Ash Development Association of Australia

COAL ASH matters

09 MAY

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THIS ISSUE - MAY 09'

Creative Genius

Undoubtedly, the issue of climate change is a serious matter. However when it comes to brainstorming solutions, it appears the more imaginative, the better. We are surrounded by talks of using sugar to generate electricity and building underground caves to store carbon emissions. Evidently, thinking outside the square is a worthwhile activity.

This issue of *Coal Ash Matters* focuses on current projects that are using innovative solutions to combat serious issues related to climate change. Included is a report on a current project undertaken by the NSW Government designed to reduce greenhouse gas emissions; a profile on the activities and processes conducted at CS Energy Swanbank Power Station and a brief introduction to one of our new members - Stanwell Corporation.

This edition also features a new Reference Data Sheet (RDS) published by our Technical Committee on the uses and benefits of incorporating fly-ash in concrete for post-tensioned elements. This RDS incorporates valuable research conducted over the past 12 months and has been included especially for our Coal Ash readers.

For more information on the ADAA, its members and the industry, or to download an electronic copy of this newsletter, please visit our website: www.adaa.asn.au

An Underco$_2$ver Mission

Whilst Londoners value the "underground" for its ability to facilitate city transportation, the NSW Government sees its potential in providing essential storage space.

Earlier this year, the Minister for Energy, Mr Ian Macdonald spoke of the NSW Government's plan to store greenhouse gas emissions from several coal-fired power stations in nearby underground reserves. Undertaking of the plan began in mid-January this year where drilling at the Munmorah power station commenced for the purpose of creating an appropriate space 800 metres under the earth to store thousands of tonnes of liquefied carbon dioxide.

Above: Munmorah Station

Above: Delta's Carbon Capture Project

Above: Close-up of Carbon Capture Project

A project both part of and supported by the Asia Pacific Partnership on Clean Development and Climate (APP), the Government anticipates that the operation will return impressive results of a 3,000 tonne reduction of carbon emission (CO_2^{-e}) per year, estimated to steadily increase by three-and-half times by 2013. These figures assure that the plan is not just a 'sweep it under the carpet' solution to combatting the greenhouse problem.

Putting this initiative into the context of coal combustion product (CCP) reuse by our members, more than 26 million tonnes of CCP [fly ash] have been used in various cementitious and/or concrete manufacturing applications since 1975 [almost 32 years]. In terms of reductions attributable to the recovery and reuse of CCP more than 18,000,000 tonnes of CO_2^{-e} have been abated through reduced cement manufacture.

Last year alone more than 1,200,000 tonnes million tonnes of CO_2^{-e} was abated or displaced through the recovery and reuse of CCP in the manufacture of cement and concrete respectively, thus conserving limited and valuable natural resources.

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Membership

COMPANY MEMBERS

A primary role of the ADAA is to bring together producers and marketers of coal combustion products (CCP). 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. If you would like more information on the Association and how you can become involved, please complete the information section at the end of this newsletter. Current membership is listed below.

- Adelaide Brighton Cement
- Blue Circle Ash
- Cement Australia
- Cemex
- CS Energy
- CSIRO (CMIT)
- Delta Electricity
- D2G Joint Venture
- Eraring Energy
- Flinders Power
- Flyash Australia
- Golden Bay Cement (New Zealand)
- Heeleys Consulting
- HRL Technology
- Hyrock
- Independent Fly Ash Brokers
- Intergen (Millmerran)
- International Power
- Loy Yang Power
- Nucrush
- Pozzolanic Enterprises
- Rio Tinto
- Roads Traffic Authority of NSW
- Stanwell Corporation
- Tarong North Power Station
- Tarong Energy Corporation
- TRUenergy
- Verve Energy

RELATED ASSOCIATIONS

American Coal Ash Association
www.acaa-usa.org

Institute for Water and Environmental Resource Management University of Technology, Sydney
www.iwerm.uts.edu.au

UK Quality Ash Association
www.ukqaa.org.uk

Around the Power Stations: Swanbank

Swanbank Power Station is one of the most metropolitan power stations still operating in Australia. Originally built in the 1960s by the Queensland Electricity Commission, it is only nine kilometres from the centre of Ipswich. That places it less than an hour by road from any part of Brisbane.

Swanbank is owned and operated by CS Energy and provides electricity to the national electricity market. It has one gas fired and 4 coal fired generators. Throughout the 40 years of generation since the first unit was commissioned in 1966, several million tonnes of ash has been generated. Dry fly ash (20 – 30 % of annual production) has been sold to the cement and concrete industries for decades. The balance has been stored on site in a purpose built ash lagoon awaiting future economical reuse opportunities.

CS Energy is actively pursuing reuse opportunities to utilise the ash in beneficial projects. To facilitate the easy removal of ash from the site, a dry reclaim stockpile has been constructed. Over 300,000 tonnes of ash has been extracted from the lagoon and stockpiled. Geotechnical studies have been carried out, and the resulting information is being provided to major potential clients within a reasonable transport radius of the station.

Above: Ash lagoon in top right corner

The Beneficial Re-use Approval (BRA), negotiated by the ADAA on behalf of members and issued by the Queensland EPA, is a critical element in CS Energy's strategy to develop and encourage new end-use markets which exploit the properties of CCP. For example the BRA allows for CCP to be used as:

- pipe bedding;
- selected backfill adjacent to structures;
- road pavement, base and sub-base structures;
- select layers which act as working platforms at the top of earthworks;
- fill for reinforced soil structures; and
- several other civil and structural applications.

A copy of the full exemption can be downloaded from the ADAA and QLD EPA respective websites.

One of the opportunities for CCP use arises because of the number of disused mines in the Ipswich area. Ipswich has been a coal mining district for over 100 years and there are many open cut and underground mines in the areas close to the Swanbank Power Station. Investigations are underway into the feasibility of remediating some of these disused mines, providing a possible long term viable solution to ongoing mine subsidence in the region.

The ash lagoon is visible in the top right of the photograph (above). Interestingly, one of the challenges in recovering CCP for the mine remediation project has been segregating out the self seeded vegetation to the extent shown in the provided photo. Various species including grasses have spread over a large proportion of the surface without any encouragement.

Peter Heeley

CS Energy Ash Consultant

Ash Development Association of Australia

POST-TENSIONED STRUCTURAL FLY ASH CONCRETE

REFERENCE DATA SHEET No. 9

April 2009

INTRODUCTION

One of the first major reviews of fly ash in concrete was presented at the 39th annual meeting of the Highway Research Board in the USA in 1961 (1). Since the early 1960's in Australia, fly ash has been used very successfully to produce high quality structural concretes and significant research work has been done on understanding its properties (2 ,3). In many Australian states, fly ash concretes form the benchmark Normal Class Concrete types described in Australian Standards AS3600 (4) and AS1379 (5) and supplied to most major projects.

Post-tensioned concrete is a very good and efficient construction solution for many project applications particularly common in slab and beam elements. A significant amount of fly ash concrete is used in such applications, often being the default option for concrete mix selection. In recent times, questions have been raised as to the maximum amount of fly ash (usually expressed as a percentage of the binder) that is allowable in these applications. Of particular concern has been minimising the risk of anchor failure in such concretes, in part, thought to relate to early age mechanical properties of the concrete when final stressing is applied (6). Some anchor failures have been attributed to loss of bond between the concrete and the tendon possibly as a result of the inclusion of fly ash.

Some specifications limit the percentage of fly ash allowed in a post tensioned concrete mix to be no greater than 10% by weight of Portland cement (as opposed to total binder) (7). It is thought by some that higher fly ash percentages can limit early age mechanical properties of concrete and reduce bond between tendons and concrete.

This data sheet discusses implications of using fly ash in post-tensioned concrete given its extensive use and considering new and past research on critical factors that may influence the early stressing of concrete in post-tensioned slabs or beams.

INFLUENCE OF FLY ASH ON POST-TENSIONED CONCRETE PROPERTIES

Recent Research

The early stressing of concrete in a post-tensioned slab or beam relies on the compressive, bond and tensile strength of the concrete (6). Concrete incorporating fly ash can be optimised to meet early age strength requirements as well as later age specifications (1, 2). Fly ash inclusions of up to 30% by mass of binder are routinely used to make structural concretes in Australia as they provide advantages including improved workability, reduced drying shrinkage, preventing alkali-silica reaction, reduced heat generation, and improved durability.

The common criteria for acceptance of concrete used in post-tensioned applications having 12.7 mm diameter strands in Australia are (6):-

- Minimum 28 day characteristic cylinder strength (f_c) of 32 MPa
- Compressive strength at final stress transfer of 22 MPa typically at 3 to 5 days after concrete placement
- Compressive strength of 7 MPa at 24 hours after concrete placement for initial prestressing at 25% of the ultimate stress

Methodology

Research was conducted to determine the influence of fly ash percentage by weight of binder in concrete on tendon pull out load. Fly ash contents ranged between 0% (control) and 30% fly ash. Four trials were carried out to determine properties of fresh concrete, hardened concrete including compressive strength and indirect tensile strength development with time, and to test the bond strength between the strand and concrete matrix when compressive strengths were between 22 MPa and 24 MPa. Table 1 provides the mix designs used in the trials. The control mix included 350 kg/m^3 of Type GP cement (defined in AS3972). In the other three mixes, fine grade fly ash conforming to AS3582.1 was used at 10%, 20% and 30% of the total binder (Table 1) with binder contents in the range of 365 kg/m^3 to 400 kg/m^3.

Fresh Concrete Parameters

All concrete testing was carried out to the relevant parts of AS1012 (8). Measured slump for all mixes ranged between 90 mm and 95 mm. Air contents were measured to be 1% ± 0.2% for all mixes. Bleed characteristics of the fresh concrete (defined in AS1012.9) ranged between 1.1% and 1.7%. Values determined for all concretes indicated that mixes were consistent with those supplied to typical construction applications.

Constituent-Property	Control	Fly Ash 10%	Fly Ash 20%	Fly Ash 30%
Type GP	350	330	305	280
Fly Ash	0	35	75	120
20 mm Aggregate	720	720	725	725
10 mm Aggregate	280	280	280	280
Coarse Sand	560	565	565	565
Fine Sand	280	255	230	200
Water	196	188	187	187
Water Reducer	Included	Included	Included	Included
Water : Binder	0.56	0.51	0.49	0.47
Initial Set (hr:min)	3.15	4.35	4.50	5.20
Final Set (hr:min)	4.40	6.10	6.10	6.40

Table 1: Concrete Mix Details
(Note: Constituent values in kg/m^3)

Hardened Concrete Properties

As per AS 1012.9 (9), standard cylinders were conditioned and tested for compressive strength at 1, 3, 4, 7 and 28 days. The results are presented in Fig. 1. It can be observed that the strength development characteristics for concretes having up to 20% fly ash inclusion were similar. Slightly lower strengths were observed at comparable ages for concretes having 30% fly ash inclusion.

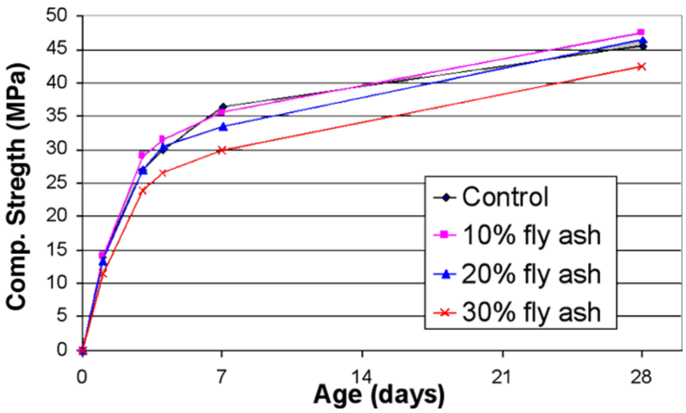

Fig. 1: Compressive Strength versus Time for Concretes Investigated

As per AS 1012 (8), concretes were tested for indirect tensile strength at 2, 4, and 28 days. The results are presented in Fig. 2. It can be observed from the data that indirect tensile strengths for the control concrete at early ages (less than 5 days) were higher than those measured for the fly ash concretes.

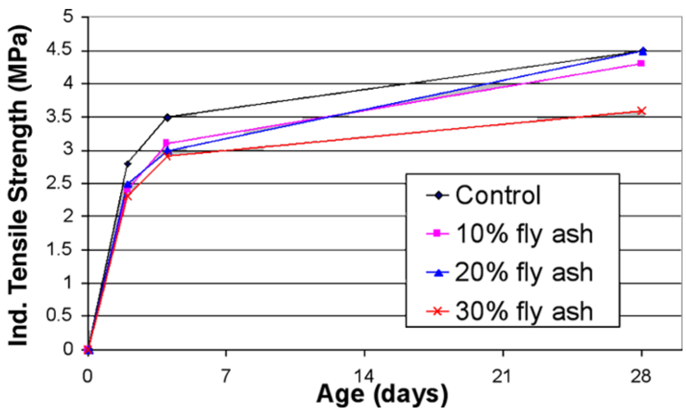

Fig. 2: Indirect Tensile Strength versus Time for Concretes Investigated

Bond (Pull-Out) Strength Determination

Special procedures were developed to determine the pull-out (bond) strength between steel tendons and concrete as there is no Australian standard procedure for measuring this parameter. Cylindrical moulds measuring 150 mm diameter and 300 mm in height were used to cast specimens for pull out testing. Prior to casting, a 50 mm layer of polystyrene foam was placed in each cylindrical mould to act as a bottom cover and strand locator. A 12.7 mm diameter seven wire post-tensioning strand was centrally located in the concrete cylinder having an embedment length of approximately 250 mm.

Three replicate specimens were cast for each concrete. Loads were applied at the AS1012 defined rate until initial failure occurred (defined as the first slip marked by a sudden and brief reversal of load). Pull-out tests were performed on the concrete specimens when measurements indicated that the compressive strength was between 23.5 MPa and 24.0 MPa. Generally, these strengths were achieved later particularly with higher levels of fly ash replacement (Fig. 1). Results of the tests are presented in Fig. 3.

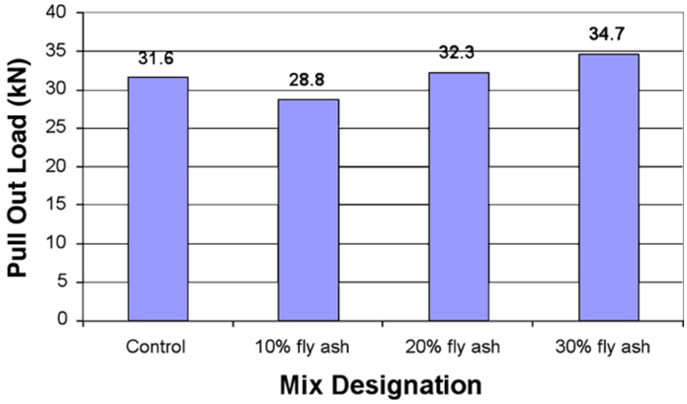

Fig. 3: Bond (Pull-Out) Strengths for Concrete Samples (Having Compressive Strengths between 23.5 MPa and 24.0 MPa)

It can be seen in Fig.3 that mean values of bond strength for all four concrete mixes range between 28.8 kN and 34.7 kN. Unlike the indirect tensile strength results, the mix with the 30% fly ash inclusion showed the highest bond strength. The evidence suggests that increasing fly ash proportions (up to 30% of total binder in concrete) will not decrease bond strength between tendons and concrete.

BOND, POST-TENSIONING, EARLY AGE STRENGTH AND THE INFLUENCE OF FLY ASH IN CONCRETE

Studies of bond in concrete date back to Duff Abrams work in 1925 in USA where it was found that bond strength was generally 10% to 15% of concrete compressive strength (10). There have been many studies on determining relationships between steel-concrete bond and concrete compressive strength (11,12). The influence of ambient temperature on early age strength of concrete and its relevance to prestressing was reported in 1958 by the Portland Cement Association (13). Reported studies indicated curvilinear relationships between concrete to steel bond and concrete compressive strength with a decreasing rate of bond increase with increasing compressive strength (13). Other studies have looked at the relationships between flexural bond and transfer bond (14).

The American Concrete Institute in its guide on fly ash in concrete (15) notes that concrete bond or adhesion to steel is dependent on a number of parameters, including the surface area of the steel in contact with the concrete, the location of reinforcement, and the density of the concrete. Fly ash usually increases paste volume and reduces bleeding. Thus, the contact at the lower interface where bleed water can collect may be increased, resulting in an increased surface contact area (15). The development length of reinforcement in concrete is primarily a function of concrete strength. With proper compaction and equivalent strength, the development length of reinforcement in concrete with fly ash should be at least equal to that in concrete without fly ash. These conclusions about concrete bond to steel are based on extrapolation of what is known about concrete without fly ash. It is concluded in ACI232 (15) that bond between tendons and concrete would be minimally affected by the use of fly ash.

More recent studies on performance of post-tensioned concrete have been reported by Sofi et al (16, 17). Whilst there are many factors found to influence post-tensioned anchor behaviour, none of these specifically relate to fly ash inclusion into concrete. Kuroda et al (18) reported on research specifically considering the influence of fly ash on bond strength. They concluded that there was general improvement in bond strength in concrete incorporating fly ash and that the degree of bond enhancement depended on the chemistry of the fly ash. Gustavson (19) reported in recent work that strand properties such as micro surface roughness and geometry strongly influenced bond to concrete. Furthermore, he reported that concrete density rather than strength influenced bond in the studies reported (19).

CONCLUSIONS

Fly ash is extensively used in concrete for structural applications. The use of fly ash in concrete in Australia dates back to the late 1950's. From studies conducted on fly ash inclusion into concrete specifically relating to post-tensioning applications, the following findings have been noted.

- Concrete strength gain characteristics for control (non fly ash) and fly ash concrete mixes are well understood and are often optimised for particular design and constructional applications.
- Bond (pull-out) strengths for control (Type GP cement only) concretes and fly ash concretes were similar.
- There is no evidence in the technical literature that suggests increasing fly ash proportions (up to 30% of total binder in concrete) will decrease bond strength between tendons and concrete.
- Fly ash concretes can be easily designed to meet early age requirements specified for post tensioning applications.

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Welcoming Stanwell Corporation

Being a recent addition to the ADAA, Stanwell is excited about 'where to from here' with respect to management of coal combustion products (CCP) generated at Stanwell Power Station in Central Queensland.

Located 20kms west of Rockhampton, Stanwell Power Station generates approximately 20% of Queensland's electricity. Fuel is sourced under long term contracts from the Bowen Basin. The fly ash produced meets the general requirements of AS 3582.1. The thermal coal used at Stanwell Power Station has a medium-to-high calorific value combined with lower ash content characteristics.

Stanwell has attempted a number of CCP reuse projects in past years, however unfortunately these projects have been largely unsustainable. Our current efforts are better focused on reducing operating costs which maybe realised through potential opportunities from beneficial reuse.

Stanwell recognises that it's geographical location has been a constraint to previous efforts however we understand that the use of virgin natural material is unsustainable and the reuse of recovered resources such as CCP, coupled with reduced carbon impacts may provide a positive influence to our own aspirations to better manage the CCP we generate.

At present Stanwell is working with customers to develop supply of CCP for cement manufacture, road base foundation, and agricultural applications from furnace bottom ash. As we continue to improve our understanding of customer needs and demands - we will be aiming to improve our plant, involvement and relationships to maximise reuse of Stanwell CCP in the Central and North Queensland markets.

Josh Lobodin

Stanwell Corporation

Results of the 2008 ADAA Membership Survey

As part of its program, the Ash Development Association of Australia (ADAA) collects information annually regarding Coal Combustion Products (CCP) production and sales by members and non-members throughout the previous calendar year.

For members, the survey data is used to calculate membership fees for the 2009/2010 budget period. Other outputs from the information provided by members and non-members assists the industry in determining production levels, and in identifying where 'effective utilisation' of CCP has occurred.

The results compiled from last year's membership survey have been analysed and showed that for CCP utilisation in 2007:

- Approximately 14.5 Mt (million tonnes) of CCP were produced within Australasia (Australia and New Zealand). On a per capita basis, this equates to about 659 kgs per person.
- Some 4.308 Mt (or 30 percent) of CCP have been effectively utilised in various value-added products or to some beneficial end over the period. On a per capita basis, this equates to about 195 kgs per person recycled or reused.
- Approximately 1.504 Mt (or 11 percent) were used in high value-added applications such as cementitious applications or concrete manufacture. This use resulted in more than 1.2 million tonnes of $C0_2^{-e}$ being abated through reduced requirements for clinker manufacture
- About 0.5 Mt (or 4 percent) was used in non-cementitious applications
- Some 2.2 Mt (or 15 percent) was used in projects offering some beneficial use (e.g. onsite mine site remediation, local haul roads etc.). These uses typically generate no economic return, that is, cost recovery only.
- Surplus CCP (10.2 Mt) are typically placed into onsite storage ponds awaiting some future opportunity for economic reuse
- More than 26 million tonnes of CCP [fly ash] have been used in cementitious applications or concrete manufacture from 1975 to 2007 [32 years] equating to about 18 million tonnes of $C0_2^{-e}$ being abated through reduced clinker manufacture

The 2009 Membership Surveys have been collated and are currently in the process of being analysed. Results of these statistics are due to be disseminated by July this year.

A new read

Coal Combustion and Gasification Products is a unique peer-reviewed journal published by the University of Kentucky's Centre for Applied Energy Research (CAER). The journal is designed to communicate coal ash research and emerging technologies and generally 'bring together research that currently is published in disparate sources'.

Invited to serve on the inaugural panel of referees for peer-review is the Ash Development Association of Australia's Chief Executive Officer, Mr Craig Heidrich. Upon accepting the offer, Craig states he is enthusiastic to serve in this capacity and invites all interested members to consider submitting Australian based research into coal combustion products for the journal.

For more information, please contact ADAA, p: 02-42281389

Changing times, changing faces

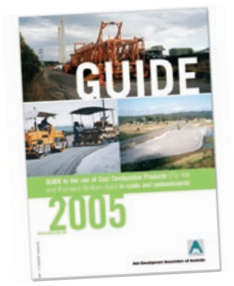
Having recently completed her studies at University, Lauren Robertson bid us all a farewell at HBM Group. Lauren worked primarily on projects for the Ash Development Association of Australia over the last four years, and recently decided that it was time for a change. Moving into a similar communications role at the University of Wollongong, we bid her adieu and wish her all the best in this new chapter of her life.

One leaves, and another comes along – replacing Lauren's role as Research Assistant, the Association welcomes Ms Niribi Charker (pictured). Niribi has recently returned from London where she worked as a Marketing Assistant for Brixton PLC, a property development company. She has returned to complete her Bachelor of Commerce at the University of Wollongong, majoring in Marketing and Management.

Working part time in our office, please join us in welcoming Niribi to our Association.

ADAA RESOURCES

The following resources can be purchased directly from the ADAA. To place your order please phone 02 4228 1389 or email adaa@adaa.asn.au



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