



# **Regency Steel Asia Symposium on Innovative Research, Advanced Design & New Construction Technologies on Steel and Composite Structures**

Wednesday, 12 June 2019 9:00 am to 5:00 pm (Registration starts at 8:30 am)

Nanyang Auditorium NEW Nanyang Technological University 50 Nanyang Avenue Singapore 639798



Organised by:

School of Civil and Environmental Engineering Nanyang Technological University, Singapore

Sponsored by: Regency Steel Asia Endowment Fund @ NTU

#### Accreditation

Qualified for 6 PDUs by the Professional Engineers Board Singapore (PEB), and 6 STUs (Structural) from The Institution of Engineers, Singapore

### The Regency Steel Asia (RSA) Pte Ltd Fund at NTU, Singapore

In May 2008, Regency Steel Asia Pte Ltd (RSA), one of Asia's largest steel distributors, broke new ground with the launch of the Regency Steel Asia Pte Ltd Fund at the Nanyang Technological University (NTU), Singapore. The RSA Fund, the first of its kind that was established at the University, charted new strategic directions in structural steel research and expertise development. Regency Steel Asia Pte Ltd donated S\$1.5 million to establish the RSA Fund and this amount was matched by one-to-one government funding, making it a total of S\$3 million.

The first research project that was funded by RSA aimed to advance the understanding and application of high strength steel in bridging structures in the industry. Through the project, the research team from NTU's School of Civil and Environmental Engineering had drawn up clear guidelines on the use of high strength steel and to promote its use for the construction industry.

### About this Symposium

The Regency Steel Asia (RSA) Symposium 2019 will be the next in a series of successful RSA Symposiums in 2008, 2011, 2013 and 2015 at the Nanyang Technological University, Singapore. The RSA Symposiums aim to support steel research and to promote the advanced design and new construction technologies to the use of steel and composite structures for a more green, sustainable and safe living environment. This year, the RSA Symposium 2019 will generally focus on applications of Innovative Research, Advanced Design & New Construction Technologies on Steel and Composite Structures. It will discuss how the latest codes and technologies can be better implemented in the research and the design of high strength steel structures as well as steel-concrete composite structures. On construction technologies, recent development and innovative examples of awarded projects will be presented during the Symposium.

### Symposium Programme

0830 hrs	Registration
0900 hrs	Welcome Address by Professor Rong WANG Chair, School of Civil and Environmental Engineering, Nanyang Technological University, Singapore
0915 hrs	Opening Address by Mr. Yasuhiro KOJIMA Chief Executive Officer, Regency Steel Asia Pte Ltd
0930 hrs	Presentation 1: Design of High Performance Composite Steel-Concrete Structures using the Eurocode 4 Approach - Professor Sing Ping CHIEW (Singapore Institute of Technology)
1000 hrs	Presentation 2: Investigation into Structural Behaviour of S690 Welded Steel Members - Professor Kwok-Fai CHUNG (The Hong Kong Polytechnic University)
1030 hrs	Morning Refreshment Break
1100 hrs	Presentation 3: Connecting High-Strength Steel for Construction - Professor Guoqiang LI (Tongji University)
1130 hrs	Presentation 4: Structural Behaviour of S960 High Strength Steel Press-Braked Angle and Channel Sections - Assistant Professor Ou ZHAO (Nanyang Technological University, Singapore)
1200 hrs	Presentation 5: Global Stability Behaviour of Q460GJ Welded Sections under Bending and Compression - Professor Bo YANG (Chongqing University)
1230 hrs	Lunch Break
1330 hrs	Presentation 6: Latest Research and Development of Demountable Composite Structures - Professor Dennis LAM (University of Bradford)
1400 hrs	Presentation 7: Recent Advances in High Performance Steel and Composite Steel Structures in Australia - Professor Brian UY (The University of Sydney)
1430 hrs	Presentation 8: <b>Design Method for Mitigating Progressive Collapse in Steel and Composite Structures</b> - <b>Professor Kang Hai TAN</b> (Nanyang Technological University, Singapore)
1500 hrs	<ul> <li>Presentation 9: Flexural Behaviour of Engineered Cementitious Composite - Lightweight Concrete Encased High Strength Steel Beam</li> <li>Professor Chi-King LEE (The University of New South Wales, Canberra)</li> </ul>
1530 hrs	Afternoon Refreshment Break
1600 hrs	Presentation 10: The Impact of Composite Construction on Height, Form and the Future - Dr. Craig GIBBONS (Arup Group Ltd)
1630 hrs	Presentation 11: Design of High Strength Composite Columns for Tall Buildings - Professor Jat Yuen Richard LIEW (The National University of Singapore)
1700 hrs	Adjournment for the Day

### **Symposium Speakers**



### Design of High Performance Composite Steel-Concrete Structures using the Eurocode 4 Approach

by Professor Sing Ping CHIEW, Singapore Institute of Technology

The current design codes for composite steel reinforced concrete (SRC) beams and columns are only applicable to normal strength materials. In Eurocode 4, only the limited concrete grades C20/25 to C50/60 and steel grades S235 to S460 are allowed to be used, while on the other hand, it is permissible to use much higher strength concrete grade (up to C90/105) in Eurocode 2 and S690 steel grade in Eurocode 3. In this presentation, a design method is proposed to utilise the full strength of high performance steel grades up to S690 and concrete grades up to C90 for the SRC columns, taking into account the effect of strain-compatibility and lateral confinement. The same high performance steel and concrete grades can also be used to form the SRC beams and together, they form a new innovative SRC structural framing system

which will be very suitable for use in heavy industrial buildings. The key advantages of using such high performance materials is to reduce the size of structural elements considerably especially for the SRC columns, thereby freeing up valuable floor space as well as to facilitate safer and more productive construction.

Dr. Sing Ping CHIEW is Professor of Civil Engineering and Director of Civil Engineering Programmes at Singapore Institute of Technology, Singapore's fifth autonomous university with a strong focus on Applied Learning. Professor Chiew was previously Head of the Division of Structural Engineering and Mechanics at the Nanyang Technological University, Singapore from 2008 to 2014. He is a Member of the Panel of Expert Advisors of the Land Transport Authority, Board Member of the Professional Engineers Board, Member of the Technical Advisory Panel of the Inland Revenue Authority and Member of the Inquiry Panel of the Law Society of Singapore.



#### Investigation into Structural Behaviour of S690 Welded Steel Members

by Professor Kwok-Fai CHUNG (The Hong Kong Polytechnic University)

In order to promote effective use of high strength steels in construction, a series of experimental and numerical investigations into structural behaviour of high strength S690 steels and their welded sections were conducted over the past 8 years. These investigations include i) mechanical properties of S690 steels and their welded connections, ii) structural behaviour of both stocky and slender columns of S690 welded H-sections, iii) structural behaviour of partially restrained beams of S690 welded I-sections, and iv) effects of welding on structural behaviour of S690 welded sections.

Dr. Kwok-Fai CHUNG is a renowned academic, researcher and structural engineer with established expertise in structural engineering and steel construction. Currently, Professor Chung is Associate Head (Academic Development) of the Department of Civil and Environmental

Engineering at the Hong Kong Polytechnic University, and Founding President of the Hong Kong Constructional Metal Structures Association. In October 2015, he was appointed by the Ministry of Science and Technology, People's Republic of China to be the Director of the Chinese National Engineering Research Centre for Steel Construction (Hong Kong Branch).

Professor Chung works on a wide range of inter-disciplinary engineering analysis and design projects, especially on modern steel and composite building structures. His research interests include limit state analysis and performance-based design of structural systems, structural fire engineering and fire protection in buildings and tunnels, and design codification. He has published about 200 conference and journal papers as well as 9 professional design guides on modern steel construction technology. Professor Chung is a frequent speaker in international conferences and symposia as well as in professional short courses for practicing engineers.



### **Connecting High-Strength Steel for Construction**

by Professor Guoqiang LI (Tongji University)

Intumescent coatings are nowadays popularly used for the fire protection of steel structures. However, many factors influence the behaviour of intumescent coatings. To assess the complicated behaviour of intumescent coatings and their thermal resistance for the protection of steel structures against fire, constant effective thermal conductivities were proposed. The influence of the steel section factor and coating thickness on the constant thermal conductivity were investigated. The effect of aging on the insulation of two types of intumescent coatings were experimentally studied and the aging mechanisms were revealed by XPS and SEM tests. The effect of topcoat on the insulation of intumescent coatings under large space fires and localized fires. Three constant thermal conductivities were proposed to effectively represent the thermal resistance of intumescent coatings in the melting, blowing and fully expanded stages.

**Dr. Guoqiang LI** is currently a Professor of Structural Engineering at the College of Civil Engineering in Tongji University, the Director of Research Centre of Education Ministry of China for Steel Construction, and the Director of National Research Centro of China for Pre-fabrication Construction. Professor Li is also a vice-chairman of the Chinese Society of Steel Construction and a vice-chairman of the Chinese Association of Construction Standardisation. In addition, he is a fellow of the Institution of Structural Engineers in the UK and a foreign member of the Royal Flemish Academy of Belgium for Science and the Arts.

Professor Li's research has been mainly in the area of hazard mitigation for steel structures, including earthquake-resistance, fire-resistance and blast-resistance. He has been the principal investigator for more than 30 research projects funded respectively by Chinese Science and Technology Ministry, Construction Ministry, Education Ministry, Natural Science Foundation and Shanghai Government. He has published 15 technical books and more than 700 journal papers in Chinese and English relevant to his research topics.



#### Structural Behaviour of S960 High Strength Steel Press-Braked Angle and Channel Sections by Professor Ou ZHAO (Nanyang Technological University, Singapore)

This presentation reports an experimental and numerical investigation into the local stability of S960 high strength steel press-braked angle and channel sections. The experimental programme was performed on four equal-leg angle sections and eight plain channel sections, and included material testing, initial local geometric imperfection measurements, concentrically loaded stub column tests and laterally restrained beam tests (about the minor principal axes for channel sections and geometric axes for angle sections). This was supplemented by a finite element modelling programme, in which numerical models were firstly developed to simulate the test structural responses and subsequently adopted to generate additional numerical data. The experimentally and numerically derived results were adopted to assess the accuracy of the codified local buckling design rules established in Europe, America and Australia. Given that there have been no established design standards for S960 high strength steel structures, the corresponding design rules for mild steel structures were evaluated for their S960 high strength steels to S960 high strength steels.

**Dr. Ou ZHAO** is an Assistant Professor in the School of Civil and Environment Engineering, Nanyang Technological University, Singapore. His principal research interests lie in high-performance steel (high strength steel and stainless steel) and composite structures as well as fire engineering. Professor Zhao is a committee member of Eurocode EN 1993-1-4 for stainless steel structures. His previous research on stainless steel beam-columns led to the current interaction formulations in EN 1993-1-4. He has been conducting a comprehensive experimental and numerical programme on S690 and S960 high strength steel open (I-, channel and angle) section members, aiming at verifying their structural performance and developing efficient design rules for incorporation into future versions of Eurocode.

### **Symposium Speakers**



#### **Global Stability Behaviour of Q460GJ Welded Sections under Bending and Compression** by **Professor Bo YANG** (Chongqing University)

With the increasing number of large-span and super-high building structures, high performance structural steel, namely GJ structural steel in China, has earned more attention and is widely used in practice due to its advantages of a lower yield ratio, better weldability and higher economic efficiency. Compared with normal strength steel members, high strength steel members have lower sensitivity to initial geometric imperfections and residual stresses, making them more vulnerable to instability failure. This presentation will discuss the experimental results regarding the global behaviour of Q460GJ steel members with welded sections.

**Dr.** Bo YANG is an excellent young academic, researcher and structural engineer with established expertise in the progressive collapse of steel and composite structures. After graduating from Nanyang Technological University, Singapore in 2013, he has since served at Chongqing University and is currently the Head of School of Civil Engineering in Chongqing University.

Professor Yang works mainly on the progressive collapse of steel and composite structures, and the mechanical properties of high strength structural steels. Recently, he extended his research interests to the material properties of high performance fibre reinforced concrete and the structural behaviour of wind turbine support systems in mountainous areas, which is related to the topographic features in Chongqing and surrounding areas.



### Latest Research and Development of Demountable Composite Structures

#### by Professor Dennis LAM (University of Bradford)

Developing new construction technologies for a sustainable built environment is a top priority for the construction industry throughout the world. Much of the environmental impact from the construction industry is associated with the consumption of resources and generation of waste. The reuse of structural components after the end of design life would allow the industry to reduce its consumption of resources and generation of construction waste. A new composite flooring system using demountable shear connectors is developed and tested to assess its potential and suitability. This presentation presents the results of a series of full-scale beam tests to demonstrate the reusability of this new form of composite flooring systems.

Dr. Dennis LAM is the Chair of Structural Engineering and the Director of Bradford Centre for Sustainable Environments at the University of Bradford, UK. Professor Lam was also formerly Chief Structural Engineer for the City of Wakefield, UK and has more than ten years of experience in engineering practice. He is a Chartered Engineer, Fellow of the Institution of Structural Engineers and Member of the Institution of Civil Engineers. He is currently a Distinguished Chair Professor at the Tsinghua University, China and Adjunct Professor at Chongqing University, China. He is the President of Association of Steel – Concrete Composite Structures (ASCCS). He is the European Editor-in-Chief for the Engineering and Physical Sciences Research Council, UK. He is also a member of the British Standard Institute and European Committee on Standardization (CEN) responsible for the Eurocode 4 and chairs the working group for the next revision of the Eurocode 4 (EN1994-1-1).



## Recent Advances in High Performance Steel and Composite Steel Structures in Australia by Professor Brian UY (The University of Sydney)

High performance steels include steels of both high strength and other high performance characteristics such as high fire resistance and improved ductility or durability. This paper will delve into the area of high strength and ultra-high strength steels, stainless steels and clad steels. These steels are becoming increasingly popular because of their improved stiffness, strength and stability characteristics. This paper will review the ongoing research into this area in non-composite and composite forms and will highlight current work that aims to develop design guidelines for these cases, particularly pertaining to Australasian Standards ASNZS2327 and ASNZS5100 Part 6 for buildings and bridges respectively.

Dr. Brian UY is Professor of Structural Engineering and Head of the School of Civil Engineering at the University of Sydney. Professor Uy is the Chairman of the Standards Australia Committee BD32 on Composite Structures and a member of BD90 on Bridge Structures which have developed standards on Steel and Composite Structures for buildings and bridges respectively. He also serves on BD01 and BD02 for Steel and Concrete Structures respectively. He is the Chairman of the Australia Regional Group of the Institution of Structural Engineers since 2012 and is the Chairman for the Australian Group of the Institution and Association of Bridge and Structural Engineering (IABSE). He regularly provides higher level consulting advice and certification for major national manufacturing and infrastructure companies and for forensic/expert witness purposes for many of Australia's leading legal practices.

Professor Uy has co-authored over 200 international journal papers and has delivered over 300 conference papers in 35 countries, including over 80 keynote/invited lectures in 20 countries and has been involved in research in steel and composite structures for over 25 years. Brian serves on the editorial boards of fifteen international journals for structural engineering and is Chief Editor (Asia-Pacific) for Steel and Composite Structures. He is also a significant contributor to international codes of practice in steel and composite construction and currently serves on the American Institute of Steel Construction (AISC) Task Committee 5 on Composite Construction and the American Society of Civil Engineers (ASCE) Structural Engineering Institute (SEI), Technical Committee on Composite Construction.



#### Design Method for Mitigating Progressive Collapse in Steel and Composite Structures by Professor Kang Hai TAN (Nanyang Technological University, Singapore)

The presentation introduces an analytical model and a simplified design approach to estimate collapse resistance of three-dimensional (3D) steel-frame-composite-slab systems (composite floors) subjected to a column removal scenario. It includes an extensive test programme, analytical and simplified models. The analytical model incorporates three branches to capture the load-deflection response at small deformation, transitional and large deformation stages. The analytical model can capture the effects of key parameters, such as the slab aspect ratio, joint type, number of bolts, slab thickness, reinforcement ratio in the slab and thickness of steel decking. Based on the idealised elastic-plastic assumption, the simplified approach considers flexural mechanism at the elastic stage and applies conservation of energy at the plastic stage. Energy is assumed to be dissipated by yield lines in slabs and plastic hinges in beams. The simplified approach is much easier to be applied and more conservative compared to the analytical model.

**Dr. TAN Kang Hai** is a Professor of Structural Engineering in the School of Civil and Environmental Engineering, Nanyang Technological University, Singapore. He is concurrently Co-Director of Surbana Jurong–NTU Corporate Lab, Co-Director of Transport Research Centre and Director of Protective Technology Research Centre. Professor Tan started working on robustness of buildings in 2004. He developed an analytical tool for progressive collapse analysis due to a blast. His team is currently involved in drafting of a Singapore design guide to mitigate progressive collapse of structures. He has authored/co-authored about 200 SCI top-tier international journal publications and another 200 international conference papers. He won the "Certificate for Highly Cited Research" in Engineering Structures in 2017. A registered Professional Engineer with specialisation in Protective Security (PE-PS), Professor Tan is in the HDB Civil & Structural Engineering Advisory Panel, Deputy-Chair of IES for Technical Committee of Infrastructure Cluster, represents IES in the Selection Panel for certifying Fire Safety Engineers and seminars, and delivered close to 90 professional short courses. His consultancies involved performance-based approach to fire scenarios or progressive collapse resistance analysis.

### **Symposium Speakers**



### Flexural Behaviour of Engineered Cementitious Composite - Lightweight Concrete Encased High Strength Steel Beam

by Professor Chi-King LEE (The University of New South Wales, Canberra)

This presentation will focus on the flexural performance of a new type of high strength steel (HSS) composite beam formed by encasing a welded HSS section with polyvinyl alcohol-engineered cementitious composite (PVA-ECC) and lightweight concrete (LWC). Results obtained from an experimental investigation on the flexural performance of beams formed by different encasing configurations and ECC thicknesses will be presented. In addition, a detailed finite element modelling procedure is also developed to predict the flexural behaviour of this type of beam.

Dr. Chi-King LEE is currently the Deputy Head of School and Professor in Civil Engineering, School of Engineering & IT, University of New South Wales, Canberra, Australia has been working in the areas of finite element modelling and structural engineering for many years.

Professor Lee's main research interests include automatic finite element mesh generation and adaptive algorithms, high strength steel structure, sustainable building structure systems and protective engineering for structures. He acts as reviewer for many international journals in the areas of numerical modelling, structural mechanics and engineering. He also worked as a consultant for the PSA Singapore on the dynamic fatigue study of container quay cranes as well as for a building design software company to provide recommendations on the implementation of their analysis and design software.

#### The Impact of Composite Construction on Height, Form and the Future



by **Dr. Craig GIBBONS** (Arup Group Ltd)

The presentation will look at how composite construction has influenced the form of buildings – how we have been able to re-define what can be achieved in tall building design and how it has also allowed engineers to challenge the vertical and develop architectural icons. Examples from the recent past will be presented. In addition, the presentation will recognise the future and how composite construction might evolve recognising current material and manufacturing trends.

**Dr. Craig GIBBONS** is an Arup Fellow, the Global Leader of the Arup Structural Skills Network and a Principal in Arup Buildings Australasia. Dr. Gibbons has played a key role in the design and delivery of a number of prestigious landmark high-rise developments around the world. These include projects in the Middle East, Hong Kong, China, Korea and more recently Australia. Included is the 440m Guangzhou Finance Centre, the award-winning Cheung Kong Centre, the 420m International Finance Centre as well as the unique CCTV building in Beijing.

Steel-concrete composite construction has featured prominently in many of the projects that Dr. Gibbons has been involved in. A key driver is the potential for seed of construction and potential for maximising off-site fabrication. Lately he has been involved in a number of 'Design for Manufacture' initiatives exploring how new production approaches can expand the potential for off-site fabrication. Dr. Gibbons has written over 40 papers on aspects of engineering design including high rise construction and construction-led design principles and has been an invited speaker at many conferences around the world. He is a Fellow of the Institution of Structural Engineers and is a Fellow of the Council of Tall Buildings and Urban Habitat.



### Design of High Strength Composite Columns for Tall Buildings

by **Professor Richard LIEW** (The National University of Singapore)

This presentation will discuss the background information related to the design guide BC4 on the use of high strength materials for concrete filled tubular columns for tall buildings. Additional research is conducted on concrete encased steel composite columns and design methods to extend its use to include high strength materials are proposed.

**Dr. Richard LIEW** is a Professor in the Department of Civil & Environmental Engineering at the National University of Singapore. Professor Liew is a Chartered Engineer in the UK, a Professional Engineer in Singapore, and a Chartered Professional Engineer of the Association of Southeast Asian Nations. He is a Fellow of the Academy of Engineering Singapore, an Honorary Fellow and the Past President of Singapore Structural Steel Society. Professor Liew has been involved in research and practice in steel and composite structures with

lightweight and high strength materials for applications in offshore and marine, defence, civil and building structures. He serves on the editorial boards of 9 international journals. He has been consulted for the design and construction of several prominent tall buildings and large span structures in Singapore. He is a key person responsible for the development of Singapore's codes of practices of steel structures and steel-concrete composite structures.