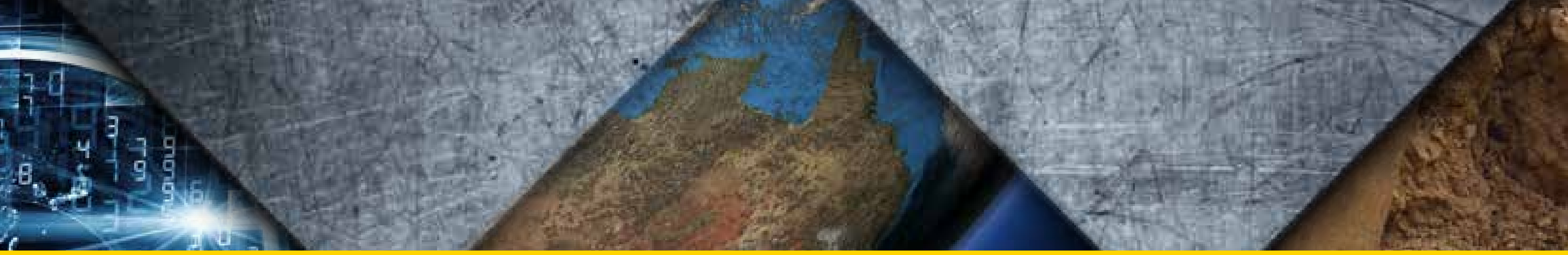


CIES - Centre for Infrastructure Engineering and Safety
Annual Report 2013

UNSW AUSTRALIA

Never Stand Still

Faculty of Engineering

School of Civil and Environmental Engineering

CIES

School of Civil and Environmental Engineering
The University of New South Wales
Sydney NSW 2052
Australia
CRICOS Provider Code 00098G

Address
CIES - Centre for Infrastructure Engineering and Safety
School of Civil and Environmental Engineering (H20)
UNSW Australia
UNSW Sydney NSW 2052
Australia

Enquiries
T +61 (0)2 9385 6853
E i.calaizis@unsw.edu.au
W www.cies.unsw.edu.au

Project Coordination
Irene Calaizis
With grateful thanks to providers of text, stories and images.

Design
Heléna Brusić
UNSW P3 Design Studio, www.p3.unsw.edu.au

contents

CIES

Director's Report

It is with great pleasure that I write this Directors Report for the Centre for Infrastructure Engineering and Safety (CIES) for 2013. I commenced the Director role in March 2013 following Professor Stephen Foster moving to the Head of School of Civil and Environmental Engineering role. Once again I would like to thank Steve for his excellent stewardship which has culminated in August 2013 of CIES completing its successful triennial review and below is an excerpt of the Centre review report by Professor Mark Hoffmann (Pro-Vice Chancellor, UNSW) which gives an indication of the success of CIES:

> ***"The Centre for Infrastructure Engineering and Safety (CIES) is a large, productive and dynamic Research Centre, which is a highly valued asset of the School of Civil & Environmental Engineering, the Faculty of Engineering and UNSW as a whole"***

The annual CIES Symposium was held again in October, 2013 which this year focussed on geotechnical engineering, "'Geotechnical Modelling: Analytical Solutions for Practising Engineers". The symposium featured an array of world class speakers in geotechnical engineering and was attended by industry leaders and academics in geotechnical engineering.

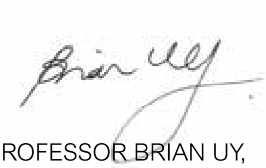
November saw the announcement of the highly competitive Australian Research Council (ARC) grants. CIES was extremely successful with ten staff featuring on seven ARC Grants totalling over $3.5 million for 2014.

CIES also had some outstanding personal successes. At its meeting on 23 March 2013, the Board of Direction of the American Society of Civil Engineers elected Professor Mark Bradford (Founding Director of CIES) to the grade of Distinguished Member of the ASCE. The Society citation for Mark was:

> ***"For groundbreaking international research contributions that have advanced the field of structural mechanics, leading to new and advanced design standards for practitioners, and for educating the next generation of engineers."***

Also, Professor Stephen Foster, past Centre Director for CIES and currently Head of School of Civil & Environmental Engineering, was recently awarded the distinguished honour of being elected as a Fellow of Engineers Australia which recognises those individuals who are true leaders of the industry and profession.

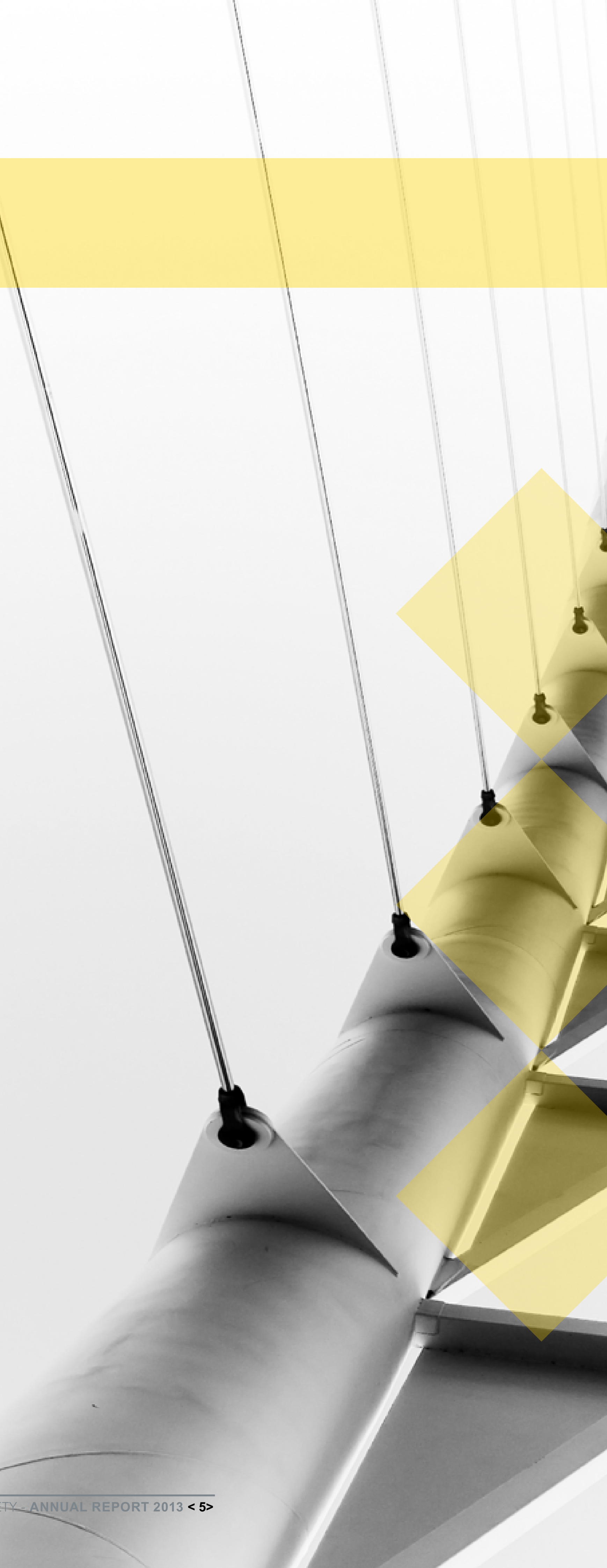
I would like to take this opportunity to thank all our CIES staff and students for their outstanding contributions to the work of the centre, as well as all our industry partners and advisory board members for the important role they play in shaping and supporting the CIES activities as they relate to industry. I do hope you enjoy reading about all these important activities and events of the Centre and I look forward to reporting on more exciting research and successes in the future.



PROFESSOR BRIAN UY,

BE PhD *UNSW*, CPEng, CEng, PE, MIEAust,
MASCE, MIStructE, MICE, MAICD

Vision



As an internationally recognised research centre our vision is in 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 2013 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, MIE Aust, MASCE, MIStructE, MICE, MAICD

Research Director
Scientia Professor Mark Bradford, BSc BE PhD *Syd* DSc *UNSW* FTSE PEng CPEng CEng Dist. MASCE, FIEAust, FIStructE, MAICD

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 Stephen Foster, BE *NSWIT*, MEngSc PhD *UNSW*, MIEAust

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

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

Dr Wei Gao BE HDU, ME PhD *Xidian*, MIIAV, MAAS

Dr Carolin Birk BE DEng *Dresden*

Dr Adrian Russell BE, PhD *UNSW*, PGCert *Bristol*

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

Dr Ehab Hamed, BSc MSc PhD *Technion*

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

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

Dr Sawekchai Tangaramvong, BE MEngSc PhD *UNSW*

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

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

Dr Michael Man, BE PhD *UNSW*

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

Dr David Kellerman BE, PhD *UNSW*

Dr Ean Tat Ooi, BE *UTM*, PhD *NTU*

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

Dr Huiyong Ban BE PhD *Tsinghua University, Beijing*

Dr Sundararajan Natarajan BE Mech Eng, PhD *Cardiff*

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

Dr Guotao Yang, BE PhD *Tongji*

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

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

Dr Saeed Salimzadeh, BSc MSc *Sharif SU)* PhD *UNSW*

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

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

Technical Team
John Gilbert
Greg Worthing
Ron Moncay

Emeritus Professors
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

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 2013 Management Board for the Centre was:

Professor **Graham Davies**, 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 Researchers lead the Civil Engineering ARC Discovery grants for 2013

CIES was one of only two Universities Australia wide dominating the 2013 round of successful ARC Discovery grants in Field of Research (FoR) Civil Engineering.

The ARC's mission is to deliver policy and programs that advance Australian research and innovation globally and benefit the community. In seeking to achieve its mission, the ARC supports the highest-quality fundamental and applied research and research training through national competition across nominated disciplines.

CIES was successful in this highly competitive grants process, being awarded 3 Discovery and 1 DECRA grants.

Ian Gilbert – "Control of cracking caused by early-age contraction of concrete"

Nasser Khalili and GaoFeng Zhao – "Dynamics analysis of unsaturated porous media subject to damage due to cracking"

Chongmin Song, Wei Gao and Yong-Lin Pi – "A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture"

DECRA: The Discovery Early Career Researcher Award scheme is a separate element of the Discovery Program. The scheme provides more focused support for researchers and creates opportunities for early-career researchers in both teaching and research, and research-only positions.

In 2013, Dr GaoFeng Zhao was awarded a DECRA Award for his project – "Dynamic fracturing in shale rock through coupled continuum-discontinuum modelling"

The objectives of the DECRA scheme are to:

- support and advance promising early career researchers;
- promote enhanced opportunities for diverse career pathways;
- focus research effort in the National Research Priority areas to improve research capacity and policy outcomes; and
- enable research and research training in high quality and supportive environments.

In addition to the above successes, our researches were partners in three LIEF Grants

The Linkage Infrastructure, Equipment and Facilities (LIEF) scheme provides funding for research infrastructure, equipment and facilities to eligible organisations. The scheme enables higher education researchers to participate in cooperative initiatives so that expensive infrastructure, equipment and facilities can be shared between higher education organisations and also with industry.

The scheme also fosters collaboration through its support of the cooperative use of international or national research facilities.

- Xiaojing Li, Linlin Ge are partners on a LIEF grant "Advanced techniques for imaging radar interferometry" in collaboration with researchers from Stanford University (US) and NASA/JPL (NASA's Jet Propulsion Laboratory)
- Nasser Khalili is a partner on a LIEF grant for "A national facility for in situ testing of soft soils" in collaboration with the University of Newcastle;
- Mark Bradford is a partner on a LIEF grant for "Performance level structural testing facility" in collaboration with The University of Queensland.

2013 CIES Geotechnical Symposium

Around 110 geotechnical engineers, including 80 from industry and 30 from universities, visited UNSW on 10 October 2013 to take part in the CIES Symposium titled 'Geotechnical Modelling: Analytical Solutions for Practising Engineers', chaired by Associate Professor Adrian Russell.

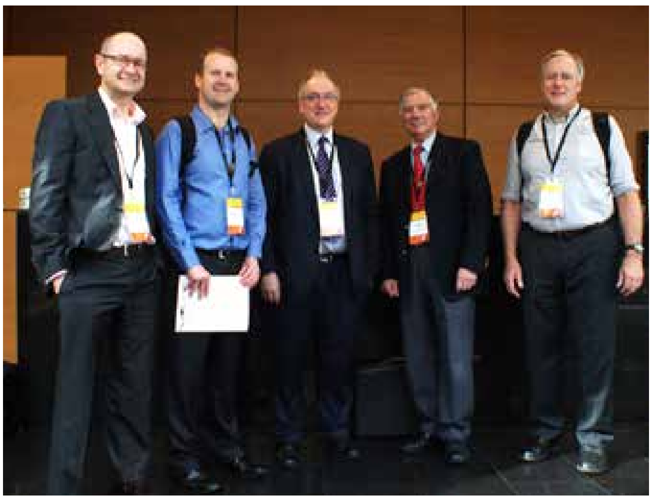
The symposium showcased a range of analytical methods applied to give quick, low-cost information about geotechnical problems.

A central theme was the development of models for analyses, which capture important complexities while being simple enough to be solved analytically and implemented easily.

A take home message of the symposium was that there is always scope to use analytical methods in the problem solving process. Also, analytical methods and more advanced computational analyses are complementary.

Leading modellers and analysts presented at the symposium including: International visitors from the UK (Professors Malcolm Bolton, University of Cambridge; Michael Davies, University of Sussex); the US (Professor Andrew Whittle, MIT).

Leading Australian speakers included Professor Harry Poulos, Coffey Geotechnics and The University of Sydney; Professor Nasser Khalili, UNSW; Professor Mark Cassidy, The University of Western Australia; Professor Buddhima Indraratna, University of Wollongong; Professor Jayantha Kodikara, Monash University; Adjunct Associate Professor Garry Mostyn, Pells Sullivan Meynink; Dr Fernando Alonso-Marroquin, The University of Sydney and Associate Professor Adrian Russell, UNSW.



Above L to R: Mr Thanh Liem Vo, Dr Adrian Russell, Mr Hongwei Yang, Ms Sumaiya Hossain, Mr Jianjun Ma

Left L-R: Dr Adrian Russell, The University of New South Wales, Professor Mark Cassidy, The University of Western Australia, Professor Michael Davies, University of Sussex, Professor Harry Poulos, Coffey Geotechnics and The University of Sydney, Professor Andrew Whittle, MIT, USA

CIES Member Achievements & Distinguished Honours

Professor Mark Bradford named a Distinguished Member of the American Society of Civil Engineers (ASCE) - the Society's highest accolade.

At its meeting on 23 March 2013, the Board of Direction of the American Society of Civil Engineers elected CIES' Mark Bradford and eleven other engineers worldwide to the grade of Distinguished Member of the ASCE. The current membership of the ASCE exceeds 140,000.

The Society notes:

> ***"A Distinguished Member is a person who has attained acknowledged eminence in some branch of engineering or in the arts and sciences related thereto, including the fields of engineering education and construction."***

The total number of Distinguished Members elected in any year does not exceed one for every 7,500 members, and in the 161 year history of the ASCE, only 626 other engineers have been similarly honoured, with Mark Bradford being the second Australian.

Mark Bradford acknowledges the great honour attached to the award, noting "the Distinguished Membership is an acknowledgement of cutting-edge research being undertaken in structural engineering in Australia. The team with whom I work punches well above its weight in delivering research outcomes in a variety of ways on the international stage, making significant contributions in fundamental mechanics, structural and computational mechanics, experimental techniques and in influencing practice by the research being taken up in international design standards. To be listed in a relatively small cohort that contains legendary practitioners and researchers of the prominence of Theodore von Karman, Zdenek Bazant, Ted Galambos, Hardy Cross, Egor Popov, Richard Gallagher Sir Douglas Fox and T-Y Lin is humbling to say the least."

Professor Stephen Foster, past Centre Director for CIES and currently Head of School of Civil & Environmental Engineering, was recently awarded the distinguished honour of being elected as a Fellow of Engineers Australia (Fellow of IEAust) which recognises those individuals who are true leaders of the industry and profession.

Through his research work in the area of reinforced and prestressed concrete structures and also in the writing of key texts in the same field, Stephen Foster has had direct involvement in the implementation of key changes to the 2009 Australian Concrete Structures Standard, AS3600. Internationally, he has engaged with the Federation of Structural Concrete (*fib*) that led to his works being incorporated into the *fib* 2010 Model Code. Professor Foster is a member of the editorial board for the Journal of Structural Concrete. He was a member of the Civil and Structural Panel, IEAust Sydney Division, from 2010 to 2012.

Fellows of The Institution of Engineers Australia have rendered conspicuous service to the profession of engineering, are eminent in engineering or an allied science, or a distinguished person whom the Council desires to honour, either for having rendered conspicuous service to the Australian people or in recognition of outstanding achievement.

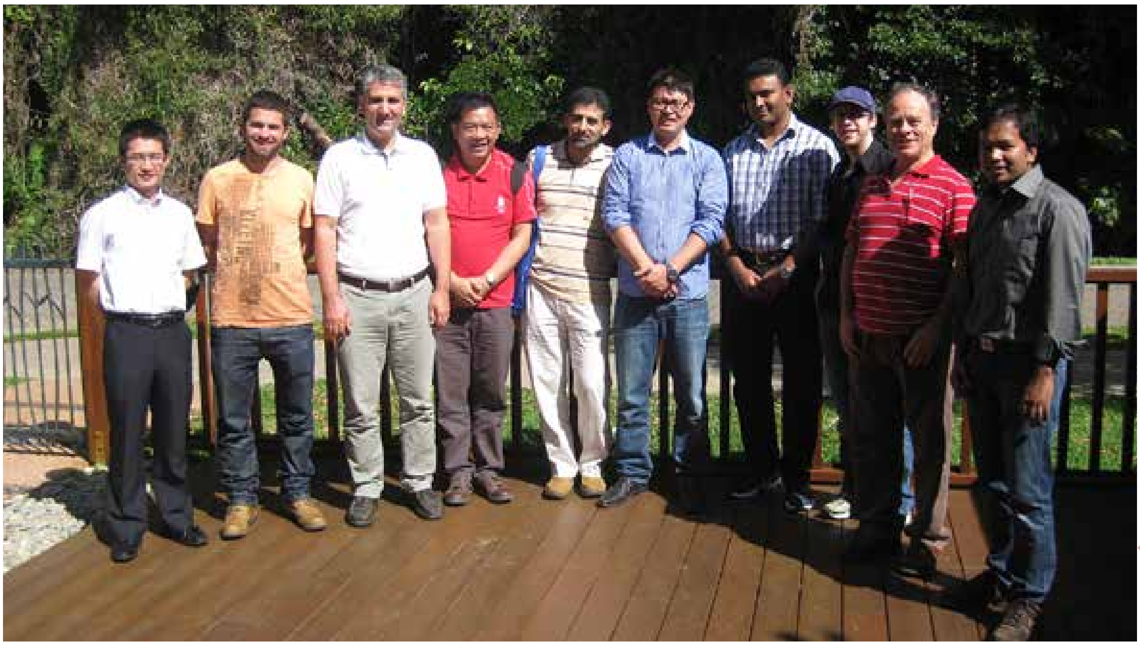
The criteria for this award include

- Contribution to the knowledge-base of the profession through research and development activities;
- Contributions to education through teaching and/or education support; and
- Contributions to the profession through professional society activities.

CIES Researchers’ International Recognition

Award for Best Conference Paper at the prestigious Symposium on Environmental Vibration (ISEV) held in Shanghai, China, 8-10 November 2013

Scientia Professor Mark Bradford and Professor Yong-Lin Pi and co authors Professors YL Guo and C Dou of Tsinghua University’s paper *Dynamic buckling analysis of an arch model* was awarded the best paper at the International Symposium on Environmental Vibration (ISEV) held in Shanghai, China, 8-10 November 2013. This is a highly regarded accolade from a field of International scholars and experts in structural engineering and reflects the international standing and recognition of the work currently being carried out by CIES members.



Composite Construction VII Conference, Palm Cove, North Queensland: 28-31 July 2013

In July 2013 CIES hosted the International Conference on Composite Construction VII with Professors Mark Bradford and Brian Uy as co-Chairs.

This conference series was run under the auspices of the Structural Engineering Institute (SEI) of the American Society of Civil Engineers (ASCE). The conference series began in 1987 at Henniker, New Hampshire and has been held every four years in a relaxed environment. Apart from the USA, it has also been held in Germany (1996), Canada (2000) South Africa (2004) and now in Australia. The conference provides opportunities for relaxed and in-depth scientific discussions into the behaviour and design of composite steel-concrete structures.

There was a total of 60 participants from 15 different nations, with 66 papers being delivered. CIES was heavily represented at the event by academic staff and PhD students, with 12 participants delivering a total of 13 papers.

Engineers Australia Eminent Speaker Tour - 2013: Professor Mark Bradford – CIES Research Director

The Engineers Australia Eminent Speaker Series enables EA members to hear presentations by notable persons from Australia and overseas on key topics of interest to the profession across a range of disciplines.

Professor Mark Bradford – CIES Research Director - was invited to be part of the 2013 Eminent Speaker Series during March, April, May 2013, touring all major cities in Australia including, Sydney, Newcastle, Melbourne, Brisbane, Mackay, Adelaide, Perth and Darwin. The tours are organised by the National Discipline Colleges & Committees of EA.

Professor Bradford's topic was "Designing Structures for End-of-Life Deconstructability".

An important aspect of designing sustainable building structures is that they should be deconstructable at the end of their service life, so as to enable the re-use of materials and to eliminate the energy associated with their demolition and disposal. In steel framed buildings with composite flooring systems attached with welded headed stud shear connectors, deconstruction is problematic because of the embedment of the headed studs in the concrete floor. This drawback can be eliminated with the use of bolted shear connectors that join precast concrete slab units to steel joists that are themselves connected to columns using deconstructable bolted joints.

The presentation discussed a research programme currently being undertaken at CIES (Centre for Infrastructure Engineering and Safety), underpinned by the Australian Laureate Fellowship scheme, that is investigating the use of bolted pre-tensioned shear connectors with precast geopolymer concrete slabs.

The pre-tension enables a frictional resistance to be mobilised at the steel/concrete interface that enables full shear interaction at service loading, thereby increasing the stiffness of the composite member, as well as allowing for the removal of the bolt in suitably proportioned clearance holes during the deconstruction phase. A simple mechanical model for representing the service-load behaviour is discussed. At overload, the performance of the shear connection is very ductile, allowing standard plastic design principles to be adopted. The use of deconstructable joints was also discussed, as well as various configurations of precast slabs in the negative moment region of a composite beam adjacent to an internal support.

ENGINEERS AUSTRALIA

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-CIES may raise issues that it would like to see addressed by 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

International Profile

Throughout 2013, 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:

Dr. Andrew H.C. Chan - Professor of Civil Engineering - Deputy Dean, Information Technology & Engineering, University of Ballarat

Professor David Muir Wood - University of Dundee, Scotland ˇ

Professor Zdenek P. Bažant - McCormick Institute Professor and W.P. Murphy Professor of Civil and Mechanical Engineering and Materials Science, Northwestern University

Dr. Xiaochun Fan from Wuhan University of Technology awarded a scholarship from Chinese Government for him to undertake research in our centre for one year.

Qing Jun Chen, an Associate Professor working in South China University of Technology

Associate Professor Wei Gu, Department of Road & Bridge, Liaoning Provincial College of Communications, China

Professor Dunja Peric – Kansas State Univ USA

Dr Hauke Gravenkamp, Federal Institute for Materials Research and Testing, Berlin, Germany.

Funding and **Finance**

2013 CIES Research Funding Summary

Researcher(s)	Research Topic	Granting Organisation	Value at 2013
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	521,911
Chongmin Song, Wei Gao, Yong-Lin Pi	A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture	ARC Discovery DP130102934	114,232
RI Gilbert	Control of cracking caused by early-age contraction of concrete	ARC Discovery DP130102966	124,617
N Khalili, GaoFeng Zhao	Dynamics analysis of unsaturated porous media subject to damage due to cracking	ARC Discovery DP130104918	103,847
L. Ge, H. Zebker, S. Hensley, H-Y Chen, L.Yue, X. Li	Advanced techniques for imaging radar interferometry	ARC Discovery DP130101694	114,232
MA Bradford	Thermal-induced unilateral plate buckling of concrete pavements: design and evaluation	ARC Discovery DP120104554	185,581
B Uy; Z Tao; F Mashiri	The behaviour and design of composite columns coupling the benefits of high strength steel and high strength concrete for large scale infrastructure	ARC Discovery DP120101944	232,967
Chongmin Song, Francis Tin-Loi, Wilfried Becker	Scaled boundary finite-element approach for safety assessment of plates and shells under monotonic and shakedown loadings	ARC Discovery DP120100742	107,843
Ehab Hamed; Stephen Foster	Nonlinear long-term behaviour and analysis of high strength concrete panels	ARC Discovery DP120102762	118,627
S Foster; Hamid Valipour	Progressive collapse resistance of reinforced concrete framed structures with membrane action	ARC Discovery DP120103328	50,343
B Uy; X Xhu; O Mirza	The use of innovative anchors for the achievement of composite action for rehabilitating existing and deployment of demountable steel structures	ARC Discovery DP110101328	103,350
RI Gilbert	Time-dependent stiffness of cracked reinforced concrete	ARC Discovery DP110103028	31,450
Gaofeng Zhao	Dynamic fracturing in shale rock through coupled continuum-discontinuum modelling	ARC DECRA DE130100457	130,387
MA Bradford	Climate adaptation technology and engineering for extreme events.	CSIRO / Flagship Collaborative Research Program	263,000
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	15,000

Researcher(s)	Research Topic	Granting Organisation	Value at 2013
Gianluca Ranzi (USYD), Raymond I Gilbert, Rodney Mackay-Sim	Behaviour of lifting inserts for precast concrete construction Partner/Collaborating Organisation: Universal Concrete Lifting Systems	ARC Linkage LP110100008	26,389
Markus Oeser, Alan Pearson, Nasser Khalili, Brian Shackel	Permeable Pavements with Concrete Surface Layers- Experimental and Theoretical Basis for Analysis and Design	ARC Linkage LP100100806	3,750
G Ranzi; B Uy; S Gowripalan; P Gabor	Behaviour of post-tensioned composite steel-concrete slabs	ARC Linkage LP0990190	2,701
PA Mendis; B Samali; B Uy	Innovative Retrofitting Techniques for the Protection of Anchorage Zones in Cable-Stayed Bridges Subjected to Blast Loads Collaborating/Partner Organisation: Road Traffic Authority (RTA)	ARC Linkage LP0883942	27,755
MA Bradford; B Uy; G Ranzi; A Filonov	Time-Dependent Response and Deformations of Composite Beams with Innovative Deep Trapezoidal Decks. Collaborating /Partner Organisation: BlueScope Lysaght	ARC Linkage LP0882929	55,497
UQ/UNSW/UWA/QUT/Adel	Performance Level Structural Testing Facility (PLSTF). Partner Organisation: Queensland Department of Transport and Main Roads	ARC LIEF LE130100089	23,500
UNSW/ UWS /UOW /UWA/QUT/UoN/ Adel/Melb	National Facility for Physical Blast Simulation (NFPBS) Partner Organisation: Defence Science and Technology Organisation	ARC LIEF LE1301100133	700,000
S Foster; E Hamed; Z Vrcelj	Advanced Composite Structures	Cooperative Research Centre for Advanced Composite Structures Ltd (CRC-ACS)	125,410
S Foster	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)	31,250
C Birk	FRG Grant	UNSW Engineering	25,000
A Castel	FRG Grant	UNSW Engineering	30,000
A Khoshghalb	FRG Grant	UNSW Engineering	39,844
A Russell	Mechanistic design tools for shallow foundations in unsaturated soils derived through numerical modelling, analysis and experimental investigation	UNSW Goldstar Awards - DP130104497	37,246
Industry funded research undertaken by the CIES Projects team	Various		88,551
		TOTAL	**$3,434,280**

Centre **Research**

CIES Research Success

This year's ARC success continues to add to the success of CIES in attracting Category 1 funding through the Australian Research Council. CIES staff currently hold over 30 ARC grants, including ARC Discovery and Linkage, LIEF and DECRA grants. CIES is also home to Australia's only ARC Laureate Fellow in Structural Engineering, Professor Mark Bradford.

Ten CIES staff have been successful in Seven ARC Grants totalling over $3.5 million for 2014. CIES staff were involved in the following four ARC Discovery Project Grants:

- DP140101887, Dr Wei Gao, Professor Yong-Lin Pi and Emeritus Professor Francis Tin Loi, $395,000
  Project Title: Stochastic geometrically nonlinear elasto-plastic buckling and behaviour of curved grid-like structures
- DP140102134, Professor Brian Uy, $530,000
  Project Title: The behaviour and design of innovative connections to promote the reduction and reuse of structural steel in steel-concrete composite buildings
- DP140103142, A/Professor Adrian Russell and Professor Nasser Khalili, $420,000
  Project Title: Shallow foundations in unsaturated soils: understanding mechanistic behaviour through numerical modelling, analysis and experimental investigation
- DP140100529, A/Professor Gianluca Ranzi, A/Professor Arnaud Castel, Emeritus Professor Ian Gilbert and Dr Daniel Dias-da-Costa, $300,000
  Project Title: Stiffness degradation of concrete members induced by reinforcement corrosion

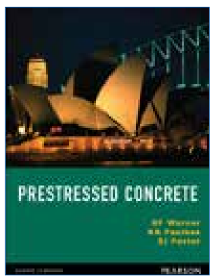
Dr Huu-Tai Thai was also successful with an ARC Discovery Early Career Researcher Award (DECRA): DE140100747, $333,157. Project ID: RG133018 Title: Reliability assessment of concrete-filled steel tubular frames designed by advanced analysis

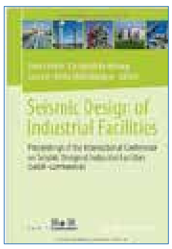
CIES Staff were also involved in successful Linkage, Infrastructure Equipment and Facilities (LIEF) grants. Associate Professor Ganga Prusty (School of Mechanical and Manufacturing Engineering) led a bid from UNSW including Professor Brian Uy that received $500,000 for a National Facility for Robotic Composites. Furthermore, Professors Nasser Khalili, Brian Uy and Adrian Russell were also part of a successful LIEF bid led by Professor Buddhima Indraratna from the University of Wollongong for a National Testing Facility for High Speed Rail which received $900,000 from the ARC.

Research Publications for 2013

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

In 2013, CIES researchers continued to have a consistently strong publishing output including 2 books, 1 book chapter, 118 refereed journal papers and 106 refereed conference papers.





CIES Research Collaborations

CIES welcomed into the group Associate Professor Linlin Ge and his team of researchers.

Linlin's core expertise is in remote sensing and he sees his research goals as making remote sensing more timely, accurate, affordable and widely applicable.

Remote sensing techniques play a central role in our daily life, from underpinning weather forecast, to monitoring ground settlement, bushfires, floods and earthquakes, and to assessing global climate change.

CIES teaming up with NASA on earth observation

Dr Scott Hensley - a remote sensing expert and space engineer from NASA's Jet Propulsion Laboratory is part of a $330,000 ARC Discovery project led by CIES Associate Professor Linlin Ge. The objective is to "develop advanced, cost-effective and accurate imaging radar techniques that can measure subtle surface changes frequently, in order to safeguard significant infrastructure".

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.

	2010	2011	2012	2013
Number of PhD students supervised by CIES members	37	42	53	62

Research & Teaching Areas of Key Centre Members

Name	Position within School	Research Areas	Teaching Areas
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 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 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 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 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 Yong-Lin Pi	Professor in Civil Engineering / Senior Research Fellow	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 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 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 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.
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 Arnaud Castel	Associate Professor of Civil Engineering	Durability of construction materials, Low Carbon Concrete Technology, Service life design, Analysis of reinforced concrete affected by steel corrosion, Repair and Strengthening using CFRP, Shrinkage and creep of concrete.	Concrete technology Engineering Mechanics Concrete Structure Analysis and Design Earthquake engineering
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 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 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	Senior Lecturer	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 Carolin Birk	Lecturer	Numerical modelling of wave propagation in unbounded domains and in bounded domains containing discontinuities. Soil-structure interaction, fluid-structure interaction. Longitudinal railway track-structure interaction. Artificial boundary conditions for diffusion. Fractional calculus.	Structural Dynamics, Engineering Mechanics, Mechanics of Solids
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 Babak Shahbodaghkhan	Lecturer	Computational Poromechanics- unsaturated soils in particular. Dynamic Soil-Structure Interaction. Constitutive Modeling of Geomaterials. Swarm-Based Optimization	Geomechanics. Numerical Methods in Geotechnical Engineering. Pavement Engineering
Dr Sawekchai Tangaramvong	Lecturer	Limit and shakedown analysis of structures with efficient adaptive FEM/SBFEM; Uncertainty analysis of structures subjected to physical instabilizing effects as softening material, cohesive fracture, frictional contact and large deformation; Optimal design of nonlinear structures under limited ductility conditions; Analysis and design of structures under high impact loading	Mechanics of Solids; Materials and Structures; Structural Behaviour and Design
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.	
Dr Michael Man	Research Fellow	Scaled boundary Finite Element Method for Plate/shell structures. Damage identification using artificial neural networks. Composite structures and piezoelectric materials	Engineering Mechanics: statics and dynamics
Dr David Kellerman	Research Fellow	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 Huiyong Ban	Research Fellow	High-performance and high-strength steel structures, flexural behaviour of steel-concrete composite beams, buckling behaviour of steel structures, residual stress.	
Dr Sundararajan Natarajan	Research Fellow	Method development (extended finite element method, iso-geometric analysis, mesh free methods), functionally graded materials, Thin-walled structures, Composite Materials, Computational Fracture Mechanics	Structural Stability
Dr Ean Tat Ooi	Research Associate	Computational/numerical methods, scaled boundary finite element method, finite element method, fracture mechanics, functionally graded materials, elasto-plastic fracture. Engineering 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 Guotao Yang	Research Associate	Stability of railway tracks under thermal loading, Fatigue reliability of steel bridges, Structural behaviour of steel-concrete composite 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 Inamullah Khan	Research Associate	Time dependent behavior 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 Saeed Salimzadeh	Research Associate	Mechanics of Multi Phase Multi Porous Media. Advanced Numerical Modelling in Geomechanics	
Dr Tai H. Thai	Research Associate	Advanced analysis; Steel structures; Steel-concrete composite structures; Beam and plate theories; Functionally graded and laminated composite plates.	Advanced analysis; Beam and plate theories
Dr Alex Hay-Man Ng	Research Associate	Remote sensing application in monitoring land surface changes	Remote Sensing

Control of cracking caused by early-age contraction of concrete.

Prof Ian Gilbert,
A/Prof Arnaud Castel,
Dr Inam Khan

ARC Discovery Project
2013-2015

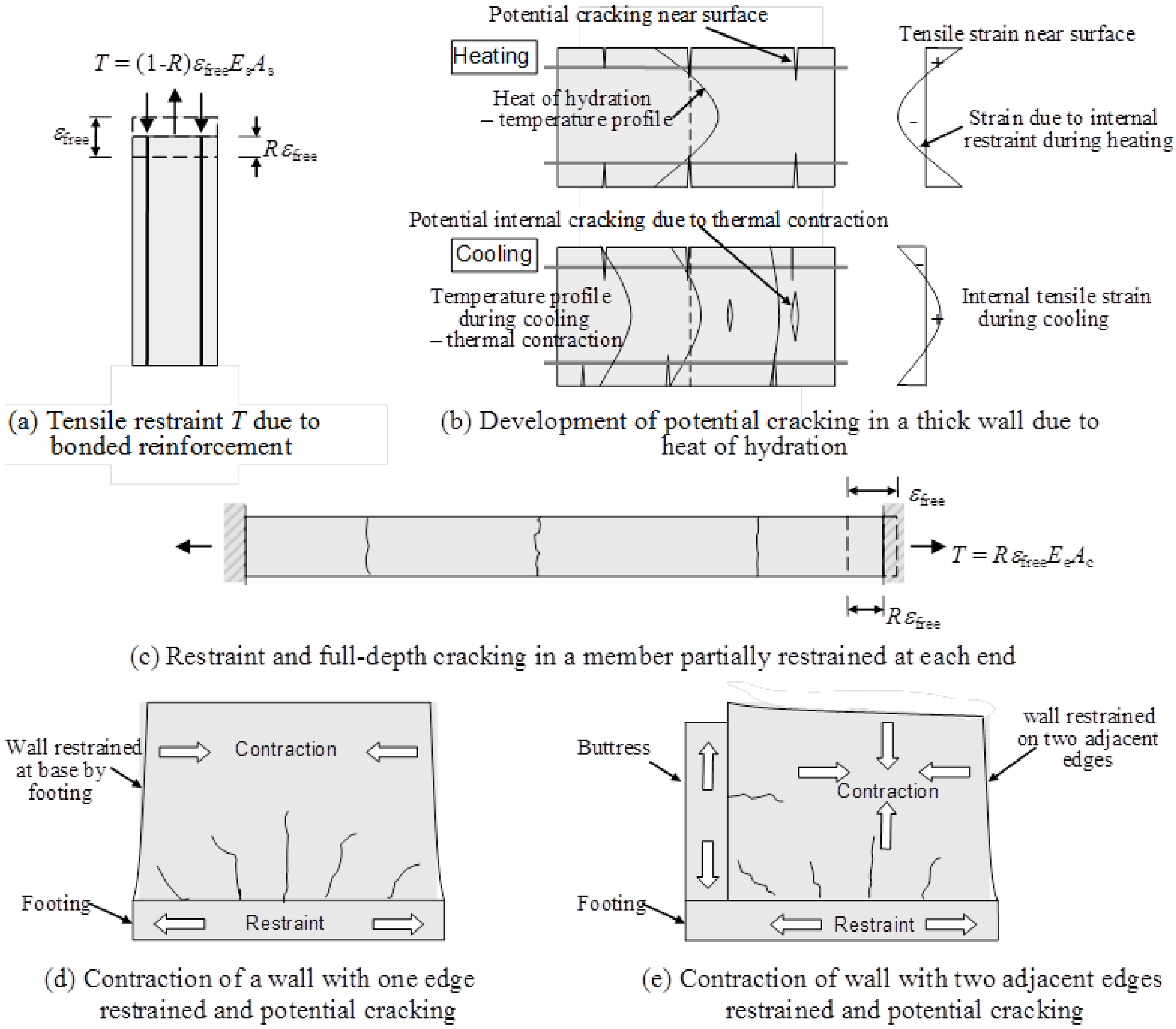
Early-age contraction of concrete may cause excessive cracking in restrained concrete slabs and walls within the first few days and weeks after casting. The repair of such cracks results in high annual costs to the construction industry. Early-age contraction of concrete is due to thermal contraction 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. Where the contraction varies through the thickness of a member, as it almost always does due to temperature and shrinkage gradients, additional eigenstresses develop that can also lead to cracking.

Some typical types of restraint in reinforced concrete structures and the consequent cracking are shown in Figure 1.

This project is aiming 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.

In 2013, the first stage of testing commenced aimed at quantifying the early-age properties of concrete, including the tensile elastic modulus, tensile creep and shrinkage strain (both drying and autogenous). Testing rigs have been fabricated to facilitate the measurement of tensile creep at early ages (see sketch in Figure 2).

Figure 1: Some typical types of restraint in reinforced concrete



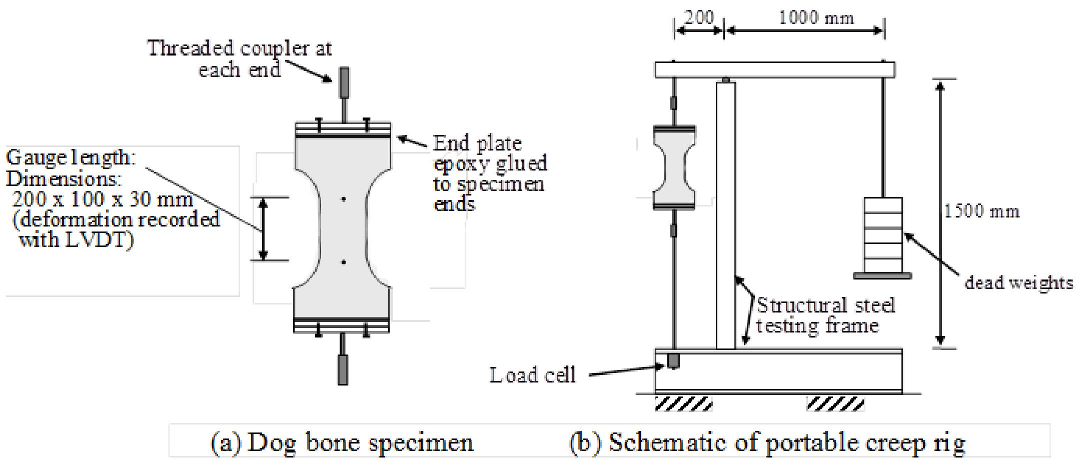


Figure 2 Tensile creep specimen and typical testing rig.

A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture

Prof Chongmin Song,
Dr Ean Tat Ooi,
Dr Hou (Michael) Man,
Dr Wei Gao

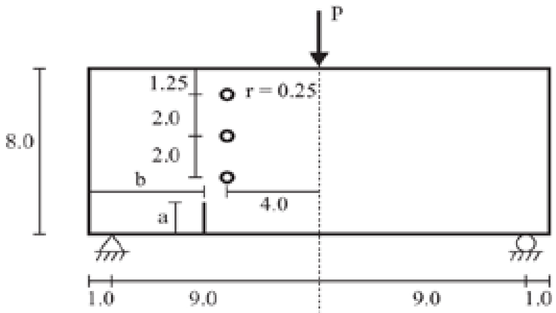
ARC Discovery Project
2013-2015

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.

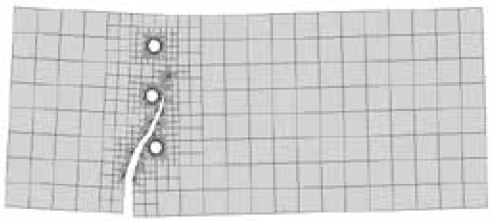
In this first stage of this project, a scaled boundary polygon element of arbitrary order is developed to model the stress concentration at the crack tip. The key parameters for a fracture analysis are conveniently determined. No local mesh refinement around the crack tip, such as in the finite element 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.



CASE	a	b
I	1.5	5.0
II	1.0	4.0

(a) Geometry



(b) Crack path of CASE I (above)
(c) Crack path of CASE II (below)

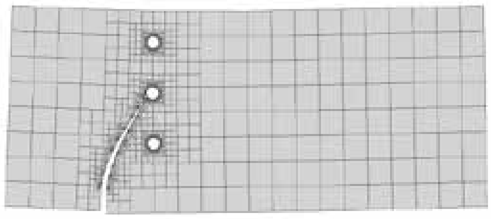
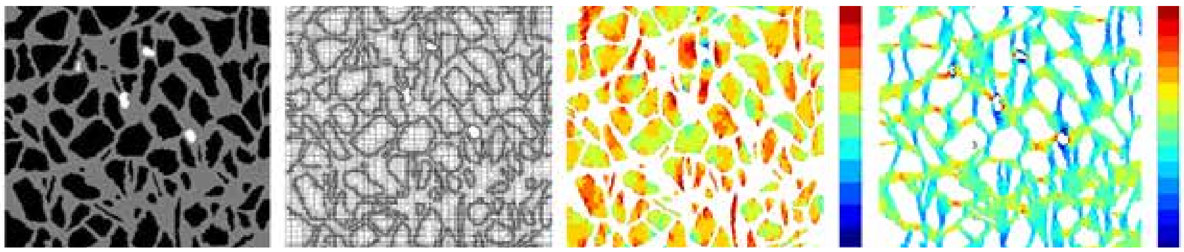


Figure 1: Crack propagation of a beam subjected to three point bending with initial crack at different locations.



(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

Progressive Collapse Resistance of Reinforced Concrete Framed Structures with Membrane Action

Prof Stephen Foster (UNSW)
Dr Hamid Valipour (UNSW)
Nima FarhangVesali (UTS)

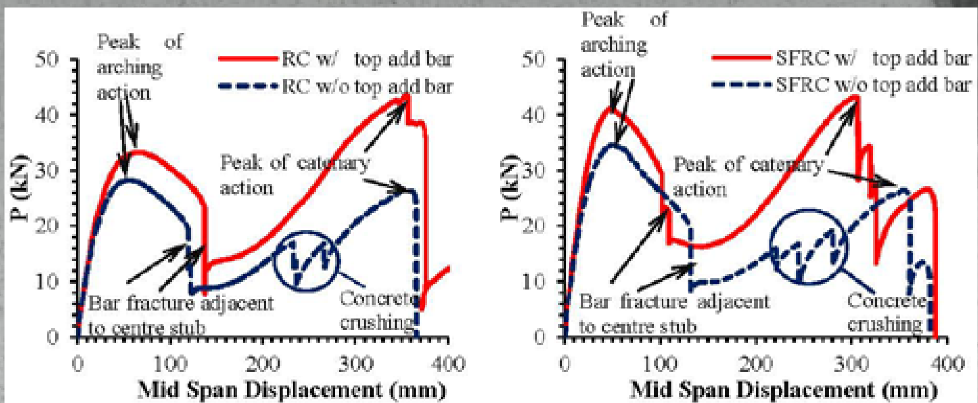
ARC Discovery Project
2012 – 2014

Among the different load redistribution mechanisms, membrane action has been identified as one of the primary mechanisms that significantly improve the progressive collapse resistance of frames during extreme loading events such as earthquake and blasts. However, little attention has been paid to membrane action of reinforced concrete members within framed structures and the contribution of membrane action in their progressive collapse resistance. Accordingly, the aims of this research project are to provide experimental baseline data and quantify the effects of boundary conditions, concrete compressive strength and detailing of reinforcement on membrane action of reinforced concrete beams within framed structures. Furthermore, efficient 1D frame and continuum-based finite element (FE) models are developed and verified by tested beam assemblages.

Presently, CIES investigators are undertaking tests on reinforced concrete beam assemblages and frames subjected to point load at mid-span. In total, eighteen reinforced concrete (RC) and steel fibre reinforced concrete (SFRC) beam assemblages with different reinforcing proportion, stirrup configuration and concrete compressive strength have been tested so far. From the experimental results, effect of passive confinement (provided by transverse reinforcement) on the arching action was found to be negligible.

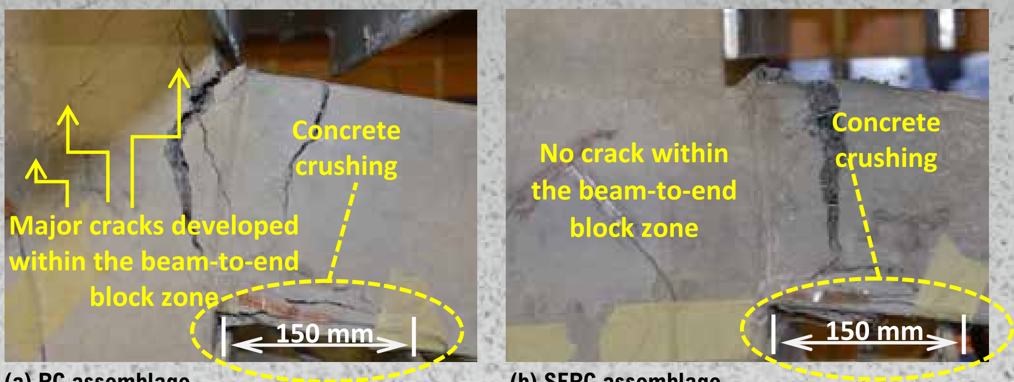
In addition, the CIES investigators have developed detailed 2D continuum-based (FE) models which can accurately capture local and global behaviour of RC and SFRC beam assemblages subject to large displacements (Figure 1). The experimental results and FE model predictions showed that peak of catenary action is similar for RC and SFRC assemblages with the same longitudinal reinforcing ratio (Figure 1), however, the extent of damage in the beam-to-end block zone and adjacent to centre stub was different in RC and SFRC assemblages. In the RC assemblages, major cracks developed in the beam-to-end block zone, whereas no crack was observed in the beam-to-end block zone of SFRC assemblages (Figures 2 and 3).

In RC assemblages, the tendency of catenary steel bars to be pulled out of concrete was resisted by the stirrups, accordingly no longitudinal cracking and spalling of concrete was observed in the sections adjacent to the centre stub (see Figure 3a). However, in SFRC assemblages, extensive longitudinal cracking and spalling of concrete cover was observed in the vicinity of centre stub (Figure 3b), owing to tendency of catenary bars to be pulled out of concrete. Nevertheless, in SFRC assemblages, the steel fibres managed to adequately arrest the longitudinal cracks and prevent extensive separation of steel bars from concrete core.



(a) RC (b) SFRC

Figure 1 Load versus vertical displacement of centre stub captured by the continuum-based FE model for (a) RC assemblages with stirrups and (b) SFRC assemblages without stirrups.



(a) RC assemblage (b) SFRC assemblage

Figure 2: Crushing of concrete in the sections adjacent to end supporting blocks.

(a) RC assemblage (b) SFRC assemblage (no stirrup)

Figure 3: Concrete cover cracking and spalling adjacent to centre stub after bar rupture.

Nonlinear long-term behaviour and analysis of high strength concrete panels

Dr Ehab Hamed

Prof Stephen Foster

ARC Discovery Project:
2012-2014

To have a safely design concrete structures with relatively new technologies that use high strength precast panels, an understanding and an investigation of their long-term creep and shrinkage behaviour are required.

The main challenge in predicting the long-term response and design lifetime of high strength concrete panels lies in the ability of the numerical models to accurately describe the time-dependent cracking, geometric nonlinearity and buckling, aging of the concrete, shrinkage, and other effects. Slender high strength concrete panels are characterized by creep buckling as shown in Fig. 1, which is accompanied with cracking and other material nonlinear effects that make predicting the long-term response a difficult and a challenging task. Describing the structural response requires a step-by-step time analysis that takes into account the change in the structural geometry, internal stresses, and material characteristics at each time increment.

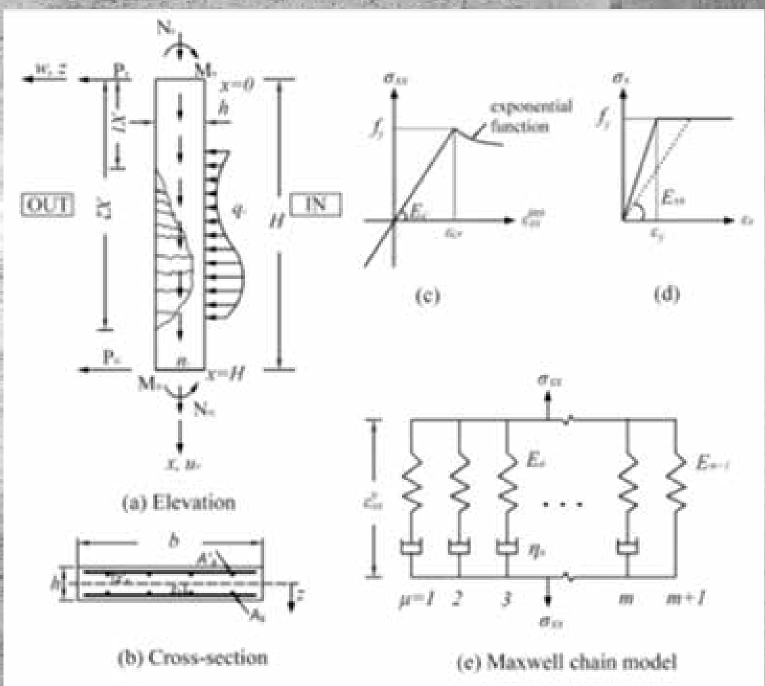
Through a 3-years project funded by the ARC, this project aims to provide a better understanding of the nonlinear time-dependent behaviour of high strength concrete (HSC) panels in order to enhance their effective design and safe use. The project involves both theoretical and experimental studies. Comprehensive theoretical models, as well as numerical and computational tools for the unidirectional short-term and long-term nonlinear analyses of HSC panels have already been established. An experimental study that investigated the short-term response of HSC panels was finalized during 2013. Full-scale panels that some of them exhibited creep buckling failures were tested under long-term sustained loading with different load levels and load eccentricities. The testing program is planned to finish by the end of 2014.

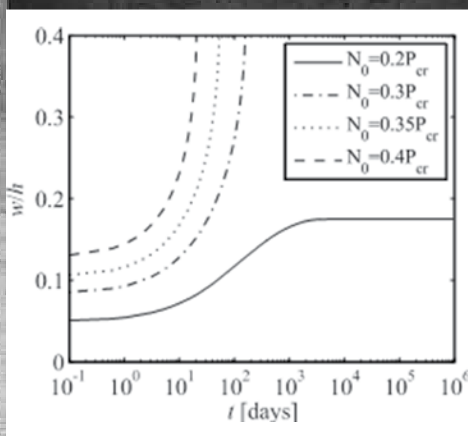
A PhD student (Huang Y) and a Senior Research Associate (Chang Z-T) are involved in this project and they are working on the mathematical formulation of the problem, and on conducting the long-term testing. The already developed long-term mathematical formulation includes a one-way model of the HSC panel that accounts for the effects of creep, shrinkage, aging, cracking, tension-stiffening, and geometric nonlinearity (as shown in Fig. 2). The model will be further calibrated and validated against the experimental results, and is currently being further enhanced and expanded to account for the two-way action of HSC panels. The two-way model is expected to be completed by mid 2014.

Left - Figure. 1: Testing of panels for time effects

Below Left - Figure 2: (a) Panel geometry, loads, coordinates and displacements; (b) Cross-section of the panel; (c) Instantaneous stress-strain curve of the concrete; (d) Instantaneous absolute stress-strain curve of the steel; (e) Maxwell chain model

Below Right - Figure 3: Influence of load level on the long-term behaviour of the HSC panel (e = h/6, ρv = 0.2%)





The use of innovative anchors for the achievement of composite action for rehabilitating existing and deployment in demountable steel structures

Prof Brian Uy (UNSW)
Dr Xinqun Zhu (UWS)
Dr Olivia Mirza (UWS)

ARC Discovery Project
2011-2013

This project began in 2011 with two PhD students being recruited, Mr Sameera Pathirana and Mr Ian Henderson. Two sets of experiments have been carried out, namely on bolts as shear connectors for new construction and bolts as shear connectors for rehabilitated structures. In addition to this, analytical and finite element models have been developed.

Publications Emanating from this Project in 2013:

Uy B; Zhu XQ; Mirza OM; Henderson I; Pathirana S, (2013) 'Smart rehabilitation of steel-concrete composite structures for enhanced structural health monitoring', in *Structural Health Monitoring for Infrastructure Sustainability*, Invited Lecture presented at 6th International Conference on Structural Health Monitoring of Intelligent Infrastructure, Hong Kong, China, 9 - 11 December 2013.

Figure 1. Flexural rigidity comparisons of non-composite and composite beam cases

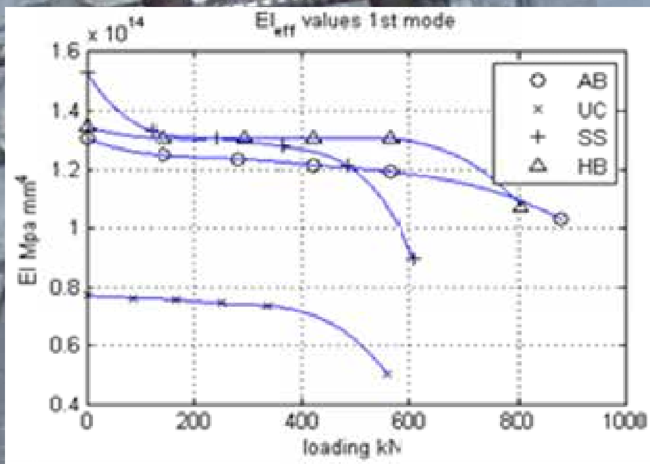
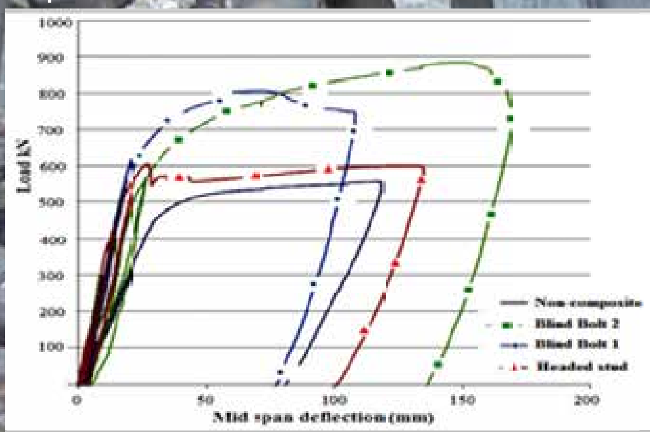


Figure 2. Load-deflection relationships of non-composite and composite beam cases



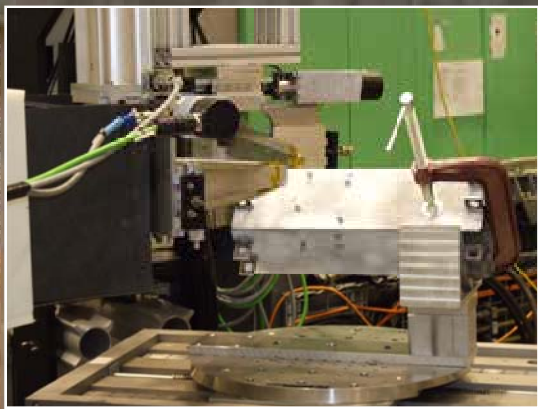
The behaviour and design of composite columns coupling the benefits of high strength steel and high strength concrete for large scale infrastructure

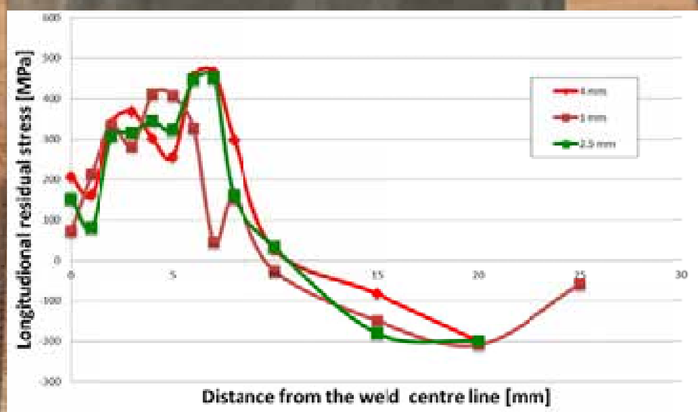
Prof Brian Uy (UNSW), Prof Zhong Tao (UWS), Dr Fidelis Mashiri (UWS), Prof Richard Liew (National Uni of Singapore),
Prof Lin-Hai Han (Tsinghua Uni)

ARC Discovery Project
2012-2014

This project began in 2012 and a PhD student Mr Mahbub Khan was appointed. Short and slender column tests on high strength steel box columns filled with high strength concrete have already been carried out at the University of Western Sydney. A postdoctoral fellow has also been appointed and the project has also been enhanced through the collaboration with Dr Anna Paradowska from ANSTO which has led to a successful bid for time to use the Kowari facility to use neutron scattering techniques to determine residual stress measurements in high strength steel.

Figure 1. Kowari strain scanner, ANSTO and residual stress patterns





Publications Emanating from this Project in 2013:

Uy B; Khan M; Tao Z; Mashiri F, (2013) 'Behaviour and design of high strength steel concrete composite columns', in *Proceedings of the 2013 World Congress on Advances in Structural Engineering and Mechanics* (ASEM13), pp. 150 - 167, Keynote Lecture presented at The 2013 International Conference on Steel and Composite Structures (ICSCS13), Jeju, Korea, 8 - 12 September 2013.

Khan M; Uy B; Tao Z; Mashiri F, (2013) 'Concentrically loaded short high strength composite columns', in *Proceedings of the 10th Pacific Structural Steel Conference* (PSSC 2013), pp. 243 - 248, presented at PSSC2013, Tenth Pacific Structural Steel Conference, Singapore, 8 - 11 October 2013.

Mashiri FR; Paradowska A; Uy B; Tao Z; Khan M, (2013) 'Measurement of residual stresses in fabricated square high strength steel tubes using neutron diffraction method', in *Proceedings of 5th International Conference on Advances in Experimental Structural Engineering*, pp. 136 - 142, presented at 5th International Conference on Advances in Experimental Structural Engineering, Taipei, Taiwan, 8 - 9 November 2013.

Scaled boundary finite-element approach for safety assessment of plates and shells under monotonic and shakedown loadings

Dr Hou (Michael) Man,
Prof Chongmin Song.
Prof Francis Tin-Loi

ARC Discovery Project
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

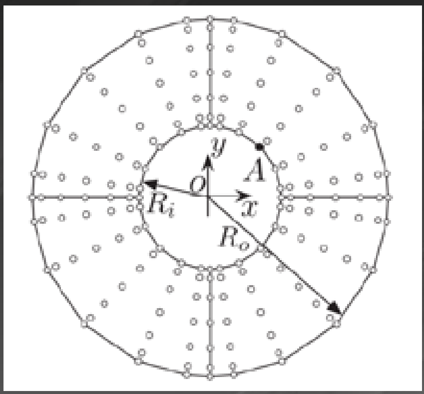


Figure 2. Comparison of computational requirement with ANSYS

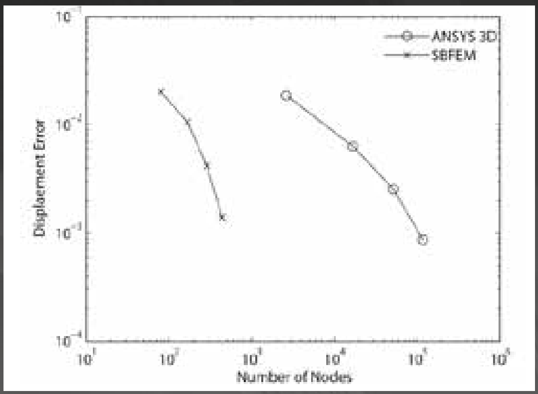
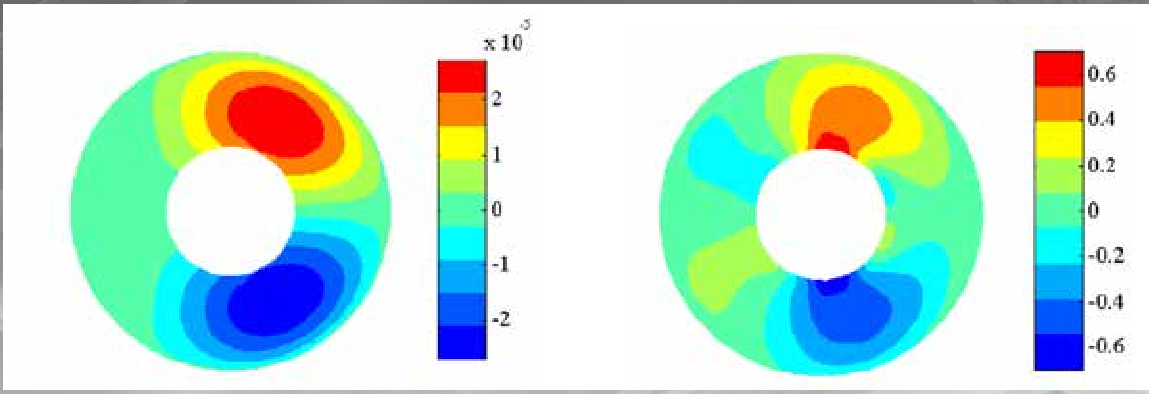


Figure 3. Normalised electric potential and in-plane axial stress of a circular piezoelectric sensor under non-uniformly distributed pressure



(a) Electric potential at mid plane

(b) Axial stress at top plane

Time-dependent stiffness of cracked reinforced concrete

Prof Ian Gilbert (UNSW),
Dr Arnaud Castel (UNSW),
Dr Gianluca Ranzi (USyd)

ARC Discovery Project
2011-2013

The deformation of a reinforced concrete member at service loads depends on the member's stiffness and this depends on the deformational properties of concrete (including creep and shrinkage characteristics), the extent of cracking and the bond between the reinforcement and concrete. Bond between the concrete and the reinforcement causes a build-up of stress in the tensile concrete between the cracks and this changes with time as the concrete creeps and shrinks, and as additional cracks develop at the concrete-steel interface.

This project aims to calibrate and quantify the time-dependent change in stiffness and will result in improved designs for serviceability and a clearer insight into the deformational characteristics and load carrying mechanisms in cracked reinforced concrete.

Stages 1 and 2 of the on-going experimental program commenced in late 2011 and has continued throughout 2013, with part of the work being undertaken at the University of New South Wales and part at the University of Sydney. In total 18 reinforced concrete prisms were tested in axial tension to monitor the instantaneous axial stiffness and the effect of early shrinkage on structural behaviour. In addition, 12 reinforced concrete slab specimens (Figure 1) and 6 larger reinforced concrete girders (Figure 2) were subjected to sustained transverse loads. The change in stiffness with time was monitored, including the gradual reduction in the contribution of the cracked tensile concrete.

Work on the analytical modelling has also progressed, with several papers published in 2013. Dr Zhen-Tian Chang (UNSW), Dr Inam Khan (UNSW) and Dr Safat Al-Deen (USYD) are assisting the CIs with the laboratory aspects of the project.

Figure 1: Slab specimens under sustained loads

Figure 2: Beam specimens under sustained loads

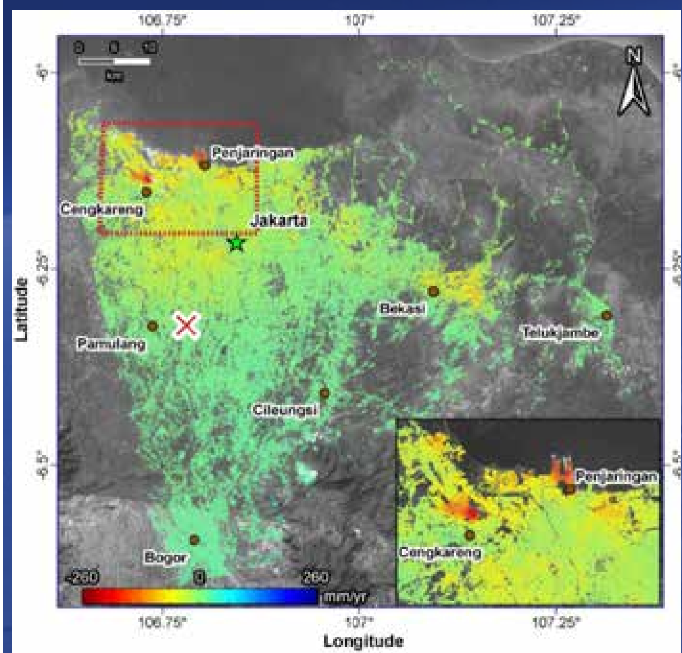
Advanced techniques for imaging radar interferometry

A/Prof Linlin Ge (UNSW), Dr Jean Xiaojing Li (UNSW), Prof Howard Zebker (Stanford), Dr Scott Hensley (NASA Jet Propulsion Laboratory), and Dr Horng-Yue Chen (Institute of Earth Sciences, Academia Sinica)

ARC Discovery Project
2013 – 2015

Persistent scatterer radar interferometry (PSI) has been increasingly used to measure ground surface deformation caused by earthquakes, groundwater extraction, underground mining, and other activities. It is an important tool in safeguarding significant infrastructure. The aims of the Project are to develop advanced techniques to further enhance PSI through exploiting SAR polarisations, incorporating the new wide-area imaging mode, and integrating multi-geometry & multi-source ground displacement measurements. The expected outcomes are a suite of innovative techniques that aim to transform PSI into a robust, cost-effective, large coverage and fully 3-dimensional remote sensing technology capable of frequently monitoring ground displacement.

Land subsidence in Jakarta, Indonesia, as mapped with PSI using 17 satellite images collected between 31 January 2007 and 26 September 2010



Artist's view of the Sentinel-1 satellite (image credit: European Space Agency)

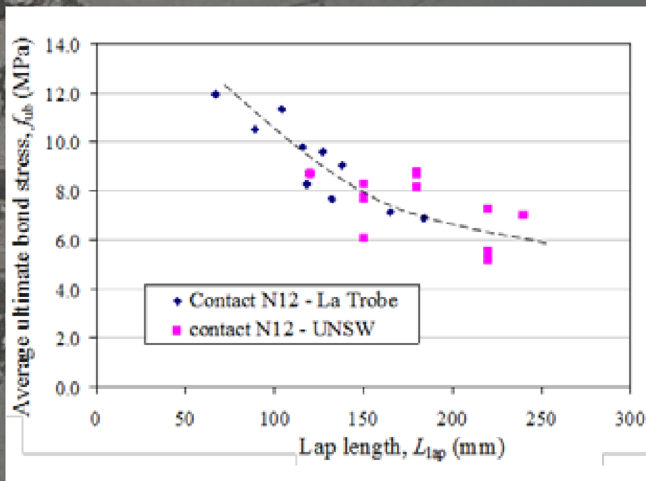
Anchorage of reinforcement in concrete structures subjected to loading and environmental extremes

Prof R.I. Gilbert (UNSW)
Prof A. Kilpatrick (La Trobe)
Mr M. Mazumder (UNSW)
Dr Z-T Chang (UNSW)

ARC Discovery Project
2010-2013

Over 50 load tests on slabs and beams containing either contact or non-contact lapped splices have been conducted at both the Centre's Heavy Structures Laboratory and at La Trobe University in Bendigo, Victoria. The aim is to assess the efficacy of the current Australian procedures for anchoring reinforcement in concrete structures from the point of view of both strength and ductility and to examine the reliability and consistency of the factors of safety. It was concluded that the provisions of AS3600-2009 are adequate for small diameter bars in slabs but may not provide an adequate factor of safety for large diameter bars in beams.

The load at which bond failure occurs depends, among other factors, on the spacing of primary cracks within the lap length and this important factor is not considered in current design-oriented code procedures. The average ultimate bond stress that develops at failure in a lap length Llap is not only heavily dependent on the bar diameter, but is also dependent on the number of cracks that cross the lap. The specimens in which Llap was small had a small number of primary cracks within the lap length, sometimes no cracks at all, and the average ultimate bond stress determined from the load at failure was high. The experimental program was completed in 2012, but work continues on the analytical and numerical studies throughout 2013, with Mr Mazumder's PhD dissertation readu for submission by the end of 2013.



Influence of lap length on average ultimate bond strength.

National facility for physical blast simulation

Prof Brian Uy (UNSW), Dr Chunwei Zhang (UWS), Prof Kenny Kwok (UWS), A/Prof Alex Remennikov (UoW), Prof Hong Hao (UWA), Prof Guowei Ma (UWA), Prof David Thambiratnam (QUT), Dr Chenqing Wu (Adelaide), Prof Priyan Mendis (Melbourne), Prof Mark Stewart (Newcastle)

ARC – Linkage Equipment and Facilities Grant (LIEF)
2013

Led by CIES Director Professor Brian Uy, a group of representatives from 7 Australian Universities (incl UNSW) and the Defence Science and Technology Organisation (part of Australia's Department of Defence - as the Collaborating Organisation), were successful in a bid for funding under the ARC's The Linkage Infrastructure, Equipment and Facilities scheme (LIEF Grant) which provides funding for research infrastructure, equipment and facilities to eligible organisations.

The scheme enables higher education researchers to participate in cooperative initiatives so that expensive infrastructure, equipment and facilities can be shared between higher education organisations and also with industry. The scheme also fosters collaboration through its support of the cooperative use of international or national research facilities.

The project is titled: "National Facility for Physical Blast Simulation (NFPBS)".

Recent terrorist attacks employing large quantities of high explosives have prompted the international demand for experimental investigation of civil infrastructure response to shock wave loadings.

The National Facility for Physical Blast Simulation (NFPBS) will be one of only a few in the world that will be suitable for conducting experimental research via a physically generated blast approach.

The objectives of the Linkage Infrastructure, Equipment and Facilities scheme are to:

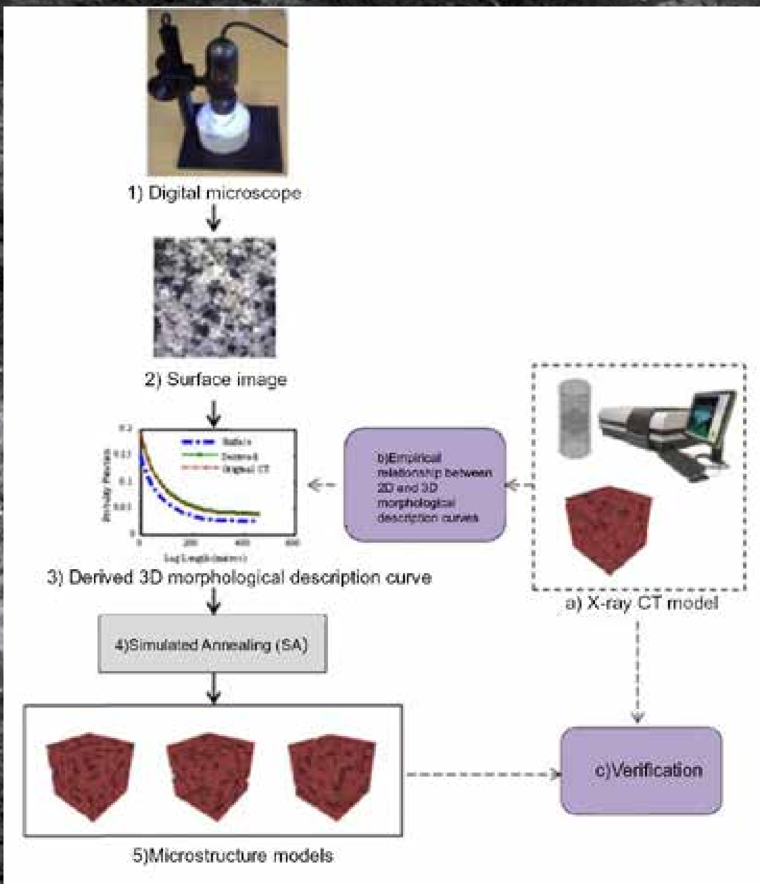
- encourage institutions to develop collaborative arrangements among themselves, across the higher education sector and with organisations outside the sector, in order to develop research infrastructure;
- support large-scale cooperative initiatives involving two or more institutions, thereby allowing expensive facilities to be shared; and
- enhance support for areas of research strength.

Dynamic fracturing in shale rock through coupled continuum-discontinuum modelling

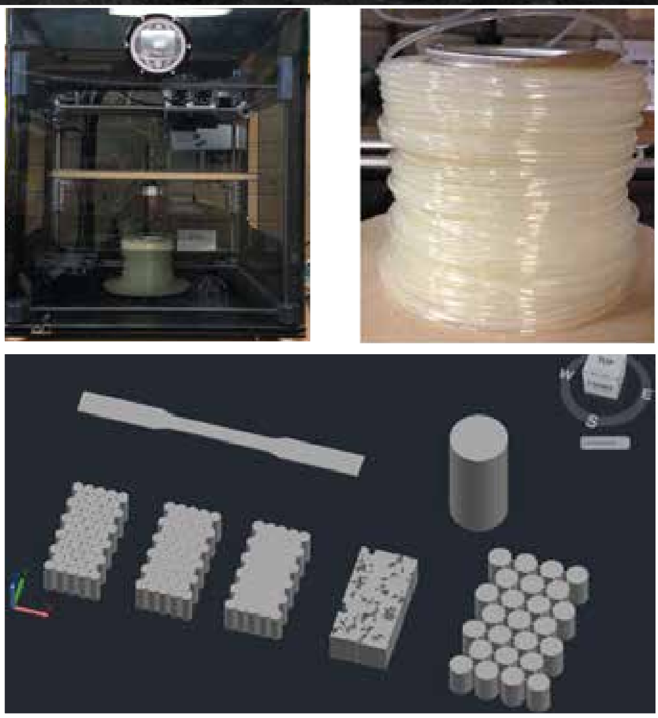
Dr Gaofeng Zhao

ARC DECRA
2013-2015

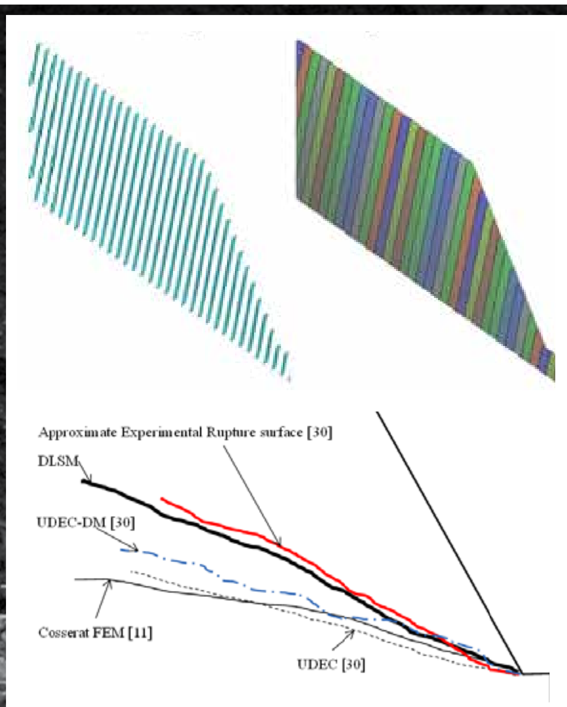
A 3D reconstruction technique was developed to build the 3D microstructure of the sandstone from its local surface image. The 3D printing was preliminarily used for rock mechanics study. The jointed DLSM model was successfully developed. SHPB tests on the Datong coal (a typical anisotropic material similar to shale) and Changsha sandstone were conducted. The strain rate dependency of the uniaxial tensile strength in Gosford sandstone was studied by the DLSM with X-ray micro CT.



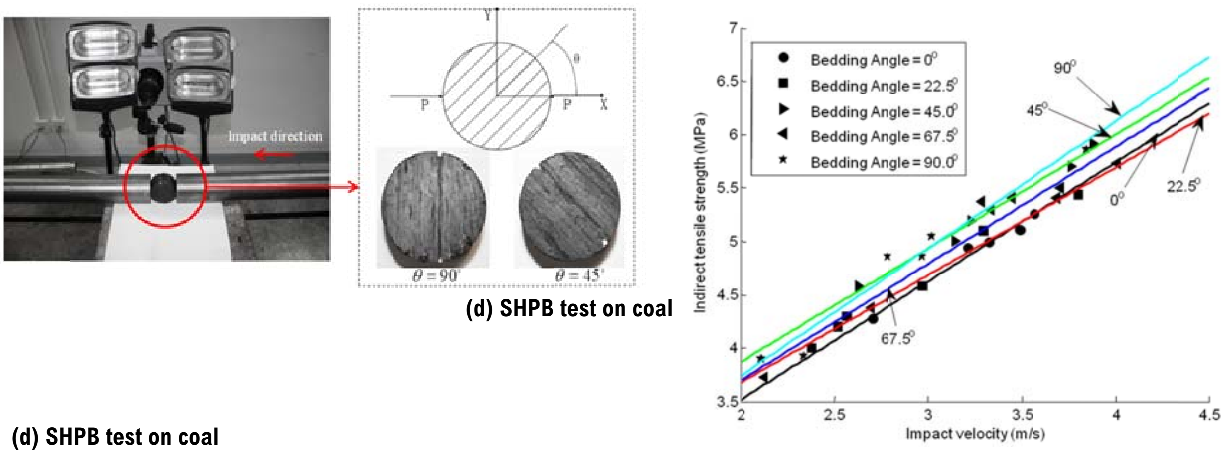
a) 3D reconstruction from surface image



b) 3D printing



(c) Jointed DLSM



(d) SHPB test on coal

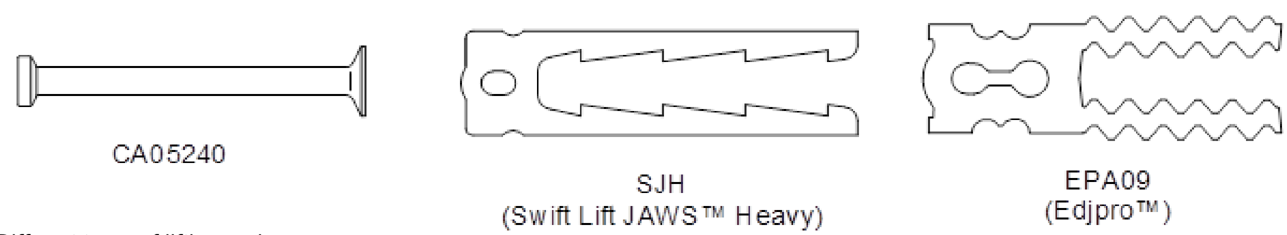
(d) SHPB test on coal

Behaviour of lifting inserts for precast concrete construction

A/Prof G. Ranzi (USyd)
Prof R.I. Gilbert (UNSW)
Mr S. Al-Deen (UNSW)
Mr R. Mackay-Sim (Unicon)

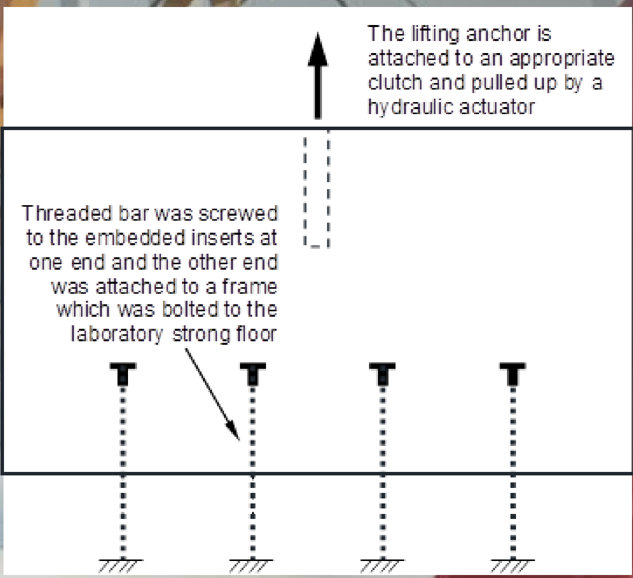
ARC Linkage Project
2011-2013
Collaborator: Unicon Systems

Precast concrete panels are a cost-efficient and effective form of construction, with simple erection procedures and tight production control. Panels are usually prepared on casting moulds, either in a factory or on site. Before pouring, special devices are inserted into the moulds to be used subsequently for all lifting and handling operations of the finished panels. These devices are usually referred to as ‘lifting inserts’, or ‘lifting anchors’. The common types of inserts include round-bodied anchors and, in Australia, ‘hairpin’ plate inserts (see figure). These are placed either on the face of a panel, or on its thin-side edges (edge-lifting). Edge-lifting is preferred by the construction industry because it optimises handling, storing, transportation and erection. This project involves an experimental and numerical study being carried out as a joint initiative between CIES, Sydney University (where the bulk of the experimental work has taken place) and anchor manufacturers Unicon Systems. The work involves investigating the strength and failure mode of the anchors when pulled out of the concrete panels in either direct tension, shear or a combination of tension and shear. In the first stage of the experimental program, twelve concrete precast samples were prepared and tested using three different types of anchors. The experimental program continued throughout 2013.



Different types of lifting anchor

Schematic of the test setup



Layout of the loading arrangement

Performance based Criteria for Concretes: Creating Pathways for Low Carbon Concrete Manufacture with Existing Standards

Prof Steve Foster (UNSW)
Prof Jay Sanchayan (SUT)
A/Prof Arnaud Castel (UNSW)

CRC Low Carbon Living
2013
Ash Development Association of Australia; Australasian (iron & steel) Slag Association

This study, undertaken collaboratively between CIES researchers at UNSW Australia and Swinburne University of Technology, reviewed the state-of-practice in two areas with regards to the manufacture of geopolymer concrete in Australia. The first was on “Pathways for Overcoming Barriers to Implementation of Low CO2 Concrete”; the second on “High Volume Applications of Fly Ash and Barriers to Commercialisation”.

Manufacture of Portland cement is carbon intensive. Its contribution to carbon emissions is second only to fossil fuels and is estimated to be 8 million tonnes of CO2 per year in Australia. Major advances has been made in the development of low carbon cement technologies in recent years, namely geopolymers using fly ash and slag, but the main barrier to their widespread adoption in industry is the current Australian standards, which do not allow concretes without Portland cements and where performance standards for important ant design aspects, such as durability, are undefined.

The widespread utilisation of Geopolymer concrete in the industry is certainly the most promising pathway to increase the rate of fly ash utilisation. Geopolymer concrete is the result of the reaction of materials containing aluminosilicate such as fly ash with alkalis to produce an inorganic polymer binder. As there is no Portland cement in geopolymer concrete mix and geopolymer binder can provide reduction of embodied CO2 of up to 80% compared to Ordinary Portland Cement.

The considerable sustainability benefits of using a geopolymer binder system composed almost entirely of recycled materials has led to considerable research on geopolymer concrete (GC) in recent years in Australia; however, geopolymer concrete has yet to enter the mainstream of concrete construction. The main barriers for widespread adoption of geopolymer concrete in the industry and the pathway to overcome those barriers have been clearly identified in the two reports produced for the CRC for low Carbon Living. In a survey undertaken to identify where the main barriers relate to the lack of awareness, the lack of design standards, design guidelines and specifications and the lack of long-term performance data. This research is continuing for 2014-2016.

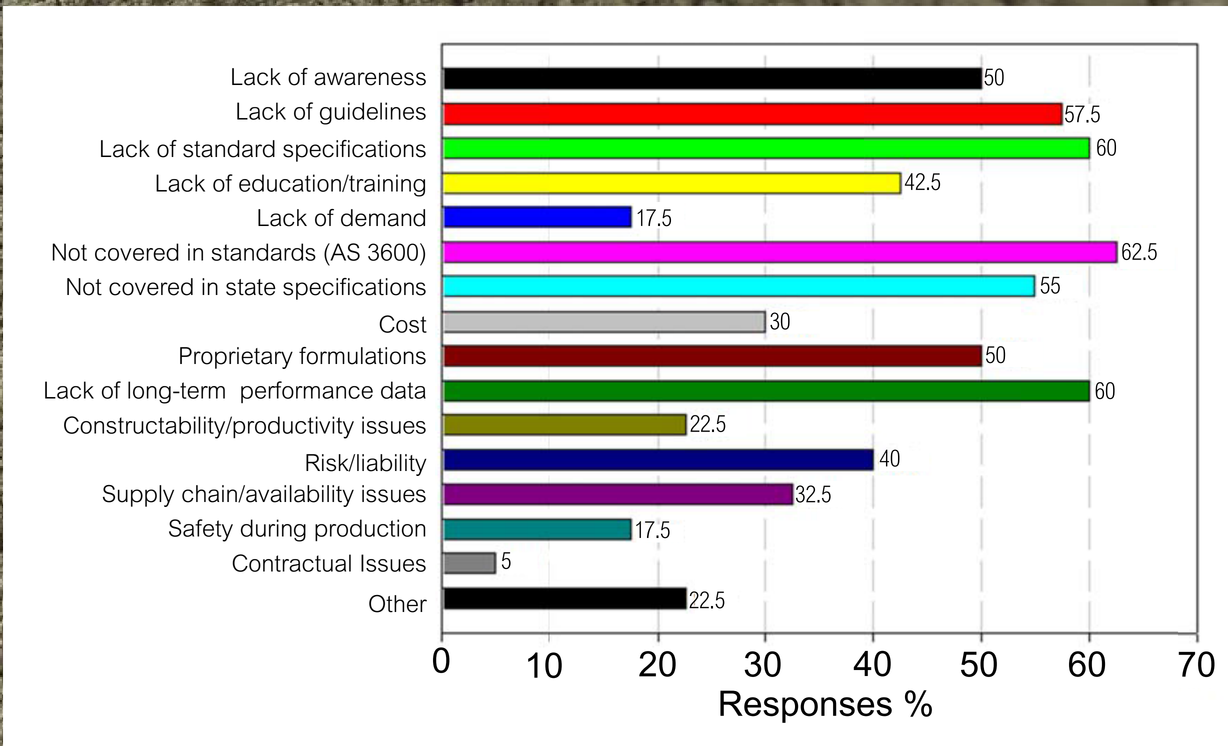


Figure 1. Survey responses to "What do you think are the barriers to widespread implementation of geopolymer concrete?"

Development of efficient, robust and architecturally-flexible structural systems using innovative blind-bolted connections

A/Prof Helen Goldsworthy (Melb)
Prof Emad Gad (Swinburne Uni)
Prof Brian Uy (UNSW)
Dr Saman Fernando (Ajax Fasteners)

ARC Linkage Project
2011-2014
Collaborators Ajax and Orrcon

The aim of the proposed project is to develop structural systems that have sufficient stiffness, strength, and ductility to withstand code-specified loads and that will be competitive in the marketplace. The development of demonstrable cost-effective structural systems is essential if these types of systems are to be widely adopted in practice, thus allowing Australian manufacturers of blind bolts and steel tubes to achieve a greater market share.

Time-dependent in-service behaviour of composite concrete slabs with profiled steel sheeting

Prof R.I. Gilbert,
Prof M.A. Bradford,
Mr A. Gholamhoseini,
Dr Z-T Chang

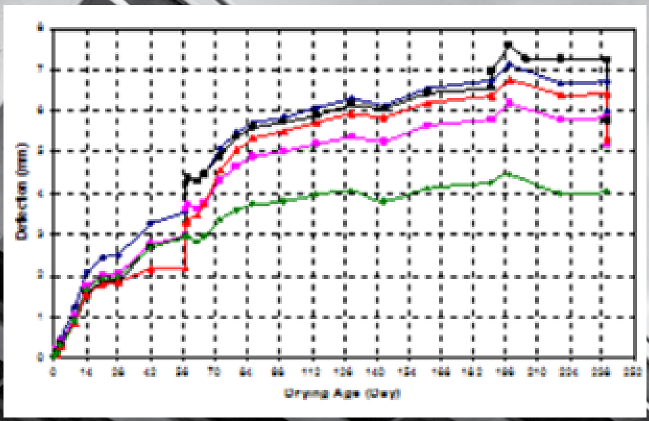
ARC Linkage Project
2009-2013
Collaborators: Fielders Australia PL, Prestressed Concrete Design Consultants (PCDC)

Relatively little research has been undertaken on the time-dependent in-service behaviour of composite concrete slabs with profiled steel decking as permanent formwork and little guidance is available to practising engineers for predicting long-term deflection. The drying shrinkage profile through the thickness of a slab is known to be greatly affected by the impermeable steel deck at the slab soffit, and for the first time, this has now been quantified satisfactorily. This on-going project involves an extensive experimental program to quantify the effects of drying shrinkage on the long-term deformation of composite slabs and to develop design guidance on how best to predict the long-term deflection of slabs.

Stage 1 of the project involved the measurement of the drying shrinkage profile through the thickness of the slab and the restraint provided by different types of steel decking, including the popular deep trapezoidal or wave-form decking. Stage 2 involved the monitoring of long term deformation of slabs with different decking profiles and subjected to different sustained loading histories. All this experimental work was completed by the end of 2012.

Stage 3 of the project involves the numerical modelling of the non-linear and time-dependent behaviour of these slabs and the development of rational design-oriented procedures for the prediction of long-term deformation. This stage was successfully completed in 2013.

Composite slabs under sustained loads



Mid-span deflection versus time curves

Towards operational monitoring of key climate parameters from synthetic aperture radar

A/Prof J. Walker, Prof K. Lowell, Prof A. Milne, A/Prof L. Ge, A/Prof J. Hacker

ARC Super Science Fellow, 2010-2013

Collaborators: Uni Melbourne, Flinders Uni

Economic, social and environmental planning for a carbon-constrained future requires a capacity to monitor climate change impacts on vegetation and soil moisture at a level of detail that does not currently exist. Whilst satellite radar measurements can provide this important information, the signals are confounded by complex interactions with the Earth's surface, necessitating advances to enable routine monitoring of these important variables across our nation. Specifically, i) terrain roughness, ii) vegetation characteristics, and iii) the underlying soil moisture status, all interact together in a complicated way. Consequently, this project is developing algorithms for accurate high resolution mapping of i) natural and agricultural vegetation properties, and ii) soil moisture, under Australian conditions, for subsequent use by operational satellite monitoring and carbon accounting systems. The algorithms arising from this research are being validated using extensive ground measurements and synergistic airborne remote sensing data (from DP0984586 plus LiDAR) seldom available to satellite based studies. However, this has required considerable effort to resolve calibration and processing issues of the airborne radar data from the Polarimetric L-band Imaging Synthetic aperture radar (PLIS). The main scientific achievements to date are:

Biomass retrieval: (i) Analysis of the sensitivity of L-band radar observations to above-ground biomass and testing of current empirical and semi-empirical models for biomass retrieval (journal publication in review); (ii) Improvement of forest biomass estimation using multi-temporal techniques (journal publication in preparation) and (iii) the synergy of radar and LiDAR (journal publication in preparation); (iv) A water cloud type model was modified to additionally accept LiDAR based forest structure information and a two-layered forest backscatter model developed and tested, with results compared with those obtained using the classic radar-only water cloud model (in progress).

Soil moisture retrieval: (i) Assessment of the accuracy of three commonly used bare surface backscatter models to reproduce observed L-band backscatters (journal publication in review);

(ii) Testing of change-detection techniques for soil moisture retrieval over bare agricultural areas (journal publication in preparation); (iii) Comparison of X-band and L-band radar data for their sensitivity to soil moisture and surface roughness in agricultural areas (in progress).

Surface roughness retrieval: roughness parameter retrieval using (i) airborne LiDAR observation (journal publication in preparation); and (ii) radar observations (in progress).

From micro to macro: Modelling multi scale characteristics of geomaterials to improve performance of large infrastructure

Dr Adrian Russell,
Dr Gaofeng Zhao,
Dr Arman Khoshghalb,
Dr Kurt Douglas,
Prof. Nasser Khalili

ARC Discovery Projects and
DECRA Projects
UNSW Faculty of Engineering

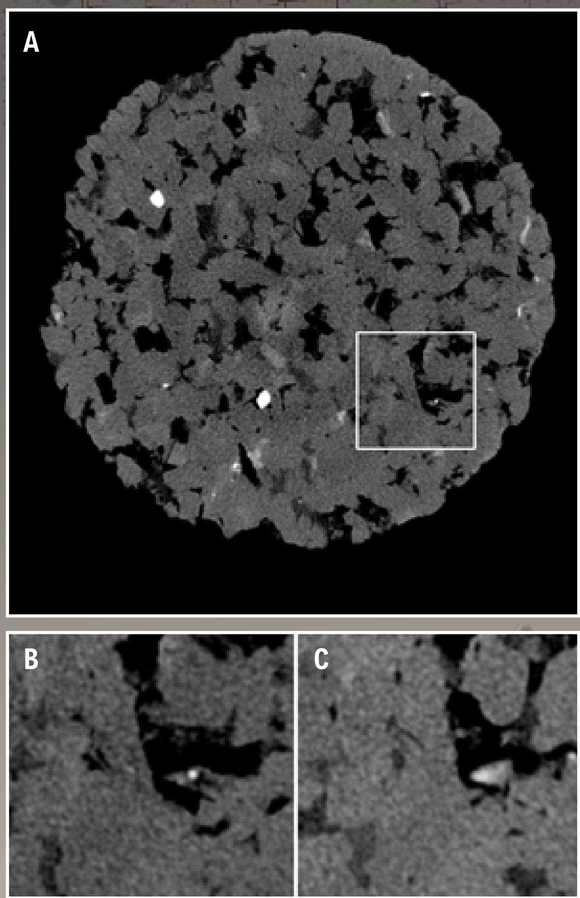
There are a number of main areas of fundamental inquiry.

One area is the identification of links between particle and pore scale properties to the ingredients of continuum type constitutive models. Success so far has been achieved in:

- defining void ratio dependent water retention and hydraulic conductivity functions for soils with all defining parameters having physical meanings. A soil-water characteristic curve for one void ration can be made applicable to any other void ratio using the easy to obtain particle size distribution curve.
- explaining uniqueness of compression lines, with defining parameters linked to pore shape and pore size distribution;
- defining yield surfaces in granular materials in terms of particle packing geometry and particle-to-particle contact strength.

Another area concerns damage evolution in rock during quasi-static and dynamic loading. X-ray CT data at 5 micron resolution has showed damage occurs during prefailure loading by pore collapse then extensive microfracturing. Using this data a virtual replica of the rock microstructure has also built using a distinct lattice spring model to simulate damage evolution in wide range of applications involving impact loading and high frequency cyclic loading.

X-ray CT images taken of sandstone core during unconfined compression loading show pore collapse occurs as load is increased (from B to C)



Durability of steel-CFRP adhesive joints under sustained loading and wet thermal cycle

Mr Ankit Agarwal,
Prof Stephen Foster,
Dr Ehab Hamed

CRC for Advanced Composite Structures
2010-2015

The primary aim of this research project is to contribute to the development of certification-ready technology using Fibre Reinforced Polymer (FRP) 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 wet thermal cycling on the long term strength and durability of steel-CFRP single lap shear adhesive joint.

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 ranges.

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).

Results (see Figure 3)

Conclusions

It is concluded that the influences of sustained load and climate are coupled and must be considered together at the time of planning the testing programs and in design codes and standards.

Figure 1: Thermal cycle apparatus

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

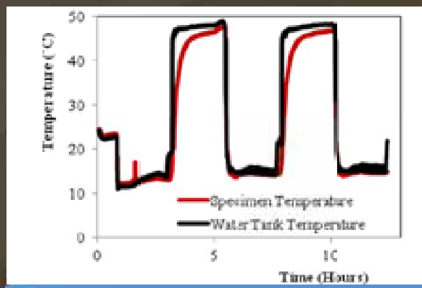


Figure 3: Displacement versus time curves of steel-CFRP joints.

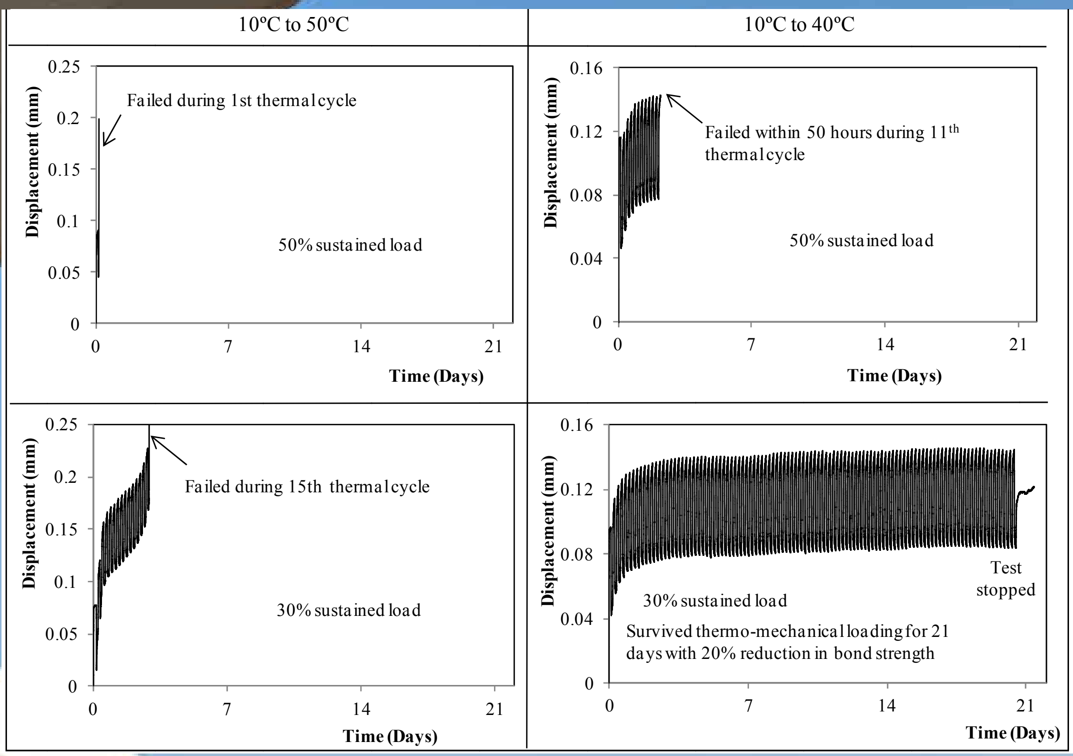
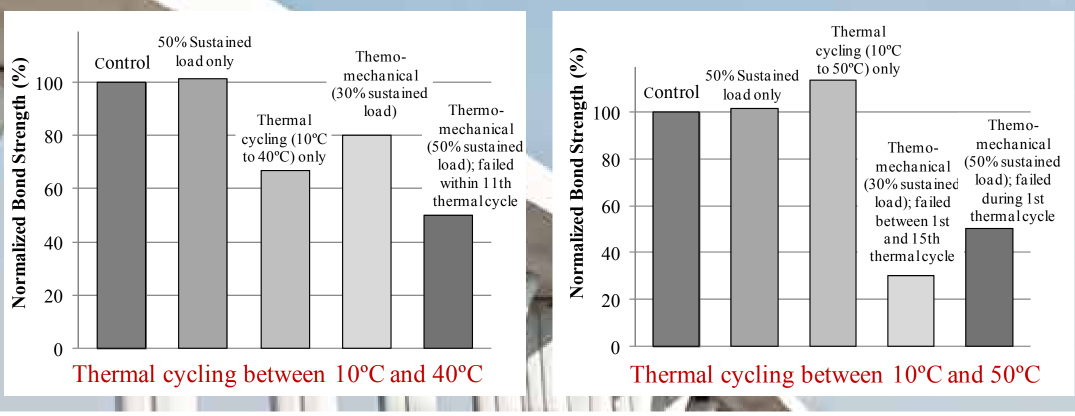


Figure 4: Normalized bond strength of steel-CFRP joints after exposure to different thermo-mechanical conditions.



Dispersion curves for 'leaky' ultrasonic waves in waveguides of arbitrary cross-section

Dr Carolin Birk

Faculty of Engineering Research Grant
2013

Non-destructive testing plays an essential role in assuring that critical infrastructure and the corresponding structural components perform their function in a safe and cost-effective way. One of the most often used non-destructive testing techniques is ultrasonic testing, which uses the transmission of high-frequency sound waves into a material to locate changes in material properties or to detect imperfections. Conventionally, this is done by using transducers to create waves which propagate through the thickness of the structure. Cracks are determined by evaluating the reflected wave signal. These conventional ultrasonic techniques are unsuitable for long and wide structures such as pipes and plates. Thus, alternative ultrasonic testing methods based on guided wave propagation have recently been developed.

The successful design of inspection techniques based on guided waves and the meaningful interpretation of test results, however, require careful model studies to be undertaken in order to fully understand the nature of waves. Guided waves are dispersive, that is the presence and velocity of different modes depends on the exciting frequency and on the geometrical dimensions of the waveguide. Lamb waves in homogeneous plates, for example, propagate with symmetric and anti-symmetric modes, depending on the frequency and plate thickness. In general, dispersion curves are used to describe and predict the relationship between frequency, phase velocity and group velocity, mode and geometric properties such as thickness .

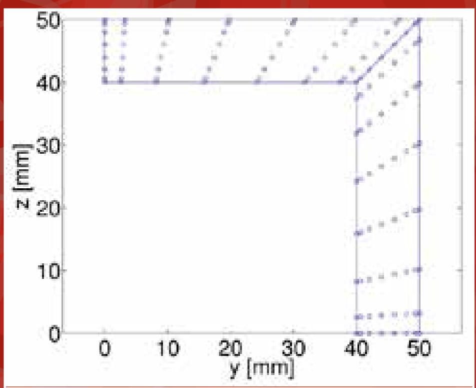
The aim of this research project was to develop and implement an efficient and innovative numerical tool for the computation of dispersion curves of waveguides of arbitrary cross-section. Of particular importance was the ability to accurately and efficiently model the effect of surrounding infinite solid or fluid media, in order to ensure applicability to real-world conditions.

The approach taken in this project is the scaled boundary finite element method, which is based on a spectral element representation of the cross-section of the waveguide and on a harmonic description along the propagation direction, and can therefore model arbitrary shapes. Dispersion properties are obtained solving a standard eigenvalue problem. The scaled boundary finite element model of a two-dimensional waveguide has been successfully combined with simple and highly efficient viscous boundaries to account for the effect of the surrounding medium. Here, the damping coefficients have been derived from the acoustic impedances of the surrounding solid medium. Results have been validated using an improved implementation of an absorbing region. Since no discretization of the surrounding medium is required for the dashpot approach, the required number of degrees of freedom is typically 10 to 50 times smaller compared to the absorbing region. When compared to other finite element based results presented in the literature, the number of degrees of freedom can be reduced by as much as a factor of 4000.

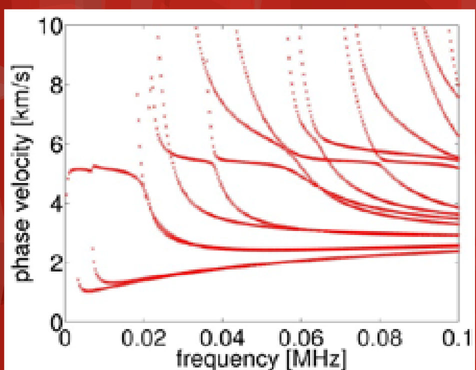
The method has been extended to waveguides embedded in infinite fluids. Here, plate structures and cylinders have been addressed. The boundary condition for the surrounding fluid is based on the analytical description of the radiation impedance. Since the radiation impedance is a function of the wavenumber in the waveguide, an iterative solution procedure, based on inverse iteration, has been proposed. The approach yields a highly stable and efficient algorithm, while the results are in agreement with those obtained using the Global Matrix Method.

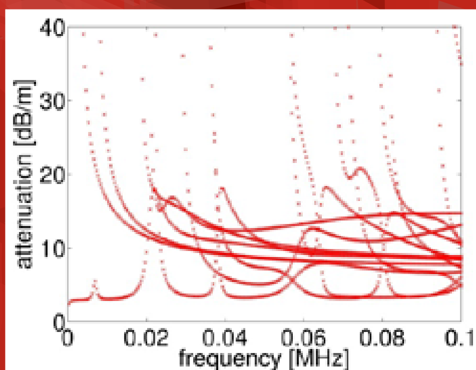
Finally, three-dimensional waveguides of arbitrary cross-section have been analysed. Here, the surrounding unbounded medium is represented by a distributed damping acting perpendicular and tangential to the cross-section as well as parallel to the waveguide direction. Results have been verified against the two-dimensional and axisymmetric formulations presented in previous work as well as results that can be found in the literature.

Scaled boundary finite element mesh of a quarter square pipe, modelled using 2 high-order quadrilateral elements of order 7.



Dispersion spectra for double-symmetric (SS) modes in a steel square pipe embedded in soil





Evaluation of the long term stability of slopes

Dr Arman Khoshghalb

Faculty of Engineering Research Grant
2013

Time has a strong effect on the engineering behaviour of slopes. Even without any externally applied load, slopes deform over time, and this is usually called creep. Creep in slopes can lead to a slope failure. There are lots of case histories of slope failures around the world which have posed risks to both property and the public.

Based on the World Health Organisation (WHO) data, there are more than 60000 deaths and 3750000 homeless associated with slope failures during the twentieth century. According to Schuster [6], the economic losses associated with slope movements reach about US$ 4.5 billion per year in Japan, US$ 2.6 billion per year in Italy, on the order of US$ 2 billion in the United States, and US$ 1.5 billion in India.

Most of the populated areas in Australia are susceptible to some form of creep slope failure. In most cities, there is little good developable land has left and marginal land has become progressively more attractive to developers. Almost all local government areas have land stability challenges of one form or another. Since 1842, there have been at least 95 reported deaths from failed slopes in Australia. Data from Australia shows that slope failure events account for 2% to 3% of fatalities due to natural hazards which is a high figure as compared to the world statistics (0.6%) given that the Australian continent is one of the flattest. Creep slope failures in Australia regularly damage buildings, roads, railways, vehicles, pipelines and communication lines as well. From 1967 to 1999, the total cost of natural slope failures in Australia is estimated at AUD $40 million. The socioeconomic cost of slope failures is even higher and was estimated at AUD $500 million in Australia for the period from 1900 to 1999. One of the major costs resulting from slope failures are the costs associated with road maintenance, relocation and repairs. It is estimated that from 1989 to 1996 the cost of repairs to railway infrastructure only in Wollongong amounted to AUD $175 million.

Exploration into long term behaviour of soils also provides engineers and the scientific community with tools and methodologies that are required for estimation of the time to slope failure (TSF) in slopes. The prediction of TSF is of crucial importance in geotechnical and mining engineering. In spite of the importance of long term behaviour of soils and the numerous investigations that have been undertaken over the past years, the study of soil creep is still in its infancy. A comprehensive constitutive model to predict the long term behaviour of soils in complex loading conditions is still lacking. In geotechnical engineering, it is still a challenge to predict the long term behaviour of slopes. Therefore, efforts are required to develop an advanced model capable of modelling the long term behaviour of slopes.

This project aims to develop a unified, elasto-viscoplastic constitutive model for prediction the time dependent behaviour of slopes. The project commenced in 2013. A comprehensive literature review was performed. Different visco-plastic models using a rate dependent yield function were investigated. The applicability of different models to investigate the long term stability of slopes in different conditions was examined through case studies from the literature. Furthermore, a comprehensive review on the conventional laboratory creep tests was performed and the main difficulties associated with these tests were identified. The possible sources of inaccuracies in the test results were examined and practical recommendations were found in the literature to minimise the inaccuracies in the results. This comprehensive literature review in the area of time dependent behaviour of slopes and creep laboratory testing, thoroughly performed in this research, have opened up new areas of research. Dr Khoshghalb has now two students working on the continuation of this research. More importantly, a significant gap in the literature has been identified through this research. Work on the findings of this project is underway to prepare an ARC discovery application for submission in 2015.

Applied unsaturated soil mechanics research

A/Prof Adrian Russell,
Dr Arman Khoshghalb,
Dr Hossein Taiebat,
Dr Gaofeng Zhao and
Prof Nasser Khalili

ARC Discovery Projects
UNSW Faculty of Engineering

For the past 15–20 years CIES geotechnical engineers have been developing the mechanics of soil behaviour under different moisture conditions, but they are now modelling and developing practical applications that will feed into design codes.

They have designed and manufactured a suite of large testing facilities to research the cone penetration test in unsaturated soils, lateral earth pressures exerted by unsaturated soils on retaining walls, and the bearing capacity of shallow foundations in unsaturated soils.

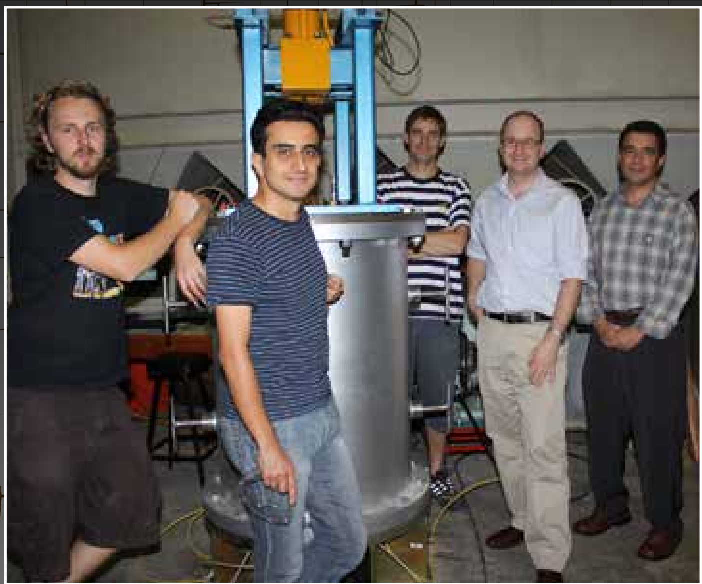
The work will be useful in everything from in situ determination of unsaturated soil properties, house construction, to much larger projects including embankment dams, airport runways and slope stability.

Their work has resulted in dozens of journal papers and numerous national and international awards and honours. They will host the 6th International Conference on Unsaturated Soils in Sydney, taking place from 2-4 July 2014, where they will show case their work.

Recent outcomes include:

- practical guidelines for the interpretation of cone penetration test results in unsaturated soils
- physical model test results showing the influence of suction on earth pressures adjacent to retaining walls
- extension of slip line theory to include suction affects with application to retaining wall and shallow foundation analyses

The team who developed the award winning calibration chamber to research the cone penetration test (from left to right): Mr Richard Berndt, Mr Mohammad Pournaghiazar, Mr Paul Gwynne, Dr Adrian Russell and Professor Nasser Khalili.



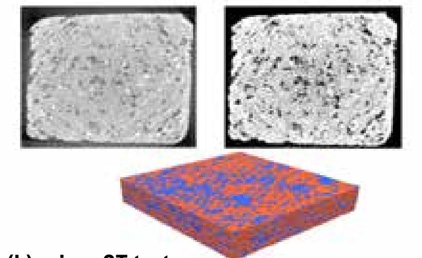
Dr Adrian Russell (right) and Mr Liem Vo (former PhD student, now Research Associate) observe the laboratory controlled failure of an unsaturated soil adjacent to a retaining wall.

Continuum-discontinuum coupled modelling of rock cutting and penetration

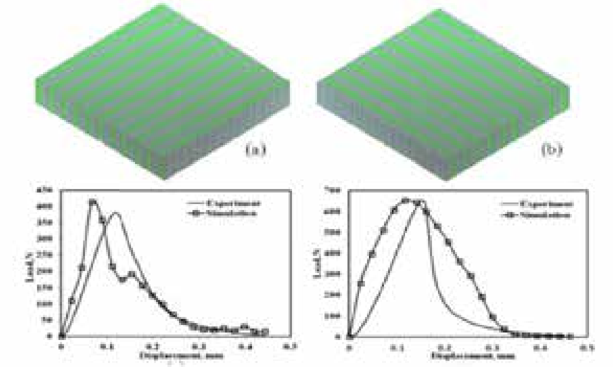
Dr Gaofeng Zhao

Faculty of Engineering Research Grant
2012– 2013

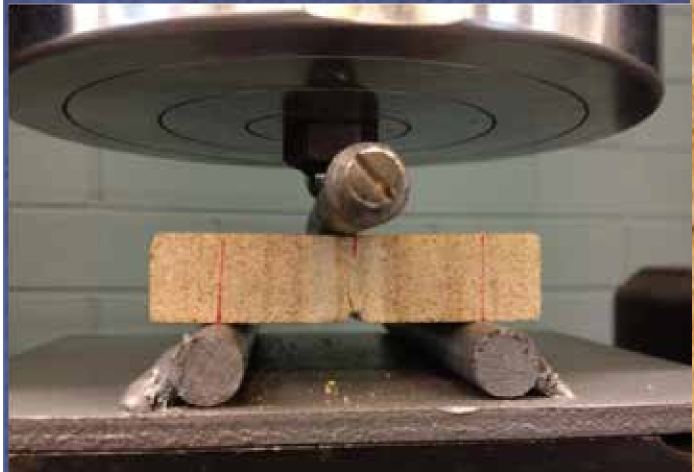
Numerical and experimental studies on rock cutting have been conducted. The coupled DDA &DLSM model was successfully developed. Experimental study on the Gosford sandstone was conducted by two postgraduate students (Mr. Yilin Gui and Mr. Peijie Yin). The influence of bedding structure on its fracture toughness and strength were studied. Numerical simulation on the dynamic behavior of anisotropic rock was conducted. Influence of cutting depth and cutting speed on the rock fragmentation of a TBM disc cutter were studied by using the developed model. The typical branch fractured zone is also reproduced from the DDA&DLSM simulation. The simulation results indicate that there exists an optimal cutting speed for the rock cutting. The related work is published in the International journal of solids and structures (A*). Another achievement from this project is the success of the ARC DECRA13 grant on dynamic fracturing in shale rock through coupled continuum-discontinuum modelling, which will continue the project.



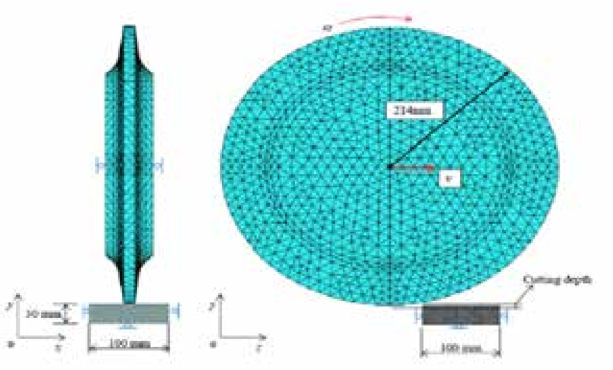
(b) micro CT test



(c) DLSM simulation on beam bending test



(a) 3PB test on sandstone



(d) DLSM modeling on rock cutting

Figure 1. Rock fracture and cutting by Distinct Lattice Spring model (DLSM).

Behaviour of Steel Fibre Reinforced Concrete Beams in Shear

Ali Amin,

Prof Stephen Foster

School of Civil and Environmental Enginering
BOSFA

Many studies have considered the possibility of utilizing steel fibre reinforced concrete (SFRC) by assigning a proportion of the shear resisting capacity of members to the fibres. This concept has been realized in the fib Model Code 2010 (2013) and more recently in the Draft Australian Bridge Code AS5100.5: Concrete (2014). Despite increased awareness of this material in industry and research, SFRC is yet to find common application in load bearing building structures, even though significant potential exists for full or partial replacement of costly, manually placed, shear reinforcement.

CIES investigators are currently undertaking a critical examination to investigate the combined effect of steel fibres and traditional transverse reinforcement on the response of ten large scale beams subjected to four-point loading. The specimen dimensions and testing arrangements are illustrated in Figure 1. The beams had an overall depth of 700 mm, were 300 mm wide and spanned 4500 mm, all reinforced with varying fibre and transverse reinforcement ratios. The fibres used in this study were the double end-hooked Dramix 5D-65/60-BG fibre and provided by BOSFA, Australia. The beams were tested in centre's Instron 5000 kN testing frame. Some preliminary results are presented in Table 1 and are shown to compare well to the predictions made by the alternative fib Model Code model (presented on the left hand side) and Draft Australian Bridge Code model.

Furthermore, CIES investigators have analysed their beams using the FE software ATENA and combined with predicative law previously developed within the centre, which can accurately predict the cracking behaviour as well as the overall response of the beams. Figure 2 presents the results from the non-linear FEA for beam B25-450-10-450.

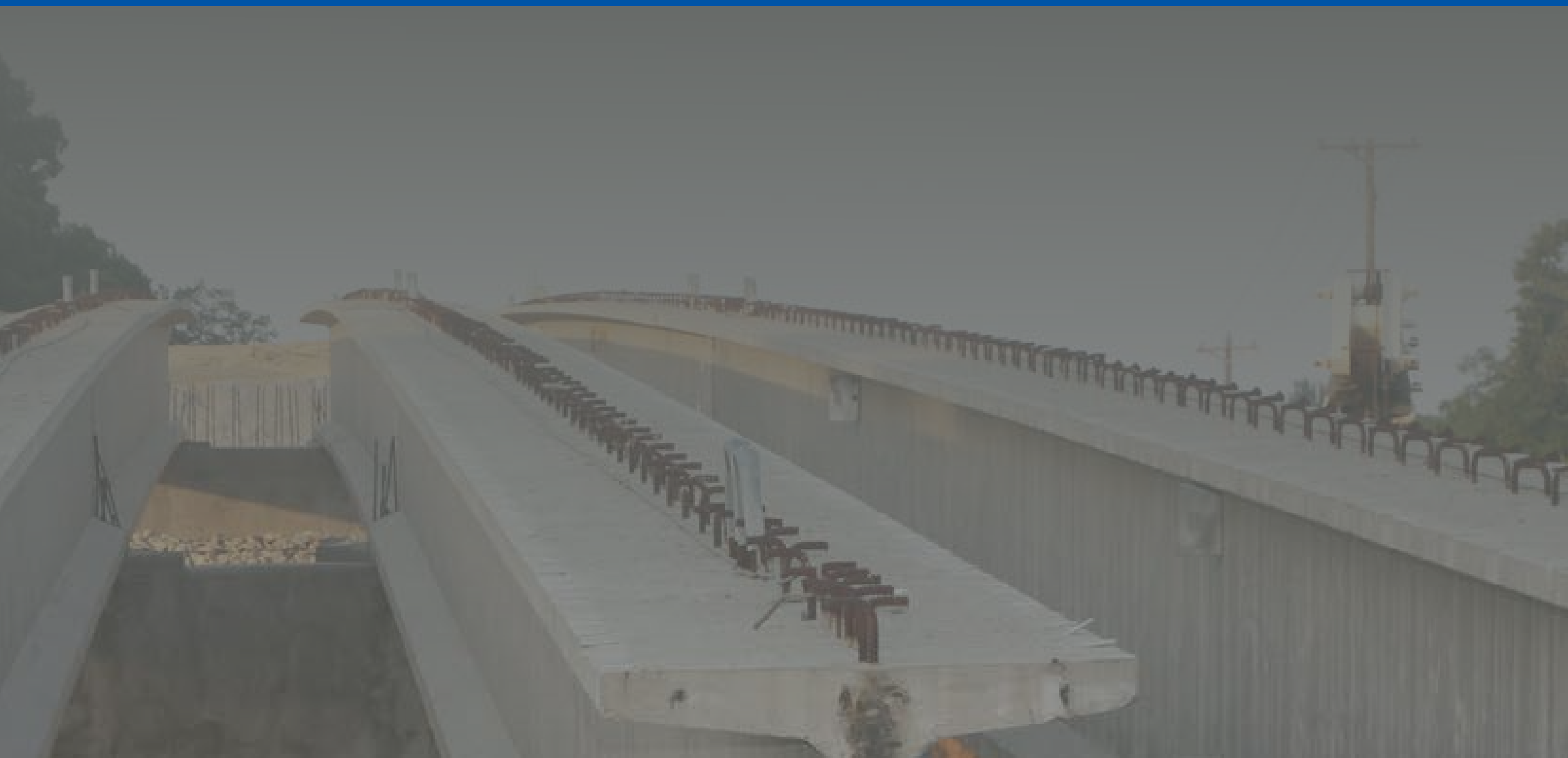


Figure 1: Experimental arrangement and specimen dimensions (in mm): (a) Test setup; (b) Cross Section

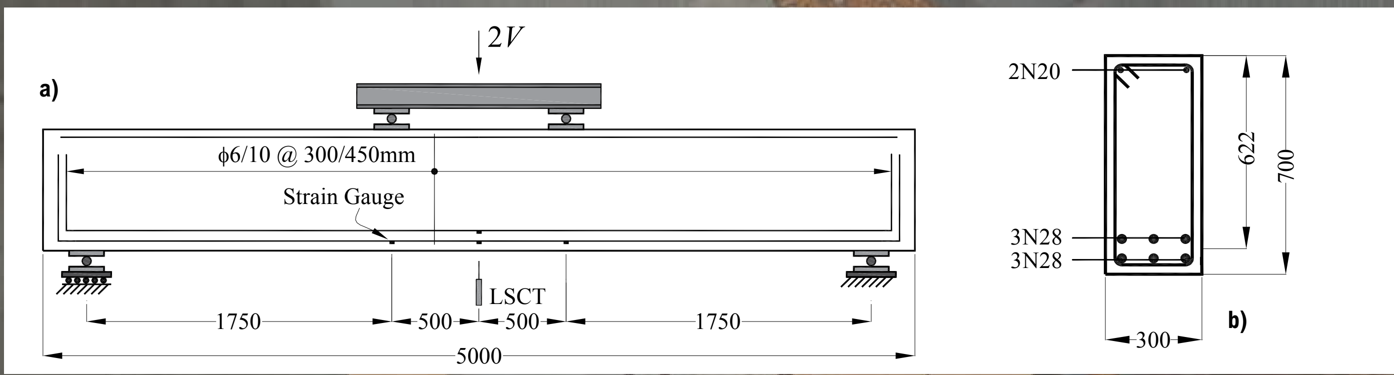


Table 1: Predictions of shear resistance compared to experimental data

Beam ID	Fibre Dosage (kg/m^3)	Stirrup Spacing (mm)	V_{test} (MPa)	$\frac{V_{fib\ MC\ 2}}{V_{test}}$	$\frac{V_{DR\ AS5100}}{V_{test}}$
B0-450-10-450	0	450	236	1.00	1.00
B25-0-0-0	25	-	274	1.06	1.02
B25-450-10-450	25	450	334	1.07	1.05
B50-550-6-450	50	450	462	1.08	0.90
B50-450-10-450	50	450	535	1.08	0.93

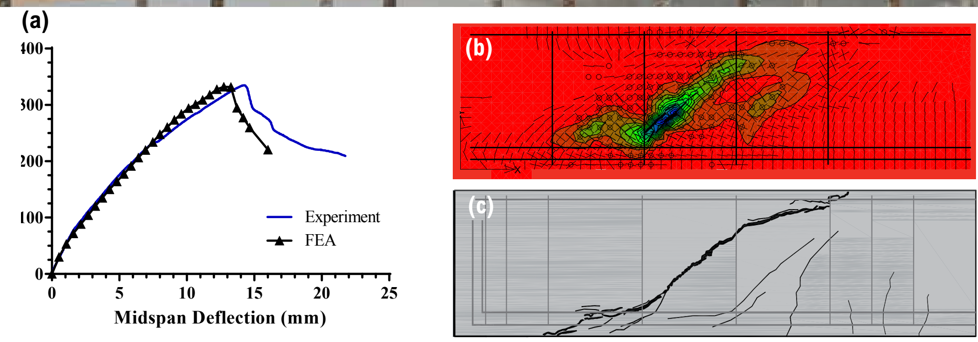


Figure 2: Response and crack patterns for beam B25-450-10-450: (a) shear verses mid-span deflection;
(b) Maximum principal strain at a deflection of 15 mm; (c) crack pattern recorded from the experiment.

Technology development: Fibre reinforcement of soils

A/Prof Adrian Russell and
Dr Hossein Taiebat

Soil's inability to carry tension puts significant constraints on its use as a construction material. Vertical cuts may collapse, for example, so batter slopes or anchoring systems are needed to make working areas safe. CIES researchers are working with industry in developing a new technology to give soil tensile strength. It will deliver steeper cuts and slopes, stronger foundations and retention systems, and resistance to earthquake induced liquefaction.

The technology involves mixing discrete flexible fibres into soil. This is not a new idea. Ancient Egyptian tomb paintings illustrate the process of making bricks with clay and straw. But what is new is the mechanistic modelling framework developed by CIES researchers that describes the massive strength gains for any soil and fibre types and any fibre orientation distribution. The research so far has received two international awards and resulted in six journal papers.

A pilot study is underway with Wagstaff Piling. A field trial was conducted in which polypropylene fibres were mixed with soil and cement to form an anchored retaining wall. The fibres provide tensile strength, reduce potential for cracking, and save on expensive steel which would otherwise be used as reinforcement.

Wagstaff Piling in-kind
2012 and 2013

Fibres (in dissolvable paper bags) add to the cement-soil mixing process.

Sample from exhumed fibre-soil-cement trial wall showing effective mixing and dispersion of fibres.

Dynamic analysis of unsaturated porous media subject to damage due to cracking

Prof Nasser Khalili,
Dr Babak Shahbodagh Khan

Faculty of Engineering Research Grant
2012– 2013

The development of constitutive and computational models for the behaviour of unsaturated materials has significantly lagged behind similar developments for saturated soils. This has largely been due to the inherent complexities associated with the behavior of multiphase porous materials, e.g. simultaneous flow of fluids such as water and air through the medium, complex interaction of fluid flow and deformation fields, and existence of various sources of nonlinearity in the governing equations.

This research relates to rigorous analysis of nonlinear dynamic response of unsaturated soils. It will lead to cost savings in many geotechnical engineering practices as it will provide a better understanding of the behaviour of unsaturated soils under dynamic loading and a greater confidence in the prediction of the performance of earth-structures. As a part of this research project, a numerical model based on the mixture theory was developed for the nonlinear dynamic analysis of flow and deformation behaviour of unsaturated porous media. Starting from the conservation laws, finite element incremental formulations for large deformation static and dynamic analyses were derived in the updated Lagrangian framework, whereas the time integration was conducted using the Newmark technique. The coupling between solid and fluid phases was established using the effective stress principle. The effect of hydraulic hysteresis on the effective stress parameters and soil water characteristic curve was also taken into account. The computational model was successfully applied to several nonlinear fundamental problems in geotechnical engineering and the applicability and accuracy of the model were demonstrated. The model is currently being further developed to a more complex rate dependent continuum damage-elasto-plastic model for variably saturated porous media including damage due to straining and the stiffening effects of suction.

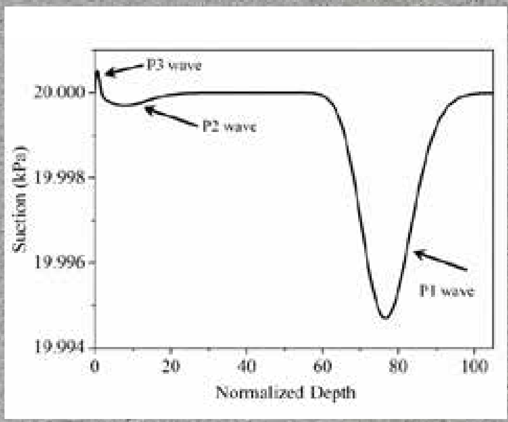


Fig 1. Existence of three types of compressional waves in unsaturated soil column subjected to transient load.

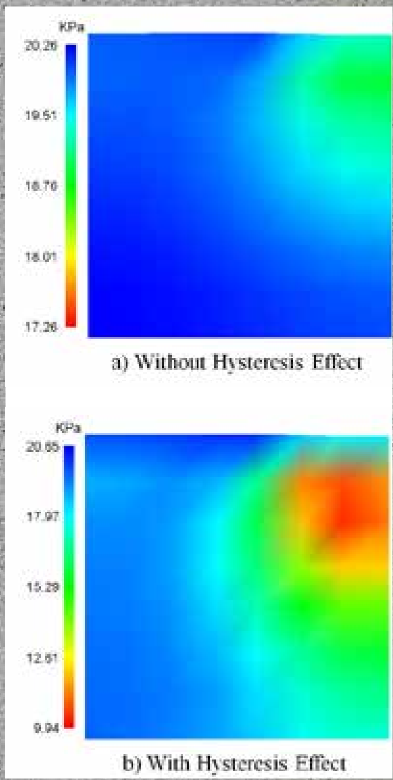


Fig 2. Effect of hydraulic hysteresis on response of unsaturated soil under partial dynamic load: Suction distribution with sInitial=20KPa.

A new approach to structural design that incorporates the effect of non-structural components

Prof G. Hutchinson,
Dr P. Collier, A/Prof L. Ge,
Dr X. Li and A/Prof C. Duffield

ARC Linkage Project
2010-2013
Collaborators: Uni Melb, C.R. Kennedy and Company Pty Ltd, Leica Geosystems, Survey21 Land and Engineering Surveyors

The aim of this project is to use full-scale measurements from a variety of modern sensors to determine the impact of non-structural components on the lateral strength and stiffness of high-rise buildings. This data will be used to inform the structural design process and "calibrate" the structural model to achieve economies in the construction process. We aim to tackle this problem through a multi-disciplinary approach that builds on strengths in academia and industry and brings together two leading universities and three industry partners who are leaders in their fields. To this end, we propose:

- To develop an integrated structural monitoring system built on a diverse range of measurement technologies,
- To develop a procedure for calibrating the conventional structural model of a high rise building to account for the effect of non-structural components on structural performance, and
- To contribute to a new approach to structural design that will lead to considerable economies in the construction process.

Progress

After the ARC Linkage project was approved, equipment has been provided and delivered to the researchers. After a number of unsuccessful attempts data is now being obtained from high rise buildings in Russia. One PhD student has been allocated and has been working since 18 October 2010; the proposed second PhD student did not eventuate and this role has been converted to a Research Fellow position. This Research Fellow is making good progress in both theory and analysis of field data.

The first student's research is focused on the development of an integrated structural monitoring system for high-rise buildings. The student has just finished an industry placement with our newly added Partner Organization in Russia where he has been involved in instrumenting buildings. The high-rise building data obtained is being analysed and integrated into finite element models.

A number of outcomes have already been achieved as evidenced by the refereed journal papers, which have been delivered along with refereed conference papers. Two additional journal articles and two conference papers were ready for submission in 2012.

Orthotropic elasticity: a fundamentally new approach.

Dr David Kellerman
A/Prof Mario Attard

School of Civil and Environmental Engineering

Figure 1. The structure of classical continuum mechanics

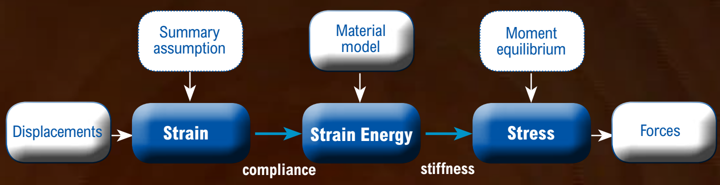
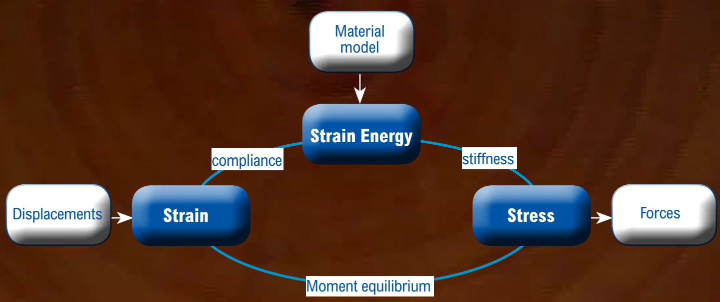


Figure 2. The proposed implicit system of continuum mechanics



Researchers within the CIES have been developing a new elasticity theory based on the total elimination of Cauchy's 190 year old fundamental assumption of tensor symmetry. Research Fellow Dr David Kellermann and Associate Professor Mario Attard have been looking at anisotropic materials, which include any material with directional properties such as fibre-reinforced concrete, high performance carbon fibre and nano-composites, and also most human tissue. Engineering simulation of these materials has come up against limitations in the otherwise scrupulously developed theory of classical elasticity. Indeed, Occam's Razor dictates that the only approach to resolve these limitations was to make classical theory simpler, which is executed by means of elimination of Cauchy's symmetry assumption. The fundamental structure of the proposed system is compared with the classical system in Figures 1 and 2.

Mathematically, this implicit structure is achieved through implementation of a new class of physical tensors called Intrinsic-Field Tensors that allow for variation of – for example – the asymmetry of strain, varying over the range of possible intrinsic properties such as material stiffness. Determinacy of the otherwise infinite possibility of solutions is attained through a reconnection of the moment equilibrium back into the displacement field through an interdependency with the strain energy function (Figure 2).

This ultimately promises improved modelling for various contemporary engineering challenges such as fibre-reinforced structural elements, composite aircraft design and biomedical simulation for pre-surgery procedural analysis. At the same time, the theory remains applicable (and indeed reduces) to classical mechanics.

Appendices

1.Research Publications

BOOKS

Bradford, M. A., Bridge, R. Q., & Trahair, N. S. (2013). *Worked Examples for Steel Structures* (4th ed.). Sydney: Australian Steel Institute.

Warner, R., Faulkes, K., & Foster, S. J. (2013). *Prestressed Concrete* (3rd ed. ed.). Australia: Pearson.

BOOK CHAPTER

Birk, C. C., Chen, D., Song, C., & Du, C. (2013). The Scaled Boundary Finite Element Method for Transient Wave Propagation Problems. In S. Klinkel, C. Butenweg & B. Holtschoppen (Eds.), *Seismic Design of Industrial Facilities* (pp. 547-556): Vieweg + Teubner Verlag.

CONFERENCE PAPERS

Abas, F., Gilbert, R. I., Foster, S. J., & Bradford, M. A. (2013). *The behaviour of fibre reinforced continuous concrete slabs under load - an experimental study.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, UTS Sydney.Croydon, UK: CPI Group (UK) Ltd.

Agarwal, A., Foster, S. J., Hamed, E., & Vrcelj, Z. (2013). *Testing of steel-CFRP adhesive joints under freeze-thaw cycling.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, UTS Sydney.Croydon, UK: CPI Group (UK) Ltd.

Agarwal, A., Hamed, E., & Foster, S. J. (2013/12/11/). *Effect of adhesive thickness on the interfacial stresses in steel-frp lap-joints under freeze-thaw cycling.* Paper presented at the APFIS 2013 (Asia-Pacific Conference on FRP in Structures), Melbourne, Australia.

Agarwal, A., Ng, T. S., Foster, S. J., & Hamed, E. (2013/07/28/). *Durability of steel-cfrp adhesive joints under sustained loading and wet thermal-cycles.* Paper presented at the THE 19TH INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS, Montreal, Canada.

Amin, A., Foster, S. J., Boillet, D., & Muttoni, A. (2013). *An experimental investigation into the tensile strength of steel fibre reinforced concrete.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials. UTS Sydney, London, UK.

Amin, A., Foster, S. J., & Muttoni, A. (2013). *Evaluation of the tensile strength of sfrc as derived from inverse analysis of notched bending tests.* Paper presented at the 8th International Conference on Fracture Mechanics of Concrete and Concrete Structures, FraMCoS 2013, Toledo; Spain.

Aoki, Y., Samali, B., Saleh, A., & Valipour, H. (2013). *Assessment of key response quantities for design of a cable-stayed bridge subjected to sudden loss of cable(s).* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, ACMSM 2012.

Arnaud, C. (2013). *F.e. modelling of galvanic corrosion currents in carbonated concrete.* Paper presented at the Corrosion and Prevention 2012, Melbourne.

Arnaud, C. (2013). *Modelling of reinforced concrete beam response to repeated loading including steel-concrete interface damage.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, Sydney. Croydon, UK: CPI Group (UK) Ltd.

Bai, Y., Zhao, G. F., & Khalili, N. (2013). *Further development of RockBox on modeling multi-physical problems in geomechanics.* Paper presented at the 1st International Conference on Rock Dynamics and Applications, RocDyn-1 2013, Lausanne; Switzerland. Leiden, Netherlands.

Ban, H., & Bradford, M. A. (2013) *Flexural strength of high strength steel - concrete composite beams with varying steel grades.* Paper presented at the Composite Construction VII, Palm Cove, Queensland, Australia.

Ban, H., & Bradford, M. A. (2013) *Ductility of composite beams constructed with high-strength steel sections.* Paper presented at the The 7th International Symposium on Steel Structures (ISSS-2013), Jeju, Korea. Seoul, Korea.

Bradford, M. A. (2013). *Computational modelling of thermally-induced concrete pavement upheaval buckling.* Paper presented at the fourteenth international conference on civil, structural and environmental engineering computing, Stirlingshire, UK.

Castel, A., & Bermold, L. B. (2013). *Self-healing mortar with thermoplastic polymer.* Paper presented at the International Conference on Self Healing Materials, Ghent, Belgium.

Castel, A., Gilbert, R. I., & Ranzi, G. (2013). *Overall stiffness reduction of cracked reinforced concrete beams due to long term effects.* Paper presented at the 9th Int. Conf. on Creep, Shrinkage, and Durability Mechanics, CONCREEP 2013, Massachusetts, USA.

Chaimoon, K., Attard, M., & Chindaprasirt, P. (2013). *A model for prediction of anisotropic behavior of soft tissues under loading.* Paper presented at the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13).

Chen, X., Birk, C., & Song, C. (2013). *Efficient modeling of wave propagation in unbounded domains using the scaled boundary finite element method.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, SYDNEY.Croydon, UK: CPI Group (UK) Ltd.

Chengwei, Y., Tin-Loi, F., Tangaramvong, S., & Wei, G. (2013/10/03/). *A complementarity approach for elastoplastic analysis of frames with uncertainties.* Paper presented at the 1st Australasian conference on Computational mechanics (ACCM2013), Sydney.

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Foster, S. J., Ng, T. S., & Htut, T. N. (2013). *High performance fibre reinforced concrete: Fundamental behaviour and modelling.* Paper presented at the 8th International Conference on Fracture Mechanics of Concrete and Concrete Structures, FraMCoS 2013, Toledo; Spain.

Gao, W., Ma, J., Song, C. M., & Tin-Loi, F. (2013). *Dynamic reliability based structural optimization.* Paper presented at the 5th Asia Pacific Congress on Computational Mechanics & 4th International Symposium on Computational Mechanics, Singapore.

Ge, L., Li, X., Wu, F., & Turner, I. L. (2013). *Coastal erosion mapping through intergration of SAR and Landsat TM imagery.* Paper presented at the International Geoscience and Remote Sensing Symposium

Gholamhoseini, A., Gilbert, R. I., & Bradford, M. A. (2013/10/16/). *Time-dependent deflection of continuous composite concrete slabs.* Paper presented at the 26th Biennial Conference of the Concrete Institute of Australia, Gold Coast.

Gholamhoseini, A., Gilbert, R. I., & Bradford, M. A. (2013). *Ultimate strength of continuous composite concrete slabs.* Paper presented at the Composite Construction VII, Palm Cove, Queensland.

Gholamhoseini, A., Gilbert, R. I., & Bradford, M. A. (2013). *The effect of creep and shrinkage on the bond-slip characteristics and strength of composite concrete slabs.* Paper presented at the 26th Biennial Conference of the Concrete Institute of Australia, Gold Coast.

Gholamhoseini, A., Gilbert, R. I., Bradford, M. A., & Chang, Z. (2013). *Evaluation of time-dependent behaviour of composite concrete slabs with steel decking (an experimental study).* Paper presented at the 8th International Conference on Fracture Mechanics of Concrete and Concrete Structures, FraMCoS 2013, Toledo; Spain.

Gholamhoseini, A., Gilbert, R. I., Bradford, M. A., & Chang, Z. (2013). *Long-term deformation of composite concrete slabs under sustained loading.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, UTS Sydney.Croydon, UK: CPI Group (UK) Ltd.

Gholamhoseini, A., Gilbert, R. I., Bradford, M. A., & Chang, Z. (2013). *Evaluation of longitudinal shear bond stress and bond-slip relationships in composite slabs using partial shear connection method.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, UTS Sydney.Croydon, UK: CPI Group (UK) Ltd.

Gilbert, R. I. (2013). *Bond failure in grouted post-tensioned slab tendons with little or no initial prestress.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, Sydney.

Gilbert, R. I., & Kilpatrick, A. E. (2013). *A preliminary investigation of the strength and ductility of lapped splices of reinforcing bars in tension.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, Sydney.

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Gui, Y., Zhao, G. F., & Khalili-Naghadeh, N. (2013). *Experimental and numerical modelling of sandstone bending using modified three-point test.* Paper presented at the 1st International Conference on Rock Dynamics and Applications, RocDyn-1 2013, Lausanne; Switzerland. Leiden, Netherlands.

Hamed, E., & Huang, Y. (2013). *Effect of Supporting Conditions on the Long-Term Load Capacity of High Strength Concrete Panels.* Paper presented at the 22nd Australian Conference on the Mechanics of Structurs and Materials, Sydney.Croydon, UK: CPI Group (UK) Ltd.

Hamed, E., & Ramezani, M. (2013). *Effect of boundary conditions on the creep response of sandwich beams with a viscoelastic soft core.* Paper presented at the 22nd Australian Conference on the Mechanics of Structurs and Materials, Sydney.Croydon, UK: CPI Group (UK) Ltd.

Hassan, M. K., Tao, Z., & Uy, B. (2013). *Effect of binding bars on the integrity of end plate connections to concrete filled steel tubular columns.* Paper presented at the 10th Pacific Structural Steel Conference (PSSC 2013) – Advancements and Achievements in Structural Steel.

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Li, X., Hu, Z., & Ge, L. (2013). *SAR-based waterbody detection using morphological feature extraction and integration.* Paper presented at the International Geoscience and Remote Sensing Symposium

Linlin, Ge, Ng, A. H. M., Xiaojing, Li, Abidin, H. Z., & Gumilar, I. (2013). *Land subsidence characteristtics of Bandung Basin as revealed by ENVISAT ASAR and ALOS PALSAR interferometry.* Paper presented at the Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, Melbourne, Australia.

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Luo, K., Pi, Y. L., Bradford, M. A., & Gao, W. (2013). *Long-term in-plane analysis of concrete-filled steel tubular arches under a central concentrated load.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, UTS Sydney.Croydon, UK: CPI Group (UK) Ltd.

Luo, K., Pi, Y. L., Gao, W., & Bradford, M. A. (2013). *Finite element model for analysis of time-dependent behaviour of concrete-filled steel tubular arches.* Paper presented at the 1st Australasian conference on Computational mechanics (ACCM2013), Sydney.

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Ma, H., Li, Q., You, X., Li, X., Lu, N., & Ge, L. (2013). *Automatic road damage detection using high-resolution satellite images and road maps.* Paper presented at the International Geoscience and Remote Sensing Symposium

Ma, J., Khalili, N., & Zhao, G. (2013). *A constitutive permeability evolution model for fractured porous media.* Paper presented at the 22nd Australasian Conference on the Mechanics of Structures and Materials, ACMSM 2012, Sydney.

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2. International Visitors

Name	Institution
Dr. Xiaochun Fan	Wuhan University of Technology, China
A/Professor Qing Jun Chen	South China University of Technology, Guangzhou , China
A/Professor Wei Gu	Liaoning Provincial College of Communications, China
Dr Wolf Elber	Former Director of the Army Vehicle Technology Directorate, NASA Langley Research Center
Professor Dunja Peric	Kansas State University, USA
ProfessorUwe E. Dorka, Nasser M. Khanlou, Axel Mühlhausen and Ferran Obón	University of Kassel, Germany
Professor Yeong-Bin Yang	National Taiwan University, Taiwan
Professor Chiew Sing-Ping Professor Soh Chee-Kiong, Professor Chiew Yee-Meng,	Nanyang Technological University (NTU), Singapore
Hauke Gravenkamp	Federal Institute of Materials Research and Testing, Berlin
Professor Zdeněk P. Bažant	Northwestern University, USA
A/Professor Hongbo Ma	Xidian University, Xi'an, China
Dr Scott Hensley	NASA Jet Propulsion Laboratory California, USA
A/Professor Mohammad Mehdi Ahmadi	University of Sharif, Tehran, Iran
Professor Andrew H.C. Chan	University of Ballarat
Professor David Muir Wood	University of Dundee, Scotland, UK
Dr Suresh Palanisamy	Swinburne University of Technology

CIES International Visitors' Seminars

Name	Institution	Seminar Topic	When
Professor Andrew H.C. Chan	Professor of Civil Engineering Deputy Dean, Information Technology & Engineering University of Ballarat	Numerical modelling of dynamic saturated soil and pore fluid interaction using finite element method and combined discrete element and Lattice Boltzmann method	June 2013
Dr Scott Hensley	Deputy Manager, Radar Engineering Section NASA Jet Propulsion Laboratory	Remote Sensing Research at NASA Jet Propulsion Laboratory	October 2013
Professor David Muir Wood	University of Dundee, Scotland	Rooting for sustainable performance	October 2013
Dr Suresh Palanisamy	Air platforms Program Leader, Defence Materials Technology Centre, Swinburne University of Technology	Key Research Technologies in the DMTC.	October 2013
Professor Zdeněk P. Bažant	McCormick Institute Professor and W.P. Murphy Professor of Civil and Mechanical Engineering and Materials Science, Northwestern University	Probabilistic Nano-Mechanical Theory of Quasibrittle Structure Strength, Crack Growth, Lifetime and Fatigue	December 2013

3. Postgraduate Research Students

Agarwal, Ankit
Strengthening of tubular steel structures using CFRP
Supervisor: Foster;
Co-supervisor: Vrcelj, Hamed

Allan, Rebecca Jane
Backward erosion piping of dams
Supervisor: Douglas

Amin, Ali
Shear and Tensile Fracture of Reinforced Concrete with Steel Fibres
Supervisor: Foster;
Co-supervisor: Gilbert

Ataei,Abdolreza
Steel and composite structures
Supervisor: Bradford

Babaee,Seyed Mahdi
Durability of geopolymer concrete in marine environments
Supervisor: Castel
Supervisor: Akbar Nezhad

Bai, Yun
Coupled flow deformation analysis of multiphase multi porous media
Supervisor: Khalili;
Co-supervisor: Oeser

Bertuzzi, Robert
Estimating rock mass strength and stiffness with particular interest in the load on a tunnel lining
Supervisor: Douglas;
Co-supervisor: Mostyn

Chen, Xiaojun
Computational Mechanics
Supervisor: Song;
Co-supervisor: Man

Chiong, Irene
Scaled boundary finite-element shakedown approach for the safety assessment of cracked elastoplastic structures under cyclic loading
Supervisor: Song;
Co-supervisor: Tin-Loi

Chowdhury, Morsaleen Shehzad
Structural Engineering
Supervisor: Song;
Co-supervisor: Gao de Burgh

James Matthew
Practical modelling and analysis of concrete building and tunnel structures in fire Supervisor: Foster
Co-supervisor: Hamed

Do,Anh Tuan
Stability of composite steel concrete T-section beams continuous over one or more supports.
Supervisor: Bradford
Co-supervisor: Vrcelj

Do,Duy Minh
Structural safety assessment, non-deterministic analysis vehicle bridge interaction dynamics, numerical analysis.
Supervisor: Gao
Co-supervisor: Song

Elhadayri, Farj
Constitutive modelling of lightly cemented unsaturated soils
Supervisor: Khalili;
Co-supervisor: Russell

Esfahani Kan, Mojtaba
Earth and rockfill dams, in particular the earthquake resistance and liquefaction susceptibility of their foundations
Supervisor: Taiebat;
Co-supervisor: Al-Kilidar

Gharib, Mohammad Mahdi
Shear and tensile fracture of steel fibre reinforced concrete
Supervisor: Foster;
Co-supervisor: Gilbert

Gholamhoseini, Alireza
The time-dependent behavior of composite concrete slabs with profi led steel decking
Supervisor: Gilbert;
Co-supervisor: Foster

Gui, Yilin
Cracking in unsaturated soils
Supervisor: Khalili;
Co-supervisor: Oeser

Hashemiheidari,Seyedkomeil
Blast loading on bridges
Supervisor: Bradford;
Co-supervisor: Pi

He,Ke
Numerical Modelling of Cracking in Embankment Dams
Supervisor: Birk
Supervisor: Song

He,Xudong
Modelling of systems with discontinuities using the scaled boundary finite element method.
Supervisor: Birk;
Co-supervisor: Song

Henderson,Ian Edward James
Condition assessment of composite structures using vibration methods
Supervisor: Uy;
Co-supervisor: Bradford

Hossain,Sumaiya Bushra
Rock dynamics. Discrete element method; stress wave propagation.
Supervisor: zhao;
Co-supervisor: Russell

Huang, Yue
Long-term behaviour of high-strength concrete panels
Supervisor: Hamed;
Co-supervisor: Foster

James, Edward Malcolm
Pavement systems on soft soils
Supervisor: Russell

Khajeh, Samani Ali
Ductility in reinforced concrete columns
Supervisor: Attard;
Co-supervisor: Tin-Loi

Khan,Mahbub Hossain
Behaviour and design of composite columns coupling the benefits of high strength steel and high strength concrete
Supervisor: Uy;
Co-supervisor: Bradford

Khezri, Mani
Buckling and post-buckling behaviour of composite laminated structures with material non-linearities
Supervisor: Vrcelj;
Co-supervisor: Attard

Lee,Sing Siu Michael
Composite steel/concrete structures
Supervisor: Bradford;
Co-supervisor: Pi

Li, Chao
Structural engineering
Supervisor: Song;
Co-supervisor: Gao

Liu, Nengguang
Uncertain modelling and uncertain methods; Vehicle - bridge interaction dynamics; Wind and/or seismic induced random vibration; structural stability and reliability analysis
Supervisor: Gao

Luo, Kai
Long-term non-linear behaviour and buckling of CFST arches
Supervisors: Pi, Gao

Luu, Trung Kien
Numerical simulation of the behaviour of composite frames at elevated temperatures
Supervisor: Bradford;
Co-supervisor: Vrcelj

Ma, Jianjun
CO2 sequestration in geological formations
Supervisor: Khalili;
Co-supervisor: Oeser

Mac, Thi Ngoc
Time dependent behaviour of slope
Supervisor: Khalili; Zhao

Masoumi, Hossein
Investigation of intact rock behaviour with particular interest on micro-crack growth and scale effects
Supervisor: Douglas;
Co-supervisor: Russell

Mazumder, Maruful Hasan
Structural engineering, computational mechanics, dynamic soil-structure interaction
Supervisor: Foster, Gilbert

Mohamad Abas, Fairul Zahri
Behaviour of fibre-reinforced concrete slabs with profiled steel decking
Supervisor: Gilbert;
Co-supervisor: Foster

Mohammadi, Samaneh
Effects of unsaturated zone on stability of slopes
Supervisor: Taiebat;
Co-supervisor: Khalili

Moutabsherkati,Shahrokh
Dynamics Analysis of Unsaturated Porous Media Subject to Damage due to Cracking
Supervisor: Khalili;
Co-supervisor: Taiebat

Parvez, Md. Ahsan
Fibre reinforced concrete structures
Supervisor: Foster

Pells,Steven Edward
Erosion of rock in spillways
Supervisor: Douglas;
Co-supervisor: Fell

Rana,Mohammad Masud
Behaviour of post-tensioned composite steel-concrete slabs
Supervisor: Uy;
Co-supervisor: Bradford

Salimzadeh, Saeed
Normal simulation of carbon sequestration in geological formations
Supervisor: Khalili;
Co-supervisor: Oeser

Saputra,Albert Artha
Computational mechanics and structural analysis
Supervisor: Song; Birk

Shi, Xue
Uncertain analysis of engineering structures. Structural reliability analysis. Structural dynamics
Supervisor: Gao

Sriskandarajah, Sanchayan
Reactive powder concrete subjected to high temperature and temperature cycles
Supervisor: Gowripalan;
Co-supervisor: Tin-Loi

Su, Lijuan
Lateral buckling
Supervisor: Attard;
Co-supervisor: Tin-Loi

Sun, Zhicheng
Fracture analysis by using the scaled boundary finite element method
Supervisor: Song;
Co-supervisor: Gao

Tang,Yi
Numerical modelling of installation and pullout capacity at caissons
Supervisor: Taiebat;
Co-supervisor: Russell

Teh,Sek Yee
Upheaval buckling of pavements
Supervisor: Bradford;
Co-supervisor: Pi

Vo, Thanh Liem
Soil-structure interaction
Supervisor: Russell;
Co-supervisor: Taiebat

Wang, Chen
Computational mechanics. Structural dynamics structural analysis
Supervisor: Gao;
Co-supervisor: Song

Wang,Jun Chao
Computational mechanics
Supervisor: Song;
Co-supervisor: Birk

Wijesiri Pathirana,Indika Sameera
Use of innovative anchors as shear connectors in composite steel-concrete beams for the rehabilitation of existing structures and deployment of new structures
Supervisor: Uy;
Co-supervisor: Bradford

Wu, Di
Limit and shake down analysis, uncertain methods and nondeterministic analysis, structural analysis and optimization
Supervisor: Gao;
Co-supervisor: Tin-loi

Xiang, Tingsong
Scaled boundary finite element analysis of plates and shells
Supervisor: Song:
Co-supervisor: Gao, Hou

Yang,Chengwei
Nondeterministic analysis of linear and nonlinear structures.
Supervisor: Gao;
Co-supervisor: Song

Yang, Hongwei
In-situ testing of unsaturated soils
Supervisor: Russell;
Co-supervisor: Khalili

Yin, Peijie
Multiphase flow in porous media: a study on permeability determination of unsaturated soils
Supervisor: Gaofeng Zhao;
Co-supervisor: Khalili

Yousefnia Pasha,Amin
Numerical modelling of Cone penetration in unsaturated soils.
Supervisor: Khalili; Khoshghalb

Zhu, Jianbei
Elasto-plastic thermal lateral buckling analysis of submerged oil and gas pipelines curved in plan
Supervisor Attard;
Co-supervisors: Erkmen, Kellermann

PhD Students Graduated in 2013

Masoumi Hossein
Experimental investigation into the mechanical behaviour of intact rock at different scales.
Supervisor: Kurt Douglas;
Co-supervisor: Adrian Russell

Mohammadi Samaneh
Large deformation analysis of slopes and embankments
Supervisor: Nasser Khalili;
Co-supervisor: Hossein Taiebat