

Lifecycle Perspective of Technologies and Properties of Recycled Aggregate Concrete in Japan

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Content

- **Introduction**
- **History of Measures on Recycling**
 - Political Measures
 - Standardization
- **History of Recycling Technology**
 - Recycling technologies for existing structures
 - Completely Recyclable Concrete
- **Conclusions**

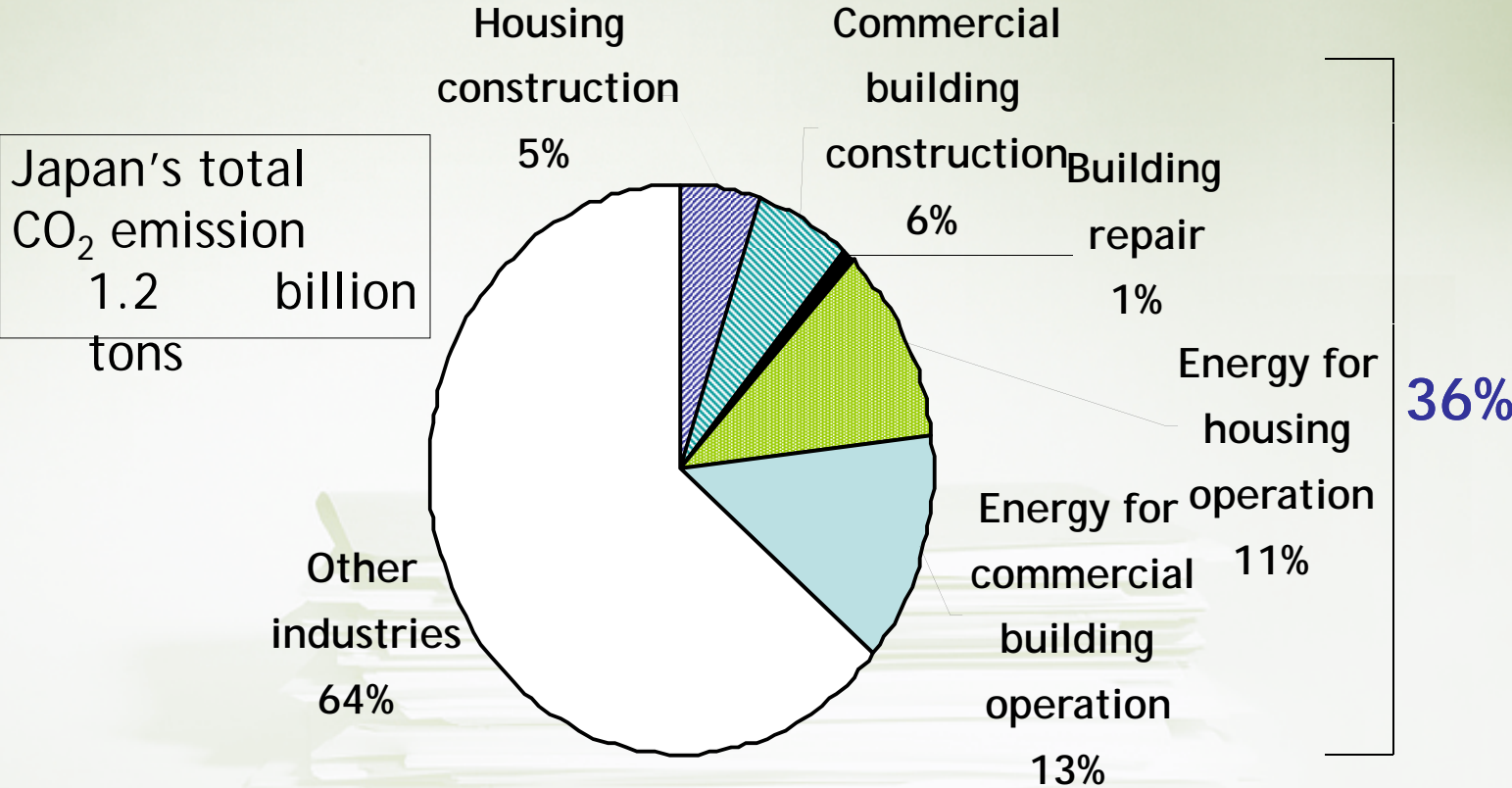
Environmental Problems in Concrete Industries

- Global warming
- Resource depletion
- Waste disposal



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Building Related CO₂ Emission



CO₂ Emission from Concrete Industries

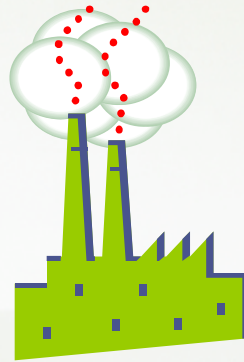


Portland cement: 1 ton

CO₂: 0.75 ton

Decarbonation of limestone (60 %)

Fossil fuel combustion (30 %)



Concrete: 1 m³

CO₂: 0.35 - 0.45 ton

Cement production (0.25 ton)

Others (0.1 - 0.2 ton)



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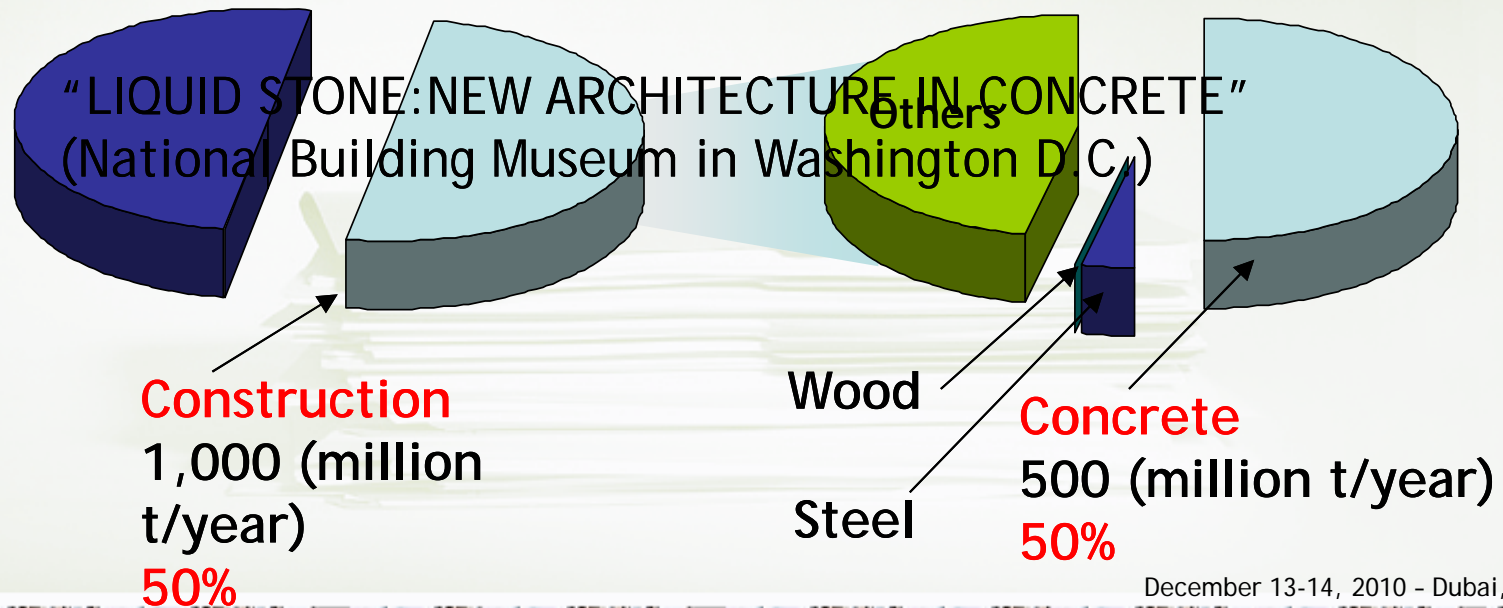
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Resource Input into Construction Industries

Total

Construction

CONCRETE is the second most widely consumed substances on Earth, after water !
Total: 2,000 (million t/year) Total: 1,000 (million t/year)

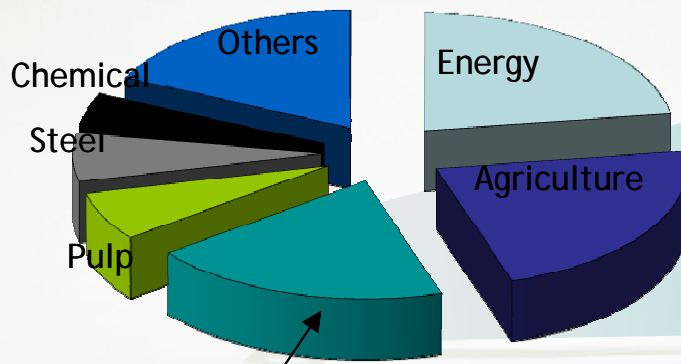


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Waste Output from Construction Industries

Industrial Waste

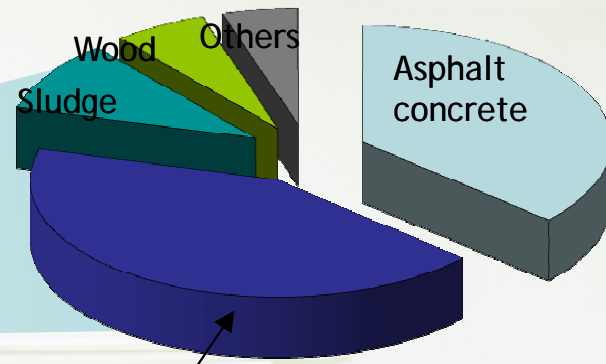
Total: 406 (million t/year)



Construction
79 (million t/year)
17%

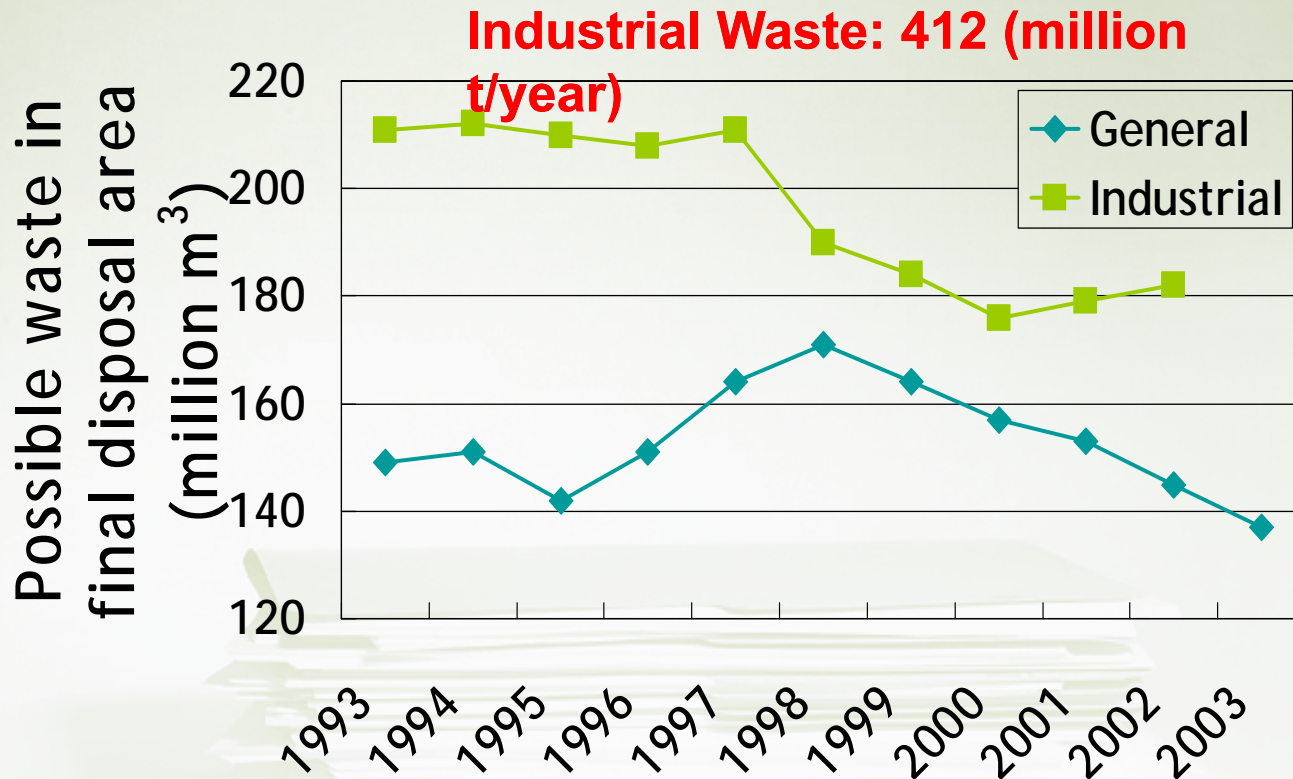
Construction Waste

Total: 79 (million t/year)

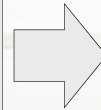


Concrete
35 (million t/year)
42%

Final Disposal Sites for Waste



Scarcity of residual capacity of final disposal areas

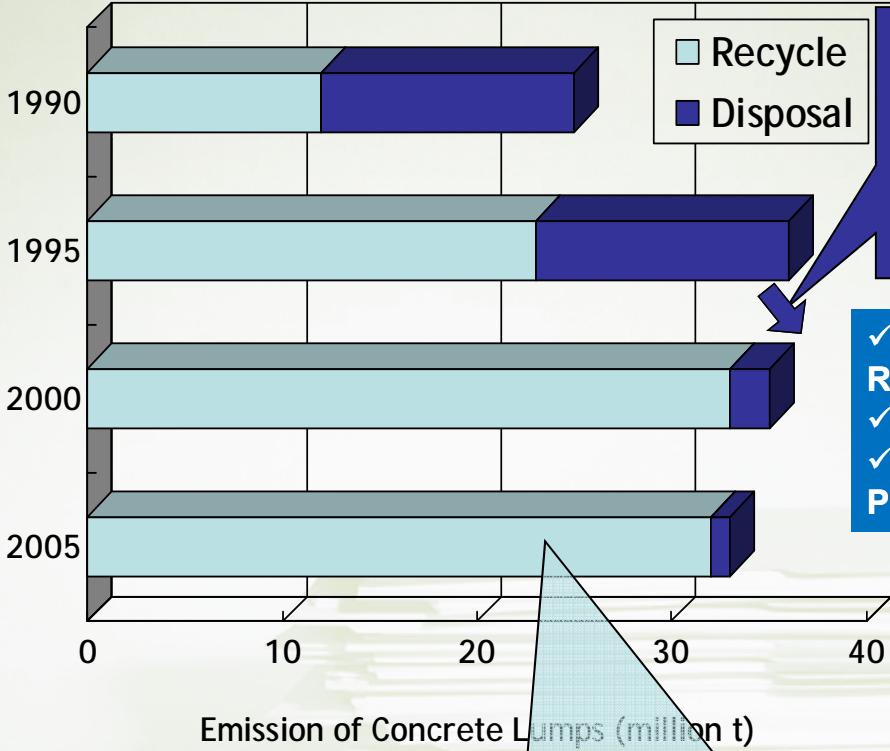


Resource-recycling society

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Recycling Ratio of Concrete



Ministry of Construction
✓ Action Plan for Construction By-products '94
✓ Promotion Plan for Construction Waste Recycling '97

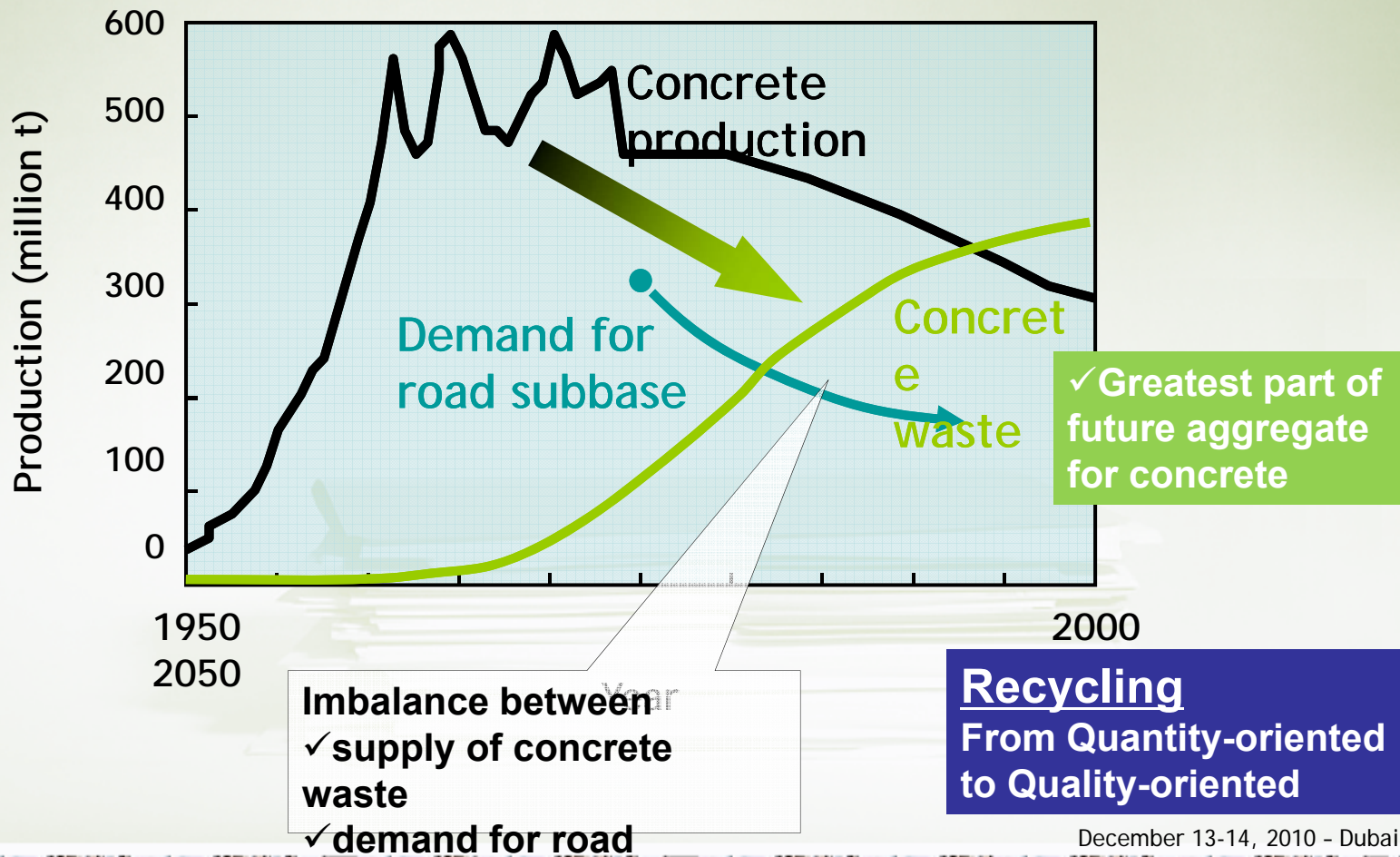
✓ Basic Law for Establishing a Recycling-based Society
✓ Construction Material Recycling Act
✓ Law on Promoting Green Purchasing

✓ For road subbase
✓ For mechanical stabilization underground



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Predicted Amount of Future Concrete Waste



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Standardization of Recycled Aggregate

1977 Building Contractors Society

"Draft standard for the use of recycled aggregate and recycled concrete"

1994 Ministry of Construction

"Provisional quality standard for reuse of"

1999 Building Center of Japan

"Accreditation criteria of recycled aggregate concrete"

2000 Ministry of International Trade and Industry

"TR A0006 (Low quality recycled aggregate concrete)"

2005-2007 Japan Industrial Standards Committee

"JIS A 5021, 5022 and 5023 (Recycled aggregate for concrete, Recycled Concrete)"

Quality requirements

- ✓ Density: **higher**
- ✓ Water absorption: **lower**

Specified Values of Recycled Aggregate in JIS

	Coarse aggregate		Fine aggregate	
	Density (g/cm ³)	Absorption (%)	Density (g/cm ³)	Absorption (%)
JIS A5021 (Class H)	2.5 or more	3.0 or less	2.5 or more	3.5 or less
JIS A5022 (Class M)	2.3 or more	5.0 or less	2.2 or more	7.0 or less
JIS A5023 (Class L)	-	7.0 or less	-	13.0 or less

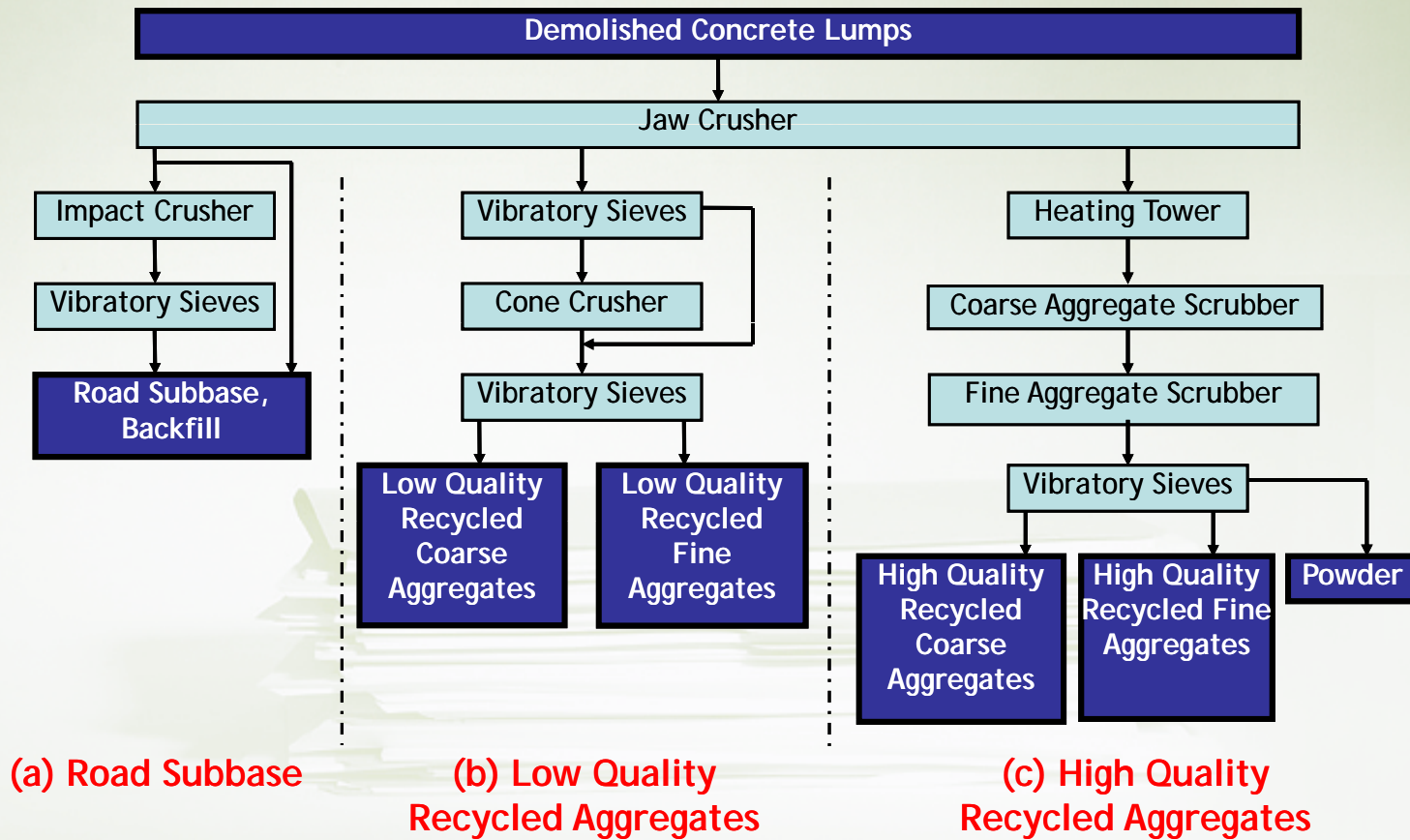
Applications of Recycled Aggregate

	Scope of application
Class - H	<u>No limitations</u> are put on the type and segment for concrete and structures with a nominal strength of 45MPa or less <u>JIS A 5308 (Ready-mixed concrete)</u> allowing to use Class-H RA for normal strength concrete
Class - M	<u>Members not subjected to drying or freezing-and-thawing action</u> , such as piles, underground beam, and concrete filled in steel tubes
Class - L	<u>Backfill concrete, blinding concrete, and leveling concrete</u>

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Classification of Recycling Technologies

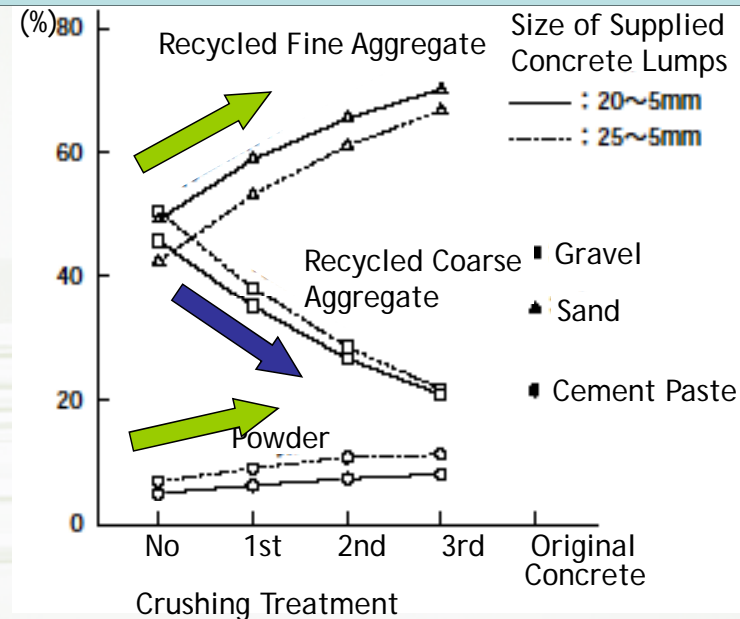
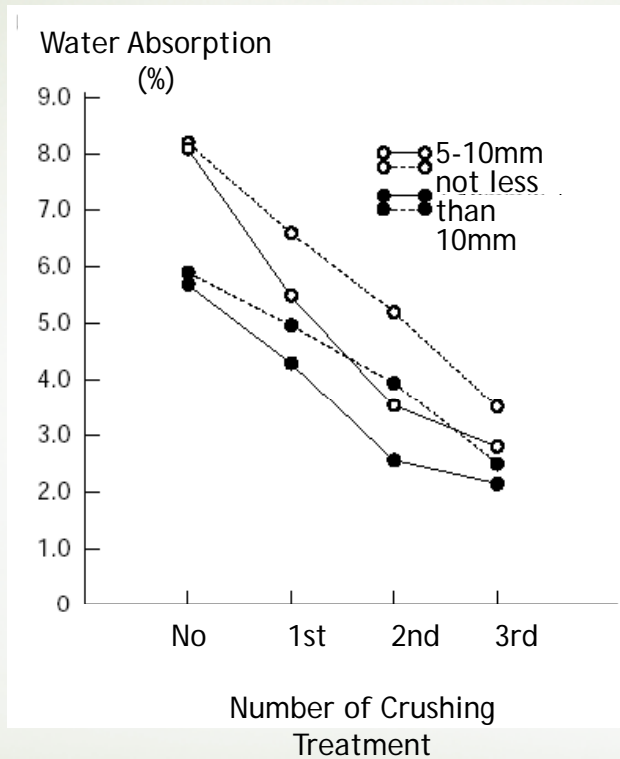


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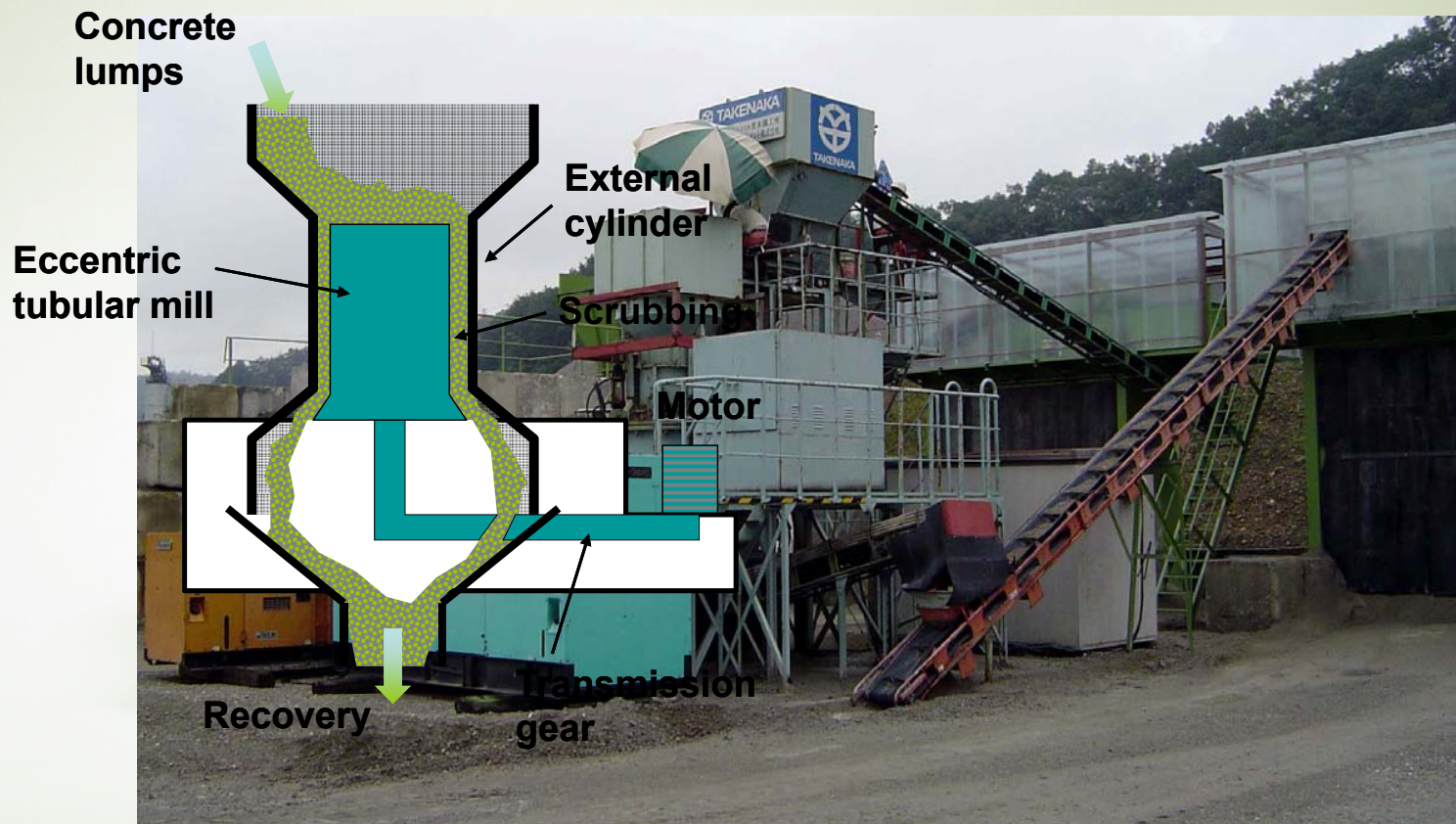
Problems in Conventional Technology to Produce High-quality Recycled Aggregate

Repeated crushing

- Recovery percentage decreasing
- Fines generation increasing



Mechanical Scrubbing Equipment for High-quality Recycled Aggregate



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Application of Mechanical Scrubbing 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 m³
(Total concrete volume: 40,000 m³)

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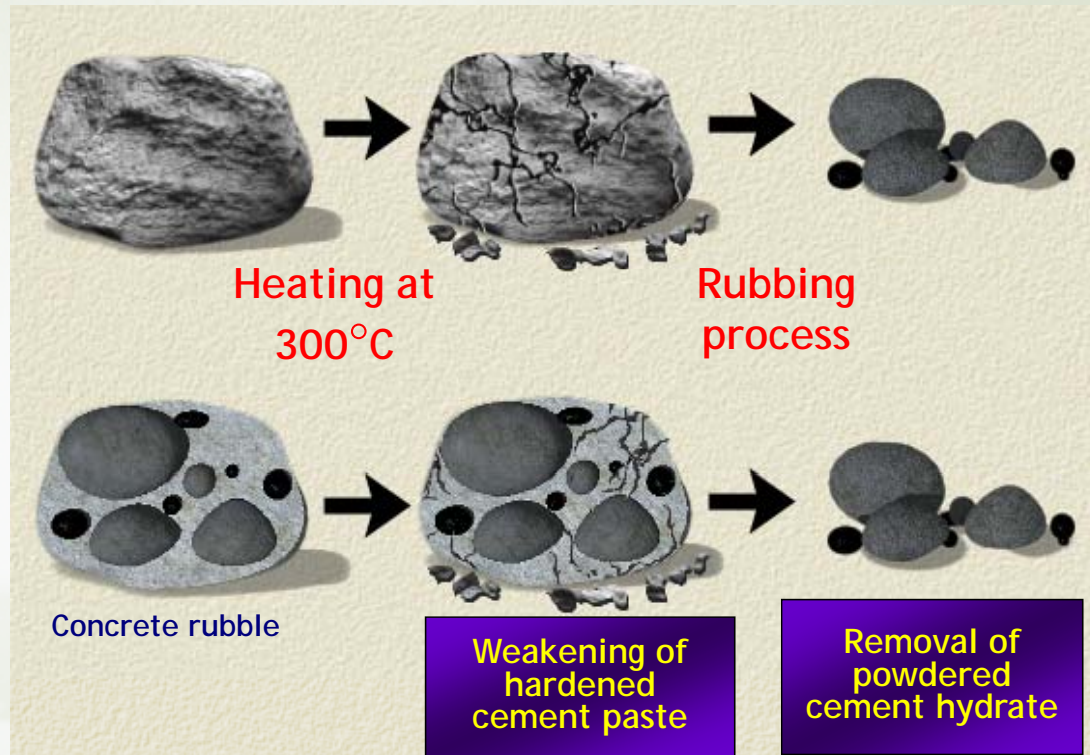
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Heated Scrubbing Equipment for High-quality Recycled Aggregate



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Mechanism of Heated Scrubbing



Application of Heated Scrubbing Method



Total volume of recycled
concrete: 25,000m³



Storehouse :

- Upper structure : SRC 6-storey
- Basement structure : RC 1-storey
- Building area : 12,800m²
- Total floor area : 62,100m²



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Problems in Current Recycling

Forward-
process
productio
n



- **Nosotropic technology**

- No recycling-conscious design applied
- Materials diffused into a wide range of industries
- Finally disposed
 - Quality degradation, Unstable supply, Unstable price, Unstable distribution, Increasing environmental impact

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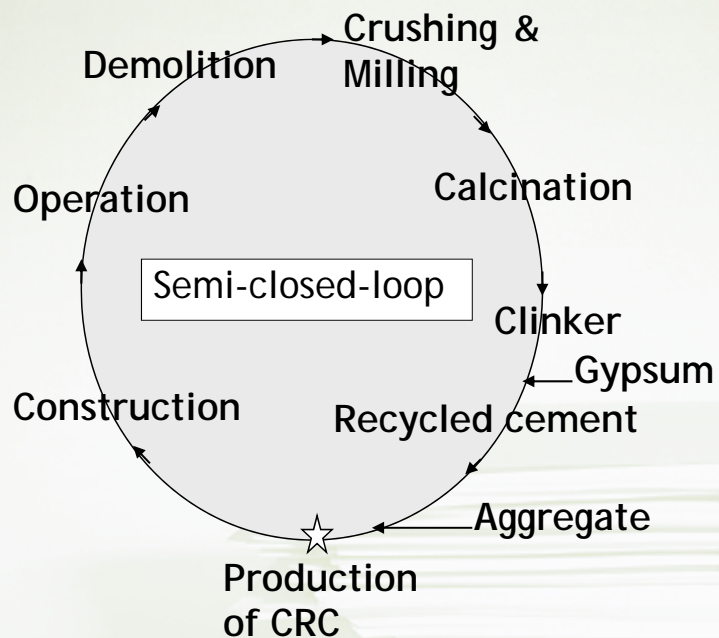
Concept of Completely Recyclable Concrete



- Proactive Technology

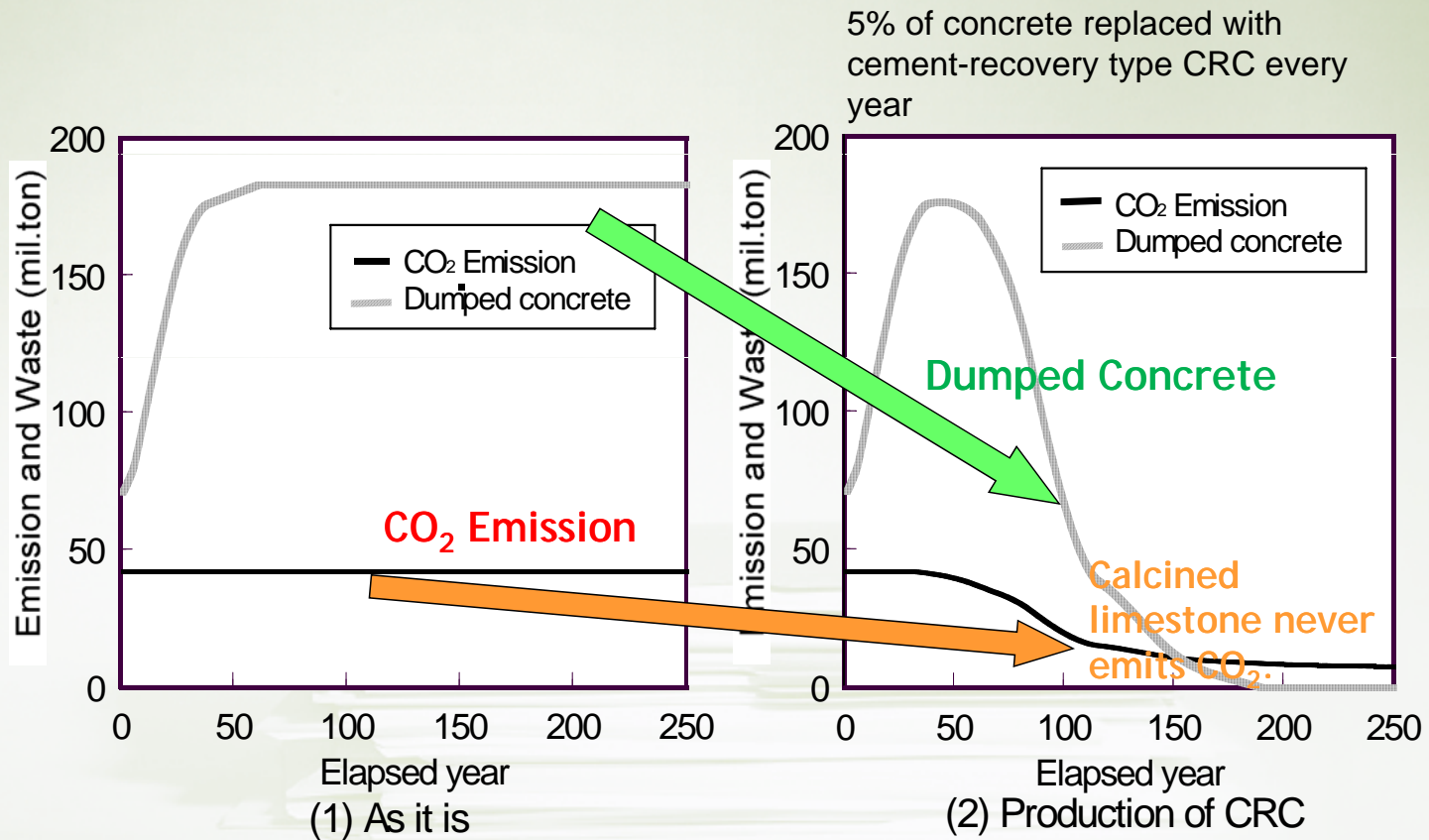
- Upstream (inverse) processes incorporated
- Components of concrete completely recycled into concrete
- Resource conserved
- Resource circulated in a closed system

Cement-recovery Type Completely Recyclable Concrete



- Concrete whose 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

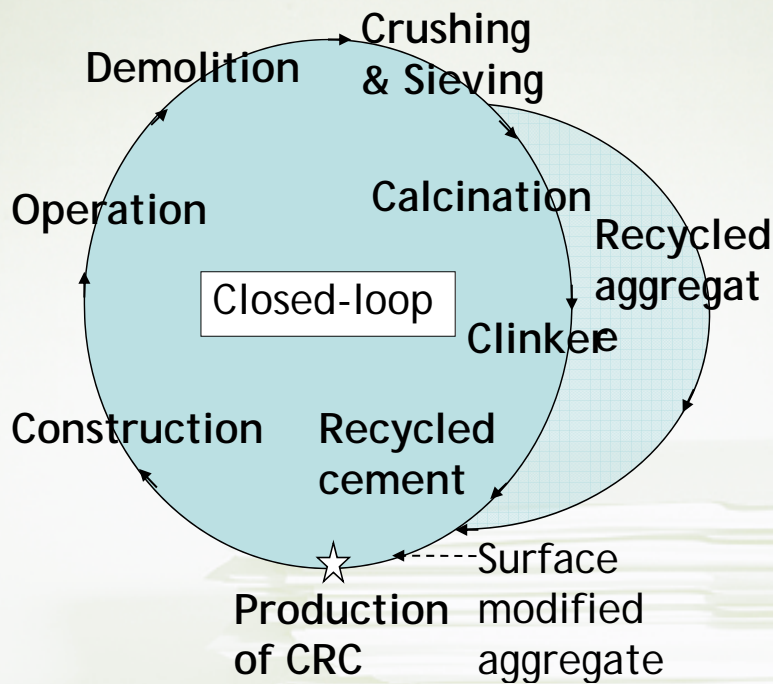
Changes in CO₂ Emissions and Dumped Concrete



Application of Cement Recovery Type CRC for "Eco-Pole"

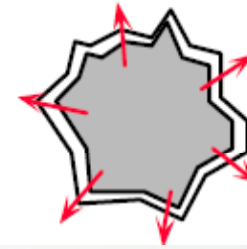


Aggregate-recovery Type CRC



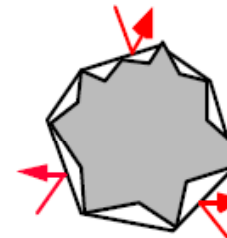
Chemical treatment

Inhibition of cement hydrate formation



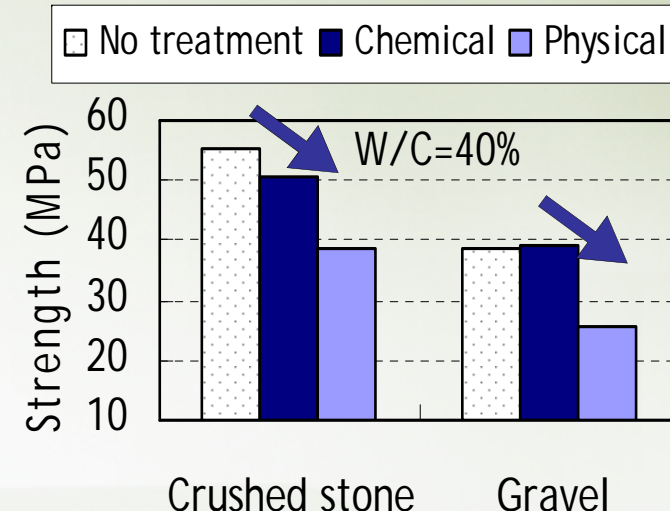
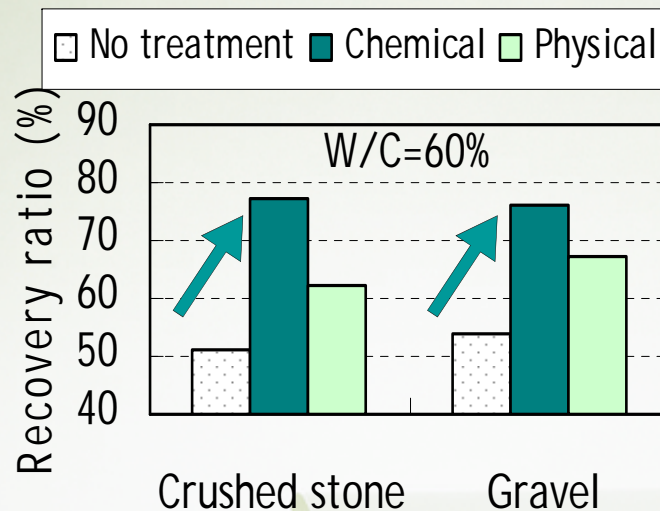
Physical treatment

Reduction of mechanical friction



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Recovery and Mechanical Property of Aggregate-recovery Type CRC

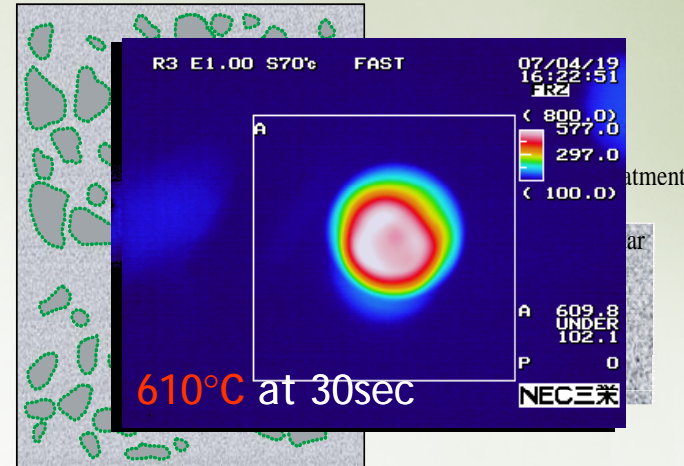


- **Trade-off relationship remained**
 - Aggregate recoverability **increased**
 - Mechanical properties of concrete **decreased**

Advanced Aggregate Recovery-type CRC

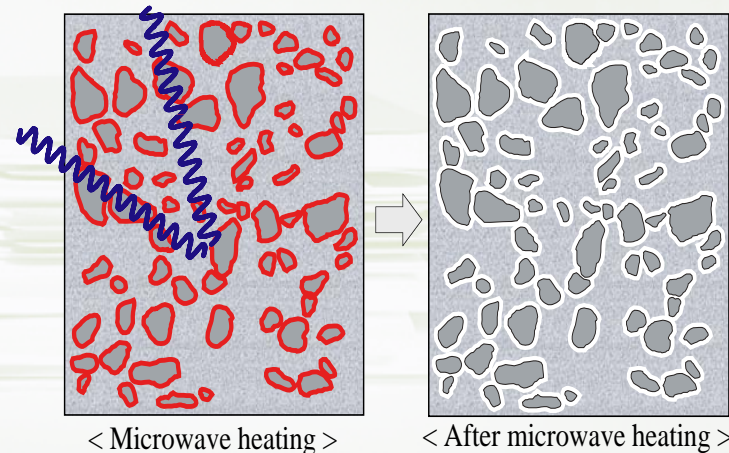
- Concrete strength enhancement

- Aggregate surface modification
- Increase bonding force between coarse aggregate and mortar
 - Fine SCM: pozzolanic reaction
 - Mineral powder: mechanical friction



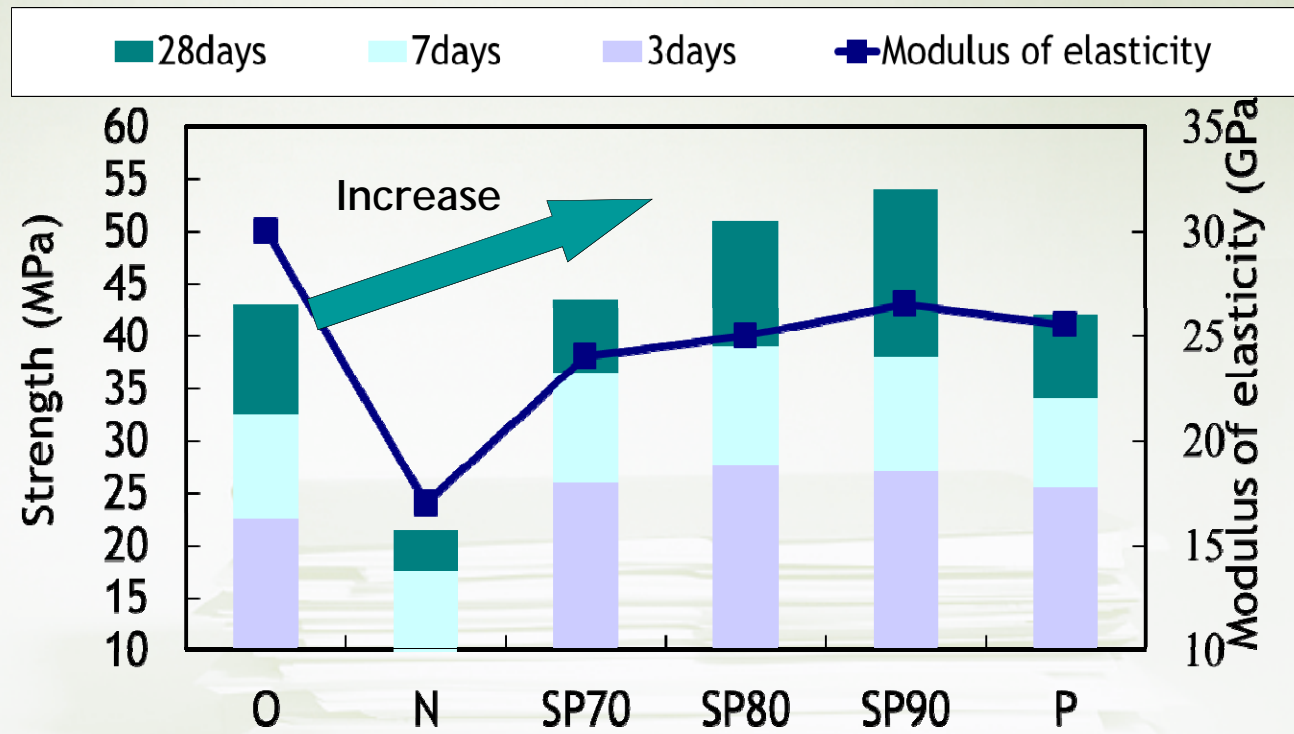
- Aggregate recoverability

- Inclusion of dielectric material
- Selective heating by microwave
- Weakening aggregate surface
- Recovery of aggregate with low energy

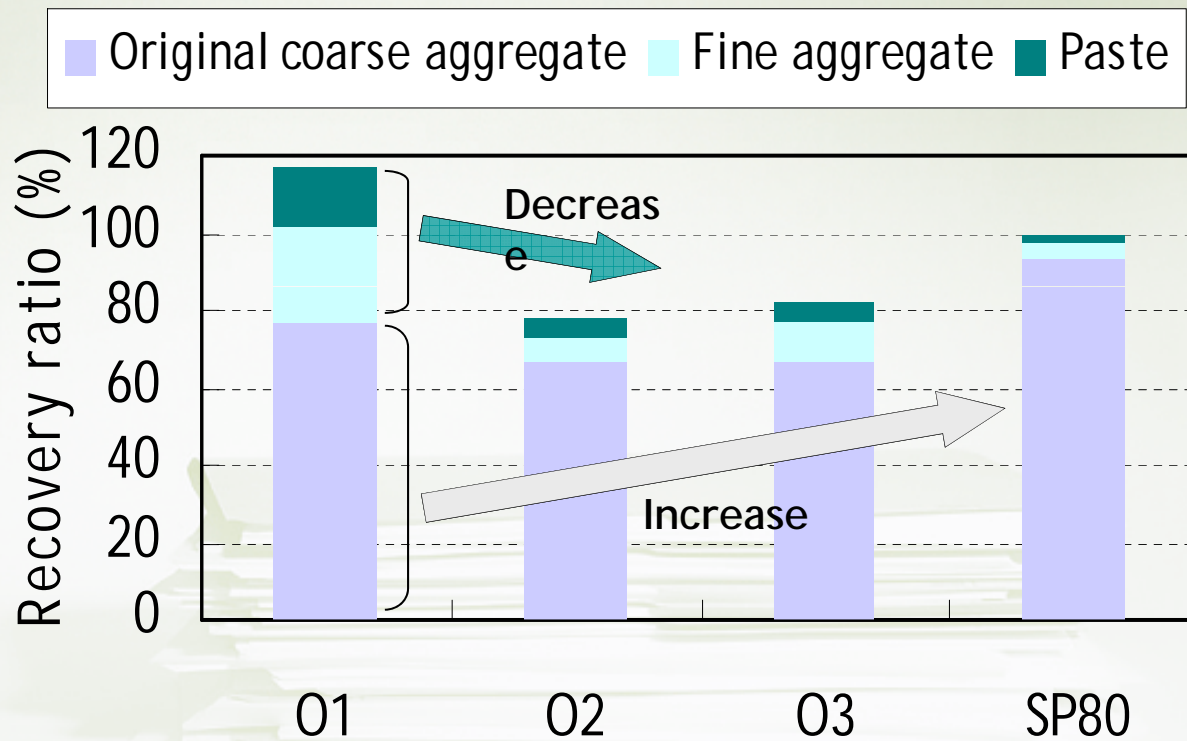


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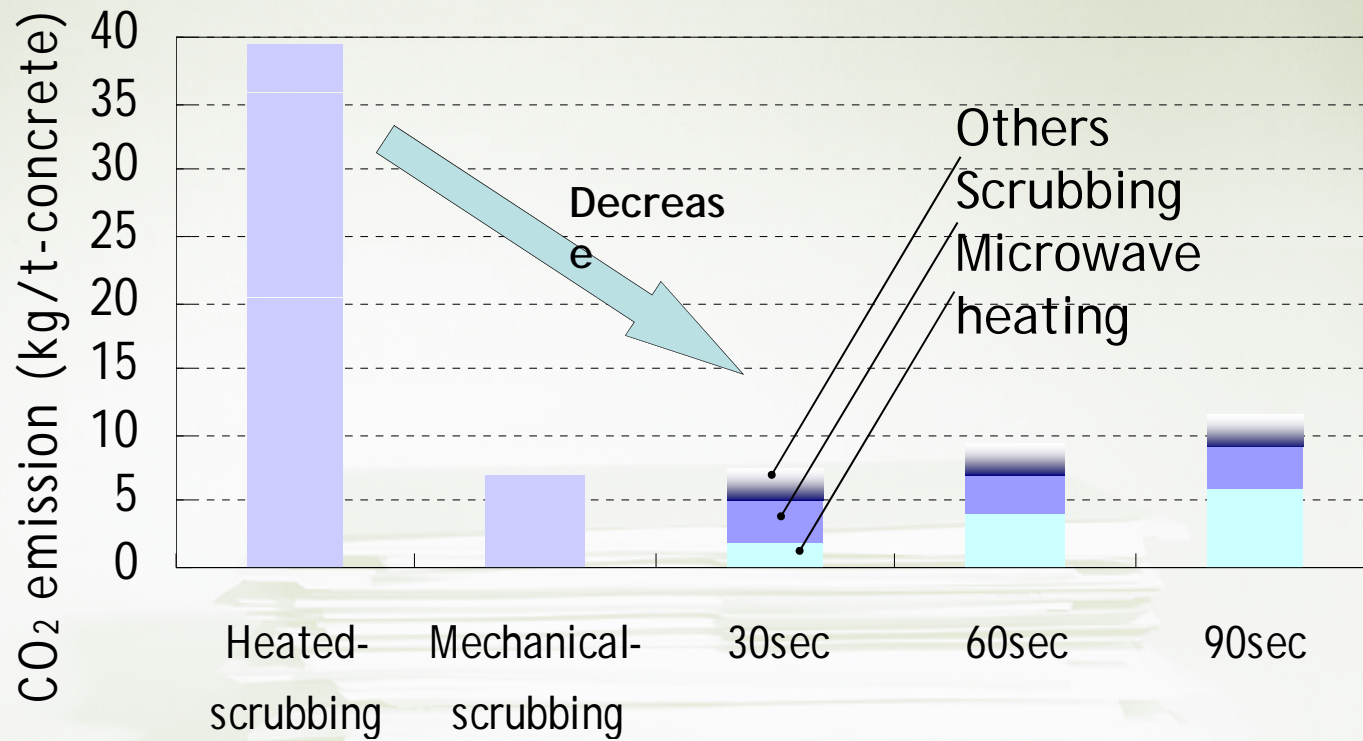
Mechanical Properties in Advanced Aggregate Recovery-type CRC



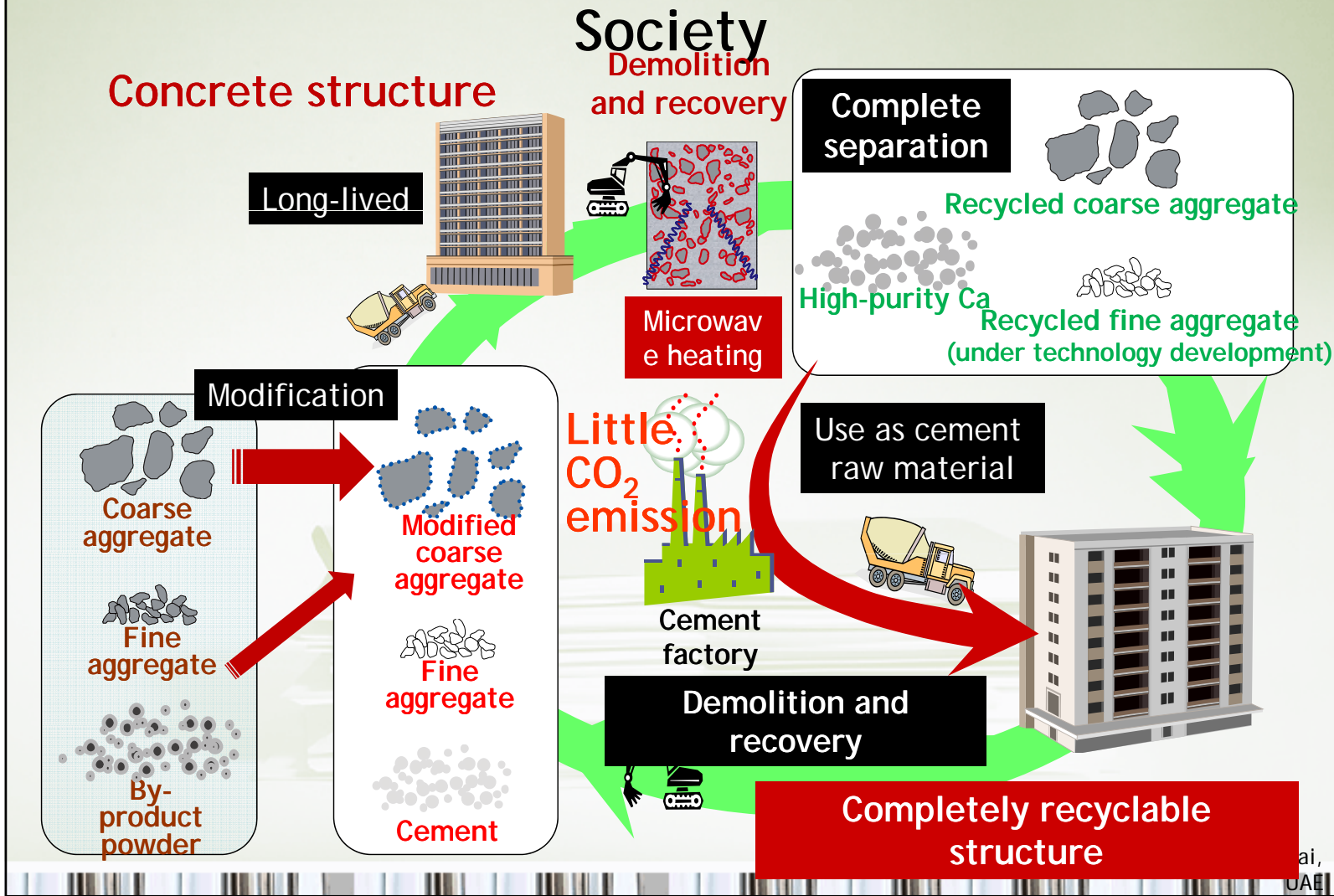
Aggregate Recovery Ratio in Advanced Aggregate Recovery-type CRC



CO₂ Emission in Concrete Recycling Process



Sustainable Resource Recycling Concrete



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Conclusion

- Toward **sustainable resource-recycling society**
 - Concrete recycling in **closed system**
 - Current method: Some technical and social problems
 - Adoption of technology enhancing **resource conservability** at the stage of design
 - **Completely recyclable concrete**
 - New technology with **aggregate surface modification** and **microwave radiation**
 - Overcoming inherent conflicting properties in concrete recycling
 - Achieving high performance of concrete
 - Energy saving and **small CO₂ emission** in concrete recycling
 - **Fully recovering** original aggregate
 - Generating cement raw materials which **never emit CO₂**

