang@adfa.edu.au, gyechun@kaist.edu*

## Abstract

Xanthan gum, an organic biopolymer produced by microorganism *Xanthomonas campestris*, has been kwon to reduce the environmental concerns induced by pre-existing agents such as cement. Xanthan gum absorbs pore-fluids and increases the viscosity, which can be related with shear strength of media. Additionally, xanthan gum forms bridges between clay particles via hydrogen bonding and direct electrical interaction. The interactions among xanthan gum, pore-fluid, and clay particles enhances the geotechnical properties of soils. This study analyzes the undrained shear strength of xanthan gum treated fine-grained soils exposed to salinity. The undrained shear strength was measured by a series of fall-cone tests. The results of this study show that xanthan gum has potential as shear strengthening agents, especially in the ocean area.

**Keywords:** Biopolymer, Xanthan gum, Undrained shear strength

**KAIST-36**

# A Study on the xanthan gum biopolymer as a hydraulic barrier for kaolinite

Minhyeong Lee[1], Yeong-Man Kwon[2], Ilhan Chang[2], Gye-Chun Cho[4]

[124] *Department of Civil and Environmental Engineering, KAIST, Korea*

[3] *School of Engineering and Information Technology, University of New South Wales (UNSW), Canberra, ACT 2600, Australia*

*minhyeong@kaist.ac.kr, yeongman.kwon@kaist.ac.kr, ilhan.chang@adfa.edu.au, gyechun@kaist.edu*

## Abstract

Permeability is one of the most important characteristics in engineering analysis of soft clay because it is related to consolidation behaviors and contamination transport. This study presents the results of consolidation test using Xanthan gum, which is ecofriendly microbial biopolymer, forming hydraulic barrier inside kaolinite soil. And permeability of kaolinite for untreated and treated with xanthan gum (1% of soil mass ratio) under variation of effective stress is calculated based on the obtained parameters. Under consolidation process, permeability generally decreased with reduction of void ratio. In addition, xanthan gum biopolymer absorbs the pore fluid to fill the pores with a viscous hydrogel, thereby resulting a 1/100 of permeability compared to untreated condition. The results shows that xanthan gum biopolymer can be utilized as hydraulic barriers or contaminant barriers.

**Keywords:** Permeability, Consolidation, Biopolymer, Xanthan gum, hydraulic barrier

**KAIST-37**

# Anomaly Detection of Hydro Turbine using Autoencoder

Jun Lee[1], Donggun Kim[2] and Hoon Sohn[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*leejun@kaist.ac.kr, dgkim1003@kaist.ac.kr, sohnhoon@kaist.ac.kr*

## Abstract

For hydroelectric power plant, hydro turbine is one of the main power generating members, and the integrity of the hydro turbine is critical for the power generation. However, the hydro turbine condition monitoring is difficult due to its immersion in water and rotated condition during operation. This study presents a data classification method for anomaly detection by monitoring data from sensors installed outside of the hydro turbine. Specifically, autoencoder is employed to build a classification model for anomaly detection based on all sensors attached to the hydro turbine. The methodology is tested and demonstrated using real data collected on a hydro turbine structure. The results show that the autoencoder- based method owns a 90% accuracy for anomaly detection.

**Keywords:** Anomaly detection; Autoencoder; Machine Learning; Data management; Structure health monitoring;

**KAIST-38**

# Loosened Bolt Detection and Quantification Using RGB-depth Sensor and Mask R-CNN

Junyeon. Chung[1], and Hoon. Sohn[2*]

[1,2]*Department of Civil and Environmental Engineering, KAIST, Korea*

*jjysh014@kaist.ac.kr, hoonsohn@kaist.ac.kr*

## Abstract

Recently, vision-based approaches have gained the significant attention in structural health monitoring since they are robust to environmental conditions and require less cost compared to conventional methods. As trend, there have been several attempts to detect loosened bolts in infrastructures based on machine vision technology. However, they are impossible to detect the loosened bolts with images taken at high angle and to quantify how much the bolts were loosened. In order to overcome the limitations, we presents a novel loosened bolt detection and quantification method using RGB-depth sensor with the integration of a deep neural network called mask region based convolutional neural network (Mask R-CNN). A series of lab-scale experiments were conducted to validate the proposed method, and they shows that the minimum loosened length which can detect the looseness is 3 mm and the accuracy is higher than 97% with the various angles and distances.

**Keywords:** Loosened bolt, Looseness classification & quantification, RGB-D sensor, Deep learning, Automatic damage detection

**KAIST-39**

# FIR Filter Based Bridge Displacement Estimation Using Strain and Acceleration Measurements

Zhanxiong. Ma[1], and Hoon. Sohn[2*]

[1,2]*Department of Civil and Environmental Engineering, KAIST, Korea*

*mazhanxiong@kaist.ac.kr, hoonsohn@kaist.ac.kr*

## Abstract

In this study, a finite impulse response (FIR) filter-based displacement estimation technique is proposed for bridge monitoring by fusing strain gauge and accelerometer measurements. First, the relationship between displacement and strain is established, and the parameter associated with this strain–displacement transformation is estimated from the strain and acceleration measurements using a recursive least squares algorithm. Next, the low-frequency displacement estimated from the strain measurements and high-frequency displacement obtained from an acceleration measurement are combined using a FIR filter for high-fidelity displacement estimation. The feasibility of the proposed technique was examined via numerical simulations of beam models and a real bridge model.

**Keywords:** Displacement estimation, FIR filter, Neutral axis location, Strain gauge, Accelerometer

**KAIST-40**

# Influence of temperature on swelling pressure in Korean domestic bentonite

M.S. Kim[1], S.R. Lee[2], E.N. Cheon[3], M.J. Kim[4] and Y. Seok[5]

*[1,2,3]Department of Civil and Environmental Engineering, KAIST, Daejeon, 34141, Republic of Korea*

*[4]Deep Subsurface Research Center, Korea Institute of Geoscience and Mineral Resources, Daejeon 34132, Republic of Korea*

*[5]Radioactive Waste Disposal Division, Korea Atomic Energy Research Institute, Daejeon 34057, Republic of Korea*

*hellopdlms@, srlee@, enokjun@, kmjda1@kaist.ac.kr, syoon@kaeri.re.kr*

## Abstract

The effect of temperature on mechanical behaviors was observed in a Korean domestic Ca-bentonite which has been considered as a potential buffer material in the engineering barrier of a high level radioactive waste(HLW) disposal system. Laboratory tests have been conducted on Korean Kyeongju bentonite blocks that were compacted in different dry densities. Swelling pressure tests at various temperatures between 30 and 90 were carried out by supplying de-ionized water. The study revealed that with increases in temperature the bentonite swells faster, but its absolute value of swelling pressure decreases.

**Keywords**: Bentonite, Temperature, Swelling pressure

**KAIST-41**

# Simplified Resonant Column Testing Apparatus for Small-Strain Stiffness and Damping coefficient

Dong-Hwa Noh[1], and Tae-Hyuk Kwon[2]

*[1,2]Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*

*dhnoh@kaist.ac.kr, t.kwon@kaist.ac.kr*

## Abstract

Small-strain properties of soils, such as wave velocity and damping coefficient, are often measured using the resonant column (RC) test and/or torsional shear (TS) test. These methods require fairly complex equipment configurations. In this study, we suggest a simplified resonant column testing system. This system involves torsional and flexural vibrations manually excited by a rubber band and a vacuum pressure for isotropic effective confining stress. Therefore, this testing apparatus does not require a magnet driving plate and a pressure chamber as in the Stokoe-type RC/TS method. The suggested apparatus was validated with the small-strain properties of the air-dried sand obtained by using the developed device.

**Keywords**: Resonant column, small-strain stiffness, attenuation, torsional vibration, flexural vibration.

**KAIST-42**

# Coupled CFD-DEM modeling of soil erosion at a particle level

Soo-Min Ham[1] and Tae-Hyuk Kwon[2]

[1,2] *Department of Civil and Environmental Engineering, KAIST, Korea*

*soomin.ham@kaist.ac.kr, t.kwon@kaist.ac.kr*

## Abstract

The fluid-particle interaction is the key mechanism in modelling soil erosion. This study presents the numerical method to model the fluid-driven erosion of sands at the particle scale by coupling computational fluid dynamics (CFD) and discrete element method (DEM). The particle motion is described with DEM by solving Newton's laws of motion and the fluid flow is simulated with CFD by solving the volume-averaged Navier-Stokes equations. In addition, the k-ω turbulence model describes turbulent flows in the fluid phase. In simulations of the fluid-driven erosion processes, the particle-level forces, including drag force, buoyancy force, pressure-gradient force, and viscous force, are considered for the fluid-particle interactions. The simulation results are discussed in comparison to the experiment test results. This work shows that the coupled CFD-DEM can be a promising tool to analyze the soil erosion behavior at the particle scale.

**Keywords:** CFD-DEM; soil erosion; numerical simulation

**KAIST-43**

# Advanced geomorphological survey method using UAV-LiDAR system for landslide analysis

Shin-Kyu Choi[1], Tae-Hyuk Kwon[1], Hyun Myung[2] and Sungwook Jung[2]

[1] *Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*

*newsk@kaist.ac.kr, t.kwon@kaist.ac.kr*

[2] *School of Electrical Engineering, KAIST, Daejeon 34141, Korea*

*hmyung@kaist.ac.kr, sungwook87@kaist.ac.kr*

## Abstract

High-resolution topographic information on landslide-prone areas are essential for accurate prediction of landslide occurrence. Arial survey is used to obtain those topographic information with meter-scale resolution, however, it is expensive and time-consuming for frequent usage. Recent advancement in Unmanned Aerial Vehicle (UAV) and Light Detecting and Ranging (LiDAR) technologies provide an unique opportunity to develop a system that can be deployed in a convenient and economical way. In this study, we developed a UAV-LiDAR system to obtain dense 3D point clouds and high-resolution digital elevation map (DEM). A survey of a densely wooded slope using the developed system resulted in a group of dense 3D point clouds. The developed system can provides a high-resolution DEM of the terrain after filtering of canopy woods, and the obtained topographic information is expected to be used not only for prediction of landslide occurrence, but also for topographic change detection by landslide events.

**Keywords:** Landslides; Topographic information; UAV-LiDAR; Point cloud; DEM

**KAIST-44**

# Preliminary Result on Full-Scale TBM Excavation Tests

Gi-Jun Lee[1], Tae-Hyuk Kwon[2], Gye-Chun Cho[3] and Kyoung-Yul Kim[4]

*[1,2,3]Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea*
*[4]Structural and Seismic Technology Group, KEPRI, Daejeon 34056, Korea*
*gijun@kaist.ac.kr, t.kwon@kaist.ac.kr, gyechun@kaist.ac.kr, solasido@kepco.co.kr*

## Abstract
Tunnel boring machines (TBMs) re-used, refurbished in fields often show the performance degradation, which can cause unexpected construction problems and economic losses. Therefore, performance of such refurbished TBMs needs to be examined prior to field deployment. In this study, we present the full-scale testing method on TBM excavation performance examination. A small-section TBM machine with 3.54 m radius was operated for excavation tests on rock-like concrete and mortar samples. The results show that the penetration depth is almost constant regardless of the cutterhead rotation speed. However, the penetration rate increases with the cutterhead rotation speed. In addition, the penetration efficiency appears to be affected by the number of operated shield jacks and thus the thrust forces.
**Keywords**: Tunnel boring machine (TBM); Full-scale test; Excavation; Penetration

**KAIST-45**

# Feasibility Study of Using Enzyme-induced Biopolymer Formation for Bioclogging

Yong-Min Kim[1], Sun-Gyu Choi[2] and Tae-Hyuk Kwon[3]

*[1, 3] Department of Civil and Environmental Engineering, KAIST, Korea*
*amiamam@kaist.ac.kr, t.kwon@kaist.ac.kr*
*[2]Disaster Prevention Research Division, National Disaster Management Research Institute, Ulsan, Korea*
*sungyuchoi@korea.kr*

## Abstract
Bioclogging is clogging of pores in soils caused by bacterial activities and their by-products. Some types of bacteria can produce insoluble biopolymers, such as dextran and xanthan, as microbial products to be potentially used for bioclogging. This study explores the feasibility of using enzyme-induced biopolymer formation (EIBF) to reduce hydraulic conductivity of clean sands. The bacterial enzyme, called dextransucrase was extracted from the model bacteria *Leuconostoc mesenteroides* and used to stimulate formation of insoluble biopolymer called dextran using sucrose solutions without bacterial cells. First, a series of batch test was performed, varying the enzyme/sucrose ratio, sucrose concentration in the growth medium, number of treatment repetition, to optimize the enzyme extraction process. Second, the bioclogging experiment was carried out in clean sand-packs to examine reduction in hydraulic conductivity. The obtained results promise possible use of EIBF for bio-sealing methods.
**Keywords:** Bioclogging; Enzyme; Insoluble biopolymer; Bacteria; Hydraulic conductivity

**KAIST-46**

# Application of deep learning techniques for determination of crack signals in structural damage monitoring

Gyeol Han[1], Yong-Min Kim[2], and Tae-Hyuk Kwon[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*g.han@kaist.ac.kr, amiamam@kaist.ac.kr, t.kwon@kaist.ac.kr*

## Abstract

Natural disasters such as earthquakes and typhoons can cause damages in structures. In particular, any damage to the foundations of a structure can lead to critical problems. Many studies on real-time structural health monitoring have attempted to estimate the locations and sizes of cracks and damages using acoustic emission signals. However, field implementation of these techniques still poses a challenge because of difficulty in identifying damage signals from ambient noises. Therefore, this study investigates the feasibility of using a deep learning algorithm based on a convolutional neural network (CNN) method to identify damage signals from ambient noise signals. The results show that the developed CNN algorithm effectively distinguishes the acoustic emission signals from cracking concrete and the randomly synthesized ambient noise signals. It is presumed that this algorithm will eventually enable effective, real-time monitoring of structures.

**Keywords: S**tructure Health Monitoring; Machine Learning; Accelerometer; Acoustic Emission, Convolutional Neural Network

**KAIST-47**

# Development of hydro-mechanically coupled pore network model

Min-Kyung Jeon[1], Amin Hosseini Zadeh[2], Seunghee Kim[3] and Tae-Hyuk Kwon[4]

[1,4] *Department of Civil and Environmental Engineering, KAIST, Korea*

[2,3] *Department of Civil Engineering, University of Nebraska-Lincoln, USA*

*gmk909@kaist.ac.kr, seunghee.kim@unl.edu, amin@unl.edu, t.kwon@kaist.ac.kr*

## Abstract

The fluid-driven deformation of porous media ubiquitously takes place in geotechnical and geological engineering practices, such as viscous grout injection and geologic carbon storage. This study presents a hydro-mechanically coupled pore network model which couples the fluid flow and solid deformation in porous networks. A porous medium is modeled by the combination of a pore network for fluid flows and a solid network described by using a block-spring model. A two-way coupling method enables simulation of deformation of fluid-saturated porous media caused by viscous fluid injection. Effects of mechanical coupling, injecting fluid viscosity, solid stiffness are examined while monitoring the flow patterns, solid deformation behaviors and pressure responses. The results reveal that the pore opening effect by deformation reduces the inlet pressure.

**Keywords:** Hydro-mechanical coupling; Pore network model; Block-spring model; Two-phase flow

**KAIST-48**

# InSAR-based Detection and Mapping of Seismically-induced Ground Deformation in Pohang City using Sentinel-1

*Ryan A. Ramirez[1] and Tae-Hyuk Kwon[1]

[1] *Department of Civil and Environmental Engineering, KAIST, Korea*

*raramirez@kaist.ac.kr, t.kwon@kaist.ac.kr*

## Abstract

The 2017 Pohang earthquake which occurred on 15 November 2017 was the second strongest instrumentally recorded seismic event in South Korea with a moment magnitude 5.4. This study investigates the seismically-induced ground surface deformations before, during, and after the mainshock by using a standard two-pass interferometry called the Differential Interferometric Synthetic Aperture Radar (D-InSAR) technique using Sentinel-1B SAR images. The study also suggests the use of coherence change between pre-seismic and co-seismic interferometric pairs in order to detect and map damaged structures and infrastructures both in urban and non-urban areas. The D-InSAR analysis of co-seismic pair reveals a surface displacement of more than 5 cm, which is consistent with the previous studies. In addition, the coherence index appears to be effective in identifying and assessing the spatial distribution of damaged buildings and regions due to the earthquake. This is believed to be useful for emergency responses applied to regional-scale problems.

**Keywords:** D-InSAR; Pohang earthquake; surface displacement; coherence index; damage assessment

**KAIST-49**

# Estimation of Response Distribution Considering Structural Nonlinearity

Heekun Ju[1], Seung-Soup Jin[2] and Hyung-Jo Jung[3]

[1,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

[2] *Sustainable Infrastructure Research Center, KICT, Korea*

*heekun.ju@kaist.ac.kr, seungsab@gmail.com, hjung@kaist.edu*

## Abstract

For probabilistic risk assessment of structures under seismic excitation, the structural demand and capacity should be represented in a probabilistic sense. These are obtained after probabilistic analysis of structures considering uncertainties arising from various sources as input motion, material properties of structures. Seismic response obtained from probabilistic analysis is conventionally assumed to be log-normally distributed, but the assumption is not always true especially in a case where the nonlinearity exists. For example, concrete shear walls exhibit nonlinear hysteretic behavior under strong cyclic loading which can cause peak frequency change of floor response spectrum. This can lead to discontinuous change of floor spectral acceleration under the uncertainties of shear wall material properties. In this paper, a numerical model of reactor containment building with shear wall is used to implement probabilistic seismic analysis. Non-traditional form of response distribution is estimated from the analysis results.

**Keywords:** Response distribution; Structural Nonlinearity; Floor response spectrum

**KAIST-50**

# Dynamic Centrifuge Testing to investigate the dynamic behavior of gravity-type quay wall

*Y.S. Kim[1], K.W. Ko[2] and D.S. Kim[3]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*yeonsamkim@kaist.ac.kr, kwko@kaist.ac.kr, dongsookim@kaist.ac.kr*

## Abstract

After the Great Hanshin earthquake in 1995 caused a great deal of damage, interest in the dynamic behavior of port and harbor structures increased. In this study, dynamic centrifuge testing technique to investigate the dynamic behavior of gravity-type quay wall was developed. In addition, the dynamic behavior of quay wall was investigated using the technique. Investigation of the behavior was carried out by the simplified model of quay wall and saturated soil. The investigation was conducted by analyzing the records of acceleration, excess pore water pressure and lateral displacement of the quay wall.

**Keywords:** Dynamic Centrifuge Modeling, Quay wall, Saturation, Liquefaction

**KAIST-51**

# Reviews on recent advancements of sensing and heating cementitious nanocomposites

D.I. Jang[1], H.N. Yoon[2], and H.K. Lee[3,*]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*svs2002@kaist.ac.kr,yhn0307@kaist.ac.kr, haengki@kaist.ac.kr*

[*] *Corresponding author*

## Abstract

Recently, studies have focused on the fabrication of multi-functional cementitious nanocomposites for piezoresistive sensors, and self-heating composites [1, 2]. Carbon nanotubes have been considered as a candidate for piezoresistive sensors and self-heating composites due to their superior mechanical characteristics, outstanding electrical and heating properties [2, 3]. However, the dispersion of carbon nanotubes have been a difficulty to be applied in carbon nanotubes-based cementitious nanocomposites. Although most of the related studies have focused on the applications of carbon nanotubes-based cementitious nanocomposites [1-3], few studies were given to improve the dispersion of carbon nanotubes in the fabricating process of sensing and heating cementitious nanocomposites. In this regard, this paper reviews recent studies carried out to manufacture carbon nanotubes-based sensing and heating cementitious nanocomposites. Various dispersion techniques of carbon nanotubes are also reviewed.

**Keywords:** Carbon nanotubes; Piezoresistive sensor; Self-heating composites;

**KAIST-52**

# Effect of Electrode Geometries on Electrical Resistivity Measurement in Limited Space

C.H. Hong[1], S.H. Chong[2], and G.C. Cho[3,*]

[1,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

[2]*Department of Civil and Environmental Engineering, Suncheon National University, Suncheon, Jeollanam-do, 57922, Korea*

*hello-hch@kaist.ac.kr, shchong@scnu.ac.kr, gyechun@kaist.ac.kr*

## Abstract

Electrical resistivity method has been frequently employed to analyze the characteristics of subsurface such as soil layers, anomalies, and groundwater level. Even though only spacing between electrodes is considered in field tests, the geometries of the electrodes should be also taken into account for electrical resistivity measurement in limited space (e.g. laboratory scale tests). In this study, the effect of the electrode geometries especially radius, penetration depth and shape on the electrical resistivity measurement in limited space is studied by deriving the theoretical equations and they are verified with the experimental tests.

**Keywords:** Electrical resistance, spherical electrode, cylindrical electrode, penetration depth, shape

**KAIST-53**

# Performance of an Equivalent Shear Beam (ESB) Model Container for Dynamic Centrifuge Tests using Partially Saturated Soil

*H.I. Lee[1], Y.A. Kim[2] and D.S. Kim[1]

[1,2,3] *Department of Civil and Environmental Engineering, KAIST, Korea*

*haein2da@kaist.ac.kr, yoonah@kaist.ac.kr, dongsookim@kaist.ac.kr*

## Abstract

The ESB (equivalent shear beam) model container can be used to provide appropriate boundary conditions in dynamic centrifuge tests. In 2013, performance of ESB containers in KAIST centrifuge facility was evaluated using dry clean sand in limited gravitational level. This study aims to re-evaluate whether the ESB container performs properly even though it has been aged about 10 years, using partially saturated weathered soil in higher g-level. It is found that the natural period of the empty ESB container is slightly increased than it used to be. However, the performance of it is still good enough to minimize the boundary condition.

**Keywords:** Physical modelling; Geotechnical centrifuge; ESB container; Boundary condition

# *Abstracts from Kyoto University*

**KU-01**

# Dynamic 2D Finite Element Analysis of Interlocking Brick Wall

J.J. Prasetyo[1], A. Furukawa[2] and J. Kiyono[3]

[1,2,3] *Department of Urban Management, Graduate School of Engineering, Kyoto University, Kyoto 615-8540, Japan*

*prasetyo.jefry.84x@st.kyoto-u.ac.jp, furukawa.aiko.3w@kyoto-u.ac.jp, kiyono.junji.5x@kyoto-u.ac.jp*

## Abstract

Masonry structure is one of the most commonly seen building types in many developing countries due to its inexpensiveness and material availability. While masonry structure is intrinsically strong in resisting its own gravitation load, it is weak in resisting earthquake forces. Due to this reason, reinforcement for masonry structure against earthquake is deemed necessary. Interlocking brick is considered as one of the appealing reinforcement methods as it does not require extra material and it is easy to implement.

Recent studies have proofed that interlocking brick was able to provide reinforcement to masonry walls against in-plane lateral load. However, since earthquake is a combination of bi-directional horizontal forces, more studies are needed to prove that interlocking brick can be used as a reinforcement method for masonry structure.

In this research, 2D dynamic FE analysis of masonry walls with two types of interlocking brick shapes was conducted to investigate its performance against in-plane and out-of-plane horizontal excitations. Through the analysis, it was found that the interlocking bricks displayed better performance in resisting both in-plane and out-of-plane horizontal excitations compared to the conventional bricks. To confirm the result of this analysis, in the future, the proposed interlocking brick shapes will be used as a model to be tested under the shaking table experiment.

**Keywords:** FEM, Interlocking Brick, Masonry Structure, Dynamic Analysis

**KU-02**

# Study on Earthquake Resistance Improvement Effect for Masonry Buildings using Interlocking Blocks

K. Asano[1], A. Furukawa[2] and J. Kiyono[3]

[1,2,3]*Department of Urban Management, Kyoto University, Kyoto 615-8540, Japan*

*asano.kyosuke.32n@st.kyoto-u.ac.jp, furukawa.aiko.3w@kyoto-u.ac.jp, kiyono.junji.5x@kyoto-u.ac.jp*

## Abstract

Nearly half of the deaths from natural disasters in the world are due to the collapse of low seismic resistance masonry structures that are often built in developing regions. Masonry structures with interlocking mechanisms has been proposed as an aseismic reinforcing method to prevent collapse during earthquakes and to extend the time from earthquake occurrence to collapse. Previous studies have conducted two-dimensional experiments and analysis using masonry walls with interlocking mechanisms, but there is not much research about the effect of interlocking mechanisms on seismic performance in three-dimensional structures.

In this paper, we aimed to investigate the effect of the interlocking mechanism on the earthquake resistance in a three-dimensional masonry building. The finite element method was used to analyze masonry buildings made of rectangular blocks and interlocking blocks respectively, and their seismic performance was compared and examined.

**Keywords:** Interlocking; Masonry; FEM; Earthquake Resistance.

**KU-03**

# Development of Tension Estimation Method for a Cable with a Damper using Natural Frequencies

K. Hirose[1], A. Furukawa[2] and R. Kobayashi[3]

[1,2]*Department of Urban Management, Kyoto University, Kyoto 615-8540, Japan*
*hirose.katsuya.86w@st.kyoto-u.ac.jp, furukawa.aiko.3w@kyoto-u.ac.jp*
[3]*Shinko Wire Company, Ltd., Amagasaki 660-0091, Japan*
*kobayashi.ryosuke@shinko-wire.co.jp*

## Abstract

At present, tension of a bridge cable is generally estimated by the high order vibration method which utilizes natural frequencies of a cable. However, this method is not appropriate for a cable with a damper since the damper changes the cable's natural frequencies. In this paper, a new tension estimation formula for a cable with a damper is proposed, The estimation formula was derived from wave equation of a cable, two boundary conditions at the both ends and a continuity condition at the location of the damper. The proposed method estimates cable tension from natural frequencies. In order to verify the proposed method, numerical simulations were conducted for various cable and damper models. It is confirmed that the accuracy of estimated tension by the proposed equation is significantly improved compared to the conventional higher order vibration method, and the error is within 5%. The validity of the proposed method was also confirmed using the natural frequencies of a real bridge cable. The proposed method was able to estimate tension more accurately than the conventional method.
**Keywords:** Tension estimation; Cable; Damper; Natural frequency; Vibration method.

**KU-04**

# Collisions of Vehicles Running on Highway during an Earthquake

K. Fukunaga[1], J. Kiyono[2], M. Shinohara[3] and T. Ito[4]

[1,2]*Department of Urban Management, Kyoto University, Kyoto 615-8540, Japan*
*fukunaga.kenji.38m@st.kyoto-u.ac.jp, kiyono.junji.5x@kyoto-u.ac.jp*
[3,4]*Engineering Department, Hanshin Expressway Company Limited, Osaka 530-0005, Japan*

## Abstract

Probability of large earthquake such as the coming Nankai-trough earthquake, Japan, is extremely high, therefore enough attentions should be paid to the occurrence of severe accidents of vehicles on the highway. When such severe accidents occur, not only the damage of the accident itself but also the trouble of transportation route causes a delay of emergency response. The influence of earthquakes on running vehicles and the countermeasures to avoid such accidents has to be considered in advance.

This study focused on seismic response analysis of highway vehicles during an earthquake. Previous studies pointed out that when an earthquake occurs, collisions occurs between vehicles. We here developed car-collision model on the result of experiment about vehicle-to-vehicle and vehicle-to-wall collisions. The model can express collisions with non-linear spring, and it can reproduce the experiment results accurately.
**Keywords:** Earthquake; Vehicle; Car-following; Collision model; Handling model.

**KU-05**

# Detection of Crack and Delamination of Concrete by Optical Imaging of Surface Acoustic Wave

Takuya WATANABE[1], Takahide HATAHORI[2], Shigeru KAYANO[3], Yuichi HIRANO[1], Atsushi HATTORI[2],and Hirotaka KAWANO[3]

[1,5,6] *Department of Urban Management, Kyoto University, Kyoto, Japan*
[2] *Technology Research Laboratory, Shimadzu Corporation, Kyoto, Japan*
[3] *Hanshin Expressway Coorporation, Osaka, Japan*
[4]*Depertment of Civil and Earth Resources Engineering, Kyoto University, Kyoto, Japan*
*Watanabe.takuya.33c@st.kyoto-u.ac.jp*

## Abstract

Optical imaging of acoustic wave is a method to detect concrete crack and delamination. It is confirmed that the method can detect cracks of smooth surface of specimen and structure like formwork surface. However, it is not considered which conditions the method is suitable. It needs to be confirmed that how much a surface condition, a position of vibrator and a difference of vibration frequency affect this method. In this study, the cut surface, core surface and surface of bonded steel plate of cut out of a bridge deck slab were measured to confirm effects of those factors. As a result, it is possible to detect cracks of the cut surface and the core surface. Further more, the method can detect cracks even when the vibrator is placed on a surface perpendicular to the measured surface. As the vibration frequency increases, measurable area decreases, while cracks of smaller width can be detected.
**Keywords:** Optical Imaging of Surface Acoustic Wave; Surface Condition; Crack; Delamination; Nondestructive Inspection

**KU-06**

# Fessibility Study on Monitoring System with Micro Energy Harvester for Bridge Pier Scouring

Kawabata Kohei[1], Hashimoto Katsufumi[2], Hattori Atsushi[3], Kawano Hirotaka[4] and Shiotani Tomoki[5]

[1,2,3,4,5] *Kyoto University, Japan*

*kawabata.kohei.85n@st.kyoto-u.ac.jp*

## Abstract

At present, effective monitoring system for bridge maintenance is required to detect damage at bridge piers and deck slabs. The failure risks due to heavy rainfalls and typhoons have been increasing year by year. In this study, it is aimed to establish a simple system that can be easily installed and identify the structural damage by introducing Micro Energy Harvesters (MEH) by using their self-sustainable power generation and sensor function. MEH quantify the alteration of vibration characteristics from its power generation amount. Vibration characteristics are analyzed on bridge pier models before and after scouring targeted in this study. Application method of MEH on the bridge is investigated and proposed for scouring monitoring system.
**Keywords:** Bridge pier, Scouring, Micro Energy Harvester, Vibration characteristics

**KU-07**

# Optical Imaging of Surface Acoustic Wave for Fatigue Crack Detection at Trough Rib on a Steel Box Girder Viaduct in Service

Takuya MUNEOKA[1], Atsushi HATTORI[2] Shinpei YAMANA[3], Takahide HATAHORI[4] Kentaro NAKAO[5], and Hirotaka KAWANO[6]

[1,2,6] *Department of Urban Management, Kyoto University, Kyoto, Japan*
[3]*Sho-bond Corporation, Tokyo, Japan*
[4]*Technology Research Laboratory, Shimadzu Corporation, Kyoto, Japan*
[5]*Nagoya Expressway Public Corporation, Aichi, Japan*
*muneoka.takuya.28w@st.kyoto-u.ac.jp*

## Abstract

Optical imaging of surface acoustic wave is a method to detect damage such as cracks on concrete or steel, peeling and uplifting of coating. The method optically visualizes surface waves introduced by a vibrator installed on the surface of concrete or steel material (synchronized measurement). Previous studies have confirmed that early minor damage can be detected and invisible damage due to surface coatings can also be detected without removing them as long as the vibration of the base material can be selectively captured. Furthermore, damage can be detected even with environmental vibration such as vibration caused by passing through traffic. In this study, the method was employed for steel box girder viaduct in service and applicability to field measurement was examined. Obtained results showed that fatigue cracks under surface coatings could be detected in the synchronized measurement.
**Keywords:** Optical imaging of surface acoustic wave; Fatigue crack; Nondestructive inspection; Steel box girder viaduct; Trough rib.

**KU-08**

# Impacts of Cable Corrosion on Cable-stayed Bridge Structure

M.T. Dao[1], T.C. Nguyen[2], T.H. Ho[3] and D.T. Nguyen[4]

[1] *Department of Civil and Earth Resources Engineering, Kyoto University, Japan*
[2]*Enspan (Vietnam) Co., Ltd*
[3]*Faculty of Civil Engineering, VNUHCM – University of Technology, Vietnam*
*dao.thu.33e@st.kyoto-u.ac.jp, tuancuong@interspan.com.vn, hothuhien@hcmut.edu.vn, ndthang@hcmut.edu.vn*

## Abstract

Many cases in which bridge cables have suffered from corrosion have been recorded worldwide, especially in areas exposed to airborne salt. Even though cable protection systems are designed and implemented to minimize the impacts of corrosion, corrosion can occur on the surface and inside the cables. Surface corrosion tends to appear at the position where cracks of sheath take place. Given that these cracks are not repaired, corrosion will expand and propagate inside the cables. This study aims to investigate the impacts of corroded cable cross-section area on the structural behaviors of a particular cable-stayed bridge by analyzing it in different virtual corrosion scenarios. In the case of Cao Lanh Bridge, the most sensitive parameter is the deck deflection at mid-span. Studying structural behaviors under the influence of cable corrosion and combining a corrosion rate forecasting model can assist with diagnosing condition of cables and establishing a feasible inspection schedule.
**Keywords:** Corrosion; Cable-stayed bridges; Cable deterioration

**KU-09**

# Investigation of Wake-induced Vibration of Parallel Cables Based on Unsteady Aerodynamic Forces

H. Fukushima[1], T. Yagi[2], T. Shimoda[3] and K. Noguchi[4]

[1,2,3]*Department of Civil & Earth Resources Eng., Kyoto University, Kyoto, 615-8540, Japan*

*E-mail: fukushima.haruki.73c@st.kyoto-u.ac.jp, yagi.tomomi.7a@kyoto-u.ac.jp,*

*shimoda.takuya.47a@st.kyoto-u.ac.jp, noguchi.kyohei.7z@kyoto-u.ac.jp*

## Abstract

Aerodynamic vibrations such as wake galloping and wake-induced flutter appear in parallel circular cylinders utilized for cable-stayed long-span bridges. These aerodynamic instabilities have studied for a long time. Their mechanisms, however, have not sufficiently been revealed. In this study, forced vibration tests and two-degree-of-freedom flutter analysis were used to investigate the mechanisms of aerodynamic instabilities changing the arrangement of two circular cylinders and the reduced wind velocity. The mechanisms of aerodynamic instabilities depended on a slight difference in the arrangement of two circular cylinders. Furthermore, some arrangements of two circular cylinders have different mechanisms depending on the reduced wind velocity because of the dramatic change of the unsteady aerodynamic derivative $H_1$*.

**Keywords:** Wake galloping; Wake-induced flutter; Circular cylinder; Parallel cables; Unsteady aerodynamic force.

**KU-10**

# Effects of Side Openings on Galloping Instability of Rectangular Cylinder

S. Yamamoto[1], T. Yagi[2], J. Wang[3], J. Ushioda[4], H. Ichikawa[5] and K. Noguchi[6]

[1,2,3,5,6] *Department of Civil and Earth Resources Engineering,*
*Kyoto University, Kyoto 615-8540, Japan*
[4] *Japan Airlines Co., Ltd., Tokyo 140-8635, Japan*
*yamamoto.soichiro.66v@st.kyoto-u.ac.jp, yagi.tomomi.7a@kyoto-u.ac.jp*
*wang.jiaqi.4n@st.kyoto-u.ac.jp, ushioda.q63s@jal.com*
*ichikawa.hidekazu.44n@st.kyoto-u.ac.jp, noguchi.kyohei.7z@kyoto-u.ac.jp*

## Abstract

The butterfly web bridge has recently been introduced owing to its good structural and aerodynamic performance due to side openings. This research conducted a series of wind tunnel experiments to investigate the relationship between the size of the side openings and the aerodynamic performance of the rectangular cylinder with a side ratio of 2. The opening area ratio (*OR*) was defined as the ratio of whole span length of the opening areas to the span length of the model. With the increase of opening area ratio, the onset velocity of galloping gradually increased. Thus, the rectangular cylinder with side openings was stable against galloping from the viewpoint of appearance. Meanwhile, the negative aerodynamic damping increased with the increase in *OR* from 0 (totally closed) to 0.75 and then decreased because the time-averaged shear layers approached the trailing edges with the increase in *OR* and finally reattached on the side surfaces at *OR* = 0.875 and larger.

**Keywords:** Butterfly web bridge; Side openings; Rectangular cylinder; Galloping; Flow field.

**KU-11**

# Comprehending Large Amplitude Aerodynamic Vibrations of Rectangular Cylinder in terms of the Time Derivative of Relative Angle of Attack

T. Okunishi[1], T. Yagi[2], T. Komatsu[3], T. Ono[4], H. Matsumiya[5]and K. Noguchi[6]

[1,2,4,6]*Department of Civil and Earth Resources Eng., Kyoto University, Kyoto, 615-8540, Japan*
*okunishi.tomoya.68m@st.kyoto-u.ac.jp, yagi.tomomi.7a@kyoto-u.ac.jp*
*ono.takumi.48c@st.kyoto-u.ac.jp, noguchi.kyohei.7z@kyoto-u.ac.jp*
[3] *Net Protections Holdings, Inc., Tokyo, 102-0083, Japan*
*ktakahiro@netprotections.co.jp*
[5]*Civil Engineering Research Lab., Central Research Institute of Electric Power Industry, Japan*
*hisato-m@criepi.denken.or.jp*

## Abstract

Evaluating the stability of long span bridges against self-induced aerodynamic vibrations is necessary. Previous researches have focused only on the responses with small-amplitudes around their onset velocities, not the behavior of the large-amplitude aerodynamic vibrations. The authors observed 2DOF-dominant vibrations with large amplitudes by using a rectangular cylinder with the side ratio of 5. To elucidate the mechanism of the large-amplitude vibrations, the aerodynamic forces based on time derivatives of relative angle of attack ($\dot{\alpha}$) were newly formulated and obtained from the body under the condition of a constant rotational velocity. The unsteady aerodynamic derivatives derived from the formulated forces is equivalent to those measured by oscillating the body with a torsional 1DOF sinusoidal wave. Finally, the time series analysis using the aerodynamic forces based on $\dot{\alpha}$ reproduced with the observed responses well.

**Keywords:** Torsional Flutter, Large Amplitude Vibration, Relative Angle of Attack

**KU-12**

# Tracking of Airborne Sea Salt Particles around a Rectangular Prism in Smooth Flow by LES

Y. Tsuda[1], K. Noguchi[2], Y. Tsubokura[3] and T. Yagi[4]

[1,2,3,4]*Department of Civil and Earth Resources Engineering, Kyoto University,*
*Kyoto 615-8540, Japan*
*tsuda.yuki.43s@st.kyoto-u.ac.jp, noguchi.kyohei.7z@kyoto-u.ac.jp*
*tsubokura.yuuta.73s@st.kyoto-u.ac.jp, yagi.tomomi.7a@kyoto-u.ac.jp*

## Abstract

Bridges in Japan have been damaged because many were constructed during the period of the rapid economic growth. The main cause is corrosion because of airborne sea salt and deicing salt particles. However, although many methods to evaluate the amount of salt adhering to bridge surfaces have been developed based on wind tunnel tests and numerical analysis, they are still time and money consuming. Thus, the authors numerically calculated wind flows around rectangular prisms by Large Eddy Simulation to investigate the motion of airborne sea salt particles and the salt deposition for realizing a simple evaluation method. The adhesion of particles concentrated at the edges of each face and less particles adhered to the mid of faces. In addition, it was found that particles adhered to the back side of the prisms owing to Karman vortex shedding in the cases of a small Stokes number.

**Keywords:** LES; Airborne sea salt; Corrosion; Stokes number

**KU-13**

# Improving accuracy of acceleration-based drive-by road profile identification by correcting sensor inclinations

N. Toshi[1], C.W. Kim[2] and K.C. Chang[3]

[1,2,3]*Department of Civil and Earth Resources Engineering, Kyoto University, Japan*

[1]*toshi.naoya.88n@st.kyoto-u.ac.jp* [2]*kim.chulwoo.5u@kyoto-u.ac.jp* [3]*chang.kaichun.4z@kyoto-u.ac.jp*

## Abstract

Drive-by bridge inspection is the method using the responses of a vehicle passing over a bridge to identify various characteristics of the bridge. It needs only accelerometers installed on a test vehicle, so it is time-, cost- and labor-saving and portable. The accurate identification of road profile is essential for this method because it excites the test vehicle the most and governs the identification accuracy of other characteristics. In past laboratory and field experiments, the accuracy of road profile identification remains an open problem. This study aims to improve the identification accuracy in a field bridge test by correcting the inclinations of sensors. The initial inclinations were estimated by an existing method, and its reliability was evaluated by the ratio of standard deviation and correlation coefficient between horizontal and vertical accelerations. From the result, the method of correcting sensor inclinations was proposed and validated.

**Keywords:** Drive-by bridge inspection; Vehicle-bridge interaction; Road profile; Sensor inclination

**KU-14**

# Changes in Modal Frequencies and Structural Behavior at Supports on a steel plate girder bridge Caused by Local Damage and Varying Temperature

T. Hirooka[1], C.W. Kim[2], G. Hayashi[3] and Y. Goi[4].

[1,2,3,4]*Department of Civil and Earth Resources Engineering, Kyoto, Kyoto 615-8540, Japan*

*hirooka.takumi.82s@st.kyoto-u.ac.jp, kim.chulwoo.5u@kyoto-u.ac.jp, hayashi.gen.2c@kyoto-u.ac.jp, goi.yoshinao.2r@kyoto-u.ac.jp*

## Abstract

This study is intended to investigate how the local damage and varying temperature affect changes in modal frequencies of a steel plate girder bridge. A damage experiment on a real bridge was conducted. Observations showed frequency of the 1st bending mode increased due to artificial damage though frequencies of the 2nd bending mode and 3rd bending mode decreased. FE analysis is conducted considering changes in spring constant which models the cantilever steel pivot bearings at support due to the damage as well as temperature change to examine the reason why the frequency change of each mode. FE analysis demonstrated the 1st bending mode was more sensitive to changes in the boundary condition than changes in stiffness of girder. In addition, FE analysis also showed the boundary condition was changed by not only the stiffness reduction of girder due to the damage but also thermal expansion due to varying temperature.

**Keywords:** Damage Experiment; Steel Plate Girder Bridge; Temperature; Modal Frequency; Structural Behaviour.

**KU-15**

# Benefits of Implementation of Building Information Modeling (BIM) in Bridge Projects

Ahmed Mohamed Waheed[1], Chul Woo Kim[2]

[1, 2] *Department of Civil and Earth Resource Engineering, Kyoto University, Japan*

*ibrahim.mostafa.48n@st.kyoto-u.ac.jp, kim.chulwoo.5u@kyoto-u.ac.jp*

## Abstract

Bridge engineering is usually associated with problems and disputes between all parties related to the engineering and delivery methods. This leads to a delay in the delivery of the bridge, reduction of quality, and over costs. The traditional approach is time-consuming along with the errors associated with manual calculations, and difficult coordination. Over the past few years, Building Information Modeling has been studied and implemented to overcome these problems. However, some problems have not been fully tackled like crane location assessment and linking BIM to bridge maintenance as well as health monitoring. This study aims to identify the impacts of utilizing BIM in infrastructure construction and management through the process of decision making by planning the construction site through a scoring system. The results show that this process is relatively faster than the traditional methods implemented by most companies such as manual calculations.

**Keywords:** Building information modeling; Bridge construction management; Maintenance; Structure health monitoring.

**KU-16**

# Vibration test and system identification of Gerber-type steel plate girder bridge

Xin Zhou[1], Chul-Woo Kim[2], Yoshinao Goi[3], Gen Hayashi[4], and Haru Hiraide[5]

[1,2,3,4,5] *Department of Civil & Earth Resource Engineering Graduate School of Engineering, Kyoto University, JAPAN*

*zhou.xin.28n@st.kyoto-u.ac.jp, kim.chulwoo.5u@kyoto-u.ac.jp, goi.yoshinao.2r@kyoto-u.ac.jp, hayashi.gen.2c@kyoto-u.ac.jp, hiraide.haru.63n@st.kyoto-u.ac.jp*

## Abstract

The experimental modal analysis, which can provide dynamic characteristics of structures, is widely used to get the performance of bridge structure. This paper presents a vibration test and modal analysis of a Gerber-type steel plate girder bridge in Japan. Field tests were conducted in the target bridge using twelve accelerometers. Both Bayesian operational modal analysis and stochastic subspace identification method are used for identifying modal parameters. Observations showed that identification results from both Bayesian operational modal analysis and stochastic subspace identification method were comparable with each other despite of some missing modes in each method. It demonstrates that utilizing multiple system identification methods is preferable for the system identification of the bridge structures as operational bridge vibrations usually contain many types of noises.

**Keywords:** Field vibration test; Bayesian operational modal analysis; Stochastic subspace identification; System identification.

**KU-17**

# Remaining Capacity of Damaged Weathering Steel Bridge by Long-Term Atmospheric Corrosion

Wint Thandar[1], Yasuo SUZUKI[2], Yasuo KITANE[3], Yoshinao GOI[4]
and Kunitomo SUGIURA[5]

[1,3,4,5]*Department of Civil and Earth Resources Engineering,*
*Kyoto University, Kyoto 615-8540, Japan.*
[2]*Department of Civil Engineering, Toyama University, Toyama, Japan.*
*wint.thandar.83w@st.kyoto-u.ac.jp, suzuki@sus.u-toyama.ac.jp,*
*kitane.yasuo.2x@kyoto-u.ac.jp, goi.yoshinao.2r@kyoto-u.ac.jp,*
*sugiurak@mbox.kudpc.kyoto-u.ac.jp*

## Abstract
Atmospheric corrosion is the most destructive form of corrosion, which causes tremendous economic losses in all around the world. Therefore, study of infrastructures' performances under corrosive environment is compulsory for structural engineers. This study focuses on behaviors of weathering steel bridge under corrosion in Delta Region of Myanmar. A Finite Element Model (FEM) was used to investigate the characteristics of bridges with alternative thicknesses reduction according to long-term predicted corrosion losses. Prediction equation was modeled by least-square method. Stress level in each component and failure mode under the critical load and predicted losses were examined after steady-state dynamic analysis in ABAQUS. This study is useful for the weathering steel bridge service life forecast under corrosive environment in similar weather condition in the future.
**Keywords:** Weathering steel bridge; Atmospheric corrosion losses; Capacity evaluation; Stress variation.

**KU-18**

# A feasibility study of sound-based inspection in hammer test

Yiran. YU[1], Kunitomo. SUGIURA[2], Yasuo KITANE[3] and Yoshinao GOI[4]

[1,2,3,4]*Department of Civil and Earth Resource Engineering, Kyoto University, Kyoto 615-8540, Japan*
*yu.yiran.58a@st.kyoto-u.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp, kitane.yasuo.2x@kyoto-u.ac.jp,*
*goi.yoshinao.2r@kyoto-u.ac.jp*

## Abstract
In Japan, infrastructures built during the high economic growth period are now facing aging deterioration problems. Under the circumstance of rising labor cost and decreasing of skilled technicians, the development of novel inspection techniques is essential for the management of infrastructures. Hammer test is widely used in visual inspection of infrastructures such as bridges and tunnels; however, its accuracy depends on the perception and experience of technicians. To minimize the subjectivity of this method, it is essential to quantify the sound signals and clarify the evaluation criterion. An inspection method using sound signals in the hammer test is presented in this paper. Sound signals generated in the hammer test of steel plates are collected by a microphone and processed by Fast Fourier Transformation, then statistical analysis is used in the discrimination and classification of the processed data. Properties of the plates such as thickness variation and presence of defect can be identified and categorized. By combing the classified features with the hammering position data recorded by a camera, the visualization of the inspection result is generated. Feasibility of the proposed method is verified in this preliminary experiment.
**Keywords:** Hammer test; Defect inspection; Statistical analysis.

**KU-19**

# Influence of Repair Plate Shape in GFRP Repairing

A. Sato[1], G. Hayashi[2], Y. Kitane[3], M. Matsumura[4] and K. Sugiura[5]

[1,2,3,5] *Department of Civil and Earth Resources Engineering, Kyoto University, Japan*

[4]*Center for Water Cycle, Marine Environment and Disaster Management, Kumamoto University, Japan*

*sato.akhiko.45m@st.kyoto-u.ac.jp, hayashi.gen.2c@kyoto-u.ac.jp, kitane.yasuo.2x@kyoto-u.ac.jp, matsumura-m@kumamoto-u.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp*

## Abstract

Fiber reinforced polymer (FRP) is a composite material which consists of fiber and polymers. These days, FRP has been used not only as a repairing material but also as structural members of water gates and pedestrian bridges. FRP structures suffer from environmental degradation and external force damage. However, Guidelines of Design and Construction of FRP footbridges shows repairing method only for environmental degradation. Therefore, this research aims to develop a repairing method against external force damage. In a previous study, the authors focused to adhere repair plate on both sides of GFRP and to conduct uniaxial tensile test. The experimental result showed that adhered repair plate decrease tensile strength when the base plate was not damaged. Stress concentration occurred in the repair plate edge. Therefore, this paper altered the shape of the repair plate and examined stress on the base plate analytically. Based on the analysis, ideal shape of repair plate is proposed.

**Keywords:** GFRP; Repairing; Stress concentration; FEM

**KU-20**

# Study on shear deformation performance of rubber bearing with steel plate

Kosuke Mine[1], Masahide Matsumura[2] and Kunitomo Sugiura[3]

[1,3]*Department of Civil and Earth Resources Engineering, Kyoto University, Japan*

[2]*Center for Water Cycle, Marine Environment and Disaster Management, CWMD*

*Disaster Migigation Lab*

*E-mail: mine.kosuke.72n@st.kyoto-u.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp, matsumura-m@kumamoto-u.ac.jp*

## Abstract

In Japan, high dumping rubber bearings have been widely used since 1995 to prevent bridges from being damaged by earthquakes. To support vertical loads, the bearings require a larger bearing area than steel bearings. In addition, it is common to install a huge side block at the end of girder to suppress deformation in the transverse direction. However, the bearing part of the existing bridge is narrow and it is difficult to secure a sufficient area. Therefore, it is desirable to provide simpler rubber bearings there. This research proposes to add the thin steel plate on the side of conventional rubber bearings and change the horizontal rigidity of them. It is analytically examined that the proposed bearing suppresses the deformation in the transverse direction. In finite element analysis, flat steel plate and corrugated steel plate were attached to a rubber bearing, and deformation in two horizontal directions and bending deformation were examined.

**Keywords:** rubber bearing; steel plate; finite element analysis; deformation performance

**KU-21**

# Pounding Effect of Skew Bridge and Method of Mitigation

Jing Yixiong[1], Kunitomo SUGIURA [2] and Masahide MATSUMURA [3]

[1,2] *Department of Civil and Earth Resources Engineering, Kyoto University, Japan*
[3]*Center for Water Cycle, Marine Environment and Disaster Management, CWMD*
*Disaster Migigation Lab*
*jing.yixiong.83w@st.kyoto-u.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp,*
*matsumura-m@kumamoto-u.ac.jp*

## Abstract

Nowadays due to the complexity of interchanges shape and the lack of space in the urban areas and sometimes the limitations from the geographic conditions, the skewed highway bridges are frequently employed in the transportation systems. And unique geometric properties make this type of bridge vulnerable to the earthquake excitations due to the pounding of thermal gap between deck and abutment. This research is to measure the pounding behaviors of skew bridges in terms of different geometric properties by first using the shaking table experiment to measure relatively simple specimen, simple FEM model built by Opensees further generally validates the effectiveness of pounding element utilized for representing the thermal span. Finally, more precise FEM bridge model installed with rubber was carried out to prove by using such shock absorption equipment the pounding effects could possibly be mitigated.

**Keywords:** Skew bridge; Pounding; Mitigation.

**KU-22**

# Experimental and Analytical Study of Temperature Effect on Different Colored Steel Bridges caused by Solar Radiation

Ruobing SUN[1], Kuo-chun CHANG[2], Kunitomo SUGIURA[3],and Yasuo KITANE[4]

[1]*Department of Environmental Management, Kyoto University, Kyoto 6158540, Japan*
[2]*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
[3,4]*Department of Civil and Earth Resources Engineering, Kyoto University, Kyoto, Japan*
*sun.ruobing.46z@st.kyoto-u.ac.jp; ciekuo@ntu.edu.tw;*
*sugiura.kunitomo.4n@kyoto-u.ac.jp; kitane.yasuo.2x@kyoto-u.ac.jp*

## Abstract

Temperature stress caused by solar radiation on structure is nonuniform and may cause a local damage or even destruction. Thus, temperature stress involves an unpredictable risk for bridge safety. On this basis, color of the bridges is an apparent factor that may cause different degrees of absorption of the sunlight. This paper investigates the influence of solar radiation on temperature of steel bridges by means of field measurement and numerical simulation. A steel arch bridge in Taiwan is selected to measure the temperature change during daytime. Moreover, steel specimens with various colors were placed horizontally and exposed to sunlight to measure temperature changes over the course of a day. Numerical simulations have been carried out to analyze the changes in deformation associated with temperature effect by establishing a detailed 3D finite element model of the target bridge in ABAQUS. The above observations may have reference value for the analysis of temperature effect for similar bridges in the same region.

**Keywords:** Temperature effect, solar radiation, steel bridge, deformation

**KU-23**

# Fundamental study on health monitoring of steel girder bridge using displacement and slope at girder end

Thant Yin Tun[1], Kunitomo Sugiura[2]

[1,2,]*Department of Civil and Environmental Engineering, Kyoto 615-8540, Japan*

*thant.tun.3e@st.kyoto-u.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp*

## Abstract

Inspection is important in maintenance of bridges both for safety and for longer lifespan. Bridge inspection using sensors could help to determine the current condition and performance of the structures. Moreover, the obtained data can also be used for future maintenance. In this research, sensors are to be placed only at the movable end of the girder to collect static information such as deflection and rotation angle. Before performing in a real bridge, the relationship between slope and horizontal displacement at the girder end of a simply supported beam was investigated analytically. A short span steel girder bridge is adopted for field investigation. Also, simulation by ABAQUS is performed to make comparison between field data and simulation results. From this comparison, the changes in slope-deflection relationship are extracted. The pattern of these changes can be used to determine the location and severity of a single damage. This method avoids complex procedure to detect damage. Also, the proposed method will help to reduce the number of applied sensors and to save the installation time.

**Keywords:** field experiment; health monitoring; simple beam.

**KU-24**

# ASSESSMENT OF A BRIDGE STRUCTURE SUBJECTED TO FLOOD LOADINGS “CASE STUDY OF LICUNGO BRIDGE”

C.S. Mafuiane[1], K. Sugiura[2], E. Harada[3], T. Tanaka[4]

[1]*Urban Infrastructure Engineering Laboratory, Kyoto University, Japan*

*mafuiane.lopes.48m@st.kyoto-u.ac.jp*

## Abstract

The climate change, which is assumed to influence on the flood frequency and on raising of water level of rivers, increases the vulnerability of public infrastructure such as roads and bridges. This research is conducted based on the Mozambican current scenario of natural disasters such as abnormal winds and rainfall which result in floods. The existing structures were designed based on the old Portuguese design code named RSA (1961), which only refer to hydrodynamics on piers and neglecting the possibility of water level reach the superstructure. In this study, the structural behavior of an existing bridge superstructure and piers subjected to flood and debris loading is investigated based on real past events. The structural evaluation has been performed using a finite element analysis software package, Abacus. Indicators of performance show the tendency of failure, i.e. fracture due to bending and sliding due to shear force.

**Keywords:** Hydrodynamic Stability; flood; debris loading

**KU-25**

# Early stage detection method of vehicle loads induced fatigue cracking under the coating film in steel bridges

M. Mboup[1], K. SUGIURA[2]

[1,2]*Department of Civil and Earth Resources Engineering, Kyoto daigaku-katsura, Nishikyo-ku, Kyoto 615-8530, Japan*

*mboup.mariama.32e@st.kyoto-u.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp*

## Abstract

In this paper, method of displacement analysis to find the cracking zone of a steel plate based on digital image correlation and advanced multi-processor graphic card procedure is presented. For the discussed displacement and strain measurement method, high measurement sensitivity is obtained by simultaneously minimizing the measurement time consumption. The developed digital procedures to evaluate correlation of images are used as an example of displacement analysis in the crack propagation testing in bridges for a few years. The material model is based on multi-component form of isotropic and kinematic hardening variables in conjunction with von Mises yield criterion. The accuracy of the computational procedure is tested by comparing the computed results with the real experimental data.

**Keywords:** fatigue crack; digital image correlation; finite element modelling

**KU-26**

# A statistical response of GFRP channel member performance considering material variability

G. Hayashi[1], Y. Kitane[2], K. Sugiura[3] and I. Nishizaki[4]

[1,2,3] *Department of Civil and Earth Resources Engineering, Kyoto University, Kyoto*
[4] *Advanced Materials Team, Public Works Research Institute, Tsukuba, Ibaraki, Japan*
*hayashi.gen.2c@kyoto-u.ac.jp, kitane.yasuo.2x@kyoto-u.ac.jp,*
*sugiura.kunitomo.4n@kyoto-u.ac.jp, nisizaki@pwri.go.jp*

## Abstract

Glass Fiber Reinforced Polymer, GFRP provides unique mechanical properties such as high strength, high corrosion resistance, light weight and so on. However, there is a variation in the material properties of GFRP. Statistical evaluation on material properties are needed to understand the inherent uncertainty of GFRP composites. Furthermore, it is important to examine the influence of these variations on member performance. For GFRP formed into channel cross section by hand lay-up molding method, this study presents results of tensile, compressive and bending tests, and also modal properties. Coupon test specimens, cut from several locations of the GFRP channel members, are used in tensile and compressive testing. In addition, Monte Carlo simulation is performed using the observed data to evaluate tensile, compressive, bending and modal properties statistically in whole cross sections of the member.

**Keywords:** statistical response; GFRP; Channel member; material variability;

**KU-27**

# Study on Improvement of WRF Accuracy for the Evaluation of Dew Condensation on Steel Bridges

Zabihullah Rasoli[1], Kazutoshi Nagata[2], Takeshi Kitahara[3] and Kunitomo Sugiura[4]

[1,2]*Department of Civil Engineering, Nagoya Institute of Technology, Aichi 466-8555, Japan*
[3]*Department of Civil Engineering, Kanto Gakuin University, Kanagawa 236-8501, Japan*
[4]*Department of Civil and Earth Resource Engineering, Kyoto University, Kyoto 615-8540, Japan*
*30515009@stn.nitech.ac.jp, nagata@nitech.ac.jp, kitahara@kanto-gakuin.ac.jp, sugiura.kunitomo.4n@kyoto-u.ac.jp*

## Abstract

Dew condensation is an important factor in the occurrence of bridge corrosion and contributor to the deterioration of the protective coating. Therefore, an evaluation method of dew condensation has been developed using a weather research and forecasting (WRF) numerical weather prediction technique over the past few years. In this study, an accuracy enhancement of WRF for the evaluation of dew condensation was discussed to achieve more accurate results. The WRF uses land use data based on USGS by default, which yields into inaccurate results to a certain extent in Japan. In this paper, the land use data provided by the Geospatial Information Authority of Japan was employed to improve the accuracy of WRF simulation model. Moreover, a temperature modification factor was proposed to obtain the actual girder temperature from the atmospheric temperature.
**Keywords:** Steel bridges; Dew condensation; Maintenance and management.

**KU-28**

# Consideration on Response of Seismic Isolated Elevated Bridges due to Slightly Strong Earthquakes

Yin Xiang[1], Takahashi Yoshikazu[2]

[1,2,3]*Department of Civil and Earth Resources Engineering,*
*Kyoto University, Kyoto, 615-8540, Japan*
*yin.xiang.48a@st.kyoto-u.ac.jp, takahashi.yoshikazu.4v@kyoto-u.ac.jp*

## Abstract

Japan, located in earthquake prone regions has always been on the forefront of utilizing advanced technologies to improve structure behavior against strong earthquakes. The seismic base isolated devices have been introduced into more and more structures after the Great Hanshin Earthquake. The behavior of seismic isolated devices under large scale earthquakes (>M7.0) have been analyzed well by several studies, but few of them include behavior of them under slightly strong earthquakes (M4.0~M6.9). In this study, system identification has been used to analyze the behavior of seismic isolated structures under slightly strong earthquakes with the response record of a seismic isolated structure under main shock of the earthquake in Osaka-Fu Hokubu on 18th June 2018. The objective structure, Pier 408 of Matsunohama Viaduct is located in the southwest direction, 30 km away from the epicenter. Lead rubber bearings (LRBs) are installed between the pier top and the girder as a seismic base isolated device to improve seismic response of the viaduct. Result shows that the actual stiffness of bearing appears to be larger than its designed value when exposed to slightly strong earthquakes. It is hard to predict the equivalent shear modulus and stiffness in slightly strong earthquakes based on the Specification for highway bridge bearings.
**Keywords:** Seismic Isolation; Elevated Bridge; 2018 Osaka-Fu Hokubu Earthquake

**KU-29**

# Development of Plastic Hinge Replaceable Bridge Piers under Gravity Load based on Metabolism Concept

Maeda Hiroto[1], Hayashi Manabu[2] and Takahashi Yoshikazu[3]

[1, 3] *Department of Civil and Earth Resources Engineering,*
*Kyoto University, Kyoto, 615-8540, Japan*
*maeda.hiroto.45r@st.kyoto-u.ac.jp, takahashi.yoshikazu.4v@kyoto-u.ac.jp*
[3]*Muramoto Construction Co.,Ltd., Osaka, 543-0002, Japan*
*mhayashi@muramoto.co.jp*

## Abstract
There are a lot of earthquakes in Japan. Seismic design code would be updated after tremendous earthquake. So, we need a structure which satisfies not only the current seismic design code but also the change of design code in future. This research is to develop a structure of pier whose seismic performance is renewable according to a change of the code. We call it metabolism seismic pier structure. Specifically, it consists of two parts. One is a core part which supports axial force and shearing force. The other one is a shell part which provides energy absorption performance. Such a double structure allows us renew the shell part easily. We made a shell replace experiment supporting axial force and a cyclic loading experiment. As a result, it is possible to replace a shell part, applying axial force. Furthermore, its seismic performance can be almost guaranteed. Finally, we organized what is required for a shell part.
**Keywords:** Metabolism; Replace; Core

**KU-30**

# Nonlinear Dynamic Response of Structures with negative stiffness in Skeleton Curves

Watanabe Kousuke[1], Uemura Keita[2], Takahashi Yoshikazu[3]

[1,2,3]*Department of Civil and Earth Resources Engineering,*
*Kyoto University, Kyoto, 615-8540, Japan*
*watanabe.kousuke.75e@st.kyoto-u.ac.jp, uemura.keita.35a@st.kyoto-u.ac.jp,*
*takahashi.yoshikazu.4v@kyoto-u.ac.jp*

## Abstract
In this study, the dynamic stability of a structure with negative stiffness in the skeleton curve was theoretically investigated. For theoretical research, the frequency response function derived by Caughey and the discriminant of the instability of the response solution are used. As a result, it was found that the range in which the structure shows a stable steady response in the range where load decreases is determined by the ductility of the skeleton curve and the negative stiffness in the range. Moreover, as a result of conducting a parametric study about ductility and negative stiffness in the range where load decreases, it was suggested that dynamic stability is not secured in the range where load decreases if ductility is too large.
**Keywords:** Steady State; Dynamic Stability; Negative Stiffness; Ductility; Parametric Study

**KU-31**

# Experimental/Numerical Investigation on Mechanism of Vertical Crack Generation on Mesnager Hinge

K. Uemura[1], Y. Takahashi[2] and H. Goto[3]

[1,2] *Department of Civil and Earth Resources Engineering,Kyoto University, Kyoto, Japan*
[3] *Disaster Prevention Research Institute, Kyoto University, Gokaho, Uji, Kyoto, Japan*
*uemura.keita.35a@st.kyoto-u.ac.jp, takahashi.yoshikazu.4v@kyoto-u.ac.jp,*
*goto@catfish.dpri.kyoto-u.ac.jp*

## Abstract

In mesnager hinge, vertical cracks are known to generate on concrete in the hinge throat and considered to be caused by transmission force due to bond between concrete and crossing reinforcing bars in Japanese seismic code. However, few researches investigated the mechanism of the crack generation. Therefore, cyclic loading tests were conducted for rocker piers with mesnager hinge. As a result, vertical cracks generated in all specimens including one with crossing plain reinforcing bars, and the cracks did not propagate along crossing reinforcing bars. Thus, it was considered that the mechanism of vertical crack generation is not correct in Japanese seismic code. Therefore, vertical crack generation on concrete in the hinge throat was simulated with X-FEM. The results of simulation with X-FEM showed that the vertical cracks were generated by compression load on concrete in the hinge throat.
**Keywords:** Mesnager hinge; Crack generation; Cyclic loading test; Extended finite element method

**KU-32**

# A Method of Bi-directional Displacement Demand Assessment for Bridge Bearings Subjected to Ground Motions with Directionality Effects

Xinhao He[1], Akira Igarashi[2]

[1]*Department of Urban Management, Kyoto University, Kyoto, Japan*
*he.xinhao.25u@st.kyoto-u.ac.jp*
[2]*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*
*igarashi.akira.7m@kyoto-u.ac.jp*

## Abstract

The unidirectional analysis is adopted to assess the seismic performance of bridges in typical design codes. However, the bi-directional analysis, taking advantage of the development of the bi-directional modelling technique of structures, should be advantageous to improve the reliability of seismic performance assessment considering the bi-directional nature of the actual ground motions. Although the percentage rules combining two unidirectional demands in orthogonal directions are typically applied to evaluate the bi-directional demand, the results of nonlinear time history analysis indicate that the bi-directional demand to the bridge bearings considering the bi-directional nature of ground motions cannot be accurately estimated by the above methods. In the present study, a method of bi-directional displacement demand assessment for bridge bearings subjected to bi-directional ground motions with directionality effects is proposed. The idea of the proposed method is to combine the unidirectional responses to two orthogonally incremental components, so that the resulting bi-directional response can correctly reflect the bi-directional displacement demand. Firstly, the mean of the decrease/increase ratio of the maximum response in the major axis is estimated by applying a simple stochastic dynamic approximation with white-noise excitation to a SDOF system. Secondly, the minor-axis increment is estimated by considering the deviation angle of the absolute maximum responses between the bi-directional and the unidirectional conditions. The accuracy of the proposed method is validated by the analysis using the synthesized bi-directional ground motions and the actual strong ground motions.
**Keywords:** Bi-directional ground motions; Seismic performance assessment; Bridge bearings; Elastomeric bearings; Slide bearings.

**KU-33**

# Finite Element Modeling and Performance Evaluation of Strip Scrape Tire Rubber Pad Base Isolator

M.B. Zisan[1] and A. Igarashi[2]

[1] *Department of Urban Management, Kyoto University, Japan*
[2] *Disaster Prevention Research Institute, Kyoto University, Japan*
*zisan.basir.33m@st.kyoto-u.ac.jp, igarashi.akira.7m@kyoto-u.ac.jp*

## Abstract
The elastomeric bearings are found cost-ineffective for low-to-medium rise buildings, especially in developing countries. This cost-prohibition and limiting modern technologies here are significantly retarding the practice of earthquake-resistant design strategies. This paper focused on structural performance and viability of a cost-effective and lightweight strip-shaped isolator made with Scrape Tire Rubber Pad (STRP) materials that are expected to be applicable for low-to-medium rise buildings. For this purposes, a three-dimensional finite element analysis of the isolator is carried out using Mooney-Rivlin hyperelastic and viscoelastic material models that include the material damage also. The model verification and responses evaluation are done for a series of cyclic lateral loads that are applied along with two orthogonal directions of isolators for different length to width ratios. The performances of the strip isolators are investigated in terms of force-displacement relations, horizontal stiffness and structural damping under large lateral displacement control. It has found that strip STRP isolators subjected to lateral load along with two orthogonal directions show two distinct force-deformation relationships, different stiffness and damping properties that are also influenced by length to width ratios of the isolator.
**Keywords:** Low-cost, Strip STRP isolator, Mooney-Rivlin, Lateral load, Stiffness, Damping

**KU-34**

# Systematic Understanding of the Ground Motion Amplification on Three-dimensional Basin Structure

Yuki Tanaka[1], Hiroyuki Goto[2] and Sumio Sawada[3]

[1]*Department of Urban Management, Kyoto University, Japan*
[2,3]*Disaster Prevention Research Institute, Kyoto University, Japan*
*tanakay@catfish.dpri.kyoto-u.ac.jp, goto@catfish.dpri.kyoto-u.ac.jp,*
*sawada@catfish.dpri.kyoto-u.ac.jp*

## Abstract
Seismic wave propagation and ground motion amplification in/on the complicated 2-D and 3-D basin structure are important issues in considering the input motion for seismic design for civil engineering structures. In this research, we discuss the effect on ground motion amplification from the complicated structure, especially on the basis of the existence of eigenmodes for whole the basin system. 3D numerical simulations investigate that almost the common peak frequencies appear in transfer functions of the basin system regardless of the deposit layer thickness, and the spatial variation of the peak values is evident in the eigenmodes. When the basin model is excited by a pulse-like input motion, the spatial distribution of maximum amplitudes can be explained from the eigenmodes. This implies that mode analysis of the entire ground structure enables us to systematically understand the effect on ground motion amplifications.
**Keywords:** Ground motion; 3D site amplification; Sedimentary basin; Modal analysis.

**KU-35**

# Deep learning model to predict time series of real-time ground motions

Ryota Otake[1], Jun Kurima[2], Hiroyuki Goto[3] and Sumio Sawada[4]

[1,2]*Department of Urban Management, Kyoto University, Japan*

[3,4] *Disaster Prevention Research Institute, Kyoto University, Japan*

*otake@catfish.dpri.kyoto-u.ac.jp, kurima@catfish.dpri.kyoto-u.ac.jp*
*goto@catfish.dpri.kyot-u.ac.jp, sawada@catfish.dpri.kyoto-u.ac.jp*

## Abstract

Spatial distribution of earthquake ground motion is important to seismic disaster risk management. We propose a deep learning model that estimates time series of the ground motion from the records at permanent seismometers. Temporal seismometers are installed to obtain the training records. The model consists of multiple LSTM layers and it can estimate the time series satisfying the causality. The model is verified by using the records at K-NET MYG006 and F11 in Furukawa district, Miyagi, Japan, from 2012 to 2018. The prediction performance is better or approximately similar to adopt the input data directly, in terms of PGV and SI values. The deep learning model, on the other hand, can train the wave propagation as well as the site amplification naturally. This means that the deep learning approach is a possible future solution to increase the accuracy of earthquake early warning.
**Keywords:** Earthquake; Seismic wave; Deep learning.

**KU-36**

# Application of arbitrary particle domain interpolation to soil-water coupled consolidation analysis using Material Point Method

Goto Yoshikazu[1], Higo Yosuke[2], Kiriyama Takatoshi[3]

[a]Department of Urban Management, Kyoto University, Japan

[b]Shimizu Institute of Technology, Japan

E-mail: gotou.yoshikazu.34u@st.kyoto-u.ac.jp

## Abstract

Recently, big earthquakes frequently occurred in Japan and caused huge damages of earth structures. Therefore, development of analysis methods which can predict large deformation problem of soil is important. Many mesh-free methods have been developed to simulate large deformation of soil, for example Material Point Method (MPM) with use of the Generalized Interpolation Material Point (GIMP) scheme. Arbitrary Particle Domain Interpolation method (APDI) is a new particle domain integration method which enables us to calculate large deformation keeping continuity of particle domains and to evaluate boundary values due to the clear definition of continuous particle domains. APDI was applied to a soil-water two-phase coupled analysis and was applied to Terzaghi's consolidation problem. We compared the results of APDI with the results of theoretical solution and GIMP to verify the validity of this analysis.
**Keywords:** Material Point Method, Consolidation, Arbitrary Particle Domain Interpolation

**KU-38**

# Effect of contact-area variation within a single granite fracture on hydraulic properties

C.L. Song[1], S. Nakashima[2], H. Yasuhara[3] and K. Kishida[4]

[1,4]*Department of Urban Management, Kyoto University,606-8501, Japan*
[2]*Department of Civil and Environmental Engineering, Yamaguchi University,755-8611, Japan*
[3]*Department of Civil and Environmental Engineering, Ehime University,790-8577, Japan*
*E-mail: song.chenlu.72m@st.kyoto-u.ac.jp, nakasima@yamaguchi-u.ac.jp,*
yasuhara.hideaki.me@ehime-u.ac.jp, *kishida.kiyoshi.3r@ kyoto-u.ac.jp*

## Abstract
Laboratory experiments are performed to measure the flow behavior of fractured rocks under various conditions. Flow within the fractured rock may be bypassed by the contact area. A larger contact area may alter the flow path, and then it may further effect the permeability evolution. However, fracture contact-area changing under different conditions is not fully understood. Therefore, it is necessary to estimate the fracture contact-area variation through some advanced technique. In this study, a single granite fracture sample was utilized to evaluate the distribution of aperture and contact area within a fracture through a microfocus X-ray CT observation. Moreover, the change of the contact-area ratio at different positions were also studied. Results indicated that the flow within the fracture should be influenced by contact area that were locally and randomly distributed, which gives a significant impact on the permeability evolution.
**Keywords:**Granite; Single fracture; Flow behavior ; Contact-area variation ; X-ray CT observation

**KU-39**

# Soil-water coupled analysis of excavation process in deep cylindrical shaft

T. Tangjarusritaratorn[1], Y. Miyazaki[2] Y. Sawamura[3] and K. Kishida[4]

[1,2,3,4] *Department of Urban Management, Kyoto University, Japan*
*tangjarusritaratorn.tanawat.87n@st.kyoto-u.ac.jp, miyazaki.yusuke.6w@kyoto-u.ac.jp,*
*sawamura.yasuo.6c@kyoto-u.ac.jp, kishida.kiyoshi.3r@kyoto-u.ac.jp*

## Abstract
In recent years, utilization of cylindrical shaft has become popular in deep shaft construction with beneficial structural geometry of ring effect. Besides, a groundwater issue is always concerned with deep constructions facing high ground water level. Due to heaving by the high seepage force and immersion by the high pore water pressure, prediction of safe excavation process remains difficult. Nevertheless, the estimation of the water problem is only based on the real time monitoring due to lack of research reviews. Therefore, the aim of this analysis will be the clarification of mechanical behavior of cylindrical shaft undergoing with high groundwater level. In order to represent the behavior of soil-water interaction, the soil-water coupled finite difference method was applied in the simulation. As results, dewatering location has a great influence on trigger of heaving during the excavation process of the deep cylindrical shaft.
**Keywords:** Cylindrical shaft; Excavation; Groundwater; Soil-water coupled analysis; FDM.

**KU-40**

# Discussion on the frictional healing of single rock fracture in consideration of the rock weathered condition

J.T. Zhang[1], K.Matsumoto[2] and K. Kishida[3]

[1,] *Department of Urban Management, Kyoto University, Japan*

[2,] *Central Nippon Expressway, Japan*

*zhang.jintong.38w@st.kyoto-u.ac.jp, k.matsumoto.ah@c-nexco.co.jp,*

*kishida.kiyoshi.3r@kyoto-u.ac.jp*

## Abstract

Frictional healing of rock fracture plays a key role in determining earthquake stress drop among the seismic cycle. It increases with the loading time when the sliding surfaces of rock joint are under static contact condition. In this study, we employ two different weathering state granite specimens with a single fracture. Then, slide-hold-slide direct shear tests are conducted to clarify the influence of weathering state on shear strength recovery. Additionally, to examine the impact of the thermal and confining pressure, the experiments are carried out under various temperatures and several confining stresses. From the experimental results, it is confirmed that the shear strength recovery increases with the elevated normal loading and the temperature. During the second slide process, the weathered specimens have shorter cut off time and faster cut off velocity in contrast with the unweather rock joints.
**Keywords:** frictional healing; rock fracture; direct shear test; weathering state

**KU-41**

# Dynamic Centrifuge Tests on Three-hinge Type of Precast Arch Culvert under Asymmetrical Overburden

K. Ambai[1], Y. Miyazaki[2], Y. Sawamura[3], K. Kishida[4] and M. Kimura[5]

[1,2,3,4] *Department of Urban Management, Kyoto University, Japan*

[5] *Department of Civil and Earth Resources Engineering, Kyoto University, Japan*

*ambai.kyohei.85a@st.kyoto-u.ac.jp, miyazaki.yusuke.6w@kyoto-u.ac.jp,*

*sawamura.yasuo.6c@kyoto-u.ac.jp, kishida.kiyoshi.3r@kyoto-u.ac.jp*

*kimura.makoto.8r@kyoto-u.ac.jp*

## Abstract

Some three-hinge type of precast arch culverts suffered severe damage in the Great East Japan Earthquake (11, March, 2011); loss of serviceability. The culverts were installed in the road embankment at an oblique angle, which seems to cause asymmetrical overburden to the culverts near the mouth. Standing on this viewpoint, we conducted dynamic centrifuge tests to clarify the seismic effect of the uneven overburden on the three-hinge type of precast arch culverts. As results, we found that the uneven overburden with small covering thickness is likely to spoil the unity with the culvert and the surrounding ground during the earthquake. At the same time, about the internal forces of the arch culverts, the uneven overburden induces the unstable stress state of the arch culverts. Therefore, uneven overburden is likely to spoil the arch mechanism with unexpected change in the design of bending moment and axial force during the earthquake.
**Keywords:** Three-hinge type of precast arch culvert; Asymmetrical overburden; Dynamic centrifuge tests

**KU-42**

# Application of Hoek-Brown Criterion on tunnel excavation simulation under high overburden condition with fault zone

Ryota Kashima[1], Sho Ogata[2] and Kiyoshi Kishida[3]

[1,2,3] *Department of Urban Management, Kyoto University, Japan*

*kashima.ryota.52z@st.kyoto-u.ac.jp,ogata.shou.32m@st.kyoto-u.ac.jp, kishida.kiyoshi.3r@kyoto-u.ac.jp*

## Abstract

The ground behavior during high overburden tunneling should be significantly affected by groundwater environment, ground/geological conditions and earth pressure. When the fault zone appears in relatively hard rock, it is assumed that unexpected spring water and large deformation may occur. Even if the fault zone is not observed on tunnel face, occurrence of large deformation is expected. In this study, by applying Hoek-Brown Criterion, which is derived by material properties of targeted rock obtained from uniaxial compression tests and Brazilian tests, 2D tunnel excavation analyses based on FDM (Finite Difference Method) are conducted. Under the various conditions of overburden pressure and lateral pressure coefficient, the ground behavior during tunnel excavation when the fault zone of low strength locates near the excavated zone is predicted. From predicted results, the influence of ground conditions that do not appear on the face of tunnel is investigated and it may contribute to predict the presence of such ground conditions in order to carry out the countermeasures in the early stages of actual operations.

**Keywords:** Fault zone; Tunnel excavation; Hoek-Brown Criterion; Numerical analysis

**KU-43**

# Single Rock Fracture Modeling through CT data and Its Application for Grouting Injection Flow

Kyosuke Iseki[1], Yoichi Yoshizu[2] and Kiyoshi Kishida[3]

[1,3]*Department of Urban Management, Kyoto Univercity*

[2] *NEWJEC Inc*.

*iseki.kyosuke.66a@st.kyoto-u.ac.jp, kishida.kiyoshi.3r@kyoto-u.ac.jp*

## Abstract

Most of the permeability experiments and analyses in rock fracture were conducted by parallel plate model. However, the parallel plate model could not consider a roughness on the actual rock fracture. In this research, the authors proposed a simplified single rock fracture model that could express the roughness by applying FFT to rock fracture information extracted by using the microfocus X-ray CT and conducted permeability analysis for it. As a result, it was confirmed that the flow rate and Reynolds number are affected by the phase difference between upper and lower fracture roughness. In addition, the grouting injection analysis considering the inertia term was conducted for a simplified model to study the effect of roughness and phase difference to grout injection. As a result, it was confirmed that the injection rate of grout at the initial stage is greatly affected by the phase difference and the effect of the setting injection pressure on grout injection is smaller than the effect of fractures open width.

**Keywords:** Rock fracture, Grouting, Joint surface roughness

**KU-44**

# Behaviors of an undercut slope with a plane of discontinuity observed in centrifugal acceleration field

K. Aroonwattanaskul[1], T. Pipatpongsa[2], T. Kitaoka[3] and H. Ohtsu[4]

[1,2,3,4] *Department of Urban management, KU, Japan*
*aroonwattanaskul.krit.23z@st.kyoto-u.ac.jp*
*pipatpongsa.thirapong.4s@kyoto-u.ac.jp*
*kitaoka.takafumi.6e@kyoto-u.ac.jp*
*ohtsu.hiroyasu.6n@kyoto-u.ac.jp*

## Abstract
Nowadays the theoretical idealization of undercut slope has been applied to the actual site. However, the faults existing at the actual site might affect the stability of the slope. This study investigated the failure modes and their behaviors before the onset of failure through an undercut slope with a plane of discontinuity under a centrifugal acceleration field. Testing conditions were varied by the width of an undercut slope. The experimental centrifugal acceleration of the first failure was compared to the theoretical idealization based on the beam failure assumption. It is expected that the results of the present study can develop the design criteria in the actual site.
**Keywords:** Undercut slope; Discontinuous plane; Centrifuge model; Slope stability; Failure mechanisms.

**KU-45**

# Dynamic model tests on beam action and arch action in embankments subject to subsidence of foundation

T. Gondai[1], T. Pipatpongsa[2], T. Kitaoka[3] and H.Ohtsu[4]

[1,2,3,4] *Department of Urban management, KU, Japan*
*gondai.tomoki.35c@st.kyoto-u.ac.jp*
*pipatpongsa.thirapong.4s@kyoto-u.ac.jp*
*kitaoka.takafumi.6e@kyoto-u.ac.jp*
*ohtsu.hiroyasu.6n@kyoto-u.ac.jp*

## Abstract
A lot of embankments on non-liquified and deformable ground such as clay and peat deposit were severely damaged in 2011 Off the Pacific Coast of Tohoku Earthquake. In this study, dynamic centrifuge model tests of embankments on rigid base and soft urethane base were conducted to investigate the liquefaction resistance in association with the change of the stress distribution due to basal subsidence. Experimental results reveal lateral spreading deformation causes beam action shown as horizontal earth pressure drop along the bottom of embankments due to concave basal settlement. Moreover, arch action occurred underneath the core of embankment as vertical earth pressure drop was observed due to the basal subsidence and loosening of inner zone after supply of viscous liquid inside the embankment. Comparisons between embankments built on urethane base and on rigid base imply basal subsidence decreases liquefaction resistance in embankments.
**Keywords:** Beam action; Arch action; Centrifuge test; Basal subsidence; Liquefaction resistance.

# *Abstracts from National Taiwan University*

**NTU-01**

# The Focus on Promoting CSR and Issuing CSR Reports for Construction Firms

C.Y. You[1], S.P. Ho[2]

[1,2] *Department of Civil Engineering, National Taiwan University, R.O.C*

*d07521004@ntu.edu.tw, spingho@ntu.edu.tw*

## Abstract

To understand the focuses of Corporate Social Responsibility (CSR) disclosure of the construction industry and provide the reference to the construction industry and the competent authority for the attention of promoting and disclosing of CSR activities, this study bases on the CSR reports of ENR's top 100 ranking International construction contractors in 2017 to identify the focus of CSR promotion and disclosure. This study also determines the high relevance between these focuses of CSR with the Sustainable Development Goals (SDGs) and the United Nations Global Compact (UNGC). Those focuses of CSR can provide as a valuable reference for the construction industry in setting the priority of CSR goal and also for the competent authority in setting norms and policies of promoting CSR for the construction industry.

**Keywords:** ENR, International Construction Contractor, Corporate Social Responsibility, Global Reporting Initiative, GRI

**NTU-02**

# Promoting Urban Renewal through the Application of Security Token Offering and Building Information Modeling (BIM)

Hao-Yang Cheng[1] and Po-Han Chen[2]

[1,2]*Department of Civil Engineering, National Taiwan University, Taiwan*

*r07521709@ntu.edu.tw, pohanchen@ntu.edu.tw,*

## Abstract

Security token offering (STO) is a fundraising method for applying blockchain technology, where security token is a kind of beneficiary certificate with ownership or currency certificate representing the rights of profit distribution and voting. Tokenization helps real estate owners raise capital more efficiently, and provides investors with access to investments more easily by splitting assets into tokens. With STO, it would be promising to attract investors to participate in urban renewal, and the bulk reward and various offers would be the main sources of profits. Besides, bringing building information modeling (BIM) to urban renewal would provide investors with a clear understanding of the project at all stages of construction, which might even encourage investors to go for the second- or third-round of investment. In this research, a system combining smart contracts and BIM will be proposed to assist the owners with capital-raising through performing the rights of tokens, and to help with urban renewal at the same time.

**Keywords:** Blockchain; Security token offering; BIM; Urban renewal

**NTU-03**

# Application of blockchain in construction industry loans

Hong-Lin Ko[1] and Po-Han Chen[2]

[1,2]*Department of Civil Engineering, National Taiwan University, Taiwan*
*r07521706@ntu.edu.tw, pohanchen@ntu.edu.tw,*

## Abstract

Due to the huge cost required for construction of most built facilities, it is common for owners and contractors to take loans to meet the capital requirement in the construction industry. As capital chain rupture of the loan-taker may lead to high risk of bankruptcy, banks are usually extremely cautious with provision of loans, and will investigate potential loan-takers' credit history before providing loans. Although the process of investigating loan-takers' credit history would greatly reduce fraud cases, it incurs additional costs for the bank and prolongs the waiting time for the loan-taker. To increase the efficiency and effectiveness of the investigation process, blockchain is brought into this context in this study, so that companies with good credit history could get loans more easily, and banks could screen out companies with poor credit history more effectively. Blockchain is a distributed ledger technology that uses smart contracts to program the lending process and ensure the immutability of data. This study aims to identify the key data, which could be used for the blockchain applications, for the construction industry, so as to expedite the loaning process.
**Keywords:** Loan; Blockchain; Smart Contracts; Construction Industry

**NTU-04**

# Assessing Ridership Forecast Risk by Delphi Technique and Polynomial Tree for HSR under PPP

Teh-Ping Wang[1], Luh-Maan Chang[2]

[1,2]*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
*d02521009@ntu.edu.tw*

## Abstract

Understanding the uncertainty of the revenue forecast of High Speed Rail (HSR) is important for analyzing the financial feasibility. Over the decades, many studies tried to provide better methods for the ridership forecast, but there is still no consensus on the results of the forecast. Since ridership is the key factor of revenue, Taiwan HSR suffered a financial crisis caused by the tremendous gap between the actual and forecasted ridership. China HSR seemingly faces similar issues with ridership forecast, on top of the heavy debt of its HSR projects. When the HSR projects are under a Public Private Partnership (PPP), the inappropriate length of the concession period, resulted from revenue forecast, may later cause the financial difficulties of the project. This paper presents a conceptual framework to assess the risk of the ridership forecast for HSR project through Delphi technique and polynomial Decision Tree.
**Keywords:** HSR; PPP; Ridership forecast risk; Delphi Technique; Polynomial Decision Tree

**NTU-05**

# IRENO-ARCHITECTURE
# A Possible Adaptation of Architecture for Peace in Honduras

Moisés D. Osorto Carrasco [1,2], Edgardo R. Derbes[1 †] and Po-Han Chen[2]

[1] *School of Art and Design, Universidad Tecnológica Centroamericana, Honduras*

[2] *Department of Civil Engineering, National Taiwan University, Taiwan*

*r07521717@ntu.edu.tw, pohanchen@ntu.edu.tw*

## Abstract

Young people living inside informal communities around the capital of Honduras, are easily recruited by gangs. One such place is the community of Nueva Capital in western Tegucigalpa, where certain socially oriented organizations are building infrastructure to tackle this problem. Nevertheless, these neighborhoods demand better quality architecture that is able to play a role as promoter of peace. In order to provide solid bases for new architectural solutions, data from various resources was used to perform several analysis and studies regarding similar projects, the development of violence in Honduras, as well as the city's growth and the specific neighborhood. This resulted in certain design criteria, and a target audience to whom social architecture, in the specific context of Honduras, should be aimed. This is exemplified through an architectural proposal, inserted in a hilly terrain, common to many informal communities of the city. The study provides evidence that socially oriented private investment, has served as an excellent catalyst for the development of infrastructure in these communities, providing a starting point for future investigations and management on the subject.

**Keywords:** Urban renewal; community; social architecture; architecture for peace; Honduras; urban acupuncture; violence

**NTU-06**

# Promoting Urban Renewal through the Application of Security Token Offering and Building Information Modeling (BIM)

Hao-Yang Cheng[1] and Po-Han Chen[2]

[1,2]*Department of Civil Engineering, National Taiwan University, Taiwan*
*r07521709@ntu.edu.tw, pohanchen@ntu.edu.tw,*

## Abstract

Feng Shui is part of the inheritance of Chinese culture for thousands of years. Whether people believe it or not, there is no denying that most people hold the idea that "rather believe it to be truth than not." Therefore, a building with better Feng Shui may have a better price. "Luban ruler" is also part of Feng Shui. It is used to measure the dimension details of a building and judge whether the dimensions are good to those living in it. Nowadays, the Luban ruler standard is mainly used in the stage of interior design and decoration. In this paper, using Revit API to develop a plugin tool for Autodesk Revit as a demonstration, dimensions of BIM model components, such as doors, windows, walls, etc., will be automatically modified to meet the Luban ruler standard. It is expected that the developed tool could serve as a handy one for architects in the building design phase, and help reduce the potential cost for Feng-Shui-related dimension changes by the owner.

**Keywords**: BIM; Revit API; Feng Shui; Luban ruler; Design phase.

**NTU-07**

# The Correlation between Job Stress and Heart Rate Variability of Engineers in Engineering Consultant Companies

Tsai-Ning Yang[1], Wei-Cheng Chen[2] and Hui-Ping Tserng[3]

[1,2,3]*Department of Civil Engineering, National Taiwan University, Taiwan*

*r07521702@ntu.edu.tw, bob62563@gmail.com, hptserng@ntu.edu.tw*

## Abstract

In the construction industry, the mental fatigue suffered by the engineers in engineering consultant companies is a considerable issue. They are easily neglected of their mental health among many kinds of workers. The sources of their job stress can be from the bosses, colleagues, working hours, deadlines, and performance, etc. The research subjects are the engineers working in an engineering consultant company, including design, supervision, and other departments. Through the Daily Fatigue Impact Scale (D-FIS) questionnaire, we can collect the subjective stress index of the participants. For the heart rate measurement, Kubios HRV Standard, which is a Heart Rate Variability (HRV) analysis software, can output heart rate variability data. With the previous data collection, we can analyze the correlation between job stress and heart rate variability. It is expected that the research results can be applied to the job stress prediction system for the future study.

**Keywords:** Engineering Consultant Company; Mental Fatigue; Job Stress; Daily Fatigue Impact Scale (D-FIS); Heart Rate Variability (HRV)

**NTU-08**

# Development on Monitoring and Alarm System of Scaffold Collapse

Jing-Xian Lin[1], Guan-Ren Wang[2] and Hui-Ping Tserng[3]

[1,2,3] *Department of Civil Engineering, National Taiwan University, Taiwan*

*r07521703@ntu.edu.tw, r05521704@ntu.edu.tw, hptserng@ntu.edu.tw*

## Abstract

Scaffolds are one of the most commonly used equipment in construction process. While most of the time, the scaffolds are assembled and installed by the worker's experience, and the amount of scaffold is numerous in the construction site, which make it difficult to maintain the quality of each scaffold. In order to keep workers safe on scaffolds, this research working on design a kind of wireless system which base on the ultrasonic sensor, Arduino and Raspberry pi. By monitoring the distance and angle of the scaffold continuously, we hope the alarming system could give workers alert whenever the change of these two values exceed our setting, which could warn workers the scaffold might not be stable right now. Let the workers have time to escape from the scaffold.

**Keywords:** WSN, Scaffold, Monitoring System, Rapsberry Pi, Arduino

**NTU-09**

# Application of PPG Bracelet on Fatigue and Stress Evaluation of Tunnel Construction Using Heart Rate Variability

K.Y.Chen[!], W.C.Chen[2] and H.P.Tseng[3]

*Department of Civil Engineering, NTU, Taipei, Taiwan*

*r06521702@ntu.edu.tw, d03521020@ntu.edu.tw, hptserng@ntu.edu.tw*

## Abstract

The issue of occupational accidents in construction worksite especially for high-risk activities is always a great concern in the civil engineering industry. Accidents result from various factors, and among all the factors, fatigue and stress are the commonest ones. These factors can be detected in both physiological and psychological ways. In this paper, heart rate variability (HRV) analysis is applied, which has been proved as one's representation of the psychological state, utilizing PPG bracelet devices, medical signal analyze software Kubios, and statistical methods. The study included 10 healthy physically active male labors in the construction worksite of a shield tunnel. Time and frequency domain parameters of heart rate variability (HRV) were measured during the three working stages of each workday (morning, lunch break, afternoon). Data on the labors of different work tasks are also concerned. Besides, the influence of noise was considered as well. Other conditions are excluded due to technical limitations. The result shows the variance of HRV parameters between each working stage. According to the result, we can identify the more hazardous tasks and working stages. In this way, we can prevent the potential risk in advance and can reduce occupational accidents eventually.

**Keywords:** Tunnel Construction; HRV; PPG; Kubios

**NTU-10**

# Stability Analysis of Unsaturated Slope Using Random Finite Element and Monte-Carlo Methods

C.H. Hsiao[1], Louis Ge[2]

[1,2]*Department of Civil Engineering, NTU, Taipei 10617, Taiwan*

*r05521112@g.ntu.edu.tw, louisge@ntu.edu.tw*

## Abstract

Factor of Safety (*FS*) has been an essential indicator of geotechnical analysis for decades. In the past, we expected it to point out whether the design was safe. It seems that utilization of *FS* is instinctive and confident. But in the recent years, engineers started considering soil variability and reliability of designs, and reconsidering *FS* as probability of failure, which means *FS* could not reflect uncertainty of in-situ soil and assess designs perfectly. In this study, we are going to use a wide-known finite element software, PLAXIS 2D, and its newly Python scripting to build a 2D random field slope model, which considers the soil variability and spatial correlation length, with rainfall condition. Furthermore, we apply Monte-Carlo method to determine the relation between *FS* and probability of failure.

**Keywords:** reliability analysis; spatial variability and correlation length; PLAXIS 2D.

**NTU-11**

# Large Deformation Analysis for The Failure Process and Post-Failure Behavior of Slopes Subjected to Rainfall

Y.K. Wu[1] and K.H. Yang[2]

[1,2,] *Department of Civil Engineering, National Taiwan University, Taiwan*

*R07521110@ntu.edu.tw, khyang@ntu.edu.tw*

## Abstract

In recent years, due to the global warming effect, the landslide disasters in Taiwan have become more frequent and collapses are the most serious in slope disasters. The finite element method is unable to simulate the large deformation behavior in the geotechnical engineering because it is based on continuum mechanics. Therefore, this study used the material point method (MPM) to simulate the large deformation behavior during and after the slope failure. Specifically, the failure mechanisms, failure process, and the influence area of the failed slope were investigated. The objective of this research is to understand the influence of soil properties and slope conditions of the post-failure behavior. The study is divided into two stages: the first stage of this research is to verify the proposed numerical model using the well-documented landslide case history while the second part is to conduct a series of parametric studies to evaluate the influence of soil properties and slope conditions on the post-behavior of the slope.

**Keywords:** Material point method; Slope failure; Large deformation

**NTU-12**

# Effects of Sand Cushions on the Performances of GRS Wall Subjected to Rainfall

T. L. Tseng[1], H. M. Wu[2] and K. H. Yang[3]

[1,2,3] *Department of Civil Engineering, National Taiwan University, Taipei 106, Taiwan*

*kobe010494@gmail.com, z7275358@gmail.com, khyang@ntu.edu.tw*

## Abstract

Geosynthetic reinforced soil wall (GRS wall) is an ecology engineering and can against the heavy rainfall. Due to the economic consideration that GRS wall usually applies marginal backfill. However, marginal backfill has low permeability that easily accumulate the pore water pressure and decrease the soil shear strength. In this research, adopt sand cushions as a method to prevent the accumulation of pore water pressure and increase the interaction between soil and reinforcement. A series of reduced scale model tests were performed to investigate the performance of GRS wall and the effectiveness of adding sand cushions on enhancing the stability of GRS wall. The wall deformation, pore water pressure and the volumetric water content were observed in the research. The results of the tests showed that sand cushions can accelerate the dissipation of water and effectively improve the wall deformation. Finally, optimal design of sand cushions thickness was evaluated through model test.

**Keywords:** Geosynthetic reinforced soil wall (GRS wall); Model test; Sand cushions; Rainfall

**NTU-13**

# Numerical Simulation of Geosynthetic-Reinforced Soil Foundation Subjected to Faulting

Y.H. Chan[1], J. Chiang [2] and K.H. Yang [3]

[1,2,3] *Department of Civil Engineering, National Taiwan University, Taiwan*

*r07521113@ntu.edu.tw, chiang838@gmail.com, khyang@ntu.edu.tw*

## Abstract

A fault rupture may bring serious structural damages. In order to prevent potential damages, building should not be constructed near fault zone. However, certain linear infrastructure such as highways and tunnels have been inevitably planned across the surface rupture. To mitigate the damages, one possible solution is to use geosynthetic-reinforced soil (GRS) foundations to cross the fault. This study focused on the performance of GRS foundations subjected to fault-induced differential settlement. A series of numerical simulations are conducted in finite element program and validated with physical model tests. The validated numerical model is then used to investigate the mechanism of reinforcement to prevent fault rupture propagation. Afterwards, a serious parameter study is conducted through changing reinforcement parameters which are stiffness, length, location and number of layers to assess the optimal design of GRS foundation.

**Keywords:** Geosynthetic-reinforced soil foundation; Fault rupture; Differential settlement

**NTU-14**

# Seismic Damage Analysis of Pile Foundations Considering Ground Movement

Y.W. Fu[1]and J.S. Chiou[2]

[1,2]*Department of Civil Engineering, NTU, Taipei 10617, Taiwan*

*waynefu1996@gmail.com, jschiou@ntu.edu.tw*

## Abstract

Pile foundations are deeply buried in the ground. When subjected to seismic loading, they may sustain the inertial force from the supper structure as well as the kinematic ground movement. This study uses dynamic analysis to investigate the damage of pile foundations caused by inertial forces and ground movement effects during earthquakes. The analysis model adopted in this study is modified from Lee (2018). It combines a ground response analysis model and a structure-pile-soil interaction model. Besides, plastic hinges are set in the pile elements to simulate the nonlinear flexural response of the pile. Through a series of parameter analyses, effects of ground motions of different characteristics and intensities, and effects of ground movement and inertial force on development of plastic zones in the pile are explored.

**Keywords:** Structure-pile-soil interaction; Kinematic ground movement; Inertial force; Plastic hinge.

**NTU-15**

# Determination of nonlinear dynamic properties of sand from centrifuge shaking table testing

C.L. Chen[1] and J.S. Chiou[2]

[1,2]*Dpartment of Civil Engineering, NTU Taipei 10617, Taiwan*

*b03202035@ntu.edu.tw, jschiou@ntu.edu.tw*

## Abstract

The dynamic properties of soil are essential to influence ground responses under seismic loading. Laboratory tests, centrifuge shaking table testing, lg shaking table testing, or seismic downhole arrays can be performed to investigate the dynamic characteristics of soil. Many approaches have been proposed to retrieve the dynamic soil properties based on measured ground accelerations. Most of them focus on linear properties, or on shear modulus degradation curves along with damping ratio curves for frequency domain analysis. However, procedure to build nonlinear shear stress-strain relationship for time-domain analysis has not been well developed. In this study, we propose a method to utilize the ground accelerations measured from centrifuge shaking table tests on sand to establish the maximum shear modulus profile and the shear stress-strain curve in terms of a hyperbolic function. With the deduced dynamic properties, a series of time-domain ground response analysis results show good agreement with the measured acceleration responses.

**Keywords:** Centrifuge tests; Shaking table tests; Ground response analysis; Nonlinear soil dynamic properties.

**NTU-16**

# Representative Elements Volume of Hydraulic Conductivity of Fractured Rock Mass

Chia-Min Tsao[1], Tai-Tien Wang[2]

[1,2] *Department of Civil Engineering, National Taiwan University, Taiwan*

*r07521120@ntu.edu.tw, ttwang@ntu.edu.tw*

## Abstract

The intricate discontinuous surface leads to the heterogeneity and anisotropy of the hydraulic characteristics of the fractured rock mass. Current hydrogeological test can only obtain the equivalent hydraulic parameters of the rock mass, and it differs from the analytical solutions suggested by Snow (1969) and Oda (1985) by several orders of magnitude or more. This study is validated by the Nantou Heshe well site, and the parameter characterization technique is established to effectively determine the statistically significant permeability parameters. Comparing the degree of variation after the error propagation formula and the results of in-situ multi-scale hydrogeological test, the representative elements volume of the site can be determined. In the future, the effects of different in-situ stress on the spatial distribution of the fractures will be considered, and permeability tensor of the rock mass can be estimated.

**Keywords:** Permeability tensor; Scale effect; Joint roughness coefficient; Representative element volume

**NTU-17**

# Lining Crack Patterns Corresponding with 3D Displacements for Rock Tunnels in Operation Revealed by Numerical Simulation

Yi-Chen Li[1], Tai-Tien Wang[2], Ya-Chu Chiu[3], Shin-Ting Huang[4]

[1,2,3,4]Department of Civil Engineering, National TAIWAN University, Taipei, Taiwan
r07521115@ntu.edu.tw, ttwang@ntu.edu.tw, r03521133@ntu.edu.tw, clarice.chiou@gmail.com

## Abstract

Tunnel is limited by underground space and belongs to highly statically indeterminate structure so the mechanical behavior is quite complicated. In case of long-term operation, many lining anomalies are often developed. Lining crack is the highest proportion in all kinds of lining anomalies. The occurrence of lining cracks indicate that the external force has exceeded the allowable strength of the material. Analyzing tunnel displacement is a conventional and effective approach for diagnosing possible causes of structural anomalies. The lining crack development and evolution are important indicators for diagnosing the integrity of tunnels. The lining image, tunnel section displacement monitoring data and the stress increment by numerical simulation are presented on the lining crack diagnosis platform. Thus, the relationship between the development of lining cracks and physical mechanics in the tunnel will be established.

**Keywords:** Tunnel in operation; Lining crack; Numerical simulation; Crack diagnosis platform

**NTU-18**

# Predicting Natural Frequency of Piled Raft Foundation by Finite Element Method

M.Y. Yang[1], Louis Ge[2]

[1,2]*Department of Civil Engineering, NTU, Taipei 10617, Taiwan*
*R06521121@.ntu.edu.tw, louisge@ntu.edu.tw*

## Abstract

Piled raft foundation combines pile foundation and raft foundation to reduce the differential settlement and the large settlement on the soft soil, which can be used as the foundation of superstructures and offshore wind turbines. However, foundation is subjected to seismic loading and frequency is close to the nature frequency, the effect of resonance occurs. The resonance effect makes the foundation settlement greater than allowable value. In this study, PLAXIS 3D is used to find out the natural frequency with different variables with three kinds of method. In addition, the results from finite element software will also compare with those from analytical solution.

**Keywords:** piled raft foundation; natural frequency; numerical modelling and analysis

**NTU-19**

# Investigation of Post Cyclic Behavior of Sands under the Framework of Binary Packing

Y.H. Yang[1], Y.R. Li[2], M.C. Chu[3], Louis Ge[4]

[1,2,3,4]*Department of Civil Engineering, National Taiwan University, Taiwan*
*r07521107@.ntu.edu.tw, r06521104@.ntu.edu.tw, d05521005@ntu.edu.tw, louisge@ntu.edu.tw*

## Abstract

Disasters along with liquefaction occur. Earthquakes may decrease the soil strength and make buildings tilted or cause ground settlement. In-situ soils are composed of various sizes and different types of soils. The fabric may change the behavior of the mixtures. Therefore, the research employed the framework of binary packing to observe the post-cyclic behavior of the granular mixtures. This study adopts different proportions of non-plastic fine sands by weight.By series of triaxial tests, the post-cyclic behaviors were evaluated. . The results point out different proportions of fine sands during the cyclic loading test lead to different reduction factor in soil strength. Based on previous experimental results from the triaxial tests, the verified reduction factor of soil strength in proposed framework will be applied to predict the reduced strength of in-situ soils.
**Keywords**: non-plastic soil, fine sand proportion, post-cyclic behavior, binary packing

**NTU-20**

# Effects of Fines Content on the Mechanical Properties of Binary Mixtures

Y. H. Lin[1], Y. H. Yeh[2], Y. S. Jhuo[3] and Louis Ge[4]

[1,2,3,4] *Department of Civil and Environmental Engineering, Taipei, Taiwan*
*r07521108@ntu.edu.tw, r05521127@ntu.edu.tw, ymca0777@gmail.com, louisge@ntu.edu.tw*

## Abstract

In the past, the mechanical properties of single size soil particles had been completely investigated. However, in the reality, in-situ soils are composed by multiple sizes and different types of particles. The arrangement of particles in the soil and its behavior may be quite complicated. The issues of soil packings for soil mixtures have been puzzled for decades. Hence, plenty of studies have been done to investigate on binary or ternary packings. In this paper, Vietnam silica sands mixtures constituted at different fines content ranging from 0 to 100% are used, and a series of one-dimensional consolidation tests and resonant column tests are conducted to observe the effects of fines content on compression characteristics and dynamic characteristics. It is expected to establish a comprehensive correlation between fines content and mechanical properties of binary mixtures.
**Keywords:** Fines content; Binary mixtures; One-dimensional consolidation tests; Resonant column tests.

**NTU-21**

# IStability Analysis of Jointed Rock Masses Influenced by Rock Joint Geometrical Properties

Yu-Hsuan Chang, Shao-Ru Lin and Ming-Lang Lin

*Department of Civil Engineering,National Taiwan University, Taipei, Taiwan*
*coco8527gogo@gmail.com*

## Abstract
Bridge Minbaklu which is located in the southern of Taiwan is the main road for local people. During the heavy rainfall, the slope near the bridge has high potential to happen failure. The discontinuities dominate the geomechanical behavior on the slope. The photogrammetric techniques and 3D point cloud analysis are carried out in this study to identify the dominant joints sets on a rock slope. Basing on scanline and window sampling, the spacing and the persistence of the joints can be acquired. 3DEC (3 Dimension Distinct Element Code) is also used in the study to construct a 3D slope model with fracture network. The kinematic and dynamic behavior on the rock slope can be evaluated. Different geometrical properties of the joint such as orientation, spacing and persistence may lead to different failure mode. Joints having high persistence and small spacing lead to large-scale landslide with numerous falling blocks; and joints having low persistence and big spacing caused rockfall with huge volume. It is believed that the study can enhance the way for stability analysis of complex fractured rock slopes.
**Keywords**: Fracture network; Persistence; Spacing; Slope stability

**NTU-22**

# Raft Foundation Structural Deformation Characteristics Induced by the Normal Fault: Investigations Based on Numerical Model

Ru-ya Fang[1], Chien-Hui Hung[2], Chun-Yuan Liu[3], Chien-Hung Li[4], and Ming-Lang Lin[5]

[1,2,3,4,5]*Department of Civil Engineering,National Taiwan University, Taipei, Taiwan*
*r08521111@ntu.edu.tw, r07521106@ntu.edu.tw,r06521103@ntu.edu.tw,*
*d04521001@ntu.edu.tw mlin@ntu.edu.tw*

## Abstract
Besides the inertial force of the strong ground motion, another main reason why the near-fault structure is damaged by the earthquake is that, the deformation of the overburden soil interacted with foundation caused by the displacement of the bedrock faulting. The Sanchiao Faults which is a normal fault pass through the western margin of the Taipei Basin where is densely populated. The are many high-rise buildings with raft foundation on the fault. Therefore, it is necessary to explore the deformation of the overburden soil and the deformation behavior of the underground structure induced by normal faulting.
In the past, the discrete element method ($PFC^{3D}$) was rarely used to investigate the deformation behavior of raft foundation structures with basement subjected to normal faulting. It can be located close to the overburden soil deformation during the growth of normal faults. At the same time, the deformation and fracture of the foundation structure can be observed. In this paper, different locations of the fault tip on the raft foundation with basement are considered. Foundation structural deformation characteristics affected by the normal fault along with the slight left shift component are discussed. Results show that the raft foundation located in the triangular shear zone of the overburden soil in addition to displacement, rotation and inclination, also has a large deformation amount. If the building cannot avoid located within the fault triangular shear zone, it should be as far away from the fault fracture as possible.
**Keywords:** raft foundation; deformation; normal fault; numerical analysis; discrete element method

**NTU-23**

# Experimental Investigation of Soil Behavior of Partially Saturated Penghu Calcareous Sand

Jia-Ren Liu[1] and On-Lei Annie Kwok[2]

[1,2] *Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*

*r07521122@ntu.edu.tw, annieonleikwok@ntu.edu.tw*

## Abstract

Calcareous sand is composed of calcium carbonate, and is fragile compared to common quartz/silica sand. Calcareous sand has high void ratio and angular particle shape. They can be found in offshore and coastal area. In this study, soil behavior of partially saturated Penghu calcareous sand is investigated through laboratory testing. More specifically, the soil water characteristic curve is determined by using the flow pump method. In addition, a series of consolidated-undrained triaxial compression (CIUC) test is used to determine the critical state behavior of the partially saturated Penghu sand. The experimental results are then compared to those for silica sands.

**Keywords:** Calcareous sand; Partially saturated soil; Flow pump method; CIUC test.

**NTU-24**

# A Global Database for Deep Excavation and Wall Deformation

Shih-Hsiang Yuan[1] and Jian-Ye Ching[2]

[1,2] *Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*

*r07521116@ntu.edu.tw, jyching@ntu.edu.tw*

## Abstract

This paper demonstrates a database of deep excavation case history. It contains plenty of excavations cases worldwide, where excavation geometry and sequence, soil profiles and properties, wall stiffness and deformations, etc. are known. We will inspect the information about the database we constructed to see if there is any correlation between each parameter, e.g., if the excavation width is larger, there will be a large wall deformation, and therefore we can confirm that the excavation width and wall deformation have strong positive correlation. Subsequently, we will compare the database with some empirical formulas, to see which ones are more accurate. The comparison will be illustrated in the following part.

**Keywords:** deep excavation; correlation; wall stiffness.

**NTU-25**

# Site Response at the Vertical Arrays in the Taiwan Surface-Downhole Monitoring Network

Chun-Chieh Yao[1] and On-Lei Annie Kwok [2]

[1,2] *Department of Civil Engineering, National Taiwan University, Taiwan*
*r07521128@ntu.edu.tw, annieonleikwok@ntu.edu.tw*

## Abstract

In recent years, the Central Weather Bureau in Taiwan has constructed and maintained the Surface-Downhole Monitoring Network which contains several dozens of vertical array stations. In this study, we investigate the site response characteristics at selected vertical arrays. Using weak motions, we evaluate whether the one-dimensional wave propagation assumption is valid at the vertical arrays. In addition, we explore if there are any differences in the surface and downhole horizontal-to-vertical H/V spectral ratios and identify the factors that would lead to such differences.

**Keywords:** Taiwan Surface-Downhole Monitoring Network, Site Response, Vertical array

**NTU-26**

# Pile analysis based on cone penetration tests considering spatial variability and model uncertainty

Mohammad Tabarroki and Jianye Ching

*Department of Civil Engineering, National Taiwan University, Taiwan*
*{tabarroki, jyching}@gmail.com*

## Abstract

One of the common methods for predicting pile capacity is to base it on data from cone penetration test (CPT) results. This predicted capacity deviates from the measured one given the presence of several sources of uncertainties. This poses a challenge in the decision-making process for pile design. The present paper considers two sources of uncertainties, i.e., spatial variability and model uncertainty. The former is due to the point to point variation of CPT data. The latter is due to the empirical correlative relationships between CPT data and pile capacity. These uncertainties are then incorporated into the analysis of two full-scale piles from the Bolivian Experimental Site for Testing Piles (B.E.S.T). The results demonstrate the merits of dealing with uncertainties in a rational way and help with decision-making.

**Keywords:** Pile capacity; CPT; Spatial variability; Model uncertainty

**NTU-27**

# A Re-identification System for Multi-Target, Multi-Camera Tracking of Building Occupants

S.H. Hsu, T.H. Lin, T.Y. Dai and S.H. Hsieh

*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
*b02501030@gmail.com, zihaolin@caece.net, kevin860500@gmail.com, shhsieh@ntu.edu.tw*

## Abstract

Due to the climate change impact, sustainable development has become a popular issue in recent years. Since it is reported that 40 percent of total energy is consumed by buildings, there is a significant need to avoid waste of energy caused by inappropriate human control on devices like air conditioning and lighting. Increasing researches on building management have tried to improve automatic control strategy for electrical equipment through occupancy detection. According to the occupancy information, the building manager can not only determine the operation time of HVAC (Heating, Ventilation, and Air Conditioning) but also predict the occupancy changes for early responses. Due to the high availability of cameras in the building surveillance system, they are often used for occupancy detection. However, most applications are limited to occupancy detection in an individual room or a public space and few researches are on tracking of occupants in building level for providing global views of occupants' activities in the building to help achieving better overall building energy efficiency.

This paper reports a research effort on implementing a re-identification system for multi-target, multi-camera tracking with surveillance cameras to obtain building level occupancy data. Although tracking with deep learning techniques has shown good performance, the development of the techniques is so fast that there are rarely concerning studies aiming to validate them in practice. As a result, this research proposes and implements a distributed re-identification system for tracking occupants cross non-overlapping cameras and then examines its ability to collect building level occupancy data.

Firstly, multiple object tracking is performed under each camera and the probe images of occupants provide appearance and location information. Secondly, appearance descriptors for different identities are extracted from the images by the convolutional neural network and are further used to concatenate trajectory data from different cameras. Finally, from tracking building occupants, we can acquire the building level information about when occupants entered or left an area, how long they stayed inside a room and the interrelationships between different monitoring areas can be acquired. With the information, the building manager can not only validate and revise the energy saving strategy but also enhance public safety and better respond to emergency conditions.

**Keywords:** Computer vision; Deep learning; Multi-target, multi-camera tracking; Occupancy detection; Building management

**NTU-28**

# Numerical Modeling of Surface Waves Triggered by Bottom Disturbances

H.-E. Wang[1] and I-C. Chan[2]

*Department of Civil Engineering, National Taiwan University, Taipei 10617, Taiwan*
*r06521309@g.ntu.edu.tw, ichichan@ntu.edu.tw*

## Abstract

Ocean surface waves are caused by energy passing through the ocean water. Depending on the source of the energy, there are three main types of ocean waves, namely the wind-driven waves, the tides generated by the moon's gravitational pull, and the tsunami waves triggered by abrupt disturbances. Here we study numerically the surface waves generated by a bottom disturbance, which can be viewed as a simplified model for describing the generation and propagation of common oceanic tsunamis. A numerical model based on the Reynolds-averaged Navier-Stokes equations (RANS) is employed to study both the near-field and far-field waves resulting from either a uniform bottom displacement of a tilting seafloor. We focus on the wavelength, the wave period, and the wave height associated with the waves generated by the designed abrupt bottom motion. The relationship among the size of the disturbance and these wave characteristics will be analyzed.

**Keywords:** Surface wave; Bottom disturbances; RANS

**NTU-29**

# Influence of Group Composition on Group Dynamics in a Transdisciplinary Project-based Course

Y. H. Pan[1], S. H. Hsieh[2], M. M. Song[3], S. Y. Lai[4], T. S. Chang[5]

[1,2]*Department of Civil and Environmental Engineering, NTU, Taipei, Taiwan [3]Stanley Wang D-School, NTU, Taipei, Taiwan [4]Graduate Institute of Building and Planning, NTU, Taipei, Taiwan [5]Department of Education and Human Potentials Development, NDHU, Hualien, Taiwan hannahpan@caece.net, shhsieh@ntu.edu.tw, meimeifutures@gmail.com, luasuyao@gmail.com, achang@gms.ndhu.edu.tw*

## Abstract

The research reported in this paper is based on the study of a transdisciplinary project-based course titled "Innovative Social Design Engineering" at the Stanley Wang D-School@NTU, available for the students from all disciplines, in the spring of 2019. The offering of the course is part of the effort in a three-year integrated project titled "Transdisciplinary Engineering Education for Creativity" since December 2016. The course had been re-designed on the basis of the previous curriculum experiences, including nine workshops and the same course offered in the spring of 2018. For example, there were two weekend workshops, "Design for the Future" and "Participatory Design", integrated into the Spring 2019 curriculum. In addition, students were asked to present their final projects to the community at the end of the course. In the course, students were divided into groups according to discipline, gender, grade, and observed learning attitude so that each group composition was made as similar as possible. Group dynamics occurs when group members interact. It was found that the way the group faced the conflicts inside and criticism from outside of the group was usually determined by the attitude of the group members, which may also influence the cohesion of the group. Strong cohesion could bring positive effect to group communication and collaboration.

**Keywords**: Group composition; Group dynamics; Group communication; Group collaboration; Transdisciplinary project-based course.

**NTU-30**

# Consumer Behaviors in Certified Green Buildings -An Empirical Study

W.C. Hsu[1], S.C. Wen[2] and S.P. Ho[3]

[1,2,3] *Department of Civil Engineering, NTU, Taiwan*
*d07521003@ntu.edu.tw, d06521012@ntu.edu.tw, spingho@ntu.edu.tw*

## Abstract

Globally, green buildings (GBs) are receiving more and more attentions and being considered a major strategy for the goal of sustainable development. Although the importance of GBs has been recognized by many governments, evidence shows that real estate developers are still reluctant to develop certified green houses. In other words, in spite of governments' long years' efforts in promoting GBs, the developers do not perceive that housing buyers are willing to pay for the green premium of certified GBs. We argue that the failure of promoting GBs in housing market is mainly because of the lack of knowledge on the consumers' behaviors in certified GBs. Therefore, this study aims to study what factors motivate the housing buyers to consider buying a certified green building and to propose suitable strategies for governments in further promoting GBs in housing markets. In this study, we study the consumer behaviors of Taiwanese because the certification of GB has promoted around 20 years, we can't observe the result in the housing market in Taiwan obviously. An empirical study was conducted with 472 responses from Taiwanese to test the proposed hypotheses on the factors that may affect the housing buyers' willingness to purchase a certified green house. The result of econometric analysis confirmed the importance of many hypothesized factors, including age, income, environmental awareness, knowledge of GBs, perceived personal benefits from GBs, and the perceiving of GBs as an honor. And, different result response in 2% of extra cost and 5% of extra cost. Then, by combining the results from the empirical study and literature review, a series of strategies are proposed for promoting green buildings.

**Keywords:** Green buildings, consumer's behaviors, Taiwan, econometric analysis

**NTU-31**

# Crossing the Line: Interdisciplinary Learning for Engineering Students

M.M. Song[1], S.H. Hsieh[2], and S.Y. Lai[3]

[1]*Stanley Wang D-School, National Taiwan University, Taipei 10617, Taiwan*
[2] *Department of Civil Engineering, National Taiwan University, Taipei 10617, Taiwan*
[3]*Graduate Institute of Building and Planning, National Taiwan University, Taipei 10617, Taiwan*
*meimeifutures@gmail.com, shhsieh@ntu.edu.tw, luasuyao@gmail.com*

## Abstract
As the complexity of the world around us increases, how to cultivate engineering students that can not only *solve problems* but also *solve wicked problems* is gaining more and more significant attention in engineering education. One way to achieve this objective is to engage engineering students in classrooms with students outside the field of engineering so that they can be more accustomed to understanding issues from different perspectives and thinking outside the box. This paper discusses the prospect of interdisciplinary curriculum for engineering students based on the authors' 2-year experience with a course, titled "Innovative Social Design Engineering." The curriculum design of the course stemmed from 6 year's cooperation among faculty of different disciplines—namely, Futures Studies, Civil Engineering, and Architectural Design. The course was offered at D-School@NTU (the virtual school at National Taiwan University that allows students from all academic background to take credit courses) in 2018 and 2019 and attempted to experiment with the mixture of engineering vs. non-engineering students in the coursework. Preliminary findings derived from student interviews, teacher reflection, and classroom observation with regard to students' academic background (engineering vs. non-engineering) are reported, including students' demonstrated behaviors and self-reported perspectives. Benefits and challenges of such course design are also discussed.
**Keywords:** STEAM; Interdisciplinary Education; Engineering Education.

**NTU-33**

# A Framework for Integrated Energy-Efficient Building Design

T.A. Phan[1], Y.C. Chan[2]

[1,2] *Department of Civil Engineering, NTU, Taipei 10617, Taiwan*
*r06521723@ntu.edu.tw, ychan@ntu.edu.tw,*

## Abstract
The integrated energy-efficient building design has become an appropriate trend for environmentally friendly buildings, contributing to building a sustainable living environment for users. While there are several stages from schematic design - concept - basic - technical - execution design and commissioning to hand over in the construction process, the best stages for architects to apply the design options regarding energy efficiency for buildings without increasing the investment cost of the project are the schematic, concept and basic design stages. However, the integration between stages, software and tools used for modeling architectural form is limited. Meanwhile energy efficiency isn't the only aspect, the ultimate goal for architects is to create high-quality products not only in architectural, environmental but also other relevant issues such as optimizing the design process, time and budget. They need a clear guideline and framework for applying passive design strategies and how to carry the project from one stage to another. Currently, there is not any software which fits all of the requirements above. As a result, many consulting companies have difficulties in selecting software to apply the integrated energy efficient building design process for their projects. This research demonstrated a framework of design workflow which provides answers to the given problem based on the process optimization criteria by converting interaction models between software and in three design phases: schematic, concept and basic design.

Following steps have been conducted for doing this research: Literature Review, survey, testing, comparison of results, and conclusion, namely: 1 Identify the important indicators based on climate and microclimate conditions for each stage of the three project design phases. 2 Identify some design solutions correspond to each indicator. 3 Provide a list of techniques and simulation tools with pros and cons and its portability. 4 Provide a list of the design workflow which used for the case study. 5 Case studies demonstration.

This paper suggested the workflow in corresponding to design phases based on the model compatibility criteria when switching between phases or between software. A list of techniques and simulation tools with pros and cons and its portability also be provided together with a list for designing indicators and demonstration of suggested design workflow with a demonstration buildings study.
**Keywords:** Integrated design framework; Passive design; Façade; Building Energy Simulation Software

**NTU-34**

# A low-cost freeway data collection system based on photogrammetric and positioning techniques

Y.T. Lin[1], J.Y. Han[2], J.F. Kang[3], Y.H. Cheng[4], T.T. Yang[5], C.Y. Tsai[6], N. Lee[7] and H.C. Cheng[8]

[1,2]*Department of Civil Engineering, National Taiwan University, Taipei 10617, Taiwan*
[3,5]*Freeway Bureau, MOTC, New Taipei 24303, Taiwan*
[4,6,8]*Integrated Engineering Evaluations, Corp., Taipei 11491, Taiwan*
[7] *Northern Region Branch Office, Freeway Bureau, MOTC, Taipei 11467, Taiwan*

## Abstract

Freeways connect states, cities, and various transport hubs, and they are also closely related to transportation convenience and national economy, wherefore the maintenance of freeways is always a crucial concern to governmental sectors. Effective freeway maintenance depends on a complete facility database. Light detection and ranging (LiDAR), the latest road scanning technique, could help acquire the freeway geometric data, but it is expensive and can increase the complexity of the analysis process due to a large amount of point cloud survey data. In this study, a vehicle-borne system for road pavement mapping and analysis will be developed with an emphasis on its low-cost and efficiency. By incorporating the latest dual-camera photogrammetric technologies and integrated positioning techniques, the integrated system is appointed for both road pavement width acquisition and dynamic positioning. The research showed that the error of road width measurement system was less than 50 cm, and the precision of integrated positioning was better than 10 m. Notably, the obtained freeway geometric data is sufficiently qualified for meeting the requirement of maintaining transportation facilities. Consequently, this approach provides a reliable and low-cost mapping investigation for Freeway Bureau of Taiwan.

**Keywords:** Freeway survey; photogrammetry; integrated positioning technology; road width measurement

**NTU-35**

# A Study on Hysteresis Modeling of Reinforced Concrete Columns

Y.C. Ling[1] and S.J. Hwang[2]

[1,2]*Department of Civil Engineering, NTU, Taipei 10617, Taiwan*
*R06521209@ntu.du.tw, sjhwang@ntu.edu.tw*

## Abstract

Accoding to seismic design code of buildings, non-linear time history analysis is required for seismic assessment of mid-to-high-rise buildings. The analysis must accurately reflect structural members' non-linear behaviors such as yielding strength, failure mechanism and hysteretic behavior. Columns as the major structural members in the lateral load-resisting systems. Hence, the hysteresis behavior prediction of columns is extremely importance in seismic design.

In this study, a hysteretic model of columns and its model parameters' formulas had been proposed based on the Pivot Hysteretic Model. A database of column specimens subject to cyclic loading has been collected from literature for the model optimization. The model optimization method was executed base on energy dissipation. Simulated annealing algorithm was used to calibrate the response with experimental results and to identify model parameters. Simultaneously, the relationship between the structural characteristics and model parameters was resolved by regression analysis, hypothesis testing and simulated annealing algorithm. The analytical results based on proposed model formulas can accurately reflect hysteretic behavior of columns such as unloading behavior and pinching effect in flexure failure mode.

**Keywords:** reinforced concrete column; hysteretic behavior; Pivot model; simulated annealing; pinching effect

**NTU-36**

# Development of Nano-Fluid Viscous Damper

S.K. Peng[1] and K.C. Chang[2]

[1,2]*Department of Civil and Environmental Engineering, NTU, Taiwan*
*d06521006@ntu.edu.tw, ciekuo@ntu.edu.tw*

## Abstract

Taiwan, located on the Pacific Rim seismic belt, frequently experiences earthquakes; hence structures should be not only designed with the consideration of earthquake hazard, but also remain functional after earthquakes. Therefore, passive or semi-active control systems have been developed and are being widely used. Viscous dampers are widely utilized in buildings, bridges and structures as a passive damping energy dissipating elements. However, the dampers on the market adjust their mechanical behaviors through altering physical geometry, which often entails high-cost production and modification in both the developmental and manufacturing phases. Furthermore, these dampers cannot be customized. Thus engineers will be limited by the fixed damper size during structural design. This study is dedicated to the development of a passive-type nano-fluid viscous damper, which is a simple physical mechanism and only requires a suitable compound ratio of the nano-fluids to achieve the purposes of controlling the damping coefficient C and non-linear coefficient α. Nano-fluid viscous dampers have three main advantages: First, due to uncomplicated physical geometry, the production cost is relatively low. It is also needless to produce new dampers for calibration after testing, just to replace the internal filling of the damper, which may save on considerable R & D funding. Second, according to the characteristics of variable viscosity of the nano-fluid, it enable nano-fluid viscous dampers with two kinds of α value, matching $\alpha>1$ and $\alpha<1$ performance under small and large velocity respectively. If designed properly, the damper may ameliorate the existing bridge damper oil seal wear caused by daily temperature difference and vehicle vibration. Furthermore, the damper enhances isolation system performance during small earthquakes. Last, through the establishment of a full range nano-fluid database, the manufacturer can produce customized dampers in the future, and consequently meet the engineers' design, which can improve the accuracy and security of the structure.

**Keywords:** Non-Newtonian fluid; Nano-fluid; Rheology; Viscous Damper.

**NTU-37**

# Design and Analysis of Piezoelectric Tuned Mass Damper for Taipei 101

Y.W. Ho[1], Y.A. Lai[2] and L.L. Chung[3]

[1,3]*Department of Civil Engineering, NTU, Taipei, Taiwan*
[2]*Department of Civil Engineering, NCU, Taoyuan, Taiwan*
[3]*National Center for Research on Earthquake Engineering, Taipei, Taiwan*
[3]*Department of Civil Engineering, NCKU, Tainan, Taiwan*
*R06521256@ntu.edu.tw, r98521211@ntu.edu.tw, chung@ncree.narl.org.tw*

## Abstract

Tuned mass damper (TMD) is an effective system to reduce the vibration of structures under wind load. While conventional tuned mass damper dissipates vibration energy by dampers, a new type of tuned mass damper, piezoelectric tuned mass damper (Piezo-TMD), is developed to convert structural vibration energy to electricity by a piezoelectric material device. Equation of motion of Piezo-TMD mounted on SDOF structure is derived. Taipei 101 is simplified to be a single-degree-of-freedom structure and further implemented with a Piezo-TMD. The structural system is analyzed when subjected to the design wind forces. The simulation results show that the Piezo-TMD can achieve the same performance as the conventional TMD in structural vibration reduction and turn the absorbed energy into power for reuse. Optimal design procedure of Piezo-TMD for maximal energy harvesting is applied to design for Taipei 101.

**Keywords:** Tuned mass damper; Piezoelectric material; Taipei 101; Energy harvesting.

**NTU-38**

# Experimental Investigation on Isolated Strut Behavior of High Strength Steel Fiber Reinforced Concrete Panels

C.C. Kuo[1], C.W. Hung[2*] and W.C. Liao[3]

[1,2,3]*Department of Civil Engineering, National Taiwan University, Taipei 10617, Taiwan*
*R06521229@ntu.edu.tw, R07521220@ntu.edu.tw, wcliao@ntu.edu.tw*

## Abstract

High strength steel fiber reinforced concrete (SFRC) has been regarded as a progressive concrete material for its enhanced tensile strength and toughness. In the past few years, SFRC is expected to replace certain amount of transverse reinforcement for better construction workability; however, the mechanical properties of SFRC in discontinuity region have not been verified clearly yet. In this study, a series of SFRC panel experiments conducted to verify the contribution of steel fiber for the isolated strut behavior. The result shows that the addition of steel fiber can reduce the angle of resulting force, which leads to a larger effective tie area. In the specimen with 0.75% and 1.5% volume fraction of steel fiber, the effective tie area can raise up to 40% and 50%, respectively. The presence of steel fiber in high strength concrete could indeed improve the strut behavior in discontinuity region.

**Keywords:** Steel fiber; Panels; High strength concrete; Strut-and-tie.

**NTU-39**

# Experimental Investigation for Corrosion Current Density of Corroded Steel Rebars with Different Corrosion Degrees in Different Media

K.C. Lin[1], M.L. Wu[2] and W.C. Liao[3]

[1,2,3]*Department of Civil Engineering, NTU, Taipei, Taiwan*
*r06521235@ntu.edu.tw, r07521240@ntu.edu.tw, wcliao@ntu.edu.tw*

## Abstract

Reinforced concrete is often used in building structures nowadays. Since corrosiveness of steel bars would reduce the seismic capacity and the reduction of steel bar's performance is mainly measured by the weight loss ratio of steel bars in the seismic evaluation, it is important to obtain the weight loss ratio of steel bars efficiently and accurately. Furthermore, the theoretical weight loss ratio of steel bars can be calculated by Faraday's law after measuring corrosion current density, so the factor affecting measurements of corrosion current density will affect the theoretical weight loss ratio of steel bars indirectly, and then impact on seismic evaluation.

First of all, this experiment changed the resistance of the concretes with different water-cement ratio and adding different concentrations of chloride ion, then simulated severe corrosiveness of the steel bars by using electrical corrosion method to make steel bars achieve larger weight loss ratio, and furthermore mounted the steel bars into the concretes with different mixture proportioning and Melamine Sponges. In this phase, three different instruments Gecor 8, GalvaPulse and AutoLab, are used to constantly measure the corrosion current and Wenner Four Electrodes are applied to trace the developments of concrete resistance. Finally, integrating the relationship between time and the concrete's corrosion current to obtain the theoretical weight loss ratio, and moreover verify applicability of Faraday's law of the three corrosion current instruments.

The preliminary results of this experiment indicate that different water-cement ratio and amounts of chloride ion have no effect on the resistance of the concretes when the concrete age is short, and however, need sufficient time to make a difference on the resistance of the concretes; and that corrosion current density is mainly controlled by concentrations of chloride ion before passivation film is destructed, however, concrete resistance will affect the difficulty of external substances invading surfaces of steel bars and then effect on the magnitude of corrosion current density after passivation film is destructed; and that the trend of corrosion current density in different corrosiveness of reinforce concretes is similar and the initial corrosion current density is not obviously related to the weight loss ratio.

The results of measurement have not obtained the steady corrosion current density values in the late stage until now. It needs to constantly measure the corrosion current density and concrete resistances, observe the development trend of steady values in the late stage, and verify the preliminary experimental results.

**Keywords:** Electrical corrosion method; Corrosion; Corrosion current density; Chloride ion; Concrete resistance; Weight loss ratio of steel bars; Faraday's law

**NTU-40**

# Development of Shrinkage and Creep Formula in Taiwan Based on Database Analysis

W.Y Chin[1], H.C Huang[2] and W.C. Liao[3]

[1,2,3]*Department of Civil Engineering, NTU, Taipei, Taiwan*
*r04521236@ntu.edu.tw, r07521237@ntu.edu.tw, wcliao@ntu.edu.tw*

## Abstract

Concerning safety and long-term serviceability of concrete structures, strength, deformation and durability must to be taken into consideration in design. However, except strength, effect of concrete deformations, including shrinkage and creep, on service life and serviceability of concrete structures are rarely involved. More recently, concrete deformation databases have been established in the US, Europe, Japan, and Taiwan. The purpose of such databases is twofold: first, to provide a reference and design tool for researchers and engineers; second, to facilitate the development of prediction models for deformation in localized concrete. This study presents a new processing method for the use of concrete deformation databases of code development purpose in Taiwan. Moreover, for the purposes of efficiently mining and analyzing huge sets of data and placing the database on the Cloud in the future, this study selected MSSQL, a Database
Management System (DBMS), to establish the database, and selected Python to establish the analysis program. It can enhance the efficiency of research of concrete around the world and can also benefit the establishment of codes or design of structures no matter the country or region.

**Keywords**: Concrete, database, Shrinkage, Creep.

**NTU-41**

# Piezoelectric Tuned Mass Damper Designed for Footbridges

Y.F. Deng[1], L.L. Chung[2]

[1,2]*Department of Civil Engineering, NTU, Taipei, Taiwan*

[2]*National Center for Research on Earthquake Engineering, Taipei, Taiwan*

[2]*Department of Civil Engineering, NCKU, Tainan, Taiwan*

*jamiedeng3922@gmail.com, chung@ncree.narl.org.tw*

## Abstract

An aesthetic appearance and a design that blends in well with the environment are some important considerations when designing footbridges. Nowadays, footbridges are often designed to be lightweight long span structures, which causes low-vibrational frequency and lowly-damped behavior. Pedestrian load is the main factor that causes the footbridge to vibrate. The resonant phenomenon appears when the frequency of the structure falls in the region of the frequencies of the pedestrian load. Adding tuned mass damper (TMD) on the structure is a common and effective way to reduce the vibration while remaining the aforementioned appearance of the footbridge. Although conventional TMD can effectively reduce the vibration, the vibrational energy is dissipated. We hope to utilize the vibration energy instead of wasting it in the damping process. To solve this problem, a new type of tuned mass damper, piezoelectric tuned mass damper (Piezo-TMD) is proposed, which converts the structural vibrational energy to electricity. In this article, we'll take as an example the Da-Yuan bridge at Dharma Drum Institute of Liberal Arts located in New Taipei City. In our simulation, the Da-Yuan bridge is simplified as a structure with single degree of freedom and implements the Piezo-TMD. The time history simulation results show that the Piezo-TMD can achieve vibration comfort of the footbridge and harvest more than a half of the structural vibration energy.

**Keywords:** Footbridges; Piezoelectric tuned mass damper; Energy harvesting.

**NTU-42**

# EPerformance of Friction-Pendulum Bearing Systems Subjected to Near-Fault Ground Motions

Ya-Heng Yang[1], Yu-Chen Lin[1], Chang-Ching Chang[2], and Yin-Nan Huang[3]

1. *Graduate student, Department of Civil Engineering, National Taiwan University, Taiwan*
2. *Associate Research Fellow, National Center for Research on Earthquake Engineering, Taipei, Taiwan*
3. *Associate Professor, Department of Civil Engineering, National Taiwan University, Taiwan*

*r06521206@ntu.edu.tw, r05521218@ntu.edu.tw, ccchang@ncree.narl.org.tw, ynhuang@ntu.edu.tw*

## Abstract

A series of shaking table tests were conducted using a friction-pendulum isolation system subjected to four sets of ground motions. Set 1 (Set 2) includes pulse-like records with pulse periods ranged between 0.5 and 2 (2 and 6) seconds; Set 3 are non-pulse-like records with average spectral accelerations similar to that of Set 2; and Set 4 are synthetic gourd motions spectrally matched to the response spectra of the records of Set 2. The displacement demand of the tested isolation system for Set 2 is much greater than that for Set 1 despite that both sets are all pulse-like records. Also, similar average spectral accelerations for Sets 2, 3, and 4 over a wide period range did not result in similar average responses of the isolation system.

**Keywords:** friction pendulum bearing, base isolation, near fault, pulse-like ground motion, shaking table test

**NTU-43**

# 3D Modal Feature Extraction Based on Video Measurement

J.Y. Chou[1]and C.M. Chang[2]

[1,2] *Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
*d06521008@ntu.edu.tw, changcm@ntu.edu.tw*

## Abstract

Structural integrity can be accessed by means of modal properties, i.e., natural frequencies, mode shapes, and damping ratios. In the past, structural responses are commonly used to perform diagnosis of structural integrity through contact sensors. However, the number of sensors that can be instrumented on a single structural component is typically limited. Alternatively, with the aid of computer vision techniques, vibrations of structural components can be captured using cameras. Moreover, out-of-plane measurements can be shown by means of color maps determined from stereo vision algorithms. In this study, vibrational measurements of structures are acquired and subsequently decomposed using the Riesz pyramid. Then, frequency-domain stochastic subspace identification is applied in the phase difference time history to extract modal properties. The mode shapes of each pyramid level in terms of image are then reconstructed using the Riesz transformation. Finally, the modal properties are identified. To evaluate the proposed method, a flexural column is numerically developed. Both in-plane and out-of-plane video responses are generated, and the modal properties are extracted using the proposed method. As a result, the proposed method is capable of identifying modal properties with high accuracy, and the 3D near-continuous mode shapes are determined with a high-level similarity as the numerical model.

**Keywords:** Structural health monitoring; Riesz pyramid decomposition; 3D modal property extraction.

**NTU-44**

# Influence of Deep Steel Columns on Seismic Collapse Response of Steel Special Moment Frames

T.Y. Wu[1], S. El-Tawil[2] and J. McCormick[3]

[1]*Department of Civil Engineering, NTU, Taipei 34141, Taiwan*

[2,3]*Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, Michigan, USA*

*tungyuwu@ntu.edu.tw, eltawil@umich.edu, jpmccorm@umich.edu*

## Abstract

Deep, wide-flange steel columns have been widely used in U.S. seismic zones since the late 1990s. However, their susceptibility to local and global instabilities under seismic loading is not yet fully understood. This paper presents recent studies that computationally investigate the seismic behavior of deep steel columns and their influence on overall system response. The employed finite element models are capable of capturing the full range of instabilities and frame collapse behavior. A parametric study at member-level is performed to identify key variables affecting axial capacity of deep steel columns. The subsequent system-level simulations confirm that the identified variables also can be influential in collapse capacity of frames. Based on the simulation results, seismic provisions that consider all key variables are proposed to ensure adequate ductility of special moment frames with deep columns under severe seismic loading.

**Keywords:** Deep steel columns; Collapse simulation; Seismic loading.

**NTU-45**

# Application of Convolutional Neural Networks for Structural Damage Detection.

I.C. Hwang[1], P.H. Chiu[2], Y.L. Chen[3], C.W. Huang[4] and S.W. Chang[5]

[1,4] *Department of Civil Engineering, Chung Yuan Christian University, Taoyuan, Taiwan*
[2,3,5]*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
*n26764195@gmail.com, r07521219@ntu.edu.tw, b05501056@ntu.edu.tw, cwhuang@cycu.edu.tw, changsw@ntu.edu.tw*

## Abstract

This paper proposed a novel approach for damage detection of structures. The standard process of structural health monitoring (SHM) can be categorized into four levels: detection of the presence of damage, assessment of the damage location, quantification of the damage, and prediction of service life. In this paper, a machine learning based classifier is proposed to classify 9 types of structural damages through convolutional neural networks (CNN). The results show that the integration of structural analysis and CNN provides a new method for detecting the damage conditions of structures. This approach can be further integrated with other SHM methods to provide a more accurate and efficient way for SHM.

**Keywords:** Convolutional Neural Networks; Deep Learning; Machine Learning; Image Classification; Damage Detection;

**NTU-46**

# Development and experimental verification of Dual-length nonlinear pendulum for seismic protection of buildings

X. Wang
[1,2,3]*Department of Civil Engineering, NTU, Taipei, Taiwan*
*r07521239@ntu.edu.tw*

## Abstract

Tuned Mass Damper (TMD) is one of well-known passive control systems that can effectively reduce structural responses under seismic excitations. However, due to the high fundamental frequency in low-rise buildings, the allowable displacement is insufficient to accommodate excessive responses during severe earthquakes. In addition, the functionality of a single tuned mass damper is limited to tune an individual frequency, leading to overestimated performance while variation of stiffness occurs. Therefore, an innovative passive control system, entitled "Dual-length Nonlinear Pendulum", is proposed in this study. This pendulum can provide variable resonances during swinging and result in an applicable frequency range. By means of a specific stopper, the length of a pendulum can be suddenly changed to a short one and yield a high-frequency resonance. Then, the energy from earthquakes is more effectively transferred to high frequencies, and the structural responses can be quickly damped out. Therefore, a pendulum with a stopper has higher capability of mitigating structural responses during severe to extreme earthquake events.

In this study, the dual-length nonlinear pendulum is developed and experimentally verified for a seismically-excited model building. First, the numerical model of this nonlinear pendulum is established to understand the dynamic behavior and control performance. A series of parametric studies are carried out to explore the effectiveness and functionality of this nonlinear pendulum for a low-rise building (e.g., with a relatively high fundamental frequency). These studies include the instantaneous natural frequency and mode shapes with respect to positions, frequency-domain amplitudes under harmonic excitation, frequency content due to impulsive loads, energy distributions during earthquakes, and seismic performance. Then, a design example is provided in accordance with the parametric studies, and the dual lengths of the nonlinear pendulum are to tune the first and second natural frequencies of a building. Seismic performance of the building with the optimally designed nonlinear pendulum is also numerically evaluated. Moreover, a two-story, shear-type model building is fabricated to experimentally investigate and verify seismic performance of the proposed dual-length nonlinear pendulum. During the test, records from 1999 Chi-Chi earthquake are considered as the ground excitation. Performance of the nonlinear pendulum is also compared to the uncontrolled bare frame building and the building with a tuned mass damper. This nonlinear pendulum exhibits a high ability to reduce structural responses during relatively large earthquakes. As seen in the experimental results, the proposed dual-length nonlinear pendulum has higher performance than the conventional tuned mass damper, in particular when structural degradation occurs or seismic intensity becomes large.

**Keywords:** Structural Control; Dual-length Nonlinear Pendulum; Experimental Verification; Seismic Performance; Low-rise Buildings

**NTU-47**

# Crack Detection Based on Deep Learning and Computer Vision Algorithms

J.W. Yu[1], J.Y. Chou[2] and C.M. Chang[3]

[1,2,3] *Department of Civil Engineering College of Engineering, NTU, Taiwan*
*r07521241@ntu.edu.tw, d06521008@ntu.edu.tw, changcm@ntu.edu.tw*

## Abstract

This study exploits deep learning and transfer learning, e.g., the tools in the category of artificial intelligence, to train and establish a concrete segmentation model that can identify the locations of cracks in images. In this model, the crack features can be obtained from the convolutional neural network and then automatically identify whether the cracks are present and where the cracks are. Then, the image processing and computer vision are implemented to highlight and extract these cracks from images. Finally, the geometry of these cracks (i.e., lengths and widths) can be calculated by image measurement techniques.

To verify the proposed method, this study employs the images of concrete surface cracks obtained from the real-world structures and then evaluate the reliability of this method. In the verification, the pre-calibrated stereo camera model with a two-camera setup is used to verify the actual lengths and widths of cracks. The calculated results are compared with the actual measurements. As a result, the proposed method can successfully determine crack geometry. Moreover, the method also benefits users to obtain crack information and to turn into performance evaluation of concrete structures for structural health monitoring.

**Keywords:** Structural Health Monitoring; Artificial Intelligence; Deep Learning; Computer Vision; Image Processing; Image Measurement.

**NTU-48**

# The displacement restraint mechanism of seismic isolation buildings

Yu-Jen Lai[1] and Lap-Loi Chung[1, 2, 3]

[1]*Department of Civil Engineering, National Taiwan University, Taipei, 10668, Taiwan*
[2]*National Center for Research on Earthquake Engineering, Taipei, 10668, Taiwan*
[3]*Department of Civil Engineering, National Cheng Kung University, Tainan, 70101, Taiwan*
*cpes40913@gmail.com* and *chung@ncree.narl.org.tw*

## Abstract

In recent years, earthquakes occur more frequently around the world. And on September 21st, 1999, a 7.3 earthquake hit central Taiwan, which was called Chi-Chi earthquake. Seismic Code were revised and became more restrict in the aftermath of the disaster. However, many buildings in Taiwan that were built earlier are lack of seismic capacity and are not safe based on the revised Seismic Design Code. Therefore, building retrofit, such as seismic conventional retrofit and seismic isolation system, is a measure to improve these old structures' safety.

The effectiveness of the isolation system has been proved by many researches, however, some other researches also indicated that excessive displacement response due to near-fault ground motion may cause such a system with long period to fail. Thus, a displacement restraint mechanism is suggested to be installed between the isolated structure and the retaining wall. It is clear from the simulation results that as the isolated structure strikes the displacement restraint system, the maximum absolute acceleration of the total system is increased due to the impact. Therefore, the displacement restraint system should be properly designed to remain the design targets. Also, the corresponding displacement restraint system of the different structure with different damping ratio and period should be designed properly.

**Keywords:** building restrofit; seismic isolation system; displacement restraint mechanism

**NTU-49**

# Global Stability of BRBs using Truss Restrainer

Chun Chen[1], Keh-Chyuan Tsai[2]

[1,2] *Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
*r06521210@ntu.edu.tw, kctsai@ntu.edu.tw*

## Abstract

Buckling-restrained braces (BRBs) have been widely adopted as cost-effective energy dissipaters for seismic steel buildings. Recently, a novel type of BRB, namely triple-truss-confined BRB (TTC-BRB) with the constant depth of the trusses have been developed and tested. The TTC-BRB is constructed by assigning an additional structural system composed of open-web trusses outside the steel casing to increase its flexural restraining stiffness. In this approach, the initial deflection caused by the BRB's self-weight can be reduced when it is adopted in the long-span and large axial capacity BRB designs. In this study, a new type of truss system of a varying depth for the BRB restrainer is investigated. It allows a more efficient design than the case of using constant depth trusses in terms of material usage and structural aesthetic.

Key design parameters including equivalent flexural, shear stiffness and the elastic bucking strength of compressed members with an arbitrary varying cross section are presented. It is illustrated that the elastic buckling strength can be computed by incorporating the Timoshenko shear effect into the Euler equation. Further considering the inelastic material behavior, the notional load and plastic analysis, developed in a prior study is applied. FEM analysis techniques using ABAQUS are introduced in this study. It is demonstrated that the results of using the proposed finite element modeling techniques agrees extremely well with test results of a number of large scale BRBs under different levels of initial imperfection and out-of-plane drift. In order to verify the effectiveness of the proposed design and analysis procedures for the varying-depth truss-BRBs, a test program is arranged. Two 1/4-scale BRB specimens with two different confining truss frame designs are tested. Experimental performance of the two truss-BRBs are discussed. Recommendations on the seismic design and analysis of the proposed truss-BRBs are given in this paper.

**Keywords:** buckling restrained brace, truss, restrainer, flexural stiffness, shear stiffness, elastic buckling strength, flexural stability, out-of-plane stability

**NTU-50**

# Characteristics of Correlation Coefficient and Duration of Near-Fault Pulse-Like Ground Motion

S.H. Chiu[1], Y.N. Huang[2], Y.Y Jan[3] and K.J. Liu[4]

[1,2,3,4]*Department of Civil Engineering, National Taiwan University, Taipei 10617, Taiwan*
*b04501066@ntu.edu.tw, ynhuang@ntu.edu.tw, b04501079@ntu.edu.tw, b03501037@ntu.edu.tw*

## Abstract

In 2018 Hualian earthquake, lots of near-fault ground motions were recorded with moderate- to long-period velocity pulses, which might result in significant damage observed in tall buildings wounded in the event. This implies the need to further understand near-fault ground motions for structural seismic design. Response history analysis provides detailed evaluation of seismic responses of structures. Ground motion records used in a response-history analysis are usually required to reflect the site condition and governing earthquake scenarios for the site. Moreover, in ASCE standard 4-16, correlation coefficient of two orthogonal ground-motion components used in a response-history analysis are also regulated. Hancock and Bommer (2006) concluded a positive correlation between strong-ground-motion duration and structural damage indicating duration should also be considered for the selection of ground motions for response-history analysis. In this study, 300 pulse-like near-fault ground motions with magnitude ranging from 5 to 7.9 are selected to investigate the following parameters: 1) correlation coefficient of two orthogonal components, 2) durations. In the first item, the correlation coefficients of two orthogonal components of the selected pulse-like ground motions are compared with those for typical strong ground motions. The correlation coefficients of two orthogonal horizontal components of near-fault pulse-like ground motions are generally higher than that of typical strong ground motions. Next, the applicability of the strong-motion duration prediction model (Bommer et al., 2009) on pulse-like ground motions is investigated. New sets of coefficients to predict pulse-direction durations are provided in this study.

**Keywords:** Strong ground motion, near-fault ground motion, correlation coefficient, duration.

**NTU-51**

# Optimization of Deployment and Repositioning in Dock-less Electric Scooter Sharing Systems

F.Y. Liao[1], James C. Chu[2], Y.H. Yu[3]

[1,2,3] *Department of Civil Engineering, NTU, Taiwan*

## Abstract

Dock-less Electric Scooter Sharing System (DESSS), which is one of sharing mobility system, is popular because of its power efficiency and flexibility. Under DESSS, since the distribution of trips is imbalanced, strategies of deployment and repositioning are vital for remaining ideal service level. This research developed an optimization model to simultaneously solve deployment and operator-based dynamic repositioning problems. A mixed-integer programming model with a double-layered network structure was first proposed, and solved by a two-staged heuristic algorithm. Besides, this research also adopts the novel mobile battery swapping service and operational guidelines are provided by numerical experiments and case study. Therefore, this model may be beneficial for the operation and decision of DESSS.

**Keywords:** Electric Sharing Mobility Systems, Fleet Deployment, Operator-based Dynamic Repositioning, Mixed-integer Programming Model, Pickup-and-Delivery Vehicle Routing Problem, Heuristic Algorithm

**NTU-52**

# Comparison of solution methods of dial-a-ride problems for rural areas

Shih-Kuan Yang[1], James C. Chu[2], Yen-Hung Chou [3],
Mu-Han Wang [4], Chien-Pang Liu[5] ,Yu-An Xiao[6]

[1,2, 6]*Department of Civil Engineering College of Engineering National Taiwan University*
[3] *thi consultants inc Vice General Manager*,[4]*Ministry of transportation and communications R.O.C Supervisor*,[5] *Ministry of transportation and communications R.O.C Director*

## Abstract
The transportation agencies in Taiwan have attempted to satisfy public transportation demand in rural areas via dial-a-ride services. This research studies the dial-a-ride problems focusing on the characteristics of the demands in the rural areas. This study first compares the three representative solution algorithms of the dial-a-ride problem in the literature. To improve the past algorithms, this study applies the waiting strategy to the feasibility check and the waiting strategy to fix time window. Finally, this study tests algorithms under the different parameters and strategies.
**Keywords:** Heuristics; Paratransit services; Dial-a-ride problem; Waiting strategies; Rural area

**NTU-53**

# VRP-based Model for Lane Marking Assessment with MRU Vehicle

Yu-Chun Lin[1], Si-Ting Liao[2], Chieh (Ross) Wang[3], and Albert Y. Chen[4]

[1,2,4]*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
*r06521515@ntu.edu.tw, r07521501@ntu.edu.tw, albertchen@ntu.edu.tw*
[3]*Energy and Transportation Science Division, Oak Ridge National Laboratory, Knoxville, TN ,USA*
*cwang@ornl.gov*

## Abstract
Compared to traditional manual methods, using the Mobile Retroreflrctivity Unit (MRU) to measure the quality of lane markings is more efficient and safer. In addition, with a comprehensive schedule of system-wide lane marking assessments, many operational costs can be reduced and the scope of detection can be extended. Therefore, this study proposes a Vehicle Routing Problem (VRP) based model to optimize the routing of MRUs and provides an assessment schedule. We use Gurobi and column generation with branch and bound to solve the model respectively, test the two methods on instance from Florida's MRU program, and compare their execution results. Computational experiments show that both methods can provide a feasible schedule of assessment plan. However, the execution time will increase when the task size enlarges.
**Keywords:** Vehicle routing problem (VRP); Mobile retroreflectivity unit (MRU); Column generation; Branch and bound

**NTU-54**

# Exploring Urban Trip-Activity Patterns Based on Smart Card Data and Land-Use Characterization

Kuan-Chieh Lee[1] and Yu-Ting Hsu[2]

[1,2]*Department of Civil Engineering, NTU, 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan*
*r07521503@ntu.edu.tw, yutinghsu@ntu.edu.tw*

## Abstract
Automated fare collection (AFC) system has been extensively adopted in a variety of public transportation systems. The smart card data collected by AFC system continuously and comprehensively record itinerary information of cardholders, and thereby the exploration of such data presents both opportunities and challenges to reveal the hidden trip/activity patterns in a cost-effective manner. This study integrates the smart card data of multimodal transit, and the potential activity-relevant information is extracted to construct activity-based data. The activity-based data are also transformed into a card-based structure, where each card(holder) is characterized by his/her activity patterns. K-means clustering is then applied to both datasets to categorize activities and cardholders into different groups of trip/activity patterns. One-month smart card data collected from the metro and public bike sharing system in Taipei, Taiwan, are investigated in this study. The data integration procedure well combines the multimodal data and links trips across different transit systems. The clustering of the extracted activity-based data also results in the groups of trip/activity patterns that can provide relevant interpretation in connection with land use data. Furthermore, the clustering results of the data in card-based structure distinguish regular commuters, local residents, and cardholders who contribute irregular usage of the smart card, by factoring the characteristics of activities including their starting time and duration. The derived research insights may enable a better understanding of cardholders and their trip/activity patterns in a multimodal environment, which can support quality and more effective decision-making.
**Keywords:** Smart card data, K-means clustering, Travel pattern, Activity pattern, Activity duration

**NTU-55**

# Dynamic Traffic Assignment upon Short-Duration Intense Rainfall Events

Chi Chang[1], Yu-Ting Hsu[2], Jin-Song Lai[3] and Kai-Yuan Ke[4]

[1,2]*Department of Civil Engineering, NTU, Taiwan*
[3,4]*Center for Weather Climate and Disaster Research, NTU, Taiwan*
*r07247003@ntu.edu.tw, yutinghsu@ntu.edu.tw, jslai525@ntu.edu.tw, kent0115@gmail.com*

## Abstract
Climate change has been leading to global impact in two different ways: global warming and extreme weather. This global change can also directly influence the subordinate hierarchy, such as regional weather systems. More frequent events of concentrated precipitation with increasing intensity haven observed in Taiwan in recent years. Not only Typhoons but some regional convective systems can cause severe inundation in urban areas. Hence, the interactions between inundation events and urban systems can be crucial issue to the society. In the study, we focus on the effect of floods on urban traffic flows. Upon the scenario of high rainfall intensity concentrated in short duration and the consequent flood, the roadway capacity in urban area can be severely reduced or even disrupted. A mesoscopic traffic simulation model is constructed to capture and clarify the dynamic relationships between rainfall, inundation and traffic flows. The simulation environment is developed within a specific urban area, where the roadway capacity is subject to the depth of flooding water and may vary over time. The roadway capacity plays an important role in the traffic assignment problem, since the variances among unimpeded, half-blocked or fully-blocked conditions can directly affect flow dynamics. Based on the simulation for different traffic assignment objectives, the routing strategies over alternate roads, potential bottlenecks, and critical links are identified. The relevant research findings can help traffic network operators better prepare for or respond to the deteriorated traffic conditions before or during such short-duration intense rainfall events resulting from extreme weather.
**Keywords:** Climate change; Extreme weather; Short-duration intense rainfall events; Depth of flooding water; Dynamic traffic assignment; Traffic flow simulation.

**NTU-56**

# Stochastic Dynamic Dispatch Model for Freeway Incident Response

Hong-Yi Li[1] and Yu-Ting Hsu[2]

[1,2]*Department of Civil Engineering, NTU, 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan*
*r07521511@ntu.edu.tw, yutinghsu@ntu.edu.tw*

## Abstract
Incident response is critical for freeway management and challenging as well, as a freeway network is a semi-closed roadway system. Longer time to clear an incident may not only cause more serious delay to traffic but also induce potential danger to the driving environment. Hence, Efficient dispatch of emergency response teams is one of the key factors for prompt incident response. In most of the current Freeway-Incident-Management programs, dispatch strategy is made upon an incident reported and based on the instantaneous traffic conditions. However, due to the limited number of response teams, it is also necessary to consider the probability of potential incidents occurring in the responsible area where each response team is located. This study proposes a stochastic dynamic dispatch model with the objective to minimize the total response time over a planning horizon, where the stochasticity of incident occurrence is considered. A case study in made over the freeway network taken charge by the Northern Region Engineering Office, Freeway Bureau. It is expected to introduce a holistic perspective for freeway management and avoid myopic optimal strategies, thereby enhancing the robustness of response teams dispatch.
**Keywords:** Freeway management; Incident response; Stochasticity; Robust optimization; Dispatch model

**NTU-57**

# Scheduling and Charging Optimization of Electric Buses

Jou-Chun Yeh[1], James C. Chu[2], Yen-Hung Chou[3], Hui-Pei Huang[4] and Yao-Jen Chang[5]

[1,2,5] *Department of Civil Engineering, College of Engineering, NTU, Taiwan*

[3,4] *THI Consultants Inc.*

## Abstract
The research studies the optimization of scheduling and charging of electric buses by using discrete-event simulation. It considers major factors in operation of electric buses, including capacity of battery, safety level of power, consuming and charging efficiency, and the cost of buses, batteries, chargers and electricity. Given the type of the bus and charger, the discrete-event simulation model estimates the required numbers of buses and chargers, and arranges the dispatching and charging plans of each electric bus. Through the simulation optimization approach, the combination of bus and charger with the minimum total cost can be found. Finally, the research will conduct a sensitivity analysis to understand the change of result.
**Keywords:** Discrete event simulation, Charging, Scheduling, Electric bus, Optimization

**NTU-58**

# A mesoscopic model for large-scale pedestrian simulation

Yu-Ting Wei[1], An-Long Shih[2], James C. Chu[3]

[1]*Department of Civil Engineering, National Taiwan University, Taiwan.*
*E-mail: r06521509@ntu.edu.tw*
[2]*Department of Civil Engineering, National Taiwan University, Taiwan*
*E-mail: r07521507@ntu,edu.tw*
[3]*Department of Civil Engineering, National Taiwan University, Taiwan*
*E-mail: jameschu@ntu,edu.tw*

## Abstract

In recent years, many computer models for pedestrian simulation have been developed to understand the efficiency of pedestrian evacuation under disasters. This study constructs a mesoscopic pedestrian model to improve the efficiency of large scale pedestrian evacuation simulation. In addition, this study also considers the dynamic environment, that is, the hazardous areas may vary over time and pedestrians can re-plan the path according to the updated environment. The developed mesoscopic model has three major features that improves simulation efficiency and maintains the accuracy of pedestrian simulation, which are static floor field, large and medium grid, and directional factor. Through the above features, this study drastically reduces the simulation time, enhances the accuracy of pedestrians' movement paths, and reflects the interactions between hazardous areas and pedestrians.
**Keywords:** mesoscopic pedestrian simulation; large-scale pedestrian simulation; static floor field; directional factor; dynamic environment factor

**NTU-59**

# Stochastic Sediment Transport with Memories

Serena Y. Hung[1] and Christina W. Tsai[2]

[1,2]*Department of Civil Engineering, NTU, Taipei, Taiwan*
*d05521007@ntu.edu.tw, cwstsai@ntu.edu.tw*

## Abstract

Over the past few decades, a wealth of research on analyzing sediment transport in stochastic manners has increased rapidly. Influence of turbulence such as eddies of various size and mixing process in a flow results in the random and uncertain behaviors of sediment particles. In essence, stochastic diffusion particle tracking models (SD-PTMs) are powerful Lagrangian models for simulating random particle behaviors in turbulent flows. Using Wiener process, the random term simulates influences of turbulent effect on particle motions. The increments of the random term are independent which can model the particle behaviors in the ordinary turbulent flows well.

However, in reality, instead of statistical independence, flow events or phenomena are time persistent and might cause an increasing/decreasing statistical dependency of sediment movements. To model these distinctive behaviors, the fractional Brownian motion (fBm) is introduced in this study. The fBm is a transformed form of ordinary Brownian motion with the most well-known property: the dependent and correlated increments. The mathematical property of correlated increments makes fBm a potential method to model the random behaviors subject the long-range memory events. In this study, random and individual suspended sediment trajectories subject to time-persistent flow events are simulated using the SD-PTM with fBm.
**Keywords:** fractional Brownian motion, stochastic diffusion particle tracking model, stochastic sediment transport

**NTU-60**

# Seismic Evaluation of Reinforced Concrete Bridges Using Capacity-Based Inelastic Displacement Spectra

W.C. Cheng[1], P.H. Wang[2] and K.C. Chang[3]

[1]*Department of Civil and Environmental Engineering, NTU, Taipei, Taiwan, r07521216@ntu.edu.tw*

[2]*Assistant Technologist, National Center for Research on Earthquake Engineering, NCREE, Taipei, Taiwan, phwang@ntu.edu.tw*

[3]*Department of Civil and Environmental Engineering, NTU, Taipei, Taiwan, ciekuo@ntu.edu.tw*

## Abstract

Capacity-based inelastic displacement spectra comprised of an inelastic displacement ratio (CR) spectrum and a corresponding damage index (DI) spectrum are proposed in this study as an innovative seismic evaluation method for reinforced concrete (RC) bridges. The proposed spectra are constructed by using a new smooth hysteretic model which can realistically simulate the hysteresis behaviors of RC bridge columns. The Damage index proposed by Park and Ang is demonstrated to be a good indicator for assessing the strength deterioration and actual visible damage condition of column regardless of its loading history. A three-span continuous box girder bridge is used as an example bridge to demonstrate the accuracy and reliability of the proposed spectra. Nonlinear time history analyses of the bridge are conducted using OPENSEES and SAP bridge models, as well as the new smooth hysteresis model when subjected to near-fault and far-field ground motions. The analytical results show that the proposed spectra can appropriately predict the seismic responses of the bridge. Furthermore, it is found that the OPENSEES and SAP models could underestimate the inelastic displacement of bridge when compared to the new smooth hysteretic model, especially under near-fault ground motions.

**Keywords:** bridge column; damage index; far-field; inelastic displacement; near-fault; reinforced concrete

**NTU-61**

# Using System Identification and Interpolation Method to Develop Optimal Sensor Placement with High-Rise Building without Numerical Model

Yen-Yu Yang[1] and Liang-Jenq Leu[2]

[1,2] *Department of Civil Engineering, NTU, Taipei 10617, R.O.C*
*yyyang7307@ntu.edu.tw, ljleu@ntu.edu.tw*

**Abstract**

To ensure the building safety, monitoring the building before and after natural disasters is crucial. Using stochastic subspace identification with data collected from multiple sensors in a single structure, we can predict accurate frequencies from modal frequency. However, setting sensors in high-rise building on each floor is very difficult and expensive. This study developed the OSP (Optimal Sensor Placement) method which uses Cubic Spline Interpolation method, K-means Clustering method, and Genetic Algorithm to allocate the best location for sensors placement and the number of sensors we need. The measurements can be simplified and retake to monitor the same structure repeatedly. The proposed method is verified by in-situ measurements at Civil Engineering Research Building at National Taiwan University.

**Keywords**: Stochastic Subspace Identification; Optimal Sensor Placement; System Identification

**NTU-62**

# A Study of Improving Geoid Model by Hybrid Method - A Case Study of Taiwan Area

C.J. Huang[1], J.Y. Han[2]

*[1,2]Department of Civil Engineering, NTU, Taipei , Taiwan*
*d05521008@ntu.edu.tw, jyhan@ntu.edu.tw*

## Abstract

The global navigation satellite system (GNSS) is becoming a perfection positioning technique. This technique has been applied in many control surveys as well as in engineering applications. However, the transformation from the GNSS-derived geometric heights to orthometric heights as adopted in national datum is still an important topic to be studied. To carry out this transformation, a high accurate geoid undulation model needs to be first determined. Typical geoid undulation model relies on quality gravimetric observation data which is costly and time-consuming. This study aims to improve the accuracy of the geoid undulation by refining the mid-wavelength components in a much cost efficient manner. The geoid undulation has been rigorously computed for Taiwan using earth gravity model with spherical harmonic model. In addition, the influence on the residual terrain model is also considered. The hybrid method is used to construct a high-accuracy medium-wavelength component model in conjunction with the remove-compute-restore method, which included surface curve fitting method and local approximation method. Based on the numerical results, it has been illustrated that the obtained geoid undulation model in Taiwan area by the proposed approach enables the transformation between the GNSS-derived geometric heights and orthometric heights, reaching the accuracy level that fulfils the needs of most engineering applications, but with less cost compared to the traditional approach.

# *Abstracts from National University of Singapore*

**NUS-01**

# A field implementation of a remote crack detection system based on plastic optical fiber sensors to monitor cracks in concrete pedestrian pavements

V. Ramani[1], Y.J Zhou[2] and K.S.C. Kuang[3]

*Department of Civil and Environmental Engineering, National University of Singapore 117576, Singapore*

*vasantha.ramani@u.nus.edu, e0127376@u.nus.edu, kevinkuang@nus.edu.sg*

## Abstract

Pavements are ubiquitous in public areas and these walkways alongside roads have been built to provide a safe and convenient footpath for pedestrians and users of personal mobility devices (such bicycles, e-scooters, motorized wheel chairs and others). In many areas of Singapore, trees are planted close to these pavements to provide shades for users from the sun as well as an integral part of the green ambition of the city-state. Frequently, as a result of the growth of the roots of these tress, or other factors, pavements close to them are subjected to stress loading leading to cracking of the pavements. The aim of this paper is to outline an attempt to implement a crack-sensing system based on a low-cost plastic optical fiber and an SMS-based remote monitoring setup to provide warning of crack initiation to the public agencies to carry out further investigation and reinstatement works to ensure public safety and general aesthetics. There are remains many challenges to be overcome however it is envisioned that the proposed system could serve as initial prototype for pavement condition monitoring which could be easily scaled up at a low cost for nationwide implementation.

**Keywords:** cracks; pavement; damage detection; plastic optical fiber; sensors; remote monitoring

**NUS-02**

# Spudcan-pile interaction in two-layered soils: stiff overlying soft clay

Kencana E. Y.[1], Leung C. F.[2], and Chow Y. K.[3]

[1,2] *Centre of offshore and research engineering,*
*Department of Civil & Environmental Engineering,*
*National University of Singapore, SINGAPORE*
*E0008638@u.nus.edu, ceelcf@nus.edu.sg, chowyk@nus.edu.sg*

## Abstract

Soil displacement due to the installation of spudcan foundation can induce additional forces on the adjacent existing piles. Should additional forces be excessive, it can compromise the pile's integrity. Hence, detailed analysis shall be conducted to assess the impact of spudcan penetration for offset spacing (edge-to-edge distance between spudcan and pile) lesser than one spudcan diameter [BS EN ISO 19905-1]. The available design chart [Leung et al, 2012] can be used to predict the additional pile bending moment due to spudcan penetration in soil with linearly increasing shear strength. This paper presents an extension for spudcan-pile interaction in two-layered soils with stiff overlying soft clay. This paper begins with discussion on efficient three-dimensional modeling with its validation comparing the computed pile responses to the measured in centrifuge test. Using the validated model, this paper reveals the fundamental of spudcan-pile interaction in two-layered soils. Finally, discussion for modifying the design chart is presented.

**Keywords:** Spudcan-pile interaction; large deformation finite element analysis; stiff overlying soft clay.

**NUS-03**

# Size Effect of Laboratory Samples on Consolidation and Creep Behaviour in Oedometer

N.G.L.H. Lee[1] and S.C. Chian[2]

[1,2]*Department of Civil and Environmental Engineering, National University of Singapore, Singapore 117576*
*e0031470@u.nus.edu, sc.chian@nus.edu.sg*

## Abstract
The scaling of soil performance from laboratory to field conditions is key in the design of geotechnical projects, including the estimation of consolidation settlement. This is especially important for soft soils that exhibit considerable creep, a phenomenon whose nature remains highly debated. Limited research has been conducted on the relationship between sample size of soil and its consolidation and creep properties within laboratory analysis, which is the first step to correlating laboratory results to a field scale. In this paper, a series of oedometer tests were conducted on remoulded Singapore marine clay (SMC) samples with varying dimensions of the consolidation ring to ascertain its influence on consolidation parameters. Results show that while the sample diameter has minimal effect on consolidation and creep, a positive correlation exists between sample thickness and the rate of secondary consolidation $C_\alpha$, where strain rate and end-of-primary (EOP) strain increases with thickness. The $C_\alpha/C_c$ ratio for SMC was also determined to remain relatively constant with sample size.
**Keywords:** Oedometer test; size effect; consolidation; creep.

**NUS-04**

# Slot and Grout Connection for Steel and Composite Modular Construction

T.Y. Cheong[1], Z.Q. Dai[2] and S.D. Pang[3]

[1,2,3]*Department of Civil and Environmental Engineering, NUS, Singapore 117576 , Singapore*
*e0014201@u.nus.edu, ziquan.dai@u.nus.edu, ceedhacd@nus.edu.sg*

## Abstract
Steel and steel-concrete structures continue to be a popular choice in new constructions. However, our increasingly fast-paced and advancing world demand that constructions be quicker and more productive. Modular construction has been advocated to be one such solution, by shortening construction times while using less manpower. An issue is that steel and composite structures built via this method requires and employs the use of many unconventional connections. These unconventional connections pose an obstacle to builders striving to achieve the ideal time savings through the adoption of modular construction. Therefore, in this paper, a fast and constructible composite connection, the Grouted Sleeve with Slotted holes (GSS) connection, is proposed as an alternative connection in such structures. Due to a failure mode which has not been well documented, the Concrete Dowel effect, a combination of numerical and experimental analyses were utilized in determining the strength of the connection to evaluate its feasibility as an alternative connection as well as to gain an insight as to how the connection may be optimized. Results show that the GSS connection, which is employable in modular constructions, is sufficiently strong and is easily optimizable and may be a viable alternative as a connection in steel and composite structures.
**Keywords:** Modular construction; Steel and composite structures ; Concrete Dowel.

**NUS-05**

# Capturing the Size Effect in Quasi-Brittle Fracture with Localizing Gradient Damage Enhancement

Y. Zhang[1] and L.H. Poh[2]

[1,2] *Department of Civil & Environmental Engineering, National University of Singapore, Singapore 117576, Singapore*

*yi_zhang@u.nus.edu, ceeplh@nus.edu.sg*

## Abstract

The strength of quasi-brittle materials shows a strong "size effect", where the load-carrying capability of the structure is influenced by the specimen size. Many theoretical approaches have been proposed to describe the size effect of strength in quasi-brittle materials. Numerically, there are also attempts to reproduce the size effect of quasi-brittle materials. Classical continuum damage models cannot capture any size effect. The linear elastic fracture mechanics (LEFM) can only approximate the size effect for very large specimens. Limited success in capturing the size effect was reported using the nonlocal damage enhancement. However, the numerical studies presented in literature have shown that the nonlocal enhancements, both integral and gradient approaches, cannot correctly capture the size effect for different problems, e.g. notched and unnotched specimens, using one set of material parameters. In this presentation, the localizing gradient damage enhancement is adopted to examine the structural size effect for concrete beams under mode I fracture. It is shown that the localizing gradient enhancement can capture the experimentally observed size effect in concrete beams, using only one set of material parameters.

**Keywords:** Quasi-brittle fracture; Size effect; Localizing gradient enhancement.

**NUS-06**

# Near-surface Monitoring in Urban Environments based on Extremely Short Period of DAS Recordings

Y. Zhao[1], G. Fang[2] and Y. E. Li[3]

[1,2,3]*Department of Civil & Environmental Engineering, NUS, 119077, Singapore*

*yumin_zhao@u.nus.edu, elita.li@nus.edu.sg, ceefg@nus.edu.sg*

## Abstract

Distributed acoustic sensing (DAS) is a newly developed technology, and it is getting more attention in the energy industry, civil engineering investigations and geo-hazard studies due to its dense sensor spacing, low cost of fiber cables and high repeatability for monitoring. Long-term monitoring by DAS brings us huge amount of data, processing of which is laborious and time consuming. Most importantly, the data should be processed in real time when monitoring the potential hazards in the near-surface. We use the DAS data recorded by the Stanford DAS array to demonstrate that reliable information can be extracted using extremely short recordings. We apply denoising, missing data interpolation, seismic interferometry, dispersion analysis and surface wave inversion to the DAS data. Using pieces of 100-second recording, the phase velocity changes with frequency have been obtained. The dispersion results are consistent with those obtained using month-long data recordings, which demonstrates that reliable information can be extracted using extremely short period of DAS recordings due to anthropogenic activities. Besides, we have observed some velocity changes due to the basement construction based on the dispersion curves.

**Keywords:** Near-surface Monitoring; DAS; seismic interferometry; Dispersion Analysis.

**NUS-07**

# GROUTED SLEEVE CONNECTION FOR MODULAR CONSTRUCTION

S.D. Pang[1], Z.Q. Dai[2] and J. Y. Liew[3]

[1,2,3]*Department of Civil and Environmental Engineering, NUS, Singapore 117576 , Singapore*
*e0014201@u.nus.edu, ziquan.dai@u.nus.edu, ceedhacd@nus.edu.sg*

## Abstract

Modular construction has become popular with the government push for higher productivity. Since modular units need to be connected on site, the ease of module connection directly determines the efficiency of the modular project. Bolted connections are mostly proposed for module connections, but they often suffer from limited access and tolerance issues. Therefore, this paper presents a lego-like grouted sleeve connection to solve these issues. This paper presents a feasibility study by carrying out numerical investigations. An assembled module joint using the proposed connection was compared with a continuous module joint. It can be proved that the proposed connection is able to provide satisfactory performance. The failure mechanism is discussed, and future study is given.
**Keywords:** Modular construction; Module connection ; Grouted sleeve connection.

# *Abstracts from Tongji University*

**TU-01**

# Liquefaction-induced settlement of existing structures: experimental and numerical investigations

Wuwei Mao[1], Ikuo Towhata[2] and Rouzbeh Rasouli[3]

[1] *Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai, China. maowuwei@tongji.edu.cn*
[2] *Department of Civil Engineering, University of Tokyo, Tokyo, Japan towhata.ikuo.ikuo@gmail.com*
[3] *Jacobs, Toronto, Ontario M2J 1R3, Canada rouzbeh.rasouli@gmail.com*

## Abstract
Seismic liquefaction is commonly observed in most of the large earthquakes. Settlement of structures, especially residential buildings resting on liquefiable soils has drawn continuous public concerns. The present study deals with the problem of structure subsidence through the framework of computational fluid dynamics. The liquefied ground was simulated using a viscous fluid model and the upper structure was modelled as a rigid body moving through the computational domain. In order to verify the proposed method, a series of 1-G shaking table tests were performed to obtain the subsidence behavior of a simulated structure resting on the liquefied ground. The results showed that settlement of structure obtained from the proposed numerical model was comparable with the measured settlement from shaking table test. It is therefore suggested that the proposed method could be used for assessment of house settlement problems in liquefaction prone regions.
**Keywords:** liquefaction; shaking table test; computational fluid dynamics; viscous

**TU-02**

# Multi-Mode Cable Vibration Control using MR Damper based on Nonlinear Modeling

H.W. Huang[1], T.T. Liu[2] and L.M. Sun[3]

[1,3]*State Key Laboratory for Disaster Reduction in Civil Engineering, Tongji University, 1239 Siping Road, Shanghai, China. hongweih@tongji.edu.cn*
[2]*Hunan Provincial Communication Planning, Survey & Design Institute, Changsha, Hunan, China*

## Abstract
One of the most effective countermeasures for mitigating cable vibration is to install mechanical dampers near the anchorage of the cable. Most of the dampers used in the field are so-called passive dampers where their parameters cannot be changed once designed. The parameters of passive dampers are usually determined based on the optimal damper force obtained from the universal design curve for linear dampers, which will provide a maximum additional damping for the cable. As the optimal damper force is chosen based on a predetermined principal vibration mode, passive dampers will be most effective if cable undergoes single-mode vibration where the vibration mode is the same as the principal mode used in the design. However, in the actual engineering practice, multi-mode vibrations are often observed for cables. Therefore, it is desirable to have dampers that can suppress different modes of cable vibrations simultaneously. In this paper, MR dampers are proposed for controlling multi-mode cable vibrations, because of its ability to change parameters and its adaptability of active control without inquiring large power resources. Although the highly nonlinear feature of the MR material leads to a relatively complex representation of its mathematical model, effective control strategies can still be derived for suppressing multi-mode cable vibrations based on nonlinear modelling, as proposed in this paper. Firstly, the nonlinear Bouc-wen model is employed to accurately portray the salient characteristics of the MR damper. Then, the desired optimal damper force is determined from the universal design curve of friction dampers. Finally, the input voltage (current) of MR damper corresponding to the desired optimal damper force is calculated from the nonlinear Bouc-wen model of the damper using a piecewise linear interpolation scheme. Numerical simulations are carried out to validate the effectiveness of the proposed control algorithm for mitigating multi-mode cable vibrations induced by different external excitations.
**Keywords:** stay cable, multi-mode vibration, semi-active control, MR damper, optimal friction damper force

**TU-03**

# Sediment Suspension Affected by Rigid Vegetation

M. Chen[1], S. Lou[2], and H.Z.. Liu[3]

[1,2,3]*Department of Hydraulic Engineering, Tongji University, Shanghai 20092, China*
*chenming201291@163.com, lousha@tongji.edu.cn, hongzheliu@tongji.edu.cn*

## Abstract
Tidal flat is a transition zone between land and ocean. As an important part of ecosystem, tidal flat provides benefits to habitats for a large population of wildlife as well as the human being. The vegetation in tidal flat can protect the coastal areas from storm surge and tsunamis by wave energy reduction. Tidal flat also can filter parts of the artificial contaminations and reduce the pollutants discharged into the ocean. In addition, interactions between vegetation and morphology over tidal flat have strong impacts on ecological regime and morphological evolution. However, there are too many complex physical processes involving in the interaction among hydrodynamics, sediment transport and vegetation. Therefore, effects of vegetation on hydrodynamics and sediment transport were carried out in this paper. Through laboratory experiments, mean velocity, turbulent kinetic energy, and sediment distributions under pure wave, pure current and combined wave and current were analyzed. Based on the results, a modified Shields parameter based on turbulence intensity is introduced in the sediment transport model to account for sediment suspension by wake turbulence within the canopy. With the modified Shields number, sediment suspension can be reasonably simulated.
**Keywords:** Vegetated flow; Sediment suspension; Turbulent kinetic energy.

**TU-04**

# Destabilization modes of upper continental slopes undergoing hydrate dissociation induced by climate warming

Fang Liu[1,2,*], Lin Tan[1,2], Giovanni Crosta[3] and Yu Huang[2]

[1] *State Key Laboratory of Disaster Reduction in Civil Engineering, Tongji University, China*
[2] *Key Laboratory of Geotechnical and Underground Engineering (Tongji University), Ministry of Education, China*
[3] *Department of Earth and Environmental Sciences, University Milano-Bicocca, Italy*
** liufang@tongji.edu.cn*

## Abstract
Gas hydrates dissociation could induce or trigger submarine landslides, especially in upper continental slopes where hydrates are vulnerable to natural and artificial perturbations. This work investigates destabilization mechanisms of an upper continental slope undergoing hydrate dissociation and identifies spatiotemporal failure modes influenced by characteristics of the overburden above the hydrate-bearing layer (i.e. the hydrate reservoir). A Thermo-Hydro-Chemical coupled numerical model of transient pore pressure induced by hydrate dissociation is coupled with the limit equilibrium slope analysis method to study the spatiotemporal evolution of the potential sliding plane and to calculate the corresponding factor of safety. The results suggest that overpressure generated by the liberated fluid from hydrate dissociation is the primary reason for instability in a gentle marine slope. The study identifies three sliding modes, namely co-melting non-interface sliding, co-melting interface sliding, and post-melting non-interface sliding, depending on the overburden's characteristics, including overburden thickness, permeability, and cohesion. Co-melting non-interface sliding takes place during hydrate dissociation if the hydrate reservoir underlies a thin, pervious and cohesionless overburden cover. For less permeable and more cohesive overburdens, the potential sliding plane is deeper and co-melting interface sliding could be triggered due to overpressure developed at the reservoir-overburden interface. If the hydrate reservoir is covered by a thick, low-permeability and slightly cohesive overburden, post-melting non-interface sliding could occur after the hydrates are completely dissociated. This failure is delayed, because the gas/water trapped at the interface during hydrate dissociation is insufficient to trigger instability due to very high overburden stresses. However, as the gas migrates upwards over time and encounters a weak zone in the overburden deposits, failure could happen within the overburden deposits even after hydrate dissociation stops.
**Keywords:** gas hydrate; submarine landslide; upper continental slope; THC coupled analysis; pore pressure.

**TU-05**

# Influence analysis of excavation under the existing building to pile dynamic impedance

Fayun Liang[1], Ping Cao[2]

[1,2]*Department of Geotechnical Engineering, Tongji University, Shanghai 200092, China*
*fyliang@tongji.edu.cn, lawncao@ tongji.edu.cn*

## Abstract
The development of underground space of existing buildings will change the pile foundation from fully embedded to partially embedded. In the past, scholars paid attention to its influence on the static characteristics of the pile foundation but neglected the dynamic characteristics. Based on the transfer matrix method, dividing the pile to two parts, considering the influence of soil excavation from two aspects of stress state and strength parameters, the calculation model of pile foundation impedance under the condition of soil excavation is established. The calculation results are compared with the 3D-FEM to verify the correctness of the vertical, horizontal and rocking impedance results. Finally, the parameters of soil excavation depth, stress history and segment length are analyzed.
**Keywords:** Pile; Transfer matrix method; Dynamic response; Underground space development.

**TU-06**

# Study on Uniaxial Compression Bearing Capacity of Bolted Ball-Cylinder Joint

Qiang Zeng[1], Xiaonong Guo[2] and Zewei Huang[3]

[1,2,3]*College of Civil Engineering, Tongji University, Shanghai 200092, China*
*1710700@tongji.edu.cn, guo-xiao-nong@tongji.edu.cn, yayahuangzewei@126.com*

## Abstract
Bolted ball-cylinder joint (BBC joint) is a new type of joint system, proposed in recent years, that can be utilized in non-purlin spatial truss structures. Compared with the traditional structure system, structures with BBC joints have merits of attractive appearance, light weight, reasonable stress distribution and considerable material savings. To investigate the basic compression property of this joint, experiments on 5 BBC joints were conducted and finite element (FE) models were established and verified. Subsequently, detailed parametric analyses were conducted to study the effects of different parameters on the bearing capacity of the joint. The results indicated that the dimensions of hollow cylinder, rectangular tube and ribbed stiffener were the major influencing factors. Based on the theoretic derivation and regression analysis, the formulae to estimate the uniaxial compression bearing capacity of the BBC joint were obtained. Good agreement between the calculation results and experimental results shows that the fitting formulae are reliable and accurate.
**Keywords:** Bolted ball-cylinder joint; Compression bearing capacity; Finite element analysis; Fitting formula.

**TU-07**

# Probabilistic performance assessment of shield tunnels due to chloride-induced corrosion

X. R. Duan[1], and J. Zhang[2]

[1,2,] *Department of Geotechnical Engineering, Tongji University, Shanghai 200092*

*angusduan@tongji.edu.cn @ cezhangjie@tongji.edu.cn*

## Abstract

Ageing and deterioration pose threats on the serviceability and structural safety of the shield tunnels in Shanghai after their long-time in service. Corrosion of the reinforcement due to chlorides is the main cause of degradation of the strength of tunnel lining. It is highly desirable to assess the effect of such corrosion on the performance of shield tunnels for the service life prediction. Nevertheless, factors affecting the chloride-induced corrosion are in fact highly uncertain that are seldom considered before. In this paper, a 2D FDM shield tunnel model considering the joints and the installation of support is first established. Then, a probabilistic method based on reliability theory and Gamma process is suggested to evaluate the time-dependent performance of the shield tunnels due to chloride-induced corrosion, which can systematically consider the uncertainty in the soil properties and the uncertainty in the chloride-induced corrosion. The suggested method is used to analyze the potential effect of the chloride-induced corrosion on the safety of tunnels in Shanghai. The suggested method provides a practical means to quantify the risk due to the chloride-induced corrosion on the performance of the shield tunnels.

**Keywords:** Shield tunnel; Corrosion; Performance assessment.

**TU-08**

# Seismic Input of a Shaking Table Test for a Granite Façade System

Y. Fan[1], M. X. Xie[2] and W. S. Lu[3]

[1,2,3] *College of Civil Engineering, Tongji University, Shanghai 200092, China*

*yuanfan@tongji.edu.cn, moonshine@tongji.edu.cn, wally@tongji.edu.cn*

## Abstract

A shaking table test was performed to investigate the seismic performance of granite façade system, in which the testing methods for choosing appropriate motions and taking multi-stage loading procedure were studied. Specifically, five natural earthquake records and two artificial earthquake motions were rigorously selected or generated considering the seismic demands of the façade system, which related to the seismic responses of the floor accelerations and inter-story drifts of main structure, the dynamic response of the granite façade system and the dynamic behavior of the steel frame for supporting the façade system. These motions with different peak values were generated as different quake levels and input to excite the granite façade system with its supporting frame on the shaking table, for reproducing the seismic responses of granite façade system, so that the seismic performance of the granite façade system under different earthquake levels were evaluated.

**Keywords:** Shaking table test; Façade system; Record selection; Loading procedure; Seismic performance evaluation

**TU-09**

# Analysis of durability prediction models of FRP and adhesive subjected to harsh environment

Q.Q. Yu[1], R.X. Gao[2]

[1,2] *Key Laboratory of Performance Evolution and Control for Engineering Structures (Tongji University), Ministry of Education, 1239 Siping Road, Shanghai 200092, China; Department of Structural Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, China*

*qianqian.yu@tongji.edu.cn;1351137@tongji.edu.cn*

## Abstract

The long-term performance of fiber-reinforced polymer (FRP) and structural adhesive exposed to harsh environmental conditions has attracted much attention in recent years. Many prediction models of moisture absorption and mechanical behaviour degradation were proposed based on experimental data. However, there is still a lack of systematic comparison and assessment of these approaches nowadays. This paper conducted an analysis of the durability prediction models of FRP and adhesive. A total of 271 experimental data of FRP and adhesive subjected to harsh environmental conditions was collected. By evaluating the model factor, the feasibility of different models was compared and judged. The influence of environmental factors such as temperature and PH value of the immersion was discussed.

**Keywords:** FRP; structural adhesive; prediction; environment

**TU-10**

# Single-channel blowing-in longitudinal ventilation theory and its applicability analysis in road tunnel

C. Guo[1], Z.G. Yan[2]

[1,2] *Department of Geotechnical Engineering, Tongji University, 1239 Siping Road, Shanghai, China.*

*1732399@tongji.edu.cn, yanzguo@tongji.edu.cn*

## Abstract

Nowadays, a majority of extra-long road tunnels adopt longitudinal ventilation methods and combine the vertical or inclined shafts and jet fans. However, such methods have the problems of expensive civil construction costs and high operating costs. The single-channel blowing-in longitudinal method emerges in recent years. Only one ventilation channel is set be-tween the left and right main tunnels, and rich fresh air at the entrance of the downhill tunnel is sent to the exit of uphill tunnel through the ventilation channel. The authors compared the theory and applicable conditions of single-channel method and single shaft method with MATLAB. It can be concluded that the single-channel method can reduce the operation energy consumption and has a good application prospect.

**Keywords:** road tunnel; longitudinal ventilation; single channel; energy consumption.

**TU-11**

# Basic properties of recycled powders made from different sources of construction and demolition materials

S.D. Hou[1], Z.H. Duan[2] and J.Z. Xiao[3]

*[1,2,3]Department of Structural Engineering, Tongji University, Shanghai, PR China*
*hsd2017@tongji.edu.cn, 16044@tongji.edu.cn, jzx@tongji.edu.cn*

## Abstract

Some types of recycled powders (RPs) have been proved that they can be used in concrete to replace cement or fly ash (FA), such as recycled powder from waste clay brick, mixed brick powder and so on. The mechanical properties of concrete with RPs can be compared to FA. While the workability of concrete with RPs decreased significantly than normal concrete due to the rough surface and structure of RP particles, which has a negative effect on the utilization of RPs. This paper studies the basic properties of mortar with different RPs, which are clay brick powder (CBP), mixed brick powder (MBP) and dust powder (DP). Firstly, the basic properties of RPs, including microstructure, particle size distribution and hydration heat, were studied for better understanding the effect on the properties of mortar. Then, the rheological and mechanical properties of mortar were examined with different types of RPs and different dosage of superplasticizer, respectively. The results show that MBP and CBP are finer than cement, RPs have higher content of $Al_2O_3$ and alkali and lower content of $SO_3$, and pastes with RPs have higher hydration heat than cement paste in the first 30 mins. The yield stress, plastic viscosity and thixotropy are increased significantly with the alternative use of RPs, especially for DP, which has the maximum values of rheological parameters. The addition of recycled powder decreased the flowability and compressive strength of mortar. It's worth noting that the addition of mixed recycled powder and brick powder lower than 20% had a positive influence on the flexural strength of mortar. Mixed recycled powder and brick powder are recommended to replace cement in mortar, the optimized replacement ratio is lower than 30%.

**Keywords:** Recycled powder; Hydration heat; Mechanical properties; Rheological properties.

**TU-12**

# Simplified Models of Steel Moment Connections under a Column Removal Scenario

J.L. Chen[1] and J.W. Li[2]

[1,2] *College of Civil Engineering, Tongji University, Shanghai, China*
*chenjl@tongji.edu.cn, 2014lijinwei@tongji.edu.cn*

## Abstract

Pushdown analyses of welded unreinforced flange-bolted web (WUF-B) connection, web cover plated flange (WCPF) connection and reduced beam section (RBS) connection are performed using the finite element (FE) software ANSYS. Based on the component method and failure process of WUF-B, WCPF and RBS connections, simplified numerical models consisted of springs and rigid links are proposed. The parameters of simplified models are obtained from the FE analysis results of the detailed models. The FE analyses of the proposed simplified models, accounting for element failure and erosion, are conducted using explicit time integration in LS-DYNA of ANSYS. The result shows that the proposed simplified models, which are in good agreement with FE analysis results of detailed models, are capable of capturing the primary response characteristics and failure modes of WUF-B, WCPF and RBS connections.

**Keywords:** Progressive collapse; Simplified model; Component model; Steel frame connection.

**TU-13**

# Computer Vision Based Research on Human-induced Load

Ran LI[1] , Jun CHEN[2]

*1 Master student, Department of Structural Engineering, College of Civil Engineering, Tongji University, Shanghai, China, 1732426@tongji.edu.cn*
*2 Professor, Department of Structural Engineering, College of Civil Engineering, Tongji University, Shanghai, China, cejchen@tongji.edu.cn*

## Abstract

Human-induced vibrations refer to the vibrations caused by structural occupants while they are walking, jumping, bouncing, running, dancing, etc. If the induced vibrations exceed a certain level, vibration serviceability problems or even safety problems of structures could happen. In civil engineering, human-induced structural vibration problem has been a long-standing problem which once occurred in many long-span and flexible structures, such as footbridges, cantilever stands and long-span floors. There are several methods applied in the current practice of single load modeling. While the crowd load models do not exist except a few. The biggest difference between single load and crowd load is the synchronization effect. This research intends to adopt a method based on computer vision technology to accomplish data acquisition, which need not to install targets on human bodies. Consuming-level camera, namely, camera of a smart phone is chosen as acquisition device, which spends less than former researchers. Optical flow technology based on point-matching, tracking the movement of objectives and extracting the velocity time history of objectives. To verify the feasibility of proposed measurement method, a bouncing test with two participants bouncing with the metronome frequency 1.5Hz, 2.0Hz, 2.5 Hz, 3.0Hz and 3.5Hz was conducted. The ground reaction forces obtained through computer vision method are compared with that obtained by high precise force plates and The computer vision results are in good agreement with the force plate results.

**TU-14**

# Experimental Investigation and Design Method Research on Full-scaled Concrete Spread Foundation Slab with Large Width-to-height Ratio

Yuanqi Li[1], Xiaoliang Qin[2]

[1,2]*Department of Structural Engineering, Tongji University, Shanghai 200092, China*
*liyq@tongji.edu.cn, qxl1994@tongji.edu.cn*

## Abstract

In actural design, Chinese power industry standard DL/T5219-2014 and Chinese standard GB50007-2011 stipulate that the width-to-height ratio of concrete spread foundation should not exceed 2.5, and meanwhile the eccentricity should not exceed 1/6 of its width. For the foundation with width-to-height ratio greater than 2.5, there is no relevant explanation in Chinese standard. Over the past few decades, the studies mainly focused on the common foundation, in which the width-to-height ratio is no more than 2.5, and the site experimental investigation on behavior of concrete spread foundation slab with large width-to-height ratio have rarely been developed. So, the purpose of this paper is to study the failure mode, and bearing capacity of this type of foundation slab through experimental investigation and numerical simulation. First, several full-scaled concrete spread foundations with width-to-height ratio of 2.5, 3, and 4 were tested outside. Then, the numerical models with width-to-height ratio varied from 2.5 to 5 were built by finite element software ABAQUS, and the numerical results were compared with the test results. Finally, the effective width correction coefficient *k* was introduced to propose a suggested design formula for the concrete spread foundation slab with large width-to-height ratio. The results showed that there was no trapezoidal plastic hinge at the bottom of slab when the foundation was destroyed, and furthermore the failure modes mainly include bending failure, punching shear failure and flexure-punching failure. The results also showed that effective width correction coefficient *k* decreased with the development of width-to-height ratio. This paper can provide a reference for engineering practice in foundation, and it can be used for reference to further work on concrete spread foundation.

**Keywords:** Large width-to-height ratio; Concrete spread foundation slab; Bearing capacity; Site test; Numerical simulation; Suggested design method.

**TU-15**

# Continuous Mechanism for Slurry Trench Stability Analysis in Layered Soils

H.Y. Wang[1], M.S. Huang[2] and J. Yu[3]

[1,2,3] *Department of Geotechnical Engineering, Tongji University, Shanghai 200092, China*

*wanghongyu@tongji.edu.cn, mshuang@tongji.edu.cn, yujiany@aliyun.com*

## Abstract

Most of the existing failure mechanisms for slurry trench stability analysis were derived from rigid block mechanisms. The traditional approach usually produces sufficiently low upper bounds. However, as rigid block mechanism neglects soil deformation, this method fails to replicate actual ground movement induced by trench excavation. The present study proposes a new continuous deformation mechanism to address the stability analysis of slurry-supported trenches in layered c-phi soils. Unlike the conventional rigid block mechanism, the soil mass within the slip surface of the current method deforms continuously based on the compatibility rule for M-C materials. For the convenience of engineering practice, the stability upper bound is produced in terms of the factor of safety by the strength reduction technique. Parametrical studies reveal that the stability upper bounds calculated from the present study are close to the results from the finite element limit analysis (FELA). The corresponding optimal velocity field is also found to be more consistent with the numerical prediction. The proposed method can be applied to the primary stability assessment of slurry-supported trenches in engineering practice.

**Keywords:** Slurry trench; Limit analysis; Continuous mechanism; Layered soils.

**TU-16**

# Application of Wireless Sensing in Shanghai Utility Tunnel

Y.Q. Wu[1], D.M. Zhang[2] and H.W. Huang[3]

[1,2,3] *Department of Geotechnical Engineering, Tongji University, 1239 Siping Road, Shanghai, China.*

*1152344@tongji.edu.cn, 09zhang@tongji.edu.cn, hwhuang@tongji.edu.cn*

## Abstract

Wireless sensing network (WSN) has been widely used in underground structures these years, especially on maintenance period but the construction influence on structures is also vital to the structure sensing in a life cycle way. In this paper, the application of the WSN-based monitoring on utility tunnel during construction was conducted. Four stress sensors, eight wireless tilt sensor nodes and three laser distance sensor nodes were installed to measure the stress and deformation. And two wireless tilt sensors and two laser distance sensors were installed in a cast-in-place tunnel to monitor the influence of live loads to the structure. The relationship between the differential settlement and the joint opening of utility tunnel are discussed. The wireless sensing network is proven to be reliable and practical for the real time monitoring of a utility tunnel. The research findings from this paper also provide an important insight of the stress and deformation changes in the utility tunnel during construction.

**Keywords:** Wireless sensing network; utility tunnel; structural health monitoring.

**TU-17**

# Meso-scale Simulation of Bond Behavior Between Retarded-bonded Prestressed tendon and concrete

Q.S. Xiao[1], X.Y. Xiong[2]

[1,2]*Department of Structural Engineering, College of Civil Engineering, Tongji University, Shanghai, 200092, China*

*1610228@tongji.edu.cn, xueyu@tongji.edu.cn*

## Abstract

Retarded-bonded prestressed tendon is a kind of composite tendon, which consists of prestressed steel strand, retarded-bonded material, covering tube. Before construction, the liquid state retarded-bonded material is pre-grouted into the tendons. After construction, the liquid retarded-bonded material turns into solid. When the retarded-bonded material has solidified, it can provide the cohesive force to make prestressed steel strand and concrete work together in service life. In this paper, based on Cohesive Zone Model, a meso-scale model for the simulation of the bond behavior between retarded-bonded prestressed tendon and concrete is developed. The model can simulate the nonlinear bond behavior through simulating the fracture, friction and collision behavior of concrete. The simulation results can obtain satisfied effect in both mechanical characteristics and failure mode. The results show that, the frictional stress can constrain crack propagation and reestablish loading path in the softening stage, which enhances the residual bearing capacity of the specimens.

**Keywords:** Retarded-bonded prestressed tendon; Concrete; Bond behavior.

**TU-18**

# Tri-axial experiment on the influence of stress paths on clay in deep excavation

N. Xu[1], X.T. Liu[2], Y.S. Deng[3] and J.X. Wang[4]

[1,2,3]*Department of Geotechnical and Underground Engineering, Tongji University, Shanghai 200092,China*

*1710758@tongji.edu.cn, 2012liuxiaotian@tongji.edu.cn, 308851237@qq.com jianxiu_wang@163.com*

## Abstract

The response of soil to deep excavation is vital for foundation pit safety and surrounding buildings, pipes and other constructions protection. With a deep underground space exploration case of Shanghai as background, tri-axial stress path is designed to simulate the influence of the excavation on a typical clay element of a foundation pit. The behavior of the clay samples of the active and passive zones of a deep foundation pit is studied using the experiments. Distinct cases are tested including different unloading rates and different buried depths of clay. The stress-strain relationship and the change of pore pressure on undisturbed soil under different stress paths are studied. Based on the experiments, the constitutive relationship of clay is analyzed and discussed. The results can be referred in the design and optimization of a foundation pit to keep foundation pit safety and prevent urban geological hazards.

**Keywords:** Tri-axial experiment; Stress paths; Clay; Deep excavation.

**TU-19**

# An Integrated Method Based on the Probability Density Evolution Method for Structural Optimization Considering Dynamical Reliability

Jiashu Yang[1], Jianbing Chen[2] and Hector Jensen[3]

[1,2]*Department of Structural Engineering, School of Civil Engineering, Tongji University, 200092, Shanghai, China*
[3]*Department of Civil Engineering, Santa Maria University, Valparaiso, Chile*
*jiashuyang@tongji.edu.cn, chenjb@tongji.edu.cn, hector.jensen@usm.cl*

## Abstract
Structural optimization is widely recognized as a powerful approach to the tradeoff between the structural performance and cost. Therefore, great efforts have been devoted to this field in the past several decades. However, variability in structural performance induced by uncertainties in material properties, geometry dimensions and loading conditions is unavoidable and in many cases non-negligible. As a result, constraints on structural reliability or failure probability should be introduced in structural optimization problems. Several methods for structural optimization problems with constraints on static reliability have been developed, but these methods are not appropriate for dynamic reliability-based design optimization (DRBDO) problems where dynamic actions, such as earthquakes, wind and sea waves, are taken into account. In this paper, an integrated method based on the probability density evolution method (PDEM) for DRBDO problems is presented. To enhance the efficiency of the reliability analysis, metamodels in terms of augmented random variables, i.e., both random variables and design variables, are employed to approximate the dynamic response of structures. Since all the design variables are comprised in the input of the metamodels, the sensitivity of reliability with respect to design variables can be estimated without any extra deterministic structural analyses. Finally, several numerical examples are included to demonstrate the effectiveness and validity of the proposed method. Problems to be further studied are also discussed.
**Keywords:** Dynamic reliability-based design optimization; Probability density evolution method; Metamodels; Augmented space.

**TU-20**

# A Study on The Constitutive Model of Structural Steel Plasticity with Lode Angle Dependence

Zucheng Yao[1], Wei Wang[2] and Liangjiu Jia[3]

[1,2,3]*Department of Civil Engineering, Tongji University, Shanghai 200092, China*
*yaozucheng@tongji.edu.cn, weiwang@tongji.edu.cn, lj_jia@tongji.edu.cn*

## Abstract
The classical J2 theory of metal plasticity assumes that the effect of stress states on plastic flow is negligible, which is not accurate enough in the situations of determining local states of stress and strain, such as application to predict the fracture initiations of metal. This study aims to describe the elastoplastic behavior of structural steel under cyclic loadings with the consideration of Lode angle dependence. A Lode angle-dependent coefficient to define the shape of yield surface and modify the isotropic hardening of structural steel is developed and discussed firstly. Subsequently, a new constitutive model that combines the nonlinear kinematic hardening and nonlinear isotropic hardening, is formulated with a non-associative plastic flow rule. This model additionally couples the isotropic hardening with a memory surface in the plastic strain space to account for the stabilization of hysteresis loop. Calibration and verification of the proposed plasticity model are performed through numerical simulations of monotonic and cyclic tests on uniaxial plate specimens and pure shear specimens of Q235 structural steel.
**Keywords:** Plasticity model; Lode angle dependence; Structural steel; Cyclic loadings.

**TU-21**

# A Safety Management System Based on Faster-R-CNN and BIM

Bin Yang[1], Binghan Zhang[2]

[1,2]*Department of Structural Engineering, Tongji University, 1239 Siping Road, Shanghai, China.*

*yangbin@tongji.edu.cn, zhangbinghan@tongji.edu.cn*

## Abstract

Safety is always a serious problem in construction site. In the first half year of 2018, more than 1700 accidents led to 1752 death in China. Video camera is an important source for on-site information. However, the traditional safety management method depends greatly on manpower. Deep learning and computer vision based object detection can solve this problem. This paper proposes a framework of automated safety check. The process of the framework can be divided into 3 parts as Fig.1 shows. First, on-site cameras are used to collect on-site video and image data. The second part is object detection based on Faster-R-CNN method. The category and position of the detected object will be output in this stage. Finally, the object will be input into a BIM model through a coordinate transformation and provide safety check result. This paper also proposes a dataset enhancement method based on visualization BIM to enhance the accuracy of object detection when the dataset is relative shortage.

**Keywords:** BIM; Deep learning; Construction safety.

**TU-22**

# Investigation of longitudinal performance of tunnel due to surface surcharge considering soil spatial variability

J.Z. Zhang[1], H.W. Huang[2] and D.M. Zhang[3]

[1,2,3]*Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai, China*

*zhangjz@tongji.edu.cn, huanghw@tongji.edu.cn, 09zhang@tongji.edu.cn*

## Abstract

The inherent spatial variability of soil properties will lead to an uncertainty in the predicted performance of the embedded geotechnical structure especially for the slender tunnel. Surface surcharge is regarded to be one of the main factors that will cause large deformation of tunnel. Under the influence of external disturbance and internal soil spatial variability, the uncertainty of tunnel longitudinal performance will be greatly increased. Probabilistic analysis is often used to assess its performance considering uncertainty for such uncertain system. A new framework for the probabilistic analysis of tunnel longitudinal performance consider soil spatial variability was proposed. Within this framework, the random finite difference method (RFDM) is used to simulate the spatial variation of soil properties along the tunnel longitudinal direction. Monte Carlo simulations (MCS) approach is combined with finite difference analysis, therefore the variation of tunnel performance along the longitudinal direction can be assessed. The significance of this proposed framework compared with the deterministic analysis method are demonstrated through an illustrative example. The results show that it is necessary to consider the soil spatial variability.

**Keywords:** Spatial variability; Surface surcharge; Longitudinal performance.

**TU-23**

# Seismic Response Characteristics of Steel Frames Coupled with Dual-Rocking Energy-Dissipated Structures

W.J. Zhang[1], G.Q. Li[2] and Y.B. Wang[3]

[1,2,3] *College of Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, China*
*1150744@tongji.edu.cn, gqli@tongji.edu.cn, ybwang@tongji.edu.cn*

## Abstract

Coupling rocking structure and energy-dissipating elements with steel frames is capable of controlling structural deformation shape to prevent weak story and decreasing dynamic response under earthquakes, which significantly improves the seismic performance of main frame structures. However, the demand on the stiffness of normal continuous rocking structure increases dramatically with the height of main frame structures and creates difficulties for application in high-rise buildings. In order to overcome this problem, a dual-rocking structure with energy-dissipating elements is proposed.

The dual-rocking structure consists of two sub-rocking structures in series with one located at the top of another. The sub-rocking structure can be fabricated with concrete shear wall or steel truss. The lower sub-rocking structure is designed to rock at the bottom and the upper one is designed to rock at the top of the lower sub-rocking structure. Buckling-restrained steel struts (BRSs) are inserted at the bottom of sub-rocking structures to provide lateral stiffness and energy-dissipating function.

The dual-rocking structure with BRSs and without BRSs is applied to high-rise steel frames and compared with traditional braced frames, frames with normal continuous rocking structure with BRSs and without BRSs. Elastoplastic analytical models of these five structural systems are established with software OpenSees. The advantages of dual-rocking energy-dissipated structure are observed through comparative analysis with pushover analysis approach, time-history analysis approach and incremental dynamic analysis approach.

It is found from the analytical results that the steel frames coupled with dual-rocking structure have better seismic performance than that with traditional braces or coupled with normal continuous rocking structure. The dual-rocking structure is able to prevent weak story of high-rise steel frames with much less demand of stiffness. The utilization of BRSs in dual-rocking structure can further reduce dynamic response of steel frames for high-rise buildings under severe earthquakes.

**Keywords:** dual-rocking structure; high-rise building; weak story prevention; buckling-restrained strut; seismic performance.

**TU-24**

# DEM simulations of drained and undrained behaviors of sand

Jiachen Zhang[1], Xiaoqiang Gu[2]

[1,2]*Department of Geotechnical Engineering, Tongji University, Shanghai 200092, China*
*zhangjiachen@tongji.edu.cn, guxiaoqiang@tongji.edu.cn*

## Abstract

In this paper, discrete element method is used to simulate the triaxial tests of sand, which reproduces the macroscopic phenomena in laboratory tests and analyze the mechanical behaviors of sand. The tests on Japanese standard sand, Toyoura sand, are simulated and its particle-size distribution curve is adopted in the simulation. Rolling resistance linear contact model is chosen to consider the rolling resistance induced by the particle shape and the contact parameters of Toyoura sand are calibrated referring to the axial strain-deviatoric stress curves and axial strain-volumetric strain curves in experiments. The effects of different relative densities, confining pressures and loading paths on the mechanical behaviors of sand are analyzed by using the calibrated parameters. Comparing with the critical state lines obtained by experiments, the results show that the $q$-$P'$ curves in DEM are basically consistent with the experiments, while the trend of $e$-$P'$ curves in DEM is consistent with the experiments although they are lower than the experiments. On this basis, cyclic triaxial tests under undrained condition are simulated to study the deformation modes and liquefaction resistance of sand. The relationship between the cyclic stress ratio (CSR) and the corresponding number to cause initial liquefaction is determined and it is compared with the experimental results.

**Keywords:** Discrete element method; Rolling resistance; Critical state; Cyclic loading; Liquefaction.

**TU-25**

# High Damping Rubber Bearings: A Review with Emphasis on Deformation-history Integral Type Model

X.R. Hu[1], Z.G Zhou[2]

[1,2]*Department of Disaster Mitigation for Structures, Tongji University, Shanghai 200092, China*
*hu_xiao_rong@tongji.edu.cn; zgzhou@tongji.edu.cn*

## Abstract

As a kind of environmentally friendly seismic isolators with good energy dissipation and damping performance, the high-damping rubber bearings (HRB) have been used in seismic isolation applications for buildings and bridges. However, because of the strongly nonlinear stress-strain relationship of HRB which depends on vertical stress, strain rate, path history, temperature, age, etc., it is difficult to evaluate the behavior of such isolators. This paper reviews comprehensively the research achievements in terms of mechanical behavior of the HRB, and summarizes several kinds of constitutive models which can accurately simulate the mechanical properties of HRB. Specially, a hysteresis model called deformation-history integral type model (DHI model) is considered to be efficient and computationally simple. Analysis results of hysteresis loop and time history analysis using DHI model are presented which fully demonstrate the mechanical characteristics under different loading conditions of the HRB modeled by DHI model.

**Keywords:** high-damping rubber bearings (HRB); deformation-history integral type model (DHI model); seismic isolation; hysteresis model, time history response analysis

**TU-26**

# Fatigue Evaluation of UHPC-Orthotropic Steel Composite Deck

Y. Huang[1], S.M. Chen[2]

[1,2]*College of Civil Engineering, Tongji University, Shanghai 200092, China*
*huangyang@tongji.edu.cn, chensm@ tongji.edu.cn*

## Abstract

UHPC-orthotropic steel composite deck is an innovative and efficient bridge deck system, however the failure mode of this composite bridge deck under fatigue load is still not well understood, particularly when the deck is in hogging bending. To investigate the fatigue behavior of the UHPC-orthotropic steel composite deck, two multi-span full scale composite bridge decks in hogging bending were experimentally studied. Tests revealed that among the all fatigue-prone details of an orthotropic steel deck, only the longitudinal cracks were observed occurring in the low portion of rib web which was near the weld toe of the rib to the transverse diaphragm. The fatigue strength of these specific cracks longitudinally orientated can be evaluated in a term of the vertical stress range of the rib below the weld toe under the fatigue details category C of AASHTO or category 71MPa of Eurocode3. Shear connection failure of the composite deck was also found featuring with delamination between UHPC and steel bridge deck. Fatigue damage of the short headed studs was further inspected and evaluated by means of drilling test. The fatigue shear connection strength of the composite bridge deck can be assessed conservatively in a term of the fatigue shear strength of the headed studs.

**Keywords:** UHPC-orthotropic steel composite deck; Fatigue failure mode; Longitudinal crack; Shear failure; Fatigue strength.

**TU-27**

# A mesoscale modeling method of concrete material with refined aggregate shapes based on image recognition

Yue Li[1], Xin Ruan[2] and Zeren Jin[3]

[1,2,3]*Department of Bridge Engineering, Tongji University, Shanghai 200092, China*

*yueli@tongji.edu.cn, ruanxin@tongji.edu.cn, jinzeren@163.com*

## Abstract

Numerical simulation of concrete has become widely accepted. However, the aggregate shape modeling still needs to be improved, which is critical. In this paper, a modeling method is proposed based on cross-section image recognition. The geometrical data of 4407 particles are extracted, and probability distributions are investigated. The parameter rules are remarkable, and recommended functions are provided for simulation. The aggregate model is refined to a three-level framework, including size, aspect ratio, and surface texture. To investigate the method effect, experiments on 800 models are conducted. The results show that it is necessary to control aspect ratio for accurate simulation.

**Keywords:** Concrete; Modeling; Meso-scale; Aggregate shapes; Image recognition

**TU-28**

# Experimental Study on Grout Defects Identification in Precast Column Based on Wavelet Packet Analysis

X. Zhang[1], D.Y. Zhou[2] and H.S. Tang[3]

[1,2,3]*Research Institute of Structural Engineering and Disaster Reduction, Tongji University, Shanghai 200092, China*

*muzixuan@tongji.edu.cn, concrete@126.com, thstj@tongji.edu.cn*

## Abstract

Precast structures with rebars splicing by grout sleeves have been used widely. Grout defects always exist in sleeves in practical engineering, while few studies on grout defects identification are performed. Therefore, this paper proposes a combination of dynamic excitation technique and wavelet packet analysis for the sleeve defects identification in precast concrete frame structure. Hammer excitation on a 1/2-scaled two-floor precast concrete frame structure with column rebars splicing by grout sleeves is conducted to collect the column acceleration response signals. The corresponding energy spectrum based on wavelet packet analysis is obtained to reflect the grout defect state in column. Then, three defects identification indices percentage of energy transfer ( PET ), energy ratio variation deviation ( ERVD ) and energy spectrum average deviation ( ESAD ) are calculated for comparison. Robustness analysis of ERVD is carried out by adding white noise in original acceleration response signals. The results show that PET, ERVD and ESAD positively correlate with the grout defect degree, and ERVD is more sensitive in defect identification. The ERVD robustness of original signal with multiplicative white Gaussian noises inputted is better than that with additive white Gaussian noise is inputted. The proposed defect identification method can characterize the sleeve grout defects degree in column.

**Keywords:** Grout defects identification; Wavelet packet analysis; Precast column.

**TU-29**

# Application Study on the Rubber-Sleeved Stud Connectors in the Cable-tower Composite Anchorage

Bozhou Zhuang[1], Shuangjie Zheng[2], Xiaoqing Xu[3] and Yuqing Liu[4]

[1]*Department of Bridge Engineering, Tongji University, Shanghai 200092, China*
[2]*College of Civil Engineering, Huaqiao University, Xiamen 361021, China*
[3]*School of Civil Engineering, Chongqing University, Chongqing 400045, China*

*zbz@tongji.edu.cn, sjzheng@hqu.edu.cn, xq.xu@cqu.edu.cn, yql@tongji.edu.cn*

## Abstract

The Forth Tuojiang River bridge in China is a single tower cable-stayed bridge with double cable planes. The cables are anchored on the concrete tower by the Steel Anchor Box (SAB), forming the cable-tower composite anchorage. The longitudinal cable force is mainly born by SAB while the vertical one is shared by the tower through shear connectors. In the cable-tower composite anchorage of this bridge, the Rubber-Sleeved Stud (RSS) connectors are employed to mitigate the connector shear force on the steel-concrete interface edge. In order to reveal the application performance of RSS connectors, the Finite Element (FE) analysis on the cable-tower composite anchorage was conducted. Research results show that the maximum shear force could be significantly decreased and the connector shear force distribution is more uniform when RSS connectors are adopted in the steel-concrete interface. Besides, the maximum longitudinal tensile stress of concrete tower could be reduced to 4 MPa from 7 MPa. Therefore, the RSS connector is able to improve the mechanical performance of cable-tower composite anchorage.

**Keywords:** Rubber-Sleeved Stud connector; Cable-tower composite anchorage; FE analysis

**TU-30**

# Method for assessment of building function loss in an earthquake based on fuzzy logic

Haifeng Bu[1], Huanjun Jiang[2]

[1,2] *Department of Disaster Mitigation for Structures, Tongji University, Shanghai, 200092, China*

*bhf@tongji.edu.cn, jhj73@tongji.edu.cn*

## Abstract

A function loss assessment method based on fuzzy logic is proposed for buildings subjected to an earthquake, by using a quantification index of component losses and top function loss for each story. Fuzzy mapping and fuzzy operators are adopted to quantify the function loss of components and organize logic trees, respectively. A case study involving a ten-story RC building structure is provided, which demonstrates the reasonability of this method. Furthermore, story interactions of the building are also considered. Results demonstrate that stories with interactions have more function loss than corresponding independent stories. Difference of function loss between interactions and independence increases with floor number.

**Keywords:** Seismic resilience, Function loss, Fuzzy logic, Index quantification

**TU-31**

# Hydrodynamic Characteristic of A Porous Cube Artificial Reef: An Experimental Study

Y.H. Zheng[1], C.P. Kuang[2]

[1,2]*Department of Hydraulic Engineering, College of Civil Engineering, Tongji University, Shanghai, 200092, China*
*yuvaz@sina.com, cpkuang@tongji.edu.cn*

## Abstract
Artificial reefs are common auxiliary structures in coastal engineering. In this study, a flume experiment is conducted to study on the flow structure inside and outside a porous cube artificial reef by means of ultrasonic probes and Particle Image Velocimetry (PIV) method. The influence of the reef on water level and flow fields in vertical and horizontal directions were analyzed. The results show that: 1) the water level on two sides of reef gradually decreases and water level over the reef changes greatly along the course, which indicates the reef can reform the flow regime; 2) in vertical flow field, several pairs of vortices are generated inside the reef due to the interaction between inflow current from the stoss face holes and backflow behind the reef, and the outflow current through the reef crest holes enhances the water exchange over the crest; 3) in horizontal flow fields, a pair of wake vortices formed behind the reef strengthen the water exchange between inside and outside the reef, and the near crest flow field generates more and larger vortices with weaker velocity than that in the near bottom flow field owing to more energy dissipation. The study reveals the flow structure characteristics and exchange mechanism of current inside and outside the reef, which provides a scientific guidance for optimizing the reef design and effectively controlling the reef-induced flow field.
**Keywords:** Artificial reef, Flow structure, PIV, Vortex.

**TU-32**

# Return period of low tide level in the Yangtze Estuary based on nonstationarity analysis

Y.C. Zhou[1], Q Li[2] S.G. Liu[3] and S Lou[4]

[1,3,4] *Department of Hydraulic Engineering, Tongji University, Shanghai 200092, China*
[2] *Shanghai Hydrology Administration, Shanghai 200232, China*
[3] *Key Laboratory of Yangtze River Water Environment, Ministry of Education, Tongji University, Shanghai 200092, China*
*1730107@tongji.edu.cn, swzzlq@126.com, liusgliu@tongji.edu.cn, lousha@tongji.edu.cn*

## Abstract
Due to the influence of climate change and human activities, stationarity of hydrologic time series is being challenged. The Yangtze Estuary is a region with highly developed hydraulic structures and shipping. Stationarity analysis of water level in the Yangtze Estuary is of great significance. In this study, the return period of low tide level in the Yangtze Estuary is estimated with nonstationarity considered. Conventional frequency analysis and the time-varying moment method are used to analyze the annual minimum tide level (AMTL) records of Wusongkou Station and Baozhen Station on the basis of temporal change analysis. Abrupt changes are detected at 1996 and 1990 for Wusongkou Station and Baozhen Station separately. The GEV distribution with linear time-varying parameter fits best for Wusongkou Station and Baozhen Station. The AMTL series of both stations reveal a slight increasing trend. The 100-year low tide level of Wusongkou Station is approximately 0.261 meters, which is about -0.041 meters for Baozhen Station. The corresponding return period is 150 years and 119 years respectively, which indicates the existing channel standard more secure and the recalculation of design water level necessary in the Yangtze Estuary.
**Keywords:** nonstationarity; Yangtze Estuary; low tide level; time-varying moment method.

**TU-33**

# General and Pitting Corrosion Behavior of Q345 Steel under Salt Spray Environment

Cui Chuanjie [1], Ma Rujin [2], Chen Airong [3]

[1,2,3] *College of Civil Engineering, Tongji University, Shanghai 200092, China*

*1810033@tongji.edu.cn, rjma@tongji.edu.cn, a.chen@tongji.edu.cn*

## Abstract

Corrosion is one of the most common but destructive hazards of steel structures in offshore construction and maintenance which can lead to accelerated failure of components. In this research, the corrosion behaviour of Q345 steel, which is widely used in civil engineering structures, is analyzed by both the salt spray accelerated test and the numerical simulation method. Among which, the general corrosion is evaluated by the mass loss and the thickness loss of the specimens while the pitting corrosion is counted by the super-high magnification lens zoom 3D microscope. The general corrosion is simulated based on the COMSOL software and the pitting corrosion is reproduced by the 3D cellular automata model. The results show that the COMSOL simulation fit well to the experimental data with the same corrosion environments. For the pitting corrosion analysis, the Non-Homogeneous Poission Process (NHPP) and the unsteady logarithmic Gaussian distribution (ULGD) can properly describe the evolution process of the corrosion pits of Q345 steel according to the fitting results of test data. The 3D cellular automata model can better reflect the evolution randomness as well as the time-varied laws of the initiation and growth processes of corrosion pits. (This research is supported by National Natural Science Foundation of China, Contract No. 51878493).

**Keywords:** General corrosion; Pitting corrosion; Q345 steel; Salt spray environment; Numerical simulation.

**TU-34**

# Analysis of Vibration Isolation Performance of Bridge Basin Rubber Bearing and Spherical Steel Bearing

B. Wang[1], D.J. Wu[2] and Q. Li[3]

[1,2,3]*Department of Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, People's Republic of China*

*wangbing89@tongji.edu.cn, tjwdj@tongji.edu.cn, liqi_bridge@tongji.edu.cn*

## Abstract

For the research of how bridge bearing influences the vibration performance of urban rail transit bridge, the vertical stiffness characteristics of the basin rubber bearing and the spherical steel bearing used in Shanghai Rail Transit are obtained through laboratory test, and their vibration isolation performance are examined by field test. In addition, The simulation calculation was carried out by using the self-assembled vehicle-bridge coupled vibration analysis software VBC of Tongji University to analyze the effects of the vertical stiffness characteristics of the bridge bearing on the vibration of bridge beam and pier. The results show that with the increase of bearing vertical stiffness, the vertical vibration of the beam bottom at the bearing area is attenuated in the frequency band of 31.5~80Hz, but the vibration difference between the beam and the top of pier is reduced, so that the vertical acceleration of pier top has increased in the high frequency band (above 125 Hz).

**Keywords:** bridge bearing; vibration isolation performance; vertical stiffness.

**TU-35**

# Steel-concrete shear mechanism of steel reinforced concrete composite bridge

Xianlin Wang[1] and Yuqing Liu[2]

[1,2] *Department of Bridge Engineering, Tongji University, Shanghai, China*
*1810747@tongji.edu.cn, yql@tongji.edu.cn*

## Abstract

This paper introduced some numerical simulation methods of natural bond at steel-concrete interface and several bond-slip constitutive models. Then, three-dimensional nonlinear FE models of SRC push-out tests were established. The applicability of different bond-slip models was discussed. According to numerical results, the shear transferring mechanism was investigated later. Based on the verified modeling method, parametric analysis was performed to investigate the influence of different parameters. The results show that the best agreement with the experimental results is achieved by the linear-exponential model. Due to different rates of damage in various bond-slip models, the corresponding level of bond stress is different. The interfacial bond stress is saddle like distributed along the bonded length. As the maximum bond stress and friction coefficient increase, the bond stress increases. The post-peak softening rate of the load-slip curve significantly improves with the increasing of exponential function coefficient.

**Keywords:** Composite bridge, Steel reinforced concrete, Natural bond, Shear mechanism, Finite element analysis.

**TU-36**

# Determination of Drying and Wetting Soil Water Characteristic Curves by Flow Pump Technique

Yi-Wen Cui[1], Le-Dong Zhu[2]

[1] Department of Bridge Engineering, College of Civil Engineering, Tongji University, China,
*e-mail: 1732323@tongji.edu.cn*
[2] *State Key Laboratory of Disaster Reduction in Civil Engineering / Department of Bridge Engineering, college of Civil Engineering / Key Laboratory for Wind Resistance Technology of Bridges (Ministry of Transport), Tongji University, China,*
*e-mail: Ledong@tongji.edu.cn*

## Abstract

A direct measurement of flutter self-excited force on a spring-suspended sectional model of a flat box section was carried out for various cases of attack angles and wind speeds by using four deliberately-manufactured small dynamic force balance mounted inside the model. On this basis, a refined unsteady and nonlinear mathematical model was proposed to express the flutter self-excited force, and verified through comparing the calculated displacement response with the measure one. This refined model was then simplified by including only the aerodynamic damping force components for predicting the stable amplitude of flutter. The nonlinear behaviours as well as the driving and self-limited mechanisms were discussed from the view angles of energy evolution rules of different components of nonlinear flutter force by means of hysteresis plots. The evolution of total damping of the oscillation sectional model system under flutter as well as its different damping components during the whole procedure of the flutter development were also investigated to help to a better understanding on the mechanisms of the driving power source and the inherent factor of self-limited phenomenon of flutter.

**Keywords:** flat box section,flutter, nonlinear, self-excited force, mathematical model

**TU-37**

# Seismic fragility analysis of ultra-high ductility cementitious composite frame structure without steel reinforcement using incremental dynamic analysis

F.Y. Dong[1], J.T. Yu[2] and K.L. Zhan[3]

[1,2,3]*College of Civil Engineering, Tongji University, Shanghai 200092, China*
*dongfangyuan@tongji.edu.cn, yujiangtao@ tongji.edu.cn, kailizhanxm@163.com*

## Abstract
This paper numerically studies the seismic vulnerability of an ultra-high ductility cementitious composite (UHDCC) frame structure without steel reinforcement. The mechanical properties of UHDCC are observed by conducting compressive uniaxial tension test, compression tests and four-point bending test. The nonlinear finite element model of UHDCC-RC frame whose beam-column joints of reinforced concrete frame are replaced by UHDCC is established and verified against the corresponding experimental results. The above finite element analysis proves the validity for Pinching 4 model simulate the constitutive models of UHDCC material. An UHDCC frame structure is built using OpenSees and the structural seismic vulnerability is performed to evaluate its seismic behavior based on incremental dynamic analysis method. Finally, seismic vulnerability matrix of UHDCC frame structure under various structural limit states is obtained from seismic fragility curves. The results demonstrate that UHDCC frame structure satisfies the Three-level performance objectivity "Undamaged under minor earthquake, repairable under moderate earthquake, no collapsed under major earthquake" stipulated in GB 50011-2010. This research preliminary verifies the feasibility for constructing frame structures with pure UHDCC.
**Keywords:** Ultra-high ductility cementitious composite; seismic fragility analysis; incremental dynamic analysis.

**TU-38**

# Localized Corrosion Induced Damage Detection of Large-scale Reinforced Concrete Piles Using Acoustic Emission Technique

Y.J Zhou[1], Y.B. Zhou[2] and Y.L. Zheng[3]

[1,2,3]*Department of Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, People's Republic of China*

*1710202@tongji.edu.cn, yubaozhou@tongji.edu.cn, 00016@tongji.edu.cn*

## Abstract
An experimental study was conducted to apply acoustic emission (AE) technique to monitor the corrosion process and cracking behavior in large-scale RC pile specimens. In this study, six RC piles were exposed to accelerated, localized corrosion at underwater and tidal zones in the simulated marine environment to reach 5%, 10% and 20% of steel mass loss. The two piles of 20% of steel mass loss and another reference pile without corrosion were continuously monitored during the test via three attached AE sensors. The results showed that tidal action had a significant impact on the AE signals, accordingly, a novel Amplitude-Duration-Peak frequency based AE signal filter (ADPF) was proposed, which achieved better performance than the previous Amplitude-Duration based filters. Additionally, it was found that the conjoint analysis of AE signals and the fractal dimension of cover cracks throughout the corrosion period enabled the global detection of localized corrosion-induced damage of piles, regardless of sensor location. This study also presents an integrated corrosion-induced damage detection framework and four models based on the MLP-network to predict the corrosion level of piles at underwater and tidal zones in the marine environment.
**Keywords:** Localized corrosion; Piles; Marine environment; Acoustic emission (AE); Machine learning

**TU-39**

# Experimental Research on Hydrodynamic and Morphological Responses of the Submerged Artificial Sandbar to Irregular Waves

X.J. Han[1], C.P. Kuang[2] and Y. Ma[3]

[1,2,3] *College of Civil Engineering, Tongji University, Shanghai, China.*
*Hanxuejian11@live.com, cpkuang@tongji.edu.cn, mayue_mavis@tongji.edu.cn*

## Abstract

Coastal erosion is one of the most common marine disasters in the world, especially in China due to a mass of dams built in rivers, rapid urbanization, large scale coastal engineering and so on. Beach nourishment, as an effective measure for preventing coastal erosion, supplies the sediment to eroded coast and meanwhile avoids adverse effect induced by hard structures. As one component in beach nourishment, artificial sandbar has been increasingly used as a coastal defense method recently, because it performs as a feeder supplying sand to the shore and dissipates the incoming wave energy as well. It has been applied in nourishment projects in Beidaihe, China to restore and develop the tourist beaches suffered serious erosion.

To study the responses of the submerged artificial sandbar in Beidaihe to irregular waves, a series of experiments were performed in a wave flume under five different irregular wave patterns. The trapezoid-shaped model sandbar consists of resin model sand with a 3m-long flat crest and both seaward and landward slope of 1:10. The wave height and period were recorded by nine wave gauges, and the current velocity along the sandbar was measured by three ADVs (Acoustic Doppler Velocimeter). Wave dynamic, sediment suspension process and morphological evolution of sandbar were captured by cameras. Besides, Optical Back Scattering (OBS) is set about 3m behind the sandbar to record the turbidity caused by the wave. The morphological changes of sandbar were quantitatively obtained by video calibration and analysis method.

It is concluded that the total wave energy decreases with an increase in high frequency domain due to the effect of sandbar. According to the velocity data, it is found that the turbulent kinetic energy reaches peak with wave breaking on the sandbar crest. By observation, the turbid layer thickens with the increase of wave height, and the turbidity data imply that the sandbar can feed the area behind it and thus decrease the erosion at the beach. In addition, the erosion area and volumes of the sandbar are also been obtained and compared under the five wave sets. The cross-shore profile of sandbar has evolved significantly from a symmetrical shape to a highly asymmetrical shape with a steep landward slope and a mild seaward slope, due to erosion on the seaward slope and siltation on the landward slope in strong wave conditions.

**Keywords:** Artificial sandbar; Irregular wave; Wave surface elevation; Velocity change; Turbidity; Morphological response.

**TU-40**

# Seismic Resilience-Based Rating of Energy Dissipation Building Structures

Ying Zhou[1], Guangchun Zhong[2] and Yi Xiao[3]

[1,2,3] *State Key Laboratory of Disaster Reduction in Civil Engineering, Tongji University; 1239 Siping Road, Shanghai, China*
*yingzhou@tongji.edu.cn, 1732352@tongji.edu.cn, yixiao@tongji.edu.cn*

## Abstract

Resilience describes the recover capability of structures or cities after earthquakes or other disasters. In recent years, earthquake engineering researchers have been beginning to concentrate on designing a resilient structure which can achieve rapid functional recovery after strong earthquakes. Resilient structures can not only protect properties of residents but also help people regain normal life soon. To quantify structures' resilience, an effective method is needed to evaluate structures' earthquake resilience function characteristics. This paper presents an assessment of the seismic resilience of a 7-story reinforced concrete frame office building of a Power Gas Company in Dujiangyan, which experienced the 2008 Wenchuan Earthquake. Nonlinear response history analysis were conducted. The peak ground accelerations (PGA) were scaled to 0.07 g, 0.2 g and 0.4 g which correspond to the PGA under minor, moderate, and major earthquakes of intensity 8 in Chinese codes. Furthermore, in order to achieve increased levels of resilience, structural and nonstructural enhancement strategies were proposed. Viscous dampers were designed to retrofit the case building based on a two-stage design process. In addition, nonstructural components of the case building were retrofitted. The results indicate that seismic energy dissipation design and nonstructural components enhancement can improve the seismic resilience of building structures effectively.

**Keywords:** Seismic resilience-based rating, FEMA P-58, REDi, USRC, Viscous dampers, Nonstructural elements retrofit.

**TU-41**

# Flexural behavior of reinforced ultra-high performance engineered cementitious composites (UHP-ECC) beams：Experiment and analytical model

Z.W. Cai[1], K.Q. Yu[2] and Z.D. Lu[3]

[1,3] *Department of Disaster Mitigation for Structures, College of Civil Engineering, Tongji University, Shanghai 200092, China*
[2]Department of Civil and Environmental Engineering, University of Michigan, Unit
*caiziwei@tongji.edu.cn, 12kequan@tongji.edu.cn@, lzd@tongji.edu.cn*

## Abstract
Ultra-high performance engineered cementitious composites (UHP-ECC) has ultra-high mechanical properties with the mean tensile strength of 16 MPa, the tensile strain capacity of around 8 % and the compressive strength of 119.6 MPa. To investigate the feasibility of structural application of reinforced UHP-ECC, a total of eight specimens, inluding two unreinforced UHP-ECC specimens, three reinforced concrete beams and three reinforced UHP-ECC beams were designed. The reinforcement ratios of both concrete beams and UHP-ECC beams of were 0.69%, 1.86% and 2.94%, respectively. The crack propagation, failure modes, load-midspan deflection curves, strains of longitudinal bars and UHP-ECC of different specimens under the four-point bending test were compared. The test results show that UHP-ECC has higher flexural capacity and better ductility than concrete beams with the same ratio of reinforcement. With the increase of reinforcement ratios, the flexural capacity of UHP-ECC beams increases significantly. Based on the test results, a simplified analytical model of UHP-ECC beams under bending was established, and the calculation formula for the sectional flexural capacity of UHP-ECC beams was deduced. The prediction results are in good agreement with the test results. The effects of reinforcement ratio, specimen size and mechanical properties of UHP-ECC on the bending behavior of reinforced UHP-ECC beams were futher studied. The reinforced UHP-ECC beams exhibit excellent flexural performance and can be used in structural members.
**Keywords:** Engineered cementitious composites; Flexural performance; Analytical model; Reinforced concrete beams

**TU-42**

# Sensitivity Analysis for Bridge Effect based on Vehicle Mass Flow Parameter Information

X.J. Wang[1] and X. Ruan[2]

[1,2]*Department of Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, People's Republic of China*

*1182606854@qq.com*

## Abstract
In order to study the sensitivity of various overall effects for long-span cable-stayed bridges to traffic flow parameters, and then obtaining the traffic flow evaluation model based on traffic flow characteristics and effect sensitivity, traffic flow data with large differences in characteristics of five bridges from different sites were analyzed in this study. At the same time, the overall effect characteristics of three long-span cable-stayed bridges in service in China were analyzed by means of the influence line. Based on the research of traffic flow characteristics, the mass flow parameter spectrum describing the traffic information within a certain period of time is established, and the sensitivity of various characteristic effects to the traffic flow parametric spectrum type is analyzed. The results show that there are significant differences in the sensitivity of different types of characteristic effects to various vehicle flow parameters. It is necessary to establish a specific traffic flow evaluation model for various types of effects combined with predictable traffic flow parameter types at the bridge site.
**Keywords:** vehicle mass flow; parameter spectrum; characteristic effect; traffic flow evaluation model.

**TU-43**

# Effects of Center Column Enhancement on Seismic Performance Improvement for Underground Structures

C.Z. Yue[1], Z.L. Zheng[2]

[1,2]*Department of Civil Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, People's Republic of China*
*ycz_hao@sina.com, zyll@tongji.edu.cn*

## Abstract
Central columns have long been demonstrated to play a vital role in withstanding not only static gravity loads but also seismic loads like earthquakes. A series of modeling tests are implemented on shaking table instrument to reflect the mechanism of soil-structure interaction and examine the validity of method of uplifting underground structural seismic resistance through strengthening central columns. An innovative method of enhancing central columns by adhering carbon fiber cloth onto column's peripheral surface is introduced into a series of shaking table modeling tests, in which two two-layer underground model structures are constructed for comparison, one without any column remedy acts as a benchmark for reference and the other is amended with carbon fiber cloth adhered on column surface. Test results show that soft round model box adopted in tests serves well in simulating earthquake actions with negligible boundary effects on wave transfer; soil dynamic characteristics and the relative stiffness of structure to surrounding soil will interactively limit mutual motion and deformation. Racking deformation assumption may be not applicable for two-layer underground structure deformation analysis, but may be suitable for inter-layer displacement calculation for single layer in multi-layer rectangular underground structures. The adopted column enhancement measure could not only greatly increase the stiffness ratio of model structure to soil, reducing structure deformation, but also improve the integrity of underground structure by narrowing down the deformation difference between two structural layers, certifying that such a measure could be validly used in improving the seismic resistance capacity for already built underground structures without enough aseismic consideration when designed.
**Keywords:** underground structure; seismic resistance; shaking table test; column reinforcement; carbon fiber cloth.

**TU-44**

# Experimental Investigation on transverse steel damper seismic system for cable-stayed bridges under earthquake sequences

Lianxu Zhou[1], Aijun Ye[2]

[1,2] *State Key Laboratory of Disaster Reduction in Civil Engineering, Tongji University, Shanghai, China*
*csuzlx@ tongji.edu.cn, yeaijun@tongji.edu.cn*

## Abstract
The conventional transverse fixed system for cable-stayed bridges is often adopted in current engineering practices, which inevitably increases seismic demands at bents, towers and foundations. To address this issue and improve the seismic performance of cable-stayed bridges in transverse direction, a novel transverse steel damper seismic system (TSDSS) has been developed. Considering that multiple strong aftershocks may occur shortly after a destructive main shock, the reliability and seismic performance of TSDSS under ground motion sequence are experimentally studied herein. A series of experiments on a 1/35-scale model of Sutong Bridge with a main span of 1088m are conducted on a four-shake-table testing system, in which two synthetic ground motion sequences are adopted as input. Test results show that (1) TSDSS significantly reduces lateral horizontal force demands at the deck-bent/tower connections, and reduces curvature demands at bent bottoms and along tower shafts, meanwhile limiting the relative displacement at deck-bent/tower connections to an acceptable level for practice. (2) A gradual increase in residual deformations of TSD under ground motion sequences are recorded, but it has little impact on seismic performance of cable-stayed bridges. (3) In general, the TSDs seismic system is experimentally validated to be a reliable and efficient seismic strategy for cable-stayed bridges.
**Keywords:** Shake table test; Cable-stayed bridges; Isolation system; Transverse steel damper; Earthquake sequences

**TU-45**

# Multi-Mode Cable Vibration Control using MR Damper based on Nonlinear Modeling

H.W.Huang*[1,2] , L. M. Sun[1,2], and F.D.Di[1,2]

*1State Key Laboratory for Disaster Reduction in Civil Engineering ,Tongji University, 1239 Siping Road, Shanghai, China*
*2Department of Bridge Engineering, Tongji University, 1239 Siping Road, Shanghai, China*
*hongweih@tongji.edu.cn, lmsum@tongji.edu.cn, fangdiandi@tongji.edu.cn*

## Abstract

One of the most effective countermeasures for mitigating cable vibration is to install mechanical dampers near the anchorage of the cable. Most of the dampers used in the field are so-called passive dampers where their parameters cannot be changed once designed. The parameters of passive dampers are usually determined based on the optimal damper force obtained from the universal design curve for linear dampers, which will provide a maximum additional damping for the cable. As the optimal damper force is chosen based on a predetermined principal vibration mode, passive dampers will be most effective if cable undergoes single-mode vibration where the vibration mode is the same as the principal mode used in the design. However, in the actual engineering practice, multi-mode vibrations are often observed for cables. Therefore, it is desirable to have dampers that can suppress different modes of cable vibrations simultaneously. In this paper, MR dampers are proposed for controlling multi-mode cable vibrations, because of its ability to change parameters and its adaptability of active control without inquiring large power resources. Although the highly nonlinear feature of the MR material leads to a relatively complex representation of its mathematical model, effective control strategies can still be derived for suppressing multi-mode cable vibrations based on nonlinear modelling, as proposed in this paper. Firstly, the nonlinear Bouc-wen model is employed to accurately portray the salient characteristics of the MR damper. Then, the desired optimal damper force is determined from the universal design curve of friction dampers. Finally, the input voltage (current) of MR damper corresponding to the desired optimal damper force is calculated from the nonlinear Bouc-wen model of the damper using a piecewise linear interpolation scheme. Numerical simulations are carried out to validate the effectiveness of the proposed control algorithm for mitigating multi-mode cable vibrations induced by different external excitations
**Keywords**: stay cable; multi-mode vibration; semi-active control; MR damper; optimal friction damper force

**TU-46**

# Vibration Comfortability of a City: a Smartphone-based Survey Approach

J. Chen and L. Cao

*College of Civil Engineering, Tongji University, Shanghai, China*
*cejchen@tongji.edu.cn, beyond060716@163.com*

## Abstract

Rapid form of urbanization has led to millions of migrant workers moving and living in giant cities. As a result, with in the city, the population density, the number of buildings, the density of public transportation network and logistic chains has increased dramatically. Taking Shanghai City as an example, in 2018, the population is estimated to be 22 million (about 3800 people per square kilometre) and the length of subway line is 705 km. Heavy daily public transportation and other dynamic sources as machines in factories, construction activities can cause severe vibration serviceability problems to citizens. A measure thus is necessary to assess the vibration comfortability of a city. To this end, we suggest in this study a smartphone-based approach to survey the vibration issues in a city. The measurement accuracy of various kinds of smartphones available in the marker was first checked by shaking table tests. Then, an application (App) has developed to record acceleration of the smartphone using its embedded sensors. When people in a city feels vibration during their daily life in a city, they can download and open this App to record the vibration, take pictures, make videos and finish a vibration questionnaire form. They can then submit all the information to a cloud server, under the principle of voluntariness, which will be analysed to study the city's vibration comfortability. We have collected about 10,000 records so far. Preliminary statistical analysis on these records are reported in this paper with focuses on data cleaning, vibration source, vibration sites and vibration sensitivity thresholds for male and female. It is found that the proposed survey approach is applicable and a large number of records is important for a reasonable assessment.

**Keywords**: vibration comfortability, smartphone, smart city, big data