Environment, Energy, and Economic Benefits of Using Recyclable Materials for Cement and Concrete

By
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UWM 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
WA$T€ is wasted if you waste it, otherwise it is a resource. Resource is wasted if you ignore it and do not conserve it with holistic best practices and reduce societal costs. Resource is for the transformation of people and society.

Focus on turning brown fields into green fields – Opportunities are here, now!!
Basic Approach

Recycle. Recycle as is.

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

Avoided disposal leads to reduced GHGs.
Progression: 21st Century Solid Waste Management

Recycling, sustainable infrastructures, sustainable management of resources (SMR), durable construction materials, global climate change, reduced GHGs, improved air quality, CO2 reduction & sequestration, and carbon offsets.
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.
Introduction

• Over six billion tons of non-hazardous by-product materials are produced each year in USA (2008). At an average cost of $30 per ton, it would cost B$180 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 (750 Kg.) of trash per person, over 250 million tons, per year (Milwaukee Journal Sentinel, March 22, 2009); plus, industrial materials are 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.
• It was reported (The Economist, November 28, 2009) that in USA “about 40 % of its food supply” is wasted. Such wasted food “accounts for more than one-quarter of America’s consumption of freshwater, and also uses about 300 m barrels of oil a year.” In addition “a lot of methane...emerges when all this food rots.”

• Reduce, Reuse, Recycle, and Repair (do not throw away or “save” in landfills).
Solid Waste Management

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.
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).
Environmental Issues

The production of one ton of portland cement releases approximately one ton of CO$_2$ and other greenhouse gases (GHGs) into the atmosphere.
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.
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).
Use of Recovered Mineral Components (RMCs) in U.S. Cement and Concrete Projects [US-EPA]
Under the Comprehensive Procurement Guidelines (CPG) program of the United States government, US-EPA (Environmental Protection Agency) is required to designate products that are, or can be, made with recovered materials and to recommend practices for buying these products.
U.S. government purchasing agencies are required to purchase products with recycled content with the highest recovered material content level possible (e.g., the highest material content level that can be economically obtained and can provide the needed product specifications); for example, cement or concrete.
While the US Government encourages agencies to purchase products containing **recovered mineral components** (RMCs), the guidelines allow for certain exemptions from these requirements, if such items:

(1) are not available within a reasonable period of time;

(2) fail to meet the performance standards set forth in the applicable specifications or fail to meet the reasonable performance standards of the purchasing agencies; or,

(3) are only available at an unreasonable price.
• US-EPA has issued guidelines for purchasing of cement and concrete containing fly ash (under review in 2010).

• US-EPA has also designated silica fume and cenospheres from coal ash as recovered mineral components (RMCs) for cement and concrete.
Increase the Use of Recovered Mineral Components (RMCs)
## Recovered Mineral Components (RMCs) Identified by US-EPA

<table>
<thead>
<tr>
<th>RMC</th>
<th>Description</th>
<th>Uses/Applications</th>
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<tbody>
<tr>
<td>Ground granulated blast furnace slag (GGBFS)</td>
<td>A ferrous slag, produced during the production of iron, as a result of removing impurities from iron ore. Rapid quenching of molten slag yields glassy, granular product.</td>
<td>If finely ground and mixed with free lime, GGBFS can be used as cement replacement, or, if less finely ground, as concrete aggregate.</td>
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<td>Coal-combustion fly ash</td>
<td>A finely-divided mineral residue resulting from the combustion of ground or powdered coal in coal-fired boilers.</td>
<td>Replacement for cement in concrete applications to increase strength and durability.</td>
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<td>Blast furnace slag aggregate (BFSA)</td>
<td>Produced by allowing molten slag to cool and solidify slowly.</td>
<td>After crushing and screening, used as aggregate in applications such as concrete, asphalt, rail ballast, roofing, shingle coating, and glass making.</td>
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<tr>
<td>Silica fume</td>
<td>A very fine, dust-like material generated during alloyed metal production.</td>
<td>Concrete additive used to increase strength and durability.</td>
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<td><strong>Other Recovered Mineral Components (RMCs) Identified by US-EPA</strong></td>
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<td><strong>Foundry sand</strong></td>
<td>High quality silica sand that is a by-product of both ferrous and nonferrous metal castings.</td>
<td>Can be used in the manufacture of cement and as an ingredient in concrete.</td>
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<td><strong>Cenospheres</strong></td>
<td>Small, inert, lightweight, hollow, &quot;glass&quot; spheres composed of silica and alumina and filled with air or other gases. They occur naturally in coal fly ash.</td>
<td>Used as aggregate in concrete production, increasing concrete's strength &amp; durability and decreasing shrinkage and weight; also, used in metal castings.</td>
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<tr>
<td><strong>Flue gas desulfurization (FGD) gypsum</strong></td>
<td>FGD by-products are generated by air pollution control devices used (for SO\textsubscript{x} removal) at coal-fired boilers. Forced oxidation, wet FGD systems create gypsum (CaSo4.nH2O) as a by-product.</td>
<td>Replacement for natural gypsum in wallboard production and grinding with clinker to produce finished cement, as well as an additive in concrete.</td>
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<tr>
<td><strong>Flue gas desulfurization (FGD) dry scrubber material</strong></td>
<td>Dry-FGD are generated by air pollution control devices used (for SO\textsubscript{x} removal) at coal-fired boilers. Resulting by-product include calcium sulfite, fly ash, Portlandite, calcite, and CaSO4.nH2O.</td>
<td>Dry-FGD material is primarily used in concrete mixtures as a cement replacement or aggregate material. Can be used as a raw feed in the clinker manufacturing process as an alternative source of calcium.</td>
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**Center for By-Products Utilization**
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<th>Other Recovered Mineral Components (RMCs) Identified by US-EPA</th>
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<td><strong>Coal-combustion bottom ash</strong></td>
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<td><strong>Boiler slag</strong></td>
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<td><strong>Steel furnace slag</strong></td>
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<td><strong>Cement kiln dust (CKD)</strong></td>
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Energy and Environmental Benefits

- The use of RMCs can decrease the demand for virgin materials, yielding decreases in resource consumption (in energy and water for production of mined materials).
- Lower resource consumption can reduce various pollutants and have other positive environmental impacts, including reducing GHGs.
Benefits of Coal Combustion Products (CCPs) Utilization for the US Economy
• Over 125 million tons of CCPs were produced annually in the US in 2008.

• About 70 million tons of CCPs were landfilled annually; cost to electric utilities was over $420 million/year.
• Over 60 million tons of CCPs were utilized in 2008.

• Utilities saved $360 million in avoided disposal cost and generated a revenue of over $240 million from sales of CCPs.

• This revenue contributes to a lower cost of electricity, which stimulates economic growth.
It was estimated that the direct economic value of CCP utilization to the US economy was over $2.2 billion annually, and a total economic impact is approximately $4.5 billion annually in 2003.
Environmental Benefits of CCP Use

• Conservation of landfill space and virgin materials.
• Use of fly ash to replace one ton of cement results in avoidance of approximately one ton of CO$_2$ and other GHG emissions.
• When used as a flowable fill for abandoned mines, fly ash slurry prevents soil subsidence and neutralizes acid mine drainage. Heavy metal leachates are reduced due to the neutralizing effects of the ash slurry.
Engineering Benefits of CCP Use

• In general CCPs improve the performance of the cement-based products.

• For example, use of fly ash in concrete contributes to lower heat of hydration, improved placement properties, strength, and durability.
Landfilling Costs

• Avoided landfilling costs are by far the largest cost.

• If an electric company operates its own landfill, then there are land acquisition costs, many years of feasibility testing/studies, hauling, placement, dust control, leachate collection, hauling and treatment, gas collection and flaring or use in electricity generation.
• If an electric company does not own and operate a landfill, it is simply the local cost per cubic meter or per tonne disposal cost that they experience, plus transportation.

• The cost varies locally. Typical total cost in USA is estimated to be $30 per ton of CCPs thrown away – a waste of money.
Use as Supplemental Fuel

- If high-carbon CCPs are used as a supplemental fuel, there may be a BTU or energy value to the material being utilized in offsetting purchased natural gas or coal.

- This also adds to overall economic impact.
Bio-Mass/Wood Ash
Foundry By-Products
Fibrous Residuals from Pulp and Paper Mills
Recycled-Concrete Used for Aggregates
Gypsum-based Wallboard
Post-consumer Glass, Plastics, and tires
• Eliminate waste and take life-cycle responsibility/ownership.

• Think Energy, Ecology, Economy, and Equity.

• Acknowledge and balance the four-Es.
"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.
Spaceship Earth – La Bella Terra

Center for By-Products Utilization
Ci vediamo presto ad Ancona il 28 – 30 giugno 2010.
Grazie mille. Thank you very much for your interest.
Aabhar Tamaro, Afcharisto Poly, Arigatou Gozaimasu, Dziekuje, Maraming Salamat, Merci Beaucoup, Muchas Gracias, Grazie Molte, Muito Obrigado, Salamat, Shukriya, Spasibo, Thank you, Toda Raba.