TCG-JSCE JOINT SEMINAR
Nov. 20, Athens

RECYCLING CONCRETE
-The present state and future perspective-

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Concrete

- **<u>Constituents</u>: coarse aggregate, fine aggregate, cement (limestone and clay), and water**

  "The most bountiful resources on the Earth"

- **Therefore, concrete is the second most consumed material on the Earth after water.**

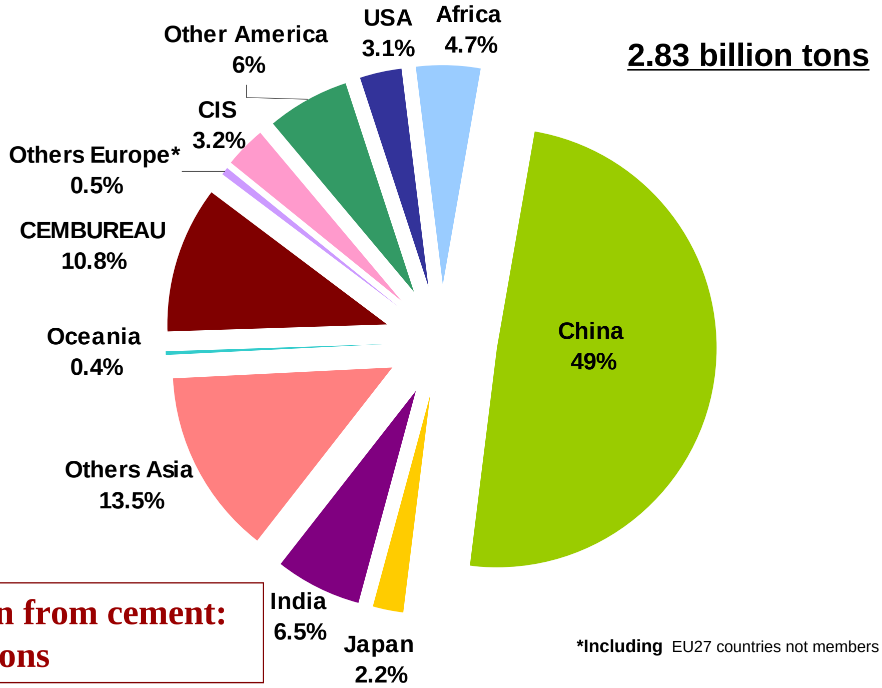
  at present: more than 20 billion tons

  1950: 2 billion tons

Environmental Problems in Concrete Sector

- Global warming
- Resource depletion
- Waste disposal

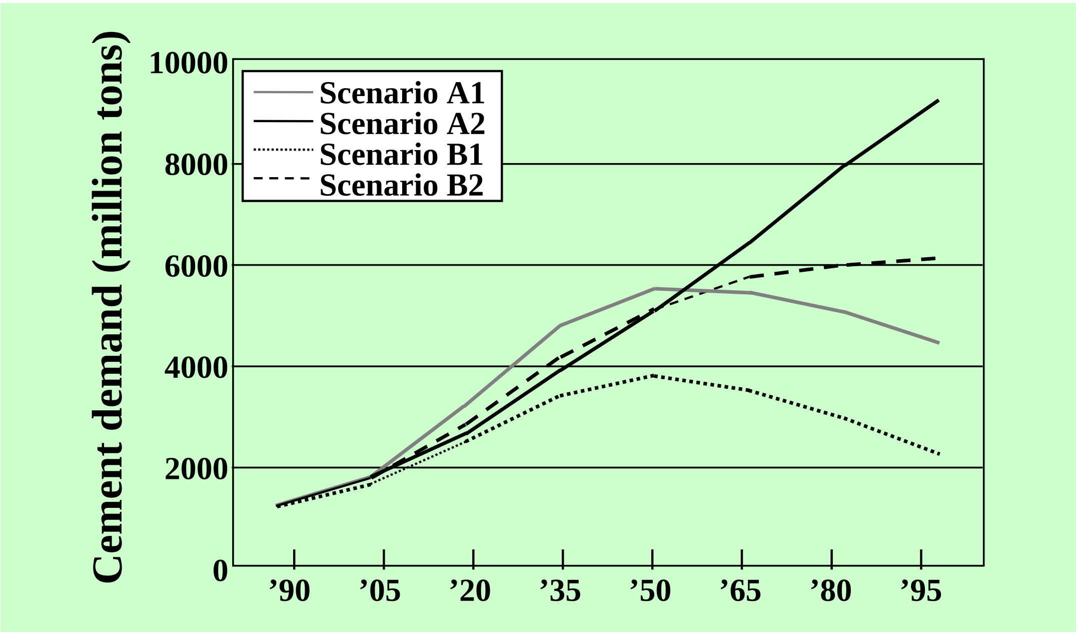
World Cement Production by Regions and Main Countries



CO_2 emission from cement:
2.46 billion tons

*Including EU27 countries not members of CEMBUREAU

Estimated Cement Demand (CSI-WBCSD)

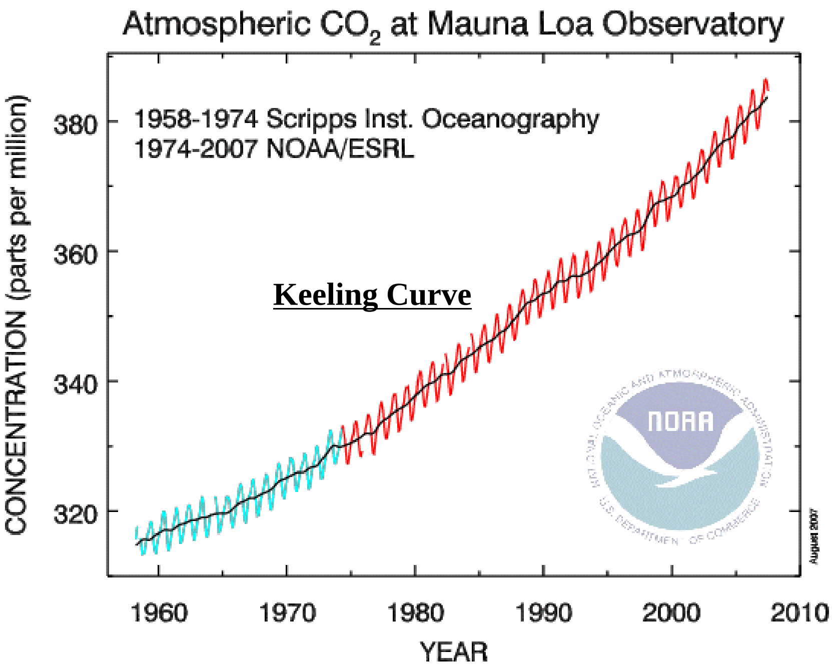


Warning by IPCC Report

"CO_2 emissions must be reduced by <u>85 - 50% by 2050</u> compared with the 2000 level to limit CO_2 to 350 -400 ppm. Even if we could do it, a temperature rise of 2.0 – 2.4 ºC will be inevitable."

<u>What is the current situation?</u>

CO_2 Observation in Hawaii



Consumption of Natural Resources on Earth

L. R. Brown: ECO-ECONOMY

Aggregates	20
Steel production (iron ore)	1
Gold production (gold ore)	0.7
Wood	3
Others	1.3
Total	26

(billion tons)

CO_2 emissions from aggregate production: 160 million tons

Total CO_2 Emissions from Concrete Sector

- **Total: about 5.9 billion tons (Cement, aggregate, steel, execution, transportation)**
- **It corresponds to 20% of the total fossil fuel origin CO_2 emissions, which is 30.0 billion tones in 2007.**

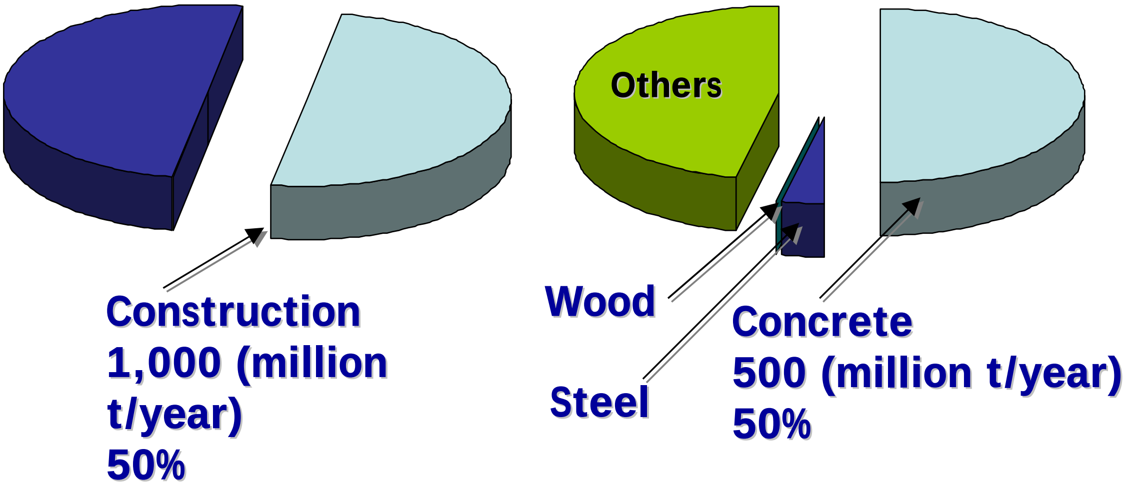
Resource Input into Construction Sector in Japan

Total

Total: 2,000 (million t/year)

Construction

Total: 1,000 (million t/year)



Amount of waste in Major Regions

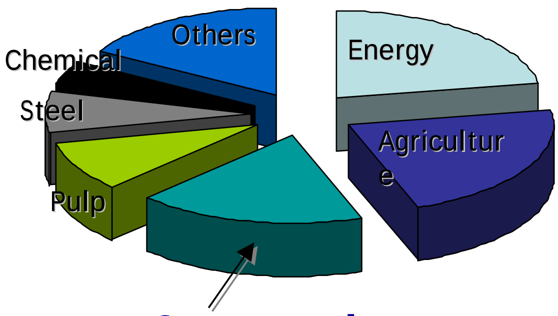
Amount of waste (Mt)	Europe	USA	Japan
Construction and demolition waste	510	317	77
Municipal waste	241	228	53

Source: CSI - Recycling concrete

Waste Output from Construction Industries in Japan

Industrial Waste

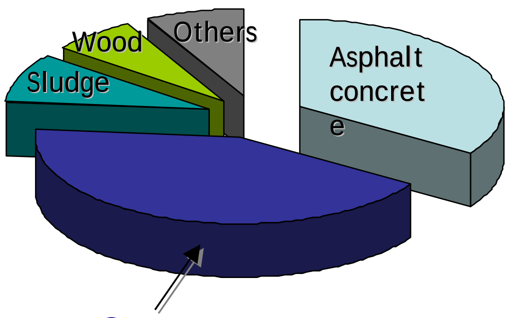
Total: 412 (million t/year)



Construction
75 (million t/year)
18%

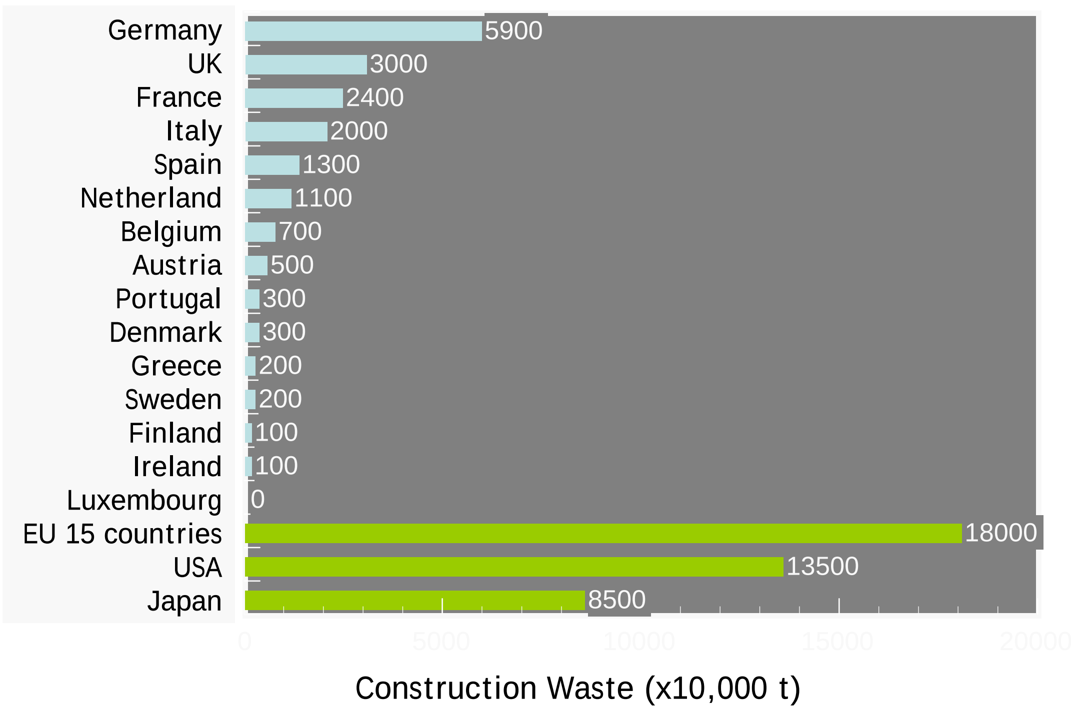
Construction Waste

Total: 75 (million t/year)

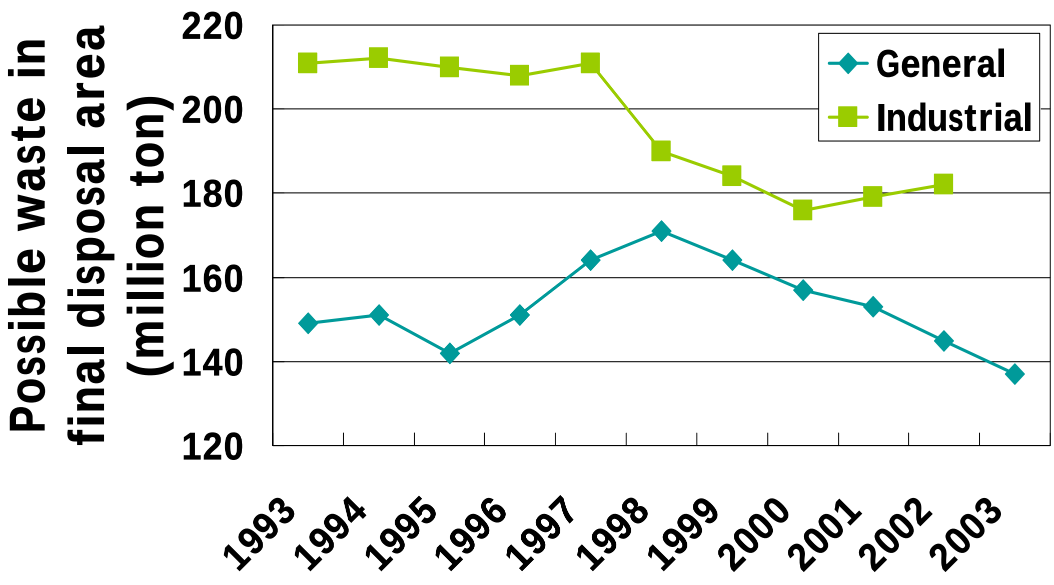


Concrete
32 (million t/year)
41%

Construction Waste in Each Country



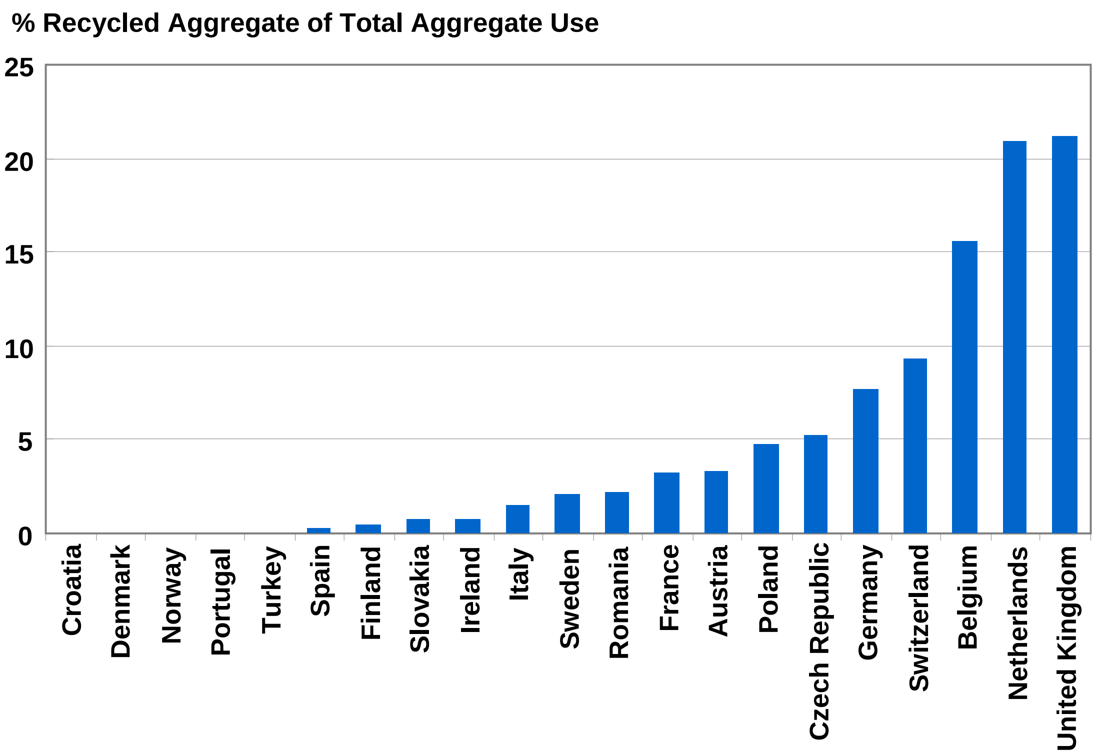
Final Disposal Sites for Waste in Japan



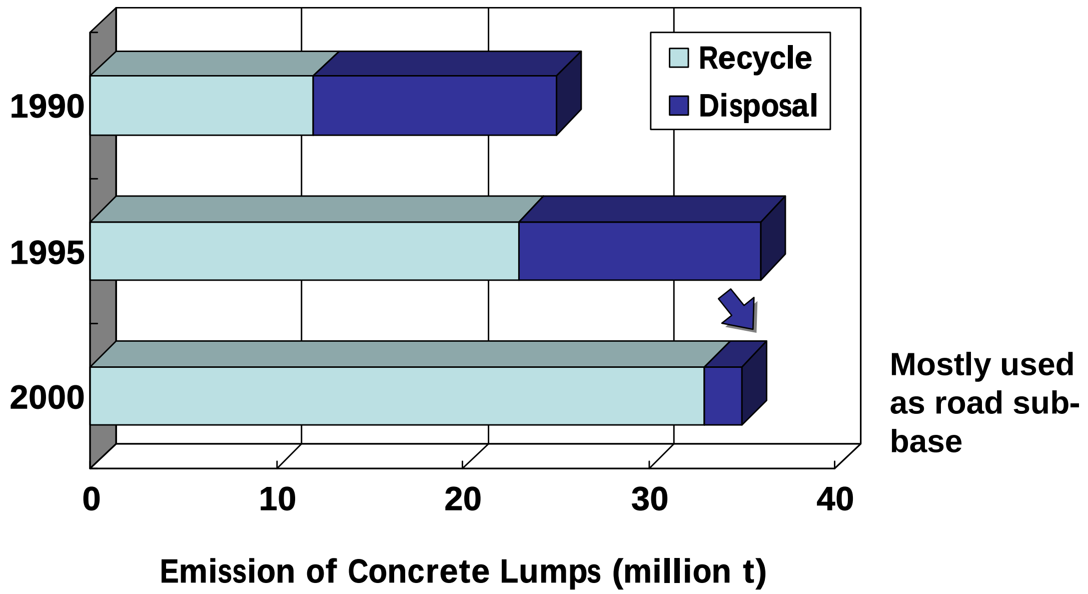
Utilization Form of Recycled Concrete

- <u>Reuse in original form</u> by cutting them into smaller blocks (very limited)
  - -slab reuse
- <u>Use as aggregate</u>
  - - road sub-base or
  - - underground stabilization
  - - concrete

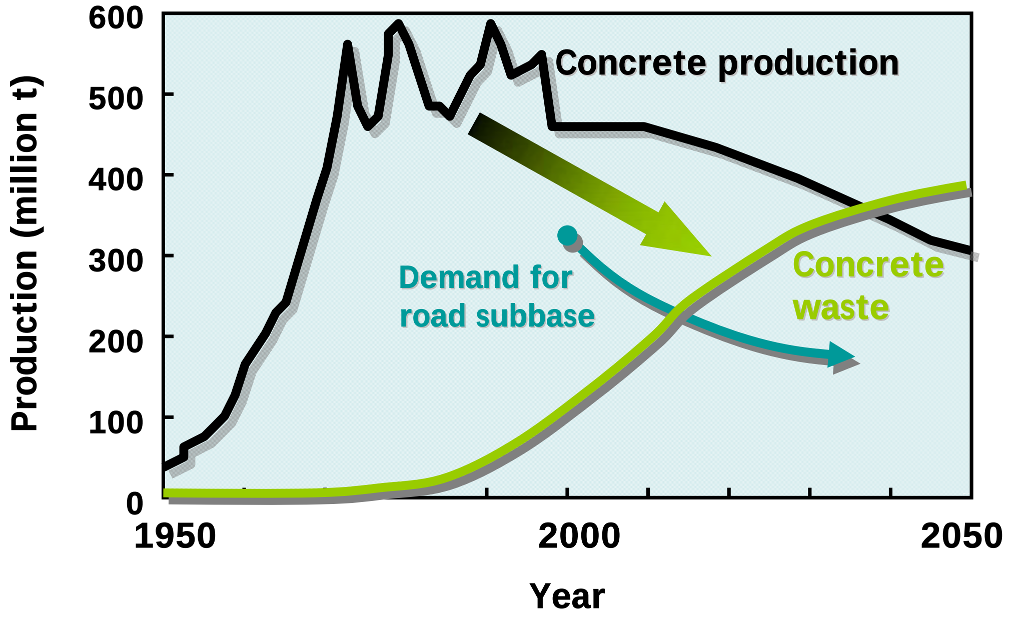
Use of Recycled Aggregate



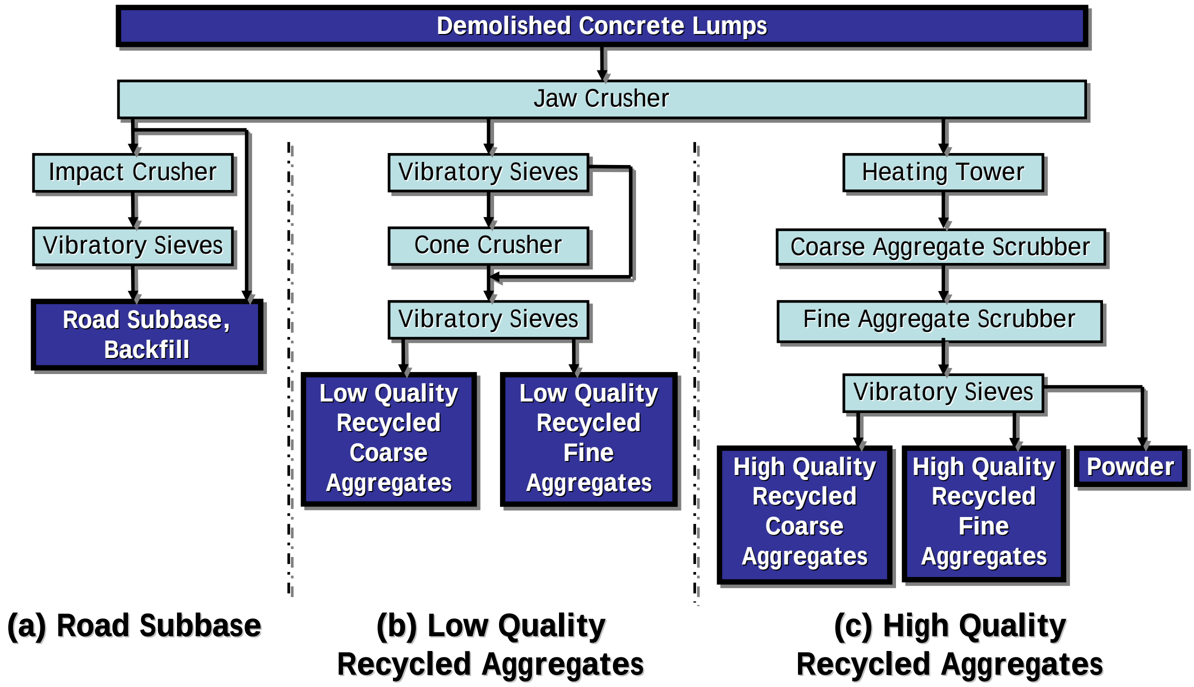
Recycling Ratio of Concrete in Japan



Predicted Amount of Future Concrete Lumps in Japan



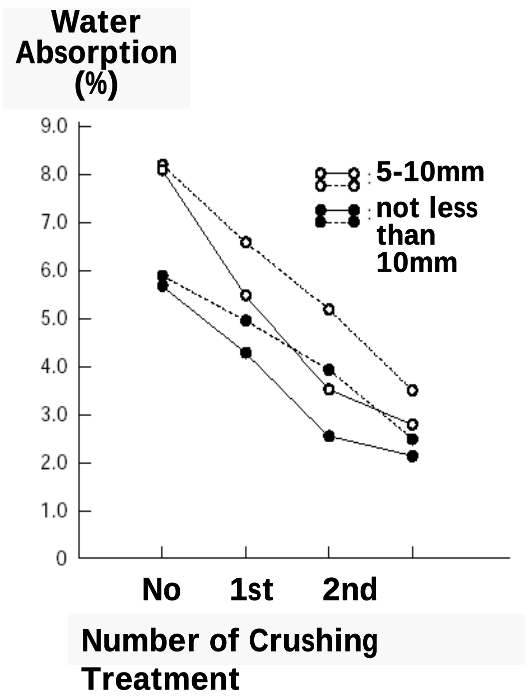
Recycling process of concrete lumps

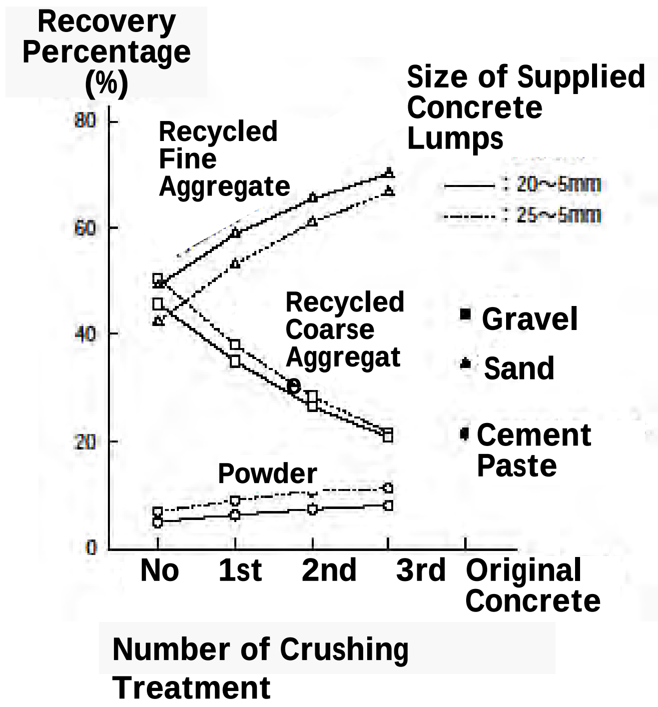


The Most General Technologies for Concrete Recycling

- Road sub-base material
- Non-structural concrete

Properties of Recycled Aggregate





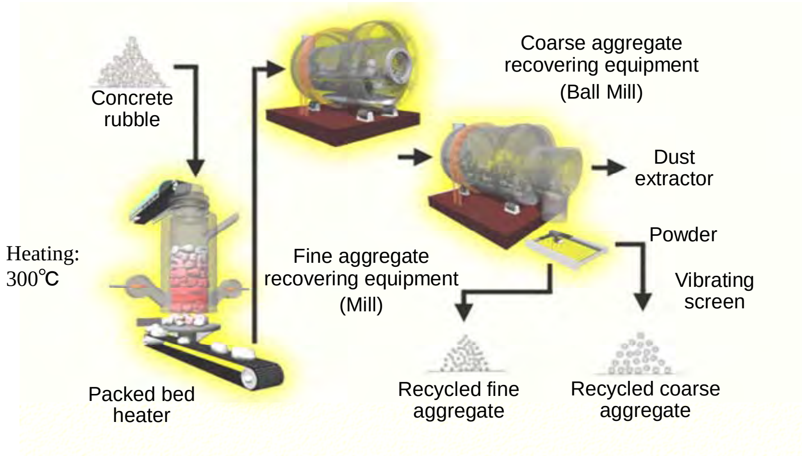
Recycling Technologies of Demolished Concrete in Japan

(1) Heating and rubbing method

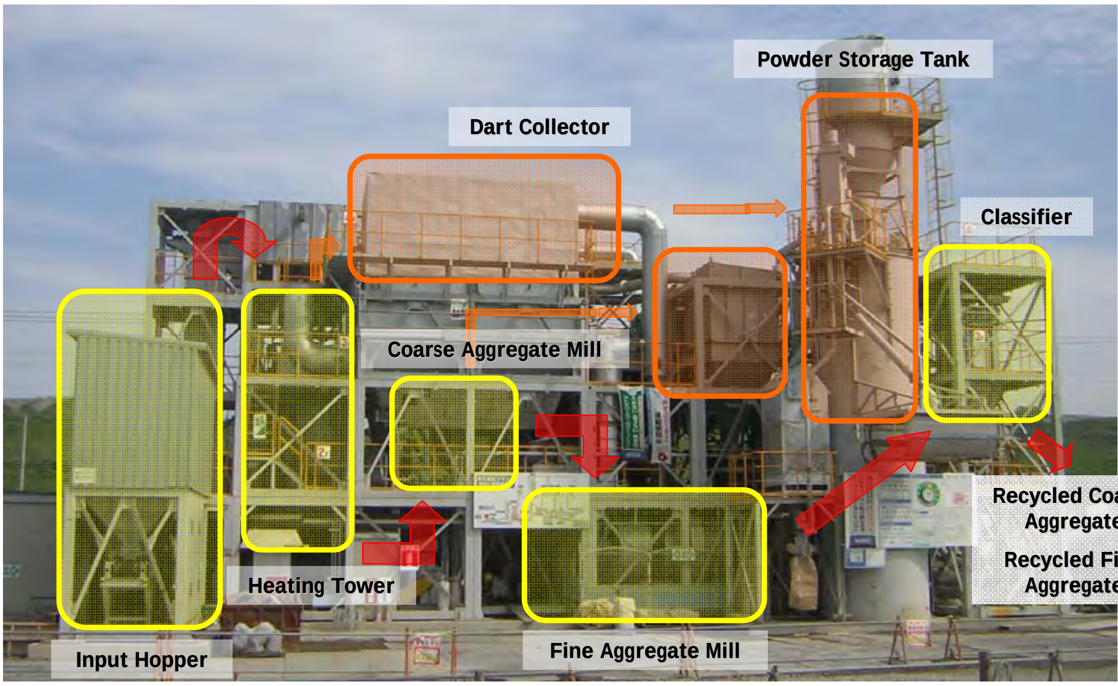
(2) Eccentric-shaft rotor method

(3) Mechanical grinding method

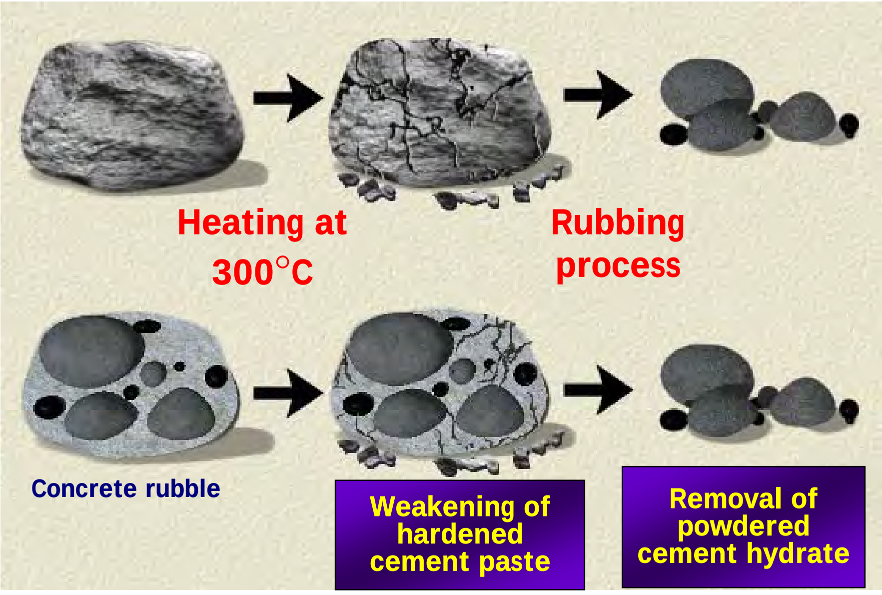
Heating and rubbing method



Heating and Rubbing Method Plant

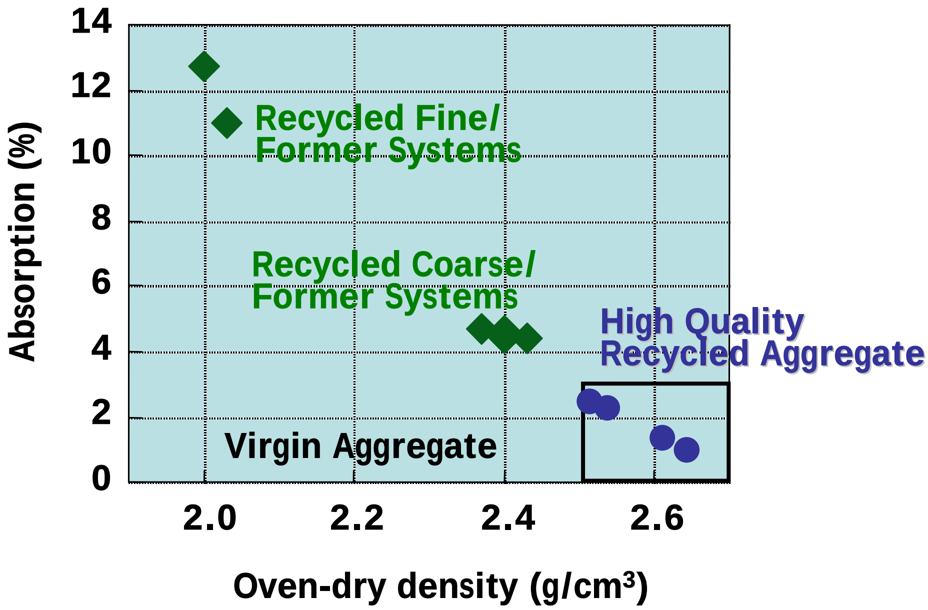


Mechanism of Heating and Rubbing Method



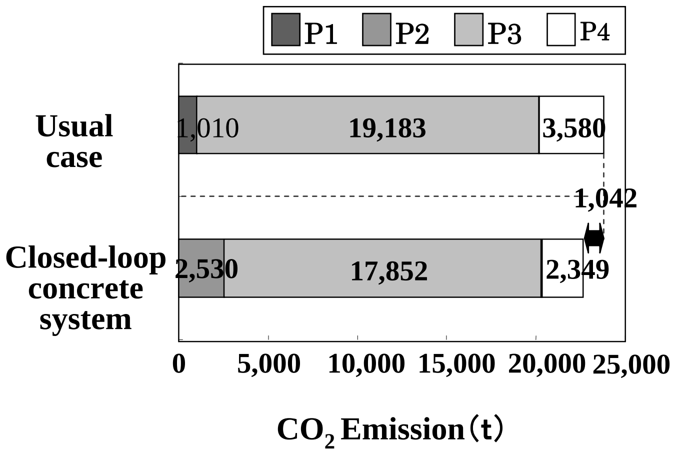
Recycled Aggregates & By-product Powder by H&R Method

Quality of Recycled Aggregates



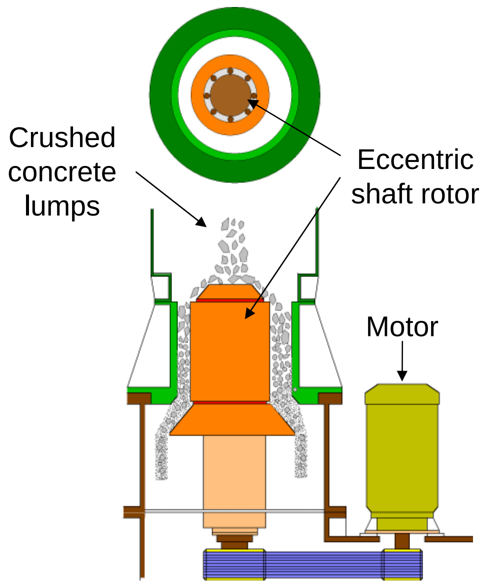
An Example of Application of Heating and Rubbing Method

On-site Concrete Resource Recycling System and CO_2



P1:Road sub-bases production, P2: Recycled aggregate recovering, P3: Concrete mixing and delivery, P4: Ground improvement

Eccentric-Shaft Rotor Method



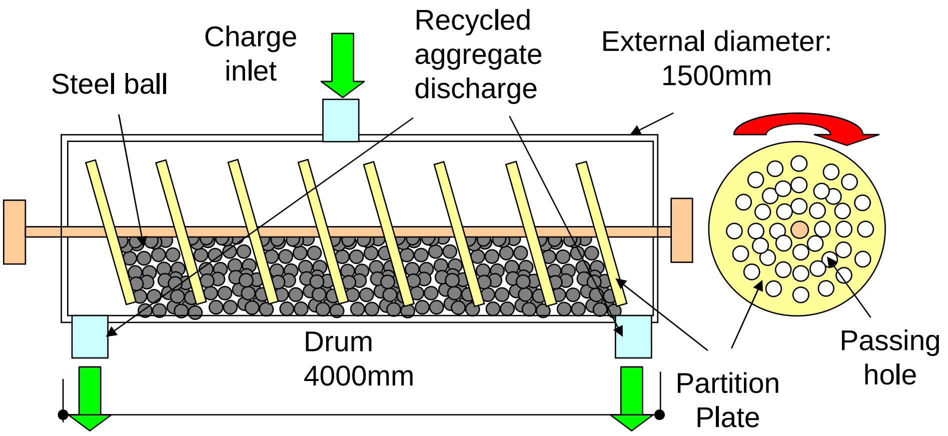
Crushed concrete lumps are passed downward between an outer and inner cylinder.

An Example of Application of Eccentric-Shaft Rotor Method

Old apartment Houses
12 x 4-storied
Concrete lump: 11,500 t

New apartment Houses
7 x 9-19-storied
Recycled coarse aggregate: 3,000 t
Recycled concrete volume: 3,000 m^3
(Total concrete volume:40,000 m^3)

Mechanical Grinding Method



Coarse and fine aggregates are produced by separating a drum into small sections with partitions.

Japan Industrial Standards for Recycled Aggregate

- **JIS A 5021**
  - **Recycled aggregate for concrete - Class H**
- **JIS A 5022**
  - **Recycled concrete using recycled aggregate Class M**
- **JIS A 5023**
  - **Recycled concrete using recycled aggregate Class L**

Specified Values of Recycled Aggregate in JIS

	Class - H		Class - M		Class - L	
	Coarse	Fine	Coarse	Fine	Coarse	Fine
Oven-dry density (g/cm^3)	not less than **2.5**	not less than **2.5**	not less than **2.3**	not less than **2.2**	–	–
Water Absorp-tion (%)	not more than **3.0**	not more than **3.5**	not more than **5.0**	not more than **7.0**	not more than **7.0**	not more than **13.0**

Limits of Amount of Deleterious Substances for RA-H

Category	Deleterious substances	Limits (mass%)
A	Tile, Brick, Ceramics, Asphalt concrete	2.0
B	Glass	0.5
C	Plaster	0.1
D	Inorganic substances other than plaster	0.5
E	Plastics	0.5
F	Wood, Paper, Asphalt	0.1
Total		3.0

Application of Recycled Aggregate

	Scope of application
Class - H	**No limitations** are put on the type and segment for concrete and structures with a nominal strength of 45MPa or less
Class - M	**Members not subjected to drying or freezing-and-thawing action**, such as piles, underground beam, and concrete filled in steel tubes
Class - L	**Backfill concrete, blinding concrete, and leveling concrete**

Utilization of By-product Powders

■ Large amount of by-product powders

- Possible uses
  - Cement material
  - Ground improving material
  - Addition to road bottoming
  - Concrete addition
  - Asphalt filler
  - Inorganic board material
- Demands
  - Quality stabilization
  - Reduction of quality control cost

Barriers of Concrete Recycling (CSI)

- Low economic cost of virgin aggregate
- Non-regular supply of construction and demolished waste (C & DW)
- C & DW on-site waste management plans are needed
- Misconception that recovered concrete is of low quality
- Classification of recovered concrete as waste can increase reporting and permit requirements. Extra limitations can be placed on use.

Barriers of Concrete Recycling (CSI)

- Processing technology for recovery of concrete should consider possible air and noise pollution impacts as well as energy consumption.
- For specialized application (e.g. high performance concrete), there are some limitations on fitness for use.

Future Technologies for Concrete Recycling

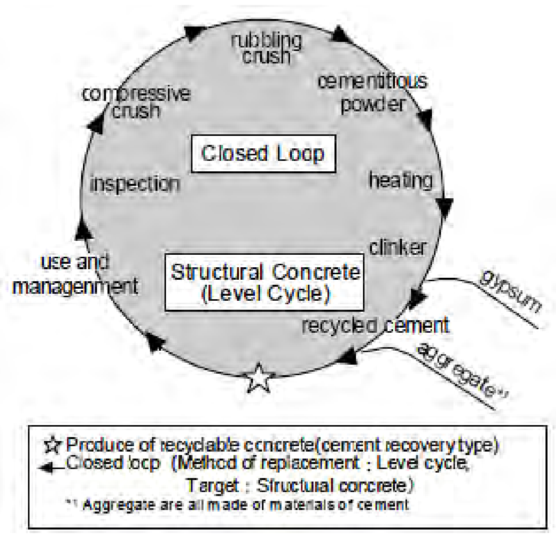
■ **Concept of Completely Recyclable Concrete**

- **Recyclable concrete like steel and aluminum**
- **Production process of concrete**
  - **Conventional downstream approach**
    - **focusing on**
      - » **Cost reduction**
      - » **Efficiency in production**
  - **New production system**
    - **incorporating upstream (inverse) processes in consideration of recyclability**

Requirements for Ideal Recycling

- **Save energy**
- **Make high performance concrete**
- **Reduce waste**
- **Conserve natural resources**

Cement-recovery Type Completely Recyclable Concrete (The Uni. Of Tokyo)

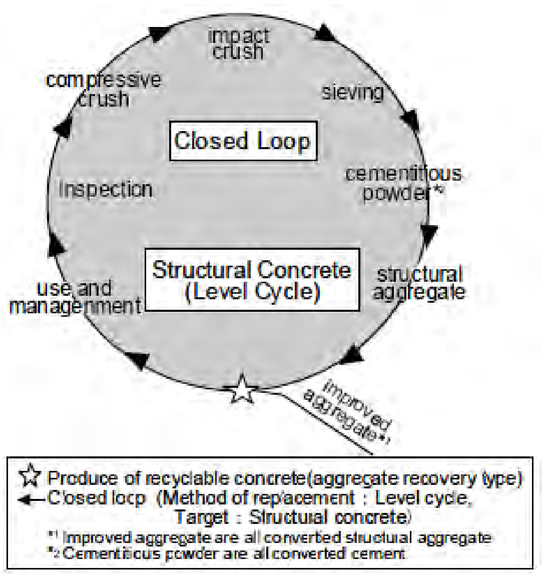


- **Concrete in which binders, additives and aggregates are all made of cement or materials of cement, and all of these materials can be used as raw materials of cement after hardening**

Application of Cement Recovery Type CRC

Precast Concrete Foundations Made from CRC in Kita-kyusyu

Aggregate-recovery Type Completely Recyclable Concrete (The Uni. Of Tokyo)



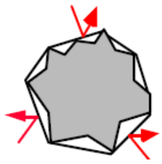
- Concrete which is designed to reduce the adhesion between aggregate and the matrix to an extent that does not adversely affect the mechanical properties of concrete by modifying the aggregate surfaces beforehand, thereby facilitating recovery of original aggregate

Mechanism of Aggregate-recovery Type CRC by Surface Modification

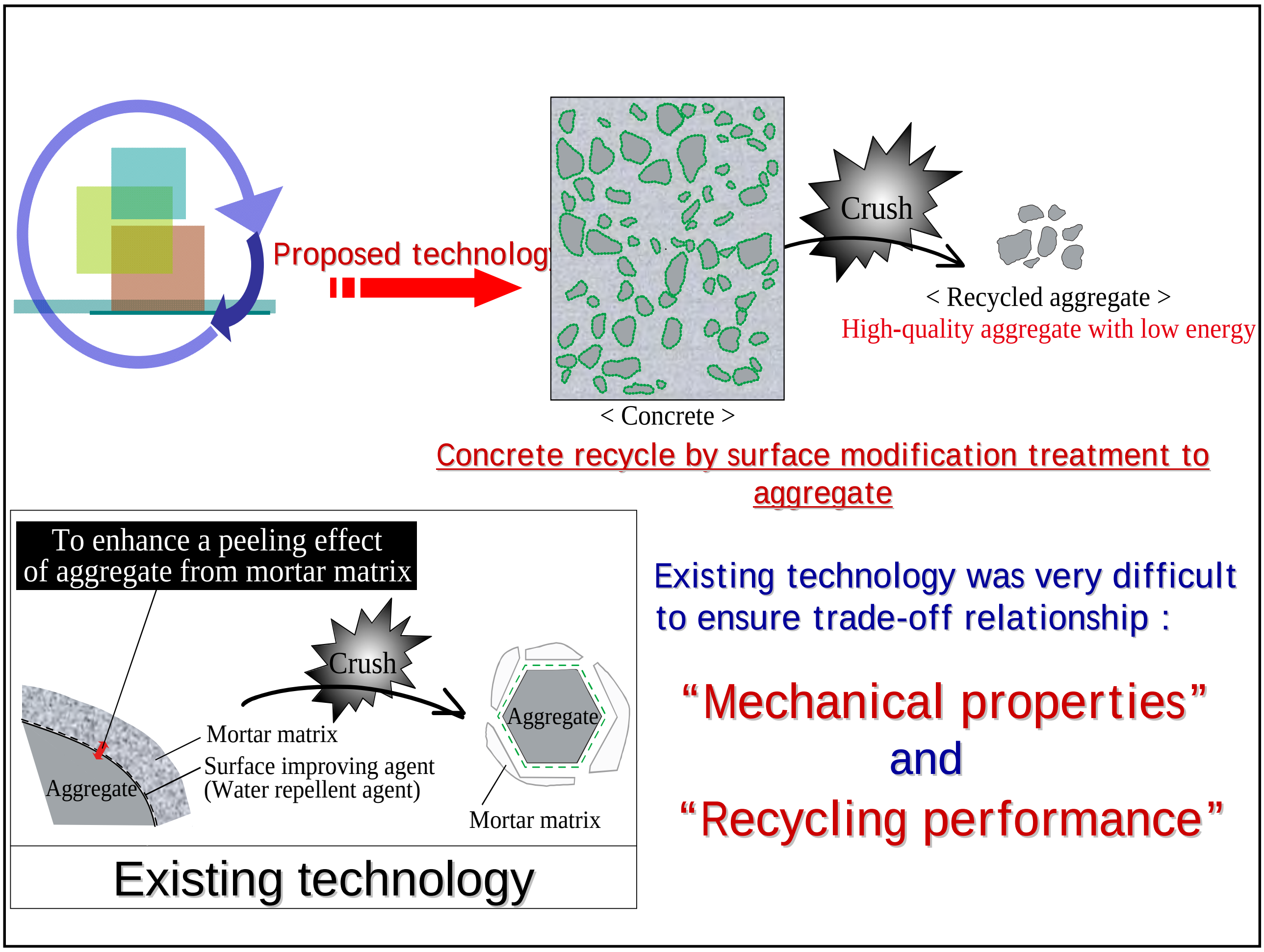
Chemical treatment

The principal ingredient of the coating agent is mineral oil. The agent hydrolyzes in alkali conditions of fresh concrete, forming acidic matter and indissoluble amalgam on the surface of the aggregate. The surface coating results in decreased amounts of cement hydrate, and leads to decreased adhesive strength between aggregate and paste matrix, allowing easy recovery of the original aggregate.

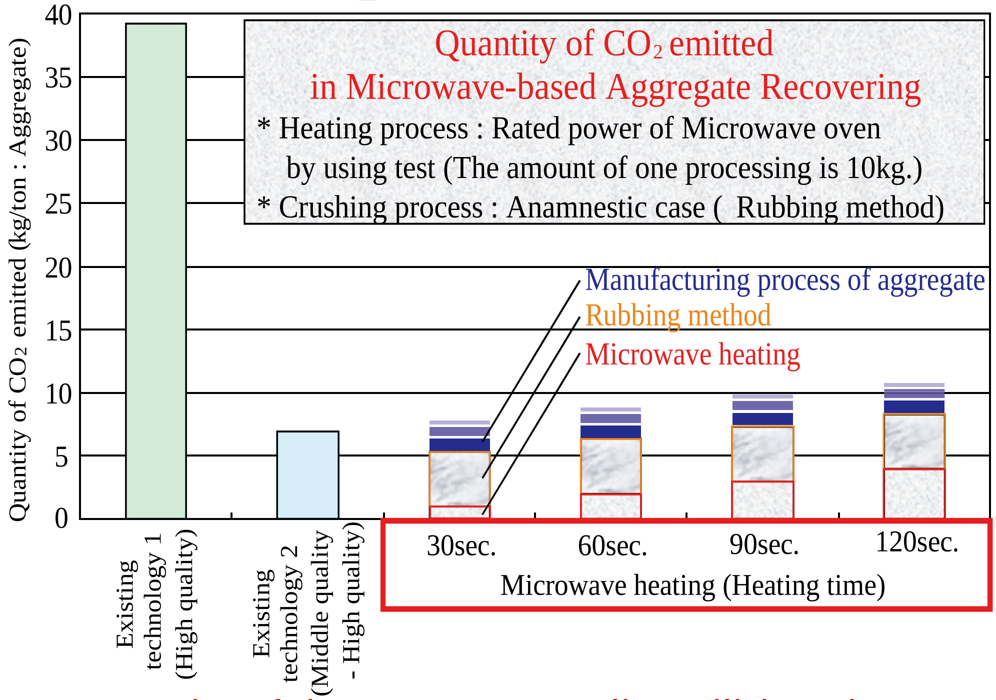
Physical treatment



The coating agent is a water-soluble synthetic resin emulsion, which is applied in process of abrasion, and which is chemically stable in fresh concrete. The uneven surfaces of virgin aggregate become smoother, the shape of the aggregate being roughly maintained. This has the effect of decreasing adhesive strength between aggregate and paste matrix.


Proposed technolog
Crush
< Recycled aggregate >
High-quality aggregate with low energy
< Concrete >
Concrete recycle by surface modification treatment to aggregate
To enhance a peeling effect of aggregate from mortar matrix
Crush
Mortar matrix
Surface improving agent (Water repellent agent)
Aggregate
Aggregate
Mortar matrix
Existing technology
Existing technology was very difficult to ensure trade-off relationship :
“Mechanical properties”
and
“Recycling performance”

Emission of CO_2 during Aggregate Recycling

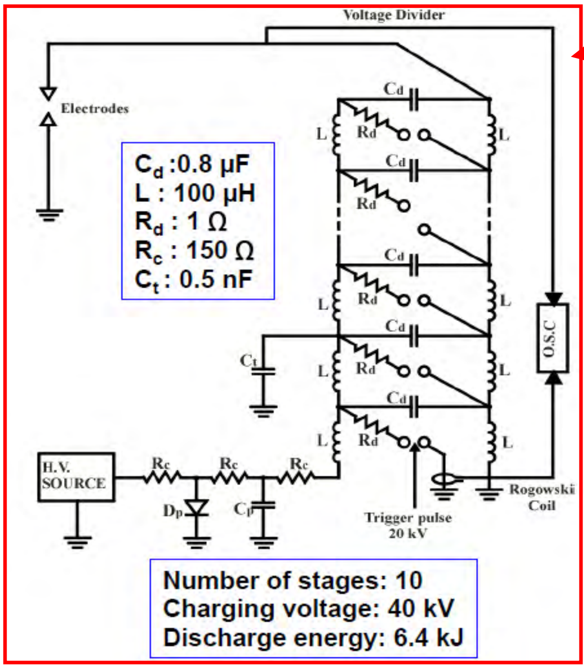


Energy consumption of the aggregate recycling utilizing microwave heating is small compared to existing technologies.

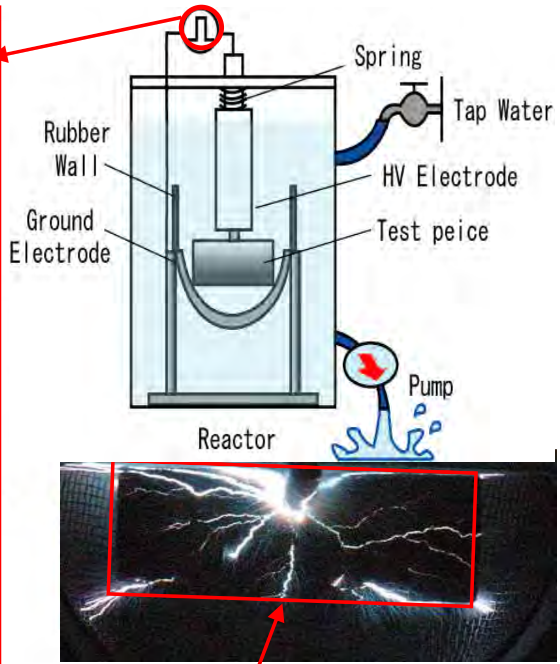
Recovery of Aggregate from Concrete Waste by Electric Pulsed Power Technology

(Kumamoto University: M. Shigeishi,
T. Namihira, M. Ohtsu, and H. Akiyama)

Pulsed Power Method

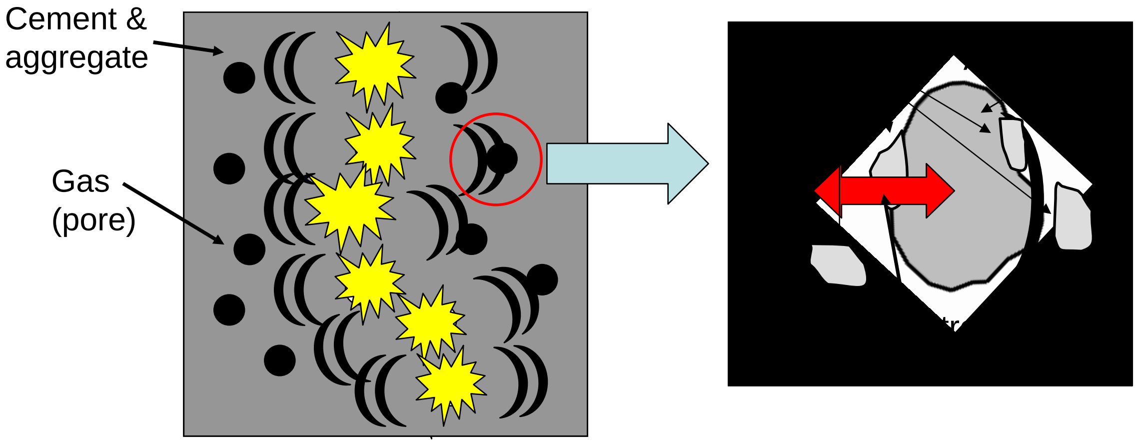


Marx Generator



Concrete

Fracture of Concrete by EPP

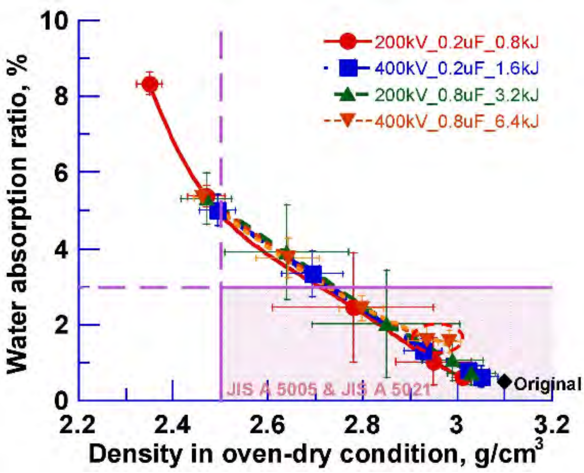


The dielectric breakdown of gas occurs in concrete by the pulsed electric discharge at first. Ionized gas forms plasma and explosive volumetric change tears concrete matrix.

The shock wave is also generated at the same time. The shock wave generates the tensile stress at the boundary and mortar is separated from aggregate.

Controllable Fracture

- 20 shots
- 60 shots
- 100 shots



Concrete can be demolished under the controlled fracture by frequency of discharge and energy of discharge per once.

Environmental Benefit

- **For processing of 1000 kg of concrete waste;**

	Rubbing method with pre-heating	Pulsed Power method
Energy Consumption	**29 kWh/t (*)**	**17.8 kWh/t (+)**
CO_2 Emission	**11.32 kg-CO_2/t (*)**	**7.24 kg-CO_2/t (+)**

(*) refer to RECOMMENDATION OF ENVIRONMENTAL PERFORMANCE VERIFICATION FOR CONCRETE STRUCTURES (DRAFT), JSCE, 2006.

(+) estimated from experimental results of processing of 4 kg of concrete.

Green Building Design and Practices to Foster Recycling (CSI)

- Sustainability in initial design (durable flexible designs, off-site prefabrication, and deconstruction design)
- Optimum use of input materials in design (reuse, recycling, building energy efficiency)
- On-site waste management plans (maximize the potential for materials reuse and recycling and minimize negative environmental and health effects)

These aspects should be reasonably incorporated into green building rating systems. At present, not enough.

Concluding Remarks
(To be cont'd)

- Concrete should be repeatedly recycled with less energy.
- More efficient recycling technologies should be developed.
- Recycling should be of high quality from the user's point of view.

Concluding Remarks (Cont'd)

- The reasonable regulations and design/green-rating systems should be established to promote concrete recycling.
- Concrete recycling will become one of the most important elements for construction sustainability

Acknowledgment

I would like to thank Dr. Noguchi, The University of Tokyo, and Dr. Shigeyoshi and Prof. Ohtsu, Kumamoto University, for providing their PPT information on concrete recycling.