Eco-Cement and Eco-Concrete

Environmentally Compatible Cement and Concrete Technology

Shunsuke HANEHARA

Iwate University

COE Workshop on "Material Science in 21st Century for the Construction Industry - Durability, Repair and Recycling of Concrete Structures"

Eco-cement and Eco-concrete technology

The cement industry has the potential to make the best use of waste and to purify the environment. This eco-cement and concrete technology is divided into four specific objectives.

i) Utilizing waste materials as alternative fuel and raw materials (AFR). An example includes "**eco-cement**" developed by Taiheiyo Cement Corporation in Japan.

ii) Purifying the environment with **concrete photocatalyst road**, whereby **TiO_2** decomposes NOx with ultraviolet rays.

iii) Encouraging natural flora and fauna, with **bio-sowed concrete** technology.

iv) Reducing the **heat island** phenomenon in urban areas through **sowed concrete technology**.

2. Manufacturing Technology for Using Waste Material

2.1 Waste Material (AFR) Use in Cement Industry

AFR: **A**lternative **F**uels and **R**aw Materials

What is the *political* CO_2 issue ?

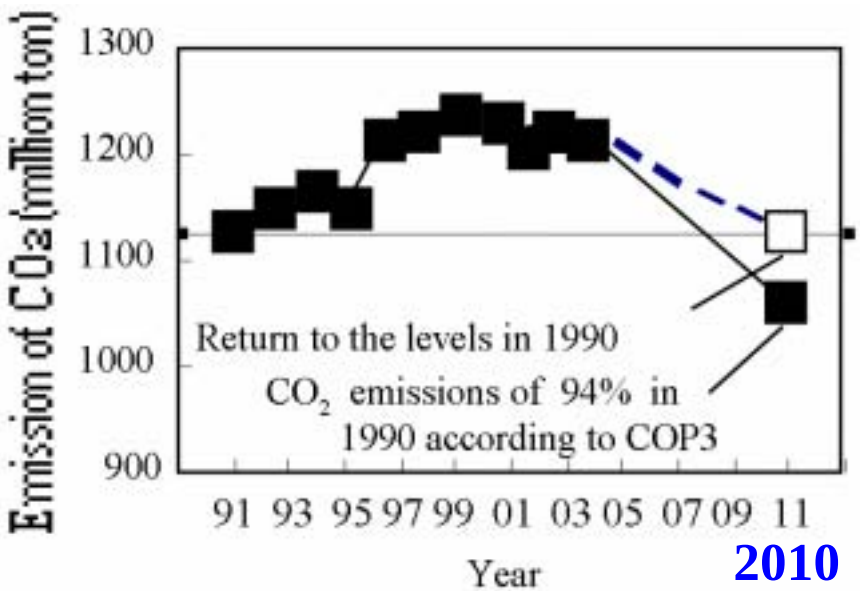
1992: Rio Earth summit:

Stabilize greenhouse gas concentrations

1997: Kyoto Protocol(COP3): Reduce total greenhouse gas emissions of developed world by

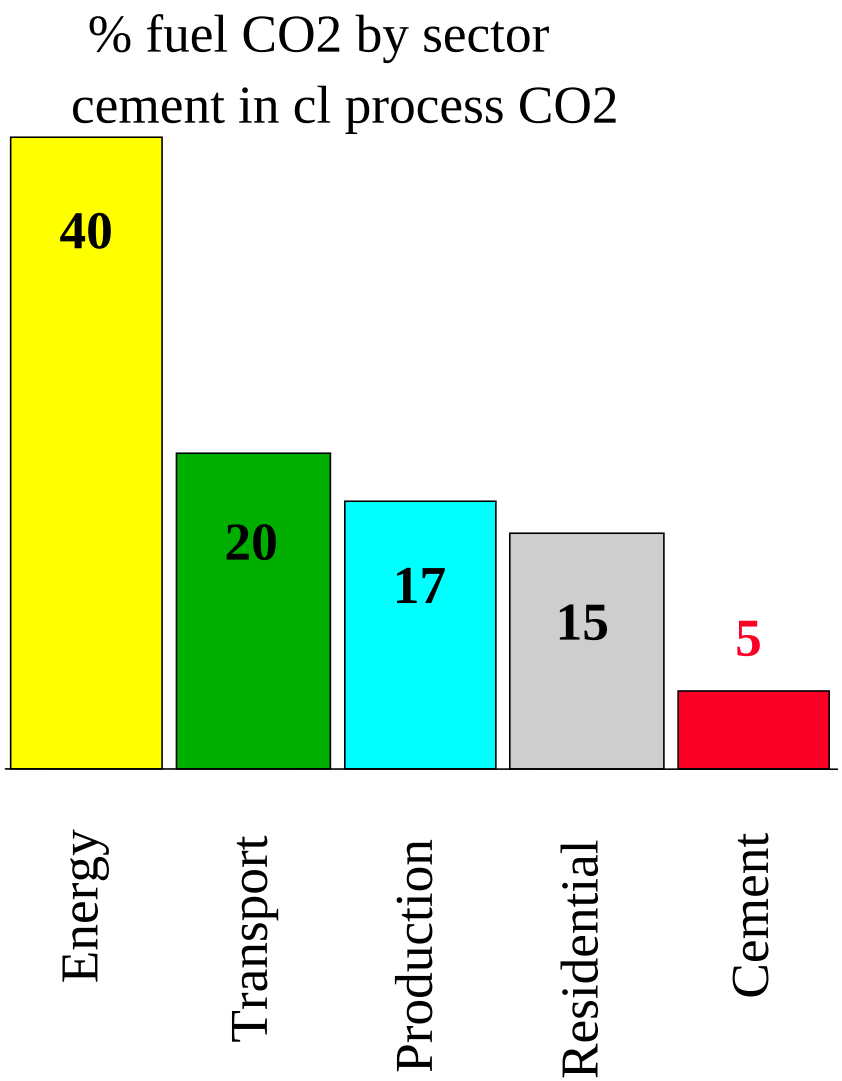
2008 ~ 2012 = 1990 - 5.2 %

2005, Feb. 16th
Effectuation of
Kyoto Protocol



Case of Japan

Impact of CO_2 issue for Cement Industries



World cement average:
0.8 to 1.0 ton CO2/t-cement

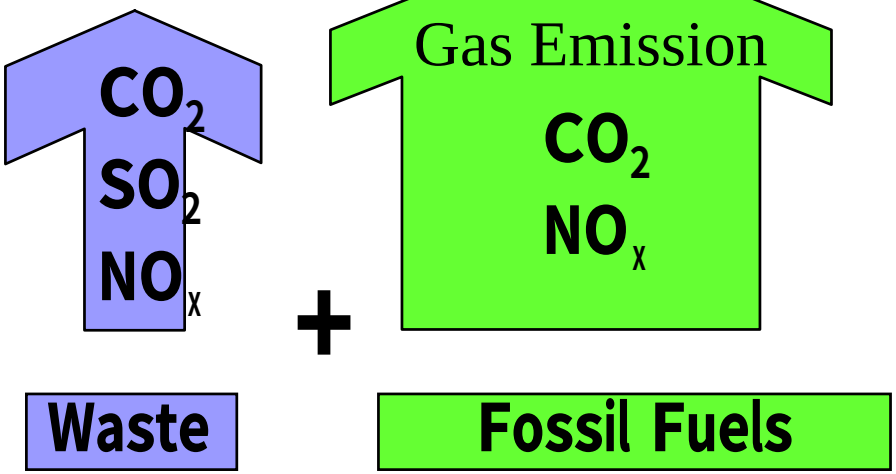
Global cement industry:
5% of global
CO2 emission

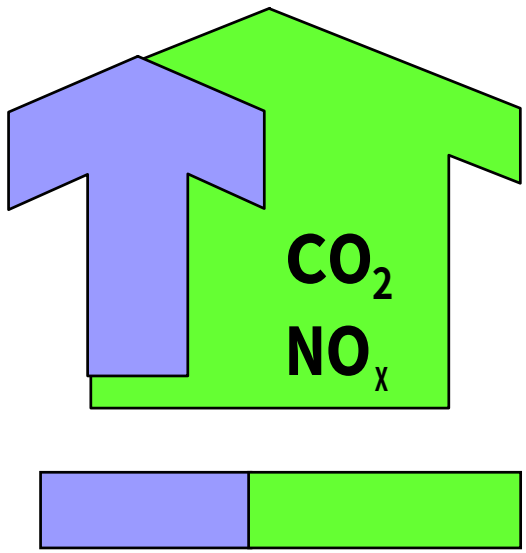
Cement industry =
largest source of
manufacturing industry

Waste Incineration plant

Cement works

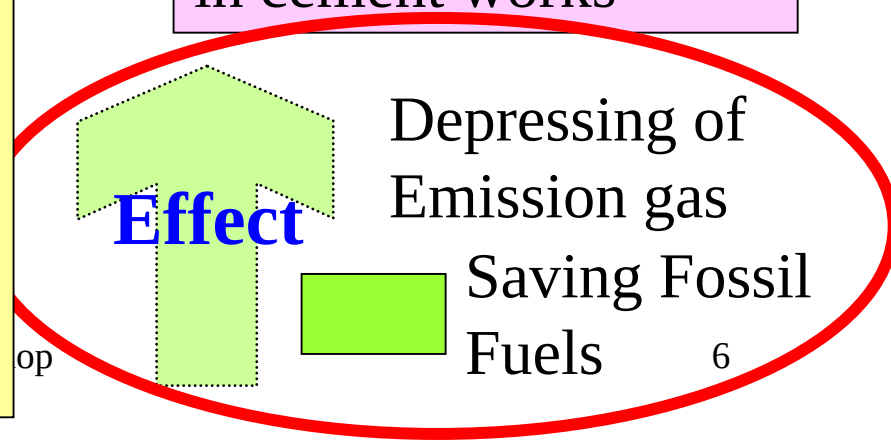
Recovery of thermal and material contents in cement works





By using waste as AFR in cement works, Large amount of fossil fuel and virgin resources can be saved and Emission of CO2 gas can be depressed.

Using waste as AFR in cement works



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Feature of cement industry

- fit for zero emission system.

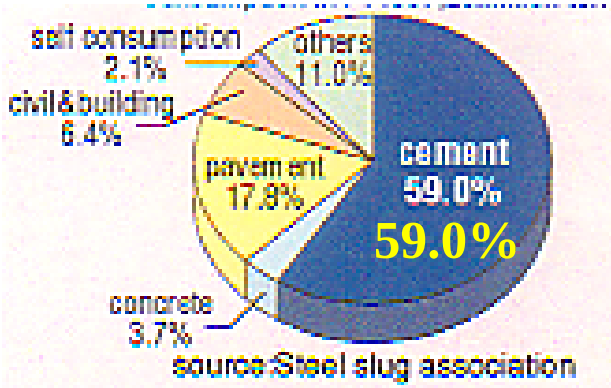
  - composition: mixture of CaO, SiO_2, Al_2O_3, Fe_2O_3,
    These elements are commonly familiar on the earth.

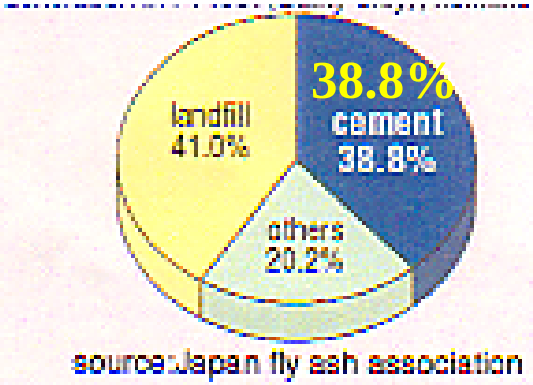
  Most industries refine the mono-component as steel making,

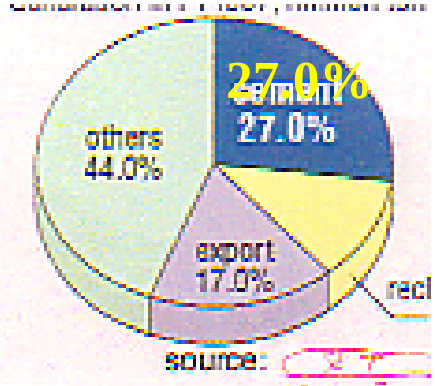
  - Two step burning at 1000 and 1500 ° C
  - Cement process applies to final treatment of combustible wastes of oil and plastics.
  - many kinds of industrial waste are possible to utilize as a cement raw material, since they are rich in superscription of 4 components.

Industrial waste used in Japanese Cement industry (1997)

Blastfurnace Slag 23Mt Fly ash: 4.8Mt Waste tire: 1.0Mt







Item	Application: Raw M	Blend M	Fuels	Amount (1000ton)
Blast furnace slag	○	○		12,684
Coal ashes	○	○		3,517
Gypsum by-product	○			2524
Coal tailing	○		○	1,772
Nonferrous slag	○			1,671
Steel manufacture slag	○			1,207
Dirt, Sludge	○		○	1,189
Ash dust, dust	○		○	543
Casting sand	○			542
Used tire			○	258
Recycled oil			○	159
Waste oil			○	117
Waste clay			○	76
Construction debris	○		○	49
Others	○			292
Total				**26,600**

26.6Million ton is 8% of summation of all of industrial and non-industrial waste.

2.2 Eco-cement

Eco-cement is a new type of Portland cement being developed not only to solve the municipal and industrial waste problem caused by limited availability of landfill sites, but also to contribute to the protection of the environment by providing a complete recycling system of wastes that would otherwise be dumped.

The targets in the development of eco-cement

- ✓As much as 50% of the raw materials have to be replaced by incinerator ash or other waste materials such as sewage sludge.
- ✓The cement has to have general wide use.
- ✓ Both the manufacturing process and the products have to be environmently-friendly.
- ✓ The entire process has to be a complete recycling system.

Key Technology in Eco-cement

Incinerator ash generally also contains a high concentration of chlorides and a small amount of heavy metals. Therefore, decomposition, removal, or enclosure of these substances is the key to the success of this project.

The metals vaporize in the form of chlorides through the burning process and are caught as kiln dust in the bag filter. The heavy metals are then extracted from the dust through the metal recovery process and delivered to a smelter for refining. This makes the eco-cement process a complete recycling system for municipal and industrial wastes.

Raw mix and incinerator ash

Incinerator ash composition

Major components (%)									
ig.loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl
11.0	22.9	19.7	5.6	30.4	4.8	2.1	3.3	2.6	8.5

Minor components (%, ppm)											
TiO_2	P_2O_5	ZnO	CuO	Cr	As	Cd	Hg	Pb	F	CN	PCB
0.9	1.8	0.6	0.6	438 ppm	55	11	3.5	311	120	ND	ND

Typical Mix Design of Raw Meal (%)

Type of cement	Incinerator ash	Limestone	Clay	Ferro M.	Alumina
Portland cement type	58.2	40	1.3	0.5	–
Rapid-hardening type	52.2	45	2.2	0.3	0.3

Composition of eco-cement

	Chemical composition (%)									
Type of cement	ig.loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Cl
Portland cement type	0.6	19.1	8.1	4.5	62.7	1.4	3.7	0.05	0.00	0.04
Rapid-hardening type	0.8	15.5	11.0	1.9	58.5	1.4	8.8	0.60	0.00	1.00
NPC	0.6	22.2	5.1	3.0	63.8	1.4	2.0	0.30	0.20	0.00

	Mineral composition (%)					
Type of cement	C_3S	C_2S	C_3A	$C_{11}A_7 \cdot CaCl_2$	C_4AF	$CaSO_4$
Portland cement type	49	12	14	–	13	7.7
Rapid-hardening type	44	11	–	17	8	15.0
NPC	56	19	9	–	9	3.4

Property of eco-cement

	Specific gravity	Specific surface area (cm^2/g)	Setting time (hr - min)	
Type of cement			Initial	Final
Portland cement type	3.19	4500	2-0	4-30
Rapid-hardening type	3.13	4600	0-9	0-13
NPC	3.17	3220	2-22	3-20

	Compressive strength (N/mm^2) (days)					
Type of cement	3hr	6hr	1	3	7	28
Portland cement type	–	–	9	22	37	53
Rapid-hardening type	10	16	23	30	38	46
NPC	–	–	11	27	43	59

Project of eco-cement

1991 Starting the eco-cement project
1994 50ton/day Test Plant Operation
2001.4 350ton/day (95,000ton/year) 1st Commercial Eco-cement plant
90,000ton/year of incinarotor ash from 2,500,000 people can be treated in Ichihara Plant (Chiba Prefecture)
2004 800ton/day (200,000ton/year) 2nd Commercial Eco-cement plant started to construction
2006 2nd Plant will start to operation.

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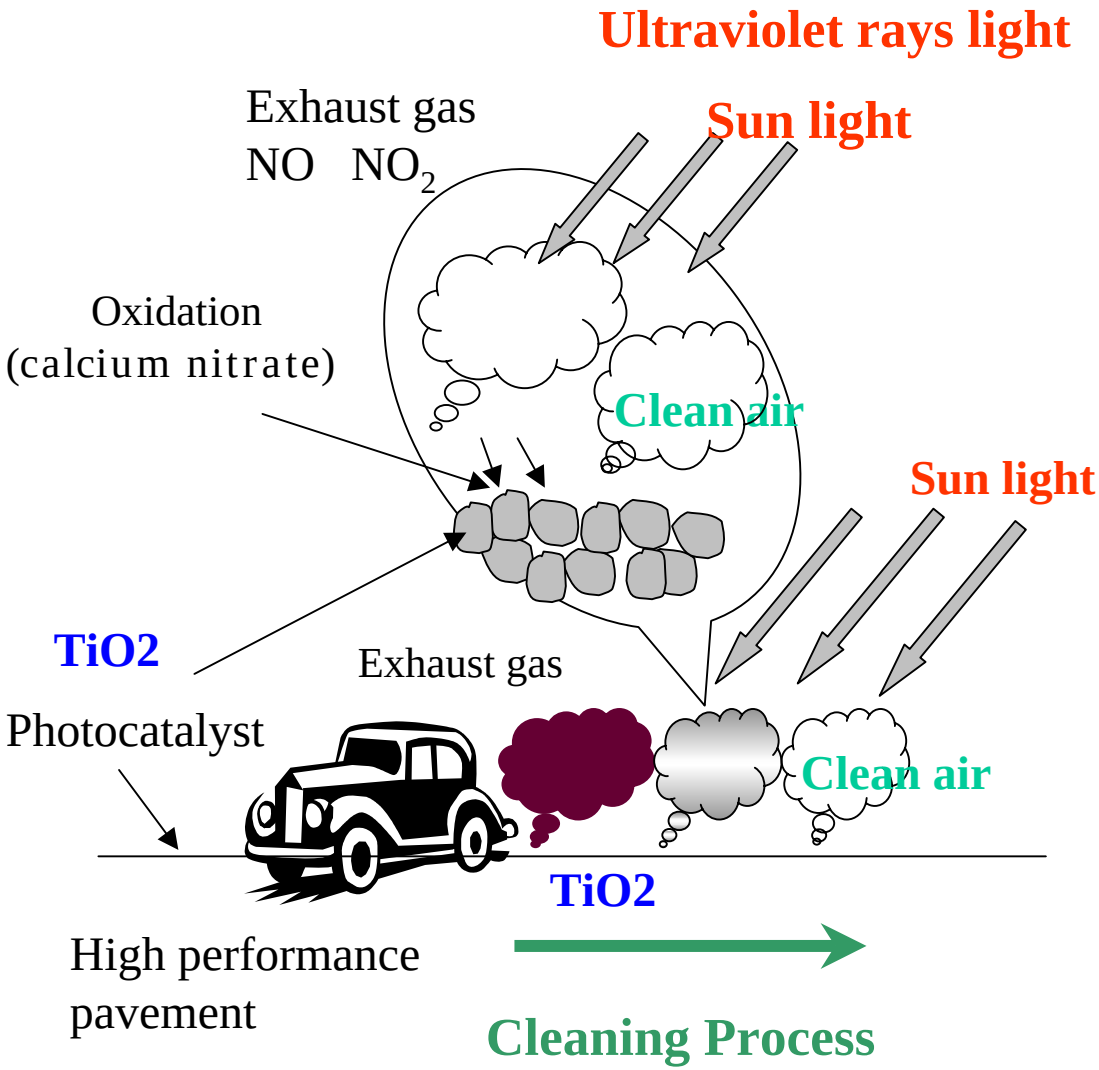
ECO

Construction work of 2nd Plant

TAMA Eco Cement

3. Purifying the environment with concrete photocatalyst road, whereby TiO_2 decomposes NOx with ultraviolet rays

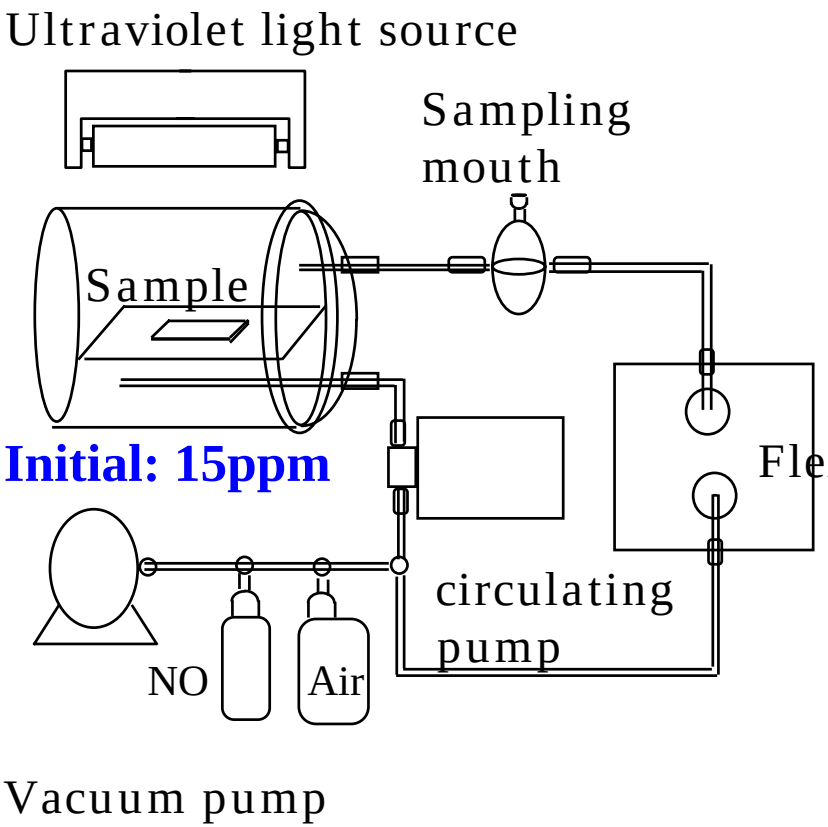


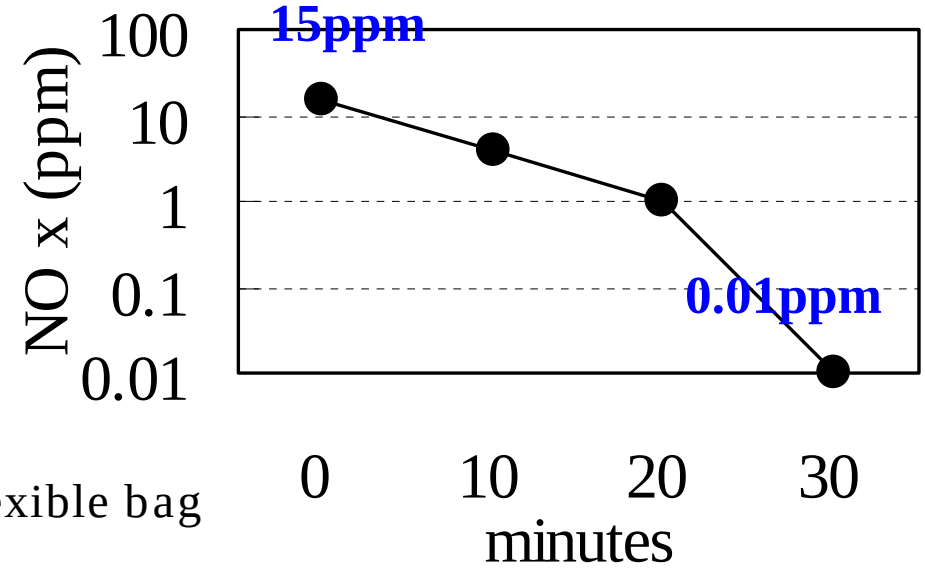
Removal principle of NOx

Air pollution of NOx by cars has become a serious problem.

The TiO_2 photocatalyst creates active oxygen molecules on the surface when the ultraviolet rays light (sun light) the TiO_2 photocatalyst.

Rapidly NOx in the air is oxidized into nitric acid by active oxygen molecules.





By 30 minutes treatment,
Concentration of NO 15ppm
Reduce to 0.01ppm.

Test equipment

Performance of reducing NOx

Application of photocatalyst TiO2 on wall

Application of photocatalyst TiO2 on road

Construction using photocalalyst TiO2 (in Japan)

year	m^2
1997	2300
1998	5000
1999	7200
2000	5200
2001	4600
2002	4700
2003	5800
2004	8700
(2005)	(12000)

Porous concrete is key technology to manage the environmental system.

Table Field of Porous Concrete Application

- Sowed concrete
- Permeable concrete
- Insulation block
- Humidity control block
- Photocatalyst pavement
- Crab libable sea wall
- Fish bank, Sea grass bed

4. Encouraging natural flora and fauna, with **bio-sowed concrete** technology

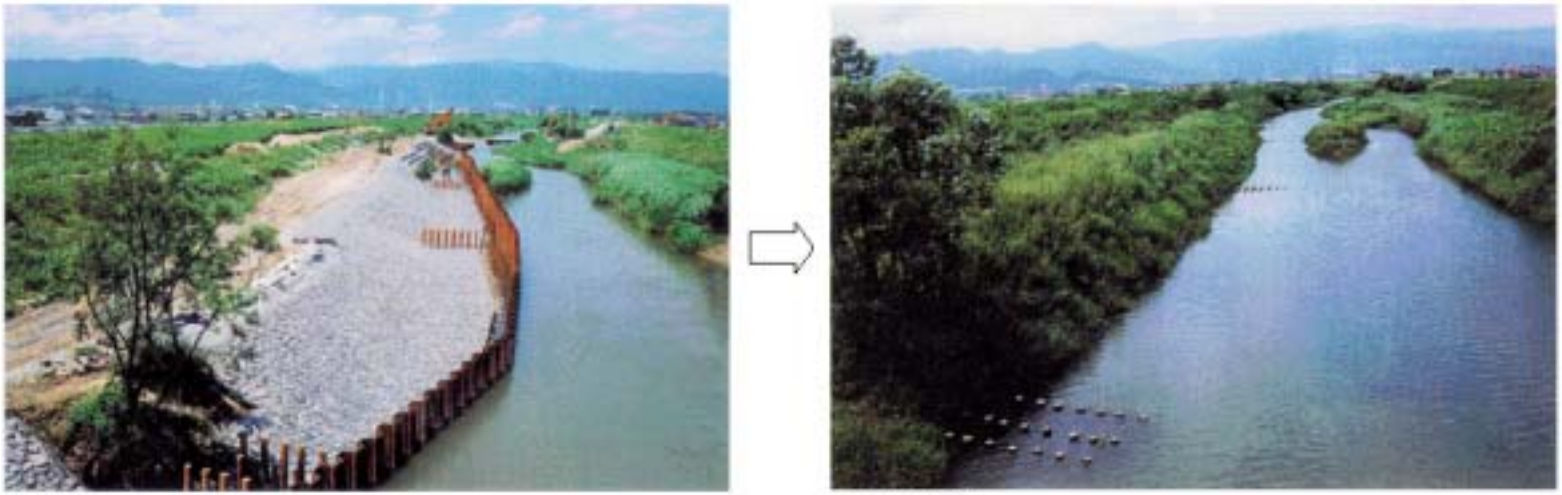
Background:

Ministry of construction of Japan changed a law concerning to management of river for the benefit of amenity of the river landscape in 1997.

The ministry is focusing on the improvement and maintenance of the river environment for natural flora and fauna in addition to previous mandates of flood control and forestry conservation.

7 years Plan (1997-2003) of Flood Control Work
(The Ministry of Construction: Japanese Government)

	Material, Construction Method	Length (km)
River slope without concrete	River slope with plant	2,300
	River slope with stone, wood etc.	1,400
River Slope inevitably covered with concrete	River slope with concrete (not exposed)	2,000
	River slope with concrete (exposed)	1,600
Total		7,300



施工中

施工後（約1年経過）

今自然型川づくり施工事例（城原川　佐賀県神埼郡神埼町）

施工直後（H10.3）

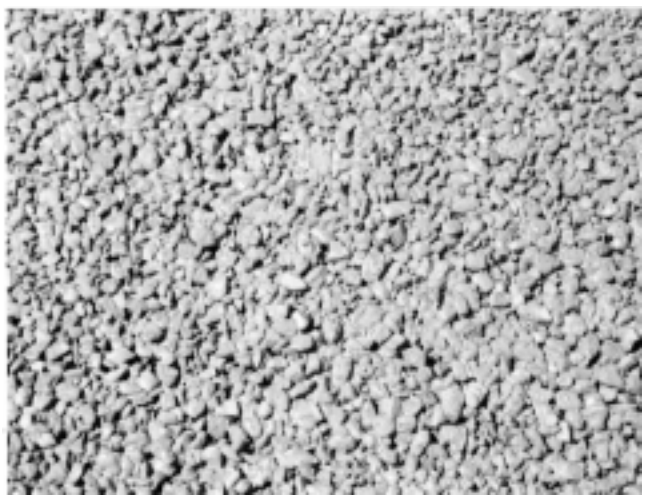
施工6ヶ月後（H10.9）

Table Sample for Mix Proportion of Porous Concrete

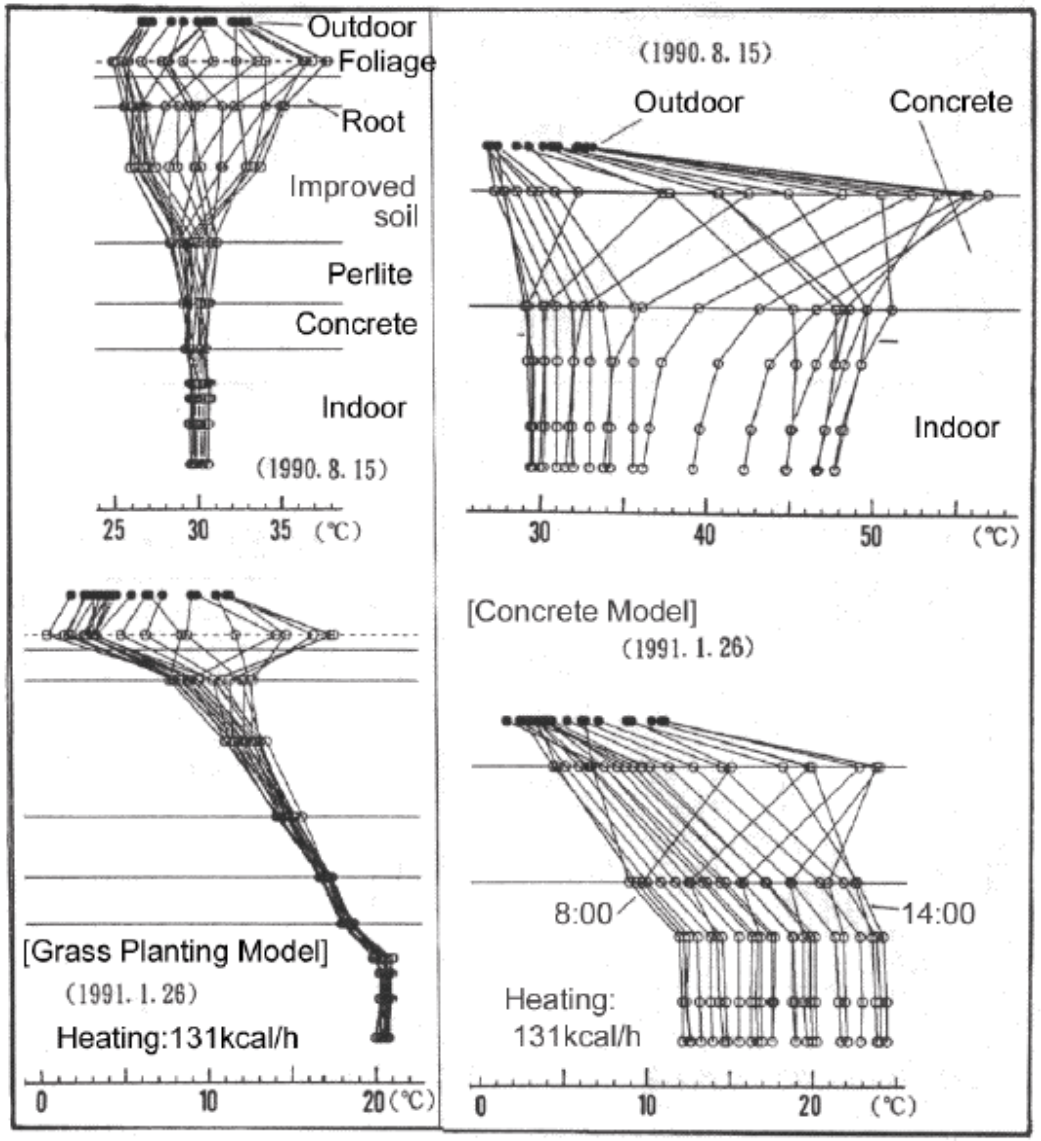
Field of concrete	Air void (vol. %)	Water/Cement (wt. %)	Unit weight (kg/m^3)				
			Water	Cement	Sand	Aggrigate	Other
Sowed concrete	25.2	30	81	271		1540	Super prasticizer 0.8
Concrete pavement	18	22	67	300	187	1461	Admixture 74

Table Compressive and Bending Strength of Porous Concrete [1]

Field of concrete	Compressive Strength (N/mm^2)			Bending Strength (N/mm^2)
	7 days	28 days	56 days	28 days
Sowed concrete	14.8	18.6	20.5	–
Concrete pavement	–	27.4	–	4.61



iv) Reducing the **heat island** phenomenon in urban areas
through **sowed concrete technology**



Closing :

Role of Cement and Concrete

The 20th century has been the century of concrete.

Throughout the 20th century, concrete has contributed to human society as the basic construction material.

Now, towards **the 21st century**, the cement industry will become a greater contributor to society by taking on a second role as an **environmental system manager**. The cement and concrete industry will also provide a solution to municipal and industrial waste problems and to manage sound environment.