



**Ash Development
Association of
Australia**

COAL ASH matters

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INNOVATIVE CCP UTILISATION



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Membership

COMPANY MEMBERS

A primary role of the ADAA is to bring together producers and marketers of coal combustion products (CCPs). Our activities cover research and development into CCP usage, advocacy and technical assistance to CCP producers and users, as well as a forum for the exchange and publication of CCP information.

For more information visit us at www.adaa.asn.au

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- European Coal Combustion Products Association (ECOBA) www.ecoba.org
- UK Quality Ash Association www.ukqaa.org.uk
- American Coal Ash Association www.acaa-usa.org
- World Wide Coal Combustion Products Network (WWCCPN) www.wwccpn.org

Editorial

The Ash Development Association of Australia (ADAA) are honoured to bring you the latest Coal Ash news from around the Globe.

Welcome to another edition of Coal Ash Matters. The Ash Development Association of Australia (ADAA) are pleased to bring you the latest Coal Ash News from around the World in the last six months.

2018 has been another productive year for the Ash Development Association of Australia (ADAA) and our members are continuing to advocate strongly for the use of coal combustion products (CCPs) in an ever-expanding range of applications. However, there are a range of myths that are common within the industry. We kick off this edition of Coal Ash Matters by debunking some of these common myths and lies that cast doubt on coal.

Also in this edition, we speak with ADAA member, Latrobe Magnesium, about their world-first venture. They are currently developing a magnesium production plant from brown coal fly ash in Victoria's Latrobe Valley, using its patented hydromet extraction process and its own newly developed fast cycle vertical retort furnace (FCR).

2018 has seen a full calendar of events for the ADAA and the industry as a whole. Most recently, CMIC18 and fib Congress. 2019 is set to be just as busy! Conference reports and updates are provided later in this edition, make sure to mark your calendars now!

Finally, the association would like to wish you all a safe and happy Christmas and New Year. We look forward to continuing our work with you in 2019 and beyond.

Happy Reading!



COAL FIRED POWER STATIONS

DEBUNKING MYTHS THAT CAST DOUBT ON COAL

There are some commonly cited criticisms that circulate political, industry and community forums which emanate from environmental non-government organisations (ENGO's) of coal fired power stations. We dive into some of these claims and debunk the common myths and lies that cast doubt on coal fired power stations and associated by-products, like coal combustion products.

Myth: We don't need coal fired power stations

One of the biggest arguments against coal fired power stations is that we can rely on renewables like solar and wind instead.

Relying on energy sources such as solar and wind simply isn't sufficient to provide power for entire cities, particularly for energy intensive industrial processes like steel production where large amounts of reliable power are needed 24/7¹. These renewables need to be supported by some form of energy storage (battery, pumped hydro etc.) before being able to provide consistent and reliable energy. Recent events in South Australia – the state regularly experienced rolling blackouts due to load shedding², highlight this lack of reliability problem. Load shedding refers to when electricity is cut-off when there isn't enough power to meet demand. The issue is exacerbated during summer periods when temperatures frequently rise above 30 degrees and power and air conditioners are turned to full-blast.

In 2017, Malcolm Turnbull pitched the role of coal in Australia's energy future as a reliable source of electricity for the country³. Scott Morrison, who at the time was the Treasurer, wielded a lump of coal and declared, "this is coal – don't be afraid, don't be scared" ². Morrison said coal has ensured the country's competitive advantage for over 100 years, delivering prosperity to all Australians and ensuring the industry remains competitive in the global market². What is needed in the energy debate or energy mix is a scientifically sound policy to ensure future investment. Recently, Scott Morrison, PM, and Angus Taylor, Energy Minister, flagged a range of policy interventions to boost investment in a reliable power generation⁴. Morrison flagged possible new investment into coal and assured that Australia would meet its commitments under the Paris climate agreement⁴ (to limit global warming to "well below" 2 °C and pursue efforts to limit warming to 1.5 °C)⁵.

Myth: Coal fired power stations aren't clean

Over decades of industrialisation, innovation and technology improvements have been built into processes of coal fired power stations to improve the efficiency and reduce environmental effects of coal extraction, preparation and use. These processes are collectively known as 'clean coal technologies'. Clean coal technologies reduce the emissions and by-products produced, as well as increase the amount of energy gained from each tonne of coal.⁶

By-products, such as coal combustion products (CCPs) from coal fired power stations, are used beneficially in a number of applications such as construction materials, agriculture and manufacturing processes as input materials. These beneficial uses of CCPs can be broadly described as being part of the circular economy. That is, CCPs are resources or outputs of the coal fired power which can become the input or valued resource of another industry, sector or process.

The use of CCPs as valued resources is well established with more than 6 million tonnes used annually in a range of applications, which is underpinned by significant industry investment. For example, for more than 30 years CCPs have been supplied and safely used in asphalt as mineral fillers, cement manufacture, concrete manufacture, road and embankment

construction applications, plus other novel applications such as carpet manufacture. These end use applications are well established and have proven economic and social benefits. The use of CCPs as a direct replacement for natural resources used in construction has had numerous environmental benefits including;

- The reduced usage of non-renewable quarry resources, fuels, limestone, sand and coal, as well as the environmental impacts associated with mining these natural resources;
- The lowering of emissions through replacing virgin raw materials with processed or partially processed materials such as CCPs; and
- The reduction of some 20 million tonnes of GHGs since 1980's resulting from the effective use of CCPs in concrete, by displacing virgin natural resources.

This list of achievements continues to grow every year, and with organisations such as the Ash Development Association of Australia, we investigate, develop and promote market opportunities for the use of these valued resources .

For example, the Ash Development Association of Australia is a foundation member of initiatives such as the Cooperative Research Centre for Low Carbon Living (CRCLCL) who "work towards lowering carbon emissions in the built environment while driving competitive advantage for Australian industry"⁷. Strategic collaboration brings together expertise from property, planning, engineering and policy organisations with leading Australian researchers. Through the CRCLCL we have developed and helped demystify new low carbon building construction materials, such as geopolymer concretes, which includes applications of coal fired power station by-products such as fly ash, to ultimately reduce carbon emissions.

¹ Chang, C 2018, 'Are you willing to pay \$4 billion to support 'clean' coal-fired power plants?', News Pty Ltd, 3 April 2017, <<https://www.news.com.au/technology/environment/climate-change/are-you-willing-to-pay-4-billion-to-support-clean-coal-fired-power-plants/news-story/1f1b51d97c0027176c96e5f596860665>>

² Chang, C 2017, 'Why South Australia's blackouts are a problem for us all', News Pty Ltd, 10 February, <<https://www.news.com.au/technology/environment/why-south-australia-blackouts-are-a-problem-for-us-all/news-story/bc3bbc8be17d80844bc05ab7f5760d56>>

³ Chang, C & AAP 2017, 'Malcolm Turnbull warns against protectionism during national press club speech', News Pty Ltd, 1 February, <<https://www.news.com.au/finance/economy/australian-economy/malcolm-turnbull-warns-against-protectionism-during-national-press-club-speech/news-story/7246a8894c12a21ac11b91ebf65184ef>>

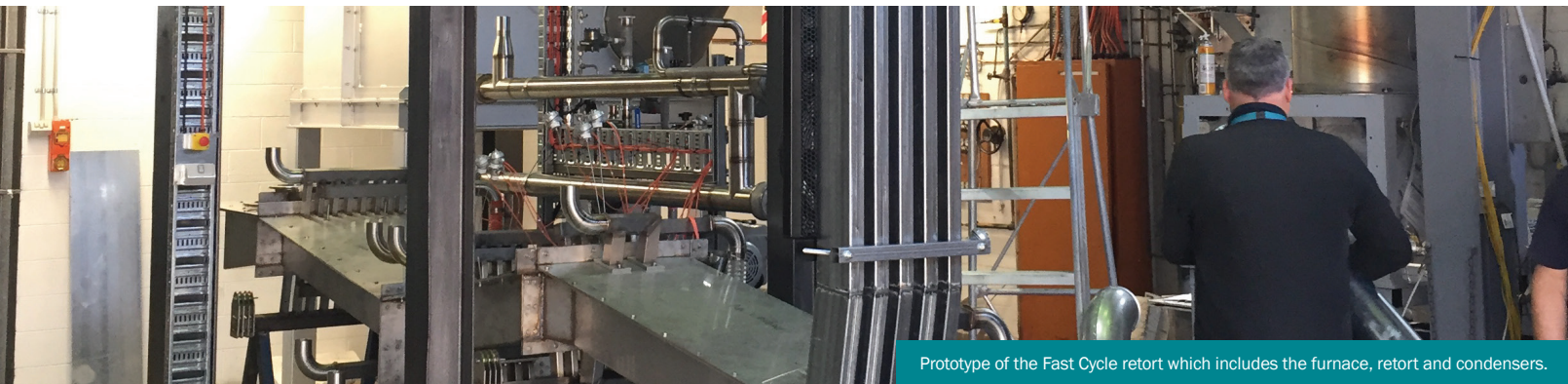
⁴ Murphy, K 2018, 'Government could support new coal power 'where it stacks up' – Morrison', The Guardian, 23 October, <<https://www.theguardian.com/australia-news/2018/oct/23/government-could-support-new-coal-power-where-it-stacks-up-morrison>>

⁵ Department of the Environment and Energy 2018, Paris Agreement, Department of the Environment and Energy, <<http://www.environment.gov.au/climate-change/government/international/paris-agreement>>

⁶ Department of Parliamentary Services 2010, Clean Coal, Department of Parliamentary Services, Australia, <https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Browse_by_Topic/ClimateChangeold/responses/mitigation/emissions/clean>

⁷ CRC for Low Carbon Living 2018, Low Carbon living CRC, Low Carbon Living CRC, <<http://www.lowcarbonlivingcrc.com.au>>.

COMPANY PROFILE: Latrobe Magnesium



Prototype of the Fast Cycle retort which includes the furnace, retort and condensers.

'Punching above its weight' Australian Innovation and Latrobe Magnesium

While the principal output from the combustion of coal is energy, significant quantities of by-products in the form of coal combustion products (CCPs) are also produced. In life cycle terms, the opportunities to exploit the low embodied energy in CCPs such as fly ash, furnace bottom ash, boiler slags and cenospheres are extensive.

Australian producers and marketers of power station ash formed the Ash Development Association of Australia (ADAA) with the objectives of conducting research, transferring knowledge, engaging with key influencers and stakeholders to develop market opportunities for CCPs use. Advancing the use of coal combustion products around the world is a challenge that must be embraced to meet the expectations of a circular economy. The ADAA features one of its innovative and non-traditional market sector members in Latrobe Magnesium (LMG). LMG is currently developing a world-first venture, developing a magnesium production plant from brown coal fly ash in Victoria's Latrobe Valley using its patented hydromet extraction process and its own newly developed fast cycle vertical retort furnace (FCR).

The LMG Project involves the extraction of magnesium and the production of a supplementary cementitious material (SCM) from the brown coal fly ash which from the Latrobe Valley power stations. The world's first patented extraction process will also be used to reclaim, reprocess and rehabilitate the coal combustion product storage ponds. LMG adopts both an Industrial Ecology and the Circular Economy model. The Project:

- Reduces raw material and ash management costs;
- Earns new revenue from residues and by-products;
- Diverts waste from landfills and reduces carbon emissions; and
- Opens up new business opportunities.

Some 95% of the fly ash can be converted into:

- Magnesium 10%
- SCM 95%

The Company is looking to convert the remaining fly ash being char and silicon into other saleable products. The products produced depend upon the chemistry of the brown coal fly ash.

Project Timetable

LMG's objective is to create a new viable industry in the Latrobe Valley utilizing the brown coal fly ash, the local infrastructure and employment available, at a cost which is competitive to China.

LMG's current development timetable is summarized below:

- Aug 2018 conduct vertical retort test work, complete feasibility study and finalise funding;
- Sept 2018 start construction of 3,000 tonnes per annum plant;
- Sept 2019 commence production at 3,000 tpa;
- July 2020 expand to 40,000 tonnes per annum; and
- July 2021 commence full production.

Products & Markets

1. Magnesium

Magnesium is commonly known as the "green metal" owing to its lightweight and strength characteristics. Magnesium has the best strength to weight ratio of all common structural metals. It is one third the weight of steel and is 33% lighter than aluminium. It has been historically used for desulfurization of steel and in aluminium for strengthening cans. It is increasingly used in the car business to lightweight cars allowing them to go further, faster and emit less CO₂. The car industry is being driven by the new vehicle emission standards which have been enacted in the USA and to be introduced in full by 2020 in the European Union. China presently produces 86% of the world's magnesium. The following countries' imports from China, in tonnes per annum, are shown below:

| Countries | Imported Tonnes per Annum |
|------------------------|---------------------------|
| USA and North Americas | 150,000 |
| Europe | 160,000 |
| Japan | 40,000 |
| Australia | 8,000 |

LMG has a MoU's with a major Japanese trading house and has completed an off-take agreement with a respected USA company to distribute its magnesium in North America. There is currently only one magnesium producer in the USA.

2. Cement Market

The Project's SCM has the same chemistry and mineralogy as Portland cement. Tests to date have concentrated on substituting 30% and 40% of the cement used in making concrete with the Project's SCM to both reduce the costs and the CO₂ emissions in making concrete.

3. Carbon Credits

The Project is a low CO₂ emitter owing to the magnesium in the fly ash being in a MgO form and not a MgCO₃ form. Similarly, the feedstock for the Company's SCM is CaO instead of CaCO₃. The project's emissions are close to 70% less than the industries' average for these two products.

Details of Latrobe Magnesium and other member's progress are published in the ADAA's bimonthly eNewsletter 'Coal Ash Flash'. To subscribe to the publication, head to the ADAA website: www.adaa.asn.au and click the subscribe button on the left side.

The ADAA values its long and close working relationship with the American Coal Ash Association, which contributes towards our shared international interests of providing shared benefits to industry members, the environment and the community. To contact the ADAA, email publications@adaa.asn.au or call +61 2 4228 1389.



ADAA TECHNICAL & EDUCATION WORKSHOP

Coal Combustion Products (CCPs) - also often referred to as “coal ash” - are solid materials produced when coal is burned to generate electricity. There are many good reasons to view CCPs as valued resources when managed effectively, rather than a waste with associated liabilities and management costs. Using CCPs within a circular economy mindset conserves natural resources, saves energy and mitigates future management cost for Generators. The last 30 years have shown products made with CCPs can perform better than products made without it.

Coal continues to be the largest energy source for electricity generation within Australia, moreover throughout the world, and significant volumes of CCPs continue to be produced and stored. Over 1.2 billion tonnes of coal ash were produced in 2017 (Heidrich 2017), an almost 40% increase on 2013 results.

The Ash Development Association of Australia, committed to providing opportunities for exchange and collaboration of information about CCPs, stimulating further research and development of CCP uses, held a National Technical & Education Forum on 16 July at the University of NSW, Sydney. During this forum we brought together a number of international speakers to share their experiences from North America and discuss how coal fired power generators are addressing the challenge of Utilisation Opportunities and Threats.

Ken Ladwig, Electric Power Research Institute (EPRI), Sr. Technical Executive provided an insight into EPRI Research on Management of Coal Combustion Products; Dr. Bob Jewell, Research Program Manager Environmental & Coal Technologies Center for Applied Energy Research University of Kentucky argued for the Functional, Low-Energy, Low-CO₂, Low Cost, Sustainable Materials from Coal Combustion By-products; Ari Lewis, Gradient, Principal discussed policy for Coal Combustion Residual (CCR) Beneficial Use Evaluation Under the CCR Rule and Other US Regulatory Updates; Prof Stephen Foster, UNSW Civil Engineering Director, Centre for Infrastructure Engineering and Safety (CIES) shared our journey 6 years on, what we have learned about geopolymer concretes; and Craig Heidrich, CEO Ash Development Association of Australia facilitated the forum discussion around the new operating paradigm for coal combustion products.

The Association in partnership with researchers and upstream users are currently focusing heavily on large volume disruptive technologies with significant potential for reclaiming CCPs that have already been placed into storage. Other countries are already exploring ways to recover CCPs from ash impoundments to secure ongoing supply to existing hard won markets in the construction sectors.

The aim(s) of the Workshop were to present and discuss;

- International Perspectives on Utilisation Opportunities and Threats with three (3) preeminent US researchers and leaders in the field of coal combustion products
- Share perspectives on ‘The Coal Ash Disposal Rule’ – lessons learned, what ‘risk factors’ generators face operating long-term ash impoundments [dams], opposed to implementing full utilisation strategies
- Our seven (7) year journey within the Cooperative Research Centre for Low Carbon Living – demystifying the specification, manufacturing and testing of geopolymer concretes
- Review of coal combustion product collected data, trends and current research focus
- Current processing capacity, utilisation and long-term storage forecast to 2025 – costs and implications

During the forum we explored and mapped out the likely impacts from the changing landscape of coal fired power on CCP generation, processing, use and regulatory implications.





CMIC18

CMIC18 was held on 19 – 21 September at the International Convention Centre, Sydney. Alex Heidrich and Aiden Chilcott attended on behalf of the Ash Development Association of Australia, offering a great networking platform for the ADAA.

CMIC18 is the seventh Constructions Materials Industry Conference, jointly hosted once again by The Cement Concrete & Aggregates Australia (CCAA) and The Institute of Quarrying Australia (IQA). As such, many key players from the Construction Materials Industry were in attendance, including CEO's, MD's and EGM's from the industry's largest and smallest players.



The conference aimed to widen the scope of information exchange and educate the industry on trends and developments. It was also a great platform for networking opportunities within the industry for the Ash Development Association of Australia.

The 3-day conference kicked off with 'Industry Innovation Day', focused on industry innovation and best practices with a series of short presentations and TED style talks from CCAA and IQA members, as well as industry suppliers. The second day's program featured similar style presentations on the future, innovation, energy markets and the construction materials market, as well as awards presentations, networking drinks and a Gala Dinner. The third and final day of the conference was geared towards presentations of the community, environment and diversity. The day wrapped up with a Business Leaders Lunch with a panel of representatives comprising of Government, Contractors and Materials Supplier representatives, who discussed the challenges associated with the cost-effective and efficient delivery of infrastructure.



The CMIC18 exhibition floor focused on maximum delegate flow and exhibitor exposure. This offered the perfect opportunity for the Ash Development Association of Australia to speak with attendees and other exhibitors, networking and advocating for the association's objectives.

fib CONFERENCE



The International Federation for Structural Concrete's 5th International *fib* Congress was held from 7 – 11 October. *fib* brought together leaders and practitioners in the concrete industry from all over the world to Melbourne's Convention and Exhibition Centre (MCEC).

The focus "Better – Smarter – Stronger" provided an excellent forum for engineers, scientists, specifiers, researchers, academics, practitioners and professionals to connect and share knowledge, learning about the advances in the industry all over the globe.

Over the six days, the Congress featured a 4-day technical program with presentations by authors of papers, key note presentations and site tours of local projects and organisations. Presentation topics covered a vast array of topics including sustainability, prefabricated & precast structures, geopolymers, high-volume fly ash concrete, applications of fly ash concrete, and much more.

Additionally, the trade exhibition ran concurrently to the *fib* 2018 congress. Up to 700 delegates and exhibitors had the chance to explore the exhibitor stands and network in a central and energised meeting place. The social program also offered attendees the chance to attend activities such as the Welcome Cocktail function, the *fib* awards ceremony and the Congress Dinner.



700 delegates & exhibitors



Brought worldwide professionals



400 presentations & key notes



6 days of industry talks & activities



Featured the *fib* awards ceremony



Huge range of topics & expertise



ENGINEERED CONSTRUCTION MATERIALS & BY-PRODUCTS

RMIT University, Melbourne hosted an invitation-only workshop focusing on engineered construction materials from recycled waste.

Recycling waste materials in construction has been a focus of a number of research projects conducted at RMIT, The University of Melbourne, Monash University and the ARC Nanocomm Hub. Most of these are sponsored by industry sectors which generate large amounts of waste. There are significant benefits that can be realised by translation of the technologies to practice and also the methods developed can be used to convert other waste materials to useful products.

The workshop aimed to:

1

Showcase current research outcomes and explore new research and development needs and opportunities, and;

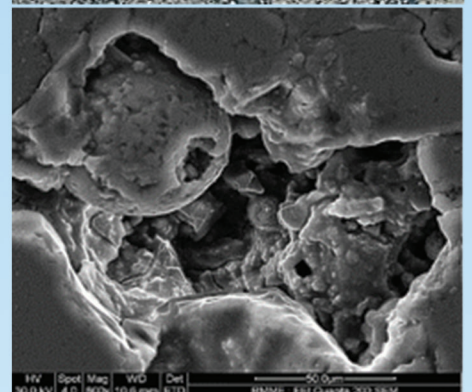
2

Identify gaps in the translation pathway to realise end-user benefits from the completed research.

The abundant program featured presentations on topics including; fly ash, waste concrete, applications of geopolymer concrete, self-healing concrete using high volumes of fly ash, and much more. The Ash Development Association of Australia's CEO, Craig Heidrich, was invited to speak at this exclusive workshop about ash development in Australia. Heidrich's presentation covered;

- Ash development in Australia
- High volume fly ash & slag concrete
- Self-healing concrete using high volumes of fly ash
- Waste concrete from concrete trucks as recycled coarse aggregate
- Geopolymer concrete
- Other recycled solutions

The workshop provided a great platform for information sharing and industry networking among attendees. The Engineered Construction Materials and Waste Workshop achieved its goals, allowing participants to showcase research outcomes and explore new research and development needs and opportunities.



Footpath - Calder Freeway Interchange



CIA AWARDS FOR EXCELLENCE IN CONCRETE



Established in 1971, the Concrete Institute of Australia's Awards for Excellence in Concrete program recognises and publicises significant contributions to the excellence in concrete design, construction and materials in Australia.

Eligible entries include **concrete related projects, technologies and innovations**. The Institute's awards program caters for organisations and projects of all size, fulfilling the Concrete Institute of Australia's mission, "to promote and develop excellence in concrete research, technology, application, design and construction".

Entries are **now open**, so make sure to get your entries finalised before the closing date of **1 March 2019**. For more information, visit www.concreteinstitute.com.au/Awards-for-Excellence/.

Entry Categories include:



Residential Buildings



Commercial Buildings



Infrastructure Projects



Repairs & Rehabilitation



Technology & Innovation

**"TO PROMOTE & DEVELOP EXCELLENCE
IN CONCRETE RESEARCH, TECHNOLOGY,
APPLICATION, DESIGN & CONSTRUCTION."**



**The World of
Coal Ash**

World of Coal Ash 2019

St. Louis Missouri USA

13 - 16 May 2019



1000+

EAGER ATTENDEES



60+

EXPERT SPEAKERS



25+

SPONSORS



1

AMAZING CONFERENCE

THE MOST ANTICIPATED INTERNATIONAL COAL ASH CONFERENCES OF THE YEAR.

World of Coal Ash 2019 is one of the most anticipated international coal ash conferences of the year. Organised by the American Coal Ash Association (ACAA) and the University of Kentucky Center for Applied Energy Research (CAER), WOCA 2019 marks the 8th joint biennial meeting. The conference will focus on the science, applications and sustainability of worldwide coal combustion products (CCPs) as well as gasification products.

The Committee is now inviting applications for unsolicited oral and poster presentations. The application deadline is 9 November 2018 – get in quickly so you don't miss out on this opportunity!

Registrations are open for WOCA 2019! Early-bird special ends 1 April 2019. For details and submission guidelines, visit worldofcoalash.org.

PRESENTATION TOPICS INCLUDE:



CCP Chemistry & Classification



Concrete, Cement & Grouts



Ash Management



Emerging Technologies



CCPs & Sustainable Construction



Project Specific Case Studies



CO₂ Emissions & the Role for CCPs



Manufactured Aggregates



CCP Storage & Management



Regulatory Issues



International Perspectives



Disposal & Waste Issues

& MUCH MORE!



UK Center for Applied
Energy Research

The World of Coal Ash (WOCA) is a joint project between the American Coal Ash Association (ACAA) and the University of Kentucky Center for Applied Energy Research.

CONCRETE 2019



International Convention Centre (ICC) Sydney
8 - 11 September 2019

Hosted by The Concrete Institute of Australia, the 29th Biennial national conference will be held at the ICC Sydney from 8 - 11 September 2019.

The International Convention Centre Sydney is at the heart of Sydney Harbour, surrounded by retail, restaurants and the vibrant public domain of Darling Harbour. Just a short walk from the CBD and surrounding university and cultural quarters, ICC Sydney is the perfect location for Concrete 2019.

Concrete 2019 will feature international keynote speakers, concurrent sessions, free paper sessions and posters. The Scientific Committee have announced the themes for the conference, now available for abstract submissions. All abstract submissions must be finalised by 1 Dec 2018.

Confirmed Scientific Themes:

- Alkali-activated concretes
- Alternative cementitious materials
- Bridge structures
- Case studies and major projects
- Concrete materials for Design and Construction – What's New?
- Construction (infrastructure, development, innovations) and major projects
- Durability (and modelling for durability)
- History of concrete and education
- Modelling and design
- New concrete component materials
- Precast and prefabricated concrete
- Reinforcing and Prestressing Materials
- Repair and rehabilitation
- Resilience
- Seismic
- Shear and Torsion
- Shotcrete
- Shrinkage and Creep
- Standards, specifications and codes
- Structural Strengthening
- Underground and Foundation Structures

For more information and to submit your abstract, visit www.concrete2019.com.au.

The Ash Development Association of Australia (ADAA) are pleased to announce that we will be an exhibitor at Concrete 2019! As a platform for information sharing and industry networking, we are excited to showcase the association and advocate our mission and objectives to the various stakeholders and attendees at the conference.



OBITUARY FOR COLIN REX WARD

31 DECEMBER 1945 - 18 SEPTEMBER 2018



A great friend and researcher of coal combustion products will be sadly missed. Prof. Colin Ward was a research leader when it came to coal ash. Colin's contributions to the scientific community are significant, but he was second to none when it came to understanding coal ash. Colin was the joint editor of the first and second edition of the Coal Combustion Products Handbook. This handbook continued the strong relationship developed between researchers, industry experts and the energy industry that was established during the term of the Cooperative Research Centre for Coal in Sustainable Development (2001–2008).

Colin was born on 31 December 1945 to Rex Alexander Ward (an ambulance officer) and Olive Barbara Ward (nee Miller). Colin's undergraduate studies were supported by a scholarship from the Joint Coal Board and included vacation work on different aspects of coal exploration and mine geology. Although his Honours thesis involved mapping the Proterozoic and Devonian strata at Fowlers Gap, north of Broken Hill, and his Ph.D. was on fluvial sedimentology of the Triassic sequence in the southern Sydney Basin, the scholarship and vacation work provided the springboard for much of his subsequent academic career.

After completing his Ph.D., Colin joined the academic staff of the New South Wales Institute of Technology (now the University of Technology, Sydney) as Lecturer in Geology, with responsibility for setting up a teaching program in sedimentary geology and related fields. This included an undergraduate program in coal geology, which was extended in 1977 to become an external short course for graduates working in the coal industry. The graduate-level course has evolved over the years, and Colin provided programs in different aspects of coal geology for companies and other organisations throughout the world. In collaboration with other industry and academic colleagues, he also developed an internationally-recognised textbook, *Coal Geology and Coal Technology*, which was published by Blackwells in 1984 and still remains a useful reference at the national and international level.

Drawing on knowledge of clay mineralogy inherited from his Ph.D. supervisor, Fred Loughnan, Colin also began research programs to investigate the mineral matter in coal. These were further developed while on study leave at the Illinois State Geological Survey in 1975. He also spent six months with the Sydney-based consultant group of McElroy Bryan and Associates in 1979, working on a range of coal resource evaluations, followed by a second period of study leave at the University of Kentucky in 1980, supported by a Fulbright Travel Award.

Colin returned to the University of New South Wales in 1984, taking up a position vacated by Fred Loughnan's retirement. This allowed a greater focus on research activities, including more in-depth work on mineral matter in coal, investigation of methane ignition by rock friction in underground coal mines, and regional studies on different aspects of the Sydney, Gunnedah and Bowen Basins. In conjunction with colleagues from other institutions, he was also involved in compiling a Photographic Guide to Cored Rocks of the Sydney Basin (University of Sydney, 1986), *Geology of Australian Coal Basins* (GSA Coal Geology Group, 1995), *Geology in Longwall Mining* (Coalfield Geology Council of NSW, 1996) and the *Coal Combustion Products Handbook* (2007 and 2014). Following promotion to Associate Professor, Colin became Head of the Department of Applied Geology at UNSW in 1993. He served in that role during a tumultuous period of change at the University until the end of 2001, when geology merged with other disciplines to form the School of Biological, Earth and Environmental Sciences.

Colin's research program was strengthened by study leave in 1998 at CSIRO and the University of Sheffield, with a focus on developing X-ray diffraction as a quantitative tool for mineralogical evaluation. He has published over 135 refereed papers on his various research projects, and a similar number of full-length papers at national and international conferences. Colin has served as a member of the Editorial Board for the *International Journal of Coal Geology* since 1990, and in 2012 was Guest Editor for a Special Issue of that journal on Minerals and Trace Elements in Coal. He has also served as Project Leader in the CRC for Coal in Sustainable Development, working on coal ash characterisation, and as a technical member of the NSW Coal Compensation Review Tribunal.

In the course of his academic career Colin developed a range of teaching and research programs in coal geology and has introduced numerous undergraduate and graduate-level students to different aspects of geology, especially coal geology, both in Australia and overseas. He has also successfully supervised more than 19 postgraduate research student projects, leading to M.Sc. and Ph.D. degrees. During the course of his professional career, Colin has worked in some 25 different countries worldwide, ranging from the jungles of northern Borneo to the back-blocks of western Mongolia, including the development of a major coal mine in northern Thailand.

Colin retired as Professor of Geology at UNSW in July 2006, but continued as a Visiting Professorial Fellow at the University and as a Visiting Scientist with CSIRO Energy Technology. Colin was awarded a D.Sc. by the University of New South Wales in 2016 and was appointed as an Emeritus Professor at the University of New South Wales in 2017. He was appointed as a Distinguished Professor at the China University of Mining and Technology, Xuzhou, China in 2017. In 2010 he was presented with the Gilbert H. Cady Award for Coal Research by the Geological Society of America, becoming the first Australian coal geologist to be recognised in this way. He has also received the Award for Excellence in Coal Geology from the Coalfield Geology Council of NSW (1998), the 2011 Ralph J. Gray Award for the best refereed paper in organic petrology from the Society for Organic Petrology and the 2017 Dalway Swaine Award for the best refereed paper in coal and hydrocarbon source rock geochemistry. Other honours include presentation of the Kenneth Mosher Memorial Lecture in 2000 and the J.J. Frankel Memorial Lecture in 2007.

Colin served as Chairman of GSA's Coal Geology Group in the early years of its formation (1979–81), and also as Secretary of the New South Wales Division (1983–84). In addition, he has served as Chairman of the Coalfield Geology Council of NSW (1985–87), as Councillor for the Australian Institute of Geoscientists (1991–2000), and as President of The Society for Organic Petrology (2004–2005). He was a Fellow of the Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists, the Geological Society of Australia and the Geological Society of America. He was a member of the International Committee for Coal and Organic Petrology, the Royal Society of New South Wales and an honorary member of The Society for Organic Petrology. In 2012 he was presented with the John Castaño Honorary Member Award from The Society for Organic Petrology, recognising his exemplary commitment to education, excellence in research and service to that Society, as well as to the wider geological community.

Although geology was his passion, during late High School and early University Colin took up skin diving and he was also instrumental in establishing the UNSW Underwater Club. On moving to Kareela he became involved in a number of different community activities, mainly in support of the children. These included serving as Group Committee President for 1st Green Point Scouts, as manager of his son David's cricket team for Sylvania Heights Community and Youth Club and as secretary of the P & C Association and an inaugural member of the School Council at David's High School.

Colin is survived by his wife Kathie, his son David and his daughter Leanne and his three grandchildren James, Alex and Georgia.

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WRITE FOR COAL ASH MATTERS

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