How to Make Concrete Greener, More Environmentally Friendly, and Save Money at the Same Time.

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There are more than 1,100 manufacturing facilities and 600 coal fired electric generating plants operating in the United States. Additional coal fired electrical power plants are in the construction or planning phase.

1.2 billion tons of coal were used in the United States in 2007, and demand is expected to rise.
(One U.S. standard ton = 0.907 Metric tonnes)

Even though their numbers are fewer, electrical power plants burn about 92% of all the coal used in the United States. In 2007, they burned 1.1 million tons.
Every ton of coal burned produces many coal combustion products (CCPs) and greenhouse gasses (GHGs).

The CCPs include fly ash, bottom ash, slag, and flue gas desulphurization products. This report deals with finding beneficial uses for the CCPs.

In 2006 over 120 million tons of CCPs were produced.

Fly ash is the largest component (60%) of the CCPs. Nearly 74 million tons were produced in 2006.
Beneficial use has steadily increased over the last 40 years.
Looking at the year 2006 from the chart, we see that over 120 million tons of CCPs were produced.

Of the CCPs, only about 54 million tons were beneficially used (about 44%).

Of the 54 million tons of beneficially used CCPs, about 35 million tons were fly ash (65%).

In 2006, 74 million tons of fly ash was produced, so the beneficially used percentage of fly ash is essentially the same that as for all CCPs (44%).

Even though fly ash is one of the easiest CCPs to put to beneficial use, and it represents nearly 65% of the beneficially used CCPs. Still, less than half of the fly ash produced is beneficially utilized.
Beneficial use has steadily increased over the last 40 years and it is expected to continue to increase, but projections show little more than 50% use many years into the future.
To recap..
Beneficial use of CCPs, especially of fly ash, has steadily increased over the last 40 years.

Beneficial use is expected to continue to increase. but much still needs to be done.

In 2006, there were still nearly 40 million tons of fly ash alone that had to be disposed of.
Disposal of CCPs is expensive.

The American Coal Council reported that in 2003 it cost over $550 million to dispose of CCPs.

The preceding charts indicate about 40% beneficial usage for that year. Therefore, the CCPs that did not have to be disposed of represent a savings of nearly $200 million in disposal costs alone.
One long accepted use of fly ash is as a cement replacement in concrete. Significantly more fly ash would be used if all concrete used some as a replacement for cement.

Currently, only about 50% of all concrete uses any fly ash at all. If more concrete used fly ash, then All the fly ash produced could be beneficially utilized in concrete production.

Fly ash replacement for cement is a proven technology.

Cement utilization in the U.S. is expected to nearly double in the next 20 years. Using fly ash has many beneficial effects for the concrete, and also helps minimize the adverse environment effects of cement production.
Using fly ash as a cement replacement for concrete has many beneficial effects.

1. Economic, capital costs: It costs millions of dollars to construct a new cement plant, roughly $250 for every ton of cement that will be produced.

2. Environmental: Cement production requires mining and transportation of raw materials, creates GHGs, and requires the burning of fossil fuels.

3. Durability, sustainability: It is widely proven that concrete made with fly ash is more durable and lasts longer than concrete made with cement alone.
Domestic production of cement has not kept pace with utilization: The graph shows that utilization in 2004 was over 120 million metric tons. But, only about 95 million tons of portland cement were produced at the 114 plants operating in 37 States and Puerto Rico. The rest was imported.
<table>
<thead>
<tr>
<th>Country</th>
<th>2003</th>
<th>2004</th>
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<tbody>
<tr>
<td>China</td>
<td>810</td>
<td>850</td>
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<tr>
<td>European Union</td>
<td>130</td>
<td>130</td>
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<tr>
<td>Japan, Korea</td>
<td>130</td>
<td>130</td>
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<tr>
<td>India</td>
<td>110</td>
<td>110</td>
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<tr>
<td>United States (includes Puerto Rico)</td>
<td>95</td>
<td>97</td>
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<tr>
<td>South America</td>
<td>70</td>
<td>73</td>
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<tr>
<td>Saudi Arabia and mid East</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Other countries (rounded)</td>
<td>550</td>
<td>550</td>
</tr>
<tr>
<td>World total (rounded)</td>
<td>1,950</td>
<td>2,000</td>
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We see from the chart that the US is a relatively minor cement producer compared to China, (100 MT versus 850 MT) and the World, (100 MT versus 2,000 MT) so the benefits of using CCPs in cement production and replacement has global implications.

Using supplementary cementitious materials such as fly ash, reduces both the need for raw materials and also the GHGs produced by cement production. Currently, these supplementary materials are little used by cement companies in the United States, which lags behind many foreign countries in this practice.

Summary

Since the U.S. uses more cement than it produces, the balance must be imported. Importing cement does not lessen the global impact of cement production.

We share the atmosphere with the world. GHGs are not just local issues.

For every ton of cement made, 1.7 tons of raw materials must be mined and moved. The supply of suitable raw materials near cement manufacturing facilities is being reduced every year, resulting in higher transportation costs.

Using fly ash in cement and concrete helps on many levels.
Summary.

The world produces and uses an enormous amount of cement every year. Cement production is a major generator of greenhouse gases.

Fly ash and other CCPs can be used not only as a cement replacement in concrete, but also as a replacement for some of the raw materials needed to make the cement itself.
One example of an industry that could benefit economically while also helping the environment by the use of fly ash and other supplementary cementitious materials is the precast concrete industry.

Why do some precast concrete manufacturers resist using fly ash?

One argument made, is that adding fly ash increases the set time and reduces the early strength.

For precast and especially prestressed concrete, it is very important to have high early strength. Research (Naik and Ramme 1990), has shown that a high volume fly ash mix can have the same or better early strength than plain concrete.
The Naik-Ramme report compared nominal 5 Ksi (34.5 Mpa) f’c concrete with fly ash for cement replacement of up to 30%:

As seen from the chart, the fly ash actually increased strength both early and at 28 days.

“High Early Strength Fly Ash Concrete for Precast/Prestressed Products.” By Tarun Naik and Bruce Ramme, PCI Journal Nov Dec 1990
A Case Study: This report looks the savings that could have been achieved by using fly ash as a cement replacement in a building that was constructed in 2006. This building is a 65,000 sq ft, 3 story medical office building. This building is constructed primarily of precast / prestressed concrete.

No fly ash was used in the concrete mix..
The building starts with a slab on grade. Hollow core plank used for the second floor, third floor, and roof. The hollow core plank is supported in the middle by prestressed inverted tee beams, and on the exterior by precast wall panels. The beams are supported by precast columns.
The total volume of concrete used for the wetcast panels, beams, columns, and stair towers was about 1,400 cubic yards (1,800 cu m).

The mix for these products used an average of 800 lbs of cement per cubic yard of concrete.

The cement used for these products totaled nearly 1,100,000 pounds, or 550 tons (4900KN).
The volume of concrete used for **hollow core plank** was about 1,100 cu yd (1,500 cu m) with 800 lbs of cement used per cubic yard of concrete.

The cement used for the **plank** was about 930,000 lbs (465 tons) (1932 KN). Therefore, the total amount of cement used for the building structure was over 1,000 tons.

The average cost of cement is **$115 per ton**.

The total cement cost for this building was over **$115,000**.

The production of this cement released over 1,000 tons of CO2 and other greenhouse gases (GHGs).
To summarize, this building used no fly ash in the concrete. If fly ash was substituted for cement at the 30% level, this would have saved over 300 tons (2,700 KN) of cement.

Since fly ash typically sells for about 1/3 the price of cement, this would have saved over $23,000. This would also have saved over 500 tons (4,500 KN) of raw materials and all the energy needed to extract, transport and process those materials.

And, this would have saved more than 300 tons (2,700 KN) of CO\textsubscript{2} and other GHGs from being released into the atmosphere during the production of the cement.

Other replacements of natural materials with “by products” would mean the saving of more money, energy, and GHGs. Examples would include the substitution of foundry sand and slag for fine and course aggregate.
We owe it to ourselves and future generations to be good stewards of the planet and its resources.