Concrete and the Environment
The Nobel Peace Prize 2007

"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"

Intergovernmental Panel on Climate Change (IPCC)

Albert Arnold (Al) Gore Jr.
There is increasing concern now that the choice of construction materials must also be governed by ecological considerations.
At the beginning of the 20th Century, the world population was 1.5 billion; by the end of the 20th Century it had risen to 6 billion.

Considering that it took 10,000 years after of the last ice age for the population to rise to the 1.5 billion mark, the rate of growth from 1.5 to 6 billion people is remarkable.
At the beginning of the 20th Century, approximately ten percent of the people lived in cities; in the year 2001 nearly three of the six billion inhabitants live in and around the cities.
Unfortunately, our technology choices have turned out to be wasteful because decisions are based on short term and narrow goals of the enterprise rather than a holistic view of the full range of consequences from the use of a technology.
Only 6% of the total global flow of materials, some 500 billion tons a year, actually ends up in consumer products whereas much of the virgin materials are being returned to the environment in the form of harmful solid, liquid, and gaseous wastes.
The greatest environmental challenge today is that of the human-made climate change due to global warming caused by steadily rising concentration of greenhouse gases in the earth's atmosphere during the past 100 years.
A new vision

In a nature-centered capitalism, the environment will no longer be treated as a minor factor of production but rather an envelope containing, provisioning, and sustaining the entire economy.
Ordinary concrete, typically, contains about 12 percent cement, 8 percent mixing water, and 80 percent aggregate by mass.

This means that, in addition to 1.5 billion tonnes of cement, the concrete industry is consuming annually 9 billion tonnes of sand and rock together with one billion tonne of mixing water.
TWO MAJOR CHALLENGES

Challenge I: Environmental Impact

World demand/year
• 11.5 billion ton of concrete
• 1.5 billion ton of cement
• 1 billion ton of water
• 9 billion ton of aggregate
Consequences (1)

1.5 billion ton of cement

- Generates 1.5 billion ton of CO$_2$
- Responsible for 5% CO$_2$ production in the world
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Consequences (2)

- 1 billion ton of water
  110,000 times the amount of water in the SF Bay
9 billion ton/y of aggregate

Depletion of natural resources
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Challenges

- Challenge II: Long-term durability
- Civil Infrastructure quickly deteriorating

Of the 597,340 bridges in this country, 73,784, or about 12.4 percent, are structurally deficient.

March 17, 2008, I-95 in Philadelphia
Major deterioration

- Corrosion of reinforced concrete
- Sulfate attack
- Alkali silica reaction
- Hot weather
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Durability (lack of):
Sixth Street Viaduct
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Facts

- National Historic Structure
- Daily Traffic: 11,000 Vehicles
Big Durability Problem

- Every 10 Years –
- City Must Apply Epoxy
- Injection and Patching
- Now facing replacement
The 11.5 billion tonnes-a-year concrete industry is thus the largest user of natural resources in the world.

The demand for concrete is expected to grow to approximately 18 billion tons (16 billion tonnes) a year by 2050.

The mining, processing, and transport of huge quantities of aggregate, in addition to billions of tons of raw materials needed for the cement manufacture, consume considerable energy and adversely affects the ecology of virgin lands.
Both in developed and developing countries, gigantic construction projects are underway in the metropolitan areas not only for new construction but also for rehabilitation or replacement of existing structures.
Portland cement is a product of an industry that is not only energy-intensive but also responsible for large emissions of CO2 -- a major greenhouse gas.

The manufacture of one ton of portland-cement clinker releases a ton of CO2 into the atmosphere.

The world's yearly cement output of 1.5 billion tonnes of mostly portland cement, accounts for nearly 7 percent of the global CO2 emissions.
Industrial ecology

- The waste product of one industry is recycled as a substitute for virgin raw material of another industry, thereby reducing the environmental impact of both.
Opportunities

- Over a billion tons of construction and demolition wastes are being disposed of in road-bases and landfills every year, in spite the fact that cost-effective technologies are available to recycle most of it as a partial replacement for coarse aggregate in concrete mixtures.
Opportunities

Most waste-waters and undrinkable natural waters can be substituted for municipal water for mixing concrete unless proven harmful by testing.
Blended portland cements containing fly ash from coal-fired power plants and granulated slag from the blast-furnace iron industry provide excellent examples of industrial ecology because they offer a holistic solution to reduce the environmental impact of several industries.
The high-volume fly ash provides a promising of how we can build concrete structures in the future that would be far more durable and resource-efficient than those made of conventional portland-cement concrete.

Whether as a component of blended cements or as a mineral admixture added to concrete during mixing, the fly ash content of HVFA concrete mixtures is typically between 50 to 60 percent by mass of the total cementitious material.
A Better Concrete in the Future

- Although as a structural material concrete generally has a history of satisfactory performance, it is expected that even a better product will be available in the future owing to overall improvements in elastic modulus, flexural strength, tensile strength, impact strength, and permeability.
Better concrete

- A reduction of the water content in a concrete mixture decreases the porosity of both the matrix and the interfacial transition zone and thus has a strengthening effect.

- Again, the presence of a pozzolan in a hydrating cement paste can lead to the processes of pore-size and grain-size refinement.
A better control of the bleeding tendency in concrete mixtures will be sought through proper aggregate grading, and the use of water-reducing and mineral admixtures (e.g., fly ash or finely ground natural pozzolans or slags).
Fiber reinforcement of concrete that is subject to cyclic or impact loads will be commonly practiced. For developing countries, the use of natural organic fibers (such as sisal fiber and rice straw) presents interesting possibilities.
The use of centralized and high-speed concrete mixers instead of truck mixing will help in the production of more homogeneous concrete than is generally available today.