AGENDA
Fly Ash in Concrete, ACI 232
March 27, 2017, 1:00 – 4:00
Marriott Greco, Detroit, MI, USA

1. Welcome by Chair (L. Sutter)
2. Introductions by attendees
3. Approval of the Agenda
4. Approval of the Minutes of the October 24, 2016 meeting
5. Membership update – 31 Voting, 49 Associate, 1 Liaison
6. Quorum Check (40% - 12 voting members)
7. Chair’s Comments
   a. Changes to membership roster – Dropped 2 Voting, Added 1 Voting
   b. TAC Breakfast Report
8. Liaison Reports
   a. TAC – M. Brown
   b. ACAA – T. Adams
   c. ASTM – L. Sutter
   d. NRMCA – K. Obla
   e. NIST – D. Bentz
   f. CIA – J. Aldred (See Attachment A and B)
9. Sessions this Meeting
   a. Beneficiation of Fly Ash for Use in Concrete Mixtures
      Tuesday 8:00 – 10:00 AM, Marriott Ambassador Salon I
      i. What Problem Am I Fixing?
         Presented By: Craig Plunk, Boral Construction Materials
      ii. Carbon Burnout for LOI Management
          Presented By: Lisa Cooper, PMI Ash Technologies
      iii. Particle Separation for Improving Fly Ash Quality
           Presented By: Cesar Constantino, Separation Technologies LLC
      iv. Chemical Control of LOI
          Presented By: Rafic Minkara, Headwaters Inc.
      v. Georgetown, SC: A Reclaiming Success Story
         Presented By: Hank Keiper, The SEFA Group
10. 232.2R Revisions - Response to TAC Comments
    a. Address comments from recent ballot of entire document.
       Ballot Result (22-6-0-0-5)
11. New Documents (See Attachment C)
    a. Tech Note – Discussion of K. Obla draft – TG Members: H. Keiper (Chair), M. Donovan, B.
       Ramme, D. Bentz, J. Tercero, A. Mukhopadhyay, C. Wallace, R. Carrasquillo, B.
       Descheneaux, K. Obla, T. Adams, M. Huffman, R. Dolbeare
    b. New 232.2R – Discuss outline
12. Future Sessions
13. Old Business
    a. Use of recovered ash - Discussion & Updates
14. New Business
15. Adjournment
Minutes for the Ash Development Association of Australia
National Technical and Education Committee

The regular meeting of the Ash Development Association of Australia held a National Technical and Education meeting on 6th February 2017 at Delta Electricity, Level 7/287 Elizabeth Street, Sydney NSW

Present
Daksh Baweja, BG&E MT
Arnaud Castel, UNSW
Donald Edwards, Origin Eraring
Jane Aiken, LendLease (W)
Joel Rickuss, InterGen Australia (W)
Peter Heeley, Heeley's Consulting

Radhe Khatri, RMS
Rhonda Rowe, Stanwell Corp (W)
Jeff Adams, Boral Quarries & Recycling (W)
Justin Flood, Delta Electricity
Craig Heidrich, HBM Group

Apologies
Samuel Harabasz
Bill Hines
David Paterson
Daniel Payne
Glen Baker

1. Welcome

Dr Dak Baweja opened the meeting at 10.38am and welcomed all present.

Apologies

See above

2. Previous minutes

Resolved to adopt the minutes of the previous meeting held on 7th November 2016 as attached.

Business arising from previous minutes

• Standards Australia Committee-status BD031 (D Baweja)
• Industry 3rd Party Accreditation Scheme (C Heidrich)
• ACI-232 sub-committee (D Baweja)
• CPN25 Fly Ash and its Use in Concrete
• Emission Reduction Fund

4. Standards Committee Activities

4.1 BD031 – Fly Ash, Slag and Amorphous Silica

Further to the recent work of the Standards Australia Committee BD031 and subsequent publication of AS 3582 Parts 1, 2 & 3 in February this year, the Association is advising our members of the current status of proposed amendments required to associated Test Method(s), namely AS 3583.6 Methods of test for supplementary cementitious materials for use with Portland cement - Determination of relative water requirement and relative strength.

In particular, Table 1 within Parts 1, 2 & 3 establishes specific limits for ‘Strength Index’ which is NOT currently referenced in AS 3583.6.
Therefore, until the Committee BD031 have developed amendments which are agreed and submitted to Standards Australia for publication, materials covered by AS 3582 series may not comply ‘technically’ with AS 3583.6 given the adoption of a 'Strength Index' which was previously called 'Relative Strength'. This terminology change may lead to confusion and unintended consequences in the market place.

The publication should be concluded by Mid 2017 and CH will keep the committee updated. **For Noting**

### 4.2 BD049 Concrete (Dr. Baweja)

**NTR**

### 4.3 CE012 Aggregates (Dr. Baweja)

DB noted work of the committee and recently circulated Project Proposal. The Project will correct a serious technical error in method AS 1141.24 and will complete the work on Project 6982 dating from about 2004 for a test method for contaminants in crushed recycled material. Otherwise the proposal complies with Standards Australia’s requirement to keep standards “up to date”. The 7 specifications, 62 methods and 1 handbook comprise the National technical requirements for the quarrying industry. Without them the industry and its major customers in the Construction industry would be seriously affected. Safety warning in many methods protect individual laboratory workers while the supply of fit for purpose product protects the public both economically and from a safety risks. **For Noting**

### 4.4 3rd Party (SCM) Accreditation Schemes

CH noted that the CemAssure Accreditation Scheme launch has now been pushed back until late 2017. The process will be trialed before it is put into place and CH will keep the committee up to date. **For Noting**

### 5. Government Activities

#### 5.1 Federal Government – Emission Reduction Fund $2.55 billion

The Ash Development Association of Australia has been assisting the Department of Environment in developing method for the ERF to recognize coal combustion products as low carbon substitutes. The Department established a TWGs, consisting of technical experts, including those from industry and relevant government agencies, such as the Clean Energy Regulator. The TWG has meet on a number of occasions to commence development of a method. The Emissions Reduction Fund (ERF) is the centrepiece of the Australian Government’s policy suite to reduce greenhouse gas emissions. It is designed to source low-cost emissions reductions by providing incentives for eligible emissions reduction projects across the economy. The Government has provided $2.55 billion to establish the ERF.

CH tabled the draft discussion paper and outlined the opportunities to members received on 13 Jan 2017.

*The proposed cement method concept paper in May 2016 has been amended to incorporate feedback from some TWG members. The Department has further examined the issues raised. Through this examination process, it has become clear that issues surrounding the use of locally produced and imported clinker would*
need more detailed investigation. In particular, the likely change in local clinker production and importation levels caused by a project would be critical in assessing whether the method meets the offsets integrity standards of ERF. The Department’s initial analysis suggests it will be very difficult to develop a method.

In short feedback was the Department have a good handle on the problems associated with carbon leakage and cement importation. In particular, issues surrounding the use of locally produced and imported clinker and the likely change in local clinker production and importation levels caused by a project would be critical in assessing whether the method meets the offsets integrity standards of ERF.

Our Association is unsure about a direction or solution which addresses the Departments key concerns which could allow for the TWG to continue its work at this stage. Should the Department decide to disband the TWG, the Association would like to ensure we are represented and kept abreast of any further work in this area, which includes Concrete.

For Noting

5.2 New South Wales, EPA

CH noted the NSW EPA will be conducting review of the currently ‘General Approvals’ once site audits are conducted of NSW based generators. Discussion paper has been drafted and ADAA will be party to these discussions. For Noting

5.3 Queensland, (EPOLA) Bill 2014

As previously circulated mid September and again in November, the Department of Environment and Heritage Protection (DEHP), has adopted the majority of proposed changes to the 2014 coal combustion products (CCPs) BUA from the Association. This substantially reduces the negative impacts from the initial draft versions.

The approved version is available on the department’s website

The end of waste (EOW) framework under Chapter 8 of the Waste Reduction and Recycling Act 2011 which promotes resource recovery opportunities and aims to transform the perception of waste from being seen as waste to being valued as a resource, and replaces the beneficial use approval (BUA) framework, came into effect on 8 November 2016. The EOW framework consists of EOW codes and approvals:

- EOW codes relate to any registered resource producers for a code.
- EOW approvals are considered on a trial basis for reusing waste as resources for which an EOW code has not been developed for the waste.

A waste can be approved as a resource if the department considers that it meets specified quality criteria for specific use. It is the waste producer’s responsibility to ensure that the resource meets the specified quality criteria prior to supplying it to the user for approved use. If a waste is approved as a resource under
the EOW framework, it is no longer considered a waste under s. 13 of the *Environmental Protection Act 1994*.

The Association will be consulting the DEPH about the transition of the current BUA to EOW codes before 31 December 2018. **For Noting**

**5.4 South Australia, Alinta Power Station**

CH noted that after the closure of the Alinta Power Station in SA, a number of negative media reports have arose regarding the long term management of the Ash Dam repository. E.g. [http://www.abc.net.au/news/2017-01-06/conversion-plan-for-port-augusta-power-station-ash/8165694](http://www.abc.net.au/news/2017-01-06/conversion-plan-for-port-augusta-power-station-ash/8165694)

Ms. Ros Degaris, former members of the ADAA National Management Committee and current member of SA EPA. Board had a brief discussion with him regarding the issue of fly ash storage and the non-existent management plans. The station closed in May 2016 and Flinders Power has been applying dust suppressant to its 250ha ash storage to prevent dust being emitted in windy conditions. However, the extreme rain and wind that lashed much of SA during the month of January 2017 have washed away the suppressant and the storage dam has since dried out. Ongoing windy conditions stirred up the dust at the site and created a large ash plume. An EPA report will be completed and a statement issued. CH will continue to monitor the issue however as Alinta is no longer a member of the ADAA. **For noting.**

**6. Research & Development Activities**

**6.1 Technical and Reference Data Sheet revisions**

**6.1.1. CIA Liaison on ACI 232 - Fly Ash committee**

DB noted that he has been invited to join CIA committee - ACI 232 Fly Ash. Professor Larry Sutter, Ph.D. contacted DB and after stepping down as an Associate Member has taken on the new role.

DB has coordinated a reference group so as to have a more frequent representation on ACI 232; members of reference group include:

- Craig Heidrich – CEO ADAA
- Dr Warren South – Director CCAA
- David Farah – National Product Manager Adelaide Brighton Limited
- Tom Benn – Lecturer, University SA and Technical Committee Chair, Concrete 2017 CIA Biennial Conference
- Vute Sirivivatnanon – Professor of Concrete Engineering, University of Technology, Sydney

DB noted some current issues to be discussed would include:

- Concrete Practice Note CPN25 under review
- Major changes within local markets and increased importation of fly ash for concrete
- Power generators and private ownership transfer
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- Australia and 400 years of coal reserves as opposed to nuclear power and waste
- Market based electricity grid

For Noting

6.1.2. CPN 25 - Fly Ash and its Use in Concrete

CH advised the Concrete Institute of Australia has invited the Association to undertake a review of CPN 25 - Fly Ash and its Use in Concrete. The Association conducted a similar review in 2003. CH has been in contact with Peter Heeley, Heeley Consultants, who has recommended that document requires a complete restructure. CH will investigate, in concert with DB the best pathway for concluding the re-drafting prior to circulating for final comment then submitted to the CIA in May 2017. For noting

6.2 CRC for Low Carbon Living

CH/AC updated the committee on progress of project/s and activities of CRC-LCL:
- Pre-mixed low carbon concretes (Sydney City Council) – UNSW (Dr Stephen Foster)
- Australian Ports and high durability Terapods using low carbon concretes (Port Kembla Port) – UNSW & ASMS (Arnaud Castel and Marc Smith)
- Industrial Pavements using low carbon concretes Swinburne & BG&E MT (Dr Jay Sanjayan & Dr Daksh Baweja)

April 2017: Handbook on standard performance based specification for geopolymer concrete initial draft will be completed April 2017
April 2017: Report on the development of synthetic lightweight aggregate from fly ash
June 2017: Handbook Final version will be published through Standards Australia

2017-18: Mainstreaming of Geopolymer Concrete for Pavements and Breakwater Armour Units.
Addresses the remaining barriers, which are the supply chain and the confidence of product delivery.
- Development of the technology into a training package that can be implemented by any concrete supplier with a modern plant facility
- Workforce training
- Large scale demonstrations of the application on pavements and breakwater armour units
- Pavements, slabs on ground and mass concrete elements represent about 70% of all concrete supplied to end-user
- Predicted rise of the sea level and the increasing frequency of massive storms due to global warming
- Aggregate density around 3.3T/m3 = +25% compared to traditional aggregates
- Strategic adaptation response by developing high-density fly ash geopolymer concrete breakwater armour units.

Action: Copy of AC presentation attached

7. Education Activities
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7.1 Publications

7.1.1 Coal Ash Matters


Table Of Content – May 2017

- Editorial
- Member Profile: (Dak Baweja)
- CRC LCL Annual Forum Review (14-15th November 2016)
- ADAA E-Book (Factbook)
- CPN25
- Membership Survey Reminder
- Jamie North (any new projects/ future plans)
- Foxground and Berry Bypass updates/completion
- Conference Updates
- CMIC16 Review (25th – 28th October 2016)
- CAA 2016 Review (19th – 20th October 2016)
- Upcoming conferences
- Concrete 2017 (22nd – 25th October 2017)
- USYD “we are wasting our waste” Updates
- Latrobe Magnesium – Commencing work in Latrobe Valley 1st quarter of 2017.
- Write for Coal Ash Matters

For Noting

7.1.3 Coal Ash Flash (e-Blast)

CH noted that Coal Ash Flash (e-Blast) was launched to enhance our current bi-annual ”Coal Ash Matters” industry newsletter; to keep our members abreast of current news and issues from around Australia and the Globe. We often come across great articles or industry updates that we would like to share with the coal ash community but the next edition is months off. http://www.adaa.asn.au/news-and-events/news. There will be four (4) e-blasts spread across the year. This edition saw 1,285 successful deliveries with 864 total opens and 126 total clicks. For Noting

7.2 Website update

CH advised website statistics for meeting feedback/commentary were tabled. For Noting

7.3 Conference (s)

CH updated meeting on the Association’s involvement in various education and advocacy activities.
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- CRC-LCL Annual Participants Forum: 15-16 Nov 2016 (Report)
- 10th AustRoads Bridge Conference ABC2017: 3-6th April 2017 Melbourne
- Institute of Quarries 2017 (IQA): 4-6th October 2017 Toowoomba
- Concrete 2017: 22 - 25th October 2017 Adelaide
- WWCCPN – May 2017 (CH to deliver paper)

For Noting

8. General Business

After some discussion regarding ash repository and sales CH offered to provide a case study to highlight best practice. Best practices are used to maintain quality as an alternative to mandatory legislated standards and can be based on self-assessment or benchmarking.

Case Study:
- Coal Fired power generators and service providers to customers in portions of Wisconsin and Michigan's Upper Peninsula
- Produce ~1,000,000 tons of CCP’s annually (201$)
- Utilizing 100% of ash since 2006 (past 10 years)
- Leadership journey started back in 1984

Success Factors
(We) Research – Initiate
(We) Leadership – collaborate
(We) Innovation – create value

WE Energy video to highlight new technology. See link to website https://www.we-energies.com for further investigation.

See slides

Next meeting: 1st May 2017 – Delta Electricity, Sydney

Dak Baweja
Technical Committee Chair

Craig Heidrich
Chief Executive Officer
Fly Ash and its Use in Concrete

1 SCOPE
This note is intended to provide:
- basic information on the local fly ash generally available in Australia.
- important properties of fly ash.
- the Australian Standards relating to the properties of fly ash and its use in concrete.
- characteristics of concrete containing fly ash.
- various applications of fly ash concrete.

2 WHAT IS FLY ASH?
Fly ash is the fine powder collected from the exhaust gases from the combustion chambers of the boilers of power stations that burn milled/pulverized coal. Fly ash particles are most commonly spherical in shape and generally resemble portland cement in appearance.

Fly ash from bituminous coal is a pozzolan, i.e. it is a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious properties but which will, in finely-divided form and in the presence of moisture, react chemically with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Fly ash is chemically different to portland cement as is illustrated in Table 1.

Fly ash from Victorian brown coal has been considered unsuitable for use in structural concrete because of its high content of soluble salts(2).

There are no sources of fly ash produced on a commercial scale in Tasmania, ACT or the NT.

Production of quality fly ash in Western Australia has been reported as intermittent in the past.

Nevertheless, good quality fly ash is available in most areas of Australia.

<table>
<thead>
<tr>
<th>Compound</th>
<th>NSW</th>
<th>QLD</th>
<th>SA</th>
<th>WA</th>
<th>Type GP cement(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>58–63</td>
<td>50–75</td>
<td>54</td>
<td>53</td>
<td>17–25</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>24–29</td>
<td>20–30</td>
<td>30</td>
<td>26</td>
<td>3–8</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3–5</td>
<td>1–15</td>
<td>4.5</td>
<td>1.1</td>
<td>0.5–6.0</td>
</tr>
<tr>
<td>CaO</td>
<td>0.5–2.5</td>
<td>0.1–5</td>
<td>5.5</td>
<td>1.5</td>
<td>60–70</td>
</tr>
<tr>
<td>MgO</td>
<td>0.5–1.5</td>
<td>0.2–1.5</td>
<td>1.8</td>
<td>0.8</td>
<td>0.1–4.5</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.1–1.0 °</td>
<td>3.0</td>
<td>0.4</td>
<td>0.5–1.3</td>
<td></td>
</tr>
<tr>
<td>K₂O</td>
<td>0.9–2.0 °</td>
<td>0.9</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO₃</td>
<td>0.2–0.4</td>
<td>0–0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Loss on</td>
<td>0.7–3.0</td>
<td>0.2–3.0</td>
<td>0.3</td>
<td>0.9</td>
<td>1.1</td>
</tr>
</tbody>
</table>

* Na₂O equiv. – acid soluble (0.4–1.0)

This Current Practice Note is an update on the original document published in 1990(1) and authored by John Ashby. The update is based on comments on the contents of the original document by specifiers, consulting engineers, scientists, government authorities, material producers and suppliers, relevant industry groups and other interested parties. The interest of all those who contributed comments is gratefully acknowledged.

The Institute acknowledges the following organisations for their contribution towards the costs of this publication:
- Arup
- Queensland Main Roads
- Ash Development Association of Australia

CPN 25 November 2003
ISBN 0 909375 61 5
3 IMPORTANT PROPERTIES OF FLY ASH

The following are considered to be the most important properties of fly ash:

- Finessness
- Loss on ignition
- Chemical/mineralogical composition
- Uniformity of these properties

**Finessness** is important as it affects the pozzolanic reactivity of the fly ash, the ability of the fly ash to fill voids in the concrete matrix and improvement of workability and pumpability of the concrete.

**Loss on ignition.** The quality of the fly ash is dependent on the coal type, burning conditions and method of collection.

In general, high carbon content usually implies incomplete burning and hence, is generally related to poor quality fly ash in terms of reactivity. High carbon content can also lead to high water demand and difficulty in controlling the air entrainment level of concrete. The carbon content of fly ash is related to the result of the loss on ignition test on the fly ash, AS 3583.3(5).

**Chemical/mineralogical composition.** One of the main factors affecting the reactivity of a fly ash is its glass content. It is not possible to predict the glass content of an unknown fly ash from its chemical composition.

Although some countries specify that the combined content of silica, alumina and iron oxide in the fly ash should not be below a particular level(6), there does not appear to be any justification to use the total chemical composition of the fly ash as an indicator of its quality.

The determination of the mineralogical composition of a fly ash is not a simple procedure, hence, is not suitable to be used for normal quality control purposes.

The chemical composition of a fly ash is, however, useful in checking the gross change in coal composition and the amounts of other materials in the fly ash that may affect the performance of the concrete, eg alkalis and SO$_3$.

Also, a high silica content, typical of Class F ashes sourced from New South Wales, Queensland and South Australia, is considered beneficial where the ash is used to control alkali aggregate reaction(7).

Experience with these fly ashes since the 1970s has led to modification of the requirements of the Australian Standard for fly ash.

These modifications have included, withdrawal of the requirement to test for magnesia content and changing the requirement making reporting of certain properties of the fly ash mandatory to “report on request.”

With global trading a reality, possible importation of foreign fly ash into Australia cannot be ruled out. Also, changes in the chemistry of fly ash produced in Australia may occur in the future due to burning of non-traditional fuels in the thermal power stations.

In the light of the above it is believed the following fly ash properties should be specified to be tested and reported, in addition to those nominated in AS 3582.1 (amended 1999)(8) as “Specified requirements.”

- Magnesia content and presence of periclase (Autoclave expansion test required if MgO is greater than 4%).
- Available and total alkali content.
- Sulfide sulfur content.
- Chloride ion content.

**Uniformity.** The uniformity of the fly ash characteristics of fineness, loss on ignition and chemical and mineralogical composition is most important. The effect of the variation in any of these properties requires careful assessment. It is understood that uniformity limits have not been included in AS 3582.1 (amended 1999)(8) because of the use of quality grading.
4 AUSTRALIAN STANDARDS RELATING TO FLY ASH

Australian Standards relating to fly ash are:

  Supplementary cementitious materials for use with portland and blended cement - Fly ash

  Specification and supply of concrete

Note that AS 3600–2001 Concrete Structures has transferred all former reference to fly ash to either AS 3582.1 or AS 1379.

The requirements currently specified for fly ash in AS 3582.1 are shown in Table 2.

Provision is made for a highly-reactive fly ash, termed “Special Grade.” This fly ash is required to comply with the requirements of Fine Grade.

In addition to the specified requirements shown in Table 2, AS 3582.1 lists what are termed “Reportable properties.” These consist of the following:

- Available alkali content.
- Relative density.
- Relative water requirement.
- Relative strength.
- Chloride ion content.

AS 3582.1 states that the fly ash supplier shall at the request of a purchaser obtaining fly ash direct from the supplier provide a certificate or statement showing the most recent test results obtained on a fly ash sample representative of the type of fly ash being supplied.

The permissible variations from the results of testing by alternative methods to those obtained by the Reference Method are also given in AS 3582.1. These are shown in Table 3.

It should be noted, this table should not be interpreted as the measure of the uniformity of the fly ash produced.

IMPORTANT NOTE: The information in these tables was accurate at the time of preparation of this Current Practice Note. It is the responsibility of the person using this information to ensure that it reflects the information contained in the current Australian Standard for fly ash at the time of its use.

### Table 3 Permissible variations of alternative test methods from Reference Method result

<table>
<thead>
<tr>
<th>Property</th>
<th>Permissible variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>0.1% moisture content</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>0.2% mass loss</td>
</tr>
<tr>
<td>Fineness</td>
<td>1%</td>
</tr>
<tr>
<td>Sulfuric anhydride</td>
<td>0.2% sulfuric anhydride content</td>
</tr>
<tr>
<td>Relative density</td>
<td>0.03</td>
</tr>
<tr>
<td>Chloride ion</td>
<td>0.01% chloride ion content</td>
</tr>
</tbody>
</table>

AS 3582.1 also suggests means of demonstrating compliance with the Standard, sampling (including frequency) and a “Suitable Test Certificate” for reporting test results.

AS 1379, cross-references AS 3582.1 for compliance of material properties.

It should be noted that AS 1379 defines “cement” as Portland or blended cement complying with AS 3972(11), alone or in combination with one or more supplementary cementitious materials complying with the applicable part(s) of AS 3582.

### Table 2 Specified requirements for fly ash [After AS 3582.1]

<table>
<thead>
<tr>
<th>Grade</th>
<th>Fineness, by mass passing 45 μm sieve (% minimum)</th>
<th>Loss on ignition (% maximum)</th>
<th>Moisture content (% maximum)</th>
<th>SO₃ content (% maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine</td>
<td>75</td>
<td>4.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Medium</td>
<td>65</td>
<td>5.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Coarse</td>
<td>55</td>
<td>6.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>
5 THE ACTION OF FLY ASH IN CONCRETE

Physical action
It is generally accepted that the fly ash reduces water requirements for a specified workability due to its spherical shape and its void-filling capacity arising from its fineness. This reduced water requirement provides increased strength, reduced drying shrinkage and reduced permeability.

Chemical action
Most of the Australian fly ashes that are used in concrete have a low calcium oxide content. Their chemical action is by way of them being pozzolanic (see Clause 2). The contribution to strength of these fly ashes by a chemical action is therefore gradual and dependent on the presence of moisture.

Fly ashes with higher calcium oxide contents tend to derive a “cementing” effect through the formation of other compounds.

6 INCORPORATION OF FLY ASH IN THE CONCRETE MIX

Fly ash can be incorporated in the mix as a separately-batched material, or as contained in a blend of fly ash and portland cement, or a combination of both. The effect of the inclusion of fly ash on the properties of the concrete in the plastic and the hardened state will depend on the properties and relative proportions of all of the constituents as well as the influence of certain external factors.

The effect of the inclusion of fly ash in the mix on the water requirement for a particular workability (and to a lesser degree the air content) should be considered in maintaining correct yield of the mix design.

The properties of the particular fly ash being considered can affect the way in which the method of incorporation in the mix will modify the properties of the resultant concrete.

The properties of the fly ash can vary from source to source and even from the one source. In this regard fly ash shares the likelihood of variation that also exists with the properties of the other ingredients, i.e. cement, sand, stone and water. It is necessary therefore to consider the properties of the particular fly ash and the previous results of its use with the other ingredients (or similar) proposed for use.

A significant contribution by the fly ash to the strength of a concrete mix cannot be achieved without a certain amount of fly ash in the mix. This “certain amount” will depend on the proportions of the mix and the characteristics of the constituents of the mix.

At the lower strength grades, the fly ash content of the concrete will normally range from 25 to 40% of the total cement in the mix. At higher strength levels, the fly ash content is more likely to be from 15 to 20% of the total cement content. Work by CSIRO\(^2\) on concrete mixes with contents of fly ash up to 50% of the cement, have been shown to have quite acceptable properties.

7 USE WITH CHEMICAL ADMIXTURES

For a particular air content level, concrete containing fly ash requires a greater dosage of air entraining agent than does portland cement concrete without fly ash\(^3\). It has generally been found that the dosage of air-entraining agent required to obtain a particular level of air entrainment in concrete has to be increased if the carbon content of the fly ash used is higher\(^4\).

The content of alkalis in the fly ash has also been found to affect the level of air entrainment that can be achieved with a particular dosage rate of air entraining agent\(^5\).

Water-reducing and water-reducing/set-modifying chemical admixtures can be used satisfactorily together with fly ash in the concrete. The satisfactory use of fly ash together with these types of chemical admixtures has been normal practice in Australia and other countries for many years\(^6\).

Research published in 1978\(^7\) concluded that superplasticisers or high-range water-reducing admixtures, are compatible with fly ash in concrete and produce no detrimental effects. Considerable experience on projects around the world since that time has confirmed these findings.
8 **BENEFITS OF FLY ASH IN CONCRETE**

When correctly used in concrete, fly ash can display the following benefits:

- Improvement in workability and pumpability.
- Reduced bleeding.
- Increased cohesiveness of the mix.
- Reduced water demand for constant workability.
- Reduced heat of hydration and rate of heat generated.
- Increased later-age strengths.
- Increased resistance to Alkali Silica Reaction.
- Increased resistance to chloride ion penetration.
- Increased resistance to sulphate attack.
- Decreased permeability.
- Reduced drying shrinkage.
- Reduced creep.
- Better definition of off-form finishes.
- Increased electrical resistance of the concrete.
- Improved resistance to acid attack, particularly combined acid and sulphate attack.

Specific performance requirements in any of these areas should be addressed to the concrete supplier.

9 **LIMITATIONS OF FLY ASH CONCRETE**

Fly ash concrete may experience the following:

- Requirement for higher dosage rate of air-entrainment agent.
- Floating out of carbon particles at excessive water contents.
- Marginally lower strengths at ages earlier than 7 days.
- Extended setting times in cold temperatures.

Situations such as these can be addressed by:

- Close monitoring of the quality of the fly ash supplied.
- Identifying bad practices and advising better ones.
- Knowing the particular performance requirements of the concrete and adjusting the mix design to suit.

10 **CURING**

All concrete needs to be cured to develop its potential strength and durability. Inadequate curing adversely affects all types of portland cement concrete.

AS 3600(10) specifies:

- Members subject to exposure classifications A1 or A2 shall be initially cured continuously for at least three days under ambient conditions, or cured by accelerated methods so that the average compressive strength of the concrete at the completion of curing is not less than 15 MPa.
- Members subject to exposure classifications B1, B2 or C shall be initially cured continuously for at least 7 days under ambient conditions or cured by accelerated methods so that the average compressive strength of the concrete at the completion of curing is not less than 20 MPa for exposure classification B1, 25 MPa for exposure classification B2, 32 MPa for exposure classification C and 40 MPa for 65 MPa concrete. In addition, for special class concrete, the minimum cement content and the cement type shall be specified.

These curing requirements apply equally to concrete containing portland or blended cement complying with AS 3972 as well as portland cement batched with fly ash as a separate material.
11 FORMWORK STRIPPING TIMES

AS 3600 specifies stripping times as shown in Table 4.

<table>
<thead>
<tr>
<th>Average ambient temperature over the period, T (°C)</th>
<th>Period of time before stripping Normal Class concrete with specified early-age strength (days)</th>
<th>Period of time before removal for reinforced members (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T &gt; 20</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>12 &lt; T ≤ 20</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>5 &lt; T ≤ 12</td>
<td>8</td>
<td>24</td>
</tr>
</tbody>
</table>

Notes [a] Reinforced slabs continuous over supports.
[b] Slabs and beams not supporting structures above.

This information should be read in conjunction with the respective conditions of clauses 19.6.2.4 and 19.6.2.5 of AS 3600.

Clauses 19.6.2.7 and 19.6.2.8 should be read for “Stripping of forms and removal of supports from soffits of prestressed slabs and beams” and “Control tests” respectively.

Concrete mixes containing fly ash in the ranges of contents in Section 6, above, can generally be designed to satisfy the stripping strength requirements of Table 4 for reinforced concrete members.

The special requirements of prestressed concrete, clause 19.6.2.7 of AS 3600, can be accommodated by using concrete containing fly ash and determining what the requirements are for compressive strength (magnitude and age when required) and proportioning the mix accordingly. The fly ash contents will generally be in accordance with those indicated in Section 6, above.

12 APPLICATIONS

Properly designed fly ash concrete is suitable for premixed and precast applications. These include all structural elements such as slabs, beams, columns, bridges, pavements, dams and other water-retaining structures, tunnel linings, high-rise structures, marine structures etc.

Fly ash concrete is also suitable for “non structural” applications such as domestic paths, driveways, kerb and gutter.

A majority of premixed concrete suppliers in Australia have developed concrete mix designs containing fly ash that are suitable for most applications. Where this is not the case, the services of persons competent to design mixes containing fly ash for various applications are available.
13 REFERENCES


3 Personal communications from members of Ash Development Association of Australia, 2002.


5 AS 3583.3–1991, Methods of test for supplementary cementitious materials for use with portland cement - Determination of loss on ignition.


7 Personal communication from G. Chirgwin, RTA (NSW), 2002.


10 AS 3600–2001, Concrete structures.


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The Issue

This Tech Note discusses the implications of limits on the quantity of supplementary cementitious materials in project specifications (NRMCA, 2015). Prescriptive specifications for concrete construction projects often include a clause that requires a limit on the quantity of supplementary cementitious materials (Obla and Lobo, 2015). The typical clause incorporated in specifications for concrete from the AIA MasterSpec (2014) states:


The MasterSpec (2014) notes inform the designer that this clause is used for concrete exposed to freezing and thawing cycles and the application of deicing salts. However, this advice seems to be ignored by specification writers. In an NRMCA review of more than 100 specifications for projects funded by private agencies, these limits were noted in 85% of the specifications, without consideration of the anticipated exposure condition for concrete members. Some specifications specifically prohibited the use of supplementary cementitious materials (SCMs).

Industry standards

Table 1 replicates Table 26.4.2.2(b) in ACI 318-14, which establishes limits on the quantity of SCMs for concrete members in Exposure Class F3 – defined as “Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals”. The concern is that surface scaling will reduce cover and result in reinforcement corrosion. Additionally, ACI 318-14 requires air entrainment, a maximum water-cementitious materials ratio (w/cm) of 0.40, and a minimum specified strength of 5000 psi (35 MPa) for structural concrete. Plain concrete requires air entrainment, but the limits on w/cm and specified strength are 0.45 and 4500 psi (31 MPa), respectively. The committee is not aware of other industry standards that place limits on the quantity of SCMs in concrete mixtures.

<table>
<thead>
<tr>
<th>Cementitious Materials</th>
<th>Maximum Percent of Total Cementitious Materials by Mass (weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash or other pozzolans conforming to ASTM C618</td>
<td>25</td>
</tr>
<tr>
<td>Slag cement conforming to ASTM C989</td>
<td>50</td>
</tr>
<tr>
<td>Silica fume conforming to ASTM C1240</td>
<td>10</td>
</tr>
<tr>
<td>Total of fly ash or other pozzolans and silica fume</td>
<td>35</td>
</tr>
<tr>
<td>Total of fly ash or other pozzolans, slag cement and silica fume</td>
<td>50</td>
</tr>
</tbody>
</table>

The Basis

Research conducted by Malhotra and Mehta (2012) has indicated that concrete mixtures containing higher quantities of SCMs than those shown in Table 1 have not performed well in tests conducted in accordance with ASTM C672/C672M. However, it is generally understood that the ASTM C672/C672M test is unduly harsh for mixtures containing fly ash and slag cement (Thomas 1997) and results from a more realistic test could allow the use of greater amounts of SCMs (Bouzoubaa et al. 2008). A significant factor in concrete surface defects such as scaling is related to improper concrete finishing and curing (CIP 2). Scaling is observed for higher slump concrete finished by manual methods and is rarely seen in machine finished concrete, as in slipform construction (Thomas 2007).
The use of SCMs generally increases the setting time and decreases the early age strength of concrete. This is beneficial in warm weather but can be a concern for construction in cooler weather. Restricting the quantity of SCMs can be an implicit attempt to attain shorter setting times and increased early age strengths. A research study using 11 fly ash sources illustrated that setting time and early-age strength of 20% fly ash mixtures can vary widely – they can be similar to or considerably delayed when compared to control mixtures without fly ash (Malhotra and Ramezanianpour 1994). Concrete temperature also has an effect on these properties of concrete. So, restricting the quantity of SCMs does not assure control of setting time and early-age strength.

Concrete producers can proportion mixtures to achieve required setting times, and early age strengths by using SCM quantities in excess of those in Table 1, through the use of chemical admixtures, and other parameters (Jeknavorian 2014; Obla et al. 2003). Concrete mixtures with up to 85% SCMs by weight of cementitious materials have been used in structural members to achieve the performance requirements mandatory on some projects (Concrete International 2009; Kite 2005).

The Problem

By limiting the quantity of SCMs:

- Mixtures cannot be assured to attain acceptable setting times and early age strengths;
- Workability/pumpability can be adversely impacted;
- Resistance to later-age durability problems, such as alkali silica reaction (ASR) or sulfate attack cannot be attained in some cases;
- Temperature control in mass concrete members can be difficult to achieve;
- Reduced permeability of concrete can be difficult to achieve, and this could impact durability, specifically by reducing the time to onset of corrosion of reinforcing steel; and
- Later-age development of strength and other mechanical properties of concrete can be curtailed.

The Alternatives

- Delete limits on quantities of SCMs in concrete mixtures, except those limits for concrete used in members that would be assigned to Exposure Class F3 as defined above;
- Include performance-based requirements, such as strength, and durability when required for the project; and
- Allow construction-related requirements for time of setting, finishability, and formwork removal to be set through separate contracts, purchase orders, and at pre-construction meetings between producers and contractors.

Conclusions and Benefits

It is well researched and established that concrete with SCMs has enhanced workability as well as improved mechanical and durability properties (ACI 232.1R-12, 232.2R-03, 232.3R-14, 233R-03, 234R-06, CIP 30). Some of these beneficial properties may not be achieved with mixtures containing only portland cement or if there are restrictions on the quantity of SCMs. Eliminating restrictions on the quantity of SCMs and adopting performance-based alternatives in specifications can:

- Allow for producing concrete mitigating damage to ASR, sulfate attack, and chloride-induced corrosion and thereby increase the service life of structures
- Improve assurance of achieving explicitly stated performance objectives rather than implied objectives such as setting time or early-age strength from a prescriptive requirement
- Reduce the responsibility of the specifier if an intended performance objective is not achieved by the prescriptive requirement
- Support sustainable construction initiatives by using concrete with a lower environmental impact
- Attract competitive bidders that are more knowledgeable and focused on performance that can benefit owner’s objectives and project schedule.
References

16. MasterSpec Section 033000 – Cast-In-Place Concrete, ARCOM, Salt Lake City, UT, June 2014.
17. NRMCA Specification in Practice by the RES Committee – SIP 1 – Limits on Quantity of Supplementary Cementitious Materials; 2015-1, 2 pp., www.nrmca.org/p2p.