

51° Congresso Brasileiro do Concreto
IBRACOM 2009
Curitiba, Brasil
Oct. 08, 2009

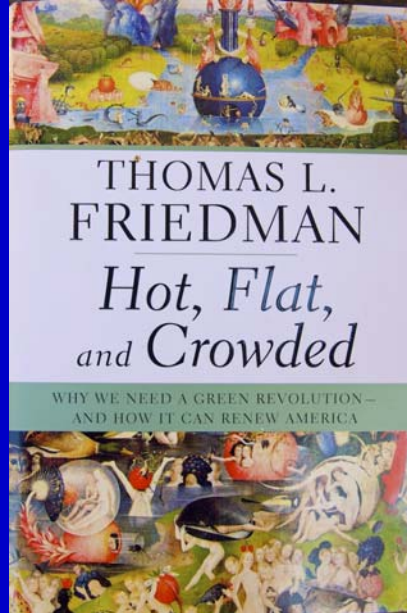
SOCIETY, SUSTAINABILITY, AND THE GLOBAL CONCRETE INDUSTRY

P.K. Mehta
Professor Emeritus
Civil and Environmental Engineering
University of California, Berkeley

Topics

- I. STATE OF THE WORLD TODAY**
– An Overview
- II. THE MOST URGENT SUSTAINABILITY ISSUE**
– Climate change (global warming)
- III. CEMENT AND CONCRETE INDUSTRIES' CARBON EMISSIONS.** Direct carbon emissions from cement kilns (2×10^9 T/y)
- IV. TOOLS FOR CUTTING CARBON EMISSIONS BY A HALF IN 20 YEARS**

I. STATE OF THE WORLD TODAY



Thomas Friedman
(2008)

CROWDED



FLAT



HOT

THE CROWDED WORLD

- ***THE 20TH CENTURY POPULATION EXPLOSION:*** FROM ONE TO SIX BILLION PEOPLE. TODAY'S POPULATION IS ABOUT 7 BILLION, AND IS PROJECTED TO GROW TO 10 BILLION DURING THIS CENTURY
- ALMOST **HALF** OF THE PEOPLE ON THE PLANET LIVE ***IN A FEW DEVELOPED NATIONS*** (e.g. USA, JAPAN, EU, AUSTRALIA) AND **FOUR COUNTRIES WITH LARGE POPULATIONS, THAT ARE ALSO RAPIDLY DEVELOPING** (CHINA, INDIA, BRAZIL, INDONESIA)

THE CROWDED AND FLAT WORLD

- As a result of *globalization of the American Model of Economic Development*, the developing countries like **China** and **India** *have achieved fast economic growth rates in two to three decades* by rapid industrialization, with little attention to **environmental pollution** from huge volumes of solid, liquid, and gaseous wastes.

- continued

- continued, The Crowded and Flat World

- Many *overcrowded large cities* (>10 million), including **15 megacities** (>15 million) are located in the developed and rapidly developing countries. Today, more than **3 billion** people live in and around large towns and cities.
- Even before the end of the 20th century, it was realized that economic growth supported by **wasteful technologies, and a life-style of wasteful consumption** by affluent sections of society, is **NOT SUSTAINABLE**.
- Before running out of non-renewable resources, already the Earth has run out of space for safe disposal of pollutants (e.g. CO₂). **Therefore, we need a new definition of sustainability.**

- continued, The Crowded and Flat World

China Emerges as a Developed Nation

- **50% of global cement production**
 - India and US follow with 6% and 3%, respectively
- **Almost 40% of global steel production**
 - Japan and US follow with 9% and 7%, respectively
- **Power generation in China today is 15% of the global power. By 2030 it is projected to *triple*.**

- continued, The Crowded and Flat World

China Emerges as a Developed Nation

- **About 80% of electric power in China is generated from coal, and the country is poised to build the equivalent of two 500-MW coal-fired power plants every week for the next 20 years**
- **Already, China has passed the U.S. as the World's largest emitter of CO₂**

- continued, The Crowded and Flat World

China Emerges as a Developed Nation – Urbanization of China

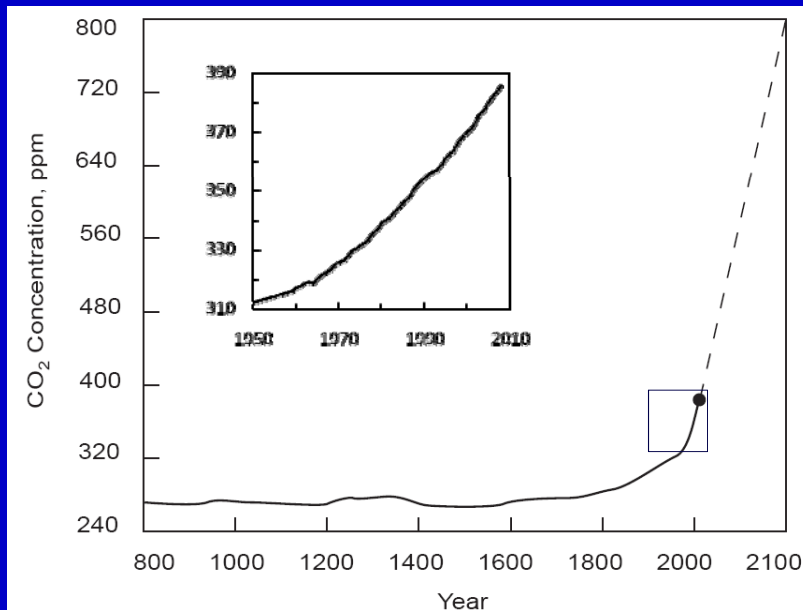
According to Friedman, the scale and scope of urbanization in China is mind-boggling. Over 40% of the 1.3 billion Chinese already live in cities. By 2020, urban population is expected to increase to 60%, adding hundreds of satellite cities, and a sky-rocketing demand for energy and energy-intensive materials (cement and steel) for construction of new buildings, highways and roads, and factories. (Note: buildings consume 40% of national energy)

THE WORLD IS HOT

CROWDED AND FLAT WORLD → GLOBAL WARMING

- Since 1950s, the Earth's surface temperature has been steadily increasing. Scientists believe that this is due to the rising concentration of greenhouse gases in the atmosphere.
- The primary greenhouse gas is CO₂. Since the 1950s, according to most recent IPCC reports, **an exponential rise in the atmospheric concentration of CO₂ has occurred, and this has resulted from human activities on the earth.**

Historical and Projected Atmospheric CO₂, ppm



(U.N. Intergov. Panel on Climate Change, Cambridge University Press, 2007)

CONCLUSION FROM THE CO₂ EMISSION DATA

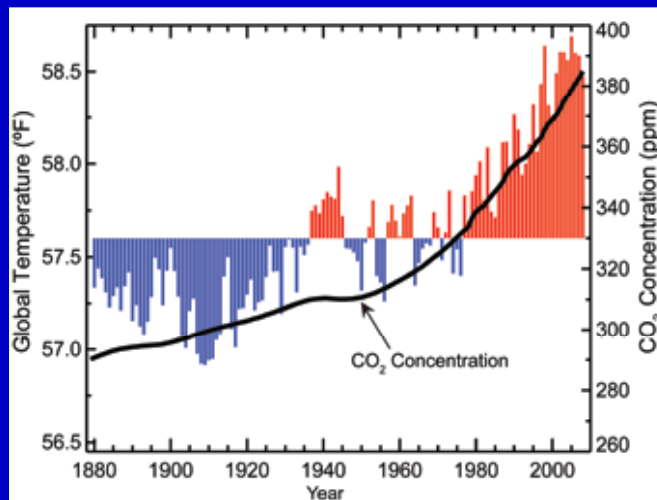
- Before the industrial revolution, the Earth's atmosphere contained about 280 parts per million CO₂. Once we started burning fossil fuels the CO₂ level began to rise. In the 1950s, it had reached 315 ppm.
- *The CO₂ level now is about 385 ppm, and since 1990 it has been rising roughly at the rate of 2 ppm annually*

II. GLOBAL WARMING AND ITS IMPACT

- A plot of the earth's average surface temperature and atmospheric CO₂ concentration from the period 1880 to 2009 confirms that there is *a correlation between carbon emissions and global warming*

- continued, Global Warming

CO₂ concentration & Global Temperature



Source: Karl, T.R. et al. June 2009 (www.globalchange.gov/usimpacts)

IMPACT OF GLOBAL WARMING AND CLIMATE CHANGE

- From the frequency and the intensity of typhoons, hurricanes, floods, fires, heat waves, and melting glaciers and ice sheets around the world, the **climate scientists worldwide have come to the conclusion that GLOBAL CLIMATE CHANGE HAS ALREADY BEGUN.**
- **We seem to have crossed a tipping point** beyond which the slow creep of environmental degradation has given way to a sudden and accelerating change in climate.

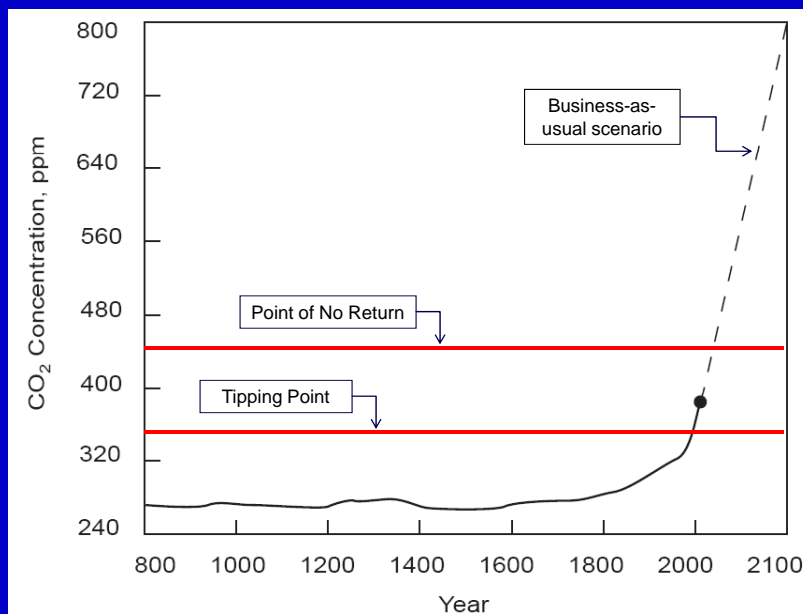
- continued, Impact of Global Warming

- Munich-Re Insurance Company of Germany has recorded that **weather-related disasters caused 50% more losses globally in 2008 over the previous year.**
- According to the Global Humanitarian Forum of Geneva, climate change-related disasters account for **315000 deaths each year**, besides heavy economic losses.
- Over 200 Eskimo villages in Alaska are already threatened by rising sea levels and rapidly melting permafrost. To finance their relocation, village councils have filed **lawsuits against oil companies** for causing the climate change.

- continued, Carbon Emissions

- According to James Hansen, a world renowned climate scientist, **350 ppm atmospheric CO₂ was “the tipping point”** that started worldwide weather-related disasters.
- Many scientists believe that **450 ppm atmospheric CO₂ is “the point of irreversible climate change”** that would lead to devastating consequences on the planet Earth

Historical and Future CO₂ Concentrations



Historical Data on Population and Carbon Emissions, 1900-2008

		1900	1950	1990	2008
Population, billions		1.6	2.6	5.3	6.8
Carbon emission	Gigatons/yr	0.53	1.63	6.14	8.47
	Atmospheric concentration (ppm)	296	312	354	386
Average rate of rise in CO₂ concentration		← 16 ppm in 50y → = 0.32 ppm/y			
			← 42 ppm in 40y → = 1 ppm/y		
				← 32 ppm in 18y → = 1.8 ppm/y	

HOW MUCH TIME DO WE HAVE BEFORE CLIMATE CHANGE BECOMES IRREVERSIBLE?

- The rate of carbon emissions now is nearly two ppm/y and it is steadily increasing, therefore **we have less than 30 years before we can stabilize and then reduce the rate of carbon emissions; otherwise the climate change will become irreversible.**
- **In conclusion, climate change has emerged as the most urgent sustainability issue of today**

III. CO₂ EMISSIONS FROM THE CEMENT AND CONCRETE INDUSTRY

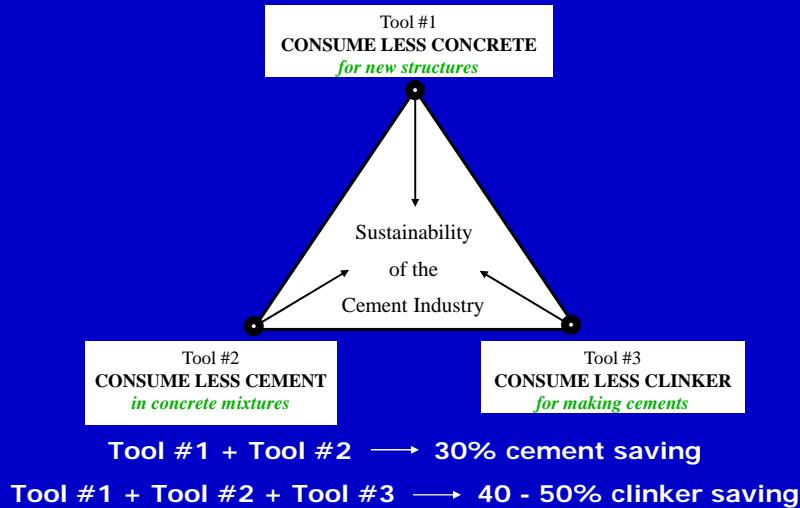
- In 1960, the world consumption of concrete was 3 billion T/y (1T/capita). Today, the estimated consumption is about 20 billion T/y (3T/capita).
- About 90% of carbon emissions from the concrete industry are attributable to portland clinker production in cement kilns. For making 1 tonne of cement clinker, approximately 1 tonne CO₂ is generated

- continued, CO₂ Emissions from Cement Production

- In 1990, direct CO₂ emissions from cement kilns were about 940 million T/y, compared to 1740 million in 2005. Thus, *during the 15-year period, carbon footprint of the cement industry almost doubled.*
- With business as usual, in the next 20 years cement demand and production is projected to grow at a rate of 6% per year. This rate of growth is not sustainable because, compared to 1990, it will triple the cement industry's carbon footprint by 2030.

CONCRETE INDUSTRY SUSTAINABILITY

A Road Map for cutting the cement industry's carbon emissions to the 1990 level in next 20 years



Source: Mehta, PK; ACI Concrete International, February 2009

TOOLS FOR CONSUMING LESS CONCRETE

Note that 45% of the world's concrete is consumed by new buildings, 15% by infrastructure projects, and 40% for repair and renovation of the built environment.

- Reduce project footprint by *innovative architecture*.
- Reduce thickness of foundations, columns, walls and beams by *smart structural designs*.
- Use highly durable *concrete mix designs* for foundations and other massive elements of new structures and for repair of old structures.

CONSUMING LESS CEMENT IN CONCRETE MIXTURES

- For foundations and piers, instead of 28-day a 56 or 91-day *strength* requirement can result in significant cement savings.
- To improve the *workability* of fresh concrete, instead of using more cement and more mixing water, use plasticizing chemical and mineral admixtures.
- Reduce the *volume of cement paste*, by using optimum size and grading of aggregate.

CONSUMING LESS CLINKER IN CEMENTS

An emerging technology shows that 50 to 70% portland cement can be replaced with one or several complementary cementing materials, such as coal fly ash, granulated BFS, natural pozzolans*, silica fume and rice husk ash, *with dramatic improvements in durability of concrete*. This can be done either by blending in a cement plant or during concrete batching.

Source: Turanli, L. et al; ACI Materials Journal, Mar-Apr 2008

A Roadmap for Reducing Global Cement Consumption and CO₂ Emissions from Clinker Production

	2010	2030
Cement Consumption (million tonnes)	2800	1960
Clinker Factor*	0.83	0.60
Clinker Requirement (million tonnes)	2300	1180
CO ₂ Emission Factor**	0.9	0.8
Total CO₂ Emission (million tonnes)	2070	940

* Tonnes of clinker per tonne of cement

**Tonnes of CO₂ per tonne of clinker

Source: Mehta, PK; Global Concrete Industry Sustainability, ACI Concrete International, Feb 2009

CONCRETE INDUSTRY SUSTAINABILITY

A June 2009 report by a consortium of the U.S. universities and corporations

- **The construction materials sector offers the biggest single opportunity of global CO₂ reduction by producing low-carbon blended cement mixtures, currently under development.**
- **By 2020, this could cut the CO₂ emissions associated with cement production by a half, thereby avoiding more that 1 gigaton CO₂ every year, compared to the current rate of about 2.1 gigaton.**

Source: www.gigatonthrowdown.org

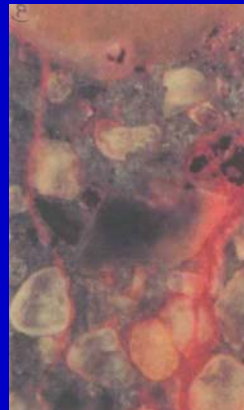
MAJOR ENHANCEMENT OF DURABILITY - A HOLISTIC TECHNOLOGY

- *Major enhancement of durability of materials is essential as a long-term strategy for sustainability, because a material saved is a material gained without incurring any financial and environmental costs.*
- **Using a holistic, rather than remedial approach**, it is possible to understand and control all of the primary causes of deterioration of concrete in field structures

Source: Mehta, PK; ACI SP-234, 2006

HETEROGENEITIES IN THE CEMENT PASTE

Interconnected microcracks: the primary cause of loss of water-tightness in concrete



A *homogeneous microstructure*, resistant to microcracking, can be obtained by using less mixing water, and a large amount of pozzolanic materials with portland cement (e.g., 50% siliceous fly ash or 60-70% GBFS or calcareous fly ash).

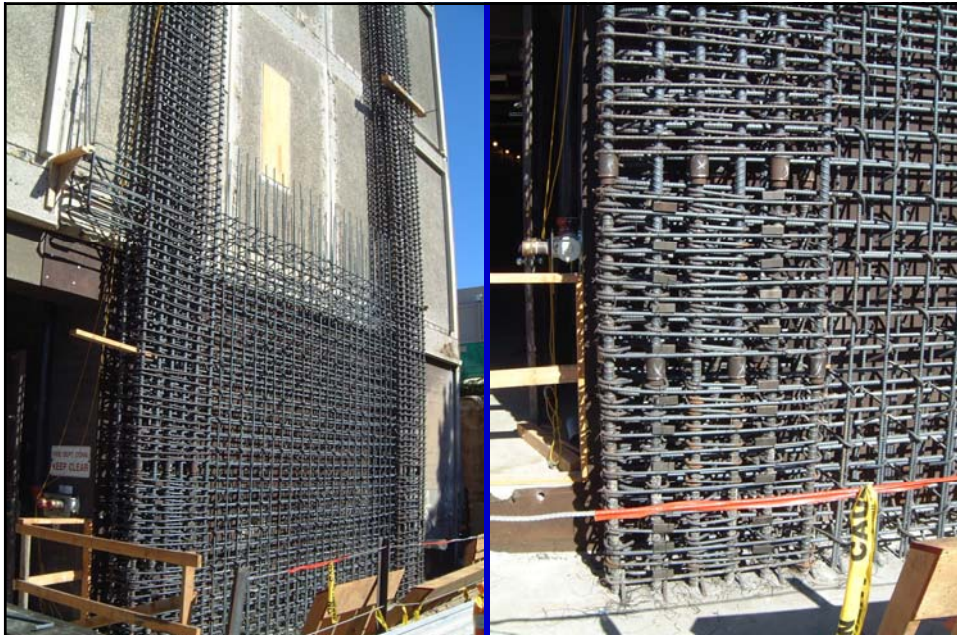


Photomicrograph of a thin section of HVFA concrete

BARKER HALL, UNIV. OF CALIFORNIA, BERKLEY, 2002
4.5m deep, 2m wide PT concrete foundation



C=160 kg/m³
FA=200
W/C=0.33
25 MPa @7-d
50 MPa @ 56-d
70 MPa @ 3-y



Wall Reinforcement

CITRIS Bldg. at Univ. of California Columns under construction (2007)

Concrete Mix, kg/m³

Type I cement = 200
 Class F, FA = 200
 Water = 140
 w/cm = 0.35-0.37
 Slump = 150 - 200 mm
 Actual strength:
 20 MPa @ 7-d
 30 MPa @28-d
 40 MPa @56-d
 50 MPa @90-d



Specifications required 27 MPa strength @ 28-d. About 1300 t CO₂ avoided by using 7000 m³ of HVFA concrete for heavily reinforced foundations, shear walls and columns. Concrete was self-consolidating and has excellent finish.

Utah State Capitol Building, Salt Lake City (2006)

Mix. kg/m³

C = 160
FA = 200
Water = 130
w/cm = 0.36



Foundations, beams, shear walls for seismic rehabilitation
4,500 m³, 27 MPa High-Volume Fly Ash Concrete specified

Utah State Capitol Building, Salt Lake City (2006)

- Utah State Capitol
- Seismic Retrofit:
 - HVFA concrete
 - w/cm = 0.38
 - 0.44 clinker factor
 - 900 t CO₂ reduction
 - 34 MPa @ 28-day



**Utah State Capitol Building,
Salt Lake City, under construction**



HVFA concrete mixtures have excellent pumpability, are non-segregating, and nearly self-consolidating

New CCTV Tower (Designed by Rem. Koolhaas)



Source: Weizu, Qin; Proc. CANMET-ACI Sustainability Workshop, China Building Materials Academy, Oct. 2008

Concreting of
Foundation of
The Tower
in Winter of
2005~2006



Mix proportions and workability

Cement, 205 kg/m³ Fly ash, 205 kg/m³ Water, 150 kg/m³
PC superplasticizer; W/B= 0.36
Slump 200~220mm

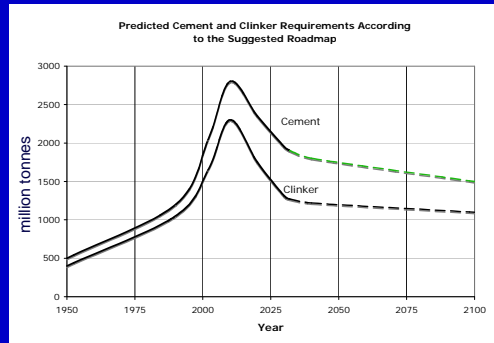
1. CONCLUDING REMARKS

- The high carbon dioxide emission rate of today's industrialized society has triggered climate changes that will **damage the earth's life support systems beyond repair in 20-30 years.**
- In 2010, to meet the global concrete demand of approx. 21 billion tonnes, about 2.8 billion tonnes cement will be required, and about 2 billion tonnes of CO₂ would be released into the atmosphere from the production of portland-cement clinker, which will continue to be a major component of modern hydraulic cements.

2. CONCLUDING REMARKS

By 2030, CO₂ emission rate from portland clinker production can be brought down to the 1990 level by:

- Reducing the global cement and concrete consumption by 30%.
- Lowering the average clinker factor of cement from 0.83 to 0.6 with blended portland cements containing 40% or more complementary cementing materials.



3. CONCLUDING REMARKS

Using a high proportion of complementary cementing materials like coal fly ash and considerably less portland-clinker, *a proven and low-cost technology* is already available for making highly durable and sustainable structural concrete products.

All we need now, is to join hands to take immediate and decisive action for implementation of this technology.

4. CONCLUDING REMARKS

- The era of unrestricted use of energy and materials is over because we have crossed the tipping point in 1990 that has triggered the climate change already underway.
- In the next 20 years, every segment of the global economy must make a determined effort to reduce their CO₂ emission to the 1990 level or less.
- The challenge before the construction community – the owners, designers, contractors, and cement and concrete producers – is to learn and use the new technologies of building sustainable structures, with sustainable designs, sustainable construction practices, and **sustainable and durable structural materials**.

· ——— · ——— · ——— · ——— · ——— · ——— ·
Thank You

· ——— · ——— · ——— · ——— · ——— · ——— ·
Obrigado
· ——— · ——— · ——— · ——— · ——— · ——— ·