State-of-the-art Recycling Technologies for Building Materials in Japan

Part 1 Cement & Concrete

Takafumi NOGUCHI

CONTENTS

1. State of Resource Recycling in Concrete
2. Environmental Aspect of Cement Production
3. Environmental Aspect of Aggregate Production
4. Environmental Aspect of Concrete Production
5. Concrete Recycling

1. STATE OF RESOURCE RECYCLING IN CONCRETE

Resource input into concrete industries

<table>
<thead>
<tr>
<th>Total</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total: 2,000 (million t/year)</td>
<td></td>
</tr>
<tr>
<td>Construction 1,000 (million t/year) 50%</td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td></td>
</tr>
<tr>
<td>Concrete 500 (million t/year) 50%</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>

Waste from concrete industries

<table>
<thead>
<tr>
<th>Industrial Waste</th>
<th>Construction Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total: 412 (million t/year)</td>
<td></td>
</tr>
<tr>
<td>Construction 75 (million t/year) 18%</td>
<td></td>
</tr>
<tr>
<td>Concrete 32 (million t/year) 41%</td>
<td></td>
</tr>
<tr>
<td>Total: 75 (million t/year)</td>
<td></td>
</tr>
</tbody>
</table>

STATE OF RESOURCE RECYCLING IN CONCRETE (3)

Final disposal sites for industrial waste

Possible waste in final disposal area (million ton)

- General
- Industrial
**COCO\textsubscript{2} emission from concrete industries**

Portland cement: 1 ton

\[ \text{CO}_2: 0.75 \text{ ton} \]

Decarbonation of limestone (60 %)

Fossil fuel combustion (30 %)

Concrete: 1 m\(^3\)

\[ \text{CO}_2: 0.35 - 0.45 \text{ ton} \]

Cement production (0.25 ton)

Others (0.1 – 0.2 ton)

**Typical Life Phases of Concrete Product / Concrete Structure**

- **Raw material acquisition**
  - mining of aggregates
  - mining of stones for cement production
  - energy sources and energy production
  - water supply

- **Realization**
  - production of concrete and concrete elements
  - design
  - construction

- **Utilization**
  - HaI
  - maintenance
  - repair
  - renovation

- **Life end**
  - demolition
  - reuse
  - recycling
  - disposal
  - landfill

**Life Cycle Phases of Concrete Structure**

- **Conceptual Design**
- **Technology Concept**
- **Detailed Design**
- **Construction**
- **Demolition**
- **Recycling**
- **Use**
- **Maintenance**
- **Repair**
- **Renovation**

**Potential Chance to Influence Degree of Environmental impact**

- Waste disposal, landfill

**Material Flows of Concrete**

- **Aggregate for Concrete**
  - Limestone: 101.448
  - Cement: 92.52
  - Water: 97.98

- **Aggregate for Asphalt Concrete**
  - Limestone: 75.86
  - Aggregate: 74.8
  - Water: 64.88

- **Recycled Crushed Stone**
  - Aggregate: 33.53

- **Concrete Lumps**
  - Recycled: 10.948

**Discharge of Concrete < 10% of Input**

- **Granite for Concrete**
  - 75.86

**Environmental importance of concrete industries**

- 10 billion ton of concrete produced annually worldwide
  - 25 % of natural resources into concrete-related industries
  - 7 - 10 % of global, manmade CO\textsubscript{2} from concrete-related industries

- Resource recycling system without extra CO\textsubscript{2} emission needed
  - Natural resource conservation
  - Prevention of global warming
ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (1)

- Raw Materials and Energy for 1 ton of Normal Portland Cement

<table>
<thead>
<tr>
<th>Raw Materials (kg)</th>
<th>Energy (Coal Equivalent, kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>1,093</td>
</tr>
<tr>
<td>Clay</td>
<td>203</td>
</tr>
<tr>
<td>Silica Stone</td>
<td>76</td>
</tr>
<tr>
<td>Gypsum</td>
<td>99</td>
</tr>
</tbody>
</table>

Highest level of energy efficiency thanks to the energy conservation measures taken during the period between 1970 and 1990.

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (2)

- Fuel for Cement
  - Coal: 85%
    - from China, Australia, Russia, and Indonesia
  - Petroleum coke: 10%
  - Industrial waste: 3%
  - Heavy oil: 1%

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (3)

- Waste and Byproducts Utilized by Cement Industry

<table>
<thead>
<tr>
<th>Type</th>
<th>Uses</th>
<th>Amount (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast Furnace Slag</td>
<td>Raw Material, Additive</td>
<td>12,162,000</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>Raw Material, Additive</td>
<td>5,145,000</td>
</tr>
<tr>
<td>Byproduct Gypsum</td>
<td>Additive</td>
<td>2,643,000</td>
</tr>
<tr>
<td>Sludge</td>
<td>Raw Material</td>
<td>1,906,000</td>
</tr>
<tr>
<td>Nonferrous Slag</td>
<td>Raw Material</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Steelmaking Slag</td>
<td>Raw Material</td>
<td>795,000</td>
</tr>
<tr>
<td>Ash Dust</td>
<td>Raw Material, Fuel</td>
<td>734,000</td>
</tr>
<tr>
<td>Coal Waste</td>
<td>Raw Material, Fuel</td>
<td>675,000</td>
</tr>
<tr>
<td>Casting Sand</td>
<td>Raw Material</td>
<td>477,000</td>
</tr>
</tbody>
</table>

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (4)

- Waste and Byproducts Utilized by Cement Industry

<table>
<thead>
<tr>
<th>Type</th>
<th>Uses</th>
<th>Amount (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrap Tire</td>
<td>Fuel</td>
<td>323,000</td>
</tr>
<tr>
<td>Reclaimed Oil</td>
<td>Fuel</td>
<td>239,000</td>
</tr>
<tr>
<td>Oil Waste</td>
<td>Fuel</td>
<td>120,000</td>
</tr>
<tr>
<td>White Clay Waste</td>
<td>Raw Material, Fuel</td>
<td>106,000</td>
</tr>
<tr>
<td>Plastic Waste</td>
<td>Fuel</td>
<td>102,000</td>
</tr>
<tr>
<td>Others</td>
<td>-</td>
<td>433,000</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>27,359,000</td>
</tr>
</tbody>
</table>

Recently: Sewage sludge, Incineration ash from municipal solid waste.
ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (5)

- Use of sewage sludge and incineration ash from municipal solid waste
  - the high temperature safely decomposes hazardous materials including dioxins
  - no new waste is generated
  - requires no additional incineration facilities
  - extends the service lives of final disposal sites

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (6)

- Utilization of Blast Furnace Slag and Fly Ash

  ![](chart)
  - Blast Furnace Slag (24,518,000t)
  - Fly Ash (6,919,000t)

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (7)

- Changes in cement production by type

  ![](chart)
  - Utilization of Blast Furnace Slag and Fly Ash

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (8)

- The increasing trend of blended cement production because of
  - Expected increase in the number of thermal power plants producing coal ash
  - Expected increase of crude steel production affected by the construction rush in economically buoyant China
  - Law on Promoting Green Purchasing in 2001 in which blast-furnace slag cement and fly ash cement were designated as green procurement products

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (9)

- “Ecocement” recently developed in Japan
  - made using incineration ash from municipal solid waste and sewage sludge
  - Dioxins completely decomposed at a high temperature without being resynthesized
    - rapidly cooled to below 200°C in a cooling tower
    - captured in a bag filter and an active coke-packed tower
  - Heavy metals contained in incinerated ash
    - recovered/concentrated
    - delivered to nonferrous metal factories for recycling

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (10)

- Chemical compositions of portland cement and incineration ash (%)

<table>
<thead>
<tr>
<th></th>
<th>CaO</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>SO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>62 - 65</td>
<td>20 - 25</td>
<td>3 - 5</td>
<td>3 - 4</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Incin. Ash</td>
<td>12 - 31</td>
<td>23 - 46</td>
<td>13 - 29</td>
<td>4 - 7</td>
<td>1 - 4</td>
</tr>
</tbody>
</table>

- Chemical compositions of portland cement and incineration ash (%)

<table>
<thead>
<tr>
<th></th>
<th>CaO</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>SO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>47 - 55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>45 - 78</td>
<td>10 - 26</td>
<td>3 - 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica sand</td>
<td>77 - 96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron source</td>
<td></td>
<td></td>
<td>40 - 90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gypsum</td>
<td>26 - 41</td>
<td></td>
<td></td>
<td></td>
<td>37 - 59</td>
</tr>
</tbody>
</table>
ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (11)

- **Raw materials combination**
  - Ecocement replaces limestone and clay with incineration ash

**Silica sand**

**Limestone**

**Clay**

**Others**

**Ecocement tank**

**Normal Portland Cement**

**Limestone**

**Clay**

**Others**

**Sewage sludge**

**Incineration Ash**

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (12)

- **Chemical Composition of Ecocement**

<table>
<thead>
<tr>
<th></th>
<th>Ig. Loss</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>SO₃</th>
<th>R₂O</th>
<th>Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Type EC</td>
<td>1.1</td>
<td>17.0</td>
<td>8.0</td>
<td>4.4</td>
<td>61.0</td>
<td>3.7</td>
<td>0.26</td>
<td>0.04</td>
</tr>
<tr>
<td>Rapid Hardening Type EC</td>
<td>0.8</td>
<td>15.3</td>
<td>10.0</td>
<td>2.5</td>
<td>57.3</td>
<td>9.2</td>
<td>0.50</td>
<td>0.90</td>
</tr>
<tr>
<td>NPC</td>
<td>1.5</td>
<td>21.2</td>
<td>5.2</td>
<td>2.8</td>
<td>64.2</td>
<td>2.0</td>
<td>0.63</td>
<td>0.01</td>
</tr>
</tbody>
</table>

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (13)

- **Physical Properties and Quality of Ecocement**

<table>
<thead>
<tr>
<th></th>
<th>Density g/cm³</th>
<th>Spec. Surf. cm²/g</th>
<th>Initial Set h-min</th>
<th>Final Set h-min</th>
<th>Comp. Str., N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3h</td>
</tr>
<tr>
<td>N-EC</td>
<td>3.17</td>
<td>4250</td>
<td>2-35</td>
<td>4-25</td>
<td>-</td>
</tr>
<tr>
<td>RH-EC</td>
<td>3.13</td>
<td>5300</td>
<td>0-30</td>
<td>0-50</td>
<td>10</td>
</tr>
<tr>
<td>NPC</td>
<td>3.16</td>
<td>3350</td>
<td>2-22</td>
<td>3-10</td>
<td>-</td>
</tr>
</tbody>
</table>

W/C=0.50, S/C=3d

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (14)

- **“Ecocement” recently developed in Japan**

**Ecocement**

**Bug Filter**

**Gypsum**

**Clinker**

**Clinker Cooler**

**Rotary Kiln**

**Tank for Homogenization**

**Tank**

**Fly ash tank**

**Heavy metal refining process**

**Administrative office & bottom ash storage facilities**

**Lot area; 16,700m²**

ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (17)

- **Ichihara Ecocement Corporation (Rotary kiln)**

**Ecocement tank**

**Rotary kiln**

**Bag filter**

**Heavy metal refining process**

**Flue gas cooling tower**

**Bag filter**

**Heavy metal refining process**

**Administrative office & bottom ash storage facilities**

**Lot area; 16,700m²**

**Ecocement tank**

**Panoramic view of Ichihara Ecocement plant**
ENVIRONMENTAL ASPECT OF CEMENT PRODUCTION (18)
 Applications of Ecocement to various concrete products

ENVIRONMENTAL ASPECT OF AGGREGATE PRODUCTION

ENVIRONMENTAL ASPECT OF AGGREGATE PRODUCTION (1)
 Changes in aggregate production

ENVIRONMENTAL ASPECT OF AGGREGATE PRODUCTION (2)
 Changes in aggregate production
 – Absolute ban on collection of sea gravel and sea sand being implemented
 – Regulations on crushed stone collection being tightened from the aspect of natural landscape protection
 – Ready-mixed concrete plants in Tokyo receiving not only crushed limestone from western Japan but also river sand from China
   • Wide-area transfer of aggregate over regions and borders

ENVIRONMENTAL ASPECT OF AGGREGATE PRODUCTION (3)
 Aggregate, 70% by volume of concrete, anticipated as a recipient of waste and byproducts from other industries

ENVIRONMENTAL ASPECT OF CONCRETE PRODUCTION (1)
 Changes in concrete production
 – Decrease due to reductions in investment in new construction of buildings and civil structures
ENVIRONMENTAL ASPECT OF CONCRETE PRODUCTION (2)

- Waste and byproducts generated from RMC plants
  - Returned concrete from 1m³ of RMC: 0.009 m³
  - Sludge cake resulting from 1m³ of RMC: 5.88 kg

CONCRETE RECYCLING

CONCRETE RECYCLING (1)

- Recycle ratio of demolished concrete

CONCRETE RECYCLING (2)

- Discrepancy between
  - the amount of concrete lumps generated and
  - the amount of concrete lumps removed from construction sites

- Reason
  - In-situ recycling as road bottoming and backfill materials
  - Inclusion in dirt and soil to be disposed of at landfill sites

CONCRETE RECYCLING (3)

- Recycle in Apartment Complex

CONCRETE RECYCLING (4)

- Changes in concrete production
  - Decrease due to reductions in investment in new construction of buildings and civil structures
**CONCRETE RECYCLING (5)**

- Reuse of concrete lumps as aggregate for concrete
  - Enormous amount of concrete lumps generated
  - Demand for concrete lumps for roads decreasing
    - New road construction gradually decreasing
    - Method of repairing existing roads shifting from repavement to “mill and overlay”

**CONCRETE RECYCLING (6)**

- Recycling process of demolished concrete lumps

- Demolished Concrete Lumps
  - Jaw Crusher
  - Impact Crusher
  - Vibratory Sieves

- Road Subbase, Backfill
  - Cone Crusher
  - Vibratory Sieves

- Low Quality Recycled Coarse Aggregate
  - Heating Tower
  - Scrubber
  - Fine Aggregate Scrubber

- Low Quality Recycled Fine Aggregate
  - High Quality Recycled Coarse Aggregate
  - High Quality Recycled Fine Aggregate

(a) Road Subbase
(b) Low Quality Recycled Aggregate
(c) High Quality Recycled Aggregate

**CONCRETE RECYCLING (7)**

- Uses for concrete lumps determined by the qualities of the recycled material
  - Density
  - Water absorption depending on
    - percentage of cement paste contained within
    - adhering to the surfaces of original aggregate
  - depending on production method

**CONCRETE RECYCLING (8)**

- Today’s conventional concrete recycling
  - Roadbed material
  - Aggregate for concrete excluding structural use

**CONCRETE RECYCLING (9)**

- High quality recycled aggregate
  - Repeating crushing
    - Recovery percentage decreasing
    - Fines generation increasing
  - Carrying out high level treatment such as heating and grinding in order to minimize the adhering cement paste

**CONCRETE RECYCLING (10)**

- Quality and recovery percentage of recycled aggregate
Efficient equipment for producing high quality recycled aggregate (1)

- Heated scrubbing

Heated scrubbing

Recycled structural aggregates & by-product powder

Quality of Recycled Aggregates

An Example of Application

Acoustic Laboratory
- Place: Koto-ku, Tokyo
- Structure: Reinforced concrete structure, three levels above the ground
- Building area: 363.41m²
- Total floor area: 667.75m²

Structure A:
- Place: Chofu city, Tokyo
- Year of completion: 1960

Structure B:
- Place: Kitakyushu city
- Year of completion: 1988
### An Example of Application

**Concrete Recycle Plant**

- Recycled Aggregate Plant

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### Efficient equipment for producing high quality recycled aggregate (2)

- **Mechanical scrubbing-1 (eccentric tubular type)**

  - **Eccentric Rotor Device**
  - **2nd Sieve**
  - **1st Sieve**

---

#### Mechanical scrubbing-1 (eccentric tubular type)

- **Crushed Concrete Lump**
- **Eccentric Rotor Device**
- **Product**
- **After the rotor device**

---

#### 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)
Efficient equipment for producing high quality recycled aggregate (3)
- Mechanical scrubbing-2 (screw type)

Efficient equipment for producing high quality recycled aggregate (4)
- Wet scrubbing and gravity classification

Political Aspects
- Former Prime Minister, Junichiro Koizumi
- The Manifesto of the Democratic Party of Japan (opposition party)
  - “From Concrete to People, People, People”

Japan industrial standards for recycled aggregate
- JIS A 5021 (March 2005)
  - Recycled aggregate for concrete - Class H
- JIS A 5022 (March 2006)
  - Recycled concrete using recycled aggregate Class M
- JIS A 5023 (March 2007)
  - Recycled concrete using recycled aggregate Class L
**Specified values of recycled aggregate in JIS**

<table>
<thead>
<tr>
<th>Material passing 75 μm sieve (%)</th>
<th>Class - H</th>
<th>Class - M</th>
<th>Class - L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water absorption (%)</td>
<td>not more than 13.0</td>
<td>not more than 7.0</td>
<td>not more than 1.0</td>
</tr>
<tr>
<td>Oven-dry density (g/cm³)</td>
<td>not less than 10.0</td>
<td>not less than 2.5</td>
<td>--</td>
</tr>
</tbody>
</table>

**Application of recycled aggregate**

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

**Limits of Amount of Deleterious Substances for RA-H**

<table>
<thead>
<tr>
<th>Category</th>
<th>Deleterious substances</th>
<th>Limits (mass%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Tile, Brick, Ceramics, Asphalt concrete</td>
<td>2.0</td>
</tr>
<tr>
<td>B</td>
<td>Glass</td>
<td>0.5</td>
</tr>
<tr>
<td>C</td>
<td>Plaster</td>
<td>0.1</td>
</tr>
<tr>
<td>D</td>
<td>Inorganic substances other than plaster</td>
<td>0.5</td>
</tr>
<tr>
<td>E</td>
<td>Plastics</td>
<td>0.5</td>
</tr>
<tr>
<td>F</td>
<td>Wood, Paper, Asphalt</td>
<td>0.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Large amount of by-product powders**

- Resulting from production of high quality recycled aggregate
- Possible uses
  - Addition to road bottoming
  - Cement material

**CO₂-uptake**

- Re-absorption of 30% of the total CO₂ emission from cement production

**Recyclable concrete like steel and aluminum**

**Production process of concrete**

- Conventional downstream approach
  - Cost reduction
  - Efficiency in production
- New production system
  - Incorporating upstream (inverse) processes in consideration of recyclability
Conventional Material Flow of Concrete Recycling

Production of Structural Concrete
Loop 1 (Target: Structural Concrete)
Loop 2 (Target: Non-structural Concrete)
Loop 3 (Target: Sub-base Materials)

Completely recyclable concrete (CRC) – Cement recovery type CRC
Concrete whose materials are entirely usable after hardening as materials of cement or recycled aggregate, since all the binders, additions, and aggregate are made of cement or materials for cement.

Completely recyclable concrete (CRC) – Cement recovery type CRC
Precast Concrete Foundations Made from CRC in Kita-kyusyu

Completely recyclable concrete (CRC) – Cement recovery type CRC
Perfect Recycle House in Kita-kyusyu

Completely recyclable concrete (CRC) – Aggregate recovery type CRC
Concrete in which the aggregate surfaces are modified without excessively reducing the mechanical properties of the concrete, in order to reduce the bond between aggregate and the matrix, thereby permitting easy recovery of original aggregate.

Completely recyclable concrete (CRC) – Aggregate recovery type CRC
The principal ingredient of the coating agent is mineral oil. The agent hydrolyzes in alkaline conditions of fresh concrete, forming scale matter and indissoluble amalgams on the surface of the aggregate. The surface coating results in decreased amounts of cement hydrates, and leads to decreased adhesive strength between aggregate and paste matrix, allowing easy recovery of the original aggregate.

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.
Resource flow in real society

One flow affects another flow.
Total impact in the whole society should be reduced.

CONCRETE RECYCLING (42)

- Material flow should be further optimized in cooperation with other industries as part of the resource recycling of society as a whole, reflecting back on the abundant resource consumption of concrete and the long service lives of buildings and civil structures.

Future system for concrete recycling

- Recycling technology should fulfill the following principles.
  - Recycling should be of high quality.
    - Recycled products are not marketable unless they are of a quality that satisfies users.
  - Recycling should be repeatable.
    - If a recycled product has to be dumped in a landfill after use with no chance of recycling, then the recycling is no better than producing waste of the following generation.

Assignment

- Select one building material in one country except concrete in Japan.
- Investigate the annual amount of production, recycle and final disposal of the selected material in the country.
- Investigate the recycling technologies of the selected material and the uses of the recycled material.

You can download the today’s presentation file at http://bme.arch.t.u-tokyo.ac.jp/class_info/index.html