Lecture Notes in Civil Engineering

Cuong Ha-Minh · Dong Van Dao ·
Farid Benboudjema ·
Sybil Derrible · Dat Vu Khoa Huynh ·
Anh Minh Tang *Editors*

CIGOS 2019, Innovation for Sustainable Infrastructure

Proceedings of the 5th International Conference on Geotechnics, Civil Engineering Works and Structures

Springer

Lecture Notes in Civil Engineering

Volume 54

Lecture Notes in Civil Engineering (LNCE) publishes the latest developments in Civil Engineering - quickly, informally and in top quality. Though original research reported in proceedings and post-proceedings represents the core of LNCE, edited volumes of exceptionally high quality and interest may also be considered for publication. Volumes published in LNCE embrace all aspects and subfields of, as well as new challenges in, Civil Engineering. Topics in the series include:

- Construction and Structural Mechanics
- Building Materials
- Concrete, Steel and Timber Structures
- Geotechnical Engineering
- Earthquake Engineering
- Coastal Engineering
- Ocean and Offshore Engineering; Ships and Floating Structures
- Hydraulics, Hydrology and Water Resources Engineering
- Environmental Engineering and Sustainability
- Structural Health and Monitoring
- Surveying and Geographical Information Systems
- Indoor Environments
- Transportation and Traffic
- Risk Analysis
- Safety and Security

To submit a proposal or request further information, please contact the appropriate Springer Editor:

– Mr. Pierpaolo Riva at pierpaolo.riva@springer.com (Europe and Americas);
– Ms. Swati Meherishi at swati.meherishi@springer.com (Asia - except China - and Australia/NZ);
– Ms. Li Shen at li.shen@springer.com (China).

Indexed by Scopus

More information about this series at http://www.springer.com/series/15087

Cuong Ha-Minh · Dong Van Dao ·
Farid Benboudjema · Sybil Derrible ·
Dat Vu Khoa Huynh · Anh Minh Tang
Editors

CIGOS 2019, Innovation for Sustainable Infrastructure

Proceedings of the 5th International Conference on Geotechnics, Civil Engineering Works and Structures

Springer

Editors
Cuong Ha-Minh
University of Paris-Saclay
Cachan, France

Farid Benboudjema
LMT Cachan
University of Paris-Saclay
Cachan, France

Dat Vu Khoa Huynh
Norwegian Geotechnical Institute
Oslo, Norway

Dong Van Dao
University of Transport Technology
Thanh Xuan, Hanoi, Vietnam

Sybil Derrible
University of Illinois at Chicago
Chicago, IL, USA

Anh Minh Tang
Ecole des Ponts ParisTech
Marne-la-Vallée, France

ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-981-15-0801-1 ISBN 978-981-15-0802-8 (eBook)
https://doi.org/10.1007/978-981-15-0802-8

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Organizing Committee

Chairmen

Ha, Minh Cuong, ENS Paris-Saclay, France
Dao, Van Dong, University of Transport Technology, Vietnam
Adeli, Hojjat, Ohio State University, USA

International Members

Bui Nguyen, Hoang, AVSE-Global & EDF, UK
Dang, Thuc Trang, Scene Plus Co. Ltd., Vietnam
Dinh, Van Nguyen, ANTS & University College Cork, Ireland
Do, Tuan Anh, Sorbonne University, France
Huynh, Dat Vu Khoa, Norwegian Geotechnical Institute, Norway
Le, Thi Xiu, ENPC, France
Le, Van Nhat, EGIS, France
Nguyen, Giang, University of Adelaide, Australia
Nguyen, Hai Nam, ENS Paris-Saclay, France
Nguyen, Quang Huy, INSA Rennes, France
Nguyen, Thuong Anh, Geodynamique et Structure, France
Nguyen, Tien Long, Tractebel, France
Nguyen, Van Minh, Tractebel, France
Pham, Cao Hung, University of Sydney, Australia
Pham, Van Hung, University of Paris-Est Marne-la-Vallée, France
Ta, Ngoc Binh, Institute of construction economics, Vietnam
Tang, Anh Minh, AVSE-Global & ENPC, France
Vu, Xuan Hong, University Lyon 1, France

Local Members (UTT)

Le, Hoang Anh, Faculty of Civil Engineering
Le, Nguyen Khuong, Faculty of Civil Engineering
Le, Thanh Hai, Department of Science, Technology and International Cooperation
Ly, Hai Bang, Faculty of Civil Engineering

Ngo, Quoc Trinh, Department of Science, Technology and International Cooperation
Ngo, Thi Thanh Huong, Faculty of Civil Engineering
Nguyen, Long Khanh, Department of Science, Technology and International Cooperation
Nguyen, Nam Hai, Faculty of Information Technology
Nguyen, Thi Thu Hien, Department of Science, Technology and International Cooperation
Pham, Thai Binh, Faculty of Civil Engineering
Phi, Luong Van, Department of Science, Technology and International Cooperation
Tran, Trung Hieu, Department of Science, Technology and International Cooperation
Hoang, Vu, Department of Science, Technology and International Cooperation
Truong, Thi My Thanh, Department of Economy of Transportation
Vu, Duy Tung, Center of Technology of Communication

International Scientific Committee

AMCS—Advanced Modelling and Characterization of Structures

Argoul, Pierre, IFSTTAR, France
Azenha, Miguel, Minho University, Portugal
Becque, Jurgen, University of Sheffield, UK
Benabou, Lahouari, Université de Versailles Saint-Quentin-en-Yvelines, France
Bui, Quang Hien, STECHCO Inc., Canada
Bui, Tan Trung, INSA Lyon, France
Couchaux, Mael, INSA Rennes, France
Dang, Cong Thuat, University of Danang, Vietnam
Elgawady, Mohamed, University of Missouri, USA
Ferrier, Emmanuel, University Lyon 1, France
Gilbert, Benoit, Griffith University, Australia
Herve-Secourgeons, Guillaume, IMSIA, EDF R&D, France
Jalil, Alan, EGIS, France
Labbe, Pierre, ESTP RENON, France
Lanos, Christophe, IUT/INSA Rennes, France
Le, Thien Phu, Université d'Évry-Val-d'Essonne, France
Meftah, Fekri, INSA Rennes, France
Mirza, Olivia, Western Sydney University, Australia
Nguyen, Giang, University of Adelaide, Australia
Nguyen, Quang Huy, INSA de Rennes, France
Nguyen, Tien Long, Tractebel France, France
Nguyen, Van Bac, University of Derby, UK
Paultre, Patrick, Université de Sherbrooke, Canada
Pham, Cao Hung, University of Sydney, Australia
Pologanathan, Keerthan, Northumbria University, UK
Potin, Gildas, Tractebel Engineering, France
Ragueneau, Frédéric, ENS Paris Saclay, France
Sansour, Carlo, University of Nottingham, UK
Tan, Ee Loon, Western Sydney University, Australia

Teh, Lip, Wollongong University, Australia
Thai, Huu Tai, University of Melbourne, Australia
Tran, The Truyen, University of Transport and Communications, Vietnam
Turmo, Coderque José, School of Civil Engineering of Barcelona, Spain
Vo, Thuc, Northumbria University, UK

Building Information Modelling (BIM)

Chi, Seokho, Seoul National University, Korea
Chia, Fah Choy, Universiti Tunku Addul Rahman, Malaysia
Han, Sanguk, Hanyang University, Korea
Han, Hoang Mai, The BIM Factory, Vietnam
Hussain, Afifuddin Husairi, Universiti Kebangsaan, Malaysia
Kang, Taewook, Korea Institute of Civil Engineering and Building Technology, Korea
Kim, Jung In, City University of Hong Kong, China
Likhitruangsilp, Veerasak, Chulalongkorn University, Thailand
Ngo, Quang Tuan, Hanoi Architectural University, Vietnam
Nguyen, Nam Trung, Power Engineering Consultancy Jsc. 3, Vietnam
Nguyen, The Quan, National University of Civil Engineering, Vietnam
Nguyen, Viet Hung, University of California, USA
Park, Jongwoong, Chung-Ang University, Korea
Park, Manwoo, Myongji University, Korea
Pham, Hong Luan, Ho Chi Minh City University of Technology, Vietnam
Preece, Christopher, Abu Dhabi University, UAE
Shim, Changsu, Chung-Ang University, Korean
Shin, Dohyoung, Inha University, Korea
Suryanto, Krishna, Institute Tecknologi Bandung, Indonesia
Ta, Ngoc Binh, Institute of Construction Economics, Vietnam
Thang, Anh Long, Structemp, UK
Wu, Wei, California State University, USA

DML—Data Mining and Machine Learning

Bui, Tien Dieu, University of South-Eastern Norway, Norway
Chou, Jui-Sheng (Rayson), National Taiwan University of Science and Technology, Taiwan
Le, Hoang Son, Vietnam National University, Vietnam
Liu, Zhongqiang, Norwegian Geotechnical Institute, Norway
Ngo, Ngoc-Tri, National University of Singapore, Singapore
Tang, Pingbo, Arizona State University, USA

GEE—Geotechnics for Environment and Energy

Bouvard, Anne, INSA de Lyon, France
Bui, Quoc Bao, Ton Duc Thang University, Vietnam
Choi, Jung Chan, Norwegian Geotechnical Institute, Norway
Collin, Frédéric, University of Liège, France
Ddani, Mohamed, Tractebel, INSA de Rouen, France
Dias, Daniel, University Grenoble Alpes, France
Dong, Jia-Jyun, National Center University, Taiwan
Gastebled, Olivier, Tractebel, INSA de Lyon, France
Huynh, Dat Vu Khoa, Norwegian Geotechnical Institute, Norway
Kaynia, Amir M., Norwegian Geotechnical Institute, Norway
Leo, Chin, Western Sydney University, Australia
Nguyen, Thanh Son, University of Ottawa and Canadian Nuclear Safety Commission, Canada
Pham, Thai Binh, University of Transport Technology, Vietnam
Taherzadeh, Reza, Tractebel, INSA de Lyon, France
Tang, Anh Minh, Ecole des Ponts ParisTech, France
Tran Nguyen, Hoang Hung, Hochiminh City University of Technology, Vietnam
Wong, Henry, ENTPE, France
Wu, Li, China University of Geosciences, China

SCMT—Sustainable Construction Materials and Technologies

Ashraf, Mahmud, Deakin University, Australia
Beakou, Alexis, IFMA/SIGMA Clermont, France
Benboudjema, Farid, ENS Paris Saclay, France
Bui, Ha, Monash University, Australia
Bui, Quoc Tinh, Tokyo Institute of Technology, Japan
Dotelli, Giovanni, Politechnico Milano, Italy
Forth, John, School of Leeds, UK
Garibaldi, Luigi, Politecnico di Torino, Italy
Golinval, Jean-Claude, Université de Liège, France
Grande, Daniel, University of Paris Est Creteil, France
Grillet, Anne-Cécile, Université Savoie Mont Blanc, France
Ha Minh, Cuong, AVSE Global and ENS Cachan, France
Ly, Hai Bang, University of Transport Technology, Vietnam
Monchiet, Vincent, University of Paris Est Marne-la-Vallée, France
Monteiro, Eric, Arts & Métiers ENSAM Paris, France
Nakarai, Kenichiro, Hiroshima University, Japan
Nguyen, Van Bac, University of Derby, UK
Nguyen, Khanh Son, Hochiminh City University of Technology, Vietnam
Nguyen, The Duong, Duy Tan University, Vietnam
Poh, Leong Hien, National University of Singapore, Singapore
Proust, Gwénaëlle, University of Sydney, Australia
Regnier, Gilles, Arts & Métiers ENSAM Paris, France

Serra, Roger, INSA Val de Loire, France
Si Larbi, Amir, ENISE, France
Tran, Minh Tung, Ton Duc Thang University, Vietnam
Vu, Xuan Hong, University of Lyon 1, France
Yvonnet, Julien, University of Paris Est Marne-la-Vallée, France

UPTE—Urban Planning, Transport and Environment

Button, Cat, University of Newcastle, UK
Chan, Tak-Ming, Hong Kong Polytechnic University, Hong Kong
Dang, Thuc Trang, Scene Plus Co. Ltd., Vietnam
Derrible, Sybil, University of Illinois at Chicago, USA
Do, Thuan An, Thuy Loi University, Vietnam
Nguyen, Frédéric, University of Liège, France
Nguyen, Hong Quan, Vietnam National University—Ho Chi Minh City, Vietnam
Hsu, Mark Shu-Chien, Hong Kong Polytechnic University, Hong Kong
Le, Hai Vu, Monash University, Australia
Nghiem, Duc Long, University of Technology Sydney, Australia
Nguyen, Chuong, CSIRO—Data61, Australia
Nguyen, Xuan Thinh, TU Dortmund University, Germany
Quan Luna, Byron, DNV GL, Norway
Rilett, Laurence, University of Nebraska-Lincoln, USA
Trinh, Toan, University of California, USA

Organisers


ASSOCIATION OF VIETNAMESE SCIENTISTS AND EXPERTS
HỘI CHUYÊN GIA VIỆT NAM


UNIVERSITY OF
TRANSPORT TECHNOLOGY

Partner

Patronage

BỘ GIAO THÔNG VẬN TẢI

MINISTRY OF TRANSPORT OF VIET NAM

Preface

Following the great success of each of the four previous consecutive events since 2010, CIGOS (*Congrès International de Géotechnique—Ouvrages—Structures*) has firmly established its international reputation and is perceived as an important conference for promoting both academic and high-quality professional exchanges in the fields of **Geotechnics, Civil Engineering Works and Structures**. This, the fifth International Conference—**CIGOS 2019**, held in Hanoi, Vietnam, was co-organized by the Association of Vietnamese Scientists and Experts (AVSE Global) in collaboration with the University of Transport Technology (UTT) and in partnership with the Ecole normale supérieure de Paris-Saclay (ENS Paris-Saclay).

CIGOS 2019 placed particular focus on the theme of **Innovation for Sustainable Infrastructure**, aiming to not only raise awareness of the vital importance of sustainability in infrastructure development but also highlight the essential roles of innovation and technology in helping to plan and build sustainable infrastructure. Having built on the success of CIGOS 2017, this year's conference saw almost double the number of published papers, which covered a broad spectrum within the following topics:

- Advanced Modeling and Characterization of Structures
- Sustainable Construction Materials and Technologies
- Geotechnics for Environment and Energy
- Urban Planning, Transport and Environment
- Data Mining & Machine Learning
- Building Information Modeling

The present CIGOS proceedings contain 201 peer-reviewed papers from 27 different countries, six of which are keynotes presented by internationally outstanding experts in their respective fields. The choice of papers was made on the basis of nearly 380 abstracts accepted. The first keynote presents the author's wide perspective on four decades of computing in civil engineering, which are highly multidisciplinary—crossing computer science, multiple engineering fields, mathematics and medicine. The second, third, fourth, and fifth keynotes address the recent novel technologies and innovations in transportation and construction, which have

been remarkable in helping to plan and build infrastructure that is increasingly more sustainable. The sixth and final keynote emphasizes that society and standards require increasingly more "risk-informed" based decisions, demonstrating that the implementation of reliability and risk-based approaches can not only provide useful complementary information both for design and for re-evaluation during the lifetime of the infrastructure but also efficiently assist the preparation of sustainable engineering recommendations and risk-informed decision making.

We wish to acknowledge the wonderful support of the scientific committee and the external reviewers, who provided valuable assistance in the review process and undoubtedly made a tremendous contribution in raising the quality of the proceedings. We are thankful to the keynote speakers, authors and participants for their enthusiastic efforts and time in preparing valuable papers as well as bringing encouragement and inspiration to the conference. Our special thanks also to the organizing committee, without whom it would have been difficult to run this conference.

Last but not least, we would also like to thank all sponsors for their support and generosity in making our CIGOS 2019 such a success.

On behalf of the CIGOS 2019's committees, we believe that the present proceedings, which include a mixture of contributions from academia and practitioners, will provide valuable up to date knowledge for all those interested in Geotechnics, Civil Engineering Works and Structures.

Cachan, France	Cuong Ha-Minh
Thanh Xuan, Hanoi, Vietnam	Dong Van Dao
Cachan, France	Farid Benboudjema
Chicago, USA	Sybil Derrible
Oslo, Norway	Dat Vu Khoa Huynh
Marne-la-Vallée, France	Anh Minh Tang

Acknowledgements We would like to thank the following invited experts for reviewing the papers: Brian Carlton, Finn Lovholt, Pascale Massaad, Thi Binh Nguyen, Thanh Tu Nguyen, Thi Thanh Thao Pham.

Sponsors pages

Gold Sponsor

VinTech City, a member of Vingroup, was founded with the aim of supporting the Vietnamese ecosystem of tech research and startups, following the success model of Silicon Valley. To realize such mission, VinTech City has identified three fundamental areas of activities: Tech talents, tech products, and an ecosystem of supporting activities. Among these factors, the workforce and tech products with competitive edges have been considered the stepping stones of the development strategy of VinTech City.

Specifically, VinTech City has designed programs focusing on tech startups, innovators, researchers, university lecturers and students, in order to support them in creating innovative research and translating them into commercialized products and companies based on applied research. In May 2019, VinTech City has officially announced six such programs, namely: (i) VinTech Fund—a grant for applied research; (ii) Research Laboratory sponsorship; (iii) University-Enterprise Co-operative Semester; (iv) SAP Training; (v) Events, workshops, or seminars sponsorship; and (vi) Tech Startup Student Clubs. Such wide range of support activities and programs demonstrates the comprehensive cooperation between Vingroup and the science and technology universities in Vietnam.

One of the most prominent programs of VinTech City is VinTech Fund—a grant for creating innovative tech products from research, or in another word "bringing lab ideas to market", which has recently announced the first batch of applied research projects receiving fundings of 86 billions VND in total (equivalent to $3.7m). Learn more about them on www.vintechcity.com.

In brief, Vietnamese researchers, who works at prestigious research institutes and universities, can contribute to the development of science and technology in

Vietnam through research collaboration, tech product development, and educational activities with domestic universities within the sponsorship framework of VinTech Fund.

We believe that VinTech City can contribute to create a catalyst for "Make in Vietnam" technology products in market and complete the mission of supporting Vietnam startup and technology ecosystem.

Silver Sponsors

Established in 2008, National Foundation for Science and Technology Development of Vietnam (NAFOSTED) has been one of the main funding agencies for research in Vietnam. Affiliated with the Ministry of Science and Technology, NAFOSTED's mission is to build a favorable research environment that meets international standards in order to enhance national Science & Technology capacity, including improving research quality and developing high-quality human resources. NAFOSTED funds both basic and applied research in all disciplines from mathematics, physics, medical and biological sciences to engineering, earth sciences, social sciences and humanities. Recently, NAFOSTED provides funds for around 400 research projects with participations of 1.200–1.500 researchers each year. With the aim of improving research capacity in Vietnam to meet international standards, NAFOSTED also supports numbers of scientific activities, encouraging international cooperation for Vietnamese scientists, through this contributes to national economic growth and competitiveness.

Officially established in Vietnam in 2007 by a group of young Vietnamese intellectuals living in Ukraine, Sun Group has now emerged as one of the leading real estate and tourism developers in Vietnam with 61 members corporations and more than 6000 employees nationwide. With a focus on strategically investing across four main categories—Leisure Travel, Recreation and Entertainment, Real Estate, Infrastructure—and placing an emphasis on the three core values of "Quality —Luxury—Distinction", Sun Group has created numerous prestigious and iconic landmarks, many of which have been hailed as architectural masterpieces.

Bronze Sponsors

STECHCO is an engineering firm specializing in building design, building structure, and construction project management. Our firm also provides professional services in the application of new construction technologies in Canada and the United States. STECHCO's rigorous and professional team is recognized and appreciated for our expertise and experience in all types of residential, commercial, industrial and institutional construction. We are members or licensees of professional orders and associations such as Order of Engineers of Quebec (OIQ), Professional Engineer of Ontario (PEO), The Northwest Territories Association of Professional Engineers and Geoscientists (NAPEG). Our professional team has participated in more than 500 projects in Canada.

NUCE has undergone over 50 years of formation and development and over 60 years of training. NUCE becomes nowadays a leading centre for training, research, technology transfer and creating high quality human resources for the country in the field of civil engineering. In addition, NUCE was one of the first four universities in Vietnam evaluated and accredited by HCERES (Haut Conseil de l'Evaluation de la Recherche et de l'Enseignement Supérieur)—an international assessment organisation for 5 years, without conditions until May 2022.

Contents