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As the world’s population approaches a staggering eight billion, infrastructure silently and steadily ages around the globe. Until a major bridge collapse or deadly gas explosion, we tend to forget what may have exceeded its design capacity or outlasted its service life. The ARC Industrial Transformation Research Hub for Nanoscience-based Construction Material Manufacturing (the Nanocomm Hub) recognises the urgency to build sustainable and resilient infrastructure and has set out to explore materials on a nanometre scale, drilling down to atoms and molecules. Through this nanoscience, the Hub can reimagine construction materials, and pioneer sophisticated nanoengineering technologies for their manufacture. As a centralised platform, the Nanocomm Hub brings together experts from across disciplines with the aim of transforming the construction materials industry into an advanced manufacturing sector.
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INTRODUCTION

1.1 About the Nanocomm Hub

Australia’s continued prosperity depends on the construction materials industry, which manufactures and distributes cement, concrete, aggregates such as gravel and crushed stone, polymer composites used, for example, in fibre-reinforced polymer composites, and chemicals. All in all, this massive industry contributes nearly $12 billion to our gross domestic product (GDP). Further, it employs 18,000 Australians directly and 85,000 indirectly.

To drive economic growth and enhance the quality of life of Australians, we must create sustainable and resilient infrastructure – infrastructure that requires less maintenance and can resist extreme weather conditions and even terrorist attacks. That’s why the Federal Government has committed a record $50 billion to infrastructure from 2014-15 to 2019-20. Combined with state, territory and private sector investment, this initiative will likely have spurred over $125 billion of infrastructure spending nationwide by 2020.

To realise investors’ ambitions, we need a steady supply of innovative construction materials from local sources. But can our construction materials industry meet Australia’s substantial infrastructure needs? Although historically a major source of jobs and revenue, the industry has recently been challenged by declining employment, rising energy costs and competition from low-cost Asian imports. Responding to these challenges, the Hub has undertaken the development of high-value products and specialised manufacturing operations that will keep the industry ahead of the game.

HUB STRUCTURE

The Hub’s network of 13 Australian and three overseas universities, along with 48 industry partners, including state government, creates a vast collaboration to truly innovate infrastructure systems. Partners from the construction materials industry – many of which are small and medium enterprises (SMEs) – operate across Australia, New Zealand, China, Singapore and South Korea.

Our research spans four areas: nanoscience, construction materials, green structures and asset management. In nanoscience, which overlaps chemistry and physics, we focus on the fundamentals at the molecular level. With construction materials, we explore how to bind together individual elements, such as cement, concrete, adhesive, glass, metal, timber, fibre-reinforced plastic, and pavement materials. When developing green structures, we cover everything from buildings, bridges, roads and dams to tunnelling, sensor technology and structural health monitoring for damage detection. Asset management involves entire infrastructure systems, such as national road networks, where we aim to optimise the performance of assets.

Together Hub teams probe the full spectrum of the construction materials industry to inspire technological innovation throughout the sector. Our overarching goal is to create lighter, more resilient materials, ultimately contributing to a more sustainable and liveable Australia.

MEETING OUR GOALS

To advance the development of construction materials and infrastructure systems, the Australian Research Council (ARC) awarded the Hub $5 million. This government funding has been complemented by $10 million invested by universities ($3.8 million) and industry ($6.2 million), in Australia and overseas. This
means that our current industry-to-ARC cash matching ratio is 1.24, well above the ARC requirement of 0.75. Thanks to this strong industry commitment, the Hub has financial leeway.

In our ARC project proposal, we outlined five primary objectives. All five remain front and centre today. Collectively, the Hub’s 37 research projects align with the first three: reducing energy consumption and CO2 emissions in the manufacture of construction materials; developing high-performance, high-durability construction materials and structures; and creating materials and structures that can resist extreme conditions and terrorist attacks.

Our 34 research fellows and higher degree by research (HDR) students meet the fourth objective: boosting the engineering capability of Australian industry with an innovative, skills-based workforce. Our fifth objective to link Australian companies to the enormous infrastructure opportunities in Asia will be reached via the Monash Suzhou (China) and Sunway (Malaysia) campuses.

Officially launched on 20 November 2017, the Hub has already made enormous strides in achieving its goals.
1.2 Vision
As a world-class research centre, the Nanocomm Hub seeks to develop materials and technologies that will elevate the global competitiveness and profitability of the Australian construction sector.

1.3 Mission
By promoting collaboration among Australia’s best minds in academia and industry, we aim to advance the construction materials and technologies through nanoscience and nanoengineering, while providing hands-on experience to our future workforce.
As a world-class research centre, the Nanocomm Hub seeks to develop materials and technologies that will elevate the global competitiveness and profitability of the Australian construction sector.
The Hub’s extensive collaboration has yielded great progress and promise during 2018. Not only have we catapulted Australia to the forefront of construction research and development (R&D), we have increased our domestic market and export potential.

Leading researchers from across the nation, and beyond, have joined forces with multidisciplinary thinkers from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the construction and construction materials industries, and the peak infrastructure body. With 37 exciting Hub projects already underway, we’ve brought on board 63 PhD students and 25 early-career researchers, with more to come.

In striving for seamless integration of operations across our wide-ranging participant organisations, we have established a steering committee comprised of four groups (i.e. chief investigators, partner investigators, research fellows and HDR students), each representing a cross section of the Hub. In this same cooperative spirit, university and industry partners share infrastructure, giving researchers access to state-of-the-art facilities. Such interactions generate additional collaboration between organisations.

After carefully selecting industry partners for their relevance to our R&D, we aim to maintain dynamic and successful relationships with them. We have set up monitoring systems to ensure that projects move forward as planned, strongly urging timely delivery. Further, the Hub has cultivated a sophisticated, skills-based workforce to convey innovations to industry. To facilitate this process, we engage, from inception to implementation, relevant end-user industry experts, manufacturers and regulators.

Showing quick, even if only small, returns on partner investment keeps up momentum and buoys confidence in our approach. With this in mind, the Hub hosts events, such as Innovation Night, Industry Showcase and our Innovation Dinner Series. These give us a chance to identify expectations for investment returns, as well as gauge what industry partners would like us to do in the future.

We take great pride in our significant scientific advances described later in this report. Not only have we produced high-quality research across extensive areas in 2018, we have published 31 papers in prestigious Q1 academic journals, such as ACS Nano, Nanoscale, Energy & Fuels, Cement and Concrete Composites, Engineering Structures, and Energy and Buildings.

The Hub has also translated fundamental research into industry applications, with six provisional patents now on file. One of these patents is for a floating forest that will act as a mega water-break and wind-break to protect the Australian coastline from increasingly strong waves and winds caused by climate change. Inventors of this patent include our Chief Investigators, Prof Chien Ming Wang from the University of Queensland and Prof Wenhui Duan from Monash University, and Partner Investigator Dr Kwanghoe Jung from Hyundai, South Korea.

That we have achieved so much so soon bears testimony to the effectiveness and efficiency of the Hub’s drive for scientific excellence, underpinned by its strong leadership and governance structures.

Our management team has made 32 visits to nodes in Melbourne, Sydney, Brisbane and Perth, as well as nodes in China and Singapore. During these visits, they met with chief investigators, partner investigators, research teams, advisory committee members and business development personnel, opening communication channels to discuss Hub
In July and December of 2018, the Hub hosted two large planning workshops, bringing together industry representatives and heads of the successful civil engineering departments of Monash University, University of New South Wales, City University of Hong Kong and National University of Singapore. These workshops provided an opportunity to share knowledge about science and technology funding: What’s industry looking for? How can we reconcile industry and university priorities? Where lie the gaps in current research? And how do we introduce students and early-career researchers to industry? Addressing these issues provided great insight.

We will keep bolstering our ties to industry partners both in and outside the Hub, through contract research, ARC Linkage Projects, Cooperative Research Centres Projects (CRC-P) and Cooperative Research Centres (CRC) schemes. Not only will the Hub continue to raise the profile of partner universities, we will pave the way to ARC Discovery Projects, Future Fellowships, Discovery Early Career Researcher Awards, Laureate Fellowships and the College of Experts. Further, the vast experience offered by the Hub, the largest hub collaboration to date, will shape industry and a workforce perfectly suited to other ARC Industrial Transformation Research Hubs (ITRHs).

For the remainder of the current ARC funding term, we will track all our KPIs for universities and industry partners alike, with a focus on translating research into industry applications. We will also explore the potential for start-up and spin-off companies. Outstanding research requires world-class talent and so the Hub will continue to recruit, develop and support high-performing researchers and HDR students from around the globe.

The Hub values gifted individuals, regardless of their social or economic circumstances. Additionally, we are committed to the ARC Gender Equality Action Plan, pursuing gender balance and resisting unconscious bias. Mindful of how certain processes may discriminate against women and families, we aim to create an inclusive research environment. We further aim to schedule meetings at times that do not disadvantage parents or carers.

United in our vision to advance the nation’s construction sector, the Hub fosters knowledge exchange, transformative research and collaborative innovation. From our many disparate parts, we’re building one enormous ecosystem where university and industry members can work hand in hand. When ARC funding ceases, we expect that research centres supported by CRC, ITRH or ARC Centre of Excellence schemes will preserve our legacy of transparency, fairness and friendship.

Wenhui Duan
Director, ARC Nanocomm Hub

This year we have achieved so much so soon, which bears testimony to the effectiveness and efficiency of the Hub’s drive for scientific excellence, underpinned by its strong leadership and governance structures.
PARTNERSHIPS

2.1 National and International Partnerships

The Nanocomm Hub has a wide array of partners, both here and overseas, from academia and industry, as well as state government. Our unique collaborative approach is the key to successful advancement of Australia’s construction materials sector.

Hub teams work closely together on projects ranging from the development of nanoscience-based construction materials and structural elements to devising innovative methods for optimal asset performance in infrastructure systems.

Our research delves into all aspects of the construction materials industry, across the Asia-Pacific regions and beyond. We aim to facilitate, at the grassroots level, the emergence of new technologies, creating a ripple effect throughout the entire sector.
2.2 University Partners

As part of various teams, researchers from 13 Australian and 3 overseas academic institutions collaborate on one or more of the Nanocomm Hub’s 37 projects.

Monash University serves as the Hub’s administering organisation, but talented researchers from all the partner universities lead projects in the areas of nanoscience, construction materials, green structures and asset management.
### 2.3 Industry Partners

Our partners from the construction materials industry – many of which are small and medium enterprises (SMEs) – operate across Australia, New Zealand, China, Singapore and South Korea.

To ensure that our research translates into marketable outputs, each Nanocomm Hub project involves a collaborating company at the forefront of innovation in its field. We take pride in all of these valuable alliances.

"The collaboration with Nanocomm Hub has taken the form of preliminary work with the aim of developing highly reliable and robust robotic systems for inspection of road condition."

– Australian Road Research Board (ARRB)
2.4 Collaborative Objectives

AGL ENERGY

AGL Energy Ltd (AGL), one of Australia’s foremost integrated energy companies, is taking action to responsibly reduce its greenhouse gas emissions, and to improve the sustainability of its power generation activities.

In collaboration with the Nanocomm Hub, AGL will provide a pathway for waste ash to be used in commercial building products. Bolstered by the Hub’s nanotechnological expertise, the AGL Loy Yang Power Station, along with its academic and industry partners, can lead this field, and propel further optimisation of product designs. Rehabilitation of AGL Loy Yang mine sites requires huge quantities of soils to cap exposed coal batters and reactive overburden material. In working with the Hub, AGL seeks in particular to develop nanoscience-based construction materials for use in mine rehabilitation works.

ANSTO

The Australian Nuclear Science and Technology Organisation (ANSTO) leads Australia in the use of neutron scattering and x-ray techniques to solve complex research and industrial problems in many important fields, including materials engineering. In collaboration with the Nanocomm Hub, ANSTO will engage in a variety of structural integrity investigations, with an aim to develop modern engineering processes.

AFM

AFM Pty Ltd, a recently founded Australian company, specialises in providing solutions, using advanced nanotechnology, in the field of 2D materials, photonics, optic imaging and sensor systems. As part of a novel joint project with the Nanocomm Hub, AFM aims to significantly advance optical sensor technology by exploring the potential of a newly developed graphene material.

AIREY TAYLOR CONSULTING

A multi-award-winning firm, Airey Taylor Consulting has made an ongoing contribution to the development of Western Australia. Its involvement with the Nanocomm Hub will strengthen the existing collaboration between the firm and University of Western Australia. Airey Taylor Consulting will at the same time establish new links to Monash University, whereby complementary research capabilities (in investigating carbon nanotubes and graphene oxide sheets in cement-based construction materials) will transform the Australian construction materials industry.

ARGOS FRP

Australian owned and operated, Argos FRP Pty Ltd partners with industry to deliver construction and corrosion solutions using pultruded fibre-reinforced polymers (FRPs). The company views its participation in the Nanocomm Hub as a key innovation opportunity in that the Hub’s objectives fit well with its strategic plan to continue development of new and innovative FRP-based solutions. Together the Hub and Argos FRP will create lightweight, strong, durable and corrosion-resistant products.
ARRB GROUP
ARRB Group Ltd (ARRB) provides research, consulting and information services to the road and transport industry. The company stands out as the leading provider of road research and best practice workshops in Australia. Its involvement in the Nanocomm Hub will fortify the collaboration between ARRB and Monash University to develop high-performance road infrastructure, as well as the required monitoring and condition-assessment techniques. The Hub’s perspective aligns closely with ARRB’s strategic goals and its mission as trusted advisor on roads and transport. Working with Monash University and Hub industry partners will expand the company’s core competencies into new areas of expertise.

AURECON
An engineering and infrastructure advisory company, Aurecon hopes to achieve its long-term objectives by association with the Nanocomm Hub. Through the Hub, Aurecon works with Swinburne University of Technology, Curtin University and industry partners to close the gap between the design and reality of energy-retrofitted buildings. The aim is to generate fresh insights, theories, models and guidelines for financing, designing, modelling and retrofitting energy-efficient buildings, as well as monitoring, measuring and improving the energy performance of existing public office buildings.

ARUP
Arup is a global planning, design, engineering and management consulting firm, with some 10,000 staff internationally. The firm has been collaborating with the University of Queensland and the Nanocomm Hub to develop a novel hybrid FRP-concrete-steel double-skin tubular truss bridge. This project will enhance Arup’s reputation as an innovative firm of engineers with a deep understanding of new materials and construction techniques. It will also position Arup to design structures within a challenging project environment.

BAO ENGINEERING
BAO Engineering Pty Ltd joins the Nanocomm Hub as a key industry partner. BAO Engineering’s overall strategic plan is to manage and develop construction systems that support a sustainable environment. The company aims to devise innovative pre-fabricated systems that facilitate the construction process in a way that is more time-efficient and financially sustainable.
CANSTRUCT

As a privately owned company operating in many parts of Australia for over 49 years, Canstruct has diverse capabilities in remote housing, bridges, tunnels, marine works and industrial/commercial buildings. Canstruct has a turnover of $150 million per annum, and 145 employees. The company has identified that replacement of level crossings, with minimal impact upon traffic and surrounding residences and businesses, is essential to Australia’s continued development. This vital issue will therefore be the focus of the first of Canstruct’s many research projects with the Nanocomm Hub and the University of Queensland. Another joint project will take an innovative approach to road and rail timber bridge replacement across Queensland.

CEMENT CONCRETE & AGGREGATES AUSTRALIA

Cement Concrete & Aggregates Australia (CCAA), the peak body for the heavy construction materials industry in Australia, has maintained a comprehensive research portfolio over many years. In conjunction with the Nanocomm Hub, CCAA will help develop the knowledge base of both industry and universities. In recognition of the industry’s aging technical personnel, this project will help prepare informed, competent candidates to assume future technical leadership within Australia.

CHONGQING IDEALTECH

Chongqing IdealTech Co, Ltd (IdealTech), a Chinese technology company established in 2013, leads unmanned aerial vehicle (UAV) research and manufacturing. IdealTech has built a successful collaboration with the Nanocomm Hub and the University of Melbourne in the field of structural health monitoring – a joint effort to increase productivity and extend the service life of road infrastructure. IdealTech understands that enhanced durability plays a critical role in the sustainability of transport infrastructure.

CEMENT AUSTRALIA

Cement Australia Pty Ltd, the nation’s leading supplier of cementitious products and services, joins the Nanocomm Hub to develop nanoscience-based materials and manufacturing technologies in Australia.
More research is needed in assessing and optimizing the performance of pavement materials in combination with emerging technologies which may transform current approaches to road maintenance, rehabilitation and new construction.

– Australian Road Research Board (ARRB)
In partnership with the ARC Nanocomm Hub, Fortis will further its optimisation of waterproof solutions to advance building construction industry

— Fortis Adhesives & Coatings
CONCRETE NZ
Concrete NZ represents a membership of more than 300 corporates and individuals who collectively account for a significant proportion of the building and construction sector in New Zealand. The association maintains an active research roadmap and technology plan to direct its research efforts. In working with the Nanocomm Hub to expand the industry and academic knowledge base, Concrete NZ can more effectively support the development of the cement and concrete industry.

CENTRE FOR PAVEMENT EXCELLENCE ASIA PACIFIC
Established a few years ago in Victoria, the Centre for Pavement Excellence Asia Pacific (CPEAP) aims to narrow the gap in knowledge concerning the stabilisation of road pavements in the Asia-Pacific region. The Nanocomm Hub’s expertise in nanotechnology will enable CPEAP to achieve greater optimisation of stabilisation designs. Together CPEAP and the Hub will produce guidelines for resilient pavement designs that can sustain exposure to natural disasters, as well as gradual degradation.

COAL ENERGY AUSTRALIA
Coal Energy Australia (CEA) is a public company registered with the Australian Securities and Investments Commission. The objectives of the Nanocomm Hub align well with CEA’s long-term strategic plan. In particular, the Hub offers the company an opportunity to test its beneficiated products in various cement rotary kilns for the production of clinker, a precursor material of cement. This will ultimately augment the penetration of CEA’s products into the domestic cement industry.

CSR
Founded in 1855, CSR is one of Australia’s oldest and largest building products companies, with revenues of over $2 billion and more than 3,000 employees across Australia and New Zealand. CSR’s collaboration with the Nanocomm Hub and Western Sydney University will widen the scope of its innovative solutions – particularly in the multifamily market. CSR envisages joint projects that will bring about unique new technologies, and an improved understanding of existing technologies, to meet CSR’s commercial and societal expectations.

ENERGY AUSTRALIA
The EnergyAustralia group of companies owns and operates a multibillion dollar energy generation portfolio, including coal, gas and wind assets. EnergyAustralia Yallourn, a member of this extensive group, is strongly committed to reducing the carbon footprint of the power production process, and to finding alternative uses for waste ash material. The Nanocomm Hub’s expertise in nanotechnology will enable EnergyAustralia Yallourn to explore the potential development of commercial building products. This research will benefit both industry and the community in terms of business sustainability and economic outcomes.

FORTIS ADHESIVES, COATINGS & SPECIALTIES
Fortis Adhesives, Coatings & Specialties (Fortis), an Australian company, specialises in the manufacture and supply of premium industrial adhesives and specialty floor coatings. This includes concrete acid stains, concrete densifiers and polished concrete enhancers. In partnership with Monash University and Professor Wenhui Duan, Fortis has previously investigated the formulation of curing compounds – looking at the impact of water-retaining efficiency on permeation depth, surface hardness and the adhesion behaviour of treated cement mortar. Now partnering with the Nanocomm Hub, Fortis will further its optimisation of products to advance local industry.
DEPARTMENT OF FINANCE, WESTERN AUSTRALIA GOVERNMENT

The vision of the Government of Western Australia’s Department of Finance (WA DoF) is to offer advice and services that will empower a high-performing public sector. Through the Nanocomm Hub, WA DoF works with Swinburne University of Technology, Curtin University and industry partners to close the gap between the design and reality of energy-retrofitted buildings. This project will generate fresh insights into how to improve the energy performance of existing public sector office buildings.

LINDBEAM

Lindenbaum Pty Ltd is an engineering-based investment and innovative technology company. One of its major missions is to develop an advanced analysis and design platform for new engineering materials and structures. Collaboration with structural analysis and design experts at the Nanocomm Hub will lead to methodological and applicable advances in performance assessment, and optimal design, of nano and composite structures.

IRONCLAD MINING MACHINERY

Ironclad Mining Machinery aims to innovatively build the safest, highest-producing and most easily maintained miners. The group plans to manufacture hybrid ABM 25 miners featuring all leading-edge technologies. The design will allow for greater ease in underground maintenance, and will incorporate new concepts for safety. The University of Wollongong and the Nanocomm Hub will enrich this project with their extensive background in mining and coal burst research.

NANJING FENGHUI COMPOSITE MATERIAL

Nanjing Fenghui Composite Material Co, Ltd has diverse capabilities in the technological development, production, sales and service of fibre-reinforced polymer (FRP) rebar and related products. In coastal regions, corrosion presents an enormous problem for civil infrastructure. Nanjing Fenghui recognises the urgency to replace prestressed steel-reinforced concrete piles with newly developed FRP piles. The company seeks, through the Nanocomm Hub, to deliver innovative solutions to this vital issue.
OSTWALD BROS

Ostwald Bros continually seeks to meet client needs across civil engineering, mining services, materials supply, facilities and accommodation management, bulk haulage and transport, and rural operations. Further, the company recognises that Australia’s continued development relies on the replacement of level crossings. In collaborating with the Nanocomm Hub and the University of Queensland, Ostwald Bros innovatively utilises locally sourced backfill material for corrugated metal pipes in road and rail infrastructure in remote areas.

QINGDAO UNIVERSITY OF TECHNOLOGY

Qingdao University of Technology offers a wide range of subjects, including art, economics, business management, law, science and engineering (with majors in mechanical, civil and environmental engineering). The scope of the Nanocomm Hub’s research complements the University’s strategic directions. Together the two can actively pursue innovative, multidisciplinary research to address engineering challenges of the 21st century.

PANGANG GROUP

A major rail producer worldwide, Pangang Group exports its rails to many countries, including Australia. By studying, with the Nanocomm Hub, plastic deformation and fatigue damage of rail welds, Pangang can develop new high-strength rail steels that perform better at rail welds for heavy-haul railways.

THE QUEENSLAND DEPARTMENT OF HOUSING AND PUBLIC WORKS

The Queensland Department of Housing and Public Works (the Department) has responsibility for achieving building sustainability in terms of economic, social and environmental targets. The Department is fully committed to financing models to make existing public office building stock energy efficient. The Nanocomm Hub will help the Department achieve this and other long-term objectives.

NU-ROCK

Nu-Rock’s breakthrough nu-cement technology converts all waste from coal-fired power stations, steel mills, non-ferrous smelters and alumina smelters into a range of unique and superior masonry products for building, construction and civil engineering. Involvement in the Nanocomm Hub strengthens the company’s collaboration with Western Sydney University in developing high-performing fire insulation materials, using the latest nanotechnology. Working with Western Sydney University and Hub industry partners will expand Nu-Rock’s core competencies into new areas of expertise.

ONEATOM 12

Formed in 2014, OneAtom 12 pursues a vision to develop high-volume graphene-related products in the commercial and industrial space. With its focus on graphene-based research, OneAtom 12 has accordingly sought out the expertise of the Nanocomm Hub. This partnership, led by the Hub, will help OneAtom 12 drive graphene-related products to market.
THE ROADS AND MARITIME SERVICES

The Roads and Maritime Services manage the oldest and most complex road network in Australia. Currently, about 30 bridges, with a replacement value of approximately $500 million, are suspected to be affected by alkali-silica reaction. In partnership with the University of Technology Sydney and the Nanocomm Hub, Roads and Maritime Services will address this critical issue.

SINOMA INTERNATIONAL

The core business of Sinoma International, a world-leading cement engineering contractor, comprises cement processing technology, equipment and engineering. The company serves as a total solution provider, working towards sustainability in the cement sector. In the next five years, Sinoma International aims to develop next-generation cementitious materials with a low carbon footprint, low energy intensity and higher performance. Involvement with the Nanocomm Hub will expand Sinoma International’s business opportunities in Australia, as well as enhance the nation’s cement and concrete industry as a whole.

SOUTHWEST JIAOTONG UNIVERSITY

Southwest Jiaotong University in Chengdu, China, specialises in research and development of railway technology. The University has been examining, in collaboration with the Nanocomm Hub, plastic deformation and fatigue damage of rail welds in heavy-haul railway systems. This research will help improve the structural integrity of rail welds, as well as facilitate the prediction of their service life.

ROCKET C

Rocket C, a privately-owned company, has broad experience in complex infrastructure projects, including Brisbane’s Airport Link, Go Between Bridge and Legacy Way. Rocket C has enlisted two road/rail authorities supporting commercialisation of innovative bridge construction. The goal is to provide a unique service in urban and remote areas. In collaboration with the Nanocomm Hub, Rocket C will develop a lightweight bridge with minimal construction duration – an innovation that will advance Australia’s industry competitiveness.

SOLAR E

Solar E, an Australian owned and operated company, provides high-quality infrastructure services including, but not limited to, solar power and Rheem solar hot water facilities. In conjunction with the University of Western Australia and the Nanocomm Hub, Solar E will develop 3D printing technologies with applications in renewable energy. The joint research aims to transform manufacturing technology for this sector.

TRITECH GROUP LIMITED

Tritech Group Limited (TGL) businesses focus on high-technology engineering products and services. In working with the Nanocomm Hub, TGL has a particular interest in creating nano-based construction materials applicable to underground space development. Exploration with the Hub of new materials will boost TGL’s future involvement in this area worldwide, and will consolidate the company’s position as leader in underground space technology, development and construction.
UBIQ AUSTRALIA
UBIQ Australia is a leading provider of lightweight, low-carbon and high-performance building construction materials. In partnership with the University of New South Wales and the Nanocomm Hub, UBIQ Australia seeks to optimise the design of magnesium oxychloride cement. This research will enhance the mechanical and physical properties, as well as the performance, of magnesium oxychloride cement products, significantly improving product reliability.

ZEOBOND RESEARCH
Zeobond Research Pty Ltd, part of the Zeobond Group, is a privately owned technology company that’s highly regarded worldwide for its expertise in the commercialisation and application of low-CO₂ emission cement and concrete technology. Zeobond joins the Nanocomm Hub to better understand the effect of nanoparticles on the phase assemblage and microstructure of cementitious binders synthesised from the chemical activation of waste precursors. This work will consolidate Australia’s lead in the utilisation of waste materials in cements, with substantial reduction of CO₂ emissions.

VICROADS
VicRoads (Roads Corporation of Victoria), the state road authority in Victoria, is responsible for management of the state’s arterial road network, as well as driver licensing and vehicle registration. In collaborating with the Nanocomm Hub, VicRoads aims to develop novel cementitious binders with a lower carbon footprint, and concrete structures that perform better under extreme conditions. This project will produce accurate and practical design guidelines for infrastructure authorities and designers.

WUHAN ZHIHE GEOTECHNICAL ENGINEERING
Wuhan Zhihe Geotechnical Engineering Co Ltd (Zhihe) has a Class B certificate in building foundations, foundation engineering and underground structures construction. In conjunction with the Nanocomm Hub, Zhihe will establish unique state-of-the-art facilities for integral casting and prefabrication of geopolymer concrete modular structures. The Hub will enhance Zhihe’s reputation as an international leader in the design and manufacture of new generations of prefabricated modular structures.
AUSTRALIAN CATHOLIC UNIVERSITY

Australian Catholic University (ACU) is committed to the pursuit of knowledge, the dignity of the human person, and the common good. Together with the Nanocomm Hub, ACU plans to create new design materials that are environmentally friendly, sustainable, affordable and accessible. The joint project addresses the ACU and national research priorities of promoting the common good and social justice. The partnership will also help initiate and establish new research areas in ACU's School of Science, as well as spark research partnerships between ACU and other institutions.

MONASH UNIVERSITY

Monash University’s existing and emerging research strengths in civil engineering, materials engineering and nanotechnology underpin the work of the Nanocomm Hub. Civil Engineering (0905) received the highest Excellence in Research for Australia (ERA) rating (5 out of 5) in 2017. Materials Engineering (0912) and Nanotechnology (1007) also received this rating in 2017. Such recognition underscores the comprehensive research capacity of Monash University in areas relevant to the Hub.

RMIT UNIVERSITY

Civil and Structural Engineering at RMIT has a 4-star ranking in the 2017 Excellence in Research for Australia (ERA) report. In 2015, RMIT built a new advanced materials and structures laboratory at the Bundoora campus. The facility features state-of-the-art equipment, including a range of actuators, data loggers and a 14 m x 8 m x 1m thick rigid floor, as well as corrosion and durability materials testing chambers and non-destructive testing equipment.

DEAKIN UNIVERSITY

Both Macromolecular and Materials Chemistry (0303) and Materials Engineering (0912) at Deakin University were awarded the top ranking of 5 in the 2017 Excellence in Research for Australia (ERA) report. The Deakin Polymers Research Group, led by Prof Qipeng Guo, takes pride in its state-of-the-art synthesis, characterisation and processing facilities for polymer materials. This lab supports the development of environmentally friendly waterborne coatings. Owing to its association with Deakin’s Institute of Frontier Materials (IFM), the Group has open access to the IFM electron microscopy centre and x-ray platform.

QUEENSLAND UNIVERSITY OF TECHNOLOGY

Queensland University of Technology (QUT), a major Australian university with a truly global outlook, provides real-world infrastructure, learning and teaching, as well as graduate skills to the next generation of change-makers. The Nanocomm Hub’s vision to advance Australia’s construction sector through nanoscience complements the strategic directions of QUT.

SWINBURNE UNIVERSITY OF TECHNOLOGY

Swinburne University of Technology (Swinburne) has ranked in the top 150 worldwide for civil engineering in the Academic Ranking of World Universities Global Ranking of Academic Subjects. Swinburne and the Nanocomm Hub are jointly investigating the gap between design intent and outcomes of energy retrofit projects. Together they aim to increase confidence in retrofit designs, save public funds from ineffective retrofit schemes, improve thermal comfort, and reduce national energy consumption and carbon emissions. All of this aligns with Swinburne’s 2020 research and innovation strategy, including its goals of research excellence, impact and internationalisation.
THE UNIVERSITY OF MELBOURNE

The Melbourne School of Engineering (MSE) has a world-class research environment and provides high-quality intellectual support for its researchers. This is reflected in the Times Higher Education World University Rankings, which places the University of Melbourne at 70 in engineering and technology subjects. The work with the Nanocomm Hub fits well within MSE’s research themes of structured matter and sustainable systems and energy. This project will be conducted across two departments of the MSE: Chemical Engineering and Infrastructure Engineering.

UNIVERSITY OF NEW SOUTH WALES

With a highly collaborative and cooperative approach, the University of New South Wales (UNSW) works effectively with other universities, institutes and industry, reflecting its commitment to adding value to society. The goals of the Nanocomm Hub, in conjunction with Lindenbaum Pty Ltd, fit well with UNSW’s strategic direction, which aims to develop an advanced performance assessment and optimal design framework for practical nano and composite structures.

THE UNIVERSITY OF WOLLONGONG

The standing of the University of Wollongong (UOW) as a world-class research-intensive university has been confirmed by the Australian Research Council’s 2017 Excellence in Research for Australia (ERA) report. Working with the Nanocomm Hub, UOW will develop innovative construction materials that will transform Australia’s construction industry. They hope to not only meet our future infrastructure needs, but make the industry more profitable and competitive in global markets.

UNIVERSITY OF TECHNOLOGY SYDNEY

The University of Technology Sydney (UTS) Civil Engineering laboratory is well equipped with advanced structural testing facilities, highlighted by its advanced shake table facility. It is also known for its highly experienced academic and support staff. UTS research outputs greatly impact the utilisation of industrial by-products, the preservation of natural construction materials, and the application of cement with reduced clinker (reduced CO2 emission) content in durable concrete structures.

THE UNIVERSITY OF QUEENSLAND

The University of Queensland (UQ) offers an outstanding environment to support and produce high-quality research. Civil and Structural Engineering at UQ received a 5-star ranking in the 2017 Excellence in Research for Australia (ERA) report. In 2013, the School of Civil Engineering moved into the new Advanced Engineering Building, which contains a new structures laboratory with state-of-the-art equipment, including a wide range of MTS actuators and data loggers, as well as a 13 m x 13 m x 0.8 m thick rigid floor and a 5 m tall reaction wall.

THE UNIVERSITY OF WESTERN AUSTRALIA

Civil engineering is a strategic area that the University of Western Australia (UWA) has supported over the years. UWA’s Structures Lab features extensive equipment, including a pendulum impact test rig, a drop-weight test rig, a high-speed camera and a dynamic data acquisition system. A Split-Hopkinson pressure bar system of 25 mm in diameter has been recently set up for testing mine tailing and microcement materials. In collaborating with the Nanocomm Hub, these resources will be of great value.

WESTERN SYDNEY UNIVERSITY

At Western Sydney University (WSU), Prof Bijan Samali serves as Director of the Institute for Infrastructure Engineering, and Prof Zhong Tao as Program Director of Infrastructure Materials. In the 2017 Excellence in Research for Australia (ERA) report, WSU Materials Engineering (0912) was assessed as “world leading” and Civil Engineering (0905) as “above world standard”. The Structural Research and Testing Laboratory at the WSU Kingswood campus has been accredited by the National Association of Testing Authorities (NATA) since 2003.
To deliver improved environmental performance across the built environment industry, Nanocomm Hub exploits nanoscience and nanoengineering for the design and production of innovative and functional materials. The main focus is on improving the performance and lowering the carbon footprint of construction materials, decreasing whole-of-life asset costs and creating a more resilient and secure infrastructure.

At this research level, the Hub aims to manipulate materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale. To achieve key changes in material performance, the Hub pursues deep understanding of nano-improvement mechanisms from experimental/theoretical foundation of nano/micro-mechanics, chemistry and physics.

Such advanced investigations are made possible by collaboration with renowned institutions such as ANSTO, Australian Synchrotron and the Melbourne Centre of Nanofabrication, providing an impressive laboratory infrastructure for advanced material characterization.

Focused on specific industry and government needs, Nanocomm Hub pursues the following research themes:

- **Nanoscience and nanoengineering in construction materials:** in nanoscience, advanced nanomaterials science and characterization techniques promote scientific investigation at the nanometre scale; in the nanoengineering aspect, nanoparticle fabrication, properties and incorporation into construction materials are investigated.
- **New chemistry in construction materials:** understanding the chemistry of nano-cement/polymer interactions, exothermicity and pozzolanicity to help improve early hydration and strength development of sustainable cementitious materials such as geopolymers and high-volume fly ash concrete.
- **Physics of nano-modification:** multi-scale physical models/characterization techniques are developed to describe the nano-, micro- and macro-reinforcing behaviour of nanofibres and nanosheets. Particular focus is on the fracture mechanics, crack bridging and tensile behaviour of nano-reinforcements in construction materials.
Nanoscience and Nanoengineering for the design and production of innovative functional materials.
3.1.1 BACKGROUND

2D nanomaterials in concrete

2D nanomaterials (such as graphene oxide and boron nitride nanosheets (BNNS)) have been found to be among the most efficient reinforcing materials for cementitious material. Besides their superior Young’s modulus and mechanical properties, another prominent advantage is their large surface area, which improves their interaction with the composite matrix. In addition, BNNSs have superior thermal and chemical stability, contributing as potential reinforcing material to be used in harsh environments, i.e. well cement system.

3.1.2 OUR GOAL

Large-scale production of 2D nanomaterials is on the way

- Nanocomm Hub PhD student Wei Wang has developed a water ultrasonication method to produce BNNSs at large scale.
- With the aid of superplasticizers, BNNSs can be dispersed in cementitious materials.
- Results indicate that BNNSs are among the most effective nanomaterials for ordinary Portland cement (OPC) composites, exhibiting promising potential for enhancing the performance of future infrastructure.

3.1.3 INNOVATION

Exfoliation and dispersion of 2D nanomaterials are among the major challenges for the fabrication of nanocomposites. Current methods for exfoliating BNNSs are still low in efficiency. The alkaline environment of cementitious material is also a challenge for the dispersion of BNNSs.

Hub HDR student Wei Wang giving a presentation to hub visitors.
BNNS large-scale production via water ultrasonication

Nanocomm researchers discovered that water can be used for ultrasonication purposes without adding any surfactants. BNNSs produced by ultrasonication are in nanoscale. The thickness of BNNSs is mainly below 10nm as measured by Atomic Force Microscopy (AFM).

The dispersion stability of BNNSs in cement pore solution can be improved with the addition of surfactants, such as sodium dodecyl sulfate (SDS) and polycarboxylate (PC).

With only about 0.003% addition of BNNSs, the compressive strength and tensile strength of OPC were improved by 13% and 8%, respectively.

The effective reinforcing effect was revealed to derive from nucleation effect, pore structure refinement, and chemical bonding.

Efforts are now in progress to scale up the production of BNNS-cement to deliver construction industry material with higher performance.

3.1.4 TEAM

Wei Wang, Shu Jian Chen, Felipe B. de Souza, Bailin Wu and Wenhui Duan

Department of Civil Engineering, Monash University, Clayton, VIC, 3800, Australia,

CSIRO Energy, Clayton, VIC, 3168, Australia

Chemical vapour deposition (CVD) for large-area, high-quality synthesis of a range of 2D nanomaterials in Physics Lab, New Horizons, Monash University.
AMG has made graphene-based cement additive research a priority, and naturally sought out the expertise of A/Prof Duan and his group at Monash University for their particular expertise in adding carbon nanotube and graphene oxide particles to cement to achieve strength improvements.

– Advanced Material Group (AMG)
3.2.3 TEAM

Xupeii Yao, Ezzatollah Shamsaei and Wenhui Duan

Department of Civil Engineering, Monash University, Clayton, VIC, 3800, Australia

Nanocomm Hub researchers developed an easy method of fabricating GO-coated fibre at large scale under mild conditions. This interface modification method is feasible for fibres with various geometries.

Atomic force microscopy (AFM) is applied to measure the thickness of self-assembled GO sheets on fibre surface. The range of thickness of the GO layer on the fibre surface is estimated to be around 50 to 300nm.

Hub HDR student Xupei Yao characterizes the modification of nanomaterial.

Lakeshore TTPX Tabletop Probe Station for precise measurement of electrical properties of nanomaterials in Physics Lab, New Horizons, Monash University.
3.3 COATING CEMENT ON GRAPHENE

3.3.1 BACKGROUND
Mixing nanomaterials in concrete

Graphene oxide (GO), as a 2D nanomaterial, has been proved to significantly enhance the mechanical properties of concrete as an additive. However, due to the agglomeration of GO in the presence of divalent cation, the poor dispersion of GO in an alkaline cement environment restricts performance with high dosage.

At Monash University, researchers are developing a novel nanocoating, to be used as a nanomaterial paint, to prevent agglomeration of GO during cement mixing. These novel 2D nanohybrids have a layer of nanoparticles coated on the surface of 2D nanosheets such as GO.

3.3.2 INNOVATION
Coating 2D nanomaterials for enhanced dispersion

Agglomeration and precipitation of GO and newly developed SiO₂@GO were tested in pore solution for the initial 30 minutes of hydration.

Researchers discovered that GO with a coated silica layer has better dispersion in an alkaline cement environment, indicating that SiO₂@GO has significant potential as an additive into cement paste for enhancement.

Now the aim is to use this novel nanotechnology to improve the durability of cement-based materials.
and mechanical properties of large-scale concrete, helping the construction industry to deliver safer and more resilient concrete infrastructure.

3.3.3 TEAM
Junlin Lin, Ezzat Shamsaei, Felipe Basquirotto de Souza and Wenhui Duan

Nanocomm Hub researchers developed a novel nano-modification method to enhance the dispersion of 2D nanomaterials in cement composites. By coating cement on graphene surface, the agglomeration of graphene is significantly reduced, enabling its use in large concrete structures. This is another promising advance from Nanocomm Hub in the use of nanotechnology for sustainable infrastructure.

The remaining challenges for progressing research on nanofiller reinforced concrete composites include achieving an even dispersion of the particles. We propose to join forces in this Industrial Transformation Research Hub to take this next step, which will lead to exciting opportunities for the development of high-performance concrete with high impact resistance and durable concrete for marine environments.

– Advanced Material Group (AMG)
3.4 HYDROPHILIC VS HYDROPHOBIC

3.4.1 BACKGROUND

Marine environment vs concrete

Australian infrastructure is mostly built near marine zones, where durability and service life of concrete structures are important factors.

At marine zones, waterborne infiltration into concrete pores allows penetration of aggressive agents like ions into concrete body. That causes corrosion of steel rebar and severe deterioration of concrete structures.

Waste amorphous carbon powder (WACP) is produced from the waste materials of a solid and liquid paraffin production factory. It is a powder with amorphous structure and has three major elements, of which the greatest portion is carbon.

3.4.2 OUR GOAL

Elegant and economic solution

- A promising method for solving the durability problem of concrete is the use of hydrophobic agents.
- Hydrophobic agents can be used to significantly limit water ingress into concrete.
- Researchers at Monash University and Iran University of Science & Technology are investigating the possibility of adding WACP as a hydrophobic admixture in cement paste and concrete to reduce the permeability of cementitious composites.
3.4.3 INNOVATION

Nanocomm Hub researchers are exploiting WACP to make concrete hydrophobic and more durable against chemical attack.

It was discovered that adding WACP in concrete is an effective method to significantly reduce the permeability of cementitious composites and make concrete hydrophobic.

In addition, the electrical resistance of concrete increases considerably with more WACP in the mix. That means lower ingress of aggressive ions through the concrete pores.

Win-win situation

Previously, carbon waste has been deposited in the environment, causing serious environmental hazards.

Now, the waste can be recycled to develop high-value products, strengthening the global competitiveness of the Australian construction industry.

3.4.4 TEAM

Ramin Shahbazi¹, Asghar H. Korayem², Amir Razmjou³, Wenhui Duan² and Chien Ming Wang⁴

1. School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran
2. Department of Civil Engineering, Monash University, Melbourne, Australia
3. Faculty of Advanced Sciences and Technologies, University of Isfahan, Isfahan, Iran
4. School of Civil Engineering, The University of Queensland, Queensland, Australia

Hub research fellow Dr Asghar Korayem (left) giving a poster presentation.
NANOSCIENCE

3.5 2D NANOENGINEERING OF CONCRETE

3.5.1 BACKGROUND

Nanoengineering of widely used concrete

There is a wide consensus in the research community that concrete, responsible for huge environmental impact across the globe, must be engineered at the nanoscale, where its properties can be truly enhanced. However, practical nanoengineering of cement composites, suitable for in-situ construction, has been long considered a fundamental challenge.

But this hurdle is about to become a thing of the past.

3.5.2 OUR GOAL

Controlling cement at nanoscale

Nanocomm Hub researchers have recently discovered a promising nanoengineering method for concrete materials. By using GO, a nanomaterial available in bulk quantities and at low cost, nano-control over cement crystals has been achieved. Future efforts are to scale up this promising technique with the view of making concrete infrastructure more sustainable.

3.5.3 INNOVATION

After years of investigation, researchers at Monash University discovered that GO, a largely available product obtained from low-cost graphite, has considerable potential to finally achieve the long-desired nanoengineering of cementitious composites.

Secret in 2D

Nanocomm Hub researchers exploited the unique synergetic properties of 2D nanomaterials to manipulate, at nanoscale, the properties of cement. With the use of advanced nano-characterization, it was discovered that 2D GO nanosheets can modify the growth of cement crystals. Cement crystals grown with GO nanosheets exhibit enhanced nanostructure and mechanical performance, essential properties for concrete durability.

3.5.4 TEAM

Felipe B. de Souza, Ezzatollah Shamsaei, Shujian Chen and Wenhui Duan

Department of Civil Engineering, Monash University, Clayton, VIC, 3800, Australia
Sinoma aims to develop next-generation cementitious materials with a low carbon footprint, low energy intensity and higher performance. Through this research hub, Sinoma Int’l proposes to work with Monash on optimizing the performance of concrete composites by the combination of synergetic nanomaterials. An important step is therefore understanding the underlying knowledge and theory for nano-level solutions and interaction. Through collaboration with Monash University and other world leaders in cement technologies, the efficient achievement of these aims and dissemination of the solutions are expected.

– Sinoma International
3.6 2D TO 3D

3.6.1 BACKGROUND

Durability of concrete and pore structure

The pore structure of concrete plays a key role in its mechanical properties, permeability and durability.

Characterization of concrete’s porosity can assist in prediction of the durability of Australian’s infrastructure. However, it is difficult to characterize detailed 3D information by conventional methods. On the other hand, 2D pore structure obtained from microscopic images cannot represent the complex pore structure of these materials.

3.6.2 OUR GOAL

A promising solution may come from statistical information

- Nanocomm Hub PhD student Yanming Liu used advanced statistics to develop a method that can reconstruct concrete porosity at nanoscale.
- The model fits closely with experimental data and the method has promise for predicting the durability properties of concrete.

3.6.3 INNOVATION

To overcome characterization limitations, researchers at Monash University developed a statistically based method for reconstructing, with nanoscale resolution, the 3D pore network of concrete materials. The method only needs 2D pore profile pictures of the material, easily accessible with a microscope.

This promising model can be described as follows. After acquiring high-resolution 2D pore profiles of cement composites, the profile images are combined into a probability map. A 2D wave function is then derived from the probability map. Fourier transform is used to decompose the wave function into multiple sine plane waves.
Finally, an ellipsoid-packing model is used to represent the sine wave and then collapse the wave function into a 3D structure.

Reconstructed models of cement composites have been simulated and compared with experimental mercury intrusion porosimetry (MIP) results. The close fit between modelling and experiments indicate that the model can be used to confidently predict the 3D structure of concrete from 2D images.

Researchers hope that this reconstruction will aid civil engineers to design more resilient concrete.

3.6.4 TEAM

Yannming Liu, Shujian Chen and Wenhui Duan

Monash University
Department of Civil Engineering, Monash University, Australia

3D reconstruction is found to accurately represent real cement porosity and it can be used by civil engineers to design more resilient concrete structures.
Currently, there is no method available for performance assessment and optimal design for nano and composite structures considering the intrinsic system uncertainties.

The ARC Nanocomm Hub nanoscience-based research fills in this gap and will definitely produce excellent research outcomes.

– Lindenbaum Pty Ltd
A Nanocomm Hub research team has developed a novel method for analysing cement porosity, which plays a key role in the durability of concrete infrastructure. The outcome is already guiding the optimization and design of nano-modified cement materials.

3.7.3 INNOVATION

Novel pore analysis

By using the RDF, the Nanocomm Hub research team has developed a novel method for analysing cement porosity, which plays a key role in the durability of concrete infrastructure.

To accomplish such advanced characterization, a combination of a metal intrusion technique, high-resolution 2D pore profile characterization, and compression and tensile tests have been developed.

The spatial pore distribution of cement paste with the addition of GO was first observed by Monash University researchers. The developed RDF method of pore analysis was found to be suitable to quantify changes in the pore structure of cement materials.

Outcomes are already guiding the optimization and design of nano-modified cement materials.

3.7.4 TEAM

Chengke Ruan, Shujian Chen and Wenhui Duan

Department of Civil Engineering, Monash University, Australia
3.8 GRAPHENE AND POROSITY

3.8.1 BACKGROUND

Light and strong

Metal foams have significantly improved structural stiffness and energy absorption, exhibiting strong potential for use in protective structures.

One practical approach for further improving the strength of metal foams is to reinforce such advanced composite material with ultra-lightweight nanofillers such as carbon nanotubes (CNTs) and graphene platelets (GPLs).

However, mechanical modeling of such nano-reinforced metal foams is still at an early stage, which prevents its structural use.

Nanocomm Hub researchers at UNSW have recently developed a mathematical analysis for enhancing the properties of nano-reinforced porous metals. The analysis brings novel insights for the design of protective structures, making infrastructure safer and more durable.
3.8.2 INNOVATION

Computational analysis for more efficient porous materials

Researchers at UNSW have developed a novel isogeometric analysis (IGA) framework to investigate free vibration and buckling analysis of metal foam nano-reinforced with GPLs.

The group of researchers discovered that the inclusion of GPLs remarkably strengthened porous metals. The more GPLs were inserted, the stiffer the porous metals. In particular, improvement of the critical buckling load is more significant than other structural performance.

The research group also noted that the dimensions of the GPLs influenced the reinforcement effects. GPLs with fewer single graphene layers and larger surface areas resulted in stiffer porous metals.

Such information is beneficial for engineering practice, and the proposed method will certainly be implemented for the real-life structural design of these promising materials.

3.8.3 TEAM

Keyan Li, Di Wu and Wei Gao

Centre for Infrastructure Engineering & Safety, School of Civil and Environmental Engineering, The University of New South Wales, NSW 2052, Australia
3.9 X-RAY CT IN CONCRETE

3.9.1 BACKGROUND

Monitoring deterioration

Deterioration of cement-based materials exposed to sulphate attack is a crucial problem throughout the world. Lack of understanding of the deterioration process prevents effective mitigation measures.

Traditional methods for studying sulphate attack on concrete include measuring the mass change, strength, and also observation of corrosion products using SEM and XRD. However, these methods cannot evaluate 3D damage evolution in concrete samples, making structural damage analysis limited and unreliable.

3.9.2 INNOVATION

Using X-rays to monitor structures

In collaboration with Southeast University, Nanocomm Hub researchers are using an in-situ X-ray CT method to track the 3D damage evolution of internal structures of cementitious materials. The method is non-destructive and therefore does not damage the delicate internal structure of the samples.

Using this novel method, the group of researchers obtained quantitative observation of sulphate attack on cement pastes. The evolution of crack spatial distribution, pore distribution and corrosion depth, crucial parameters for durability evaluation of concrete structures, was measured with nanometre-resolution.
3.9.3 TEAM

Yonggan Yang¹, Yunsheng Zhang¹ and Wenhui Duan²

¹. School of Materials Science and Engineering, Southeast University, China
². Department of Civil Engineering, Monash University, Australia

The Zeiss Xradia 520 Versa at Monash X-ray CT facility enables submicron imaging of micro-structural features of materials.

Nanocomm Hub HDR student Yonggan Yang uses X-ray computed tomography (X-ray CT) to quantitatively measure the corrosion process of cement pastes exposed to sodium sulphate. The results yield new insights for making concrete more durable in such aggressive environments and minimizing repair costs of Australian infrastructure.
3.10 DURABLE GREEN CONCRETE

3.10.1 BACKGROUND

Due to their rapid strength development and enhanced microstructure, alkali-activated materials (AAMs) have attracted increased attention for the repair of concrete. A promising application is the use of AAM to reduce the high cost of repair and maintenance of concrete in sewage systems. However, the durability of AAM in aggressive abiotic and biotic environments has not been fully explored.

3.10.2 OUR GOAL

- Produce AAMs resistant to mineral acids such as sulphuric acid and phosphoric acid
- Reduce repair costs in sewage systems

3.10.3 NANOSCALE UNDERSTANDING

Comprehensive investigation was conducted by University of Melbourne researchers to gain nanoscale understanding of the degradation process of AAM in an acid environment. Advanced video-microscope, CT scanning and other mineralogical analyses were used to accurately measure the degradation of different AAM binders.

The research team discovered that the degradation process of AAMs differs from that of OPC. The deterioration can be divided into two stages, an early stage and a later stage. The early stage delays the degradation process, with less degradation depth compared to OPC-based binders.
3.10.4 INNOVATION

Based on the nanoscale knowledge, novel AAM designs were developed to improve the acid resistance of alkali-activated binders. It was found that AAMs with the slag/fly ash ratio of 60:40 produced the best performance in the acid environment. Fundamental understanding from this study will assist future less onerous design of concrete structures for aggressive environments.

3.10.5 TEAM

Jie Ren, Rackel San Nicolas and Lihai Zhang

Department of Infrastructure Engineering, the University of Melbourne, Australia

Researchers at the University of Melbourne have studied in depth the behaviour of AAMs in acid environments. The results assisted the deve Hub researchers at the University of Melbourne study in depth the behaviour of AAMs in acidic environments. The results assist the development of more durable construction materials for sewage systems. Development of more durable construction materials for sewage systems.

This project opens a new avenue for the development of greener, stronger and more durable geopolymer concrete.

– Zeobond
This year Nanocomm Hub has witnessed a wide range of valuable outcomes in construction material innovation. Cooperating with industry and government partners, researchers from different universities worked together and achieved a series of breakthroughs in construction material creativity. Directed by Prof. Wenhui Duan, the research outcomes are focused to match specific needs of industry and government.

Project outcomes have delivered new knowledge and tools targeting:

- Low energy consumption and sustainable construction material. Current cement manufacturing processes are revolutionized by re-designing clinker mineralogy using nano-technologies in order to produce sustainable cement with lower energy consumption.
- Cementitious material with excellent in-situ performance. Outstanding mechanical properties and excellent durability play a key role in developing safer and more cost-effective construction. In-depth characterization will be undertaken to investigate the performance of novel cementitious material under complex exposure conditions.
- Advanced smart construction material. Construction materials with multiple functions are developed to provide a better living and working environment.

Advanced techniques are applied in material design, with the aim of meeting complex in-situ requirements for various applications.

The objective of this program is to lead the development of next-generation construction materials. Nanocomm Hub is keen to foster material creativity, aiming to revolutionize civil engineering with low energy consumption, high physical performance and durable cementitious material using cutting-edge nano-techniques.
Revolutionize civil engineering with low energy consumption, high physical performance and durable cementitious material using cutting-edge nano-techniques.
4.1 BACKGROUND

The cement industry is a large CO₂ emitter in Australia. In Australia, the industry is responsible for around 7.2 Mt per annum of greenhouse gas emissions. In 2013–14, the Australian cement industry produced approx. 6 million tons of cement from cement rotary kilns, consuming approx. 2 Mt coal as the fuel to heat the rotary kiln up to 1500°C.

Victorian brown coal (VBC) is the single largest energy source in the state of Victoria, of low grade though abundant. To solve the increasingly serious energy and environmental problems, brown coal is considered as a substitute fuel for feeding cement rotary kilns.

4.1.2 OUTCOME

Economic, sustainable, environmentally friendly
- Reducing the greenhouse gas emissions from brown coal
- Tailoring the level of moisture of the VBC according to the end application
- Economical method for upgrading abundant VBC as a replacement for black coal

4.1.3 INNOVATION

Novel pyrolysis method

Based on cooperation between Monash University and Coal Energy Australia (CEA), a novel pyrolysis method was applied to upgrade VBC, in order to maximize the potential of beneficial brown coal and its blends in the domestic cement industry.

The low emission carbon capture and storage technology development in this project will also benefit the cement industry, contributing to solving global energy and environmental problems.

Nanocomm Hub researchers apply Victorian brown coal beneficially for use in cement kilns to cut down the CO₂ emission from cement industry.
Work with the Nanocomm Hub opens opportunity for our beneficiated products to be tested in a variety of different cement rotary kilns for the production of clinker, a precursor material for the production of final cement. This would eventually enhance the penetration of our products into the domestic cement industry.

– Coal Energy Australia (CEA)
CONSTRUCTION MATERIALS

4.2 NANO $\alpha$-Fe$_2$O$_3$/MgO FROM WASTE

4.2.1 BACKGROUND
Fly ash, a coal combustion product that is driven out from coal-fired boilers, is widely produced. More than 1 million tonnes of fly ash is generated in Victoria every year. However, utilisation of the fly ash is low efficiency; most of it is disposed into ash ponds, with potential environmental threats to air, soil and underground water.

4.2.2 OUR GOAL
“Waste to Wealth”
With a novel sustainable technique, “waste” can be turned into “wealth”. MgO and $\alpha$-Fe$_2$O$_3$ generated from low-grade fly ash can be made into different products in a diverse range of fields, such as MgO wallboard, absorbent material, catalysis, refractory contexts, cancer therapy, and antibacterial and superconductor uses.

4.2.3 INNOVATION
Monash University has invented a novel sustainable approach for reusing fly ash, by extracting high-purity nano-minerals from the waste:

- Synthesis of high-purity nano-MgO from both low-grade Hazelwood fly ash and Yallourn fly ash at room temperature.
- Synthesis of high-purity $\alpha$-Fe$_2$O$_3$ nano sheets and regeneration of HCl gas from HCl leaching of low-rank coal fly ash.

From left to right: Hub research fellows Dr Ezzat Shamsaei, Dr Tahereh Hosseini and Dr Hanaa Hegab.
Nanocomm Hub researchers have changed “waste to wealth”, producing high-purity nano-MgO and nano-Fe₂O₃ from low-grade coal fly ash.

4.2.4 TEAM

Tahereh Hosseini, Binbin Qian, Song Zhou and Lian Zhang

MONASH University
Department of Chemical Engineering, Monash University, Australia
4.3 ACIDIC WASTE IN MINING

4.3.1 BACKGROUND

Acid waste drainage occurs naturally within some environments as part of the rock weathering process but is exacerbated by large-scale earth disturbances such as mining and other large construction activities. Improper treatment of these acidic waste can cause serious and even catastrophic environmental problems, resulting in a huge economic cost.

4.3.2 CHALLENGES

Despite the serious results of improper acid waste treatment, the drawbacks associated with the current acid waste treatment unfortunately limit its application.

- high energy consumption
- massive sludge waste
- involvement of hazardous chemicals
- lack of acid recovery

4.3.3 INNOVATION

To solve this problem, Monash University has invented graphene-polymer composite ion exchange membranes for acid waste water treatment. As an advanced atom-thin nanomaterial, graphene-based material was integrated into the membrane matrix, significantly improving the overall membrane performance.

The ultra-thin graphene-based material exhibited superior separation and acid recovery, almost 4 times better than commercial dense membrane. This is a sustainable solution for efficiently converting waste into wealth through the repeated recycling of industrial acidic waste.
4.3.4 TEAM

Hanaa Hegab, Huanting Wang

Monash University

Department of Chemical Engineering,
Monash University, Australia
CONSTRUCTION MATERIALS

4.4 LIGHT BURNT MAGNESIA

4.4.1 BACKGROUND

Magnesium oxychloride cement (MOC) is a novel, green cementitious material. Compared with Portland cement, MOC has many superior qualities, such as rapid setting and hardening, high strength, good fire resistance and low thermal conductivity. However, associated problems restrict the wide application of MOC:

- Rehalogenation, in which free MgCl2 extrudes from hardened cement and appears on the surface of MOC products;
- Wrap distortion, in which concentrated hydration heat and CaO in MOC lead to uneven volume expansion of MOC boards;
- Poor water resistance, in which unstable hydration phases in MOC result in notable strength loss of MOC after immersion.

4.4.2 OUR GOAL

Economy, high strength, excellent durability

- Develop a new MOC with enhanced material properties and water resistance.
- Study the influence of fly ash with silica fume on the properties of MOC, and set up a model combining strength retention coefficients and different parameters
- Achieve deep understanding of the mechanism of water resistance enhancement with different additives applied in MOC.

4.4.3 INNOVATION

To solve the present problems of MOC, Nanocomm Hub researchers have developed a new MOC with enhanced material properties and water resistance. The addition of fly ash and silica fume increase the water resistance and mechanical properties of MOC significantly, while decreasing the fluidity and retarding the hydration process of MOC paste.

This novel sustainable MOC shows great potential for wider application in the construction industry.

The anticipated research outcomes are to enhance the performance and the mechanical and physical properties of magnesium oxychloride cement products, leading to significant improvement in product reliability and economic benefits to UBIQ Australia.

– UBIQ Australia
4.4.4 TEAM

Yingying Guo\textsuperscript{1}, Y. X. Zhang\textsuperscript{1} and Khin Soe\textsuperscript{2}

1. School of Engineering and Information Technology, University of New South Wales, Canberra, Australia

2. UBIQ PTY LTD, Australia

Nanocomm Hub researchers analyse the microstructure of magnesium oxychloride cement (MOC) to investigate the influence of fly ash and silica fume addition. The developed novel cementitious material features enhanced material properties and water resistance with great potential for wide application towards a greener cement industry.

HDR student Yingying Guo (centre) in a hub group discussion.
The Expertise in Nano technology offered by Nanocomm Hub will enable Adbri Masonry to improve these key raw materials and products: cement substitutes; natural aggregate substitutes; recycled concrete products; permeable paving.

– Adbri Masonry

4.5 COAL FLY ASH

4.5.1 BACKGROUND

Geopolymers, as environmentally friendly alternatives to Portland cement, are made by reacting materials containing aluminate and silicate with a highly alkaline activator. Materials used include combustion products such as coal fly ash and slag.

Australia is the 4th largest brown coal producer in the world. The majority of the waste products (brown coal fly ash) are stored in ponds or sent to landfill, imposing negative environmental impacts such as groundwater contamination.

Hoping to utilise and reduce such waste materials, Nanocomm Hub aims to investigate the feasibility and develop an optimized methodology for the manufacture of brown coal fly ash geopolymer masonry product. An additional advantage of replacing Portland cement with geopolymer is the expected reduction of CO2 emission by 25-45%.
Rehabilitation of AGL Loy Yang mine sites requires huge quantities of soil to cap exposed coal batters and reactive overburden material. Our specific interest to collaborate with Nanocomm Hub is mainly through the development and use of the nanoscience-based construction materials for mine rehabilitation. We work in conjunction with the Hub to draw upon their expertise on the nano-based materials and examine their potential use in mine rehabilitation works.

– AGL Loy Yang
CONSTRUCTION MATERIALS

4.6 EXTREME LOADING

4.6.1 BACKGROUND
Brittle fractures are commonly found in rock, concrete, ceramic and other brittle materials. The size of fracture can range from micro-scale crack to several kilometres. Understanding the dynamic failure pattern and mechanism is essential in dealing with various civil engineering problems such as underground excavation projects, earthquake research, penetration and blasting events and mining.

A 3D split Hopkinson pressure bar (3D-SPHB) located in Monash University allows Dr Qianbing and Prof. Jian to test the dynamic fracturing behaviour of brittle materials. The impact velocity ranges from 3 to 50 m/s and quasi-static pressure can reach 100 MPa.

4.6.2 INNOVATION
In this project, the research team from the Nanocomm Hub has adopted a number of cutting-edge technologies to study the dynamic fracturing behaviour of brittle materials:

- A ballistic impact loading system and 3D split Hopkinson pressure bar (3D-SPHB) are used to damage samples.
- Ultra-high-speed cameras are utilised to record the dynamic fracture events of different fracture modes.
- 3D digital image correlation (3D-DIC) and acoustic emission are used to obtain full-field strain measurement and crack coalescence processes.
- SEM and X-ray CT allow us to study the micro-scale damage resulting from dynamic loading.

4.6.3 TEAM
Qianbing Zhang and Jian Zhao

Department of Civil Engineering, Monash University, Australia
Tritech Group Limited (TGL) businesses focus on high-technology oriented engineering products and services. TGL is specifically interested in the development of products, i.e., nano-based new construction materials applicable to underground space development. The collaboration and project outcomes will certainly be of benefit to TGL in the future, as TGL will be actively involved in underground space development worldwide. The new construction materials will enhance the position of TGL as the leader in underground space construction, development and technology.

– Tritech Group Limited
4.7 FIRE RESISTANCE

4.7.1 BACKGROUND

Fire protection is a fundamental aspect of building construction, as it delays the temperature increase in structures in case of fire, allowing structural members to maintain structural integrity within a specified time frame. Spray-applied fire resistant materials (SFRMs) are the most commonly used passive fire protection for steel structures.

In 2001, around 480 million tonnes of coal combustion products (CCP) were created by coal-fired power generation worldwide. Australia and New Zealand alone produced 13.5 million tonnes of CCP in 2006/2007, but currently in Australia only 13% of the CCP is utilised. These statistics demonstrate the high availability of fly ash in Australia and also bring into view the environmental implications of large amounts of wastes generated from coal.

4.7.2 OUR GOAL

The new SFRM will be cost-effective and will reduce the pressure on carbon emissions through the use of CCP.

The key expected outcomes include the new SFRMs which:
- Comply with regulatory requirements (ASTM)
- Have commercial value and are cheaper than existing products in the local market
- Are partially made of industrial combustion materials

4.7.3 INNOVATION

A Nanocomm Hub research team at WSU is developing novel “green” SFRMs by adding combustion by-products (fly ash), natural minerals and small amounts of nanomaterial to improve tensile strength, strain capacity and bond strength.

4.7.4 TEAM

Qingtao Huang, Zhong Tao, Zhu Pan and Md Kamrul Hassan

Centre for Infrastructure Engineering, WSU, Australia
Nu-Rock’s breakthrough nu-cement technology converts all waste from coal-fired power stations, steel mills, non-ferrous smelters and alumina smelters into a range of unique and superior masonry products for building, construction and civil engineering. Partnering with WSU and other industry partners in the Hub will certainly expand our core competencies into new areas of expertise.

– Nu-Rock
CONSTRUCTION MATERIALS

4.8 WATERPROOFING SOLUTIONS

4.8.1 BACKGROUND

Waterproofing is a fundamental aspect in the building construction industry, protecting structures from water damage in cases where moisture control is crucial. The waterproofing membrane market size is predicted to reach $10.9 billion USD by 2024. Fortis have recognised a significant commercial opportunity and decided to develop their very own waterproofing membrane formulation.

4.8.2 OUR GOAL

The formulated waterproofing membrane product must meet the following requirements as per AS/NZS 4858:2004:

- Elongation: the material must exceed 300% elongation at break as per AS 1145 (class III high extensibility)
- Water absorption: the water absorption capacity of the material must be recorded
- Requirement for joint movement: the material must allow at least 200% elongation over joints (class III high extensibility)
- Moisture vapour transmission rate: the material must limit the transmission of water vapour to less than 8g / m2 / 24hr as per ASTM E96
- Acceptance of cyclic movement: must satisfy CSIRO moving joint test

Hub research assistant Thomas Winnell (centre) in a group discussion at Hub End-of-Year Meeting in Brisbane.
4.8.3 INNOVATION

Liquid-applied waterproofing membranes are a paint-like product that can be applied on surfaces. The solution forms a seamless, rubber-like elastomeric membrane. Thomas from the Nanocomm Hub collaborates with Fortis to develop a liquid-applied waterproofing membrane with significant advantages by using nanotechnology:

- Low odour
- Low volatile organic compound
- Free of toluene di-isocyanate
- Low monomer content.

4.8.4 TEAM

Thomas Winnell¹ and Phillip Arena²

¹. Department of Civil Engineering, Monash University, Australia
². Fortis Adhesives & Coatings Pty. Ltd., Australia

Nanocomm Hub collaborates with Fortis Adhesives & Coatings to develop new waterproofing membranes for more effective and cost-efficient protection solutions for building industry. The developed product will be commercialized by Fortis in the future. The image shows the morphology of liquid-applied waterproofing membranes.

Applying paint-like waterproofing membranes on construction site.
4.9 GREEN PAINT

4.9.1 BACKGROUND
Solvent-borne paints are widely used in the construction industry for the purposes of corrosion protection, building protection, building decoration and waterproofing. However, traditional solvent-borne coatings contain large amount of volatile organic compounds (VOCs) and no longer meet the increasing demand for sustainability and environmental protection. This drives paint producers towards the development of waterborne paints.

Unfortunately, most existing waterborne coatings available have weak mechanical performance and haze problems. Hence, waterborne coatings cannot yet replace solvent-borne coatings.

4.9.2 OUR GOAL
The Nanocomm Hub research team in Deakin University is developing a novel kind of waterborne coating that overcomes the abovementioned weaknesses. The coatings are aqueous polymer dispersions of water-soluble polymers; once the film is formed, the coating will have good mechanical performance, hydrophobicity, gloss, flatness and light transmission as well as low haze.

4.9.3 INNOVATION
Nanocomm Hub researchers have successfully synthesized and prepared totally VOC-free green waterborne acrylic copolymer water dispersions, possessing significant thermal stability and film forming properties. In the next stage, we will conduct deep research into the curing of the water dispersions film, investigating the rheology behaviour. The polymerization formula will be slightly adjusted according to the film’s performance. The diameters of the water dispersion particles will also be adjusted by controlling the self-assembly of the micelles.
4.9.4 TEAM

Guangwu Guan¹, Sha Ji², Ming Zhou² and Qipeng Guo¹

1. Institute of Frontier Materials, Deakin University, Australia

2. Jiangsu Shisong New Material Technology Co. Ltd., China

Hub chief investigator Prof Qipeng Guo (centre) with HDR students Sha Ji (left) and Guangwu Guan (right) at Deakin University are creating a new generation of coating materials for a cleaner, safer planet.
Nanocomm Hub researchers seek to pursue routes for innovative structural design and structural performance improvement towards durable, resilient, sustainable and intelligent infrastructures and buildings, as well as a safe construction environment.

Investigation of the following aspects at structural scale is carried out in our research, with close links to government and industry:

- Design guidelines, where the behaviour of ultra-thin concrete structural members and such elements in steel/concrete composite structures are examined;
- Innovative structural design, where the novel design concepts of structures that are resilient and durable in complex environments are demonstrated, along with their unique strengths;
- Advances in 3D printing concrete technology, where the challenging issues of printed cementitious materials are studied, with novel reinforcing development towards smart, functional, lightweight and high-performance printed cementitious materials for engineering applications;
- Improvement of construction work safety, where protective structures and intelligent construction equipment with real-time responses are designed for performance and safety enhancement.

Besides the development of high performance concrete manufactured from a full range of concreting materials with advanced nanoscience-based knowledge and technologies, Nanocomm Hub also aims to enable the use of the new high performance concretes in design and construction.
Innovative structural design and structural performance improvement towards durable, resilient, sustainable and intelligent infrastructures and buildings, as well as a safe construction environment.
INNOVATIVE STRUCTURES

5.1 CONCRETE CONFINED BY FIBRE-REINFORCED POLYMER (FRP)

5.1.1 BACKGROUND

Corrosion-resistant concrete reinforcement replacing steel

Deterioration of civil infrastructure constructed from steel and concrete has led to massive rehabilitation and maintenance costs worldwide. There is thus a strong and urgent need to develop novel structures which are highly resistant to environmental attack. This is particularly important for Australia, with its long coastline where corrosion of steel structures is of great concern.

FRP composites have emerged rapidly in the past two decades as durable construction material. However, existing design methods for steel-reinforced concrete structures may not be applicable to FRP composites, due to their unique properties. Also, the long-term behaviour of FRP tubes and bars in a pile that is subject to sustained loading and harsh coastal/ocean environments remains to be investigated.

5.1.2 OUR GOAL

- To develop specific design methods for corresponding FRP-reinforced concrete structures.
- To evaluate the long-term performance of such structures under harsh coastal/ocean environments.

Nanocomm Hub researchers are designing reliable hybrid FRP-concrete tubular piles as corrosion-resistant solutions in coastal regions.
5.1.3 INNOVATION

Hybrid fibre-reinforced polymer-concrete tubular piles

Nanocomm Hub researchers from the University of Wollongong (UoW) are studying the behaviour of, and developing reliable design methods for, hybrid FRP-concrete tubular piles as a durable replacement for prestressed steel-reinforced concrete piles in coastal regions. They have designed a series of laboratory experiments and theoretical analyses to investigate the properties of hybrid FRP-concrete tubular piles.

Expected project outcomes will include:

- In-depth understanding of the mechanical behaviour and durability of hybrid piles
- Production of a design manual to facilitate the wide application of hybrid piles

To date, the design and optimization of section configuration of the novel hybrid piles against static loading has been completed.

With close collaboration with the industry partner, future work will focus on the durability and impact behaviour of the hybrid piles.

5.1.4 TEAM

Guanzheng Wu, Tao Yu and Hongchao Zhao

School of Civil, Mining and Environmental Engineering, Faculty of Engineering and Information Sciences, UoW, Australia

Replacement of prestressed steel-reinforced concrete piles with novel piles incorporating FRP reinforcement is of vital importance for civil infrastructure close to the coastal regions where corrosion is a great concern.

– Nanjing Fenghui
INNOVATIVE STRUCTURES

5.2 GLASS IN CONCRETE

5.2.1 BACKGROUND

Conventional steel-reinforced concrete structures suffer from the critical problem of steel corrosion, especially in harsh, corrosive, and coastal environments, which can cause structural failure due to greatly reduced reinforcement capacity.

As an emerging construction material, glass fibre reinforced polymer (GFRP) is completely resistant to corrosion and has high strength to weight properties. It has the benefits of low density and high strength, making it advantageous as a reinforcing component in concrete structures, instead of steel.

The main challenges to be addressed for GFRP to be applied in construction industries are lack of experimental tests and lack of an available design code.

5.2.2 OUR GOAL

- To improve the durability of GFRP-reinforced concrete structures
- To pave the way for industrial application of GFRP-reinforced concrete through the development of design guidelines.

5.2.3 INNOVATION

In this project, researchers at the University of Western Australia and the Nanocomm Hub have performed mechanical tests on designed GFRP-reinforced concrete columns and analysed their failure modes under concentric loading and four-point bending.

The current project evaluates the performance of GFRP-reinforced concrete structures and discovers the deformation compatibility between different materials. It paves the way for relevant structural guideline design and industrial application of durable and corrosion-resistant GFRP-reinforced concrete structures.
The durability of concrete structures is a complex issue for engineers and builders all over the world. GFRP bars are not subject to the same type of corrosion displayed in traditional steel reinforcement and can be quite cost-effective due to decrease in labour time and costs in construction and near elimination of maintenance costs.

– Airey Taylor Consulting
5.3 AFS: INTERFACE

5.3.1 BACKGROUND

Improving the properties of concrete and plastic formworks

Self-compacting concrete (SCC), a concrete mix featuring low yield stress, high deformability, good segregation resistance and moderate viscosity is a suitable alternative to normal concrete. However, usage of SCC causes an increase in pressure exerted on the formwork, the effects of which need to be understood for the application of these composite structures.

AFS Logicwall panels and AFS Rediwall panels are PVC wall panel systems developed by CSR Building Products, an industry partner in the ARC Industry Transformation Nanocomm Hub. These panel systems act as a permanent formwork for in-situ concrete walls and feature light weight and quick on-site installation.

These plastic formworks with concrete infill have many benefits over traditional wood, steel and aluminium formworks. An optimized strong bond between the filled concrete and the PVC wall panels will enhance the performance of the permanent formwork system.

Nanocomm Hub research team at Western Sydney University works on AFS Logicwall (left) and AFS Rediwall (right) panel systems and their bonding with the filled concrete for the optimum performance of the plastic formwork system in practice.
5.3.2 OUR GOALS

• Optimizing infill concrete pressure on Logicwall
• Improving chemical properties of plastic Rediwall formworks

5.3.3 KEY FINDINGS

The research team in WSU has found that:

• Maximum lateral pressure exerted by SCC is equal to the hydrostatic pressure of a liquid with the same density as the mix for infill concrete.
• Formwork height (casting depth) is a significant factor in SCC lateral pressure. Taller walls/columns exhibit higher pressure on the floor of the formwork.
• It is important to optimize the flowability and workability of low-flowable concrete to inhibit void between the concrete and the formwork systems.

5.3.4 TEAM

Reza Ardalan, Zahra Nouri Emamzadeh, Maryam Ghodrat, Babak Abtahi and Bijan Samali

Western Sydney University
Centre for Infrastructure Engineering, Western Sydney University, Australia
5.4 AFS: PERFORMANCE

5.4.1 BACKGROUND

In conjunction with a previous project, researchers at WSU continue to optimize the design of CSR’s loadbearing permanent formwork. Along with CSR, they examined the structural performance of AFS Logicwall and AFS Rediwall permanent formwork systems, conducting experimental lab tests and numerical simulations to justify the structural performance. Results are compared between AFS systems and conventional concrete columns to identify the pros and cons of using the systems in practice.

5.4.2 OUR GOALS

- To examine the structural performance of two permanent formwork systems with the proprietary names AFS Logicwall and AFS Rediwall.
- To conduct experimental lab tests and numerical simulations to justify the structural performance as per the requirements of AS3600:2009.
- To compare the results of AFS systems with conventional concrete columns and to identify the pros and cons of using the systems in practice.

5.4.3 INNOVATION

Six samples of Logicwall and Rediwall panels along with six samples of conventional columns instrumented with strain gauges and linear variable differential transformer (LVDT) sensors for local deformation measurement were designated for lab tests. The ABAQUS platform was used for numerical simulations using various calibrated constitutive laws based on the theory of plasticity and experimental test results.
Comparisons of the test and numerical results indicated good agreement. The test results showed a 15% improvement of the Logicwall panels in axial capacity compared to the conventional columns, with no tangible changes in the Rediwall panels. These results indicate a comparable or improved loadbearing capacity of these formwork systems compared with conventional concrete, but with superior ease of on-site installation.

5.4.4 TEAM
Kamyar Kildashti and Bijan Samali

WESTERN SYDNEY UNIVERSITY
Centre for Infrastructure Engineering, Western Sydney University, Australia

Filling AFS formwork systems with concrete on site.

Testing the failure of AFS wall sample in Western Sydney University research laboratory.

Hub research fellow Dr Kamyar Kildashti presenting at Hub Mid-of-Year Meeting 2018
INNOVATIVE STRUCTURES

5.5 GREEN CONCRETE

5.5.1 BACKGROUND

Design development in precast engineered component application

Geopolymer concrete is gaining increased attention for use as a structural material. It is an environmentally friendly binder, owing to its ability to significantly reduce the greenhouse gas emission released during the production of OPC binder. For better utilisation of geopolymer concrete, further investigation is required in two key areas: durability and structural behaviour of precast components.

5.5.2 OUR GOALS

In collaboration with Cement Australia, the Hub researchers from the University of Technology Sydney are investigating a novel powder-based geopolymer to address the aforementioned issues. They will also address overcoming production issues related to liquid activators in geopolymer.

5.5.3 INNOVATION

The following new knowledge is expected to be delivered in the outcomes:

- Structural behaviour of geopolymer concrete with a focus on precast applications and manufacturing constraints;
- Durability performance of the geopolymer concrete products in specific environments, including service life.

Nanocomm Hub researchers from UTS investigate the structural behaviour and durability issues of a novel geopolymer concrete towards its industrial application which will lead to a significant reduction of greenhouse gas emission from cement industry.
With a comprehensive understanding of the structural properties and durability of geopolymer, a design toolbox will be provided for geopolymer concrete box culverts and other precast concrete components under specific manufacturing processes upon the completion of this project. This will widen the range and standardize the utilization of geopolymer in future construction.

5.5.4 TEAM
Sumita Dangol, Tran Huyen Vu, Nadarajah Gowipalan and Rijun Shrestha

School of Civil and Environmental Engineering, UTS, Australia

Cement Australia Pty Limited is pleased to participate in the ARC Research Hub for Nanoscience-based Construction Materials Manufacturing in both the development of nanoscience-based material and manufacturing in Australia.

— Cement Australia
5.6 FLOATING FOREST

5.6.1 BACKGROUND

The Australian coastline and offshore structures are subject to damage from increasingly strong waves and wind caused by climate change. In this project, researchers in the Nanocomm Hub have designed a novel floating breakwater-windbreak concrete, the “floating forest”, to provide protection of fragile shorelines and port terminals against severe wind and wave actions in huge storms.

5.6.2 OUR GOALS

Nanocomm Hub researchers from the University of Queensland (UQ) address the following challenges:

- Nonlinear wave run-ups;
- Structural safety under extreme wave conditions;
- Viscous effects and waves breaking near the structure;
- Wind-wave coupling analysis;
- Non-steady zero displacement plane for wind analysis;
- 3D turbulence modelling;
- Balance between concerns for economics and effectiveness.

5.6.3 INNOVATION

This mega floating structure adopts an arch shape with an inclined deck so as to keep concrete structures under compression during wave action and to allow wave run-ups for more efficient wave energy dissipation. This breakwater structure can be used in various water depths, providing suitable sea-keeping systems.

The windbreak ability of this structure is enabled by the installation of artificial...
“tree” columns on the deck in arrays for the creation of air flow turbulence to dissipate wind energy. The combination of energy extraction by the structure and divergence of flow leads to a large wake region behind the structure, causing a significant reduction in wind speed.

This novel structure has the ability to create calm water on its downstream side for the preservation of marinas, seaplane landing strips, recreational sea activities, and large floating structures that carry buildings and infrastructure.

5.6.4 CURRENT WORK

The feasibility study has been completed and the floating forest concept has been proven. The work of this project currently underway includes:

- Detailed studies of the viscous effect
- Influence of various design parameters
- An experimental study of a floating forest model

5.6.5 TEAM

Chien Ming Wang¹, Mengmeng Han¹, Junwei Lyu¹, Wenhui Duan², Kwanghoe Jung³, and Sara Kang¹²

1. School of Civil Engineering, UQ, Australia
2. Department of Civil Engineering, Monash University, Australia
3. Hyundai Engineering and Construction, R&D Division, South Korea
INNOVATIVE STRUCTURES

5.7 LEVEL CROSSINGS

5.7.1 BACKGROUND
Design and construction of a hybrid double-skin tubular arch bridge

Australian governments are seeking to upgrade many of the existing railway level crossings to eliminate issues of excessive delays and safety concerns associated with these intersections. An innovative solution is required to overcome the constraints and complexities associated with railway level crossings in urban environments.

5.7.2 OUR GOALS
The outcomes of this study will allow rapid industrial application of proposed novel bridge systems, providing a much needed solution for railway level crossings.

"The current research will enhance the understanding and practicality of the connection system and improved knowledge of the basic double-skin tubular elements. The intent is to develop the design and design method to a level where it will be attractive to state government delivery agencies such that these agencies will then assist in the further development and trial bridge construction phases of the product development.

– Arup Pty Ltd

Hub researcher Dr Dilum Fernando (centre) in a group discussion.
5.7.3 INNOVATION

At UQ, in collaboration with the partners of this project, a new concept for roadway bridge overpasses, a hybrid double-skin tubular arch (DSTA), was developed as a solution for problems currently associated with level railway crossings. This novel bridge system builds on existing research into hybrid double-skin tubular members (DSTMs) which consist of an outer FRP tube, an inner steel tube and a layer of concrete sandwiched between them.

The novel design leads to enhanced stability, excellent ductility and energy absorption capability, and significantly improved durability of the arch structure with light weight. It reduces the carbon footprint and cost of the arch construction as well as prolonging the design life of the structure.

5.7.4 TEAM

Dilum Fernando1, Leo de Waal1, Shuan Jiang1, Guang-Ming Chen2, Jun-Guan Teng1, Paul Rodman4 and Peter Burnton5

1. School of Civil Engineering, UQ, Australia
2. School of Civil and Transportation Engineering, Guangdong University of Technology, China
3. Department of Civil and Environmental Engineering, the Hong Kong Polytechnic University, China
4. Rocket C Pty Ltd, Australia
5. Arup Pty Ltd, Australia

Hub researchers constructing DSTA in the structural lab at the University of Queensland.
Due to the printability requirement, current 3D printing concrete technologies are constrained by the crafting challenges of:

- Inability to embed steel bar for reinforcement;
- Uncertain durability;
- Lack of supporting system.

5.8.2 OUR GOALS

The aim of this project is to improve the printability of concrete

- Flowability: Easily pumped in the delivery system and easily deposited in the deposition system
- Extrudability: Continuously passing through the small pipes and nozzles at the printing head
- Buildability: Retaining extruded shape under self-weight and pressure from upper layers
- Setting: Maintaining a consistent flow rate
- Stiffness: Having sufficient capacity to bear applied load
5.8.3 INNOVATION

Transforming construction

It is expected that the proposed research on 3D concrete printing will result in transformation of the Australian infrastructure construction industry through the development of functional, smart, and high performance concreting materials. The project is likely to lead to the creation of new manufacturing technology in the renewable energy industry.

The following promising technologies hold great promise for improvement of the mechanical properties of 3D printed concrete:

- Method 1: Viscosity modification agent
- Method 2: Aligned fibres
- Method 3: Steel wire mesh

5.8.4 TEAM

Yimiao Huang¹ and Guowei Ma²

¹. Department of Civil, Environmental and Mining Engineering, the University of Western Australia, Australia
². School of Civil and Transport Engineering, Hebei University of Technology, China
5.9 MANUFACTURING VIA SCAFFOLDING

5.9.1 BACKGROUND

3D printing complex geometries

The 3D structuring process of materials requires highly precise manufacturing. Thus, considerable interest is attracted to additive manufacturing (AM).

However, key drawbacks of AM of concrete and cementitious materials, such as stringent mix design requirements, limited printing time and lack of suitable support material, present a challenge for this technology to obtain structures with complex geometries for advanced applications in engineering practice.

5.9.2 INNOVATION

Inspired by scaffold engineering (artificially designed scaffold + natural cell growth on scaffold), researchers at Monash University developed a 3D semi-artificial fluid structuring technique. The key of the method is to retain fresh cement fluid on the specially designed scaffold with the assistance of surface tension, allowing it to harden into a structure with optimized geometry.

This innovative 3D SFS technique developed by Dr Shujian Chen from Nanocomm Hub features light weight, high strength and progressive failure. This technology has the ability to exceed the strength and ductility limits of previously reported research into lightweight concrete and cementitious materials, thereby leading to the development of next-generation construction structural components.
5.9.3 SAFER STRUCTURES

Novel design ensures progressive failure of structure

The area highlighted in orange indicates the crack surface, showing the progressive failure mode of SFS, which can be life-saving in catastrophic situations such as earthquake.

5.9.4 PROMISING FUTURE

This technology also holds great potential for future applications of:

- Biomaterials, such as biodegradable scaffolds with hydrogel precursor coating;
- Multimaterials, such as polymer-coated metal parts with complex geometry;
- Others, such as surface modification of scaffolds for better adhesion.

5.9.5 TEAM

Shujian Chen, Wei Wang, Jia Zie Lai, Brandon Gerber and Wenhui Duan

Department of Civil Engineering, Monash University, Clayton, VIC 3800, Australia
INNOVATIVE STRUCTURES

5.10 PROTECTION IN UNDERGROUND

5.10.1 BACKGROUND

Coal or rock burst is a sudden and violent failure of coal or rock as a result of dynamic loading in underground coalmines. These dynamic hazards can lead to damage to a mining system and devastating harm to mine workers. Recent coal and rock burst incidents have occurred in Australian underground coalmines, resulting in two fatalities in an underground development gateroad using a continuous miner (CM). There is a need to develop an effective protective structure as the last line of defence for workers working on a CM.

5.10.2 OUR GOALS

Safety, energy release

This project aims to design, manufacture and implement an innovative protective structure for CMs in underground coalmines where coal burst and outburst can occur as a result of developing roadways in highly stressed and gassy coal seams.

Quasi-static and dynamic loading tests have been designed to determine the energy release and transformation during a coal burst incident. Numerical models have been developed to study the influence of coal cleat and joint systems on the dynamic failure of coals under various loading conditions.

5.10.3 INNOVATION

Extensive laboratory tests and numerical simulations have been conducted to understand and determine the behaviour of coal and coal measure rocks under different loading conditions, and to develop and design an innovative protective structure that can be installed on the CM to provide sufficient protection against dynamic loading from a typical coal burst.
Several possible protective structures have been laboratory tested and numerically studied for the design and implementation of a protective structure on the CM in underground coal mines for the enhancement of construction safety.

5.10.4 TEAM

Ting Ren¹, Alex Remennikov¹, Peter Holt², Xiaohan Yang¹, Lihai Tan¹ and Dulara Kalubadanage¹

¹. School of Civil, Mining and Environmental Engineering, UoW, Australia

². Ironclad Mining Machinery, Australia

Hub chief investigator A/Prof Ting Ren.
Hub partner investigators meeting: Mr Peter Holt (Ironclad Mining Machinery, right) and Mr Joel Chong (OneAtom 12, left).
5.11 INTELLIGENT CRANE

5.11.1 BACKGROUND

A crane is among the most essential machinery on construction sites, responsible for most horizontal and vertical transportation tasks. Crane accidents can lead to catastrophic consequences in schedule lapse, budget overrun, and loss of life. The root causes of crane accidents include spatial conflicts such as blind spots and limited visibility and operator errors such as lack of situational awareness.

A graphical user interface for visualization and warning in crane lifting operations for safety improvement designed by Dr Yihai Fang from Monash University.

5.11.2 OUR GOALS

The objective of this research is to provide real-time safety assistance for crane operators, including hazard analysis, visualization and warnings.

By successfully addressing various challenges in enabling real-time proactive safety assistance in crane lifting operations, the impacts of this project are:

- Enhancing the performance of existing lifting assistance systems:
  - Track load sway in real-time and incorporate and update as-is site condition;
  - Improve comprehension of warnings and visualization;
  - Improving operators’ situation awareness and lift performance in actual operations:
    - Short-term assistance: supplement operators’ hazard recognition;
    - Long-term assistance: improve operators’ ability to recognise hazards.
5.11.3 INNOVATION

Researchers in Nanocomm Hub aim to provide crane operators with real-time safety assistance including hazard analysis, visualization, and warnings, and to improve operators’ situational awareness of potential hazards associated with crane lifting. This project develops the framework of a safety assistance system for mobile crane lift operations, enabled by real-time crane motion monitoring, proactive hazard analysis and 3D visualization. The framework is developed by the integration of sensory systems, lift site modelling and updating, and hazard analysis and visualization.

The framework has been validated by a prototype deployed on a real crane and a field test has been conducted to evaluate the system’s performance with respect to reconstruction accuracy, timing, hazard analysis and visualization effectiveness.

5.11.4 TEAM

Yihai Fang

Department of Civil Engineering, Monash University, Australia

Dr Yihai Fang testing the interactive visualisation in mixed reality with laser-scanned point cloud of the built environment.

Real-time crane motion reconstruction in a field test.
To reduce the maintenance cost and increase the economic benefits of the built environment industry, Nanocomm Hub aims to deliver the next generation of Australian building and road infrastructure. The main focus is on improving the performance of the infrastructure system in four research directions: intelligent road materials, novel testing and inspection facilities, practical bridge deterioration models and reliable building energy consumption assessment.

Addressing the four proposed directions, Nanocomm Hub:

- Use novel binders and polymer additives developed from Section 3 to enhance the physical performance of concrete-based construction materials. Further, new magnetic boundaries will be incorporated into the pavements to make them smart materials with sensing properties.
- Bring robotic advances into the maintenance of Australian pavements. Nanocomm Hub aims to develop a highly efficient, reliable and robust robotic profiler for indoor and outdoor applications, a comprehensive model of the accelerated loading facility (ALF), a sensor-fusing technology to generate a 3D model of road surface, and a more accurate roughometer for road-data collection.
- Predict the deterioration of bridge components for justifying maintenance funding and improving asset management. In light of recent bridge accidents, Nanocomm Hub projects aim to provide a ranking list of Australian bridges and culverts for prioritizing funding and maintenance. This research direction also focus on the sourcing of materials on the construction site, quantifying and modelling the risk of alkali-silica reaction (ASR) and its impact on the structural performance of concrete.
- Investigate the causes of energy performance gaps between designed and actual green buildings. Buildings often fail to achieve the desired energy conservation goal, consuming as much as 3 times more energy than predicted, inflicting negative consequences to the environment and significant financial loss to clients and investors.

Transformation of the Australian infrastructure system is performed in close consultation with distinguished institutions such as the Australian Road Research Board (ARRB), Centre for Pavement Excellence Asia Pacific (CPEAP) and VicRoads. The research projects are described in the following information sheets.
The next generation of Australian building and road infrastructure.
6.1 ENZYME STABILIZATION

6.1.1 BACKGROUND

Soil stabilization

Unsealed roads occupy the majority of each nation's road network, with limited attention devoted to the construction. These roads are highly susceptible to costly maintenance from various issues that can lead to fatalities or injuries. Attention has been devoted to stabilizing soils using chemical stabilization technology. However, because the uses of such stabilizers have been presented as soil type and/or application specific, there is no universal standard for any of the available stabilizers which practising engineers/contractors can utilise as reliable sources in designs/constructions.

6.1.2 GOAL

- Estimate the stabilization mechanisms of soils using specific enzymes.
- Investigate the capability of using stabilized soils for cost-effective road construction.
- Enhance the safety of slopes through stabilizing in-situ/fill materials.
- Develop cost-effective house construction using innovative enzyme-based construction methods.

6.1.3 INNOVATION

Researchers at CPEAP and RMIT have been estimating the stabilization mechanisms of soils using specific enzymes and investigating the capability of using stabilized soils for cost-effective road construction. Those stabilizing in-situ/fill materials as well as innovative enzyme-based construction methods can be applied for enhancing the safety of slopes and for cost-effective house construction.

The group combines:

- **Comprehensive laboratory experiment program**, including mechanical testing (California Bearing Ratio (CBR), unconfined compressive strength (UCS), direct shear and free swell) of two different types of fine-grained soil to observe the efficacy of stabilization and nanotechnology-driven microscopic tests (SEM, X-ray diffraction technique, Micro-CT scan and porosity analysis work).

- **Numerical modelling of road pavement**: 3D finite element models to simulate the behaviour of stabilized road pavement subjected to moisture and traffic loads (single-axle-dual-tyre (SADT) configuration having total axle load of 80 KN).
Enzyme stabilization results in a significant increase in strength along with considerable reduction in wetting induced volume expansion. This investigation will substantially benefit the road construction industry as the mechanism revealed can be utilised efficiently to construct sustainable roads.

6.1.4 TEAM
Renjith, R1; Singh, J1; Robert, D1; Setunge, S1; Gunasekara, C1 and B. O’Donnell2

1. Civil & Infra. Discipline, School of Engineering, RMIT University, Australia
2. Centre for Pavement Excellence Asia Pacific Ltd

CPEAP has been collaborating with RMIT University in examining optimization of stabilization of unbound pavements using enzyme and other additives, specifically Eko Soil in pavement stabilization. This project enables the CPEAP to expand the current work to a systematic investigation of the behaviour of enzymes and additives in different types of soil and the resilience of roads stabilized using the innovative material.

– Centre for Pavement Excellence Asia Pacific Limited (CPEAP)
6.2 SPRAYED SEALS

6.2.1 BACKGROUND
Sprayed seals
Sprayed seals are widely applied in Australia due to their relatively low cost and satisfactory all-weather performance. The viscosity of the bituminous binder is of critical importance in sprayed sealing. During construction, the binder needs to be fluid enough for good wetting and adhesion of the aggregates.

6.2.2 MAIN CHALLENGES
Current deficiencies
- No well-known relationships between the properties of cutters and sprayed seal performance.
- Inefficiency of existing models for generic petroleum blends (e.g. bitumen and cutter).
- Limitations of available diffusion models for the rate of cutter loss.
- Insufficient knowledge of aggregate wetting behaviour with the use of cutter.

6.2.3 INNOVATION
Novel method
Sprayed seals consist of a thin layer of bituminous binder sprayed onto a pavement surface, on which aggregates are then spread and rolled into the bituminous binder. Cutters are added if sprayed seals are constructed at low temperatures, to ensure that the binder effectively wets and adheres to the aggregate. The cutter is then lost from the seal over time. If cutter loss is too slow, aggregates can be lost from a sprayed seal under traffic or the binder can be too liquid at high temperatures.

More research is needed in assessing and optimizing the performance of pavement materials in combination with emerging technologies which may transform current approaches to road maintenance, rehabilitation and new construction. Improved understanding of pavement response to increased loading from heavy freight vehicles and whole-of-life costs for the provision of high-performance road infrastructure is needed.

– Australian Road Research Board (ARRB)
In this study, novel construction materials are used to enhance the physical performance of roads and pavement. Future modelling will provide significant contributions that will allow prediction of mixture viscosity and sprayed seal performance, contributing to Australia’s overall economy.

6.2.4 TEAM

Afifa Tamannaa, Ezzatollah Shamsaeib, Robert Urquhartc and Wenhui Duan1

1. Department of Civil Engineering, Monash University, Australia
2. ARRB, Australia

Nanocomm Hub researchers characterize bitumen/cutter mixtures for optimum sprayed seal performance. Those novel construction materials will be used to enhance the physical performance of roads and pavement, contributing to Australia’s overall economy.

Hub HDR students Afifa Tamanna (left) and Zunaira Naseem (right).

Dynamic Shear Rheometer used to measure the viscosity of bitumen-cutter blends for viscosity modelling at ARRB.
6.3 PAVEMENT ROUGHNESS

6.3.1 BACKGROUND

Pavement roughness

Australia’s infrastructure needs to become more durable, resilient and secure, to ensure that infrastructure networks require less maintenance and can resist extreme events. The aim of this theme is to reduce the maintenance costs of infrastructure, focusing on road pavements.

6.3.2 GOAL

Next generation of facilities for testing and inspection

- design for novel pavement materials
- robotics for pavement maintenance
- hardware of the robotic system
- mechatronic device

6.3.3 INNOVATION

Nanocomm Hub researchers are bringing new robotic advances into the maintenance of pavements. The enhanced Accelerated Loading Facility (ALF). The robotic profiler used to collect temporal and spatial data of pavement deformations under load. The collected data will be processed systematically. Research projects will develop a highly efficient, reliable and robust robotic profiler for indoor and outdoor applications, a sensor-fusing technology to generate a 3D model of the road surface, and a more accurate road-data collection.
6.3.4 TEAM

Michael Stanley¹, Logan Vesty¹, Kee Tee¹, Wenhui Duan² and Chao Chen¹

1. Department of Mechanical and Aerospace Engineering, Monash University, Australia
2. Department of Civil Engineering, Monash University, Australia

The collaboration with Nanocomm Hub has taken the form of preliminary work with the aim of developing highly reliable and robust robotic systems for inspection of road condition. Research to date has shown that such systems can significantly reduce labour cost, reduce operational time, and increase the accuracy of inspection.

– Australian Road Research Board (ARRB)
6.4 DRONE IN INFRASTRUCTURE

6.4.1 BACKGROUND

Roads are among Australia’s most important assets. Road improvements make a crucial contribution to economic development and growth and bring important social benefits. The employment of unmanned aerial vehicles (UAVs) in structural health monitoring (SHM) of bridges and other civil structures is exceptional, and practical feasibilities are still under research. The deployment of UAVs for civil infrastructure monitoring is a new arena. Very few practical case studies have been undertaken for industries, monuments and other civil structures.

6.4.2 GOAL

- To develop an innovative protocol for full-field mapping of road structures involving effective use of UAVs to enable real-time SHM.
- To study the effects of wind environmental parameters on thermal images of various delaminations in reinforced concrete.
- To provide operators with more guidance for different environmental conditions.

6.4.3 INNOVATION

Nanocomm Hub researchers are developing image processing algorithms for crack and surface degradation measurement with simulation results, assessing the condition of road structures by conducting field testing using UAVs and coming out the technical specifications and capabilities of the demonstration UAV model.

A finite element model matches the experimental results well. Further parametric studies will be performed for better understanding of the parameters of interest and to provide operators with guidelines for thermographic operations on bridges. Thermography is suitable...
for fast scanning of concrete structures for subsurface damage, but special consideration of different environmental parameters is needed.

The outcomes of this project will be instrumental in the development of a wide range of new UAV technology for determining much more efficiently the cause, extent and rate of deterioration of built infrastructure.

### 6.4.4 TEAM

Babar Nasim Khan Raja, Lihai Zhang, Colin Duffield, Saeed Miramini

Department of Infrastructure Engineering, the University of Melbourne, Australia

Our products are currently widely used in emergency disaster relief, public security, fire protection, electric power, water conservancy, agriculture, logistics, transportation, radio and television, land, environmental protection and other fields.

We are confident that the outcomes of this project will contribute to increased productivity and extended service life of road infrastructure, and so enhance their durability which is an important component of transport infrastructure sustainability.

– Chongqing IdealTech Co.
6.5 BRIDGE MANAGEMENT

6.5.1 BACKGROUND

In Victoria, only 72% of concrete bridges and 35% of timber bridges are in good or very good condition. A major challenge faced by road authorities in managing their aging infrastructure is the inability to predict degradation of materials and structures, which makes maintenance decisions often reactive rather than proactive.

6.5.2 GOAL

To develop a working deterioration modelling tool including all VicRoads’ road structures. The deterioration modelling tool involves:

- development of deterioration curves for bridges, considering the construction materials and exposure conditions;
- development of algorithms for predicting deterioration of bridges, groups of bridge components or bridge components;
- development of models for risk ranking, prioritization and cost forecasting.

6.5.3 INNOVATION

Austroads is currently examining the best methods for prediction of deterioration for adoption by road authorities. A PhD project completed at RMIT demonstrated the feasibility of modelling degradation in bridge structures using a combination of the Markov process and artificial neural networks. The method has the potential to change current practice from a reactive response to a proactive prepared approach. The proposed project will address the gap in knowledge by developing comprehensive degradation
models for bridge structures owned by the roads corporation of Victoria.

During this study, deterioration modelling and a prioritization tool are being developed for predicting future conditions of bridge components, maintenance budget forecasting, understanding the risk associated with current budget levels and prioritizing a bridge for maintenance, repair or replacement to maximize investment.

6.5.4 TEAM

Sujeeva Setunge¹, Huu Tran¹ and Yew-Chin Koay²

¹. School of Engineering, RMIT University, Australia

². VicRoads

Hub research fellow Dr Huu Tran giving a presentation

Nanocomm Hub sponsored Fibre Reinforced Polymer (FRP) workshop.
6.6 FUTURE ROADS

6.6.1 BACKGROUND

Australia’s infrastructure will need to be more durable, resilient and secure to ensure that infrastructure networks require less maintenance and can resist extreme events. We know that the way people connect is changing rapidly, including physical connectivity, most of which occurs via road. But the $250b road network was designed and laid out for the past, not the future, so we need to ensure it is not a white elephant. We need to understand how the 25 million daily users of the road system think, make choices, and how those thoughts and choices change – on an ongoing basis. We need to ask users, and ask them regularly, which means that a process of continual systematic engagement with users – direct and indirect – is needed.

Nanocomm Hub researchers work on strategic appointments with continual systematic user engagement to investigate future roads towards more durable, resilient and secure infrastructure networks.

6.6.2 PROJECT

- An annotated bibliography of research on future developments in roads.
- A paper questioning some potential directions in ARR Journal.
- A pilot questionnaire for ARRB staff and Monash students.
- A questionnaire for the general public and an ARRB Journal paper seeking some potential directions.
6.6.3 INNOVATION

Main areas of research needs include:

- **Usage:**
  Roads and sustainability: The environment, resilience, and strategic assets;
  Roads and society: People, movement, place.

- **Enablers:**
  Road and funding: Finance, economics and business;
  Road planning and policy;
  Road design within the reserve, resilience, connectivity, mobility and safety;
  Construction, rehabilitation and maintenance of the road cross-section, pavement and running surface assets;
  Physical infrastructure: Materials and smart infrastructure;
  Next-generation asset management: BIMs and the total planning, design, construction, operations and management process;
  Intelligent road systems: The human/technology interface;
  Information on roads: Next-generation data collection.

- **Structural issues:**
  Outside Australia: The international roads community, China as a transport infrastructure leader;
  Research structures within Australia: A national research capability/ national transport research plan.

The future roads project is a continuing exercise of determining the questions of the future.

6.6.4 TEAM

Prof William Young1, Dr Michael Shackleton2, and Dr Alexa Delbosco1

1. Department of Civil Engineering, Monash University, Australia

ARRB Group CEO Michael Caltabiano (left) and Austroads CEO Nick Kaukoulas (right) at Hub Innovation Dinner, Monash University.

Hub chief investigator William Young giving a talk at Hub Innovation Night at Western Sydney University.

2. ARRB, Australia
6.7 CONCRETE DURABILITY

6.7.1 BACKGROUND

Limiting aggregate use to non-reactive aggregates only prevents the use of reactive aggregates. Currently, set limits for alkali in concrete are conservative, with a single limit applied to all aggregates. Mitigation strategies using supplementary cementitious materials (SCMs) are not available in all countries (e.g., New Zealand).

Potential exists for the use of Greywacke aggregate and Waikato river sand combination in concretes to mitigate the occurrence of deleterious expansion due to alkali-silica reaction (ASR). However, Greywacke is slowly reactive based on 56-day accelerated mortar bar test (AMBT) results. Therefore, the longer term effects of Greywacke aggregate and Waikato river sand combination require further investigation. A testing program is also underway to understand and develop alternative ASR mitigation methods.

6.7.2 GOAL

- Develop strategies for use of reactive aggregates in concrete without using SCMs
- Develop novel mitigation techniques for minimizing deleterious ASR in concrete
- Determine alkali threshold limits for New Zealand aggregates and concrete mixes
- Assess aggregate combinations for effective mitigation of deleterious ASRs
- Identify causative components in reactive aggregates and their effect on the extent of ASR.

6.7.3 INNOVATION

This research provides an update to New Zealand’s best practice to reflect recent international developments, and evaluation of new accelerated testing methodologies. It enables the concrete sector to confidently adopt alkali limits for marginal aggregate supplies and could establish a durable mechanism for updating the New Zealand ‘standard’ for controlling ASR risks.
6.7.4 TEAM

Elsie Nsiah-Baafi¹, Kirk Vessalas¹, Paul Thomas² and Vute Sirivivatnanon¹

1. School of Civil and Environmental Engineering, University of Technology Sydney, Australia
2. School of Mathematical and Physical Sciences, University of Technology Sydney, Australia

UTS Tech Lab for industrial partnerships

Hub researcher performing specimen characterization in UTS science laboratory at Ultimo.

Hub chief investigator Prof Vute Sirivivatnanon presenting at Hub Mid-of-Year Meeting 2018.
THE PROJECT IS EXPECTED TO GENERATE FRESH INSIGHTS, MODELS AND GUIDELINES FOR FINANCING, DESIGNING, MODELLING AND RETROFITTING, AS WELL AS MONITORING AND IMPROVING THE ENERGY PERFORMANCE OF EXISTING PUBLIC-SECTOR OFFICE BUILDINGS. THIS IS ALSO A KEY PRIORITY AREA OF THE DEPARTMENT’S CURRENT SUSTAINABILITY STRATEGY.

— Department of Finance, Government of Western Australia
This research is intended to provide increased confidence in retrofit designs, leading to greater investment and creation of 26 new business opportunities and jobs in the retrofit industry. It produces saving of public funds from ineffective retrofit schemes, improvements in thermal comfort, productivity and employee satisfaction in office buildings, as well as reductions in national energy consumption and carbon emissions.

6.8.4 TEAM

Morshed Alam¹, Patrick X. W. Zou¹, Chris Buntine², Evan Blair³ and Carolyn Marshall⁴

1. Centre for Sustainable Infrastructure, Swinburne University of Technology, Australia

2. Built Environment, Aurecon, Dockland, VIC 3008, Australia

3. Department of Housing and Public Works, Queensland, Australia

4. Department of Finance, Government of Western Australia

Nanocomm Hub researchers investigate closing the building energy performance gap between design and reality. The corresponding mitigation strategies produce saving of public funds, productivity and employee satisfaction in office buildings, and reductions in national energy consumption and carbon emissions.
The Nanocomm Hub seeks talented staff and students, irrespective of social or economic circumstances, while striving to build a connected community that is deeply engaged with the wider government, business, industry and public communities.

Further, we believe every individual has the right to be treated equally and fairly regardless of gender, race, religious belief or any other personal characteristic. We foster equity and fairness by promoting diversity within the Hub. After all, diverse teams are known to perform better than those with gender and cultural uniformity, and we recognise that the Hub will benefit from a diverse milieu in terms of productivity, creativity and efficiency.

To date, more than 21% of our members are female, with representation across all levels of the Hub. Among those industries that suffer a serious gender imbalance, this percentage is considered relatively good. Although a 50-50 blend of women and men in the construction area may seem out of reach, Nanocomm Hub has put into place various strategies to attract more women into our research.
Diverse teams are known to perform better than those with gender and cultural uniformity, and we recognise that the Hub will benefit from a diverse milieu in terms of productivity, creativity and efficiency.
To date, 21% of our members are female, with representation across all levels of the Hub.
In strong support of the ARC Gender Equality Action Plan 2018, we have undertaken to:

- monitor gender balance during recruitment of Hub members
- raise awareness of unconscious bias by highlighting it in our staff training
- create an inclusive workspace that is female- and family-friendly
- support current female Hub members and increase their overall participation via mentoring, scholarships and travel allowances
- provide opportunities for female Hub members to speak at conferences and workshops
- establish a school work experience program that engages girls
- organise a community outreach program to inspire girls to study engineering.

The table below shows the breakdown of roles currently held by women at the Hub.

<table>
<thead>
<tr>
<th>NANOCOMM HUB ROLE</th>
<th>FEMALE</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partner Investigators</td>
<td>7</td>
<td>49</td>
<td>14%</td>
</tr>
<tr>
<td>Chief Investigators</td>
<td>9</td>
<td>49</td>
<td>18%</td>
</tr>
<tr>
<td>Research Fellows</td>
<td>5</td>
<td>20</td>
<td>25%</td>
</tr>
<tr>
<td>HDR Students</td>
<td>17</td>
<td>63</td>
<td>27%</td>
</tr>
<tr>
<td>Overall</td>
<td>38</td>
<td>181</td>
<td>21%</td>
</tr>
</tbody>
</table>
GOVERNANCE

HUB DIRECTOR

MANAGEMENT TEAM
DIRECTOR, DEPUTY
DIRECTORS, ADMIN

ADVISORY COMMITTEE

STEERING COMMITTEE
DIRECTOR, DEPUTY DIRECTORS
AND GROUP FACILITATORS

RESEARCH TEAMS

RT1       RT2       RT3       ...       RT37

CIs       CIs       CIs       CIs       CI GROUP
PIs       PIs       PIs       PIs       PI GROUP
RFs       RFs       RFs       RFs       RF GROUP
HDRs      HDRs      HDRs      HDRs      HDR GROUP

Australian Government
Australian Research Council

Nanocomm Annual Report 2018
8.1 MANAGEMENT TEAM

HUB DIRECTOR
PROF WENHUI DUAN

DEPUTY DIRECTOR (OPERATIONS)
DR KWESI SAGOE-CRENTSIL

DEPUTY DIRECTOR (SYDNEY)
PROF VUTE SIRIVIVATNANON

DEPUTY DIRECTOR (BRISBANE)
PROF SRITAWAT KITIPORNCHAI

DEPUTY DIRECTOR (MELBOURNE)
PROF SUJEEVA SETUNGE

ACTING HUB MANAGER
DR BILLY ZHENYUE CHANG

EXECUTIVE OFFICER
MS IRENE WEISER
8.2 ADVISORY COMMITTEE

The Advisory Committee consists of the Hub Director, Hub Deputy Directors, and other academic and industry experts in the specific fields related to the research. The purpose of the Advisory Committee is to:

- Provide strategic advice, opinions and recommendations on the direction of Research Programs
- Provide industry input to the Hub Director
- Promote the objectives and outcomes relating to industry and engagement

8.2.1 SCIENTIFIC ADVISORY COMMITTEE

PROF YIU-WING MAI  
(Chair)  
University of Sydney

PROF DAVID NETHERCOT  
Imperial College of London

PROF JOSE TORERO  
University of Maryland

PROF JIN-GUANG TENG  
The Hong Kong Polytechnic University

PROF SER TONG QUEK  
The National University of Singapore

PROF ROSE AMAL  
The University of New South Wales

PROF MARK BRADFORD  
The University of New South Wales

MR MENNO HENNEVELD  
Menno Henneveld Consulting

8.2.2 INDUSTRY ADVISORY COMMITTEE

PROF WENHUI DUAN  
(Chair)  
Monash University

DR PHILLIP ARENA  
Fortis

DR ANNA PARADOWSKA  
Ansto

DR WARREN SOUTH  
Cement Concrete and Aggregates Australia (CCAA)

DR RICHARD YEO  
ARRB
The Steering Committee has four sub groups, i.e. Chief Investigator (CI) group, Partner Investigator (PI) group, Research Fellow (RF) group and HDR student group. Each group has one facilitator to promote the collaboration amongst hub members from different participant organisations and to provide advice to the Management Team on any concern/opportunities from CI, PI, RF and HDR.

PROF WENHUI DUAN  
Monash University

PROF SUJEEVA SETUNGE  
RMIT University

PROF VUTE SIRIVIVATNANON  
University of Technology Sydney

PROF SRITAWAT KITIPORNCHAI  
The University of Queensland

DR KWESI SAGOE-CRENTSIL  
Monash University

PROF CHIEN MING WANG  
The University of Queensland

DR WARREN SOUTH  
Cement Concrete and Aggregates Australia (CCAA)

DR CHAMILA GUNASEKARA  
RMIT University

FELIPE BASQUIROTO DE SOUZA  
Monash University
HUB MEMBERS

8.4 CHIEF INVESTIGATORS

PROF WILLIAM YOUNG
Monash University

PROF JIAN ZHAO
Monash University

PROF WENHUI DUAN
Monash University

DR QIANG ZHANG
Monash University

DR AMIN HEIDARPOUR
Monash University

A/PROF MOHAN YELLISHETTY
Monash University

DR COLIN CAPRANI
Monash University

DR CHAO CHEN
Monash University

MR PETER MUTTON
Monash University

A/PROF LIAN ZHANG
Monash University

PROF HUANTING WANG
Monash University

A/PROF QIAOLIANG BAO
Monash University

DR RUiping Zou
Monash University
8.6 RESEARCH FELLOWS

DR HUU TRAN
RMIT University

DR CHAMILA GUNASEKARA
RMIT University

DR MORSHEDE ALAM
Swinburne University of Technology

DR SAEED MIRAMINI
The University of Melbourne

DR HONG ZHANG
The University of Queensland

DR VAN THUAN NGUYEN
The University of Queensland

DR MARYAM GHODRAT
Western Sydney University

DR BOB ABTAHI
Western Sydney University

DR KAMYAR KILDASHTI
Western Sydney University

DR EZZAT SHAMSAEI
Monash University

DR BILLY ZHENYUE CHANG
Monash University

DR ASGHAR HABIBNEJAD KORAYEM
Monash University

DR SHUJIAN CHEN
Monash University
8.7 RESEARCH ASSISTANTS

DR SHAO LIU
Monash University

DR TAHEREH HOSSEINI
Monash University

DR BAIQIAN DAI
Monash University

DR YANG YU
University of Technology Sydney

DR SHIVANANJU BANNUR NANJUNDA
Monash University

DR HANAA HEGAB
Monash University

DR SHERRY QIANHUI ZHANG
Monash University

THOMAS WINNELL
Monash University

KEQUAN YU
University of New South Wales

YUGUO YU
University of New South Wales
8.8 HDR STUDENTS

ERFAN AMIRI  
RMIT University

RINTU RENJITH  
RMIT University

JASPREET SINGH POONI  
RMIT University

MUHAMMED KHDOR  
RMIT University

GUANGWU GUAN  
Deakin University

SHA JI  
Deakin University

VAN MANH PHUNG  
Swinburne University of Technology

XIAOXIAO XU  
Swinburne University of Technology

DIPKA WAGLE  
Swinburne University of Technology

BABAR NASIM KHAN RAJA  
The University of Melbourne

DANDAN SUN  
The University of Melbourne

JIE REN  
The University of Melbourne

JUNWEI LYU  
The University of Queensland

REZA BANI ARDALAN  
Western Sydney University

ZAHRA NOURI EMAMZADEH  
Western Sydney University

YINGYING GUO  
University of New South Wales, Canberra
9.1 Key Performance Indicators

The Australian Research Council Industrial Transformation Research Hubs scheme has developed a key performance indicator (KPI) system to stimulate the translation of technological innovations from academia to industry. The system relies on 27 KPIs across six categories:

- research training and education
- research links and networks
- outputs
- outcomes
- end-user links
- benefits.

These occur in three phases: talent, excellence and impact (see diagram to right). Research training and education, research links and networks, and outputs combine to bolster excellence in university research, whereas outcomes, end-user links and benefits support the commercialisation of innovations by industry. By catering to the needs of both universities and industry, the KPI system maintains a balanced and mutually beneficial relationship between them.
9.2 Research Training and Education

The Nanocomm Hub deeply values the professional development of our research team. We work hard to prepare our members for future success wherever their career may take them, whether they choose to pursue academic research or to enter the industrial workforce.

We encourage our members to attend seminars, workshops and short courses to enhance their professional development. These opportunities help Hub members build a broad range of skills, which will maximise their career options in a competitive environment. Also, we urge participation of research fellows and HDR students, as well as collaborators and industrial partners, so that they gain exposure to the latest technology in the field.

<table>
<thead>
<tr>
<th>EVENT TITLE</th>
<th>EVENT TYPE</th>
<th>VENUE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>The 1st International Conference on Energy-efficient Separation (IEESEP2018)</td>
<td>Conference</td>
<td>Melbourne, VIC</td>
<td>27 January 2018</td>
</tr>
<tr>
<td>The 1st International Conference on Bioinspired Materials and Membranes (IBM2018)</td>
<td>Conference</td>
<td>Melbourne, VIC</td>
<td>27 January 2018</td>
</tr>
<tr>
<td>Sub base Pavement Improvement – cost effective soil stabilization</td>
<td>Workshop</td>
<td>RMIT, Melbourne</td>
<td>5 February 2018</td>
</tr>
<tr>
<td>BCIA Coal to products</td>
<td>Workshop</td>
<td>Melbourne, VIC</td>
<td>7 February 2018</td>
</tr>
<tr>
<td>Research Data Management</td>
<td>Research Development</td>
<td>Western Sydney, NSW</td>
<td>8 February 2018</td>
</tr>
<tr>
<td>Cement Concrete Aggregate Australia Conference</td>
<td>Conference</td>
<td>Sydney, NSW</td>
<td>11 February 2018</td>
</tr>
<tr>
<td>The 3rd Australian Conference on Computational Mechanics (ACCM-3)</td>
<td>Conference</td>
<td>Geelong, VIC</td>
<td>12 February 2018</td>
</tr>
<tr>
<td>CIBSE Introduction to Passive House</td>
<td>Workshop</td>
<td>Dockland, VIC</td>
<td>27 February 2018</td>
</tr>
<tr>
<td>International Conference on Accelerated Carbonation for Material and Environmental Engineering</td>
<td>Conference</td>
<td>Newcastle, NSW</td>
<td>13 March 2018</td>
</tr>
<tr>
<td>Structural investigation of Architectural Formwork System under concentric axial load by means of experimental tests and numerical simulations.</td>
<td>Seminar</td>
<td>WSU, Sydney</td>
<td>14 March 2018</td>
</tr>
<tr>
<td>Novel DSTA Bridges</td>
<td>Seminar</td>
<td>Brisbane, QLD</td>
<td>28 March 2018</td>
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<tr>
<td>CPD Course on Health Monitoring in Civil Infrastructure</td>
<td>Professional Development</td>
<td>UQ, QLD</td>
<td>11 April 2018</td>
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<tr>
<td>Advanced Composite Research</td>
<td>Seminar</td>
<td>Bristol, UK</td>
<td>16 April 2018</td>
</tr>
<tr>
<td>Leadership and effectiveness – A collection of good ideas by Professor Hamid Ronagh</td>
<td>Research Development</td>
<td>WSU, Sydney</td>
<td>31 May 2018</td>
</tr>
<tr>
<td>Structural investigation of Architectural Formwork System wall panels – experimental tests and numerical simulations.</td>
<td>Research Development</td>
<td>WSU, Sydney</td>
<td>31 May 2018</td>
</tr>
<tr>
<td>Advanced Programming in Python</td>
<td>Research Development</td>
<td>WSU, Sydney</td>
<td>13 June 2018</td>
</tr>
<tr>
<td>Excel for Researchers</td>
<td>Research Development</td>
<td>WSU, Sydney</td>
<td>14 June 2018</td>
</tr>
<tr>
<td>Prediction of the lateral pressure exerted by self-compacting concrete on formwork</td>
<td>Seminar</td>
<td>WSU, Sydney</td>
<td>21 June 2018</td>
</tr>
<tr>
<td>Intermediate to Advanced Programming</td>
<td>Research Development</td>
<td>WSU, Sydney</td>
<td>22 June 2018</td>
</tr>
<tr>
<td>European Technical Coatings Congress (ETCC 2018)</td>
<td>Conference</td>
<td>Amsterdam, The Netherlands</td>
<td>26 June 2018</td>
</tr>
<tr>
<td>Outfit Template Training</td>
<td>Professional Development</td>
<td>Monash University, Melbourne</td>
<td>12 July 2018</td>
</tr>
<tr>
<td>Tenth International Conference on Computational Fluid Dynamics (ICCFD10)</td>
<td>Conference</td>
<td>Barcelona, Spain</td>
<td>13 July 2018</td>
</tr>
</tbody>
</table>

Prof Junuthula N. Reddy from Texas A&M University gives a short course on Finite Element Method (FEM) at Monash University.
<table>
<thead>
<tr>
<th>EVENT TITLE</th>
<th>EVENT TYPE</th>
<th>VENUE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPD Course on Strengthening Structures using FRP Materials</td>
<td>Professional Development</td>
<td>UQ, QLD</td>
<td>17 July 2018</td>
</tr>
<tr>
<td>Health Monitoring of Civil Engineering Structures</td>
<td>Professional Development</td>
<td>Queensland Government, QLD</td>
<td>11 August 2018</td>
</tr>
<tr>
<td>Concrete Research Innovation Forum</td>
<td>Forum</td>
<td>Melbourne, VIC</td>
<td>30 August 2018</td>
</tr>
<tr>
<td>Reliability based Australian structural design code calibration for steel and steel-concrete composite structures</td>
<td>Seminar</td>
<td>WSU, Sydney</td>
<td>30 August 2018</td>
</tr>
<tr>
<td>International Federation for Structural Concrete 5th International fib Congress 2018</td>
<td>Conference</td>
<td>Melbourne, VIC</td>
<td>6 October 2018</td>
</tr>
<tr>
<td>Earthquakes do not kill people buildings do</td>
<td>Seminar</td>
<td>WSU, Sydney</td>
<td>24 October 2018</td>
</tr>
<tr>
<td>MCATM Workshop</td>
<td>Workshop</td>
<td>Monash University</td>
<td>26 October 2018</td>
</tr>
<tr>
<td>Life-cycle Structural Performance Assessment of Bridges</td>
<td>Workshop</td>
<td>Zhejiang Province, China</td>
<td>29 October 2018</td>
</tr>
<tr>
<td>CCAA/UTS Annual ASR Workshop</td>
<td>Workshop</td>
<td>UTS, NSW</td>
<td>30 October 2018</td>
</tr>
<tr>
<td>Improving behaviour of cold formed steel profiles &amp; Introducing air purifying concrete material</td>
<td>Seminar</td>
<td>WSU, Sydney</td>
<td>11 November 2018</td>
</tr>
<tr>
<td>Australian Synchrotron User Meeting 2018</td>
<td>Conference</td>
<td>Australian Synchrotron, Melbourne</td>
<td>22 November 2018</td>
</tr>
<tr>
<td>Advancing Materials and Manufacturing CAMS2018</td>
<td>Conference</td>
<td>UoW, NSW</td>
<td>26 November 2018</td>
</tr>
<tr>
<td>International Symposium on Nanotechnology in Construction (NICOM)</td>
<td>Conference</td>
<td>Hong Kong, China</td>
<td>2 December 2018</td>
</tr>
<tr>
<td>First Aid Training</td>
<td>Professional Development</td>
<td>Mulgrave, VIC</td>
<td>5 December 2018</td>
</tr>
</tbody>
</table>
9.3 Research Networks

To boost Australian research, and to link Australian companies to the enormous opportunities in the Asian infrastructure market, we have set out to build national and international networks across industry and educational organisations.

9.3.1 VISITING STUDENTS AND FELLOWS

Inviting students and fellows to the hub from other universities has proved the most effective way to form strong bonds with our academic partners. In 2018, we have a total of 18 visiting students and fellows.

<table>
<thead>
<tr>
<th>NAME</th>
<th>INSTITUTION</th>
<th>DATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor Na Yang</td>
<td>Beijing Jiaotong University, China</td>
<td>2 January 2018</td>
</tr>
<tr>
<td>Dr Rafat Siddique</td>
<td>Thapar University, India</td>
<td>31 January 2018</td>
</tr>
<tr>
<td>Prof Zhang Chunwei</td>
<td>Qingdao University of Technology, China</td>
<td>8 February 2018</td>
</tr>
<tr>
<td>Professor Qiusheng Li</td>
<td>City University of Hong Kong</td>
<td>9 February 2018</td>
</tr>
<tr>
<td>Professor Jianzhuang Xiao</td>
<td>Tongji University, China</td>
<td>19 February 2018</td>
</tr>
<tr>
<td>Professor Ser Tong Quek</td>
<td>National University of Singapore</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Professor Gang Wu</td>
<td>Southeast University, China</td>
<td>1 August 2018</td>
</tr>
<tr>
<td>Professor Claire White</td>
<td>Princeton University</td>
<td>17 August 2018</td>
</tr>
<tr>
<td>Kaiyuan Mei</td>
<td>Southwest Petroleum University, China</td>
<td>29 October 2018</td>
</tr>
<tr>
<td>Dr Dong Li</td>
<td>Tsinghua University, China</td>
<td>4 November 2018</td>
</tr>
<tr>
<td>Renbo Zhang</td>
<td>Beijing University of Technology, China</td>
<td>4 November 2018</td>
</tr>
<tr>
<td>Professor Jin-Guang Teng</td>
<td>Hong Kong Polytechnic University</td>
<td>25 November 2018</td>
</tr>
<tr>
<td>Professor Zongjin Li</td>
<td>University of Macau</td>
<td>26 November 2018</td>
</tr>
<tr>
<td>Professor Liming Dou</td>
<td>China University of Mining Technology</td>
<td>30 November 2018</td>
</tr>
<tr>
<td>Professor David Nethercot</td>
<td>Imperial College London</td>
<td>2 December 2018</td>
</tr>
<tr>
<td>Jianxiong Miao</td>
<td>Southeast University, China</td>
<td>4 December 2018</td>
</tr>
<tr>
<td>Professor S.P Shah</td>
<td>Northwestern University</td>
<td>10 December 2018</td>
</tr>
<tr>
<td>Kaiqiang Liu</td>
<td>Southwest Petroleum University</td>
<td>29 December 2018</td>
</tr>
</tbody>
</table>
9.3.2 VISITS TO OVERSEAS LABORATORIES

The Hub offers members opportunities to visit top facilities at various educational organisations overseas. During these visits, Hub members learn about state-of-the-art research laboratories, as well as technology advancements in their field. Also, they get a chance to establish a connection with our international collaborators and engage with different world-leading research teams.

<table>
<thead>
<tr>
<th>LABORATORY/FACILITY</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southwest Petroleum University Laboratory</td>
<td>3 January 2018</td>
</tr>
<tr>
<td>Industry partner: Jiangsu Shisong’s manufacturing laboratory in Changzhou, China</td>
<td>10 January 2018</td>
</tr>
<tr>
<td>Central South University</td>
<td>15 June 2018</td>
</tr>
<tr>
<td>Sinoma International Laboratory in Beijing China</td>
<td>2 September 2018</td>
</tr>
<tr>
<td>Southeast University Laboratory</td>
<td>10 September 2018</td>
</tr>
<tr>
<td>Hyundai Laboratory in South Korea</td>
<td>5 October 2018</td>
</tr>
<tr>
<td>Texas A&amp;M University Laboratory in the USA</td>
<td>8 October 2018</td>
</tr>
<tr>
<td>State Key Laboratory of Coal Combustion – Huazhong University of Science and Technology</td>
<td>29 November 2018</td>
</tr>
<tr>
<td>Hong Kong University of Science and Technology Laboratory</td>
<td>2 December 2018</td>
</tr>
</tbody>
</table>

Dr Richard Yeo from ARRB (left) and Dr Erik Denneman from AAPA (right).
9.3.3 NATIONAL AND INTERNATIONAL EVENTS HELD BY THE HUB

The Hub holds events, such as innovation dinners, seminars, workshops and short courses, to encourage communication between participants. All events offer great networking opportunities and are capable of sparking strategic alliances matching research capacity with construction industry ambition. The events hosted, organised or sponsored by the Hub include:

<table>
<thead>
<tr>
<th>EVENT TITLE</th>
<th>EVENT TYPE</th>
<th>VENUE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 International Symposium on Dynamic Hazards in Underground Coal Mines</td>
<td>Symposium</td>
<td>UoW, NSW</td>
<td>18 July 2018</td>
</tr>
<tr>
<td>Hub Mid-Year Meeting 2018</td>
<td>Meeting &amp; Seminar</td>
<td>Monash University, Melbourne</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Neutron, X-Ray CT and Australian Synchrotron with applications in materials</td>
<td>Short course</td>
<td>Monash University, Melbourne</td>
<td>17 August 2018</td>
</tr>
<tr>
<td>Industry-Academia Forum on Advances in Structural Engineering (IFASE 2018)</td>
<td>Conference</td>
<td>Tongji University, Shanghai</td>
<td>7 September 2018</td>
</tr>
<tr>
<td>Engineered construction materials from recycled waste</td>
<td>Workshop</td>
<td>RMIT, Melbourne</td>
<td>12 October 2018</td>
</tr>
<tr>
<td>Nanocomm Hub Innovation Night – NSW</td>
<td>Research Development &amp; Seminar</td>
<td>WSU, Sydney</td>
<td>19 October 2018</td>
</tr>
<tr>
<td>First International Conference on 3D Construction Printing (3DcP)</td>
<td>Conference</td>
<td>Swinburne University, Melbourne</td>
<td>25 November 2018</td>
</tr>
<tr>
<td>Hub End-of-year Meeting 2018</td>
<td>Meeting &amp; Seminar</td>
<td>UQ, Brisbane</td>
<td>4 December 2018</td>
</tr>
<tr>
<td>Nano Engineered Cement-based Meta Materials and Durability</td>
<td>Seminar</td>
<td>UTS, Sydney</td>
<td>10 December 2018</td>
</tr>
<tr>
<td>Nanocomm Hub Innovation Night &amp; Professor Shah’s Seminar</td>
<td>Research Development &amp; Seminar</td>
<td>RMIT, Melbourne</td>
<td>11 December 2018</td>
</tr>
</tbody>
</table>

Group photo at Screw-Theory Based Methods in Robotics Summer School (sponsored by Nanocomm Hub), Monash University.

Hub chief investigator Dr Amin Heidarpour from Monash University.
9.3.3.1 2018 INTERNATIONAL SYMPOSIUM ON DYNAMIC HAZARDS IN UNDERGROUND COAL MINES

The ARC Nanocomm Hub sponsored 2018 International Symposium on Dynamic Hazards in Underground Coal Mines organised by University of Wollongong (UoW) and China University of Mining and Technology. This symposium was held at UoW Innovation Campus from 18-20 July 2018, main topics include:

- Rock/coal burst: mechanism, monitoring and best mitigation practices
- Coal and gas outburst: prediction, monitoring and controls
- Wind blast
- Case studies of risk management including catastrophic roof failures

Chair of this symposium, Hub chief investigator, A/Prof Ting Ren at University of Wollongong.

9.3.3.2 NEUTRON, X-RAY CT AND AUSTRALIAN SYNCHROTRON WITH APPLICATIONS IN MATERIALS

The ARC Nanocomm Hub short course on Neutron, X-Ray CT and Australian Synchrotron with applications in materials was held at Monash University Clayton Campus on 17 August 2018. Assistant Professor Claire White from Princeton University, Dr Asadul Haque from Monash University, Dr Maksimenko Anton from Australian Synchrotron and Dr Floriana Salvemini from ANSTO shared their experiences with examining microstructure of materials using neutron imaging, X-ray CT and Australian Synchrotron. Their talks featured the following topics:

- structure, stability and formation rates of the main binding gels in alkali-activated materials
- synergic applications of advanced computed tomographic methods
- selected applications of micro-CT in civil engineering.

Dr Floriana Salvemini

Assistant Prof Claire White
**9.3.3.3 NANOCOMM INNOVATION NIGHT SERIES – SYDNEY**

Designed to enhance the interactions between academic researchers and industry, the Nanocomm Innovation Night took place on 19 October 2018 at Western Sydney University. This event offers our members a great opportunity to engage with hub stakeholders and to support innovation within the infrastructure sector through networking and collaboration.

**9.3.3.4 HUB END-OF-YEAR MEETING 2018**

The ARC Nanocomm Hub End-of-Year meeting 2018 was held at the University of Queensland on 4 December 2018. Approximately 60 international and domestic hub members including advisory committee, chief investigators, partner investigators, hub associates, research fellows and students were gathered together to celebrate the hub’s successes so far, as well as examining its processes to ensure that the hub is laying the strongest possible foundation for the future.

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*Prof William Young gives a presentation on the hub performance review.*

*Group photo at Hub End-of-Year meeting in Brisbane.*
The ARC Nanocomm Hub End-of-Year meeting 2018.
9.3.3.5 THE AUSTRALASIAN CONFERENCE ON THE MECHANICS OF STRUCTURES AND MATERIALS (ACMSM25)

The ARC Nanocomm hub sponsored the ACMSM25 conference which was held at Brisbane Convention and Exhibition Centre from 4-7 December 2018. It attracted over 200 participants from around the world to review, discuss and present the latest developments in the broad discipline of the mechanics and materials in civil engineering. A total of 55 hub posters from current hub projects were presented in the conference.

9.3.3.6 NANOCOMM INNOVATION NIGHT SERIES – MELBOURNE & PROFESSOR SHAH’S SEMINAR

In conjunction with the Nanocomm Innovation Night- Melbourne held at RMIT 11 December 2018, Professor Surendra P. Shah from Northwestern University, a world leading and most influential expert in cement-based materials, was invited to visit the ARC Nanocomm hub and to deliver a seminar on ‘Nano engineered cement-based meta materials and durability’.

Prof Sritawat Kitipornchai (the University of Queensland, left) and Prof Hong Hao (Curtin University, right) at the conference.

Prof Surendra P. Shah’s visit to the ARC Nanocomm Hub.
9.4 Research Outputs

The Hub records research outputs as a measure of our contribution to technological innovation. Research outputs include journal article publications, industry reports and publications, as well as invited talks, papers and keynote addresses. The hub published 39 journal articles and 11 conference papers in 2018.

9.4.1 PUBLICATIONS

39 Journal Publications:

Farhad Aslani; Guowei Ma; Dominic Law Yim Wan; Vinh Xuan Tran Le, Experimental investigation into rubber granules and their effects on the fresh and hardened properties of self-compacting concrete, Journal of Cleaner Production, 2018, 172, 1835-1847.

Farhad Aslani; Guowei Ma; Dominic Law Yim Wan; Gojko Muselin, Development of high-performance self-compacting concrete using waste recycled concrete aggregates and rubber granules, Journal of Cleaner Production, 2018, 182, 553-566.

Wei Gao; Di Wu; Kang Gao; Xiaojun Chen; Francis Tin-Loi, Structural reliability analysis with imprecise random and interval fields, Applied Mathematical Modelling, 2018, 55, 49-67.

Kang Gao; Wei Gao; Di Wu; Chongmin Song, Nonlinear dynamic stability of the orthotropic functionally graded cylindrical shell surrounded by Winkler-Pasternak elastic foundation subjected to a linearly increasing load, Journal of Sound and Vibration, 2018, 415, 147-168.

Guowei Ma; Zhijian Li; Li Wang, Printable properties of cementitious material containing copper tailings for extrusion based 3D printing, Construction and Building Materials, 2018, 162, 613-627.

Yuguo Yu; Xiaojun Chen; Wei Gao; Qingya Li; Di Wu; Muyu Liu, Stochastic leaching analysis on cementitious materials considering the influence of material uncertainty, Construction and Building Materials, 2018, 184, 186-202.

Keyan Li; Di Wu; Xiaojun Chen; Jin Cheng; Zhenyu Liu; Wei Gao; Muyu Liu, Isogeometric Analysis of functionally graded porous plates reinforced by graphene platelets, Composite Structures, 2018, 204, 114-130.

Qingya Li; Di Wu; Xiaojun Chen; Lei Liu; Yuguo Yu; Wei Gao, Nonlinear vibration and dynamic buckling analyses of sandwich functionally graded porous plate with graphene platelet reinforcement resting on Winkler–Pasternak elastic foundation, International Journal of Mechanical Sciences, 2018, 148, 596-610.

A. Sarikaya; R.E. Erkmen, A plastic-damage model for concrete under compression, International Journal of Mechanical Sciences, 2019, 150, 584-593.

Guowei Ma; Junfei Zhang; Li Wang; Zhijian Li; Junbo Sun, Mechanical characterization of 3D printed anisotropic cementitious material by the electromechanical transducer, Smart Materials and Structures, 2018, 27, 075036.

M. Maizuar; E. Lumantarna; M. Sofi; Y. Oktavianus; L. Zhang; C. Duffield; P. Mendis; H. Widyastuti, Dynamic Behavior of Indonesian Bridges using Interferometric Radar Technology, Electronic Journal of Structural Engineering, 2018, 18, 24-29.

Dandan Sun; Kai Wu; Huisheng Shi; Lintao Zhang; Lihai Zhang, Effect of interfacial transition zone on the transport of sulfate ions in concrete, Construction and Building Materials, 2018, 192, 28-37.

Guowei Ma; Junbo Sun; Li Wang; Farhad Aslani; Miao Liu, Electromagnetic and microwave absorbing properties of cementitious composite for 3D printing containing waste copper solids, Cement and Concrete Composites, 2018, 94, 215-225.

Yuguo Yu; Xiaojun Chen; Wei Gao; Qingya Li; Di Wu; Muyu Liu, Stochastic leaching analysis on cementitious materials considering the influence of material uncertainty, Construction and Building Materials, 2018, 184, 186-202.


Patrick X.W. Zou; Xiaoxiao Xu; Jay Sanjayan; Jiayuan Wang, A mixed methods design for building occupants’ energy behavior research, Energy and Buildings, 2018, 166, 239-249.


Xiaohan Yang; Ting Ren; Alex Remennikov; Xueqiu He; Lihai Tan, Analysis of Energy Accumulation and Dissipation of Coal Bursts, Energies, 2018, 11, 1816.

M. Tapas; K. Vessalas; P. Thomas; V. Sirivivatnanon; J. Brenner, Effect of Limestone Content in Cement on Alkali-Silica Reaction Using Accelerated Mortar Bar Test, Concrete in Australia, 2018, 44, 41-47.


H. Zhang; C.M. Wang; N. Challamel; Y.P. Zhang, Uncovering the finite difference model equivalent to Hencky bar-net model for axisymmetric bending of circular and annular plates, Applied Mathematical Modelling, 2018, 300-315.


Dongqi Jiang; Kiang Hwee Tan; Chien Ming Wang; Khim Chye Gary Ong; Helge Bra; Jingzhe Jin; Min Oak Kim, Analysis and design of floating prestressed concrete structures in shallow waters, Marine Structures, 2018, 59, 301-320.

Jian Dai; Chien Ming Wang; Tomoaki Utsunomiya; Wenhui Duan, Review of recent research and developments on floating breakwaters, Ocean Engineering, 2018, 158, 132-151.


Ling Wan; Mengmeng Han; Jingzhe Jin; Chi Zhang; Allan Ross Magee; Øyvind Hellan; Chien Ming Wang, Global dynamic response analysis of oil storage tank in finite water depth: Focusing on fender mooring system parameter design, Ocean Engineering, 2018, 148, 247-262.

Ehsan Hosseini; Mohammad Zakertabrizi; Asghar Habibnejad Korayem; Zhenyue Chang, Mechanical and electromechanical properties of functionalized hexagonal boron nitride nanosheet: A density functional theory study, The Journal of Chemical Physics, 2018, 149 (11), 114701.

Qiandai Zhang; Jianfeng Lu; Ziyu Wang; Qingdong Ou; Yupeng Zhang; Hui Ying Hoh; Qiaoliang Bao, Degradation of Two-Dimensional CH3NH3PbI3 Perovskite and CH3NH3PbI3/Graphene Heterostructure, ACS Applied Materials & Interfaces, 2018, 10 (28), 24258-24265.

Vahid R. Adineh; Changxi Zheng; Qianhui Zhang; Ross K. W. Marceau; Boyin Liu; Yu Chen; Kae J. Si; Matthew Weyland; Tony Velkov; Wenlong Cheng; Jian Li; Jing Fu, Graphene-Enhanced 3D Chemical Mapping of Biological Specimens at Near-Atomic Resolution, Advanced Functional Materials, 2018, 28 (32), 1801439.

Baiqian Dai; Xiaojiang Wu; Lian Zhang, Establishing a novel and yet simple methodology based on the use of modified inclined plane (M-IP) for high-temperature slag viscosity measurement, Fuel, 2018, 233, 299-308.

Binbin Qian; Tahereh Hosseini; Xiwang Zhang; Yue Liu; Huanting Wang; Lian Zhang, Coal Waste to Two-Dimensional Materials: Fabrication of α-Fe2O3 Nanosheets and MgO Nanosheets from Brown Coal Fly Ash, ACS Sustainable Chemistry & Engineering, 2018, 6 (12), 15982-15987.
Ezzatollah Shamsaei; Felipe Basquirato de Souza; Xuepei Yao; Emad Benhelal; Abozar Akbari; Wenhui Duan, Graphene-based nanosheets for stronger and more durable concrete: A review, Construction and Building Materials, 2018, 183, 642-660.

Na Meng; Wang Zhao; Ezzatollah Shamsaei; Gen Wang; Xiangkang Zeng; Xiaocheng Lin; Tongwen Xu; Huanting Wang; Xiwang Zhang, A low-pressure GO nanofiltration membrane crosslinked via ethylenediamine, Journal of Membrane Science, 2018, 548, 363-371.

Seungji Kim; Ezzatollah Shamsaei; Xiaocheng Lin; Xiaomin Hu; George P. Simon; Jung Geun Seong; Ju Sung Kim; Won Hee Lee; Young Moo Lee; Huanting Wang, The enhanced hydrogen separation performance of mixed matrix membranes by incorporation of two-dimensional ZIF-L into polyimide containing hydroxyl group, Journal of Membrane Science, 2018, 549, 260-266.

Abozar Akbari; Sally E. Meragawi; Samuel T. Martin; Ben Corry; Ezzatollah Shamsaei; Christopher D. Easton; Dibakar Bhattacharyya; Mainak Majumder, Solvent Transport Behavior of Shear Aligned Graphene Oxide Membranes and Implications in Organic Solvent Nanofiltration, ACS Applied Materials & Interfaces, 2018, 10 (2), 2067-2074.

Weena Lokuge; Aaron Wilson; Chamila Gunasekara; David W. Law; Sujeeva Setunge, Design of fly ash geopolymer concrete mix proportions using Multivariate Adaptive Regression Spline model, Construction and Building Materials, 2018, 166, 472-481.

11 Conference Papers:

Maryam Ghodrat, ‘Computational Fluid Dynamics Analysis of Formwork Pressure Exerted by Self-Compacting Concrete (SCC) Casting in Reinforced wall elements’, International Conference on Computational Fluid Dynamics 10 (ICCFD10), 2018, Barcelona, Spain.

Lihai Zhang; Maizuar Maizuar, ‘Reliability-based model to determine the Residual Life of Bridges’, Sixth International Symposium on Reliability Engineering and Risk Management, 2018, Singapore.


C. Roboredo; P. Thomas; K. Vessalas; V. Sirivivatnanon; P. Thomas, ‘Alkali limit in cement with supplementary cementing materials – A review’, The International Federation for Structural Concrete 5th International fib Congress, 2018, Melbourne, Australia.

Tran Vu; Nadarajah Gowripalan; Pre De Silva; Paul Kidd; Vute Sirivivatnanon, ‘Carbonation and Chloride Induced Steel Corrosion Related Aspects in Fly Ash/Slag Based Geopolymers – A Critical Review’, The International Federation for Structural Concrete 5th International fib Congress, 2018, Melbourne, Australia.

Nadarajah Gowripalan, ‘Effect of Alkali Silica Reaction on Bond Strength and Load Capacity of Reinforced Concrete Structures’, The International Federation for Structural Concrete 5th International fib Congress, 2018, Melbourne, Australia.


9.4.2 INDUSTRY REPORTS AND PUBLICATIONS

- A comprehensive investigation into void detection technologies – A commercially viable option proposed
- A new method to quantify slag flow velocity and its correlation with slag properties
- An innovative permanent steel formwork for concrete stairs.
- Development of Protocols for the Use of Aggregate Minimising the Likelihood of Potentially Adverse Alkali Silica Reaction (ASR)
- F-GO-Based Anion Exchange Membrane for Continuous Acid Recovery
- Full Utilisation of Reactive Aggregates in High Performance Concrete
- Investigation of the High-temperature Slagging characteristics of Xinjiang Lignite
- Numerical analysis of the behaviour of AFS Logic wall columns under concentric loading with reduced number of U bars
- Release of sodium out of slag and its modelling from the mass transfer perspective
- Role of Supplementary Cementitious Materials (SCMs) and Limestone in Alkali-Silica Reaction (ASR) Mitigation
- Study on the briquetting and pyrolysis of Victorian brown coal

9.4.3 INVITED TALKS/PAPERS/KEYNOTE ADDRESSES

<table>
<thead>
<tr>
<th>PRESENTER</th>
<th>EVENT NAME</th>
<th>DATE</th>
<th>VENUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr Kirk Vesselas</td>
<td>Cement Concrete &amp; Aggregates Australia (CCAA) Academics Forum</td>
<td>12 February 2018</td>
<td>Sydney</td>
</tr>
<tr>
<td>Professor Chien Ming Wang</td>
<td>Conference on the Application and Technology of Floating Structures</td>
<td>28 February 2018</td>
<td>National University of Singapore</td>
</tr>
<tr>
<td>Professor Vute Sirivivatnanon</td>
<td>The Performance of Concrete Symposium</td>
<td>17 July 2018</td>
<td>Brisbane</td>
</tr>
<tr>
<td>Professor Chien Ming Wang</td>
<td>Centre of Marine Science’s 9th Talkfest</td>
<td>20 July 2018</td>
<td>The University of Queensland</td>
</tr>
<tr>
<td>Professor Chien Ming Wang</td>
<td>Oscar Wyatt Distinguished Lecture</td>
<td>8 October 2018</td>
<td>Texas A&amp;M University, USA</td>
</tr>
<tr>
<td>Dr Bai-qian Dai</td>
<td>Huazhong University for Science and Technology</td>
<td>9 October 2018</td>
<td>Wuhan, China</td>
</tr>
<tr>
<td>Dr Bai-qian Dai</td>
<td>The 35th Annual International Pittsburgh Coal Conference</td>
<td>16 October 2018</td>
<td>Xuzhou, China</td>
</tr>
<tr>
<td>Professor Chien Ming Wang</td>
<td>Hyundai E&amp;C Technology Conference</td>
<td>5 November 2018</td>
<td>South Korea</td>
</tr>
<tr>
<td>Professor Chien Ming Wang</td>
<td>IStructE Young Researchers’ Conference</td>
<td>29 November 2018</td>
<td>The University of Queensland</td>
</tr>
<tr>
<td>Mr. Guangwu Guan</td>
<td>IFM annual conference</td>
<td>6 December 2018</td>
<td>Geelong, VIC</td>
</tr>
<tr>
<td>Dr. Hong Zhang</td>
<td>The Australasian Conference on the Mechanics of Structures and Materials (ACMSM25)</td>
<td>7 December 2018</td>
<td>Brisbane</td>
</tr>
</tbody>
</table>
9.4.4 OTHER MEDIA

The research of the Hub has captured much attention ever since its launch. In 2018, the hub has been mentioned 6 times in various media, including television and online publications. With such a high degree of exposure, public awareness of the Hub has grown markedly.

<table>
<thead>
<tr>
<th>TITLE</th>
<th>MEDIA NAME</th>
<th>TYPE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre for Infrastructure Engineering (CIE) has launched the second phase of ARC Industry Transformation Research Hub</td>
<td>WSU</td>
<td>Press Release</td>
<td>4 February 2018</td>
</tr>
<tr>
<td>The Science of Large Floating Structures</td>
<td>Blue Frontiers</td>
<td>Online</td>
<td>17 April 2018</td>
</tr>
<tr>
<td>Polymer scientists ‘coat up’ for ‘green’ paint in China collaboration</td>
<td>Invenio</td>
<td>Online</td>
<td>17 May 2018</td>
</tr>
<tr>
<td>Apollo open platform based self-driving agricultural robot</td>
<td>Baidu</td>
<td>Online</td>
<td>4 July 2018</td>
</tr>
<tr>
<td>Why did Ponte Morandi Bridge collapse?</td>
<td>ABC Studios &amp; Media Production</td>
<td>Radio</td>
<td>11 August 2018</td>
</tr>
<tr>
<td>A bridge too far?</td>
<td>PURSUIT – Engineering &amp; Technology</td>
<td>Online</td>
<td>21 October 2018</td>
</tr>
</tbody>
</table>

To reach an even wider audience, we have used various digital platforms to spread the word on the Hub, with the main emphasis on our ground-breaking research.

In July 2018, the Hub website underwent a makeover. The site now provides comprehensive information about the Hub and broadcasts our latest research, news and events.

To engage with more professionals and the general public, the Hub has established a presence on LinkedIn and Twitter. We use both to deliver news about research, events and activities relevant to Hub members. Such forms of social media forge alliances between Hub members from different nodes, communicate the Hub’s research outcomes to the public and attract potential collaborators.

In addition to external communication tools, the Hub has been developing an internal newsletter with up-to-date news and events for all members. We envision that, upon publication of our first issue, cohesion across the Hub will progressively improve.
9.5 Research Outcomes

9.5.1 INTELLECTUAL PROPERTY FILINGS

<table>
<thead>
<tr>
<th>TITLE</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novel gripper</td>
<td>Patent</td>
</tr>
<tr>
<td>Stair formwork – 201890356</td>
<td>Patent</td>
</tr>
</tbody>
</table>

9.6 End-user Links

Research end users are the individuals, communities and organisations outside academia that will directly benefit from our research. End users will continue to support our research only if they can see its value. Hence, the Hub advocates for transparency in research outputs and outcomes.

To engage end users, the Hub has delivered several government, industry and business community briefings, invited industry visitors to the Hub, as well as given talks open to the public. In this way, we can highlight the benefits of our research to those who have funded it, as well as to those who will ultimately benefit from it. Additionally, such engagement attracts potential collaborators for future projects.

9.6.1 GOVERNMENT, INDUSTRY AND BUSINESS COMMUNITY BRIEFINGS

<table>
<thead>
<tr>
<th>BRIEFING</th>
<th>PRESENTER(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARRB – monthly meeting on project progress</td>
<td>Professor Wenhui Duan</td>
</tr>
<tr>
<td>Cement Australia – meeting on two projects progress associated with the hub</td>
<td>Rijun Shrestha, Dr Nadarajah Gowripalan, Professor Vute Sirivivatnanon, Tran Huyen Vu</td>
</tr>
<tr>
<td>CPEAP – Annual General Meeting</td>
<td>Professor Sujeeva Setunge, Dr Dilan Robert</td>
</tr>
<tr>
<td>Fortis – fortnightly meeting on project progress</td>
<td>Professor Wenhui Duan, Thomas Winnell</td>
</tr>
<tr>
<td>VicRoads – monthly meeting on project progress</td>
<td>Professor Sujeeva Setunge, Dr Huu Tran</td>
</tr>
<tr>
<td>ARRB: Roads and their future</td>
<td>Professor William Young</td>
</tr>
</tbody>
</table>
### 9.6.2 Industry Visitors to the Hub

<table>
<thead>
<tr>
<th>Visitor(s)</th>
<th>Institution</th>
<th>Date(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFS system team visit hub WSU node</td>
<td>AFS SYSTEMS PTY LTD</td>
<td>15 January 2018</td>
</tr>
<tr>
<td>Dr Erik Denneman</td>
<td>APPA</td>
<td>23 January 2018</td>
</tr>
<tr>
<td>CSR team visit hub WSU node</td>
<td>CSR Building Product Pty Ltd</td>
<td>24 January 2018</td>
</tr>
<tr>
<td>Paul Kidd &amp; Maja Caballero</td>
<td>Cement Australia</td>
<td>7 February 2018</td>
</tr>
<tr>
<td>Jianhui Zhang</td>
<td>Guangdong Provincial Transport Department</td>
<td>27 May 2018</td>
</tr>
<tr>
<td>Jianbin Zhu &amp; Ning He</td>
<td>Shenzhen Expressway Engineering Consultant Co., Ltd</td>
<td>27 May 2018</td>
</tr>
<tr>
<td>Dr Yew-Chin Koay</td>
<td>VicRoads</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Dr Warren South</td>
<td>CCAA</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Brian O’Donnell &amp; Paul Mitchell</td>
<td>CPEAP</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Peter Holt</td>
<td>Ironclad</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Dr Richard Yeo</td>
<td>ARRB</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Adnan Malik</td>
<td>CSR Building Product Pty Ltd</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Dr Phillip Arena</td>
<td>Fortis</td>
<td>30 July 2018</td>
</tr>
<tr>
<td>Nardone Arlene</td>
<td>Adbri Masonry</td>
<td>15 October 2018</td>
</tr>
<tr>
<td>Steve Pascoe</td>
<td>Energy Australia</td>
<td>15 October 2018</td>
</tr>
<tr>
<td>Paul Barrand</td>
<td>AGL Loy Yang</td>
<td>15 October 2018</td>
</tr>
<tr>
<td>Joel Chang</td>
<td>OneAtom 12</td>
<td>25 October 2018</td>
</tr>
<tr>
<td>Dr Xinhua Yu</td>
<td>Jiangxi Ganyue Expressway CO., LTD</td>
<td>1 December 2018</td>
</tr>
<tr>
<td>UoW node</td>
<td>China Coal Technology &amp; Engineering Group Corp</td>
<td>12 December 2018</td>
</tr>
</tbody>
</table>
### 9.6.3 TALKS GIVEN BY HUB OPEN TO THE PUBLIC

<table>
<thead>
<tr>
<th>TALK TITLE</th>
<th>PRESENTER</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr-based membranes</td>
<td>Professor Huanting Wang</td>
<td>25 January 2018</td>
</tr>
<tr>
<td>Structures, Sustainability and Materials</td>
<td>Professor Bijan Samali</td>
<td>30 January 2018</td>
</tr>
<tr>
<td>Structural investigation of Architectural Formwork System wall panels</td>
<td>Dr Kamyar Kildashti</td>
<td>31 May 2018</td>
</tr>
<tr>
<td>Prediction of the lateral pressure exerted by self-compacting concrete on formwork</td>
<td>Dr Maryam Ghodrat</td>
<td>21 June 2018</td>
</tr>
<tr>
<td>Graphene Oxide in Cementitious Materials</td>
<td>Felipe Basquirato de Souza</td>
<td>22 June 2018</td>
</tr>
<tr>
<td>Computational Fluid Dynamics Analysis of Formwork Pressure Exerted by Self-Compacting Concrete (SCC) Casting in Reinforced wall elements</td>
<td>Dr Maryam Ghodrat</td>
<td>17 July 2018</td>
</tr>
<tr>
<td>Integrity of PFW systems: propose a commercial available device to effectively detect the voids in the PFW systems</td>
<td>Reza Bani Ardalain</td>
<td>22 July 2018</td>
</tr>
<tr>
<td>AFS panel systems optimization</td>
<td>Professor Bijan Samali</td>
<td>14 August 2018</td>
</tr>
<tr>
<td>Effects of cold form steel studs in enhancing concrete core confinement of wall segments</td>
<td>Dr Kamyar Kildashti</td>
<td>16 August 2018</td>
</tr>
<tr>
<td>ARC Nanocomm Hub Overview – JITRI collaboration meeting</td>
<td>Professor Wenhui Duan</td>
<td>17 August 2018</td>
</tr>
<tr>
<td>ARC Nanocomm Hub Overview – CCAA Innovation Forum</td>
<td>Kwesi Sagoe-Crentsil</td>
<td>30 August 2018</td>
</tr>
<tr>
<td>2D nano-engineering of construction materials</td>
<td>Felipe Basquirato de Souza</td>
<td>8 November 2018</td>
</tr>
<tr>
<td>Environmentally Friendly Waterborne Coating Makes a Clean Planet</td>
<td>Guangwu Guan</td>
<td>6 December 2018</td>
</tr>
<tr>
<td>Development of Novel Waterborne Coatings with Low Haze</td>
<td>Sha Ji</td>
<td>6 December 2018</td>
</tr>
</tbody>
</table>
## 9.7 Hub Finance

<table>
<thead>
<tr>
<th>REPORTING PERIOD</th>
<th>2018</th>
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<tbody>
<tr>
<td><strong>INCOME</strong></td>
<td></td>
</tr>
<tr>
<td>ARC</td>
<td>1,033,064</td>
</tr>
<tr>
<td>Industry Partners</td>
<td>1,354,126</td>
</tr>
<tr>
<td>Universities</td>
<td>736,383</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>3,123,573</td>
</tr>
<tr>
<td><strong>EXPENDITURE</strong></td>
<td>2,965,422</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

The ARC Nanocomm Hub would like to acknowledge our vital funding by the Australian Research Council. Additionally, for their ongoing financial and in-kind support, we would like to thank all our collaborators: Monash University, RMIT University, The University of Melbourne, Deakin University, Swinburne University of Technology, Australian Catholic University, University of Technology Sydney, Western Sydney University, University of Wollongong, University of New South Wales, The University of Western Australia, National University of Singapore, Nanyang University and Princeton University. We also appreciate the generous in-kind contributions of our many industry partners. Assistance from each and every source sustains our quest to advance construction materials and technologies.

EDITORS:
Nanocomm Hub Team
Joan Rosenthal
Suzanne Shubart