SUSTAINABILITY OF CEMENT AND CONCRETE INDUSTRIES

By
Prof. Tarun R. Naik, Ph. D., P. E.

Presented at 15a Scuola AIMAT
Energia, Ambiente, Sostenibilità.
Hotel Continental Terme, Ischia Porto (Napoli).
15 – 19 Luglio 2009, Ischia, ITALY.

Center for By-Products Utilization
Reduce, reuse, recycle, and repair for sustainable developments.

Minimize use of manufactured materials.

Maximize environmental benefits: resource conservation, clean water, and clean air.
Basic Approach

WASTE€ is wasted if you waste it, otherwise it is a resource.

Recycle. Recycle as is.

Recycle without additional processing, (i.e., without adding any cost to it).

UWM Center for By-Products Utilization
Introduction

• Over 5.5 billion tons of non-hazardous by-product materials are produced each year in USA (2000). At an average cost of $30 per ton, it would cost B$165 to throw it all away.

• These by-products are from agricultural sources, domestic/post-consumer sources, industrial sources, and materials processing sources.
Introduction (continued)

• In USA, in 2007, people threw away about 1,600 lbs of trash per person, over 250 million tons, per year (Milwaukee Journal Sentinel, March 22, 2009); plus, industrial materials being thrown away.

• In 2007, over 60 million tons of trash was recycled, 20 million tons was composted, 30 million tons was burned, and about 140 million tons was “saved” in landfills.

• Reduce, Reuse, Recycle, and Repair (do not throw/save in landfills).
Landfills contributes to global warming because it releases GHGs (Water Vapor, Methane, and CO2). “Methane (is) 20 more powerful than CO2.” Therefore, recycling “creates a double carbon saving.” (Financial Times, March 1, 2009).

US-EPA declared in April 2009 that CO2 is a danger to human health (Financial Times April 18/19, 2009).

Alternatives: Increase recycling rates, as well as MSW to energy and composting.
RESOURCE CONSERVATION
CLEAN WATER
and
CLEAN AIR

“The earth, the sea (water), and the air are the concern of every nation.” President John F. Kennedy, fall 1963, in a speech to the U.N. General Assembly.
According to the World Commission on Environment and Development, Brundtland Report 1987, sustainability means “Meeting the needs of the present without compromising the ability of the future generations to meet their own needs.”

My definition: would the current resources last 200+ years? If yes, then the resource is sustainable. If not, we are leaving our challenges for someone else.
• Sustainability is an idea for the concern of the well-being of our planet with continued growth and human development.

• For example, if we run out of limestone (calcite not dolomite), as it is predicted to happen in some places, then we cannot produce portland cement, and, therefore, we cannot produce concrete; and, all the employers associated with the concrete industry go out-of-business, along with their employees.
• In USA, concrete construction provided 2,000,000 jobs in 2002.

• The concrete industry provides employment to many skilled employees, including batch plant operators, truck drivers, ironworkers, laborers, carpenters, finishers, equipment operators, and testing technicians, as well as professional engineers, architects, surveyors, and inspectors.

• “When the well’s dry, we know the worth of water.” Benjamin Franklin said over 200 years ago in Poor Richard’s Almanac.
CO₂ Emission and Global Warming


CO₂ has increased at a higher rate than expected in the last two years (The Japan Times, Oct. 21, 2004).

[Chart showing CO₂ concentrations over time]

[Chart showing temperature departures from the 1961-1990 average]

Long-term trend
TOO HOT!!

One deg. C temperature rise reduces rice yield by 10% (Milwaukee Journal Sentinel, June 29, 2004).

According to the TIME magazine (April 3, 2006) CO2 Concentration (PPM) in ambient air: 180, ice age; 280, 150 years ago; and 380+ today (about 0.04%). Of the 20 hottest years on record, 19 occurred since the 1980s. 2005 was the hottest year in more than a century.
Environmental Issues

The production of one ton of portland cement releases approximately one ton of \( \text{CO}_2 \) and other greenhouse gases (GHGs) into the atmosphere.
CO2 = Money

“In recent months the price of an emissions permit in European Union, where a cap-and-trade system has been up and running since 2005, has reached a peak of over €30 and a trough of less than €10, thanks to the sour economic outlook.” (The Economist, March 14, 2009).
Resource Conservation

Production of one ton of portland cement requires 1.7 tons of raw materials. These materials are primarily good quality limestone/calcite and clay.

Therefore, for about two billion tons of current (2006) cement production per year world-wide, we need about 3.5 billion tons of raw materials (about 10 million tons per day).
Sustainable Cement and Concrete

Entire geographical areas are running out of limestone resource to produce cement. Travel distance to bring limestone to produce cement, therefore, has increased. This leads to increased GHGs.

Major island-nations and metropolitan areas are running out of sources of aggregates for making concrete and other cement-based materials.
• Designing for sustainability means accounting in the design the full short-term and long-term consequences of the societal impact. Therefore, **DURABILITY** is the key issue.

• A sustainable concrete structure is one that is constructed so that the total societal impact during its entire life cycle, including during its use, is minimum.

• New generation of blended cements (OPC + OCM) and admixtures/additives are needed to improve durability.
Infrastructures are Dependent on Durable Concrete
AKITA TUNNEL

Traffic tunnel built in Akita, Japan (2001 – 2007) cost about 700 million USD (about 70 billion Yens). If it is not constructed as a durable infrastructure, with a minimum life-cycle cost, then say 40 years from now, in 2050 it would cost 700 billion Yen(?).

2004 cost was 5.5 USD (550 Yens) per person in Japan (Population: 127.6 million, in May 2004; down 50,000 from a year ago, *The Japan Times, Oct. 21, 2004*). If the population of Japan, as expected in 2050 is 100 million, then it would cost 7,000 Yen per person to re-build this tunnel. Would it be re-built?
Nitrous Oxide Emissions

For each ton of portland cement clinker, 3 to 20 lbs. of NOx are released into the atmosphere. Assuming 10 lbs of NOx per ton of clinker, this equals 10 million tons of NOx due to two billion tons of current (2006) clinker. “Nitrous oxide, a GHG (is) 300 times more powerful than CO2” (Financial Times, March 1, 2009).

Yomiuri Shimbun reported from Kobe, Japan that: “The Hyogo prefecture government on (Oct. 1, 2004) banned automobiles with emissions of nitrogen oxide (NOx) and particulate matter that exceed levels set in a law concerning these emissions from traveling in certain parts of the prefecture.”
Concrete is environmentally very friendly material.

As good engineers, we must use more of it in construction.
Portland Cement (OPC) is not environmentally very friendly material.

As good engineers, we must reduce its use in concrete; and, we must use more of other cementitious/pozzolanic (OCM/OPM) materials.
As good engineers, we must reduce the use of water; and, we must use more organic, liquid or powder admixtures, or inorganic additives, or both.
Energy, Environment, and Economy Related Issues in the Production of Portland Cement
Energy Related Issues

- After aluminium and steel, the manufacturing of portland cement is the most energy-intensive process.

- The manufacturing of portland cement requires about six million BTU of energy per ton (equivalent to about 500 Kg. of coal per ton of cement produced).
Sources of CO$_2$ Emissions in the Manufacturing of Portland Cement Clinker

- From calcinations of limestone = $\pm 50 - 55\%$

- From fuel combustion = $\pm 40 - 50\%$

- From use of Electric Power = $\pm 0 - 10\%$
Economic Issue

The cost of a new portland cement plant is in the order of 250+ million dollars per one million ton of installed capacity.
SOLUTION

As good engineers, we must use more environmentally friendly other cementitious materials (OCM) in concrete.

Use fly ash, g. g. b. f. slag, silica fume, natural pozzolans, rice-husk ash, wood ash, agricultural products ash, limestone/quarry fines (OCM). “The exhaust from a coal-fired power station is around 10% carbon dioxide.” (The Economist, March 7, 2009).

Use more application specific high-quality & durable aggregates, and organic admixtures.

Use less water.

Center for By-Products Utilization
Extinct Homo Sapiens
2500 BC - 2100 AD?

Cause of death:

Friendly fire; by excessive GHG emissions and excessive use of natural resources, including cement and water.
“We extract from earth what the planet cannot replace by an estimated 20%, meaning it takes 14.4 months to replenish what we use in 12. Sustainable developments works to reduce that.”

“The issue is not environment vs. development or ecology vs. economy; the two can be (and must be) integrated.”

“We have the human and material resources needed to achieve sustainable developments, not as an abstract concept but as concrete reality”.

Kofi Annan, U. N. Secretary-General, Johannesburg, South Africa, August 2002.
Conclusions

Recycling not only helps in reducing disposal costs, but also helps to conserve natural resources, providing technical and economic benefits, as well as helps in reducing GHGs.

This is sustainability.
• Eliminate waste and take life-cycle responsibility/ownership.

• Think Energy, Ecology, Economy, and Equity.

• Acknowledge and balance the four-Es.
• Use less portland cement.

• Use blended cements with other cementitious materials (OCM).

• Use less water.

• Use applications specific high-quality, durable aggregates.

• Use organic chemical admixtures.
RESOURCE CONSERVATION

CLEAN WATER

and

CLEAN AIR

“The earth, the sea (water), and the air are the concern of every nation.” President John F. Kennedy, fall 1963, in a speech to the U.N. General Assembly.
Ци видимо престио
ад Анкона ил
28 – 30 гіюгно 2010.
Grazie Mille.
Thank you very much for your interest.
Aabhar Tamaro, Afcharisto Poly, Arigatou Gozaimas, Dziekuje, Maraming Salamat, Merci Beaucoup, Muchas Gracias, Grazie Molte, Muito Obrigado, Salamat, Shukriya, Spasibo, Thank you, Toda Raba.