MinterEllison

LAWYERS

17 August 2010

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BY EMAIL: jasmine.tan@accc.gov.au

Ms Jasmine Tan
Australian Competition and Consumer Commission
GPO Box 3131
CANBERRA ACT 2601

Dear Ms Tan

Pozzolanic Enterprises Pty Ltd Application for Authorisation A91245

We refer to your letter of 11 August 2010 to interested parties in relation to Pozzolanic Enterprises Pty Ltd's application for authorisation A91245 (**Application**).

We confirm that we act on behalf of Tarong Energy Corporation Limited (**Tarong**) in relation to the Application.

Please find **enclosed** confidential and non-confidential versions of Tarong's submission in support of the Application.

On behalf of Tarong, we request that the confidential version of the submission be excluded from the ACCC's public register. The confidential submission contains information which is confidential to Tarong and third parties including the quantities of fly ash sought from Tarong by third parties in a confidential tender process and estimates of the total ash generated at each of Tarong Power Station and Tarong North Power Station between 1996 and 2009/10.

This information is commercially sensitive and not otherwise in the public domain.

Could you please direct all future correspondence to Justin Oliver and Kathryn Finlayson at Minter Ellison on the following email addresses: justin.oliver@minterellison.com and kathryn.finlayson@minterellison.com.

If you have any questions, please do not hesitate to contact Kathryn Finlayson on (07) 3119 6380 or on the email address set out above.

Yours faithfully
MINTER ELLISON

Minter Ellison

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enclosure

Submission to the Australian Competition and Consumer Commission

In support of the application for authorisation made by Pozzolanic Enterprises Pty Ltd

MinterEllison

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ME_87175803_1 (W2003)

Submission to the Australian Competition and Consumer Commission

Submission

1. Introduction

1.1 Background

In May 2006, Tarong Energy Corporation Limited (**Tarong Energy**) publicly advertised for expressions of interest for the sale and removal of fly ash and bulk materials at Tarong Power Station.

Following the expression of interest process, Tarong Energy issued Invitation to Tender TE1159 to the following companies:

(a) Transpacific Industries Pty Ltd;

(b) Independent Flyash Brokers Pty Ltd;

(c) Sunstate Cement Ltd (**Sunstate**);

(d) Nuash Pty Ltd (**Nuash**); and

(e) Pozzolanic Enterprises Pty Ltd (**Pozzolanic**).

Invitation to Tender TE1159:

(a) sought submissions for the acquisition of ash from Tarong and Tarong North Power Stations in the following periods:

  (i) acquisition of ash from May 2007 to March 2008 (after Pozzolanic's exercise of its rights under the existing contractual arrangements between Tarong Energy and Pozzolanic);

  (ii) acquisition of ash from March 2008 until 2010 (during the expected existing coal supply from Meandu Mine);

  (iii) acquisition of ash after 2010 (following the expected commencement of a new coal supply source); and

(b) required tenders to be lodged by 30 March 2007.

Three companies responded to Tender TE1159:

(c) Nuash, which sought to acquire:

  (i) [**CONFIDENTIAL**] of fly ash per annum from Tarong Power Station, on a firm basis; and

  (ii) fly ash from Tarong North Power Station on a non-firm basis;

(d) Sunstate, which sought to acquire [**CONFIDENTIAL**] of fly ash per annum from the Tarong North Power Station; and

(e) Pozzolanic which sought (from the expiry of the then existing contractual arrangements between Tarong Energy and Pozzolanic):

  (i) [**CONFIDENTIAL**] of fly ash per annum from Tarong Power Station; and

  (ii) [**CONFIDENTIAL**] of fly ash per annum from Tarong North Power Station.

Transpacific Industries Pty Ltd and Independent Fly Ash Brokers Pty Ltd did not respond to Tender TE1159.

As a result of Tender TE1159:

(a) Tarong Energy entered into arrangements with Sunstate and Pozzolanic to facilitate the offtake of fly ash from Tarong and/or Tarong North Power Stations; and

(b) Tarong Energy entered into arrangements with Nuash which provide Nuash with an option to facilitate the offtake of fly ash from Tarong Power Station. Nuash is yet to exercise this option.

1.2 Application for Authorisation

On 26 July 2010, Pozzolanic lodged an application for authorisation with the Australian Competition and Consumer Commission (**ACCC**) in respect of arrangements for the supply of fly ash between Tarong Energy, Tarong North Pty Ltd (**Tarong North**, a wholly owned subsidiary of Tarong Energy) and Pozzolanic arising out of Tender TE1159.

Authorisation by the ACCC is a condition precedent to the commencement of the Fly Ash Supply Agreement dated 15 July 2010 (**Agreement**).

Relevantly, clause 2.1(a) of the Agreement provides:

> '(a) This Agreement (other than clauses 1, 24, 26 and this clause 2) does not come into force and effect unless and until:
>
> (i) the Contractor obtains Authorisation on terms and conditions satisfactory to TEC; or
>
> (ii) TEC notifies the Contractor that it is satisfied, in its absolute discretion, that the Authorisation is not required.'

This submission supports the application for authorisation lodged by Pozzolanic.

1.3 Tarong Energy's Interest

Tarong Energy is a party to the Agreement and supports the application for authorisation.

In summary:

(a) Tarong Energy, as one of Queensland's most significant power generators, has the capacity to deliver approximately 25 percent of the State's electricity needs;

(b) Tarong Energy uses natural resources such as coal and water to generate electricity. Ash is Tarong Energy's biggest waste product and is produced through the burning of coal. If Tarong Energy is unable to properly dispose of its ash it would have to curtail operations increasing the likelihood of power outages and interruptions, particularly in south east Queensland during the peak summer demand period of November to February;[1]

(c) Tarong Energy is committed to minimising the environmental impact of its business activities where practically achievable by reducing, reusing and recycling wastes, such as ash;

[1] See comments made by the Coordinator General after approval was obtained for the Northern Land in 2007/08 at http://www.dip.qld.gov.au/docs/library/pdf/mp_tarong_executive_summary_nov06.pdf.

(d) Until recently, Tarong Energy stored most of the ash produced at its power stations in an ash dam. It currently stores its ash in disused mine voids at Meandu Mine (which is located adjacent to Tarong Power Station (see section 5 for further detail).

(e) Tarong Energy is able to sell some of the ash produced from Tarong Power Station to fly ash processors and distributors, as well as to manufacturers of cement. The sale of ash reduces the amount of waste ash that would otherwise be stored as landfill in the disused mine voids or ash dams or other storage areas; and

(f) Use of fly ash in cement has been shown to:

(i) strengthen and enhance the properties of the cement;

(ii) reduce the amount of carbon dioxide generated in the production of cement thereby reducing significantly the environmental impact of both the cement industry and the coal fired power industry; and

(iii) reduce the need for other materials, such as limestone, to be added in significant quantities to cement, reducing the environmental impact of mining and the depletion of limited natural resources.

2. Tarong Energy

(a) About us

Tarong Energy is a Queensland Government Owned Corporation and a public company established under the *Corporations Act 2001* (Cth). Tarong Energy was established on 1 July 1997 following the disaggregation of AUSTA Electric.

Tarong Energy sells electricity into the National Electricity Market (**NEM**) and provides ancillary services to the Australian Energy Market Operator (**AEMO**) through the Tarong, Tarong North and Wivenhoe Power Stations.

Tarong Energy owns a mix of generating and mining assets:

(i) Tarong Power Station, located near Nanango in the South Burnett region, is a coal-fired, base load station with four units with a gross generating capacity of 1,400 MW. It also has a liquid fuel-fired emergency plant with a gross generating capacity of 15 MW. Tarong Power Station is operated by Tarong Energy.

(ii) Tarong North Power Station, located adjacent to Tarong Power station, is a supercritical coal-fired, baseload station with a gross capacity of 443 MW. Tarong North Power Station is operated by Tarong North (in relation to the NEM, Tarong Energy acts as intermediary for Tarong North Power Station).

(iii) Wivenhoe Power Station, located at Wivenhoe Dam approximately one hour west of Brisbane, is a hydro-electric power station. It has two units that can generate a gross capacity of 500 MW.

(iv) Meandu Mine which is managed by contract miner Thiess Pty Ltd. The mine currently provides fuel for the Tarong and Tarong North Power Stations.

(v) The Kunioon Mineral Development Licence. Kunioon is the proposed fuel source for the Tarong and Tarong North Power Stations after it is no longer economic to obtain fuel from the Meandu Mine. The coal resource is located approximately 15km from Tarong and Tarong North Power Stations.

(vi) The Glen Wilga Coal Resource located near Chinchilla in Queensland's Surat Basin. Glen Wilga was one of the options considered as a future fuel source for Tarong and Tarong North Power Stations. While Glen Wilga and associated assets remain valuable resources, Tarong Energy is determining how best to deal with this resource.

(b) Tarong Energy's commitment to the community

Tarong Energy is committed to maintaining sustainable social and economic activity in the communities in which Tarong Energy has a presence. In 2009 an Economic Benefits Study undertaken by the University of Southern Queensland found that Tarong Energy is a major contributor to the region and a major employer. The study:

(i) estimated the change in real value added by Tarong Energy's local operations to the South Burnett at $332.2 million or 31.6 percent of the region's total output of goods and services; and

(ii) identified Tarong Energy as a major job generator in the South Burnett region, creating and sustaining more than 10 percent of all jobs. Tarong Energy directly employs more than 570 people locally but, through expenditure in the region, creates 1,224 full-time equivalent jobs.

3. Tarong Energy's Corporate History

(a) Queensland Electricity Commission

Historically, electricity generation and supply in Queensland has been the responsibility of the State Government.

In 1938, the Government established the State Electricity Commission which was responsible for electricity generation and supply until 1985 when it was amalgamated with the Queensland Electricity Generation Board to form the Queensland Electricity Commission (**QEC**).[2]

QEC's functions included:

(i) the planning of Queensland's electrical supply network (including rural electrification);

(ii) construction and operation of main power stations and main transmission systems;

(iii) electrical safety;

(iv) issuing of licences to electrical contractors;

(v) certification of electrical workers; and

(vi) overseeing the operation of the seven regional Electricity Boards which were responsible for the supply of electricity to Queensland customers.

(b) QEC to Austa Electric

In January 1995, QEC was dissolved under the *Electricity Act 1994* (Qld) and replaced by two government-owned corporations:

[2] http://www.archivessearch.qld.gov.au/Search/AgencyDetails.aspx?AgencyId=4

(i) Queensland Generation Corporation (trading as AUSTA Electric), which was responsible for electricity generation; and

(ii) Queensland Transmission and Supply Corporation (**QTSC**), which was responsible for electricity transmission, distribution and retail. QTSC was the holding company for eight subsidiaries:

(A) Queensland Electricity Transmission Corporation (trading as Powerlink), responsible for the State's high voltage transmission network; and

(B) seven distributors which were responsible for low voltage networks and retailing electricity in their respective geographic areas.

In April 1995, the State and Territory Governments agreed to form a National Competition Policy (**NCP**). As part of the NCP, reforms were introduced in the electricity, gas, water and road transport industries. In respect of electricity, all the States and Territories agreed to take all measures necessary to implement an interim competitive NEM from 1 July 1995, or on such other date as agreed. The agreed implementation date for the NEM was subsequently changed to early 1998.[3]

(c) Austa Electric to Tarong Energy

In preparation for the introduction of the NEM, in July 1997, AUSTA Electric was separated into:

(i) three independent and competing generating corporations:

(A) Tarong Energy;

(B) CS Energy Limited; and

(C) Stanwell Corporation Limited; and

(ii) one engineering services organisation: AUSTA Energy.

Tarong Energy became the owner of the Tarong Power Station and the Wivenhoe Power Station.

(d) Tarong North Power Station

Tarong North Power Station was completed in 2003 and was initially an unincorporated joint venture between TN Power Pty Ltd (**TN Power**, a wholly owned subsidiary of Tarong Energy) and TM Energy (Australia) Pty Ltd (**TM Energy**, ultimately owned by Tokyo Electric Power Company, Inc. and Mitsui & Co., Ltd). TN Power and TM Energy appointed Tarong North to manage and operate Tarong North Power Station.

TN Power acquired TM Energy's interest in Tarong North Power Station on 30 November 2009. Tarong North continues to manage and operate Tarong North Power Station.

4. Electricity Generation By Tarong Energy

(a) MW

Tarong Energy is capable of generating 2343 MW of electricity through Tarong Power Station, Tarong North Power Station and Wivenhoe Power Station:

[3] As agreed by letter of 10 December 1996 from the Prime Minister to all Premiers and Chief Ministers.

(i) Tarong Power Station is one of Queensland's largest power stations and has a gross generating capacity of 1400 MW. It also has a liquid fuel-fired emergency plant with a gross generating capacity of 15 MW;

(ii) Tarong North Power Station has a gross generating capacity of 443 MW; and

(ii) Wivenhoe Power Station has a gross capacity of 500 MW. Wivenhoe Power Station is Queensland's only pumped storage hydroelectric plant.

5. Ash at Tarong Energy

(a) Ash Generally

Collectively, Tarong and Tarong North Power Stations produce an estimated 1.9 million tonnes of ash each year as a by-product of burning coal (please refer to **Annexure A** for further detail).

The ash produced is primarily the non-combustible mineral component of coal and comprises largely aluminium and silica oxides (80-85%). The ash is characterised as Class F ash, is highly pozzolanic and reacts with various cementitious materials.[4]

Ash is Tarong Energy's biggest waste product. Tarong Energy aims to effectively manage wastes and commits to reducing, reusing and recycling wastes where possible. It has a number of methods of managing its ash including sales to third parties, storage in disused mine voids at Meandu Mine and, if necessary, storage in its ash dam.

As noted by Pozzolanic in its supporting submission dated 26 July 2010, fly ash is a 'regulated waste' under the *Environmental Protection Regulation 2008* (Qld) and 'trackable waste' under the *Environmental Protection (Waste Management) Regulation 2000* (Qld). On the 24 December 2009 the Queensland Department of Environment and Resource Management approved a beneficial reuse application for coal combustion products. This approval allows fly ash to be used in the following products:

(i) cementitious mixes;

(ii) cement products;

(iii) concrete products;

(iv) asphalt;

(v) ceramic products;

(vi) insulation;

(vii) paints;

(viii) plastics;

(ix) geopolymers; and

(x) rubbers.

(b) Types of Ash

Two types of ash are produced at Tarong and Tarong North Power Stations:

[4] ADAA website: http://www.adaa.asn.au/utilisations.htm.

(i) furnace or bottom ash – this is ash that drops to the bottom of the boiler during the combustion process in the boiler; and

(ii) fly ash – this is ash which is caught up with the fumes of the combustion process.

(c) Ash Sales

(i) Fly Ash

Tarong Energy sells a portion of its fly ash to a number of parties (including Pozzolanic) for use as a partial substitute for cement in concrete. Generally, ash requires some form of processing or classification before it can be used as a partial substitute for cement in concrete. Please refer to **Annexure A** for further detail and the quantities of ash generated and sold each year by Tarong and Tarong North Power Stations.

(ii) Bottom Ash

Tarong Energy also sells a portion of its furnace ash. It is estimated that between 7,000m^3 and 10,000m^3 of furnace ash from Tarong North Power Station was used in the Gateway Motorway Upgrade Project.

In December 2009 Tarong Energy publicly advertised a Tender for the sale and removal of furnace ash from Tarong North Power Station. Tarong Energy is currently finalising commercial arrangements with several companies for the sale and removal of furnace ash as a result of this Tender (it is estimated that up to 110,000 tonnes of furnace ash will be sold each year under these arrangements).

(d) Ash Dam

Any unsold ash is currently stored in the disused mine voids at the Meandu Mine.

Until recently, unsold ash was stored in the ash dam at Tarong Power Station. The ash dam was constructed in 1981 and is formed by a dam located on Black Creek approximately 2 km north of Tarong Power Station. The total ash production on the Tarong Power Station site has been significantly higher than originally provided for in the initial design of the dam. This is due to a number of factors including:

(i) the increased operational life of Tarong Power Station;

(ii) the construction of Tarong North Power Station; and

(iii) the use of low quality coal.

In December 2004, Tarong Energy expanded the dam to optimise its storage capacity including raising the spillway to 1.6 m, increasing the allowable ash storage capacity from 42,000 ML to 46,000 ML. Despite this augmentation, the maximum capacity of the ash dam was insufficient for the increased operational life of Tarong Power Station and Tarong Energy was required to investigate and implement alternative ash storage arrangements.

In March 2004, a Dense Phase Ash Thickening Plant (**ATP**) commenced operation at Tarong Power Station. Dense phase allows placement of the ash to be undertaken in cells, enabling progressive rehabilitation and smaller areas of exposed ash, rather than having an ash dam spread over a large area. The ATP was expected to reduce annual ash volume from Tarong Power Station by approximately 344 ML and the denser ash allowed some ash 'stacking' above the normal water level, further enhancing storage capacity.

(e) Northern Ash Land

In 2005 Tarong Energy proposed the construction of a new ash storage facility to service both Tarong and Tarong North Power Stations. The new ash storage area was to be built on land to the north of the Power Stations and would use dense phase material. Approval was obtained from the Coordinator General for the new ash storage area during 2007/08.[5] This project is currently on hold due to Tarong Energy's purchase of Meandu Mine which has facilitated the use of mine voids for ash disposal.

(f) Mine Void

Since its purchase of Meandu Mine, Tarong Energy has been trialling the use of mine voids for storage for ash. In December 2009 Tarong Energy started commissioning the disposal pipelines to the mine. This system is now fully operational removing ash from the ash system into one of the disused mine voids at Meandu Mine.

6. The Benefits of the Sale of Ash

(a) Beneficiated Usage – Cementations Ash

Fly ash has a number of beneficial uses.

According to the Ash Development Association of Australia **(ADAA)**,[6] about 85% of the current 'beneficial use' of fly ash in Australasia is as a partial cement replacement, to enhance the properties of concrete and other building materials.[7] Fly ash can compensate for variations in the quality of other constituents in concrete. For example, small particles of fly ash used in concrete can improve concrete density, act as a water reducing agent to reduce cracking and can reduce the heat generated during curing.[8] Where cement and aggregates vary over time, there is a balancing effect from the use of the fly ash that ensures that the final concrete product performs much more consistently.[9]

It has been reported that high-volume fly ash concrete structures are exceptionally free from thermal and drying shrinkage cracking. Due to the high electrical resistivity, the high-volume fly ash concrete is also highly resistant to reinforcement corrosion.[10]

Most of the fly ash currently utilised in the building and construction industries is used to partially replace Portland cement in the manufacture of concrete.[11] For every one tonne of Portland cement produced, cement plants generate approximately one tonne of carbon dioxide.[12] If 25% of Portland cement is replaced with fly ash, the figure is reduced to about 0.22t of CO2 (putting to

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[5] http://www.dip.qld.gov.au/projects/industrial/tarong-northern-land-ash-emplacement.html

[6] An association comprising producers and marketers of coal combustion products, including ash of which Tarong Energy is a member.

[7] ADAA website, http://www.adaa.asn.au/utilisations.htm.

[8] Peter R Heeley, Ash Development Association, *Good Concrete – Can you afford not to use it* from *http://www.adaa.asn.au/docs/Technical_Notes_1.pdf*.

[9] W. Barry Butler, Development Coordinator, ADAA, *How Fly Ash Can Reduce the Variation in Concrete Quality* from http://www.adaa.asn.au/docs/Technical_Notes_8.pdf.

[10] PK Mehta, Professor Emeritus, *Coal Fly Ash – The Most Powerful Tool for Sustainability of the Concrete Industry,* University of California, Civil and Environmental Engineering at http://www.acaa-usa.org/associations/8003/files/Coal_Fly_Ash-The_Most_Powerful_Tool.pdf.

[11] Alek Samarin, 'Total Fly Ash Management: From Concept to Commercial Reality *The Australian Coal Review,* November 1997 pp 34-37.

[12] Alek Samarin, 'Total Fly Ash Management: From Concept to Commercial Reality *The Australian Coal Review,* November 1997 pp 34-37.

one side the CO2 produced during the combustion process for the generation of electricity which results in the production of fly ash).[13] Professor Mehta of the University of California has argued that increasing the utilization of most of the available fly ash as a complementary cementing material is, unquestionably, the most powerful tool for reducing the environmental impact of both the cement industry and the coal fired power industry.[14] A copy of Professor Mehta's report is attached as **Annexure B** to this submission.

(b) Other Beneficiated Uses

The geotechnical properties of fly ash make it an excellent engineering fill material.[15] These include its:

(i) high internal angle of friction (typically > 30 degrees);

(ii) low unit weight (1.2 - 1.3 t/m3) compared to natural materials;

(iii) low compressibility; and

(iv) low rates of long term settlements in a fill situation.

These geotechnical properties can be utilised in flyash blocks (reducing up to 30 percent gross weight) and artificial (manufactured) aggregates. The environmental benefits of using large volumes of fly ash in fills rather than using natural materials include:

(i) reduced transportation costs;

(ii) conserving natural fill resources, and

(iii) reducing the environmental impact of mining conserving natural fill resources.

(c) Cenospheres

A small proportion of ash forms a product known as cenospheres which float on the ash dam water surface and are harvested for use in ceramics, plastics and paints. Cenospheres have also been used in the production of insulation refractories, which are known for their excellent strength to density ratios and for the thermal shock resistance.[16]

Tarong Energy currently has arrangements with Envirospheres Pty Ltd to facilitate the collection and sale of cenospheres to Envirospheres.

(d) Environmental benefits

The sale of fly ash produces a number of environmental benefits by reducing the need for ash storage facilities.

Reuse of a substantial portion of fly ash produced at the Tarong and Tarong North Power Stations limits the amount of ash which would otherwise be disposed of in disused mine voids at Meandu Mine.

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[13] Alek Samarin, 'Total Fly Ash Management: From Concept to Commercial Reality *The Australian Coal Review*, November 1997 pp 34-37.

[14] PK Mehta, Professor Emeritus, *Coal Fly Ash – The Most Powerful Tool for Sustainability of the Concrete Industry*, University of California, Civil and Environmental Engineering at http://www.acaa-usa.org/associations/8003/files/Coal_Fly_Ash-The_Most_Powerful_Tool.pdf.

[15] PD Marsh, Pacific Power, *Cost Effective Embankment Construction* from http://www.adaa.asn.au/docs/Technical_Notes_6.pdf.

[16] Alek Samarin, 'Total Fly Ash Management: From Concept to Commercial Reality *The Australian Coal Review*, November 1997 pp 34-37.

According to the ADAA, the reuse or recycling of fly ash into identified applications can have substantial environmental benefits including: [17]

(i) waste stream reduction and associated reductions in requirements for landfill;

(ii) when used as a cement replacement, fly ash use contributes to the conservation of resources such as gypsum, limestone and natural gas which would otherwise be used in cement production; and

(iii) the use of fly ash as a cement replacement also leads to reduction in Greenhouse Gas emissions from cement production of almost 1 tonne of CO_2 per tonne of cement.

7. History of Ash Contracts

Historically, QEC had a contract with Pozzolanic for the exclusive supply and removal of fly ash from all power stations owned by the Queensland Government including Tarong Power Station.

In 1995, QEC was dissolved and ownership of the State's power stations was transferred to the Queensland Generation Corporation trading as AUSTA Electric. The contract between QEC and Pozzolanic was transferred to AUSTA Electric at that time.

The term of the contract was also amended to provide that the contract was in effect from August 1999 until 1 September 2001. In December 2000, Tarong Energy entered into a one year contract with Pozzolanic to commence on 1 September 2001.

In August 2001, Tarong Energy issued an Expression of Interest No. TE363/01 for the sale and removal of fly ash at Tarong and Tarong North Power Stations. The contract was to commence once the one year contract with Pozzolanic dated December 2000 expired on 31 August 2002.

On 26 February 2003, Tarong Energy and Pozzolanic executed a fly ash agreement for the removal of fly ash from Tarong and Tarong North Power Stations (2003 Pozzolanic Fly Ash Contract).

As detailed in section 1, in May 2006, Tarong Energy publicly advertised for expressions of interest for the sale and removal of fly ash and bulk materials at Tarong Power Station and subsequently issued Invitation to Tender TE1159 to facilitate the negotiation of arrangements to replace the 2003 Pozzolanic Fly Ash Contract which was due to expire in February 2008.

The negotiation of commercial terms during the Tender TE1159 process was protracted, in part due to the:

(a) operational issues at Tarong and Tarong North Power Stations, particularly the revised generation profile implemented as a result of the drought in South East Queensland;

(b) uncertainty regarding the long term source of coal for Tarong and Tarong North Power Stations (Tarong Energy was assessing the future long term coal source during this period which had a direction impact on the long term quality and quantity of fly ash); and

(c) regulatory interest in the arrangements for the offtake of ash in South East Queensland

To facilitate the continued sale and removal of fly ash the Tarong and Tarong North Power Stations pending Tender TE1159 process, the 2003 Pozzolanic Fly Ash Contract was extended until 14 July 2010.

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[17] See http://www.adaa.asn.au/utilisations2.htm.

On 15 July 2010, Tarong Energy, Tarong North and Pozzolanic entered into an Interim Fly Ash Supply Agreement to allow Pozzolanic to seek the ACCC's authorisation in respect of the Fly Ash Supply Agreement dated 15 July 2010 (**Interim Agreement**). The Interim Agreement commenced on 15 July 2010 and continues until the earlier of:

(a) the commencement of a written agreement between Tarong Energy, the Contractor [Pozzolanic] and the Manager [Tarong North] to supersede and replace the Interim Agreement; and

(b) 30 June 2011,

unless terminated earlier under the Interim Agreement.[18]

8. Conclusion

Tarong Energy supports the application for authorisation lodged by Pozzolanic.

It believes that the arrangements for the supply of fly ash between Tarong Energy, Tarong North and Pozzolanic set out in the Fly Ash Supply Agreement dated 15 July 2010 are in the public interest.

[18] Interim Fly Ash Supply Agreement dated 15 July 2010, clause 3.

ANNEXURE A

ESTIMATED ASH VOLUMES AT TARONG AND TARONG NORTH POWER STATIONS[19]

Tarong Power Station	1996	1997	1998	1999	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Total Ash Generated (tonnes)															
Total Ash Sales (tonnes)															
Total Cenospheres Sales (tonnes)															
Percent Ash Sales															

Tarong North Power Station															
Total Ash Generated (tonnes)															
Total Ash Sales (tonnes)															
Percent Ash Sales															

[19] Tarong Energy does not record the volume of ash produced at Tarong and Tarong North Power Station (although the ash produced is estimated from time to time for reporting and monitoring purposes). Tarong Energy has prepared the estimates above using its usual methodology.

COAL FLY ASH – THE MOST POWERFUL TOOL FOR SUSTAINABILITY OF THE CONCRETE INDUSTRY

P.K. Mehta
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Introduction

It is clear that industrialization of the world is happening at an unsustainable speed. High rates of energy consumption, short service life of manufactured products, and lack of space for safe disposal of huge volumes of solid, liquid, and gaseous wastes generated by human activities are among the important sustainability issues. However, global warming has emerged as the most serious sustainability issue of the 21st century. According to a World Watch Institute report, twenty-four of the last 27 years have been the warmest on record. Weather scientists around the world have determined that a linear relationship exists between the earth's surface temperature and the atmospheric concentration of CO_2, which makes up 85 % of the greenhouse gases. The current CO_2 concentration, 387 ppm (mg/L), according to the U.S. National Oceanic and Atmospheric Administration, is highest in the recorded history. The annual global CO_2 output has reached a staggering 30,000 million tonnes. Burning fossil fuels to meet the energy and transportation needs of the world is the largest source of CO_2 emissions. Significant amounts of CO_2 are also released during the manufacture of building materials, such as cements, clay bricks, and steel.

In a series of reports, issued in 2007 by the United Nations Intergovernmental Panel on Climate Change, leading weather scientists of the world have unequivocally stated that *global warming is occurring, and that it has been triggered by human activities. They have warned about devastating consequences of global warming if immediate action is not taken by national and industry leaders to reduce the annual carbon dioxide emission rate to the 1990 level or less.*

Although climate change is a global phenomenon, it has to be tackled by every country individually, and by each of the major CO_2 emitting sectors of the economy. In this paper, the author has shown that both for the short term and the long term fly ash is highly effective in reducing the carbon footprints associated with the use of portland-cement clinker, which is the principle ingredient of modern cements.

Carbon Dioxide Emissions From Cement Kilns

The subject of environmental impact of the cement industry is covered by numerous publications (1-6). Typically, ordinary portland cement is composed of 95 % clinker and 5 %

gypsum. Gypsum is known as a complementary cementing material (CCM) because it enhances the cement performance by improving the setting and hardening characteristics of the product. In addition to gypsum, sometimes other mineral additives, commonly known as supplementary cementing materials (e.g., coal fly ash, granulated blast-furnace slag, natural and calcined pozzolans, pulverized limestone, and silica fume) can either be interground with clinker and gypsum or added directly during the concrete mixing operation. Pozzolanic additives like coal fly ash, when used as cement replacement materials, considerably enhance the performance of portland-cement concrete mixtures, and are emerging as an important player in sustainable development of the concrete industry. Therefore, instead of being referred to as *supplementary cementing materials* (SCM), it is more appropriate to refer to them as *complementary cementing materials (CCM)*.

Global statistics for 1990 and 2005 on cement production, CCM consumption, and direct CO_2 emission attributable to portland clinker manufacture, are presented in Table 1. According to the U.S. Geological Survey records, the world consumption of cement in 1990 was 1,044 million tonnes. It is estimated that, globally, the average clinker factor of cement (units of clinker per unit of cement) was 0.9, which means that 940 million tonnes of clinker and 104 million tonnes of CCM were used. The estimated average CO_2 emission rate in 1990 was 1.0 tonne CO_2/tonne clinker, therefore direct CO_2 emission from clinker production were 940 million tonnes.

According to Cembureau, global cement consumption in 2005 was 2,270 million tonnes. Due to gradual increase in the use of CCM, it is reported that the average clinker factor was down to 0.84 which means that 370 million tonnes of CCM and 1,900 million tonnes of clinker were incorporated into 2,270 million tonnes of cement. Also, in 2005, due to increase in the use of alternate, low-carbon, fuels for burning clinker, the average CO_2 emission rate dropped to 0.9 tonne per tonne of clinker. This means that, in 2005, 1,900 million tonnes of clinker was produced, with 1,700 million tonnes of direct CO_2 release to the environment. In conclusion, during the last 15 years the global cement industry has almost doubled its annual rate of direct CO_2 emissions.

Reducing The CO_2 Emissions – The Challenge

In the portland clinker manufacturing process, direct release of CO_2 occurs from two sources, namely the decomposition of calcium carbonate (the principal raw material) and the combustion of fossil fuels. The former accounts for about 0.6 kg CO_2/kg clinker and the latter 0.25-0.35 kg CO_2/kg clinker, depending on the carbon content of the fossil fuel; therefore, the global average now is 0.9 kg CO_2/kg clinker. Alternate sources of energy other than fossil fuels are being sought but, at present, they are too expensive. Also, there are some cements that do not require calcium carbonate as a raw material (e.g., magnesium phosphate cements) but they are neither economical nor technically feasible for large-scale production. Obviously, it will not be possible to achieve any drastic cuts in CO_2 emission associated with cement production as long as technical and economic reasons favor the use of portland clinker as the major component of hydraulic cements.

Comparing the 1990 and 2005 global CO_2 emissions directly attributable to clinker production (Table 1), the magnitude of the problem becomes at once clear. The annual rate of cement consumption in the world has nearly doubled during the last 15 years. Furthermore, at the current rate of economic growth in developing countries the cement requirement in the next 15 years is expected to go up to about 3,500 million tonnes a year. Global clinker production and CO_2 emission rates in 2020 would be 2,800 million and 2,520 million tonnes, respectively, if the use of complementary cementing materials goes up from 15 to 20% of the total cement. Clearly, this level (i.e. 3,500 million tonnes) of cement consumption and production in 2020 is unsustainable if we want to bring down the CO_2 emissions to 940 million tonnes (the 1990 level).

Tools for Reducing the CO_2 Emissions

If over-consumption of energy and materials is the root cause of the sustainability crisis, obviously then a sure remedy for successful resolution of the problem lies in the golden rule, "*Consume less.*" Based on this rule or *mantra* there are three ways by which the cement industry can reduce the direct CO_2 emission attributable to clinker production:

1. *Reduce the consumption of concrete*: Architects and structural designers must develop innovative designs that minimize the consumption of concrete. In the U.S., the average size of homes built during the last 20 – 30 years is much larger than those built earlier. New housing developments should give preference to smaller homes which require less materials of construction. Service life of repairable structures should be extended as far as possible by the use of proper materials and methods of repair. Low-priority projects should be postponed or even canceled when possible. Foundations, massive columns and beams of concrete and pre-cast building components, that can be assembled or dis-assembled as needed, should be made with highly durable concrete mixtures described in this paper.

2. *Reduce the cement paste volume in concrete mixtures*: Mix design procedures that involve prescriptive codes (e.g., minimum cement content, maximum w/cm, and much higher than needed strength) lead to considerable waste of cement, besides adversely affecting the durability of concrete. Such prescriptive codes have outlived their usefulness and must be replaced with performance-based specifications that promote durability and sustainability. For example, as discussed below, the enhancement of the durability of concrete, it does not depend on the w/cm but also on the cement paste content. The water content should be minimized through optimum aggregate grading and the use of plasticizing admixtures, and fly ash. The cement content can be reduced by specifying 56 or 91-day strength for those structural components that do not require a minimum 28-day strength.

3. *Reduce the clinker factor of cement*: Every tonne of portland clinker saved through the use of complementary cementing materials would reduce the direct CO_2 release from cement kilns by an equal amount. Furthermore, as explained below, concrete products made with cements of low clinker factor would be much more durable than ordinary portland cement products.

By itself, none of the above three tools would be sufficient to bring down the cement industry's CO_2 emissions to the 1990 level. However, as discussed below, the simultaneous use of all three tools together can fulfill the mission provided it is pursued vigorously and without delay.

Strategies for Sustainability

As a short-term strategy, i.e. during the next 15-20 years, we should bring down the clinker factor of cement to 0.5 or less by using one or more complementary cementing materials. Abundant supplies of coal fly ash are available for use as a complementary cementing materials. As the world moves away from fossil fuel-based power sources, eventually the coal-fired power plants will have to be shut down. Therefore, a long-term strategy for sustainability of the concrete industry is also necessary. Suppose if it were possible to enhance the durability of cement-based products by a factor of 3 or more without using any expensive technology and materials, this *in the long term*, would be an excellent strategy for minimizing the wasteful consumption of cement and other concrete ingredients for general construction. Published literature contains numerous reports on excellent durability of concrete to alkali-silica reaction and sulfate attacks when high volume of complementary cementing materials are used. In earlier publications it has been reported that high-volume fly ash concrete structures are exceptionally free from thermal and drying shrinkage cracking. Due to the high electrical resistivity, the high-volume fly ash concrete is also highly resistant to reinforcement corrosion.

Assuming that CO_2 emission rate remains at 0.9 tonne CO_2 for each tonne of portland clinker, then to bring down the emission to the 1990 level (i.e. 940 tonnes/year) by the year 2020, the portland clinker production rate would have to be reduced to 940/0.9 or nearly 1,050 tonnes/year. With the global average clinker factor at 0.5, we would be producing 2,100 tonnes of total cement, composed of equal amounts of portland clinker and CCM. By reducing the consumption of concrete and the volume of cement paste in concrete mixtures (tools #1 and #2 above), the concrete construction industry in the year 2020, should be able to manage with 2,100 tonnes/year of cement production. Estimates of different types and amounts of complementary cementing materials that are likely to be used in 2020 are shown in Table 2. Note that the coal fly ash is projected to make up 760 million tonnes or nearly three-fourths of the total CCM. Would such a large quantity of fly ash be available in 2020? It is difficult to provide a definite answer, but let us examine the assumptions under which this might be possible.

In the foreseeable future, fossil fuels will continue to remain the primary source of power generation, and due to the low cost of coal, the expansion of coal-fired power industry will continue in major coal-producing countries such as China, India, and the United States. According to one estimate, approximately 1200 million tonnes of fly ash would be generated in 2020. It would indeed be a challenging task to make sure that nearly two-thirds of the fly ash produced by coal-fired power plants is used as a complementary cementing material. This can be accomplished, provided the key players, i.e., the producers of fly ash, the manufacturers and the consumers of cement and concrete, and individuals or organizations responsible for specifications, work together to overcome the problems described below.

The power sector of the global economy is the largest single source of carbon emissions in the world. It is estimated that about 7 billion tonnes a year of CO_2 is being released today from the combustion of all fossil fuels, and that the coal-fired power plants alone generate two billion tonnes of CO_2. Besides carbon emissions, coal combustion in 2005 generated approximately 900 million tonnes of solid by-products including 600 million tonnes of fly ash (5). Due to rapidly growing rates of fly ash production and use by the two large economies of the world, China and India, which meet three-quarters of their electrical power requirement from coal-fired furnaces, accurate data on today's global rates of fly ash production and utilization are not available. However, a rough estimate shows that the current rate of fly ash production in the world is approximately 750 million tonnes/year, and nearly 140 million tonnes/year is being consumed as an ingredient of blended cements and concrete mixtures. The remaining fly ash either ends up in low-value applications, such as road sub-bases and embankments, or is disposed of in landfills or ponds.

When used as a complementary cementing material, each tonne of fly ash can replace a tonne of portland clinker. Diverting fly ash from the waste stream and using it to reduce direct carbon emissions from the cement industry is *like killing two birds with one stone.* Therefore, increasing the utilization of most of the available fly ash as a complementary cementing material is, unquestionably, the most powerful tool for reducing the environmental impact of the two major sectors of our industrial economy, namely the cement industry and the coal-fired power industry.

In spite of proven technical, economic, and ecological benefits from the incorporation of high volumes of fly ash in cements and concrete mixtures, why does the fly ash utilization rate as a complementary cementing material remain so low? Obsolete prescriptive codes, lack of state-of-the-art information to architects and structural designers, and lax quality control in power plants are among some of the reasons. Also, not all of the currently produced fly ash is suitable for use as a complementary cementing material. Cost-effective methods are however available to improve the properties of material that does not to meet the minimum fineness and maximum carbon content requirements – the two important parameters by which the fly ash suitability is judged by the cement and concrete industries (5).

A problem that requires immediate attention of environmental protection agencies is the lack of a holistic approach regarding land pollution vs. air pollution resulting from coal combustion products. As a rule, any steps taken to make air emissions cleaner make the ash less suitable for use in cement and concrete. Sometimes chemicals, such as lime and ammonia, added to clean up gaseous emissions, replace the air quality problem with a land problem. A coal ash smelling of ammonia or loaded with sulfur salts is unsuitable for use in concrete, and is diverted to the solid waste stream. It contains small amounts of toxic salts of arsenic, lead, and mercury, which may leach out to groundwater and pollute drinking water supplies. Therefore, ash disposal to landfills and ponds not only replaces one kind of health hazard with another but also deprives the concrete industry of a material that is essential for sustainability.

Finally, the author believes that codes and guidelines of recommended practice advocated by organizations, such as American Concrete Institute and U.S. Green Building Council, can play an important part in accelerating the sustainability of the concrete industry. For instance, the USGBC point-rating system for new buildings has already become a powerful driving force for sustainable designs, assigning sufficient points for sustainable site selection and energy efficiency relative to *building operation.* Now, similar attention is required for achieving a reduction in the embodied energy and carbon emissions associated with the *use of structural materials.* A driving force is needed to accelerate sustainability of the global cement and concrete industries. The USGBC and other regulatory organizations can provide this driving force by rating the structural materials used for building construction on the basis of CO_2 emissions associated with their production.

Sustainable Cements and Concrete Mixtures

Sustainable, portland-clinker based cements can be made with 0.5 or even lower clinker factor using a high volume of granulated blast furnace slag (gbfs), or coal fly ash (ASTM Class F or C), or a combination of both. Natural or calcined pozzolans, in combination with fly ash and/or gbfs, may also be used. Compared to portland cement, the high-volume fly ash and slag cements are somewhat slower in setting and hardening, but they are more suitable for producing highly durable concrete products. Unfortunately, worldwide, the conventional concrete construction practice is dominated by prescriptive specifications that do not permit the use of high volume of mineral additives.

Cements containing a high-volume of complementary cementing materials can now be manufactured in accordance with ASTM C 1157 – a new standard specification for hydraulic cements, which is performance-based. However, in North America significant amount of blended portland cements are not produced, because it is customary to add mineral admixtures at the ready-mixed concrete plants. According to American Coal Ash Association (8), at present about 14 million of the available 70 million tonnes/year fly ash is being used as a complementary cementing material in concrete mixtures. Reliable estimates are not available from China and India, however, it is reported that significant quantities of blended cements containing 20-30 % fly ash, are being manufactured in these countries.

The European Cement Specification EN 197/1, issued in 2002, contains 26 types of blended portland cements including three cement types that have clinker factors ranging between 0.35 and 0.64. Type III-A Cement covers slag cements with 36-65 % gbfs; Type IV-B Cement covers pozzolan cements with 36-55 % pozzolans such as fly ash, natural or calcined pozzolanic minerals, and silica fume; Type V-A Cement covers composite cements containing 18-30 % gbfs plus 18-30 % pozzolans. According to Cembureau statistics for 2005, the consumption of ordinary portland cement in the European Union countries has dropped to 30 % of the total cement produced, whereas blended portland cements containing up to 25 % CCM have captured 57 % of the market share, and blended cements with more than 25 % CCM are approaching 10 % of the total cement consumption.

For reducing direct carbon emissions attributable to portland clinker production, the emerging technology of *high-volume fly ash* (HVFA) concrete is an excellent example showing how highly durable and sustainable concrete mixtures, with clinker factor of 0.5 or less, can be produced by using ordinary coal fly ash (ASTM Class F or Class C), which are available in most parts of the world in large amounts. The composition and characteristics of HVFA concrete are discussed in many publications and are briefly described below. Note that concrete mixtures with similar properties can be produced by using a high volume of granulated blast-furnace slag or a combination of fly ash and slag, with or without other mineral admixtures.

The cementing material in HVFA concrete is composed of ordinary portland cement together with at least 50 % fly ash by mass of the total cementing material. The mix has a low water content (100-130 kg/m^3), and a low content of cementing materials (e.g. 300 kg/m^3 for ordinary strength and max. 400 kg/m^3 for high-strength). The plasticizing action of the high volume of fly ash imparts excellent workability even at w/cm of the order of 0.4. However, chemical plasticizers are often used, when lower w/cm are required. Occasionally, an air-entraining admixture is also included in the mix when protection against frost action is sought.

Compared to portland-cement concrete, the HVFA concrete mixtures designed to achieve the same 28-d strength exhibit superior workability without segregating even at slump values of 200-250 mm. Typically, the concrete is slow in setting and hardening, i.e. develop slightly lower strength at 3 and 7-d, similar strength at 28-d, and much higher strength at 90-d and 1-year. The pozzolanic reaction leading to complete removal of calcium hydroxide from cement hydration products enables the HVFA concrete to become highly resistant to alkali-aggregate reaction, sulfate attacks, and reinforcement corrosion (due to very low electric conductivity). Furthermore, the HVFA concrete mixtures are much less vulnerable to cracking from both the thermal shrinkage (less heat of hydration), and the drying shrinkage (less volume of cement paste). Therefore, in addition to very low clinker factor, the ability of HVFA concrete to enhance the durability by factor of 5 to10 makes it a highly suitable material for construction of sustainable structures in the future. The author has been involved with many field applications of HVFA concrete that are described in earlier publications (8-11). Some recently built structures in North America that have achieved large reduction in CO_2-emissions resulting from the use of HVFA concrete, are described below.

During 2003-2006, four similar Hindu Temples, with massive concrete foundations designed to endure for 1,000 years or more, have been constructed in Chicago, Houston, Toronto, and Atlanta. A photograph of the Chicago temple is shown in Fig. 1. The superstructure of the temple is composed of some 40,000 individual segments of intricately carved white marble. Due to poor soil conditions in Chicago and Houston, the foundations composed of large, monolith, slabs are supported by 250 drilled piers, 9 m high and 1 m diameter. All structural concrete elements are made with, cast-in-place, HVFA concrete. The concrete mix for the foundation slabs contained 105 kg/m^3 ASTM Type I portland cement and 195 kg/m^3 Class C fly ash, 2 L/m^3 polycarboxylate superplasticizer, and 100 kg/m^3 water. Note that the total cementing material was 300 kg/m^3, and the clinker factor was 0.33. The w/cm of concrete was 0.33. The fresh mix had 150-200 mm slump and showed excellent pumpability, which made it possible to place and finish 400 m^3 concrete for the main prayer-hall slab (22 by 18 by 1 m), in less than 5 hours. Typical compressive strength values at 3-d, 7-d, 56-d, and 1-y were 10 MPa, 27 MPa, 48 MPa, and 60 MPa, respectively. No structural cracks in any concrete member were reported. Also, the chloride penetration permeability, which is an excellent index of long term durability of concrete, was surprisingly low (< 200 coulombs) in 1-year old core samples. A conventional concrete mix would have required 400 kg/m^3 portland cement to achieve similar high-strength. The use of 3,000 m^3 HVFA concrete mix resulted in 900 tonnes of portland cement saving, which corresponds to about 800 tonnes of reduction in CO_2 emissions.

The Utah State Capitol Building, Salt Lake City, shown in Fig. 2a, underwent seismic rehabilitation in 2006. Due to heavily congested reinforcement in the foundations, floor beams, and shear walls, a nearly self-consolidating mix containing 160 kg/m^3 of ordinary portland cement, 200 kg/m^3 ASTM Class F fly ash, 138 kg/m^3 water, and 1 L/m^3 superplasticizer was used. The clinker factor of this mix was 0.44, and the w/cm was 0.38. The specified slump and 28-d compressive strength were 150 mm and 27 MPa, respectively. The field concrete showed an average 225 mm slump and 34 MPa strength, showed excellent pumpability and workability (Fig. 2b). It is estimated that this 4,500 m^3 HVFA concrete job, enabled 900 tonnes of reduction in CO_2 emissions attributable to clinker saving.

The CITRIS Building at the University of California at Berkeley (Fig. 3) contains 10,700 m^3 concrete out of which approx. two-third is of HVFA type. For foundations and mats, a concrete mix containing 160 kg/m^3 of ASTM Type II portland cement, 160 kg of Class F fly ash, and 123 kg/m^3 water (0.37 w/cem) was used. For heavily reinforced columns, walls, beams, girders and slabs, a concrete mix containing 200 kg/m^3 ASTM Type II portland cement, 200 kg/m^3 Class F fly ash, and 140 kg/m^3 water (0.35 w/cem) was used. In both cases the clinker factor is 0.50. The specified compressive strength was 27 MPa @ 28-d for all structural members except the foundations and mats which were designed for a specified strength of minimum 27 MPa @ 56-d. Note that the concrete used for reinforced columns and walls achieved 20 MPa strength @ 7-d, and nearly 40 MPa @ 56-d. It is estimated that, the low clinker factor of the cement used in the concrete for the CITRIS Building resulted in about 1,300 tonnes of reduction in CO_2 emissions. An innovative use of HVFA concrete was in super-stiff, close-cell, two-way waffle slabs for supporting the sensitive equipment that would be used for nanotechnology research. The HVFA concrete mixtures also tend to acquire high ultimate strength and high elastic modulus.

Built to replace the original structure damaged in a 1989 earthquake, the new structure of de Young Museum in San Francisco, California (Fig. 4), that is designed to last for 150 years, contains the largest amount, i.e. 11,500 m^3 of HVFA concrete, used in a single building. According to a recently published report (12):

> The original building footprint was reduced by 37% to return nearly two acres of open space to the surrounding park, yet designers of the 21,367 m^2 building still managed to double the amount of exhibition space. Skylights and floor-to-ceiling windows reduce power consumption and where needed, energy-efficient fluorescent lighting is used.

Concluding Remarks

The high carbon dioxide emission rate of today's industrialized society has triggered climate change that is potentially devastating to life on the planet earth. To meet the global concrete demand, which was 17,000 million tonnes in 2005, 2,000 million tonnes of CO_2 were directly released to the atmosphere from the manufacturing process of portland-cement clinker, which is the major component of modern hydraulic cements. With business-as-usual, the direct CO_2 emission from portland clinker production, in the year 2020, would triple the 1990 level unless immediate steps are taken to bring it down by making significant reductions in: (a) global concrete consumption, (b) volume of cement paste in concrete mixtures, and (c) proportion of portland clinker in cement.

Examples of recently built structures prove that by using high volume of coal fly ash and other industrial wastes as complementary cementing materials with portland clinker, we can produce low cost, highly durable, and sustainable cements and concrete mixtures that would significantly reduce both the carbon footprints of the cement industry and the environmental impact of the coal-fired power generation industry.

It seems that the game of unrestricted growth in a finite space, by reckless use of energy and materials, is over. Most sectors of the global economy have already initiated action plans to bring down their share of carbon emission to the 1990 level or less, by the year 2020. The construction industry is successfully pursuing the goal of designing and constructing sustainable buildings that consume less energy and resources for *maintenance*. Now, all segments of the construction industry – owners, designers, contractors, cement and concrete producers – should join hands to win the new game of building sustainable structures *using only sustainable materials.*

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Table 1 Global Direct CO_2 Emission from Cement Kilns (Million Tonnes)

	1990	2005
Cement consumption	1,044	2,270
Complementary cementing materials*	104	370
Portland clinker produced	940	1,900
CO_2 released	940	1,700

*Estimated amounts of CCM used in 1990 and 2005 are 10 % and 15 % of total cementing material, respectively.

Table 2 Estimated Consumption of Complementary Cementing Materials (Million Tonnes)

Year	2005	2020
Gypsum	110	100
Fly ash	140	760
Granulated slags	80	120
Limestone powder	35	50
Natural pozzolans, etc.	15	20
Total CCM	370	1,050
Total cement production	2,270	2,100
Clinker factor	0.84	0.5

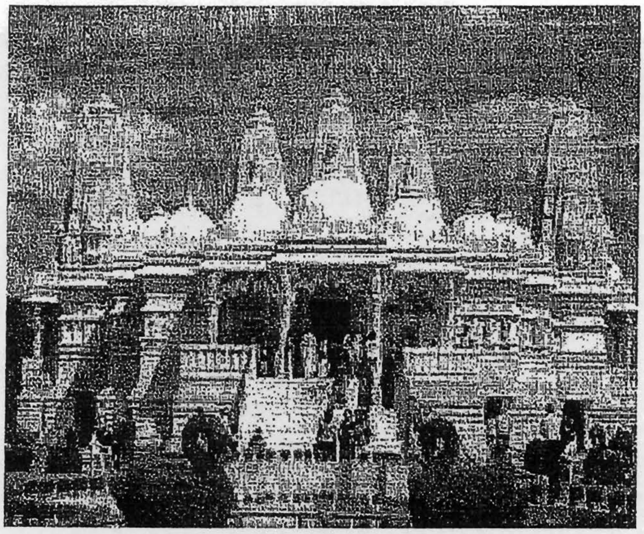

Fig. 1 The BAPS Hindu Temple, Chicago, 2004
High-Volume Fly Ash was Used for Monolith Foundations and Drilled Piers

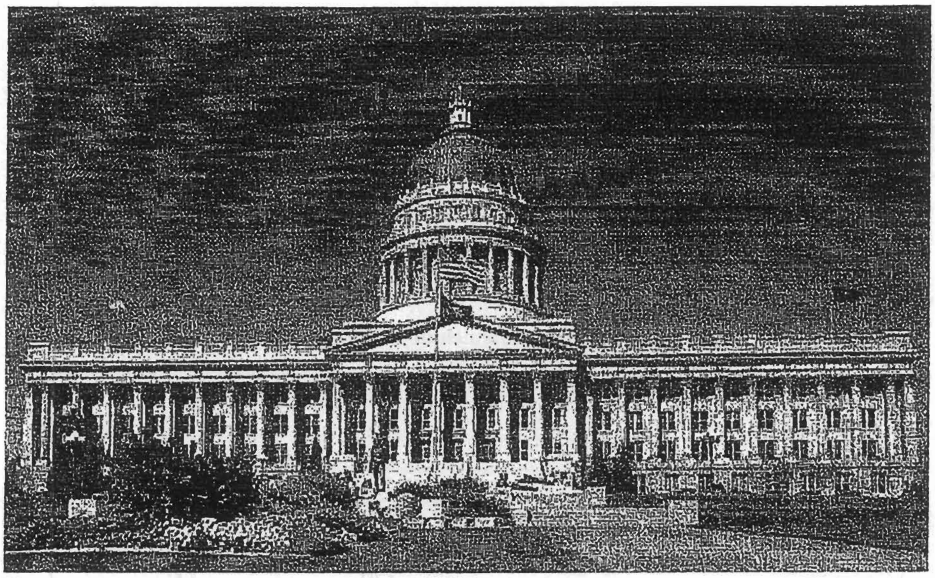

Fig. 2a Utah State Capitol Building After Seismic Rehabilitation, 2006
High-Volume Fly Ash was Used for Reinforced Foundations, Beams, and Shear Walls

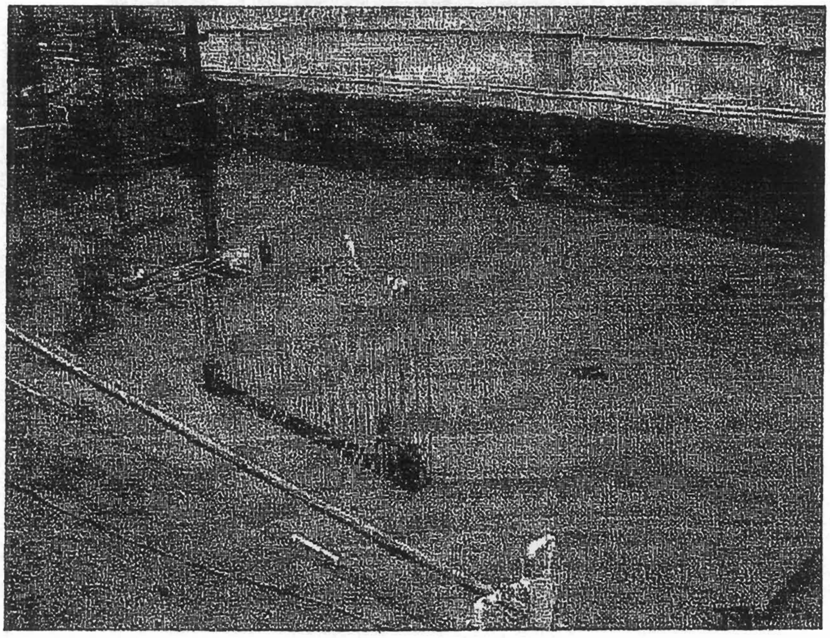

Fig. 3a Mat Foundation Under Construction
CITRIS Building, Univ. of California, 2007

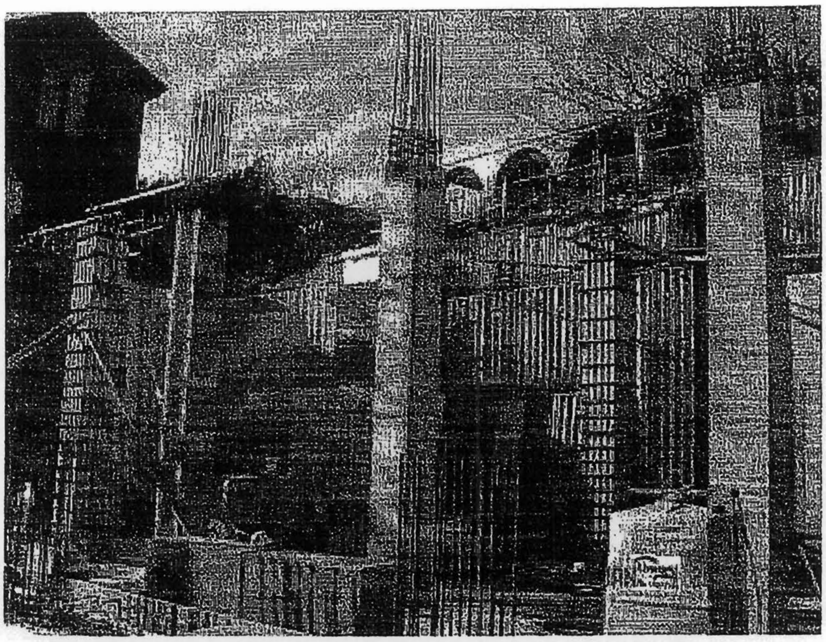

Fig. 3b Heavily Reinforced Columns Under Construction
CITRIS Building, Univ. of California, 2007

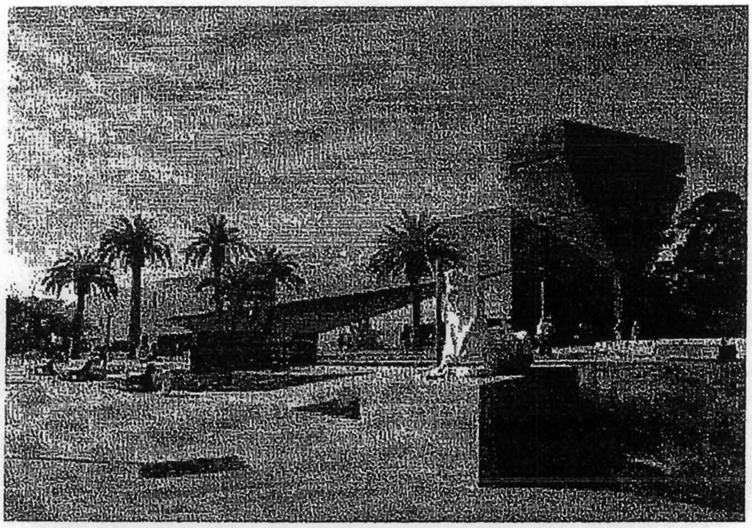

Fig. 4a Front view of the de Young Museum, San Francisco (2007)