UNSW AUSTRALIA

CIES - Centre for Infrastructure Engineering and Safety
Annual Report 2015

Never Stand Still | Faculty of Engineering | School of Civil and Environmental Engineering

CIES

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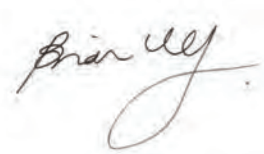
Contents

Director's Report

It is with great pleasure that I write this Directors Report for the Centre for Infrastructure Engineering and Safety (CIES) for 2015. The annual report this year again focuses on the mission of the centre, its governance structure and finances and then highlights the progress of funded national projects. In addition, the report summarises major awards achieved by staff and the publications produced by staff and students throughout 2015

One of the most important activities which staff partake in, is the annual National Competitive Grants Scheme. July saw the announcement of the Australian Research Council (ARC) Linkage grants. Five CIES staff featured in four projects totalling over $1 million. November saw the announcement of the highly competitive Australian Research Council (ARC) Discovery Grants. CIES was once again extremely successful with eleven staff featuring on seven ARC Grants totalling close to $3 million for 2016.

I would like to take this opportunity to thank all our staff and students for their outstanding contributions to the continued success of the centre. Furthermore, I also give heartfelt thanks to our industry partners and advisory board members for the important role they have played throughout 2015 in shaping and supporting the CIES activities. I do hope you enjoy reading about all the activities and events and I look forward to the continuing success of the centre.



Director
PROFESSOR BRIAN UY,
BE PhD UNSW, CPEng, CEng, PE, NER, APEC Engineer, IntPE (Aus)
FICE, FIEAust, FASCE, FIABSE, MIStructE, MAICD

I would like to take this opportunity to thank all our staff and students for their outstanding contributions to the continued success of the centre.

Vision

As an internationally recognised research centre our vision is to provide outcomes that improve the design, construction and maintenance of economic, effective and safe civil engineering infrastructure that enhances the quality of human life in a sustainable way

The Centre

The Centre for Infrastructure Engineering and Safety is focused on high-level research in structural engineering, geotechnical engineering, engineering materials and computational mechanics.

Specifically, we apply our skills to engineering and safety assessments and with the risk management of buildings, bridges, dams, roads and other infrastructure when subjected to both in-service conditions and overload (or limit) conditions, such as may occur in fire, earthquake, cyclone or blast situations, or when structures are exposed to hostile environments.

The centre aims to promote multi-disciplinary collaboration across the Faculties of Engineering, Science and the Built Environment at UNSW and to foster international and interdisciplinary research partnerships.

CIES:

- Is an established world-class interdisciplinary research team, supported by advanced analytical, computational and experimental techniques and facilities, and underpinned by structural and geotechnical engineering expertise, in the field of infrastructure engineering and mechanics.
- Provides a forum for research engineers and scientists from various disciplines to exchange ideas and to develop and lead collaborative research programs.
- Provides a platform for the submission of highly-competitive nationally peer-assessed research grant funding applications, specifically through the Australian Research Council's Discovery and Linkage Project schemes and for the development of proposals for research funding from industry.
- Promotes the application of research outcomes and deliverables to industry.
- Contributes to the education and training of high-quality postgraduate students in a wide range of relevant disciplines in engineering and applied science, and provides an outstanding research and learning environment.

Centre Management

The UNSW Centre for Infrastructure Engineering and Safety was managed in 2015 by an Executive Committee comprising of the CIES Director, Research Director, two Deputy Directors and the Centre Manager. The committee met on a regular basis to discuss strategy, performance and research opportunities.

In addition, input to CIES management is provided by the CIES Academic Group.

CIES Staff

Director

Professor **Brian Uy**, BE PhD *UNSW*
CPEng CEng PE IntPE(Aus) FIEAust FASCE FICE FIABSE MIStructE MAICD

Research Director

Scientia Professor **Mark Bradford**, BSc BE PhD *Syd* DSc *UNSW*. FTSE PEng CPEng CEng FIEAust FIStructE MAICD MASCEt MACI

Deputy Directors

Emeritus Professor **Ian Gilbert**, BE PhD *UNSW*. CPEng FIEAust MACI

Professor **Chongmin Song**, BE ME *Tsinghua*, DEng *Tokyo*

Centre Management

Centre Manager

Irene Calaizis, BCom *UNSW*

Administrative Officer

Patricia Karwan

Other Academics

Professor **David Carmichael**, BE MEngSc *USyd*, PhD *Cant*, CPEng, FIEAust, MASC

Professor **Stephen Foster**, BE *NSWIT*, MEngSc PhD *UNSW*, FIEAust

Professor **Nasser Khalili**, BSc *Teh* MSc *Birm* PhD *UNSW*

Professor **Yong Lin Pi**, BE *Tongji* ME *Wuhan* PhD *UNSW* CPEng MIEAust

A/Professor **Mario Attard** BE PhD MHEd *UNSW*, MIEAust, CPEng

A/Professor **Arnaud Castel** BE, MEngSc, PhD *Toulouse*

A/Professor **Wei Gao** BE HDU, ME PhD Xidian, MIIAV, MAAS

A/Professor **Linlin Ge**, PhD *UNSW*, MSc *Inst of Seismology*, BEng *WTUSM*

A/Professor **Adrian Russell** BE, PhD UNSW, PGCert Bristol

Dr **Ali Akbarnezhad**, BE *AUT, Tehran*, PhD *NUS*

Dr **Ali Amin**, BE, PhD *UNSW*, MIEAust CPEng RPEQ

Dr **Kurt Douglas** BE Syd. PhD UNSW, MIEAust

Dr **Ehab Hamed**, BSc MSc PhD *Technion*

Dr **Arman Khoshghalb** BE ME Sharif Uni of Tech, PhD *UNSW*

Dr **Kostas Senetakis**, BEng, MSc, PhD *AUTh*

Dr **Xuesong Johnson Shen**, BEng, MSc *Nanjing*, PhD *HKPU*

Dr **Hossein Taiebat** BSc *Isfahan* M.E.S. PhD *Syd*

Dr **Sawekchai Tangaramvong** BEng Chulalongkorn, MEngSc PhD *UNSW*, MIEAust

Dr **Hamid Vali Pour Goudarzi** BSc MSc *Tehran*, PhD *UNSW*

Dr **Ghaofeng Zhao**, BSc MSc CUMT, PhD *EPFL*

Other Research Staff

(alphabetical order)
Dr **Ankit Agarwal**, B-Tech IIT Kanpur PhD *UNSW*

Dr **Farhad Aslani**, BSC, MSc, PhD *UTS*

Dr **Huiyong Ban** BE PhD *Tsinghua University, Beijing*

Dr **Zhen-Tian Chang**, BE ME *Hunan* PhD *UNSW*

Dr **Yue Huang**, BE MPhil CityU HK, PhD *UNSW*

Dr **Mohammad Khan** BSc *BUET* MSc *NUS* PhD *UNSW*

Dr **David Kellerman** BE, PhD *UNSW*

Dr **Inamullah Khan**, BE MEngSc PhD *University of Toulouse*

Dr **Nima Khorsandnia**, BSc MSc *BIHE*, PhD *UTS*

Dr **Brendan Kirkland** BE PhD *UWS*

Dr **Jean Xiaojin Li**, PhD *UNSW*, BEng *WTUSM*

Dr **Xinpei Liu** BE *SCUT*, MEngSc MPhil PhD *UNSW*

Dr **Yan Liu**, BE ME *DLUT*, PhD *UQ*

Dr **Alex Hay-Man Ng,** PhD *UNSW*, MEngSc *UNSW*, BE *UNSW*

Dr **Vipulkumar Patel**, BE, ME, PhD *VU*

Dr **Babak Shahbodaghkhan**, BSc. *IKIU*, MSc. *Univ. of Tehran*, PhD *Kyoto Univ.*

Dr **Hossein Talebi**, BSc, MSc, PhD Bauhaus-University Weimar *BUW*

Dr **Tai H. Thai**, BE ME *HCMUT*, PhD *Sejong*

Dr **Thanh Vo**, BE/BCom *Syd*, MEngSc, PhD *UNSW*

Dr **Di Wu** BE PhD *UNSW*

Dr **Guotao Yang**, BE PhD *Tongji*

Dr **Mohammad Vahab**

Technical Team

John Gilbert

Greg Worthing

Ron Moncay

Emeritus Professor

Somasundaram Valliappan BE *Annam*, MS *Northeastern*, PhD DSc *Wales*, CPEng, FASCE, FIACM

Francis Tin-Loi BE PhD Monash, CPEng MIEAust

UNSW Members

Professor **Alan Crosky**
School of Materials Science & Engineering

Professor **Gangadhara Prusty**
School of Mechanical Engineering

Dr **Mahmud Ashraf**
School of Engineering and Information Technology (SEIT), UNSW Canberra.

Adjunct Member

Dr **James Aldred**, Adjunct Associate Professor – CIES - School of Civil & Environmental Engineering, UNSW

Visiting Academics

Professor **Xiaotong Peng**, School of Civil Engineering and Architecture, University of Jinan, China

A/Professor **Qu Hui**, School of Civil Engineering, Yantai University, China

A/Professor **Bazyar Mansoor Khani**, Department of Civil Engineering, Faculty of Engineering, Yasouj University, Iran

A/Professor **Chao Zhang**, School of Information Engineering, Inner Mongolia University of Science and Technology, China

A/Professor **Zhaoqiu Liu**, School of Civil Engineering, Yancheng Institute of Technology, China

A/Professor **Dunja Peric**, School of Civil Engineering, Colorado Kansas State University, USA

A/Professor **Dr Tengfei Xu**, Faculty of Civil Engineering, Southwest Jiaotung University, China

A/Professor **Guangyue Ma**, Wuhan University of Technology, China

A/Professor **Chen Wu**, College of Civil Engineering, Fujian University of Technology, China

Dr **Yiqian He**, Department of Engineering Mechanics, Dalian University of Technology, China

Dr **Zihua Zhang**, Ningbo University, China

Steering Committee

The Steering Committee meets throughout the year to oversee and monitor the progress of the Centre and to assist the Director in developing strategies to ensure that the goals and objectives of the Centre are realised.

The membership of the 2015 Management Board for the Centre comprised:

Professor **Mark Hoffman**, Dean, Faculty of Engineering (Chair)

Professor **Stephen Foster**, Head of School – Civil and Environmental Engineering

Professor **Brian Uy**, Director, CIES

Scientia Professor **Mark Bradford**, Director of Research, CIES.

Professor **Ian Gilbert**, Deputy Director, CIES

Professor **Chongmin Song**, Deputy Director, CIES

Scientia Professor **Deo Prasad**, Faculty of the Built Environment

Scientia Professor **Rose Amal**, School of Chemical Sciences & Engineering

In Attendance: CIES Centre Manager Ms **Irene Calaizis**

Centre Activity Highlights

CIES MEMBER ACHIEVEMENTS/ DISTINGUISHED HONOURS

CIES – As Australia's premier high level research group in structural engineering, geotechnical engineering, engineering materials and computational mechanics, our success is not only measured by the excellent track record in attaining competitive research grant funding but also in the assessment of our activities on the key dimensions of Research Relevance and Impact.

In 2015, CIES continued to engage with and to promote the application of research outcomes and deliverables to industry and to provide an outstanding research and learning environment.

Some of our highlights included:

NSW Premier's Prize for Science & Engineering

Founding CIES Director Scientia Professor Mark Bradford (pictured above with NSW Premier Mike Baird) was awarded the Excellence in Engineering & Information & Communications Technology category prize in the 2015 NSW Premier's Prizes for Science & Engineering. These Prizes seek to recognise excellence in science and engineering, and reward leading researchers for cutting-edge work that has generated economic, environmental, health, social or technological benefits for New South Wales.

Mark Bradford is an Australian Laureate Fellow, Professor of Civil Engineering, Scientia Professor at UNSW Australia and currently CIES' Director of Research. Mark has been proactive in embedding university research into industry practice, especially through design standards and textbooks. Having built a team of critical mass through his Federation and Laureate Fellowships in the areas of steel and steel-concrete structural engineering, Mark has been concentrating in recent times on progressing these disciplines into the broader paradigms of sustainable and low-carbon full-life cycle structural engineering practice, which is a challenge of immense significance in the construction sector. ■

These Prizes seek to recognise excellence in science and engineering, and reward leading researchers for cutting-edge work that has generated economic, environmental, health, social or technological benefits for New South Wales.

CIES RESEARCH FUNDING SUCCESS

This impressive result in ARC grants recognises the calibre of research underway at UNSW. Our position as number one in the country this year is a testament to the importance and impact of the work we are doing...

Best of the best – School and CIES - one of the highest UNSW achievers in ARC research grants awarded for 2015

ARC Discovery & LIEF Grants

With 4 new Discovery grants and 1 new LIEF grant, CIES won more than half the School's total and more than any other research centre in its discipline nationwide. These wonderful results consolidate CIES' position as the leading infrastructure centre in Australia.

Discovery Project Grants:

Professor **Mark Bradford**
DP 150100446 -To investigate the capacity of high-strength steel (HSS) flexural members by undertaking physical tests and numerical simulations, and proposes to craft innovative overarching design guidance for them within a paradigm of Design by Advanced Analysis.

Professor **Stephen Foster** & Dr **Hamid Valipour** - DP 150104107 - To investigate the moment-rotation performance of steel fibre reinforced concrete (SFRC) beam-column connections containing economical fibre dosages.

Associate Professor **Adrian Russell**, Prof **David Muir Wood**
DP 150104123 - To make discoveries for modelling initiation, rate of progression and consequences of seepage induced internal erosion through soils which make up critical water retaining infrastructure like dams

Professor **Chongmin Song**, Emeritus Professor **Francis Tin-Loi,** Dr **Sawekchai Tangaramvong**
DP 150103747 - To develop, directly from computer-aided design models or digital images, an automatic numerical simulation approach for the safety assessment of engineering structures in three dimensions.

LIEF – Linkage Infrastructure, Equipment and Facilities

Russell, A/Prof Adrian R; **Khalili,** Prof Nasser; **Zhao**, Dr GaoFeng; K**hoshghalb**, Dr Arman; **Sloan**, Prof Scott W; **Kouretzis**, Dr Georgios; **Indraratna**, Prof Buddhima N; **Rujikiatkamjorn**, A/Prof Cholachat; **Cassidy**, Prof Mark J; **Gaudin**, Prof **Christophe**; **Williams**, Prof David J; **Scheuermann**, Dr Alexander
LE 150100130 - To develop Australia's most advanced earthquake shaking table to investigate soil-structure interactions.

Dr **Gaofeng Zhao** and Professor **Khalili** were also involved in a successful LIEF grant (LE150100058) administered by Monash University.

Deputy Vice-Chancellor (Research) Professor Les Field welcomed the result.

"This impressive result in ARC grants recognises the calibre of research underway at UNSW. Our position as number one in the country this year is a testament to the importance and impact of the work we are doing," he said.

ARC Linkage Grants

CIES Staff were successful in receiving over $1 million in Australian Research Council (ARC) Linkage Grants for 2015

Five CIES members were successful in receipt of four ARC Linkage grants totaling over $1 million in the ARC Linkage Grants scheme announced on 7 July, 2015.

Professors **Mark Bradford** and **Brian Uy** were awarded funds to carry out research on the use of high strength steel in building frames in a project in collaboration with Tsinghua University, Beijing and the China Construction Steel Structure Corporation.

A/Professor **Arnaud Castel**, Prof **Stephen Foster** and Dr **Ali Akbarnezhad**, together with Dr Redmond Lloyd of the industry project partner Boral, received ARC funding for a project to investigate the fundamental mechanics of early age thermal cracking in mass concrete elements.

CIES Staff Successful in receiving over $1 million in Australian Research Council (ARC) Linkage Grants for 2015

Professor **Stephen Foster** and Dr **Hamid Valipour** were awarded funds in collaboration with One Steel Reinforcing to carry out research on the use of high strength steel reinforcement in reinforced concrete structures.

Professor Abhijit Mukherjee (Curtin University, Perth) in collaboration with Professor **Brian Uy** also received funds to collaborate with Lastek to develop a laser ultrasonic device for structural health monitoring of major infrastructure, with particular focus on structural steel elements.

Full details of the four CIES Linkage projects are provided below.

- LP150101196 **Bradford**, Prof Mark; **Uy**, Prof Brian; **Guo**, Prof Yanlin; **Dai**, Prof Li Xian

  Industry Partner Organisations: TSINGHUA UNIVERSITY, BEIJING; CHINA CONSTRUCTION STEEL STRUCTURE CORP. LTD

This project plans to investigate the use in building frames of composite steel-concrete members that use high-strength steel (HSS) instead of mild steel (MS). HSS is finding increased use in construction, and HSS has a much greater strength-to-weight ratio than MS, leading to lighter composite structures, less material usage and smaller foundations. Overall, this reduces the cost and carbon footprint of steel-framed buildings. The investigation is planned to involve physical testing, numerical studies, developing structural models and crafting design guidance for T-beams, columns and joints. The major intended outcome of the project is design guidance that will support the expanded use of HSS.

- LP150100725 **Castel**, A/Prof Arnaud; **Foster**, Prof Stephen; **Akbarnezhad**, Dr Ali; **Lloyd**, Dr Redmond

  Industry Partner Organisations: BORAL CEMENT LIMITED

The aim of this project is to determine the fundamental mechanics of early age thermal cracking in mass concrete elements and in members with high cement contents, and to develop a tool to predict early age cracking. Early age thermal cracking in concrete due to heat of hydration and thermal gradients is a major engineering problem and is undesirable for durability and structural performance, as well as aesthetics and project economics. The research outputs include new theories and relationships from which advanced engineering models will be derived that will support improved design and construction of mass concrete elements.

- LP150101102 **Foster,** Prof Stephen; **Valipour,** Dr Hamid; **McGregor**, Mr Graeme

  Industry Partner Organisations: ONESTEEL REINFORCING PTY LIMITED/ONESTEEL REINFORCING

The aim of this project is to develop the fundamental understanding needed to design and construct high-strength concrete columns with high-strength steel reinforcement, with the intended outcome of providing design rules for adoption by engineers and Standards bodies. With significant innovations in Australian steel bar technology, strengths grades of 750 megapascals, and higher, are becoming available. These high-strength steels can be used in reinforced concrete building construction and would increase the competitiveness of Australia's manufacturing industry and enable the export of high-value-added technologies. Significant efficiencies in construction costs and in carbon emissions are possible.

- LP150100475 **Mukherjee**, Prof Abhijit; **Uy**, Prof Brian; **Karaganov**, Dr Victor; **Stanco**, Mr Alex

  Industry Partner Organisations: Curtin University of Technology, THE TRUSTEE FOR LASTEK UNIT TRUST/LASTEK PTY LTD

This project aims to develop technologies to monitor the health of Australia's ageing infrastructure with the use of a unique laser ultrasonic device. The laser device will be used to conduct experiments that are expected to develop a set of techniques for monitoring the critical areas of structures with most frequently observed ageing problems. Precise estimates of damage will be made by processing signals from a combination of simulation and experimental modelling. Feedback from the user community is expected to further improve the techniques.

CIES RESEARCH COLLABORATIONS

> ...CIES continues to promote a sustainable concrete technology within the CRC for Low Carbon Living...

CIES – Promoting Sustainable Concrete Technology

CIES continues to promote a sustainable concrete technology within the CRC for Low Carbon Living under the leadership of A/Professor Arnaud Castel and Professor Steve Foster.

In July 2014, this new project was approved by the CRC-LCL Board with a cash contribution of $1,100,000 in combination with the In-kind contributions from partner organisations of $1,900,000.

Geopolymer concrete has an 80% lower carbon footprint compared to the conventional Portland cement concrete.

Using field and laboratory data, a comprehensive Handbook for geopolymer specification will be developed and published through Standards Australia.

Partner organisations include CIES at the UNSW, Swinburne University of Technology, ADAA, ASA, AECOM, Sydney Water and Standards Australia. The project coordinators also obtained letters of support from the main Australian geopolymer concrete suppliers: Zeobond Pty Ltd, Wagners Concrete Pty Ltd, Milliken Infrastructure solutions as well as RMS Pavement Structures, Transport and Main Roads QLD, Vicroads. ■

CIES RESEARCH IMPACT

> ...an opportunity for CIES to engage with the precast industry and to contribute to the industry by providing structural solutions that are more economic, durable, environmentally friendly and sustainable...

CIES & UNSW the first Tertiary Institution member of National Precast Concrete Association Australia (NPCAA).

Dr Ehab Hamed was prompted to contact the NPCAA after seeing a news story on the new Sandwich Panel Recommended Practice in the CIA (Concrete in Australia) magazine. He saw this as an opportunity for CIES to engage with the precast industry and to contribute to the industry by providing structural solutions that are more economic, durable, environmentally friendly and sustainable.

Precast concrete walling is a great alternative to traditional construction techniques. The benefits offered by precast walling along with the growing availability of mobile cranes and the rising cost of bricklaying, have seen precast panels becoming the product of choice in the Australian construction market. In many cases, however, precast concrete wall panels are used blindly to some extent without adequate research findings to support methodologies.

Through NPCAA, Dr Hamed was invited to give a presentation about his work in their August 2015 meeting at Brisbane, where he aims to gain interest from industry about his research activities. ■

CIES RESEARCH LEADERSHIP

New reference text provides a unique focus on the treatment of serviceability aspects of design.

Emeritus Professor Ian Gilbert, Deputy Director of the Centre for Infrastructure Engineering and Safety, has published the second edition of his book Design of prestressed Concrete to AS3600-2009 (CRC Press in Florida, USA). The book (co-authored with Professors Neil Michleborough -Hong Kong University of Science and Technology and Gianluca Ranzi - University of Sydney, contains the most up-to date and recent advances in the design of modern prestressed concrete structures, as well as the fundamental aspects of prestressed concrete behaviour and design that were so well received in the first edition. The text is written for senior undergraduate and postgraduate students of civil and structural engineering, and also for practising structural engineers.

The work has gained much from the membership of Professor Gilbert on committees of Standards Australia and the American Concrete Institute and his involvement in the development of AS 3600-2009 over the past 35 years. Design of Prestressed Concrete to AS3600-2009 is a valuable source of information and a useful guide for students and practitioners of structural design. ■

CIES Workshop - on the Engineering of Advanced Cementitious Materials and Durable Structures.

In August 2015, CIES hosted this important workshop which attracted high profile National and International speakers and attendance from industry leaders, CIES academics and research staff and visiting members of fib (International Federation for Structural Concrete).

International speakers included: Professor Frank Dehn (Leipzig University, Germany); Professor Marco di Prisco (Politecnico Milano, Italy); Professor Harald S. Müller (Karlsruhe Institute of Technology, Germany)

The workshop was an opportunity for recent research advances in this important area to be shared with a group of key influencers from both the academic and industry spheres. ■

> Ian provided his extensive research and knowledge in these areas to provide delegates with specific information that can be applied to create better concrete outcomes for designers, suppliers, placers, contractors, project managers, and asset owners

CIES MEMBER EXPERTISE

Cracks and Crack Control in Concrete Structures - Emeritus Professor Ian Gilbert

Every year the CIA (Concrete Institute of Australia) conducts educational programs which aim to increase knowledge through the dissemination of fundamental and applied information for the benefit of the concrete and construction industry in general.

The programs aid in the facilitation of communications, sharing of knowledge and experience and provide an opportunity for peers within the concrete industry to interact and network.

CIES's Deputy Director and Emeritus Professor **Ian Gilbert** was invited to present the CIA series of workshops on "Cracks and Crack Control in Concrete Structures" across all 6 capital cities during October 2015.

With his concrete expertise with respect to cracking, crack control requirements, and the practical implications of these, Ian provided his extensive research and knowledge in these areas to provide delegates with specific information that can be applied to create better concrete outcomes for designers, suppliers, placers, contractors, project managers, and asset owners.

Professor Gilbert has been an active member of Standards Australia's Committee BD-002 for over 30 years, responsible for the on-going development of the Australian Standard for Concrete Structures AS3600. Ian is also an active member on the Australian Standards committee BD-090 for Concrete Bridges AS 5100.5. He is the author of five text books on the analysis and design of reinforced and prestressed concrete and over 350 technical publications. As the Chairman of Durability Task Group 6, Ian has led the development of Z7-06 – Cracks and Crack Control. ■

CIES Director appointed to Australian Research Council (ARC), College of Experts for 2016-2018

CIES Director Professor **Brian Uy** has been appointed to the ARC College of Experts from 2016-2018 and will serve on the Engineering, Information and Computing Sciences (EIC) Panel.

Members of the ARC College of Experts assess and rank ARC grant applications submitted under the National Competitive Grants Programme, make funding recommendations to the ARC and provide strategic advice to the ARC on emerging disciplines and cross-disciplinary developments.

This is Brian's fourth major appointment to ARC research assessment panels spanning a ten year period. He was previously a member of the ARC College of Experts for Engineering and Environmental Sciences from 2007-2009 and served as the Deputy Chair in 2009. He then followed this with a three year term on the Selection Advisory Committee for the Australian Laureate Fellowships program from 2011-2013. Most recently he was a member of the Excellence in Research Australia (ERA) Research Evaluation Committee on Engineering and Environmental Sciences. ■

INDUSTRY ACTIVITIES

CIES Industry Advisory Committee (IAC)

The CIES IAC was established in 2011 to provide a mechanism for receiving input from industry stakeholders and the broader community on a wide range of planning issues. The IAC (CIES) provides industry's views on the research directions of the Centre, on trends and directions within the profession, and on emerging technologies and opportunities in the broad research areas of civil engineering infrastructure.

From time to time, particular briefs will be provided to the IAC-CIES to address specific issues that arise in the Centre and provide advice to the Director. In addition, the IAC may raise issues that it would like to see addressedby the Centre.

The committee is comprised of the CIES Directors and representatives from the following companies:

AECOM, Unicon Systems, Pells Sullivan Meynink (PSM), Aurecon, BOSFA, HYDER, Australian Steel Institute, ARUP, ECLIPSE Consulting Engineers Pty Ltd, Laing O'Rourke ■

INTERNATIONAL PROFILE

Throughout 2015, CIES continued to attract senior academic visitors on collaborative visits and also a program of delivering seminars which draw on international excellence and expertise.

Visitors included:

Professor **Xiaotong Peng**, School of Civil Engineering and Architecture, University of Jinan, China

A/Professor **Qu Hui**, School of Civil Engineering, Yantai University, China

A/Professor **Bazyar Mansoor Khani**, Department of Civil Engineering, Faculty of Engineering, Yasouj University, Iran

A/Professor **Chao Zhang**, School of Information Engineering, Inner Mongolia University of Science and Technology, China

A/Professor **Zhaoqiu Liu**, School of Civil Engineering, Yancheng Institute of Technology, China

A/Professor **Dunja Peric**, School of Civil Engineering, Colorado Kansas State University, USA

A/Professor Dr **Tengfei Xu**, Faculty of Civil Engineering, Southwest Jiaotung University, China

A/Professor **Guangyue Ma**, Wuhan University of Technology, China

A/Professor **Chen Wu**, College of Civil Engineering, Fujian University of Technology, China

Dr **Yiqian He**, Department of Engineering Mechanics, Dalian University of Technology, China

Dr **Zihua Zhang**, Ningbo University, China ■

Research Funding

2015 CIES RESEARCH FUNDING SUMMARY

RESEARCHER(S)	RESEARCH TOPIC	GRANTING ORGANISATION	VALUE AT 2015
MA Bradford	An Innovative and Advanced Systems Approach for Full Life-Cycle, Low-Emissions Composite and Hybrid Building Infrastructure	ARC Laureate Fellowship including Faculty of Engineering & UNSW support ARC FL100100063	$446,518
Chongmin Song	From CAD and digital imaging to fully automatic adaptive 3D analysis	ARC Discovery DP150103747	$132,328
A. Russell	Internal erosion of soils: microstructural modelling	ARC Discovery DP150104123	$111,970
MA Bradford	Buckling capacity of high-strength steel flexural members	ARC Discovery DP150100446	$132,328
S Foster, H Valipour	Rotation Capacity of Joints in SFRC Moment Resisting Beams and Frames	ARC Discovery DP150104107	$91,612
B Uy	The behaviour and design of innovative connections to promote the reduction and reuse of structural steel in steel-concrete composite buildings	ARC Discovery DP140102134	$178,274
A Russell, N Khalili	Shallow foundations in unsaturated soils: mechanistic design through numerical modelling, analysis and experimental investigation"	ARC Discovery DP140103142	$136,327
W Gao, Y-L Pi, F Tin-Loi	Stochastic geometrically nonlinear elasto-plastic buckling and behaviour of curved grid-like structures	ARC Discovery DP140101887	$141,571
G Ranzi (USYD), A Castel, R I Gilbert, D Dias-da-Costa	Stiffness degradation of concrete members induced by reinforcement corrosion.	ARC Discovery DP140100529	$50,000
C Song	A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture	ARC Discovery DP130102934	$119,792
RI Gilbert	Control of cracking caused by early-age contraction of concrete	ARC Discovery DP130102966	$114,347
N Khalili	Dynamics analysis of unsaturated porous media subject to damage due to cracking	ARC Discovery DP130104918	$108,902

RESEARCHER(S)	RESEARCH TOPIC	GRANTING ORGANISATION	VALUE AT 2015
L Ge	Advanced techniques for imaging radar interferometry	ARC Discovery DP130101694	$119,792
G Zhao	Dynamic fracturing in shale rock through coupled continuum-discontinuum modelling	ARC DECRA DE130100457	$171,520
T Thai	Reliability assessment of concrete-filled steel tubular frames designed by advanced analysis	ARC DECRA DE140100747	$127,562
A Russell	An earthquake shaking table to investigate soil-structure interactions	ARC LIEF Grant LE150100130	$400,000
MA Bradford	Climate adaptation technology and engineering for extreme events.	CSIRO / Flagship Collaborative Research Program	$127,300
N Khalili	Experimental investigation and constitutive modelling of weak rocks subject to mechanical and moisture degradation	ARC Linkage LP140101078	193,822
B Uy	Development of novel viscoelastic sprayed material for the effective blast resistance of critical and resource infrastructure	University of Western Sydney / ARC Linkage Project Shared Grant-LP140100030	$59,480
B Uy	The behaviour and design of innovative connections to promote the reduction and reuse of structural steel in steel-concrete composite buildings	ARC Discovery DP140102134	$195,742
H M Goldsworthy, E Gad, B Uy, S Fernando	Development of efficient, robust and architecturally-flexible structural systems using innovative blind-bolted connections	ARC Linkage LP110200511	$30,000
S Foster; E Hamed; Z Vrcelj	Advanced Composite Structures	Cooperative Research Centre for Advanced Composite Structures Ltd (CRC-ACS)	$83,265
S Foster; A Castel	Performance based Criteria for Concretes: Creating Pathways for Low Carbon Concrete Manufacture with Existing Standards	Cooperative Research Centre for Low Carbon Living Ltd (CRC LCL)	$228,189

RESEARCHER(S)	RESEARCH TOPIC	GRANTING ORGANISATION	VALUE AT 2015
A Castel	Equipment to develop a world class laboratory for carrying out durability tests at the material and structural level	MREII (UNSW Major Research Equipment and Infrastructure Initiative Scheme	$160,969
K Senetakis	Interferometer which applies the white light interferometry principle to capture and quantify surface characteristics of materials, including soil particles and rock samples.	MREII (UNSW Major Research Equipment and Infrastructure Initiative Scheme	$118,900
S Tangaramvong	FRG Grant	Faculty of Engineering	$30,000
K Senetakis	FRG Grant	Faculty of Engineering	$30,000
A Akbarnezhad	FRG Grant	Faculty of Engineering	$29,265
E Hamed	Coupled hygrothermal-creep effects in adhesively bonded lap joints	UNSW Goldstar Award	$40,000
A Akbarnezhad	Industry Research	Boral Cement	$53,350
Industry funded research undertaken by various CIES Projects team	Various		$188,084
		TOTAL	**$3,955,467**

The CIES Team

A world-class centre in such a broadly based and exciting field attracts world-class research staff and academics. The team at CIES are working together to challenge and change how things are done in this industry. Often being called upon to provide advice to government and industry, helping to set standards that raise the bar across the industry.

Research opportunities

Infrastructure needs around the world are changing – materials, demands, and expectations are all changing. At CIES, our research is contributing to advanced solutions to improve the way we plan, design, build, maintain and rehabilitate the things we build, from bridges and dams to roads, rail and other critical infrastructure. Better, stronger, longer lasting

CIES Facilities

The Centre for Infrastructure Engineering and Safety is supported by some remarkable facilities to enhance research across the board. These include the Randwick Heavy Structural Laboratory, and the Materials Research Laboratory and Geotechnical Engineering Laboratories, collectively known as the Infrastructure Laboratories

Centre Research

REHABILITATION RESILIENCE & SAFETY SUSTAINABILITY

RESEARCH PUBLICATIONS FOR 2015

Research Publications are an important output of Centre related research activities.

In 2015, CIES researchers continued to have a consistently strong publishing output including 4 books, 140 refereed journal papers and 58 refereed conference papers. See page 60.

POST GRADUATE RESEARCH STUDENTS

Most academic staff involved with the Centre also supervise higher degree research (HDR) students.

All new HDR income associated with Centre students is distributed to the Faculties and Schools in which they are enrolled. Since its inception, there has been a steady growth in new PhD student enrolments associated with CIES member supervision.

	2012	2013	2014	2015
Number of PhD students supervised by CIES members	53	62	69	84

Since its inception, there has been a steady growth in new PhD student enrolments associated with CIES member supervision.

RESEARCH & TEACHING AREAS OF CENTRE MEMBERS

Name	Position within School	Research Areas	Teaching Areas
Dr Brian Uy	Professor of Civil Engineering	Composite steel-concrete structures, critical infrastructure protection systems, deconstruction techniques, rehabilitation and strengthening techniques, steel structures, structural health monitoring, structural systems, sustainable construction materials	Composite steel-concrete structures, steel structures, structural design
Dr Mark Bradford	Federation Fellow, Scientia Professor and Professor of Civil Engineering	Structures subjected to elevated temperature. Steel, concrete and composite steel-concrete structures. Curved members, including members curved in plan and arches. Structural stability. Numerical techniques (FE, finite strip, non-discretisation methods). Time-dependent behaviour of concrete arches and domes.	Engineering mechanics. Structural analysis and design. Steel and composite steel-concrete structures. Structural stability.
Dr Stephen Foster	Professor of Civil Engineering	Analysis and design of reinforced concrete deep beams, corbels and nibs. High strength and reactive powder concretes. Nonlinear 2-D and 3-D modelling of concrete structures. Confined concrete structures.	Engineering mechanics and engineering design. Structural analysis and design. Concrete structures.
Dr Ian Gilbert	Emeritus Professor	Serviceability of concrete and composite structures. Creep and shrinkage of concrete and time-dependent behaviour of concrete structures, including prediction of deflection and cracking. Impact of low-ductility reinforcement on strength and ductility of concrete structures. Nonlinear FE modelling of concrete structures. Structural applications of high strength and reactive powder concrete.	Engineering mechanics and engineering design. Structural analysis and design. Concrete structures.
Dr Chongmin Song	Professor of Civil Engineering	Scaled boundary finite element method. Dynamic soil-structure interaction. Fracture mechanics. Elasto-plastic damage constitutive modelling.	Computing. Foundation engineering. Pavement analysis and design. Numerical techniques.
Dr Francis Tin Loi	Emeritus Professor	Large-scale limit and shakedown analyses. Limit analysis in the presence of constitutive instabilities. Identification of quasi-brittle fracture parameters. Smoothing of contact mechanics problems.	Strength of materials. Structural analysis and design. Bridge engineering.
Dr Nasser Khalili	Professor of Civil Engineering	Numerical methods. Unsaturated soils. Remediation of contaminated soils. Flow and contaminant mitigation.	Numerical methods. Geotechnical engineering. Foundation engineering.
Dr David Carmichael	Professor of Civil Engineering	Sustainable construction Adaptable and flexible infrastructure Carbon projects Infrastructure investment Project delivery and contracts Risk	Project and construction engineering and management Construction, building Systems studies/operations Research Problem solving
Dr Somasundaram Valliappan	Emeritus Professor of Civil Engineering	Stress analysis in soil and rock mechanics. Stability of large dams. Wave propagation. Fracture mechanics. Fuzzy analysis. Biomechanics. Smart materials and structures. Earthquake engineering.	Numerical analysis. Continuum mechanics. Soil mechanics.

Name	Position within School	Research Areas	Teaching Areas
Dr Mario Attard	Associate Professor in Civil Engineering	Finite strain isotropic and anisotropic hyperelastic modelling. Fracture in concrete and masonry. Crack propagation due to creep. Ductility of high-strength concrete columns. Structural stability.	Mechanics of solids. Structural analysis and design. Design of concrete structures. Finite element analysis. Structural stability.
Dr Yong-Lin Pi	Professor in Civil Engineering	Advanced nonlinear mechanics. Members curved in plane, including beams curved in-plan and arches. Nonlinear FE techniques. Thin-walled structural mechanics. Structural dynamics.	Engineering mechanics and mathematics.
Dr Kurt Douglas	Pells Sullivan Meynink Senior Lecturer	Rock mechanics. Probabilistic evaluation of concrete dams and landslides. Numerical methods.	Geotechnical engineering. Engineering geology. Design of tunnels, slopes, retaining walls
Dr Adrian Russell	Associate Professor in Civil Engineering	Unsaturated soils. Fibre reinforced soils. Particle crushing in granular media. Wind turbine foundations. In-situ testing and constitutive modelling of soils.	Geotechnical engineering. Soil mechanics.
Dr Linlin Ge	Associate Professor in Civil Engineering	Remote Sensing and Applications Near Real-time Satellite Remote Sensing Interferometric Synthetic Aperture Radar (including InSAR, DInSAR and PSInSAR/PSI) and Applications Integration of Remote Sensing, GIS and GPS Structural Deformation and Health Monitoring Natural Hazard Monitoring (e.g. Landslide, Bushfire, Flood, Tropical Cyclone, Beach Erosion, Earthquake and Volcano) Ground Deformation Monitoring (e.g. Mine Subsidence) Carbon Capture and Storage (CCS), especially site stability monitoring	Remote Sensing and Photogrammetry Radar Remote Sensing Satellite Remote Sensing and Applications Surveying for Civil Engineers Surveying for Mining Engineers Surveying and GIS
Dr Arnaud Castel	Associate Professor in Civil Engineering	Durability of construction materials: Steel corrosion in concrete, chemical attacks Low Carbone Concrete Technology: Geopolymer concrete, blended cements, Manufactured aggregates Time-dependent behaviour: Shrinkage and creep of concrete Modelling of Time-dependent steel corrosion process in concrete Repair and Strengthening using CFRP	Concrete technology Engineering Mechanics Concrete Structure Analysis and Design Earthquake engineering
Dr Hossein Taiebat	State Water Senior Lecturer of Dam Engineering	Embankment dams, Erosion and piping, Numerical modellings, Slope stability analysis. Fibre reinforced clays, Analysis of offshore foundations, Liquefaction analysis.	Applied geotechnics, Fundamentals of geotechnics; Advanced foundation engineering, Ground improvement techniques, Embankment dams
Dr Wei Gao	Associate Professor in Civil Engineering	Uncertain modelling and methods. Vehicle/bridge interaction dynamics. Wind and/or seismic random vibrations. Stochastic nonlinear systems. Smart structures.	Dynamics. Structural analysis and design.
Dr Hamid Valipour	Senior Lecturer	Structural Mechanics, Constitutive modelling of concrete and timber, Finite element modelling, Localisation limiters, progressive collapse analysis and structural dynamics.	Mechanics of Solids, Steel and Timber Design, Bridge Design, Design of reinforced concrete

Name	Position within School	Research Areas	Teaching Areas
Dr Ehab Hamed	Senior Lecturer	Viscoelasticity of concrete and composite materials, Creep buckling of concrete domes and shells, Strengthening of concrete and masonry structures with composite materials (FRP), Nonlinear dynamics of concrete structures.	Steel and Composite Structures
Dr Arman Khoshghalb	Lecturer	Mechanics of unsaturated soils Numerical modelling of porous media Large deformation problems Meshfree methods Soil water characteristic curve Coupled flow-deformation	Soil Mechanics Fundamental of Geomechanics
Dr Gaofeng Zhao	Lecturer	Rock dynamics Microstructure constitutive model Computational methods Mutiphysical modelling	Pavement engineering Advanced Topics in Geotechnical Engineering Water & Soil Engineering
Dr Sawekchai Tangaramvong	Lecturer	Structural safety assessment; Optimal design and retrofit of strctures; Limit and shakedown analysis; Elastoplastic analysis; Contact mechanics; Mixed finite element method; Structural uncertainty	Steel Structure Design; Reinforced Concrete Design; Structural Analysis; Mechanics of Solids
Dr Kostas Senetakis	Lecturer	Experimental Mechanics, Soil Dynamics, Micromechanics, Earthquake Engineering, Pavement Engineering.	Foundation Engineering, Soil Dynamics and Earthquake Engineering, Structural Dynamics
Dr Babak Shahbodagh-Khan	Lecturer	Computational Poromechanics, Dynamic Soil-Structure, Interaction Analysis, Constitutive Modelling of Geomaterials, Swarm-Based Optimization	Numerical Methods in Geotechnical Engineering, Pavement Engineering, Civil Engineering Practice
Dr Ali Akbarnezhad	Lecturer	Construction Materials Design for Sustainability Sustainability Assessment Building Information Modelling Operations Research	Sustainability in Construction Project Management
Dr Xuesong Johnson Shen	Lecturer	Construction Automation and Robotics, Structural Health Monitoring, Smart Sensing, Sustainable Construction.	Construction Methods, Design of Construction Projects, Project Management.
Dr Ali Amin	Associate Lecturer	Analysis, Design and Structural Applications of Fibre Reinforced and High Performance Concretes. Sustainable Construction Materials. Nonlinear FE Modelling of Reinforced Concrete Structures. Deconstruction techniques.	Construction Technology. Reinforced Concrete Design and Analysis. Strength of Materials. Structural Mechanics
Dr Zhen-Tian Chang	Senior Research Fellow	Corrosion of reinforced concrete, concrete repair, structural analysis	
Dr Xiaojing Li	Research Fellow	Algorithms for information extraction from optical and radar imagery for earth surface change detection Structural deformation monitoring using DInSAR, PSI and GPS techniques.	

Name	Position within School	Research Areas	Teaching Areas
Dr David Kellerman	Research Associate	Continuum Mechanics, Computational Mechanics, Advanced Composite Materials, Forming Analysis, Fibre Kinematics, Biomechanics, Orthotropic and Hyperelastic Material Modelling, Finite Deformation, Nonlinear Finite Element Analysis, Buckling and Stability	Mechanics of Solids Engineering Mechanics Computational Mechanics
Dr Xinpei Liu	Research Associate	Composite steel and concrete structures, Numerical modelling of structures, Non-linear analysis and behaviour of curved members, Quasi-viscoelastic behaviour of concrete.	
Dr Huiyong Ban	Research Associate	High-performance and high-strength steel structures, flexural behaviour of steel-concrete composite beams, buckling behaviour of steel structures, residual stress.	
Dr Guotao Yang	Research Associate	Stability of railway tracks under thermal loading, Fatigue reliability of steel bridges, Structural behaviour of steel-concrete composite structures	
Dr Inamullah Khan	Research Associate	Time dependent behaviour of concrete, Steel Corrosion in RC structures, Service life design of Reinforced concrete structures exposed to severe environment	Structural Analysis, Design of concrete structures.
Dr Tai H. Thai	Research Associate	Advanced analysis; Steel structures; Steel-concrete composite structures; Beam and plate theories; Functionally graded and laminated composite plates.	Engineering Design
Dr Ankit Agarwal	Research Associate	Durability of steel-FRP joints under thermal loading, Numerical Modelling	
Dr Yue Huang	Research Associate	Nonlinear short-term and time-dependent behaviour of high-strength concrete panels, analysis and numerical modelling of RC structures, creep buckling of structures	
Dr Nima Khorsandnia	Research Associate	Structures: Timber, concrete, steel, timber-concrete and timber-timber composites; Numerical Modelling: Non-linear finite element modelling of structures, finite difference method, computational mechanics, 3D continuum-based elements, frame and fibre elements, force-based formulation, coupled analysis; Time Dependent Analysis: Long-term behaviour of timber, concrete and timber-concrete composite structures; Progressive collapse of RC structures	
Dr Alex Hay-Man Ng	Research Associate	Remote sensing application in monitoring land surface changes	Remote Sensing
Dr Vipulkumar Patel	Research Associate	Demountable connections, Residual stresses, Concrete-filled steel tubular columns.	

Name	Position within School	Research Areas	Teaching Areas
Dr Hossein Talebi	Research Associate	Scaled boundary Finite Element Method for modelling damage and elastoplasticity Multiscale methods High Performance Computing	
Dr Farhad Aslani	Research Associate	Composite steel-concrete structures, Steel structures, Reinforced concrete structures, Analytical and numerical modelling of structures, Fire performance of reinforced concrete structures.	Composite steel-concrete structures
Dr Thanh Vo	Research Associate	Physical and Theoretical Modelling of Interactions between Unsaturated Soils and Structures	
Dr Mohammad Khan	Research Associate	Low carbon concrete technology i.e. geopolymer concrete and blended cement concrete. Utilisation of industrial by-products to reinforced concrete. Durability and sustainability of reinforced concrete structures.	Engineering materials Advanced concrete technology Design of reinforced concrete structures. Engineering mechanics
Dr Yan Liu	Research Associate	Finite element mesh generation Computational Mechanics Scaled Boundary Finite-Element Method Image-Based Analysis	
Dr Di Wu	Research Associate	Structural analysis with stochastic and non-stochastic uncertainties. Structural safety assessment against low-probability but high-consequence events. Time-dependent structural reliability analysis with various uncertain effects. Robust structural optimization against uncertain parameters. Stochastic and non-stochastic uncertainty analysis and design of composite materials.	
Dr Mohammad Vahab	Research Associate	Computational geomechanics, Hydraulic fracturing, saturated/unsaturated porous media, X-FEM	Finite element method, Advanced numerical modeling, Continuum, X-FEM, Solid mechanics, Analysis of structures

Research Highlights

Project Name:	An Innovative and Advanced Systems Approach for Full Life-Cycle, Low-Emissions Composite and Hybrid Building Infrastructure
Principal Investigator:	Scientia Professor **Mark Bradford**
Funding Body:	ARC Australian Laureate Fellowship
Project Duration:	2011-2015

The aim of this research Project was to develop a feasible scientific methodology for sustainable composite framed building infrastructure embodying reduced-emissions concrete and steel components in its construction. The provision for deconstructability at the end of its service life with a maximisation of component recycling was also part of the Project. The composite frame system utilises innovative geopolymer concrete and “low carbon” concrete flooring as well as high strength steel components, with tensioned bolted shear connectors joining them. The significant challenges in modelling frames with these components have been addressed. The fourth year of the Project saw the completion of joint tests, considering semi-rigid connections with H-section and CFST columns, high-strength steel, low-carbon Portland cement-based concrete and bolted shear connection. Two types of slab were tested as shown in Fig. 1, since consideration for the precast slab being in tension in a connection is essential. Beam testing was completed in the final year of the Project and extensive numerical studies were conducted (Fig. 2), showing that ABAQUS software can model the response of joints very closely, and so providing a means for conducting parametric studies to craft design guidance. This guidance has been published in a number of journal articles and keynote and invited international conference presentations. Research Associate Dr Xinpei Liu was closely associated with the work, and Dr Reza Ataei undertook both experimental testing and computation modelling as part of his PhD studies. ■

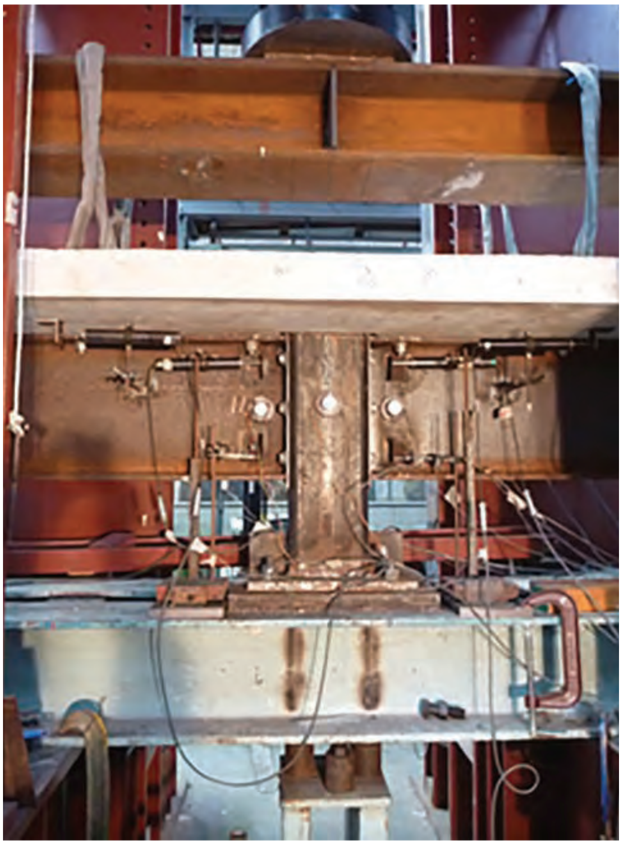


Figure 1. Joint testing

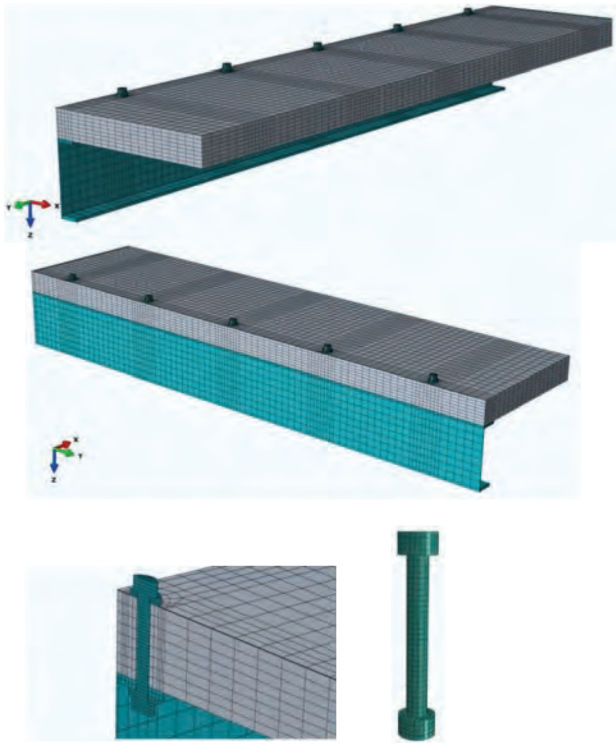
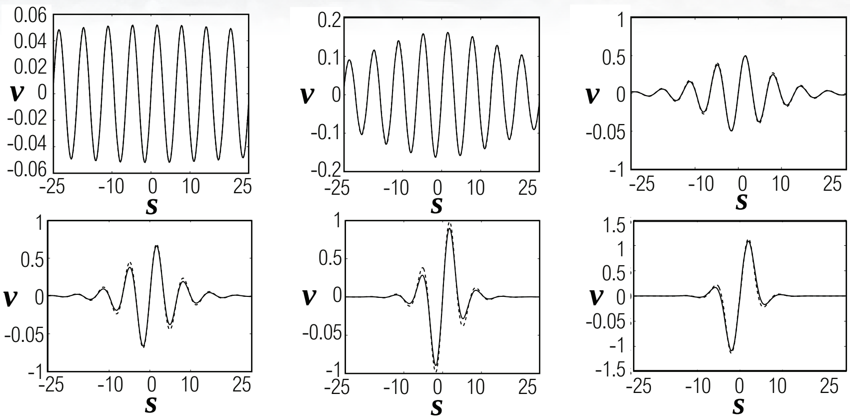


Figure 2. Computational Modelling

Project Name:	Thermal-Induced Railway Buckling
Principal Investigator:	Scientia Professor **Mark Bradford**
Funding Body:	Climate Adaptation Technology and Engineering for Extreme Events. CSIRO / Flagship Collaborative Research Program
Project Duration:	2013-2016

Figure 1 Buckled Railway



Figurem 2 Increasing localisation in the post-buckling range as force parameter decreases: p = 1.999, 1.99, 1.9, 1.8,1.5, 1.0 (p = 2 at bifurcation buckling)

This Project has as its focus the buckling of railways, and particularly curved railways, during heatwave events. One such buckle is illustrated in Fig. 1. These buckling instances are becoming quite frequent during heatwaves in Australia, and particularly in Melbourne. The Project aims to provide a deterministic modelling to be used with a stochastic one, so that a reliability analysis can be undertaken to determine the probability and cost of buckling events. The Project has employed Dr Gaotao Yang as a Research Associate.

The critical temperature for a snap-through type buckle has been established in closed form. It has been found, however, that the ballast resistance is non-linear with softening characteristics the behaviour is somewhat different. In this case, the ballast has an initial elastic restraining response and the railway buckles in a bifurcation mode, as is predicted by the theory of struts on an elastic foundation. Following this, the postbuckling mode is unstable and the deformations not only grow, but localise, as shown in Fig. 2 which represents the lengthwise buckling deformation as the load parameter p decreases with an increase of temperature. This observation is consistent with the field results of Fig. 1 and differs from "established" buckling theory which predicts harmonic buckling shapes. More sophisticated modelling of the foundation characteristics have been determined and implemented into a flow rule with non-associated hardening to provide a computational treatment of the phenomenon. Finally, a vulnerability study was undertaken to determine the expected number of railway buckles (Fig. 3).

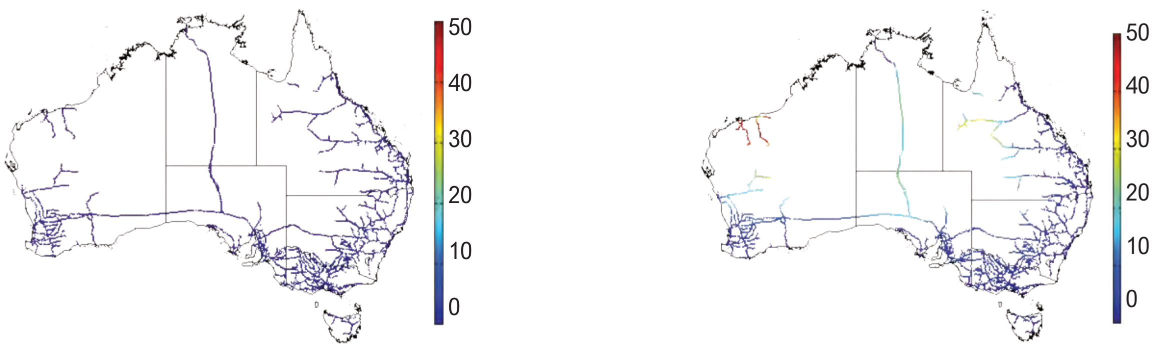


Fig. 3. Expected annual number of buckles per 100 km of track for 53 kg/m rail, for no climate change.

Project Name:	Buckling capacity of high-strength steel flexural members.
Principal Investigator:	Scientia Professor **Mark Bradford**
Funding Body:	ARC Discovery Project
Project Duration:	2015-2019

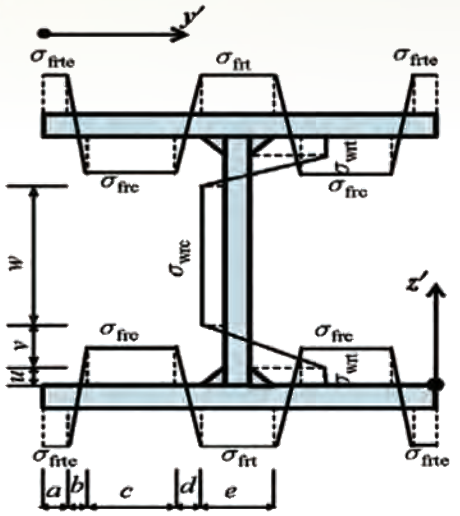


Figure 1 Residual stresses induced by welding.

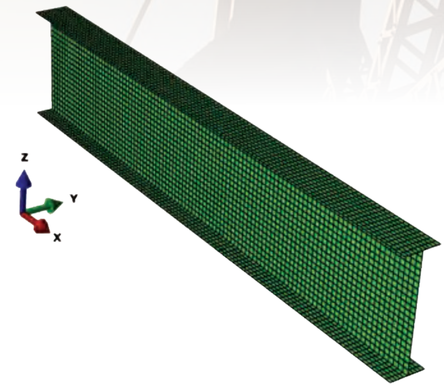


Figure 2 Finite element modelling.

This Project aims to investigate the capacity of high-strength steel (HSS) flexural members by undertaking physical tests and numerical simulations, and proposes to craft innovative overarching design guidance for them within a paradigm of Design by Advanced Analysis. HSS structures are significant as they are lighter than their mild steel counterparts and so use less material, with a much lower carbon footprint. Modern metallurgical process can produce HSS of Grade 1000 Megapascals or higher, but there is no specific structural code governing their design. Surprisingly little research has been reported on HSS flexural members which fail by lateral buckling, and this is the focus of the project, filling the gap needed to produce an advanced design standard. During 2015, the Project engaged Prof Yong-Lin Pi, Dr Xinpei Liu and Dr Reza Ataei, and two PhD students. Empirical formulations for residual stresses induced by welding (Fig. 1) have been included in a FE modelling (Fig. 2) and a buckling strength vs modified slenderness curve obtained (Fig. 3). This study has indicated that the strength curve in Fig. 3 is different to that for the buckling strength of mild steel beams in current design codes, and further work is needed.

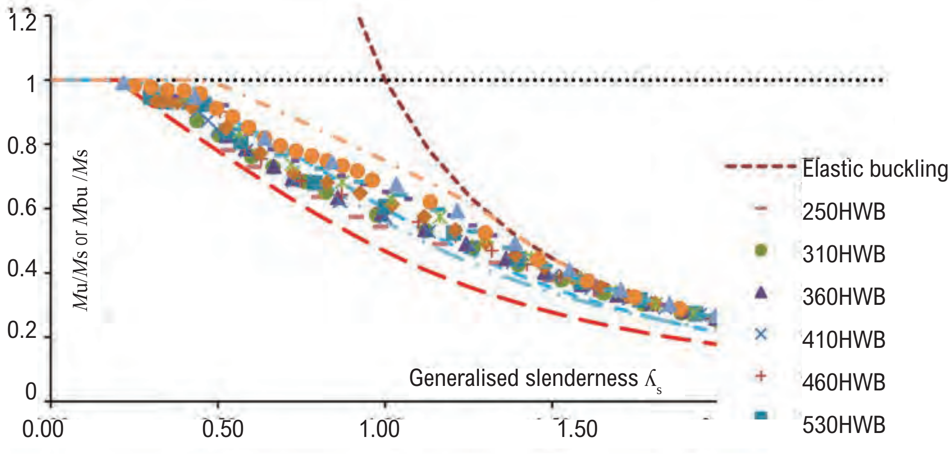


Figure 3 Comparisons of FE analysis results with buckling curves from current design codes.

Project Name:	Durability of steel-CFRP adhesive joints under sustained loading and thermal cycles
Principal Investigators:	Dr. **Ankit Agarwal**, Prof. **Stephen Foster**, Dr. **Ehab Hamed**
Funding Body:	CRC for Advanced Composite Structures
Project Duration:	2010-2015

The primary aim of this research project is to contribute to the development of certification-ready technology using Fibre Reinforced Polymer (FRP) and epoxy adhesive for the repair and rehabilitation of steel structures. The specific objective is to improve our basic understanding about the adhesive bonded joint between steel and carbon fiber reinforced plastic (CFRP) using the tensile testing of steel-CFRP single lap shear adhesive joints.

BACKGROUND

Large numbers of steel structures, like pipelines, bridges etc, are deteriorating due to corrosion or are coming to the end of their design life. Such structures are in need of retrofitting and replacement; and many of them are located in regions that regularly experience fluctuating thermal (hot-cold) conditions. Applications of Carbon Fiber Reinforced Plastic (CFRP) composites in the repair and rehabilitation of existing steel structures have gained significant attention due to their high strength to weight ratio, installation flexibility, and long term durability (Hollaway and Cadei, 2002, Zhao and Zhang, 2007). A number of research works have been conducted to investigate the impact of environmental conditions on the bond strength of steel-FRP joints (Dawood and Rizkalla, 2010, Al-Shawaf et. al., 2009, and others) but in few of these studies were the environmental field conditions and loading simulated. The influence of these combined loadings (environmental and mechanical) on the behavior and failure modes of FRP strengthened steel structures is crucial for their safe use and effective design, and requires further investigation.

OBJECTIVES

The specific objectives of this research is to investigate the impact of combined sustained load and thermal cycling on the long term strength and durability of steel-CFRP single lap shear adhesive joint. Two types of CFRP (commercial CFRP1 and non-commercial CFRP2) and two types of adhesives (commercial Adhesive B and non-commercial Adhesive C) were used in the testing.

Experimental Program and Thermal Cycle Apparatus:

Four different thermo-mechanical conditions were investigated, which are as follows:

1. **Control test** (no thermal cycle and no sustained load).
2. **Sustained load only**: Two levels of sustained loads were applied: 30% and 50% of the short-term bond strength of steel-CFRP joint (as obtained from control test).
3. **Thermal cycle only**: Two thermo-cyclic ranges were investigated: 10ºC to 50ºC and 10ºC to 40ºC. Both temperature ranges are below glass transition temperature of the Sikadur®30 adhesive used (62ºC).
4. **Thermo-mechanical loading**: Combination of sustained loads and thermal cycle range in both wet and dry conditions.

The thermal cycle equipment, shown in Figure 1, was designed and manufactured to apply the thermo-mechanical loading on six specimens simultaneously. The thermal cycle profile obtained from the apparatus is also shown in Figure 2. The cycle time for cold and hot cycle is 150 minutes each. The intended length of the full test was to be 21 days (108 thermo-cycles).

Figure 1: Thermal cycle apparatus

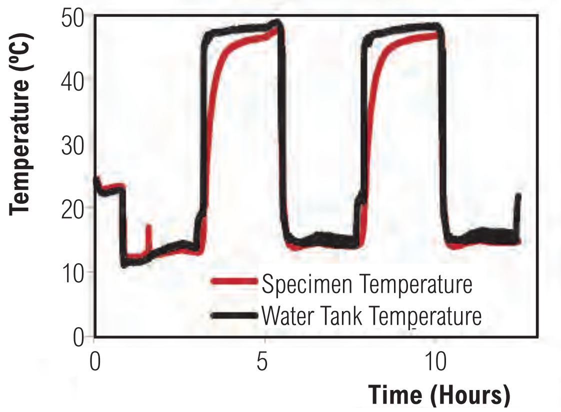


Figure 2: Thermal Cycle profile obtained from the thermal cycle apparatus.

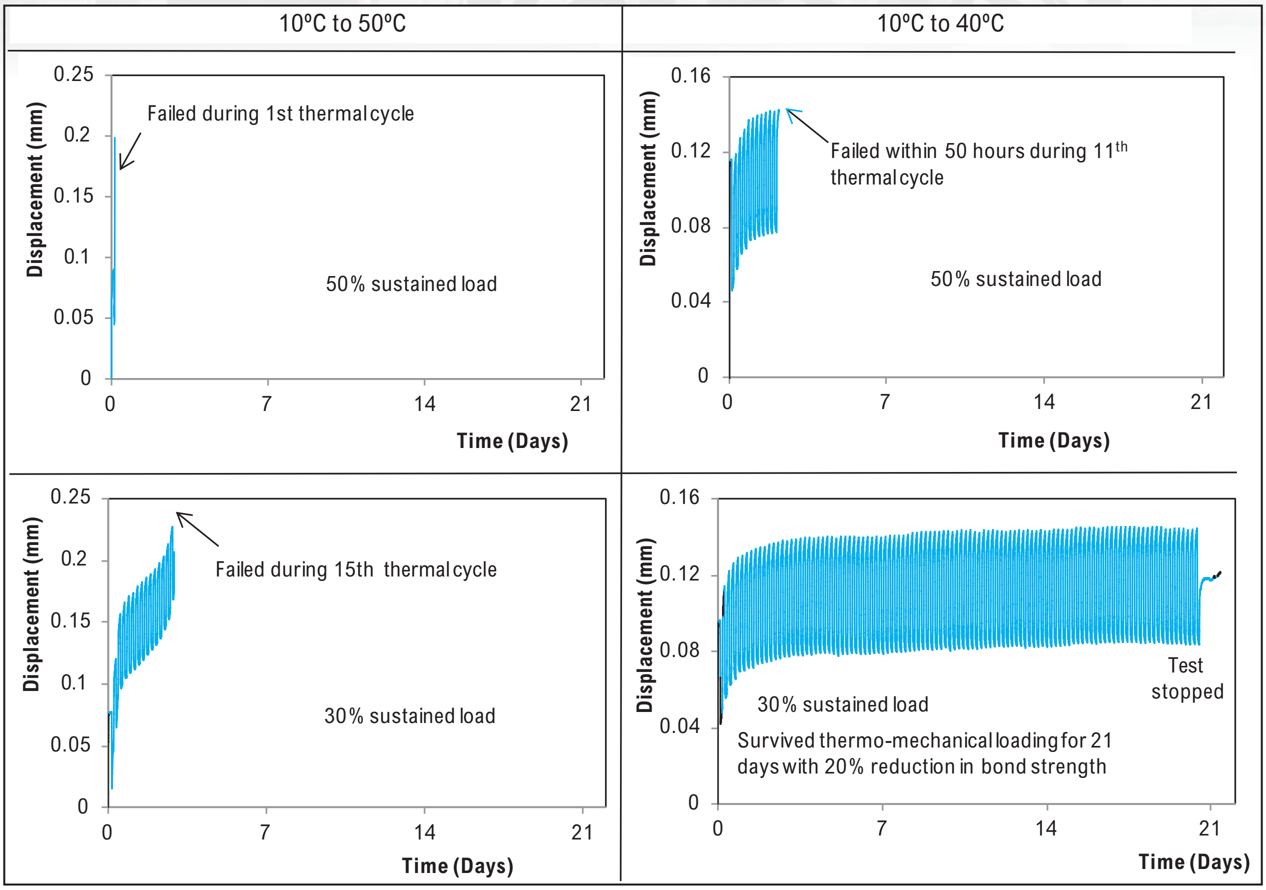


Figure 4: Normalized bond strength of steel-CFRP joints (CFRP1 and Adhesive B) after exposure to different thermo-mechanical conditions.

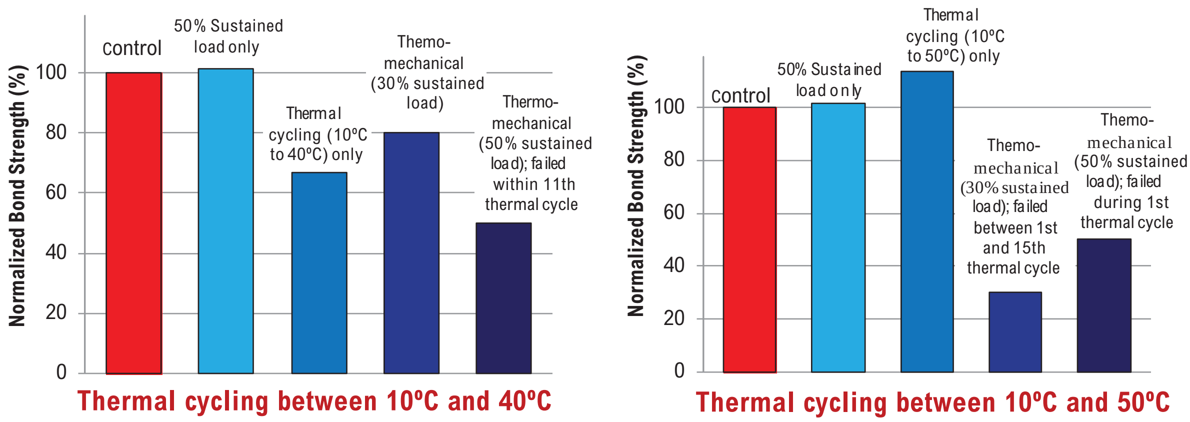
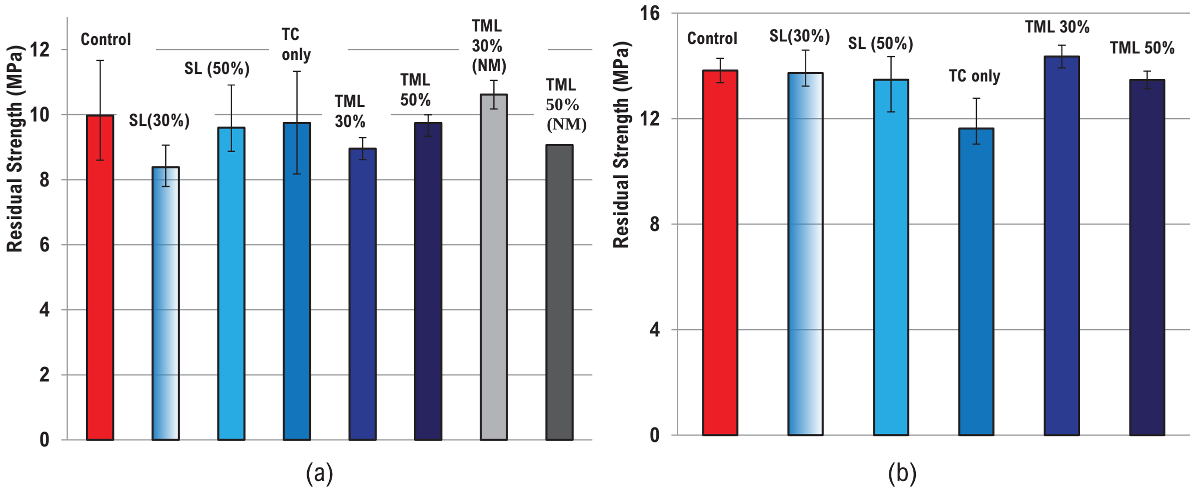


Figure 4: Normalized bond strength of steel-CFRP joints (CFRP1 and Adhesive B) after exposure to different thermo-mechanical conditions.



Control = Control specimens with no thermal cycle and no sustained load

SL (30%) = 30% Sustained Load only

SL (50%) = 50% Sustained Load only

TC only = Thermal cycle only between 10°C and 50°C

TML 30% = Thermo-mechanical loading with 30% sustained load

TML 50% = Thermo-mechanical loading with 50% sustained load

TML 30% (NM) = Thermo-mechanical loading with 30% sustained load and No Moisture

TML 50% (NM) = Thermo-mechanical loading with 50% sustained load and No Moisture

Figure 5: Summary of the residual strength of steel-CFRP joints with Adhesive C under different thermo-mechanical conditions: (a) CFRP1 and (b) CFRP2.

CONCLUSIONS

It is concluded that the influences of sustained load and climate are coupled in case where service temperature is closer to glass transition temperature of the adhesive (Adhesive B); while adhesives with higher glass transition temperature (Adhesive C) can sustain thermo-mechanical loading without significant degradation in bond strength.

Project Name:	Stiffness degradation of concrete members induced by reinforcement corrosion
Principal Investigators:	A/Professor Gianluca Ranzi (USyd), A/Professor **Arnaud Castel**, Professor **Ian Gilbert**, Dr Daniel Dias-da-Costa (USyd)
Funding Body:	ARC Discovery Project
Project Duration:	2014 - 2016

Corrosion of steel reinforcement is the major cause of deterioration of reinforced concrete structures exposed to coastal and marine environments. This is particularly important for Australia, considering that most of its large cities are coastal. At early active corrosion stage, serviceability is a lot more affected than ultimate capacity because of the high sensibility of the bending stiffness to corrosion induced steel-concrete bond loss, with the consequent development of excessive deflections and deformations as well as undesired concrete cracking and delamination. In normal service condition, the bending stiffness can be affected by both time-dependant effects and steel corrosion. This project aims to quantify the respective contribution of creep, shrinkage and steel corrosion on the stiffness reduction. Experimentations are carried out using accelerated corrosion methods applied to reinforced concrete beams subjected to sustained loading. Models are developed and calibrated aiming to provide efficient tool for corroding structures assessment.

The project is currently running on schedule. Figure 1 shows photos of the experimental setup including sustained loading and accelerated corrosion systems. A current of 150 μA/cm2 is applied to the reinforcement. The beams are currently experiencing significant reinforcement corrosion leading to concrete cover cracking (Figure 1).

Figure 1 - Arrangement of testing setup for accelerated corrosion

Project Name:	A mix design approach to reduce early-age thermal cracking of concrete
Principal Investigators:	A/Professor **Arnaud Castel**, Dr **Ali Akbarnezhad** Professor **Steve Foster**, Dr **Redmond Lloyd** (BORAL)
Funding Body:	ARC Linkage Project with BORAL
Project Duration:	2015 - 2018

The aim of this project is to determine the fundamental mechanics of early age thermal cracking in mass concrete elements and in members with high cement contents. A tool is to be developed for its prediction using a mix design approach. Early age thermal cracking in concrete due to heat of hydration is a major engineering problem and is undesirable for durability and structural performance, as well as aesthetics and project economics. The research outputs will allow for development of new theories and relationships, from which advanced engineering models will be derived and impact on design and construction of mass concrete elements, which are subject to high risk of early-age cracking due to heat of hydration and thermal gradients.

Project Name:	Equipment to develop a World class laboratory for carrying out durability tests at the material and structural level
Principal Investigators:	A/Professor **Arnaud Castel**, Dr **Ali Akbarnezhad**
Funding Body:	UNSW MREII
Project Duration:	2015

In the future, infrastructure needs will increase with the growing world population and urbanization process. Researchers and engineers face a crucial challenge to reduce the environmental impact of the construction sector and the concrete industry. Development of sustainable design approaches by seeking lower environmental impact and better durability is necessary. Managing the ageing of existing infrastructure is another critical challenge for engineers especially considering the huge amount of deteriorating construction all over the world.

The project aims to develop a world class laboratory for carrying out durability tests on construction materials. The equipment obtained improves greatly the CIES capability to carry out research on the durability of infrastructures and buildings including the development of innovating construction materials such low carbon concretes.

Project Name:	Reducing Barriers for Commercial Adaptation of Construction Materials with Low-Embodied-Carbon
Principal Investigators:	Professor **Steve Foster**, Professor Jay Sanjayan (SUT), A/Professor **Arnaud Castel**
Funding Body:	CRC-LCL
Project Duration:	2014 - 2017

Carbon emissions due to the manufacture of Portland cement are second only to burning fossil fuels. Production of Portland cement in Australia is responsible for 7.2 million tonnes of carbon emissions according to the cement industry figures. This does not include the carbon emissions caused by the imported cements which tend to have a larger rate of carbon emissions than Australian cements but typically one tonne of CO_2 per tonne of cement is a commonly quoted figure. In Australia, 14 million tonnes of fly ash is produced as a by-product from coal power stations. The fly ash can potentially replace all or part of the 9 million tonnes of Portland cement currently being consumed in Australian construction industry. Currently, only 1.9 million tonnes per year are used to partially replace the Portland cement in concrete. Slag, an industrial by-product from iron blast furnace process, is also commonly used in blended cements and also has a low carbon footprint due to its status as an industrial by-product. According to the CRC-LCL-2013 scoping study, the widespread utilisation of Geopolymer concrete in the industry is the most promising pathway to increase the rate of fly ash utilisation and reduce the Embodied-Carbon of construction materials. Indeed, in geopolymer concrete technology, all of the Portland cement is replaced by fly ash, slag and activators, hence has a low carbon footprint (about 80% carbon reduction).

Geopolymer concrete (GC) is the result of the reaction of materials containing aluminosilicate such as fly ash and slag with alkalis to produce an inorganic polymer binder. GC has been under intensive research around the world during the last 15 years and Australia is a leader in this research field. However, in Australia or anywhere else in the world, geopolymer concrete has yet to enter the mainstream of concrete construction. The CRC-LCL-2013 scoping study identified that the major barriers to geopolymer widespread adoption by the construction industry is the lack of standard specifications, track record and exclusion from current standards (e.g., AS 3600 or Eurocodes). The considerable sustainability benefits of using a binder system composed almost entirely of recycled materials has led to considerable research on GCs in recent years in Australia and three separate commercial suppliers of GC. With regards to the number of independent commercial producers, Australia currently leads the world in the field application of this technology. Australian industry and researchers have the opportunity to lead the widespread commercial use of geopolymer concrete, if adopted by rest of the world, it can potentially save many more millions tonnes of carbon emissions.

A pathway to overcome the main barriers to the widespread adoption of GCs is to develop confidence in this material by monitoring and reporting the performance of geopolymer in the field. The development of standards and standard specifications for geopolymer concrete also needs to be undertaken to overcome barriers. The standard specifications need to be performance-based since there are many proprietary geopolymer mixes and suitable for use by engineers when specifying materials for construction projects.

Chemical reactions characterising alkali-activated binder systems differ drastically from conventional hydration process of Portland cement. Thus, the mechanisms by which concrete achieves potential strength and durability are different between the two types of binders. As a result, testing methods and performance requirements for geopolymer must be developed that can be incorporated in a standard. The proposal aims to determine: What are the best methods and protocols for testing a geopolymer concrete in laboratory and field environments? What are the performance requirements that should be specified? How do these correspond to in-service performance of real structure?

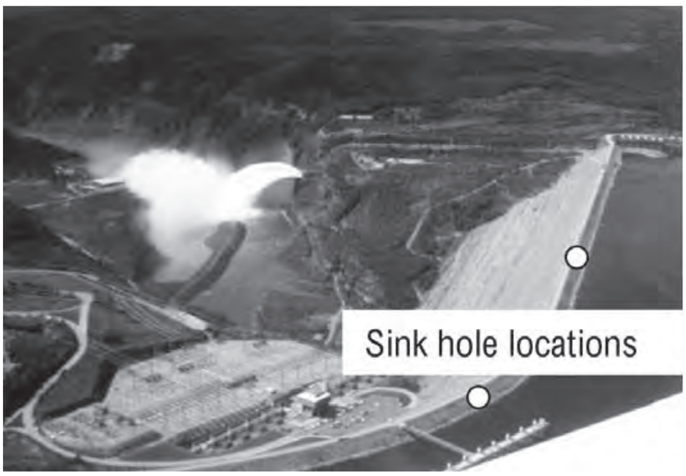
The handbook (HB) will be published through Standards Australia to assist engineers and end-users in specifying and using geopolymer concrete with greater confidence and less risk. The HB will also build on the Recommended Practice prepared by the Concrete Institute of Australia.

Project Name:	Internal erosion of soils: microstructural modelling
Principal Investigators:	A/Prof **Adrian Russell** and Prof David Muir Wood (Chalmers University, Sweden)
Funding Bodies:	ARC Discovery Project
Project Duration	2015 - 2017

Water retaining structures such as embankment dams, levees and dykes are critical elements of modern civil infrastructure. They retain reservoirs for water supply and production of electricity, and provide protection from flooding, and are expected to perform safely for many decades. However, internal erosion of the soils forming the containment structures may occur and lead to expensive maintenance costs or, in extreme cases, total collapse.

CIES researchers and an international collaborator have received funding from the ARC to produce models for the initiation, rate of progression and consequences of internal erosion. The project will integrate theories of soil microstructure and its large-scale behavior, experimental investigation and constitutive modelling. The outcomes will include a rigorous understanding of how fundamental soil particle and pore-scale properties governing internal erosion have the potential to destroy critical infrastructure.

This will be the first time that stress-strain behaviour has been coupled with the development of internal erosion. It will have a significant impact on the construction and management of embankment dams, levees and dykes.



Photographs 1 and 2. BC Hydro's WAC Bennett Dam showing the location of two sink holes (left), along with a closer view of one sink hole (right). Thirty years after construction was completed the two sink holes were discovered. To make the dam safe, authorities began releasing overflow and did so for weeks. The lake was lowered, the sink holes fixed, and the dam returned to running at full capacity. It is possible that the sink holes were indicative of ongoing erosion within the core of the dam. (Stewart, R.A., Watts, B.D., Sobkowicz, J.C. & Kupper, A.G. (1997). Bennett dam sinkhole investigation. Geotech. News. June. 32-40.).

Project Name:	Shallow foundations in unsaturated soils: mechanistic design through numerical modelling, analysis and experimental investigation
Principal Investigators:	A/Prof **Adrian Russell** and Prof **Nasser Khalili**
Funding Bodies:	ARC Discovery Project
Project Duration	2014 – 2016

CIES's geotechnical engineering researchers are building innovative design tools that account for the complex interactions between shallow foundations and unsaturated soils.

Current design tools for shallow foundations are only applicable for soils that are fully saturated or dry. This is alarming, since roughly 60 per cent of the world's population lives in regions where the surface soils – to a depth of several metres – are unsaturated.

Unsaturated soils have an internal suction that increases the contact forces between particles meaning they are generally stronger and stiffer than completely saturated or dry soils.

The ARC funded project involves integrating the group's expertise in unsaturated soil mechanics, theory of elasto-plasticity, numerical modelling, limit analysis and experimental investigation.

- The research involves:
- Rigorous theoretical analyses using the method of characteristics and the finite element method to quantify bearing capacity and load-settlement response.
- Use of a full-scale shallow foundation testing rig to generate relevant experimental evidence for validation of theory.
- Establishment of reliable and safe design tools.

Engineers need tools for incorporating the influence of suction on bearing capacity, settlement and safety. The proposed research will meet this need and will be the most comprehensive of its kind ever undertaken.

Project Name:	Dynamics analysis of unsaturated porous media subject to damage due to cracking
Principal Investigators:	Prof **Nasser Khalili**
Funding Bodies:	ARC Discovery Project
Project Duration	2014 – 2016

Unsaturation can markedly alter the dynamic response of porous media leading to out-phase movement, differential settlement, and longitudinal and transverse cracking. Typical recent examples of damage in geo-structures subject to dynamic loading and due to unsaturation include: Austrian Dam (California, suffered serious damage during the 1989 Loma Prieta earthquake), Matahina Dam (New Zealand, major piping developed after suffering damage after Bay of Plenty earthquake), Upper San Fernando Dam (California, suffered serious damage in both the 1971 San Fernando earthquake and 1994 Northridge earthquake) among others. The presence of such cracks affect the deformation characteristics and alter the fluid flow pattern within an embankment, which can lead to accelerated evolution of damage, and the subsequent failure due to piping [e.g. Matahina Dam in NewZealand (Gillon, 1988)]. This ARC funded project aims at advancing theoretical and computational bases for the dynamic analysis of variably saturated porous media which may experience damage due to cracking. A fundamental analysis of the coupled process involved in such media is undertaken using a systematic theoretical approach and fully validated computational tools are being developed for immediate use by practicing engineers.

Project Name:	An earthquake shaking table to investigate soil-structure interactions
Principal Investigators:	A/Prof **Adrian Russell**, Prof **Nasser Khalili**, Dr **Arman Khoshghalb**, Dr **Gaofeng Zhao**, Prof Scott Sloan (University of Newcastle), Dr Georgios Kouretzis (University of Newcastle), Prof Buddhima Indraratna (University of Wollongong), A/Prof Cholachat Rujikiatkamjorn (University of Wollongong), Prof Mark Cassidy (University of Western Australia), Christophe Gaudin (University of Western Australia), Prof David Williams (University of Queensland) and Dr Alexamder Scheuermann (University of Queensland)
Funding Bodies:	ARC Linkage Infrastructure, Equipment and Facilities Project, UNSW, UoN, UoW, UWA and UQ
Project Duration	2015

Geotechnical engineering researchers in CIES and four other universities have received funding to install at UNSW Australia's most advanced earthquake shaking table. The facility will simulate earthquakes and enable controlled testing of three-tonne models of foundation and soil-structure interaction systems typical of Australian infrastructure. The discoveries made using the facility will be integral to the modernisation of Australia's seismic design standards so that earthquake induced damage can be minimised.

Earthquakes are a problem of great significance to Australia. History shows that they may occur in places with no previous seismic activity. Australian cities are at risk as they comprise old infrastructure made of unreinforced brick and masonry, which is particularly susceptible to earthquake damage. Large areas in Australian cities are underlain by soils which may experience strength loss and turn to a fluid-like state (liquefaction) in an earthquake. Reinsurance companies rate an earthquake in Sydney in their 20 top risk exposures worldwide.

The facility will be operational from September 2016.

Project Name:	Experimental investigation and constitutive modelling of weak rocks subject to mechanical and moisture degradation
Principal Investigators:	Prof **Nasser Khalili** and Dr **Arman Khoshghalb**
Funding Bodies:	ARC Linkage Project, Roads and Maritime Services
Project Duration	2015 - 2018

Weak rocks constitute a major portion of the shallow stratum globally. In Australia, much of the surface rocks are geologically old, and have escaped the scraping off effects of ice age glaciations. Consequently, they are deeply weathered, weak cemented, friable and easily erodible. Nevertheless, the mechanical characteristics of weak rocks are poorly understood in the practice of geotechnical engineering. This is partly due to: (a) difficulties in obtaining undisturbed specimens of the rock unaffected by drilling and sampling processes, (b) inherent complexities in the behaviour of weak rocks, due to microstructural alterations and de-bonding of dominant grains at moderate stresses, (c) drastic change in strength and stiffness in exposure to moisture, and (d) inability of conventional theories of soil and rock mechanics to capture the behaviour weak rocks in a consistent and coherent way. The lack of predictive tools for the behaviour of weak rocks have over the years led engineers to adopt a conservative, worst case approach to design at considerable cost to the public.

Figure 1 shows a vertical cut in weak sandstone in the Blue Mountains, NSW, which is supported through extensive soil nailing, due to uncertainties in its behaviour, whereas experience and precedent show that the cut could be left unsupported without any ill effects (Figure 2). Similarly, in bridge design, where economical spread footings may be appropriate, deep foundations are specified due to the uncertainty in the strength and bearing capacity of weak rock over the service life of the project.

The overall aim of this research is to advance the theoretical and experimental bases for constitutive modelling of weak rocks subject to mechanical, environmental and cyclic degradation and provide the associated design tools.

Questions that are addressed include: (a) What are the influences of the applied stresses and moisture on the load carrying capacity of weak rocks and how will the microstructural alterations influence the response? (b) What are the combined effects of the deviatoric and mean stresses on de-bonding of grains and how they can be quantified? (c) What are the conditions where the microstructural compaction/damage and the subsequent material weakening can occur at stresses below the conventional peak strength (i.e. determined according to the standard compression testing procedure), and perhaps what is the relevance of such peak strength for stability assessments in the field? (d) How does moisture alter the rock stiffness and strength and to what extent? (e) What are the impacts of repeated cyclic loading and unloading on the mechanical response and weakening of the rock particularly at small strain cycles? This latter question is of particular relevance to road cuttings and bridge design where weak rock is subjected to various loading and unloading episodes.

Figure 1: Heavy soil nailing and retaining wall construction for cutting in Banks Wall Sandstone, Blue Mountains, Leura, NSW.

Figure 2: 100 year old unsupported vertical railway cut in Banks Wall Sandstone at Mt Victoria, Blue Mountains, NSW.

Project Name:	Interferometer to capture and quantify surface characteristics of geo-materials
Principal Investigators:	Dr **Kostas Senetakis**, A/Prof **Adrian Russell**, Dr **Arman Khoshghalb**, Dr **Gaofeng Zhao**, Dr **Babak Shahbodagh**, Prof **Nasser Khalili**, Dr **Hossein Taiebat**, Dr **Kurt Douglas**
Funding Bodies:	MREII (UNSW Major Research Equipment and Infrastructure Initiative Scheme
Project Duration	2015

CIES researchers have acquired an interferometer to capture and quantify surface characteristics (e.g. roughness, asperities) of materials, including soil particles and rock samples. The interferometer works both in 2-d and 3-d modes to quantify roughness and irregularity of surfaces. Also it works in quantifying changes in surface characteristics of soil grains before and after laboratory tests on soil samples (e.g. shearing, compression, dynamic-cyclic-testing). Because of its configuration, it enables non-conforming types of particle to particle contacts to be identified which is of major importance in advanced micro-mechanical testing and modelling.

In particular the testing facility will open new areas of experimental research and technology development and will strengthen current research works of the geotechnical group of UNSW related to:

- Experimental micromechanics for soils – quantification of surface characteristics of soil grains and modelling of particle to particle contact response.
- Energy dissipation mechanisms of soils: link between micro-scale response quantified in the interferometer and macro-scale element testing with major importance in modelling the deformation characteristics of soils and ground response against cyclic-dynamic induced loads.
- Thorough study of creep phenomena and its link to grain breakage and settlements of coarse-grained soils with major applications in Australia.
- Analytical and numerical modelling of ground response, in particular, associated with stiffness and damping characteristics from small to medium strains with major applications in unsaturated soil mechanics, soil dynamics and engineering geology (e.g. rockfill dam engineering).

Project Name:	Control of cracking caused by early-age contraction of concrete.
Principal Investigators:	Professor **Ian Gilbert**, A/Professor **Arnaud Castel**, Dr **Inam Khan**
Funding Body:	ARC Discovery Project - DP130102966
Project Duration:	2013 – 2015

Early-age contraction of concrete may cause excessive cracking in restrained concrete slabs and walls within the first few days and weeks after casting. The repair of such cracks results in high annual costs to the construction industry. Early-age contraction of concrete is due to thermal contraction and shrinkage. Thermal contraction occurs as the concrete cools from its peak hydration temperature to its lowest ambient temperature (usually within the first few days after casting). Contraction also occurs due to shrinkage as the concrete dries in the days and weeks after casting (drying shrinkage) and during the hydration process (autogenous shrinkage). When early-age contraction is restrained by embedded reinforcement or by the supports or adjacent parts of the structure, tensile stresses develop in the immature concrete and, to some extent, cracking is inevitable.

The aims of this project are to: (i) calibrate and quantify the early-age deformational characteristics of Australian concretes; (ii) to develop analytical and numerical models to predict the width and spacing of early-age cracks in reinforced concrete structures; and (iii) to develop procedures for use in structural design to determine the amount of steel reinforcement required to satisfactorily control early-age cracking.

The first series of tests is completed with the early age properties of a variety of concrete mixes measured on dog-bone shaped specimens (see Figs.1) and on reinforced concrete prisms. Some typical results are shown in Figure 2. The results of the experimental program have been used to calibrate and further develop several analytical models and non-linear numerical computer models previously developed by the CI for predicting cracking (spacing and width) under service load conditions. The second series of tests on restrained shrinkage cracking in slabs and walls commenced in late 2015 and is continuing.

The following publications have resulted from the project:

Gilbert, R.I. (2015), "Shrinkage and early-age temperature induced cracking and crack control in concrete structures", 2nd International Conf. on Performance-based and life-cycle structural engineering (PLSE2015), Dec.

Castel, A., Foster, S.J., Ng, T., Sanjayan, J. and Gilbert, R.I. (2015), "Creep and drying shrinkage of a blended slag and low calcium fly ash geopolymer concrete", *Materials and Structures*, DOI:10.1617/s11527-015-0599-1.

Khan, I., Murray, A., Castel, A. and Gilbert, R.I. (2015), "Experimental study of creep and shrinkage in early-age concrete", *Concrete in Australia*, 41(4), December, pp 40-45.

Khan, I., Murray, A., Castel, A. and Gilbert, R.I. (2015), "Experimental and analytical study of creep and shrinkage in early-age concrete", *CONCREEP10, Proc. 10th International Conference on Mechanics and Physics of Creep, Shrinkage and Durability of Concrete Structures,* 21-23 Sept, Vienna, pp 1066-1075.

Khan, I., Murray, A., Castel, A. and Gilbert, R.I. (2015), "Experimental study of creep and shrinkage in early-age concrete", *CONCRETE 2015, 27th Biennial Conf. of the Concrete Inst. of Australia*, Melbourne, p 9.

Castel, A. and Gilbert, R.I. (2014), "Influence of time-dependent effects on the average crack spacing in reinforced concrete beams", *Structural Concrete, Journal of the fib,* Vol. 15, No. 3, pp 373-379.

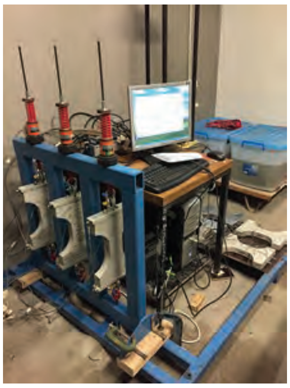


Figure 1. Dog-bone specimens under sustained tension

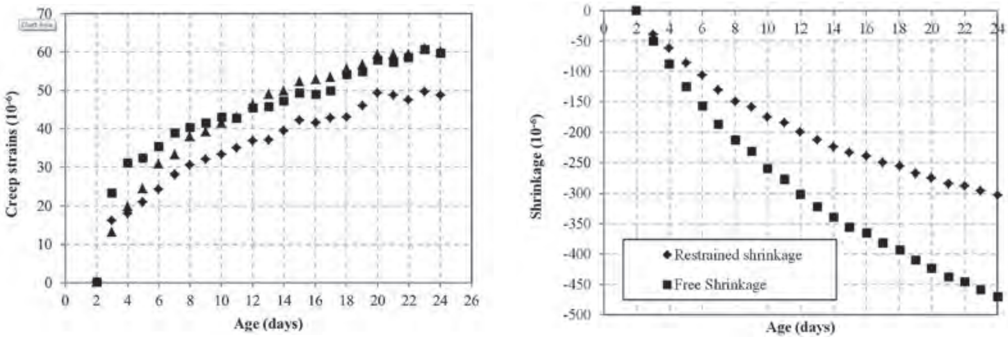


Figure 2. Creep and shrinkage data from dog-bone tests

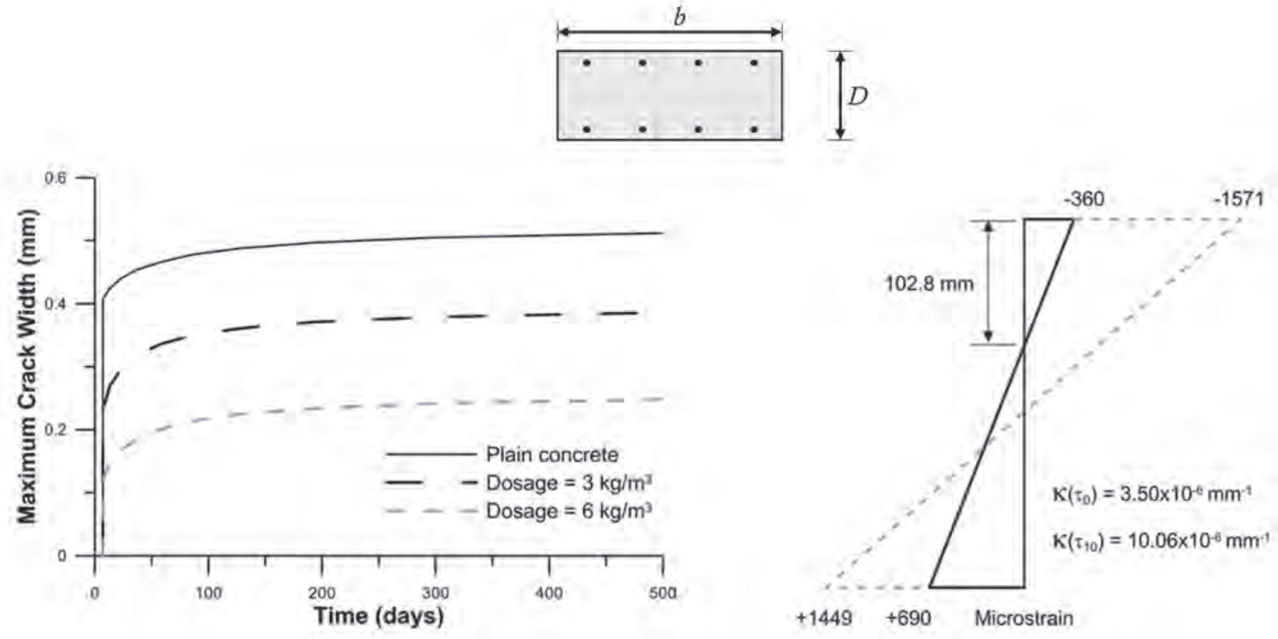
Project Name:	Time-dependent deformation of cracked reinforced concrete containing macro-synthetic fibres.
Principal Investigators:	Professor **Ian Gilbert**
Funding Body:	Elasto-Plastic Concrete, Australia and TSE Pty Ltd, Australia
Project Duration:	2014 – 2015

When macro-synthetic fibres are included in reinforced concrete significant improvements in both the serviceability and durability of the structure can be achieved, including:

- reduced crack widths – better control of both flexural and direct tension cracking;
- better confinement of concrete in compression leading to reduced spalling of the cover concrete;
- improved seismic performance;
- reduced anchorage lengths for bar reinforcement;
- reduced time-dependent deformation of cracked cross-sections due to creep and shrinkage of concrete; and
- improved fatigue performance for pavements and other members subject to repetitive loading.

Macro-synthetic fibres have recently been proposed for inclusion in segmental reinforced concrete tunnel linings. However, concerns have been raised about the long-term performance of these fibres in respect of creep and the associated consequences for crack width development with time under sustained flexural loads. To address these concerns, a method is being developed in this project to determine the effects of creep and shrinkage on the time-dependent behaviour of cracked, macro-synthetic fibre reinforced concrete cross-sections containing conventional bar reinforcement subjected to a sustained bending moment and axial force. Various constructive relationships are being trialled to model the time-dependent behavior of the cracked fibre-reinforced concrete and creep and shrinkage of the concrete are included in the analysis using a step-by-step method of geometric and temporal discretisation and relying on the principle of superposition.

Although the inclusion of fibres in the concrete has only a minor effect on the flexural strength of the cross-section, the fibres reduce time-dependent in-service deformations and significantly reduce maximum crack widths when used in combination with conventional reinforcing bars. Some typical results for a cracked doubly reinforced cross-section (D = 300 mm, b = 1000 mm, A_{st} = A_{sc} = 1000 mm^2/m, with M = 100 kNm and N = -300 kN) are shown below.



Project Name:	Stiffness degradation of concrete members induced by reinforcement corrosion.
Principal Investigators:	Prof Gianluca Ranzi (USYD), A/Prof **Arnaud Castel**, Prof **Ian Gilbert**, Dr **Daniel Dias-da-Costa**
Funding Body:	ARC Discovery Project - DP140100529
Project Duration:	2014 – 2016

Corrosion of steel reinforcement is the major cause of deterioration of reinforced concrete structures exposed to coastal and marine environments. Corrosion of steel reinforcement can occurs when structures are exposed to marine environments or subjected to repeated applications of de-icing salts and can lead to the degradation of the structural performance in term of both ultimate capacity and serviceability. The detrimental consequences of corrosion are mainly attributed to: (i) the reduction of the steel reinforcement area caused by the corrosion process; (ii) cracking of the concrete cover produced by expansion of the corroded material as it occupies a larger volume than its original metal; (iii) deterioration of the steel-concrete bond, observed to be more pronounced in concrete elements subjected to a sustained load.

This project involves the development of tools for the accurate prediction of the performance of corroding concrete structures, especially in view of the growing issues associated with aging of structures. T**he aim is to advance fundamental knowledge and understanding of the behaviour of reinforced concrete structures when subjected to reinforcement corrosion and to enhance durability design methodologies.** In particular, the main objectives are (i) to develop a new theoretical model to accurately predict the occurrence of corrosion accounting for time effects and for the presence of different levels of sustained loads and shrinkage, (ii) to develop clear design guidelines, and (iii) to acquire new experimental data from full-scale tests to provide benchmark results to validate analytical and numerical models.

. Accelerated corrosion experiments are underway to obtain new experimental data for benchmarking purposes. A current of 200 μA/cm2 is applied to reinforced concrete specimens. The corrosion process will involve cycles of 4 day wetting of the sample in a NaCl solution followed by 2 day drying. In this arrangement, the steel reinforcement acts as an anode, through which an electric current is induced during the wetting cycles, and a stainless steel element immersed in the NaCl solution acts as a cathode. The wetting process is applied from the bottom of the sample as shown in Fig. 1. The container for the NaCl solution is supported by means of a scissor table to enable the wetting and drying operation to take place by simply moving the scissor table up and down. For the continuous beam samples, to be tested in 2016, corrosion will be induced over the internal supports. In the corroded samples, the mid-span deflections will be measured from the top of the specimens.

This project will couple the corrosion behaviour to the time-dependent response of concrete structures. A new numerical model will be developed to distinguish between the effects of corrosion and the effects of shrinkage on the time-dependent degradation of stiffness of beams and slabs. Recent experimental work performed by the CIs has highlighted the enormous differences in measured deflections and deformations for samples cured under different conditions when subjected to shrinkage effects and their own self-weight.

Publications to date:

Castel, A., Khan, I and Gilbert, R.I. (2015), "Development length in reinforced concrete structures exposed to steel corrosion", *Australian Journal of Structural Engineering*, 16(2), pp 89-98.

Castel, A., Gilbert, R.I., Ranzi, G. and Foster, S.J. (2014), "A non-linear steel-concrete interface damage model for reinforced concrete after cracking", *Aust. Journal of Structural Engineering*, 15(2), pp. 221-229

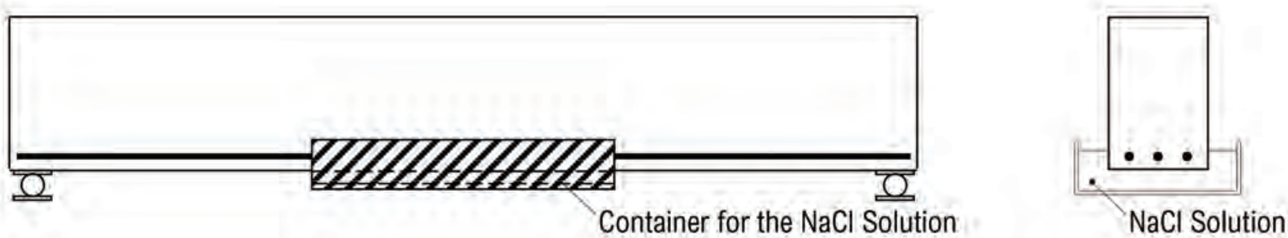
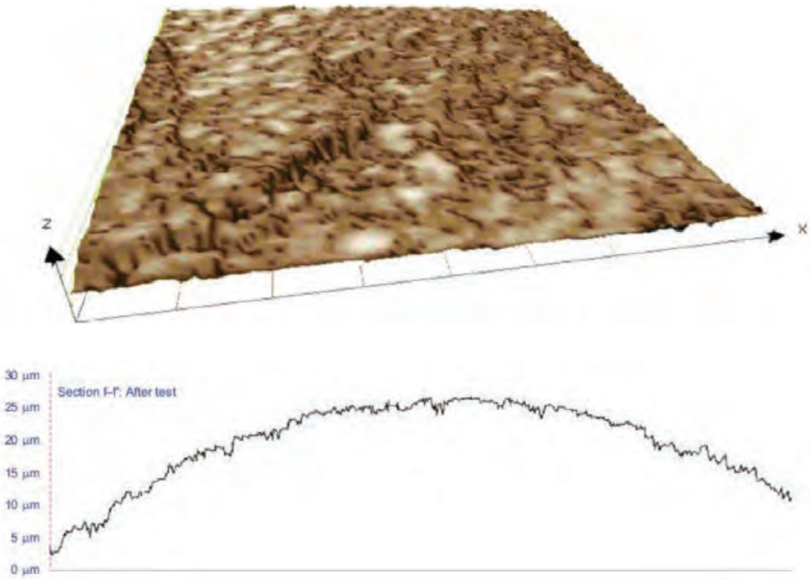


Figure 1 - Arrangement of testing setup for accelerated corrosion

Project Name:	The use of white light interferometry principle to capture and quantify surface characteristics of materials, including soil particles and rock samples
Principal Investigator:	Dr **Kostas Senetakis**
Funding Body:	MREII – Major Research Equipment UNSW
Project Duration:	2015

The aim of this project is to quantify the surface roughness of soil grains using the white light interferometry principle which is an advanced technique used in science and engineering research and applications. Particularly, the measurement of surface roughness of soil grains with the interferometer will provide important information associated with the properties of soils at the grain nano-scale which play an important role in the overall mechanical and dynamic response of soils. The results will be combined with dynamic element testing in order to quantify and better understand the important mechanisms that take place at the micro-to-nano scale and control the energy dissipation mechanisms in soils subjected to wave propagation. Previous research by CI Senetakis have shown a direct link between surface characteristics (morphology, mineralogy, geometric quantities) and grain contact behaviour which is responsible for important phenomena that take place during the cyclic-dynamic response of soils. The interferometer will quantify the morphological characteristics of soil grain surface and will provide a strong indication of surface damage and its role on material damping and stress-strain response of soils. The project will contribute to understand the micromechanics of soils and formulate proper analytical tools that can express the force-deflection behaviour of soils which is the basis for advanced modelling in geotechnical engineering.

Interferometer



Typical flattened surface area of soil grain (20x20 microns) which captures and quantifies the surface roughness at the nanoscale (top image: 3-dimensional image, bottom image: 2-dimensional cross-section area quantifying surface damage)

Project Name:	A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture
Principal Investigators:	Prof **Chongmin Song**, Dr **Ean Tat Ooi**, Dr **Hou (Michael) Man** & A/Prof **Wei Gao**
Funding Body:	ARC
Project Duration:	2013-2015

Cracks appear in many ageing infrastructure such as dams, bridges and buildings. After an extreme loading event such as impact, blast, cyclone and earthquake, a structure often sustains damages in the form of cracking. For ageing and damaged structure, uncertainties of the system parameters for structural analysis exist. For the safe and cost-effective management of aging structures, it is essential to consider the uncertainties in evaluating the stability of cracks and crack propagation.

The aim of this project is to develop an advanced numerical framework for the reliability assessment of structures considering uncertainties in structural parameters and loading. Of particular importance is the ability to assess crack propagation and its effect on structural safety, which is a major challenge to existing numerical methods. Underpinning the project is the development of the stochastic scaled boundary finite-element method and its application to reliability analysis.

A scaled boundary polygon element of arbitrary order is developed to model the stress concentration at the crack tip considering the hybrid uncertainties in material properties and crack geometry. The key parameters for a fracture analysis are conveniently determined. No local mesh refinement around the crack tip, such as in the finite element method, or asymptotic enrichment, as in the extended finite element method, is needed. An approach for determining the reliability of cracked structures has been developed. This work leads to a highly accurate and efficient technique in modelling crack propagation as illustrated in the following figures.

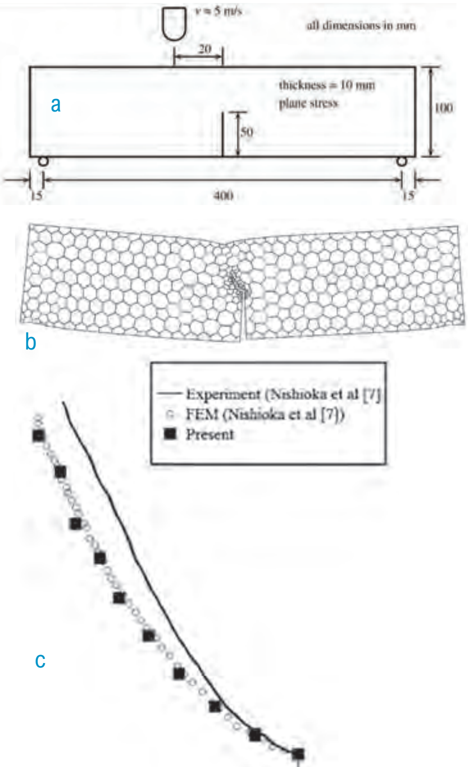


Figure 1: Crack propagation of a beam subjected to impact. (a) Geometry. (b) scaled boundary polygon mesh. (c) Comparison of crack path.

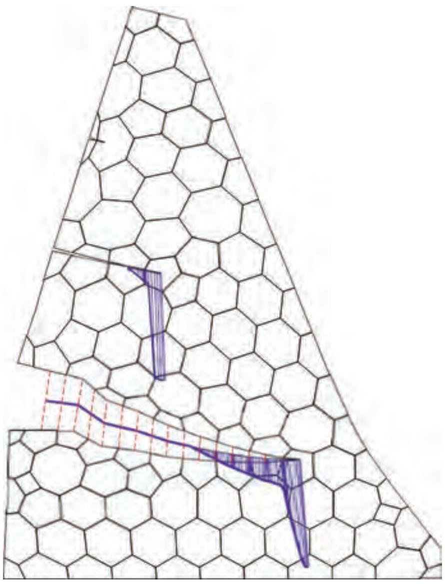


Figure 2: Cracking of concrete gravity dam

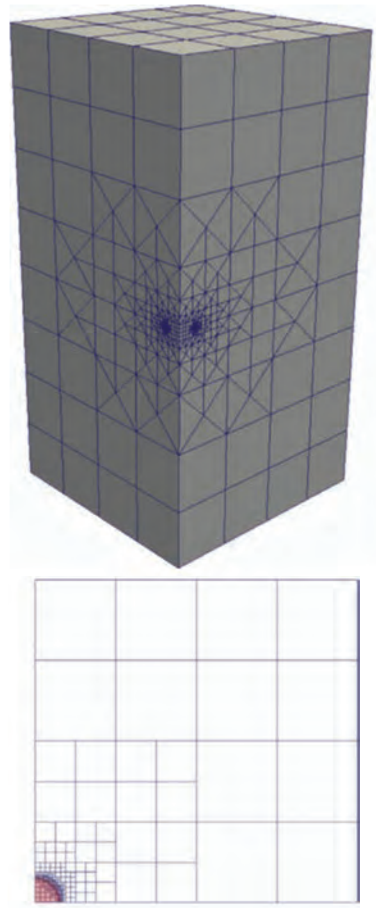


Figure 3: Modelling of a 3D penny crack

Project Name:	From CAD and digital imaging to fully automatic adaptive 3D scaled boundary analysis for monotonic and shakedown loadings
Principal Investigators:	Prof **Chongmin Song**, Prof **Francis Tin-Loi**, Dr **Albert Saputra** & Dr **Yan Liu**
Funding Body:	ARC
Project Duration:	2015-2017

The aim of this research project is to propose and implement an automatic numerical simulation approach of engineering structures in 3D (three dimensions) directly from their CAD (computer-aided design) models or digital images.

The designs of engineering structures are routinely performed on CAD platforms. At the present stage of development, the use of computer software for the simulation of the CAD models of engineering structures necessitates significant user interaction, and is often a time-consuming and daunting task for engineers. Furthermore, digital imaging technologies are increasingly being applied in engineering to study historical buildings and meso-structures of materials. The use of digital images in numerical simulation poses significant challenges to established technologies.

The approach of this project is based on the scaled boundary finite element method. Polyhedral elements of arbitrary number of faces and edges are developed. The high degree of flexibility in the shape of the element greatly reduces the burden on mesh generation. An automatic mesh generation technique based on the simple and efficient octree algorithm, which is highly complementary with the scaled boundary polyhedral elements, is employed. Preliminary results of elastic analysis of CAD models and digital images are shown in the following figures. The analysis processes are fully automatic.

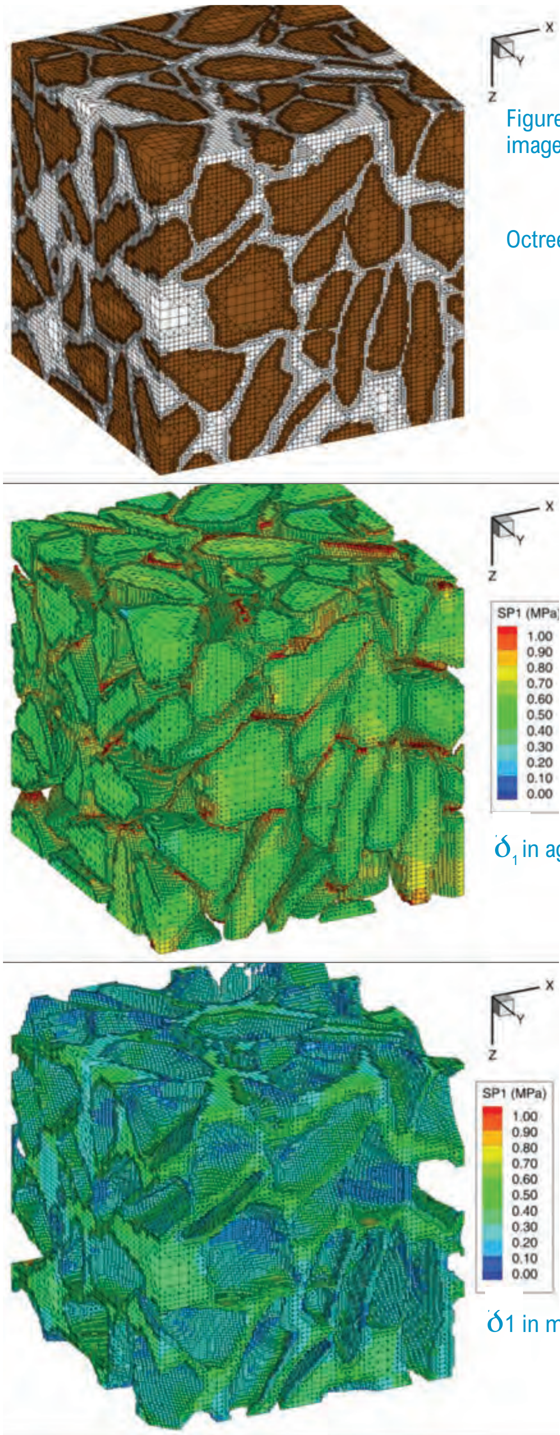


Figure 1: Simulation of XCT image of concrete specimen

Octree mesh

δ_1 in aggregates

$\delta 1$ in mortao

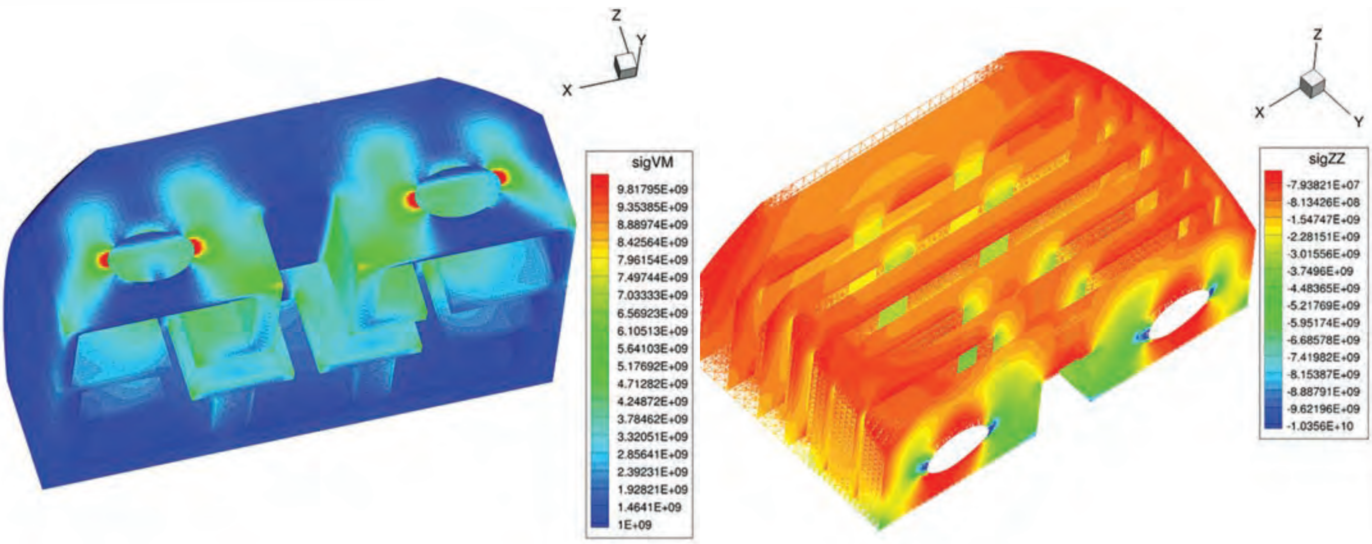


Figure 2: A house structure.

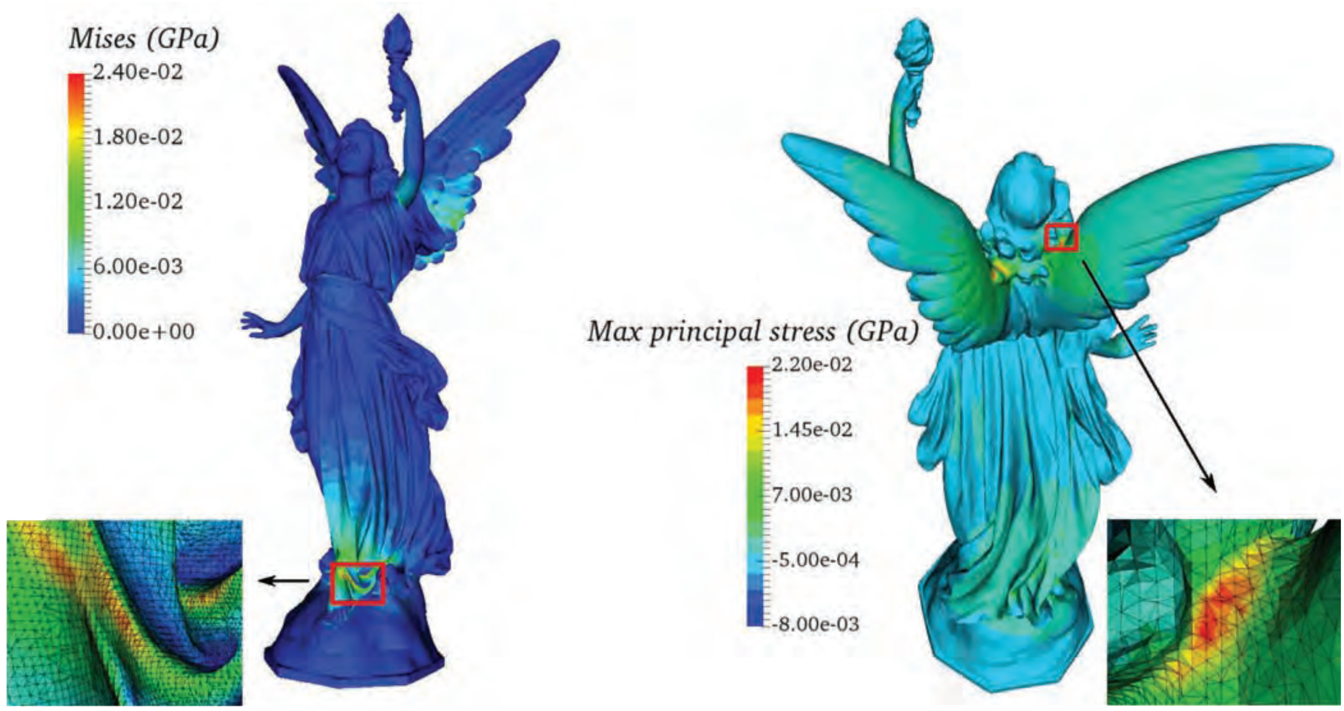


Figure 3: The stresses of a statue under its self-weight.

Project Name:	The behaviour and design of innovative connections to promote the reduction and reuse of structural steel in steel-concrete composite buildings
Principal Investigators:	Professor **Brian Uy**
Funding Body:	ARC Discovery Grant
Project Duration:	2014-2016

Reducing, reusing and recycling steel have been identified as having potential for future composite high rise buildings. The main aim of this project is to promote the reuse of structural members by designing demountable connections. The reduction of structural steel is also encouraged through the use of concrete-filled steel tubular columns.

The material and geometric parameters for the experimental program on demountable column-column splice connections have been carefully selected based on initial finite element studies. The experiments on demountable column-column splice connections will be carried out at the end of 2015 at the Randwick Heavy Structural Laboratory (UNSW) using hydraulic actuators with force capacities up to 5,000 kN. Experimental ultimate strengths and axial load-strain curves of demountable column-column splice connections will be used to verify the accuracy of the ABAQUS finite element models. The verified model will then be utilised to investigate the effects of important parameters on the behaviour of demountable connections.

Composite beams have been widely used in steel-concrete buildings and bridges for many years. A finite element model has been developed for determining the behaviour of demountable composite steel-concrete beams with profiled steel decking, hollowcore slabs and bolted shear connectors. The influence of oversized holes for demountability of composite beams has also been evaluated. Dr Vipulkumar Patel, research associate, and Mr Dongxu Li, PhD scholar, are currently working on this project under the close supervision of Professor Brian Uy.

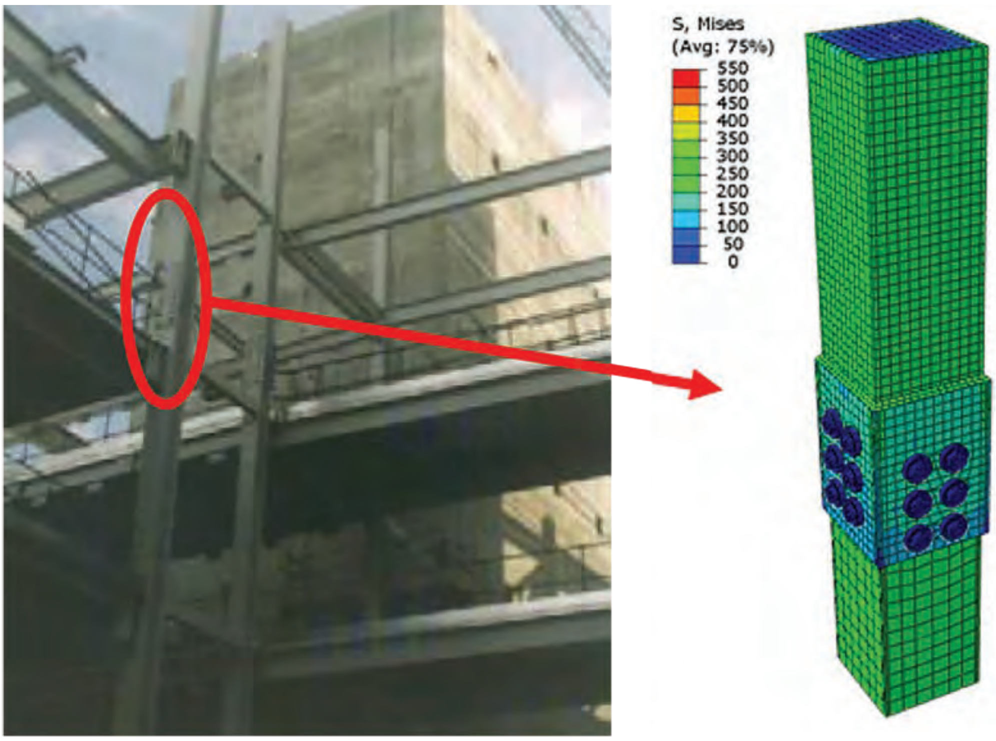


Figure 1: Demountable column-column connections

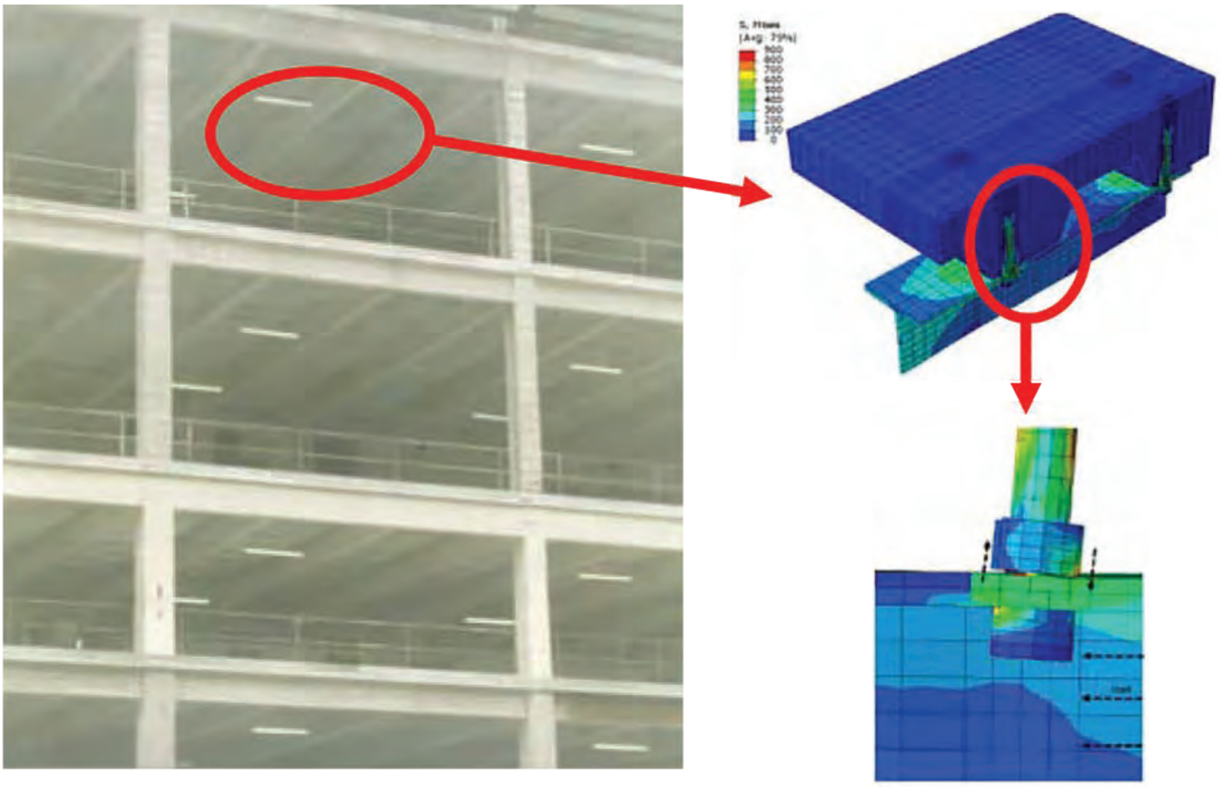


Figure 2: Demountable composite beam

Project Name:	Stochastic geometrically nonlinear elasto-plastic buckling and behaviour of curved grid-like structures
Principal Investigators:	A/Professor **Wei Gao**, Professor **Yong-Lin Pi**, Emeritus Professor **Francis Tin-Loi**
Funding Body:	ARC Discovery Grant
Project Duration:	2014 – 2016

Uncertainties are pervasive in engineering practice due to inherent variability and lack of knowledge. It is vital to assess reliably the safety of large spatially curved complex structures addressing the inevitable uncertainties in structural parameters and loads for design and rehabilitation purposes. Curved structures are commonplace in structural engineering and are particularly sensitive to material variation and geometric imperfection. Their behaviour becomes quite nonlinear even when the external load is much lower than the failure load and their deformations often possess elasto-plastic characteristics.

The aim of this project is to develop an advanced stochastic framework for the nonlinear elasto-plastic analysis and reliability assessment of curved structures considering uncertainties in their material, geometry and loading. Novel formulations and effective algorithms are devised to account for the random geometric nonlinearity and material elasto-plasticity. An efficient tool is developed for reliability assessment of this class of structures.

In the first stage of this project, time-variant stochastic response analysis and reliability assessment have been investigated for concrete-filled steel tubular (CFST) arches addressing the inevitably uncertain viscoelastic effects of the concrete infill. A computationally efficient probabilistic method has been proposed to determine the time-variant statistical characteristics of the random structural responses of CFST arches. Furthermore, the proposed computational scheme has been extended to estimate the time-variant structural reliability of CFST arches with uncertain viscoelastic effects. The applicability, accuracy and efficiency of the proposed scheme have been rigorously testified. Figures 1 and 2 show the evolution of probability density function (PDF) and cumulative distribution function (CDF) of central radial displacement of a pin-ended CFST arch respectively. Figures 3 and 4 show the time-variant sensitivity of reliability of serviceability and reliability of strength of a pin-ended CFST arch respectively. Matrix plot of a pin-ended CFST arch illustrating the various correlations between concerned random variables is explicitly presented in Figure 5.

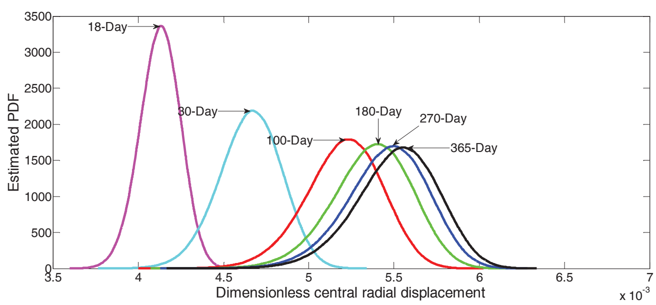


Figure 1 PDF of central radial displacement

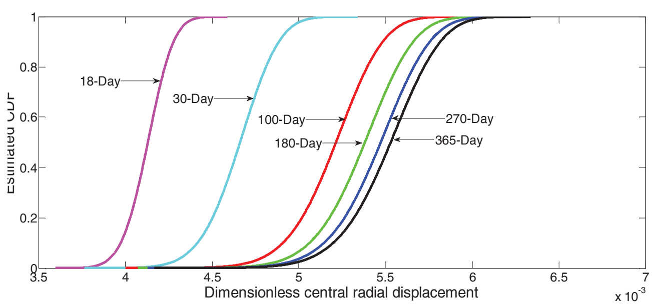


Figure 2 CDF of central radial displacement

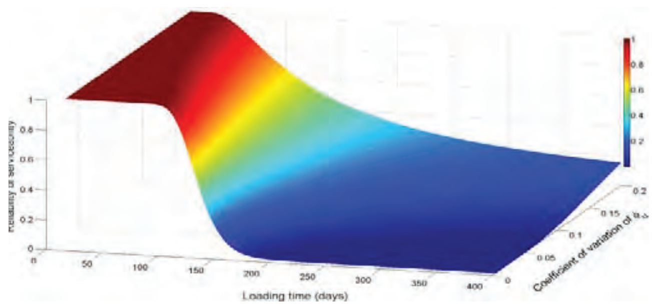


Figure 3 Sensitivity of reliability of serviceability

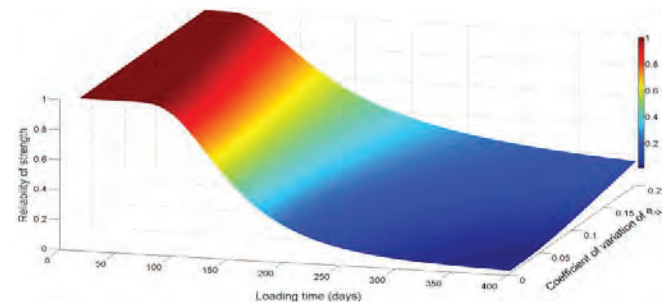


Figure 4 Sensitivity of reliability of strength

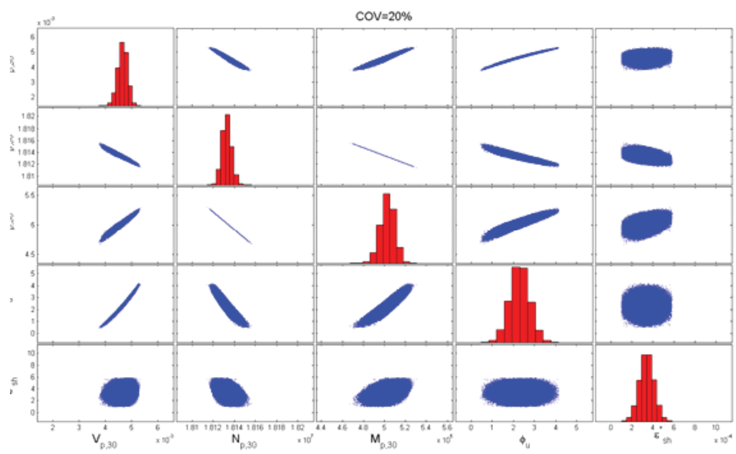


Figure 5 Matrix plot

Project Name:	Reliability assessment of concrete-filled steel tubular frames designed by advanced analysis
Principal Investigators:	Dr **Tai Thai**
Funding Body:	ARC DECRA
Project Duration:	2014 – 2016

Concrete-filled steel tubular (CFST) structures have been increasingly used in high-rise buildings, bridges and other infrastructure due to their enhanced properties such as high strength, high ductility and large energy absorption capability. The existing studies on CFST structures are restricted to deterministic approaches in which the influence of uncertainties on the structural safety is neglected. The consideration of system reliability in the design of CFST structures will increase the safety of structures, and consequently, provide greater security against physical and financial losses.

The aim of this project is to evaluate the system reliability of CFST frames designed by advanced analysis. The influences of inherent uncertainties in loads, material properties and geometric properties on the system reliability of CFST frames will be studied. The outcomes of this research will be used to develop the provisions for the system reliability-based design of CFST frames to achieve a target reliability range.

In the first state of this project, the semi-rigid behaviour of beam-to-column composite joints in framed buildings is investigated to obtain a moment-rotation model for this kind of composite joint. Figure 1 shows the finite element simulation of a half of a typical blind bolted endplate composite joint with a CFST column. The obtained moment-rotation model is then included in a fibre beam-column element (see Figure 2 and References [R1-R2] for more details) to predict the ultimate strength of CFST frames. Monte Carlo simulation is used to calculate the system probabilities of failure and evaluate the system reliability of the CFST frame.

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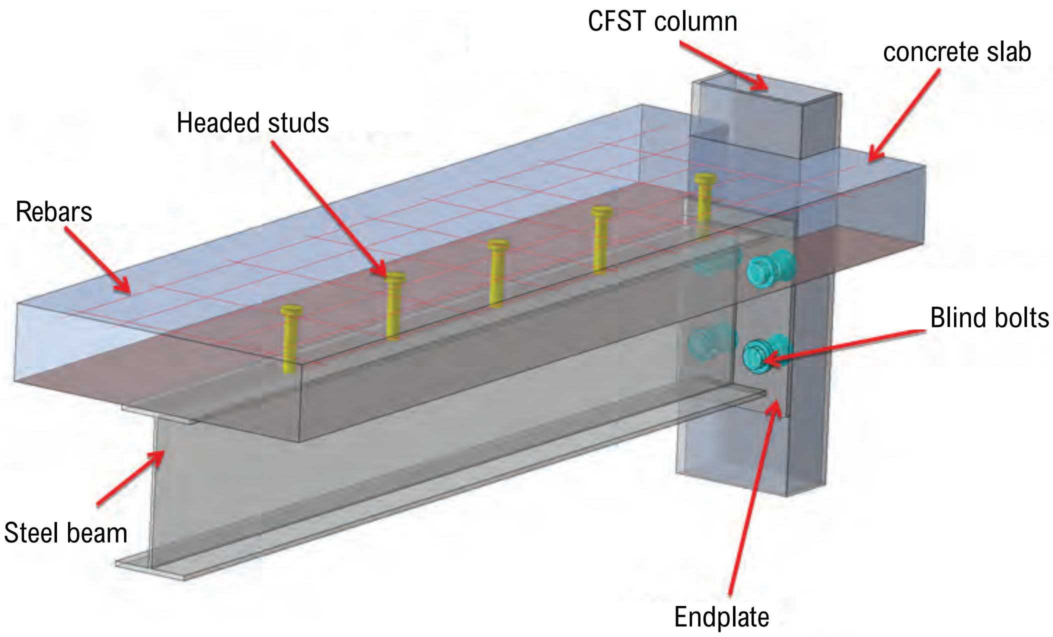


(a) Configuration

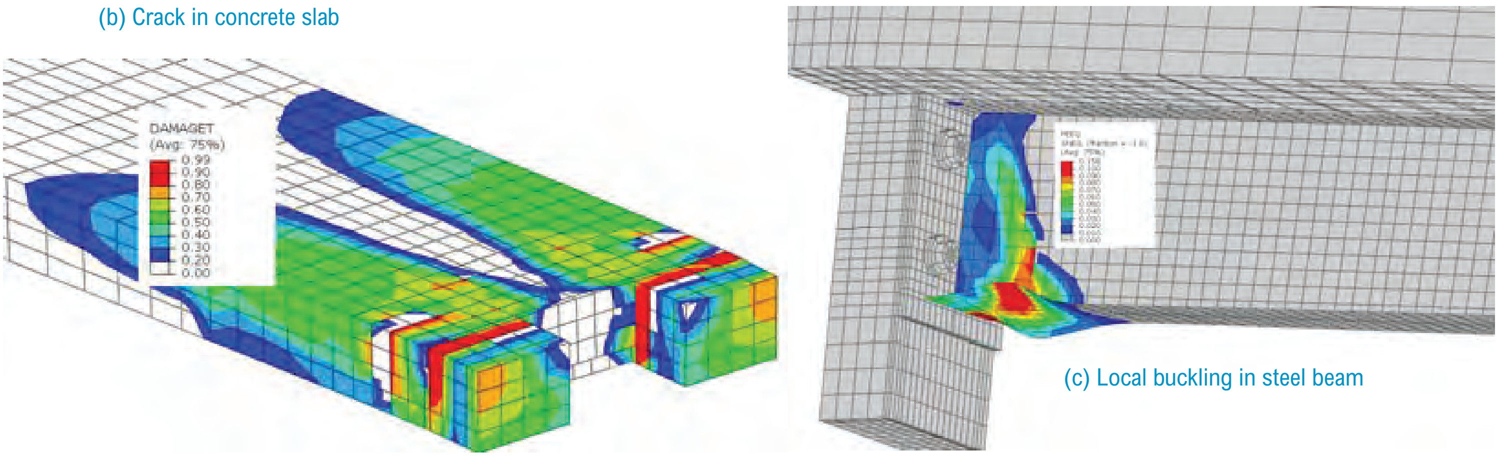


Figure 1. Modelling of a half a typical bind bolted endplate composite joint with a CFST column

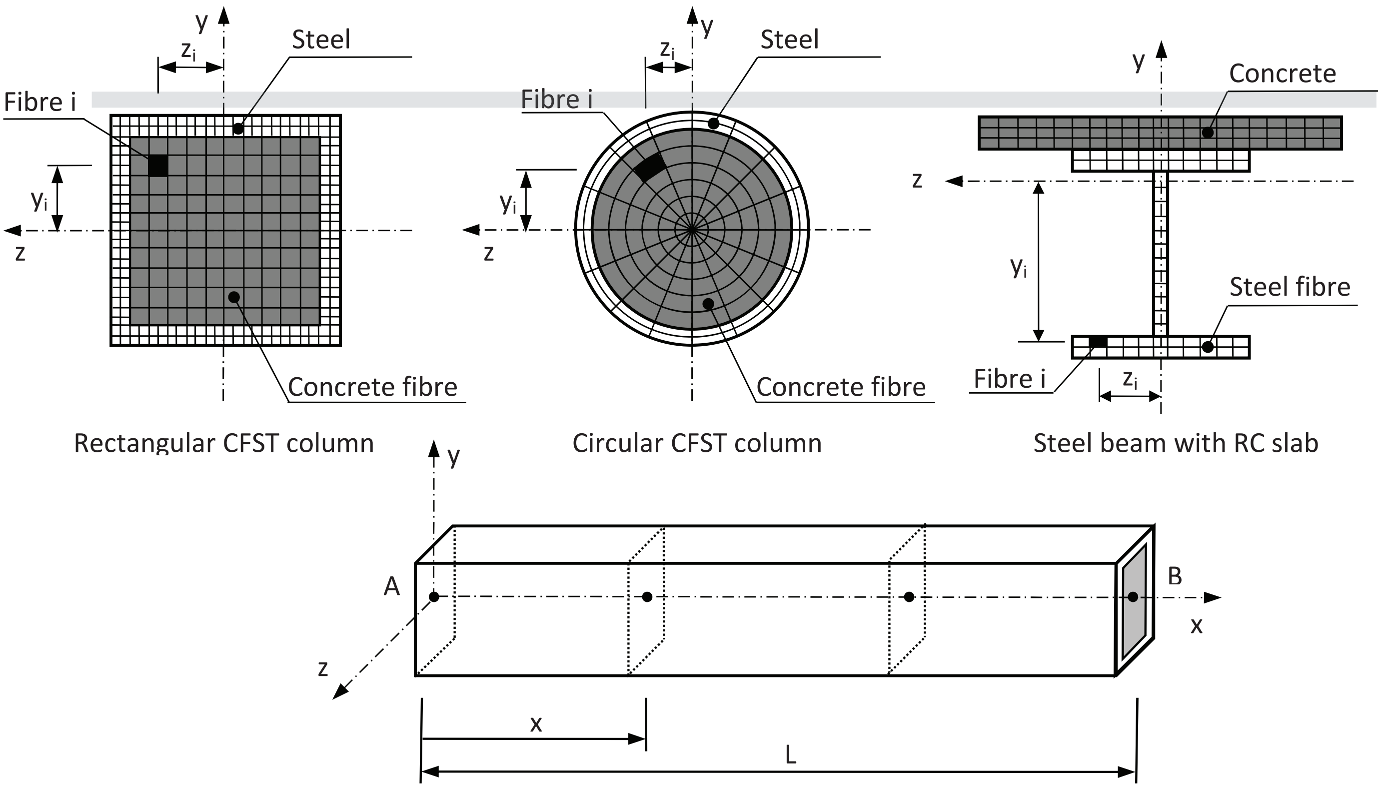


Figure 2. Fibre beam-column element

Project Name:	Scaled boundary finite-element approach for safety assessment of plates and shells under monotonic and shakedown loadings
Principal Investigators:	Dr **Hou (Michael) Man**, Professor **Chongmin Song** & Professor **Francis Tin-Loi**
Funding Body:	ARC, UNSW
Project Duration:	2012-2014

Piezoelectric materials are widely used in sensing devices and actuators for engineering applications due to their unique electro-mechanical coupling characteristics. Their increasing usage in smart structures and structural health monitoring, both continuously ensure structural safety, has emphasised the significance in reliably simulating the responses of piezoelectric materials even in their design stage.

This project aims to develop a computer tool to analyse plate and shell structures made of composite and piezoelectric materials. The approach is based on the scaled boundary finite element method. The in-plane dimensions are discretised into high-order elements. The through thickness behaviour is expressed analytically. This leads to a highly efficient technique while maintaining 3D consistency and accuracy. The through-thickness electric potential in the piezoelectric plate, which shows high-order behavior, is captured accurately.

This novel technique has been shown to be highly accurate and efficient, especially when dealing with piezoelectric materials. Figure 1 shows a circular piezoelectric sensor with a central hole under a non-uniformly distributed pressure and is grounded at the top and bottom surfaces. It is commonly appeared in the designs of piezoelectric sensor. Only 4 high order elements are used to discretise the sensor. The results in Figure 2 show that the proposed technique (denoted by SBFEM) requires significantly less number of nodes than the solid elements of ANSYS for the same accuracy (no shell element in ANSYS can be used for piezoelectric bending analysis). Figure 3 further shows the distribution of the electric potential and the axial stress, which are both consistent with the ANSYS 3D results.

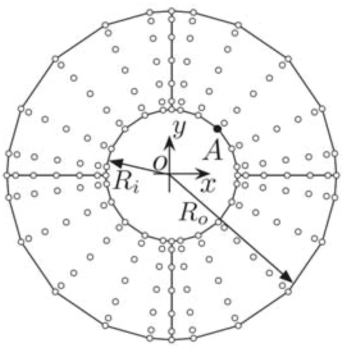


Figure 1. Circular piezoelectric sensor

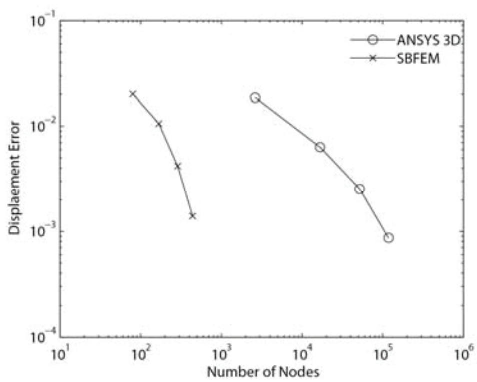
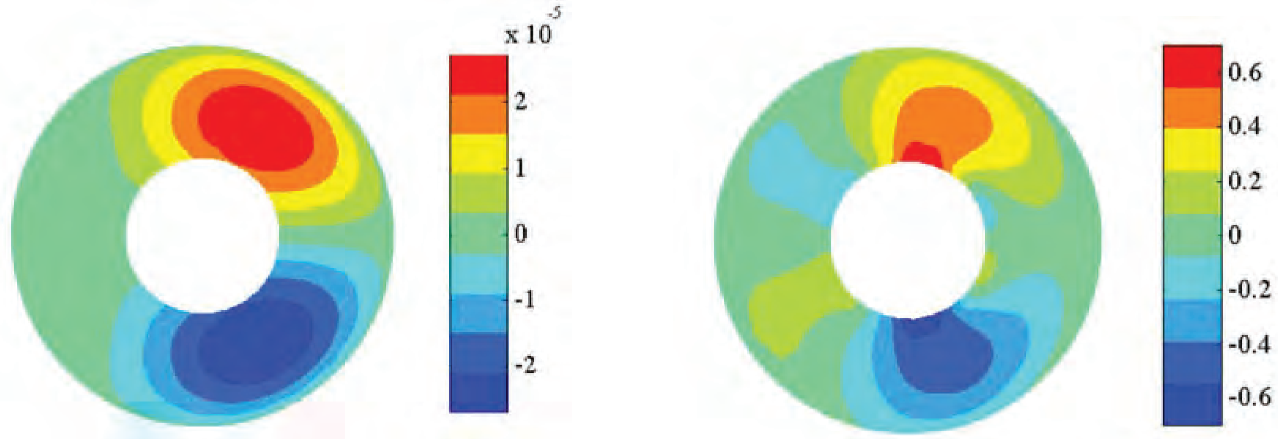


Figure 2. Comparison of computational requirement with ANSYS



(a) Electric potential at mid plane

(b) Axial stress at top plane

Figure 3. Normalised electric potential and in-plane axial stress of a circular piezoelectric sensor under non-uniformly distributed pressure

Project Name:	A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture
Principal Investigators:	Professor **Chongmin Song**, Dr **Ean Tat Ooi**, Dr **Hou (Michael) Man** & A/Professor **Wei Gao**
Funding Body:	ARC Discovery Grant
Project Duration:	2013-2015

Cracks appear in many ageing infrastructure such as dams, bridges and buildings. After an extreme loading event such as impact, blast, cyclone and earthquake, a structure often sustains damages in the form of cracking. For ageing and damaged structure, uncertainties of the system parameters for structural analysis exist. For the safe and cost-effective management of aging structures, it is essential to consider the uncertainties in evaluating the stability of cracks and crack propagation.

The aim of this project is to develop an advanced numerical framework for the reliability assessment of structures considering uncertainties in structural parameters and loading. Of particular importance is the ability to assess crack propagation and its effect on structural safety, which is a major challenge to existing numerical methods. Underpinning the project is the development of the stochastic scaled boundary finite-element method and its application to reliability analysis.

In this first stage of this project, a scaled boundary polygon element of arbitrary order is developed to model the stress concentration at the crack tip. The key parameters for a fracture analysis are conveniently determined. No local mesh refinement around the crack tip, such as in the finite element method, or asymptotic enrichment, as in the extended finite element method, is needed. The scaled boundary polygon element is ideally suited to the quadtree technique for automatic mesh generation. This work leads to a highly accurate and efficient technique in modelling crack propagation.

This technique has been successfully applied to various problems in fracture analysis of cracked structures. An example is shown in Figure 1. Significant advantages and potential of the developed approach are demonstrated. For example, Figure 2 shows the modeling of the XCT image of a concrete specimen to predict its material properties.

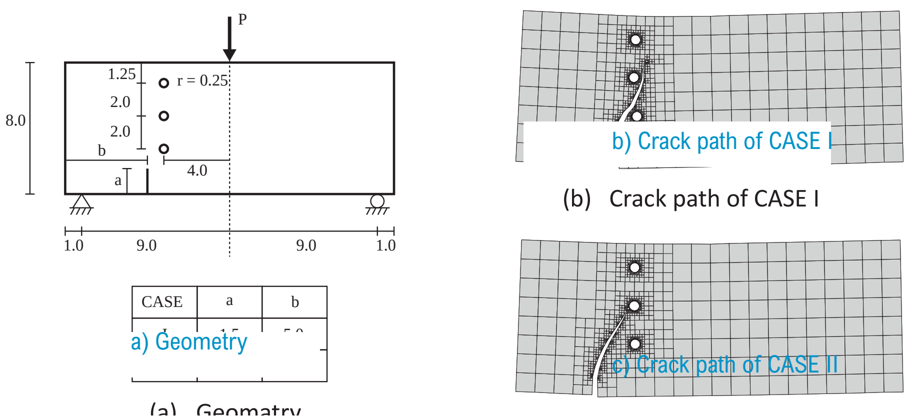
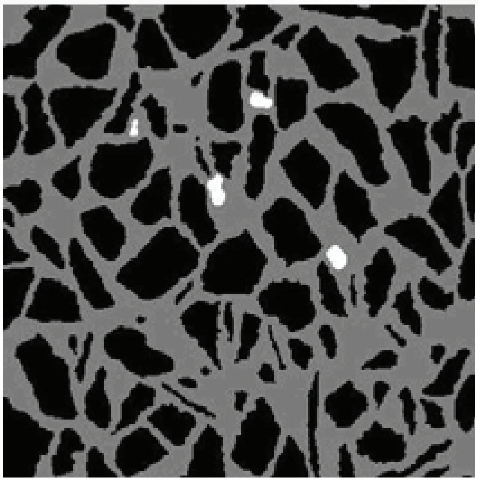
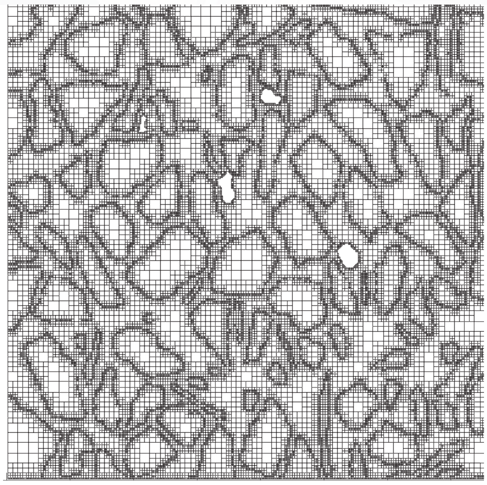


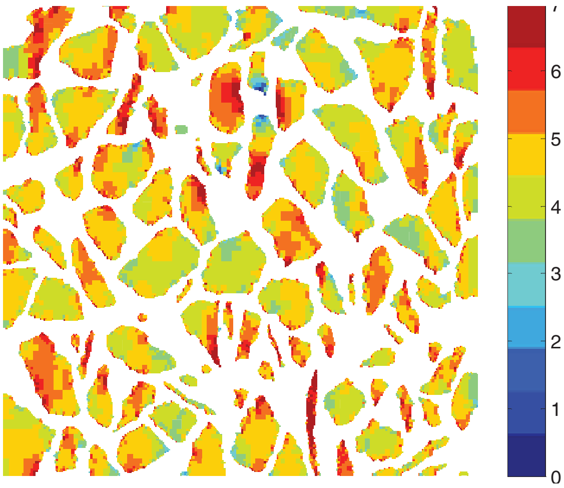
Figure 1: Crack propagation of a beam subjected to three point bending with initial crack at different locations.



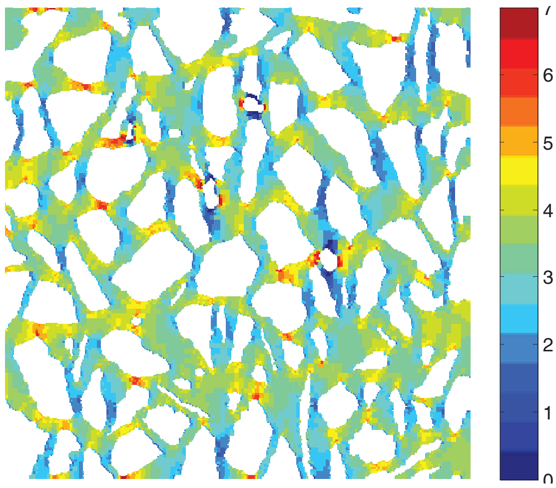
a) Image of concrete



b) Quadtree mesh



c) σ_1 in aggregates



d)σ_1 in mortao

Figure 2: Modelling of XCT image of concrete specimen

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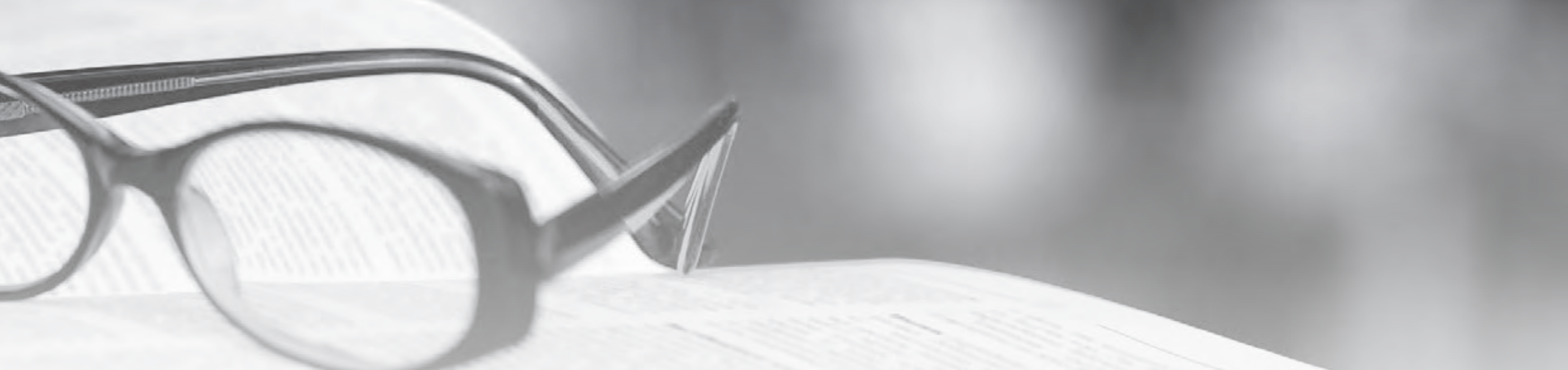

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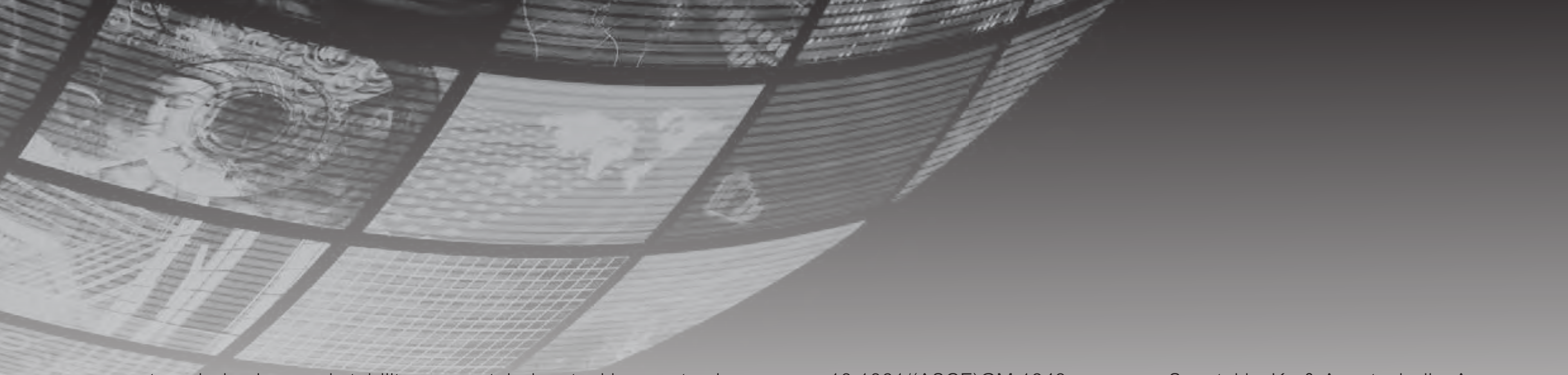

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2. CIES VISITORS' SEMINARS

Name	Institution	Seminar Topic	When
Professor Lin-Hai Han	Tsinghua University, China	Some recent new developments on concrete-filled steel tubular (CFST) structures	February 2015
Professor A.P.S.Selvadurai	McGill University, Canada	Measurement of Permeability of an Argillaceous Limestone	March 2015
Dr Wei Chen	Northwestern University, USA	Design of Emerging Engineered Materials System	June 2015
Professor Joseph Davidovits	Géopolymère Institute, Saint-Quentin, France	An update on Geopolymer science and technologies	September 2015
A/Professor WenHui Duan	Monash University	Sustainable and resilient infrastructure materials – new perspective from emerging nanomaterials	October 2015
Professor Mehdi Banazadeh	Amirkabir University of Technology, Tehran	Explicit Probabilistic Demand and Consequence Models for Seismic Risk Prediction	November 2015
Professor G. R. Liu	University of Cincinnati, Ohio, USA	S-PIM and GSM: Theory, Formulation, and Applications to Fluid-Structure Interaction (FSI) problems	November 2015
Professor Gintaris Kaklauskas	Vilnius Gediminas Technical University, Vilnius, Lithuania	CONSTITUTIVE MODELLING FOR SERVICEABILITY ANALYSIS OF RC STRUCTURES	December 2015

3. POSTGRADUATE RESEARCH STUDENTS

RESEARCH STUDENTS 2015

Name / Topic / Supervisor/s

Mohamadamin **Afshar**
Early Age Thermal Cracking of Concrete [Castel, Arnaud; Akbarnezhad, Ali]

Alireza **Ahmadian Fard Fini**
Predicting delay and minimizing its impact in construction context
[Waller, S Travis; Akbarnezhad, Ali]

Alireza **Akbarzadeh- Chiniforosh**
A novel theoretical method of non-destructive health monitoring of structures
[Valipour, Hamid; Akbarnezhad, Ali]

Zeinab **Aliabadian**
Dynamic fracture of rock by continuum - discontinuum coupled model
[Zhao, Gaofeng]

Golnaz **Alipour Esgandani**
Numerical modelling of unsaturated soils under earthquake loading
[Khoshghalb, Arman]

Rebecca Jane **Allan**
Backward erosion piping of dams
[Douglas, Kurt J]

Abdolreza **Ataei**
Steel and composite structures
[Bradford, Mark A]

Seyed Mahdi **Babaee**
Durability of geopolymer concrete in marine environments
[Castel, Arnaud]

Yun **Bai**
Coupled thermo-chemoflow-deformation analysis of multiphase multi-porous media. [Khalili, Nasser]

Noor Adnan Sadik **Baktash**
Creep in unsaturated soils
[Khoshghalb, Arman; Khalili, Nasser]

Khalegh **Barati**
Construction resources networks tracking and management
[Shen, Xuesong]

Robert **Bertuzzi**
Estimating rock mass strength and stiffness with particular interest in the load on a tunnel lining.
[Douglas, Kurt J]

Jin Jerry **Dang**
Durability of construction materials, low -carbon concrete technology, timedependent behaviour
[Shen, Xuesong]

James Matthew **de Burgh**
Modelling and analysis of concrete building and tunnel structures in fire
[Foster, Stephen J]

Dilina **Dissanayake**
Automated image-based modelling for elastoplasticity and damage analysis
[Song, Chongmin]

Duy Minh **Do**
Stochastic interval analysis of structures with a mixture of random and interval uncertainties [Gao, Wei]

Xi **Du**
Damage and fracture development in jointed rocks
[Khalili, Nasser]

Zheyuan **Du**
New synthetic aperture Radar Interferometry for Earth surface deformation detection.
[Ge, Linlin]

Farj **Elhadayri**
Constitutive modelling of lightly cemented unsaturated soils. [Khalili, Nasser]

Jinwen **Feng**
Advanced methods for structural analysis, structural safety and reliability, structural dynamics and optimisation
[Gao, Wei; Li, Guoyin]

Jean **Foerster**
Natural resource projects
[Carmichael, DG]

Kang **Gao**
Advanced methods for structural analysis, structural safety and reliability, structural dynamics and optimisation
[Gao, Wei]

Omid **Ghaffaripour**
Numerical algorithms for penetration problems in variably saturated porous media [Khoshghalb, Arman]

Maryam **Ghareh Chaei**
Mechanical and durability properties of ultra high performance geopolymer mortar and concrete using fly ash [Akbarnezhad, Ali]

Mohammadmahdi **Gharib**
Numerical modelling for service life prediction and performance evaluation of deteriorated reinforced concrete structures due to climate change impacts
[Foster, Stephen J]

Nassim **Ghosni**
Fibre reinforced concrete structures
[Valipour, Hamid; Foster, Stephen J]

David Kristopher **Green**
Probabilistic analysis in computational mechanics with applications in civil engineering. [Gao, Wei; Douglas, Kurt John]

Dinesh Mahanama **Habaragamu Arachchige**
Durability of Geo-Polymer Concrete with respect to Alkali Aggregate Reaction (AAR) [Castel, Arnaud]

Ahmed W A **Hammad**
Multi-Objective Optimisation
[Akbarnezhad, Ali; Rey, David]

David Soedibyo **Hartanto**
Durability of FRP-concrete and FRP-steel lap-joints
[Hamed, Ehab]

Seyedkomeil **Hashemiheidari**
Evaluating bridges subjected to extreme loading
[Bradford, Mark A]

Amirhossein **Hassanieh**
Development of steel-timber composite system for large scale construction
[Valipour, Hamid]

Huan **He**
Dynamics and micromechanics of biogenic sand
[Senetakis, Konstantinos]

Ke **He**
Numerical Modelling of Cracking in Embankment Dams
[Song, Chongmin]

Ian Edward James **Henderson**
The use of innovative anchors for the achievement of composite action for rehabilitating existing and deployment in demountable steel structures
[Uy, Brian]

Ying **Hong**
BIM adoption criteria: measuring potential advantages of BIM before implementation
[Akbarnezhad, Ali]

Edward Malcolm **James**
Pavement systems on soft soils
[Oeser, Markus; Russell, Adrian]

Chao **Jiang**
Hydraulic fracture
[Zhao, Gaofeng; Khalili, Nasser]

Nicka **Keipour**
Development of a reliable nonlocal model for flexibilitybased frame elements with strain-softening materials
[Valipour, Hamid]

Hammad Anis **Khan**
Concrete technology
[De Silva, Premalatha; Castel, Arnaud]

Mohammad **Khoshini**
Fault Rupture Propagation through Soils
[Khalili, Nasser]

Dongxu **Li**
Structure Engineering - composite structures
[Uy, Brian]

Liyuan **Li**
SAR and optical imagery registration
[Ge, Linlin]

Shijin **Li**
Internal erosion of soils: Microstructural modelling
[Russell, Adrian]

Lei **Liu**
Noise and vibration analysis using the scaled boundary finite element method
[Song, Chongmin]

Youtian **Liu**
InSAR Technique for Earthquake Studies
[Ge, Linlin]

Thi Ngoc **Mac**
Time dependent behaviour of slopes
[Khalili,Nasser]

Saeed **Masoumi**
Multiscale modeling of FRP Concrete interface
[Valipour, Hamid]

Afshin **Mellati**
The Iterative Limit and Shakedown Analysis of Structures using A Scaled Boundary Finite Element Method
[Tangaramvong, Sawekchai; Tin Loi, Francis Shay Khiet]

Hugh David **Miller**
Nanotechnological improvements to ultra-highperformance concrete.
[Akbarnezhad, Ali; Foster,

Stephen J] Hamed **Moghaddasi Kelishomi**
Constitutive modelling of weak rocks subject to mechanical and moisture degradation [Khoshghalb, Arman; Khalili, Nasser]

Masoud **Moradi**
Structural mechanics and numerical methods
[Valipour, Hamid]

Zahra **Moussavi Nadoushani**
Estimation of life cycle carbon of residential and office buildings
[Akbarnezhad, Ali]

Angus Lachlan **Murray**
Structural Engineering / Concrete Technology
[Castel, Arnaud; Gilbert, Raymond Ian]

Nur Kamaliah **Mustaffa**
Sustainability: Carbon emissions in construction.
[Carmichael, David G]

Tuan Anh **Nguyen**
Infrastructure projects - options, risk, Vietnam.
[Carmichael, David G]

Farshid **Nouri**
Progressive collapse of outrigger - braced tall structures assigned to earthquake loads.
[Valipour, Hamid]

Amin **Noushini**
Low carbon concrete design.
[Castel, Arnaud; Gilbert, Raymond Ian]

Daniel John **O'Shea**
Finite element implementation of intrinsic field tensors for the analysis of orthotropic materials.
[Kellermann, David C; Attard,

Mario M] Meghdad **Payan**
Study of small strain dynamic properties of saturated and unsaturated soils.
[Khoshghalb, Arman]

Steven Edward **Pells**
Erosion of rock in spillways. [Peirson, William L; Douglas, Kurt J]

Bambang **Piscesa**
Ductility of reinforced concrete frames.
[Attard, Mario M]

Mohammad Masud **Rana**
Behaviour of post-tensioned composite steel-concrete slabs. [Uy, Brian]

Albert Artha **Saputra**
Computational mechanics and structural analysis.
[Song, Chongmin]

Samad M E **Sepasgozar**
Technology adoption decision making in construction management.
[Davis, Steven R; Carmichael, David G]

Babak **Shahbazi**
Shallow foundations in unsaturated soils: understanding mechanistic behaviour through analysis and experimental investigation.
[Russell, Adrian]

Lijuan **Su**
Lateral and post buckling with shear effects.
[Attard, Mario M]

Adnan **Sufian**
Multi-scale modelling of granular material.
[Russell, Adrian]

Yuting **Sun**
LCA, LCC applications.
[Carmichael, David G]

Zhicheng **Sun**
Fracture analysis by using the scaled boundary finite element method.
[Song, Chongmin]

Reza **Taheriattar**
Sustainability and adaptable/ flexible infrastructure.
[Akbarnezhad, Ali; Carmichael, David G]

Yi **Tang**
Numerical modelling of foundation on unsaturated soils. [Taiebat, Hossein]

Arash **Tootoonchi**
Numerical modelling of behaviour of unsaturated soils under large deformation.
[Khoshghalb, Arman]

Jia **Wang**
Steel and composite structures. [Uy, Brian]

Junchao **Wang**
Computational mechanics.
[Song, Chongmin]

Rumman **Waqas**
The development of efficient, robust and architecturally flexible structural systems using blind bolted connections.
[Uy, Brian]

Dinusha **Wijesekara**
Prediction of Strong Ground Motions by Advanced Numerical Modelling of Seismic Wave Propagation.
[Song, Chongmin]

Indika Same **Wijesiri Pathirana**
Use of innovative anchors as shear connectors in composite steel-concrete beams for the rehabilitation of existing structures and deployment in new structures. [Uy, Brian]

Binhua **Wu**
Advanced methods for structural analysis, structural safety and reliability, structural dynamics and optimization.
[Gao, Wei]

Tingsong **Xiang**
Scaled boundary finite element analysis of plates and shells. [Song, Chongmin]

Weiwei **Xing**
Computational mechanics.
[Song, Chongmin; Tangaramvong, Sawekchai]

Chengwei **Yang**
Non-deterministic analysis of linear and nonlinear structures. [Tangaramvong, Sawekchai; Gao, Wei]

Yang **Yang**
Upheaval buckling.
[Bradford, Mark A]

Amin **Yousefnia Pasha**
Study of soil-water characteristic curve in deformable porous media.
[Khoshghalb, Arman; Khalili, Nasser]

Junqi **Zhang**
Computational mechanics.
[Song, Chongmin]

PhD Students Graduated in 2015

Name *Topic* [Supervisor/s]

Ali **Amin**
Post Cracking Behaviour of Steel Fibre Reinforced Concrete: From Material to Structure.
[Foster, Stephen J]

Xiaojun **Chen**
Development of the scaled boundary finite element method for dynamic soil-structure interaction analysis in the time domain.
[Song, Chongmin; Birk, Carolin C]

Yue **Huang**
Nonlinear long-term behavior of highstrength concrete wall panels.
[Hamed, Ehab; Foster, Stephen J]

Mani **Khezri**
Generalised RKP-FSM and its application in analysis of thin plates with abrupt rigidity changes and generally laminated composite plates.
[Bradford, Mark A]

Kai **Luo**
Long-term analysis of structural behaviour and stability of concrete-filled steel tubular arches.
[Gao, Wei; Pi, Yong Lin]

Md Ahsan **Parvez**
Fatigue behaviour of steel-fibre-reinforced concrete beams and prestressed sleepers.
[Foster, Stephen J]

Xue **Shi**
Uncertain analysis of engineering structures, structural reliability analysis, structural dynamics. [Gao,Wei; Pi, Yong Lin]

Di **Wu**
Interval analysis framework for structural safety assessment.
[Tangaramvong, Sawekchai; Tin Loi, Francis]

Peijie **Yin**
Micromechanics of Unsaturated Flow in Fractured Porous Medium. [Zhao, Gaofeng]

Jianbei **Zhu**
In-Plane Nonlinear Localised Lateral Buckling of Pipelines and Rail Tracks under Thermal Loading.
[Attard, Mario M; Kellermann, David]

Thi Ngoc **Mac**
A bounding surface viscoplasticity modelfor soils.
[Zhao, Gaofeng; Khalili Naghadeh, Nasser]

Xinlei **Zhang**
Alternative Project Management Practices in Earned Value and Black-Scholes.
[Carmichael, David G]