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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:

“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, CEng, 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 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, MStructE, 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, MIAV, 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 Khoshghalib BE ME Sharif Uni of Tech, PhD UNSW
Dr Sawekchai Tangaramvong, BE MEngSc PhD UNSW

**Technical Team**
John Gilbert
Greg Worthing
Ron Moncay

**Emeritus Professors**
Somasundaram Valliappan BE Annam, MS Northeastern, PhD DSc Wales, CEng, FASCE, FIACM
Francis Tin-Loi BE PhD Monash, CEng MIEAust

**UNSW Members**
Professor Alan Crosky
School of Materials Science & Engineering
Professor Gangadhar 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
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 researchers 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
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.
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

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.
### 2013 CIES Research Funding Summary

<table>
<thead>
<tr>
<th>Researcher(s)</th>
<th>Research Topic</th>
<th>Granting Organisation</th>
<th>Value at 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA Bradford</td>
<td>An Innovative and Advanced Systems Approach for Full Life-Cycle, Low-Emissions Composite and Hybrid Building Infrastructure</td>
<td>ARC Laureate Fellowship including Faculty of Engineering &amp; UNSW support ARC FL100100063</td>
<td>521,911</td>
</tr>
<tr>
<td>Chongmin Song, Wei Gao, Yong-Lin Pi</td>
<td>A high-performance stochastic scaled boundary finite-element framework for safety assessment of structures susceptible to fracture</td>
<td>ARC Discovery DP130102934</td>
<td>114,232</td>
</tr>
<tr>
<td>RI Gilbert</td>
<td>Control of cracking caused by early-age contraction of concrete</td>
<td>ARC Discovery DP130102966</td>
<td>124,617</td>
</tr>
<tr>
<td>N Khalili, Gaofeng Zhao</td>
<td>Dynamics analysis of unsaturated porous media subject to damage due to cracking</td>
<td>ARC Discovery DP130104918</td>
<td>103,847</td>
</tr>
<tr>
<td>L. Ge, H. Zebker, S. Hensley, H-Y Chen, L. Yue, X. Li</td>
<td>Advanced techniques for imaging radar interferometry</td>
<td>ARC Discovery DP13010694</td>
<td>114,232</td>
</tr>
<tr>
<td>MA Bradford</td>
<td>Thermal-induced unilateral plate buckling of concrete pavements: design and evaluation</td>
<td>ARC Discovery DP120104554</td>
<td>185,581</td>
</tr>
<tr>
<td>B Uy; Z Tao; F Mashiri</td>
<td>The behaviour and design of composite columns coupling the benefits of high strength steel and high strength concrete for large scale infrastructure</td>
<td>ARC Discovery DP120101944</td>
<td>232,967</td>
</tr>
<tr>
<td>Chongmin Song, Francis Tin-Loi, Wilfried Becker</td>
<td>Scaled boundary finite-element approach for safety assessment of plates and shells under monotonic and shakedown loadings</td>
<td>ARC Discovery DP120100742</td>
<td>107,843</td>
</tr>
<tr>
<td>Ehab Hamed; Stephen Foster</td>
<td>Nonlinear long-term behaviour and analysis of high strength concrete panels</td>
<td>ARC Discovery DP120102762</td>
<td>118,627</td>
</tr>
<tr>
<td>S Foster; Hamid Valliour</td>
<td>Progressive collapse resistance of reinforced concrete framed structures with membrane action</td>
<td>ARC Discovery DP120103328</td>
<td>50,343</td>
</tr>
<tr>
<td>B Uy; X Xhu; O Mirza</td>
<td>The use of innovative anchors for the achievement of composite action for rehabilitating existing and deployment of demountable steel structures</td>
<td>ARC Discovery DP110101328</td>
<td>103,350</td>
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<tr>
<td>RI Gilbert</td>
<td>Time-dependent stiffness of cracked reinforced concrete</td>
<td>ARC Discovery DP110103028</td>
<td>31,450</td>
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<tr>
<td>Gaofeng Zhao</td>
<td>Dynamic fracturing in shale rock through coupled continuum-discontinuum modelling</td>
<td>ARC DECRA DE130100457</td>
<td>130,387</td>
</tr>
<tr>
<td>MA Bradford</td>
<td>Climate adaptation technology and engineering for extreme events.</td>
<td>CSIRO / Flagship Collaborative Research Program</td>
<td>263,000</td>
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<tr>
<td>H M Goldsworthy, E Gad, B Uy, S Fernando</td>
<td>Development of efficient, robust and architecturally-flexible structural systems using innovative blind-bolted connections</td>
<td>ARC Linkage LP110200511</td>
<td>15,000</td>
</tr>
<tr>
<td>Researcher(s)</td>
<td>Research Topic</td>
<td>Granting Organisation</td>
<td>Value at 2013</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>Gianluca Ranzi (USyD), Raymond I Gilbert, Rodney Mackay-Sim</td>
<td>Behaviour of lifting inserts for precast concrete construction Partner/Collaborating Organization: Universal Concrete Lifting Systems</td>
<td>ARC Linkage LP110100008</td>
<td>26,389</td>
</tr>
<tr>
<td>Markus Oeser, Alan Pearson, Nasser Khalili, Brian Shackel</td>
<td>Permeable Pavements with Concrete Surface Layers- Experimental and Theoretical Basis for Analysis and Design</td>
<td>ARC Linkage LP100100806</td>
<td>3,750</td>
</tr>
<tr>
<td>G Ranzi; B Uy; S Gowripalan; P Gabor</td>
<td>Behaviour of post-tensioned composite steel-concrete slabs</td>
<td>ARC Linkage LP0990190</td>
<td>2,701</td>
</tr>
<tr>
<td>PA Mendis; B Samali; B Uy</td>
<td>Innovative Retrofitting Techniques for the Protection of Anchorage Zones in Cable-Stayed Bridges Subjected to Blast Loads Collaborating/Partner Organisation: Road Traffic Authority (RTA)</td>
<td>ARC Linkage LP0883942</td>
<td>27,755</td>
</tr>
<tr>
<td>MA Bradford; B Uy; G Ranzi; A Filonov</td>
<td>Time-Dependent Response and Deformations of Composite Beams with Innovative Deep Trapezoidal Decks. Collaborating/Partner Organisation: Blue-Scope Lysaght</td>
<td>ARC Linkage LP0882929</td>
<td>55,497</td>
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<tr>
<td>UQ/UNSW/UWA/QUT/Adel</td>
<td>Performance Level Structural Testing Facility (PLSTF). Partner Organisation: Queensland Department of Transport and Main Roads</td>
<td>ARC LIEF LE130100089</td>
<td>23,500</td>
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<tr>
<td>UNSW/ UWS /UOW/UQT/UoN/Adel/Melb</td>
<td>National Facility for Physical Blast Simulation (NFPBS) Partner Organisation: Defence Science and Technology Organisation</td>
<td>ARC LIEF LE1301100133</td>
<td>700,000</td>
</tr>
<tr>
<td>S Foster; E Hamed; Z Vrcelj</td>
<td>Advanced Composite Structures</td>
<td>Cooperative Research Centre for Advanced Composite Structures Ltd (CRC-ACS)</td>
<td>125,410</td>
</tr>
<tr>
<td>S Foster</td>
<td>Performance based Criteria for Concretes: Creating Pathways for Low Carbon Concrete Manufacture with Existing Standards</td>
<td>Cooperative Research Centre for Low Carbon Living Ltd (CRC LCL)</td>
<td>31,250</td>
</tr>
<tr>
<td>C Birk</td>
<td>FRG Grant</td>
<td>UNSW Engineering</td>
<td>25,000</td>
</tr>
<tr>
<td>A Castel</td>
<td>FRG Grant</td>
<td>UNSW Engineering</td>
<td>30,000</td>
</tr>
<tr>
<td>A Khoshghalb</td>
<td>FRG Grant</td>
<td>UNSW Engineering</td>
<td>39,844</td>
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<tr>
<td>A Russell</td>
<td>Mechanistic design tools for shallow foundations in unsaturated soils derived through numerical modelling, analysis and experimental investigation</td>
<td>UNSW Goldstar Awards - DP130104497</td>
<td>37,246</td>
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<tr>
<td>Industry funded research undertaken by the CIES Projects team</td>
<td>Various</td>
<td></td>
<td>88,551</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>$3,434,280</strong></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
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<td>Dr Brian Uy</td>
<td>Professor of Civil Engineering</td>
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<td>Dr Adrian Russell</td>
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<td>Dr Wei Gao</td>
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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

(a) Tensile restraint $T$ due to bonded reinforcement

(b) Development of potential cracking in a thick wall due to heat of hydration

(c) Restraint and full-depth cracking in a member partially restrained at each end

(d) Contraction of a wall with one edge restrained and potential cracking

(e) Contraction of wall with two adjacent edges restrained and potential cracking

Figure 2: Tensile creep specimen and typical testing rig.
Cracks appear in many ageing infrastructure such as dams, bridges and buildings. After an extreme loading event such as impact, blast, cyclone and earthquake, a structure often sustains damages in the form of cracking. For ageing and damaged structure, uncertainties of the system parameters for structural analysis exist. For the safe and cost-effective management of aging structures, it is essential to consider the uncertainties in evaluating the stability of cracks and crack propagation.

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

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

This technique has been successfully applied to various problems in fracture analysis of cracked structures. An example is shown in Figure 1. Significant advantages and potential of the developed approach are demonstrated. For example, Figure 2 shows the modeling of the XCT image of a concrete specimen to predict its material properties.
Figure 1: Crack propagation of a beam subjected to three point bending with initial crack at different locations.

(a) Geometry

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

Figure 2: Modelling of XCT image of concrete specimen

(a) Image of concrete  (b) Quadtree mesh  (c) $\sigma_1$ in aggregates  (d) $\sigma_1$ in mortar
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.
Furthermore, was blasts.

**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.

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

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

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)

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.

Publications Emanating from this Project in 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)

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.
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.
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 \( L_{lap} \) 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 \( L_{lap} \) 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 ready for submission by the end of 2013.
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 Chengqing 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.

ARC – Linkage Equipment and Facilities Grant (LIEf) 2013
Dynamic fracturing in shale rock through coupled continuum-discontinuum modelling

Dr Gaofeng Zhao

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
Funding Project

Body:

The DLSM was successfully modified to model a typical jointed sandstone studied at Changsh (mrs: DLSM, Changsha, Zhin, NEechanical W/UPDATo). Numerical experiments were conducted to obtain the mechanical properties of the jointed sandstone, with the help of the 3D printing technology. The physical properties of the jointed sandstone were obtained using the imaging technology. The mechanical properties were measured using the jointed DLSM. The SHPB test was used for the coal.

Approximate Experimental Rupture surface [10]

Impact direction

(d) SHPB test on coal

(d) SHPB test on coal
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

CA05240

SJH (Swift Lift JAWS™ Heavy)

EPA09 (Edipro™)

Schematic of the test setup

The lifting anchor is attached to an appropriate clutch and pulled up by a hydraulic actuator.

Threaded bar was screwed to the embedded insert at one end and the other end was attached to a frame which was bolted to the laboratory strong floor.

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)

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.
Relatively little research has been undertaken on the time-dependent in-service behaviour of composite concrete slabs with profiled steel sheeting 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.
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

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).
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.
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: 10°C to 50°C and 10°C to 40°C. Both temperature ranges are below glass transition temperature of the Sikadur®30 adhesive used (62°C).  
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.
Thermal cycling between 10ºC and 50ºC

Figure 1: Thermal cycle apparatus

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

Conclusions

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.

Normalized Bond Strength (%)

Time (Days)

0.25
0.2
0.15
0.1
0.05
0
0
0 7 14 21

Failed during 1st thermal cycle
50% sustained load

Failed during 15th thermal cycle
30% sustained load

Failed within 50 hours during 11th thermal cycle
50% sustained load

Test stopped

30% sustained load
Survived thermo-mechanical loading for 21 days with 20% reduction in bond strength

Normalized Bond Strength (%)

Time (Days)

0 7 14 21

Thermal cycling between 10ºC and 40ºC

Thermal cycling between 10ºC and 50ºC
Dispersion curves for ‘leaky’ ultrasonic waves in waveguides of arbitrary cross-section

Dr Carolin Birk

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.
Evaluation of the long term stability of slopes

Dr Arman Khoshghalb

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

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
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.
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

<table>
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<tr>
<th>Beam ID</th>
<th>Fibre Dosage (kg/m³)</th>
<th>Stirrup Spacing (mm)</th>
<th>$V_{test}$ (MPa)</th>
<th>$V_{fib,MC}$²</th>
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<th>$V_{test}^{AS5100}$</th>
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</table>

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.
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.
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.
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

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

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


BOOK CHAPTER


JOURNAL ARTICLES


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## 2. International Visitors

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

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<th>Institution</th>
<th>Seminar Topic</th>
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<td>Professor Andrew H.C. Chan</td>
<td>Professor of Civil Engineering Deputy Dean, Information Technology &amp; Engineering University of Ballarat</td>
<td>Numerical modelling of dynamic saturated soil and pore fluid interaction using finite element method and combined discrete element and Lattice Boltzmann method</td>
<td>June 2013</td>
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<tr>
<td>Dr Scott Hensley</td>
<td>Deputy Manager, Radar Engineering Section NASA Jet Propulsion Laboratory</td>
<td>Remote Sensing Research at NASA Jet Propulsion Laboratory</td>
<td>October 2013</td>
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<tr>
<td>Professor David Muir Wood</td>
<td>University of Dundee, Scotland, UK</td>
<td>Rooting for sustainable performance</td>
<td>October 2013</td>
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<td>Dr Suresh Palanisamy</td>
<td>Air platforms Program Leader, Defence Materials Technology Centre, Swinburne University of Technology</td>
<td>Key Research Technologies in the DMTC.</td>
<td>October 2013</td>
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<tr>
<td>Professor Zdeněk P. Bažant</td>
<td>McCormick Institute Professor and W.P. Murphy Professor of Civil and Mechanical Engineering and Materials Science, Northwestern University</td>
<td>Probabilistic Nano-Mechanical Theory of Quasibrittle Structure Strength, Crack Growth, Lifetime and Fatigue</td>
<td>December 2013</td>
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<td>Strengthening of tubular steel structures using CFRP</td>
<td>He, Ke</td>
<td>Numerical Modelling of Cracking in Embankment Dams</td>
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<td>Shear and Tensile Fracture of Reinforced Concrete with Steel Fibres</td>
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<td>Steel and composite structures</td>
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<td>Durability of geopolymer concrete in marine environments</td>
<td>Esfahani Kan, Mojtaba</td>
<td>Earth and rockfill dams, in particular the earthquake resistance and liquefaction susceptibility of their foundations</td>
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<td>Bai, Yun</td>
<td>Coupled flow deformation analysis of multiphase multi porous media</td>
<td>Gharib, Mohammad Mahdi</td>
<td>Shear and tensile fracture of steel fibre reinforced concrete</td>
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<td>Bertuzzi, Robert</td>
<td>Estimating rock mass strength and stiffness with particular interest in the load on a tunnel lining</td>
<td>Gholamhoseini, Alireza</td>
<td>The time-dependent behavior of composite concrete slabs with profiled steel decking</td>
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<td>Chen, Xiaojun</td>
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<td>Chiong, Irene</td>
<td>Scaled boundary finite-element shakedown approach for the safety assessment of cracked elastoplastic structures under cyclic loading</td>
<td>Hashemiheidari, Seyedkomeil</td>
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<td>Chowdhury, Morsaleen Shehzad</td>
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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

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

Moutabsherkat, 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