ACI Concrete Sustainability Forum
Part 3 of 3
ACI Fall 2009 Convention
Nov. 7, New Orleans, LA

ACI Web Sessions
The audio for this web session will begin momentarily and will play in its entirety along with the slides.
However, if you wish to skip to the next speaker, use the scroll bar at left to locate the speaker’s first slide (indicated by the icon in the bottom right corner of slides 9, 50, 87, 128, and 151). Click on the thumbnail for the slide to begin the audio for that portion of the presentation.

ACI Web Sessions
ACI is bringing you this Web Session in keeping with its motto of “Advancing Concrete Knowledge.” The ideas expressed, however, are those of the speakers and do not necessarily reflect the views of ACI or its committees.

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ACI Web Sessions

ACI Web Sessions are recorded at ACI Conventions and other concrete industry events. Each week, a new set of presentations can be viewed on ACI’s website free of charge.

After one week, the presentations will be temporarily archived on the ACI website or made part of ACI’s Online CEU Program, depending on their content.

Spring 2010 ACI Seminars

- ACI/PCA Reinforced Concrete Design
- ACI/PCA Simplified Design of Reinforced Concrete
- Buildings of Moderate Size and Height
- Troubleshooting Concrete Construction
- Concrete Repair Basics
- Concrete Slabs-on-Ground
- ACI/PCA Simplified Design of Concrete Buildings of Moderate Size and Height

Locations and Dates:
- San Francisco, CA
  Apr. 20-21
- Orlando, FL
  May 11-12
- New Brunswick, NJ
  May 25-26
- Cincinnati, OH
  June 8-9

Locations and Dates:
- Chicago, IL
  Mar. 25
- Washington D.C.
- Los Angeles, CA
  May 6
- Atlanta, GA
  May 20

Locations and Dates:
- San Diego, CA
  Apr. 1
- Jacksonville, FL
  May 5
- Washington, D.C.
  Apr. 8
- Portland, OR
  Apr. 15
- Atlanta, GA
  May 20
- Dallas, TX
  June 10
- Philadelphia, PA
  Apr. 14
- Indianapolis, IN
  Apr. 21
- San Antonio, TX
  May 19
- Miami, FL
  Apr. 6
- Milwaukee, WI
  Apr. 13
- Baltimore, MD
  Apr. 20
- Phoenix, AZ
  May 4
- Nashville, TN
  May 18

Locations and Dates:
- Seattle, WA
  Apr. 1
- Charlotte, NC
  Apr. 15
- Boston, MA
  Apr. 29

ACI Conventions

ACI conventions provide a forum for networking, learning the latest in concrete technology and practices, renewing old friendships, and making new ones. At each of ACI’s two annual conventions, technical and educational committees meet to develop the standards, reports, and other documents necessary to keep abreast of the ever-changing world of concrete technology.

With over 1,300 delegates attending each convention, attendees are afforded ample opportunity to meet and talk individually with some of the most prominent persons in the field of concrete technology. For more information about ACI conventions, visit www.aciconvention.org.
ACI Web Sessions

This ACI Web Session includes five speakers presenting at the ACI Concrete Sustainability Forum held in New Orleans, LA, on Nov. 7, 2009, just prior to the ACI Fall 2009 Convention.

Additional presentations will be made available in future ACI Web Sessions.

Please enjoy the presentations.

Peter Richner is a member of the board of Empa and Head of the Department of Civil and Mechanical Engineering in Switzerland. He is also the current President of Rilem (International Union of Laboratories and Experts in Construction Materials, Systems and Structures) and a member of the Board of ENBRI (European Network of Building Research Institutes). He is teaching Construction Materials at ETH (Swiss Federal Institute of Technology) Zurich. He graduated in Chemistry from ETH Zurich and earned an Executive Master of Business Administration from the University of St. Gall.
Sustainability and the Built Environment – A closer Look from a European Perspective

Dr. Peter Richner, Empa
ACI 2009 Fall Convention
7 November 2009

When is construction sustainable?

Vitruvius (1. century BC.)

- Firmitas: durable, solid
When is construction sustainable?

Vitruvius (1. century BC.)

- Firmitas  durable, solid
- Utilitas  useful

Gotthard Tunnel

- Start of Construction:  September 1872
- Start of Operation:  June 1882
- Cost:  66.7 Mio
- Total of Passengers:  ~ 700 Mio (2008: 10.9 Mio)
When is construction sustainable?

Vitruvius (1. century BC.)

- **Firmitas**: durable, solid
- **Utilitas**: useful
- **Venustas**: beautiful
Challenges

- Climate Change
Global CO₂-Concentration

<table>
<thead>
<tr>
<th>Year</th>
<th>CO₂ Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>290 ppm</td>
</tr>
<tr>
<td>1965</td>
<td>310 ppm</td>
</tr>
<tr>
<td>1975</td>
<td>330 ppm</td>
</tr>
<tr>
<td>1985</td>
<td>350 ppm</td>
</tr>
<tr>
<td>1995</td>
<td>370 ppm</td>
</tr>
<tr>
<td>2005</td>
<td>390 ppm</td>
</tr>
<tr>
<td>2015</td>
<td>410 ppm</td>
</tr>
</tbody>
</table>

Pre-industrial level: ≈ 275 ppm

Source: Dr. Pieter Tans, NOAA/ESRL (http://www.esrl.noaa.gov/gmd/ccgg/trends/)

**Challenges**

- Climate Change
- Energy supply

**Energy Consumption in Switzerland 2006**

- Industry, Services, SME's: 24%
- Agriculture: 24%
- Mobility: 28%
- Buildings: 48%

69% of the Total are Fossil Fuels.
Share of Final Energy Consumption for Buildings [%]

<table>
<thead>
<tr>
<th></th>
<th>Industry, Commercial Buildings</th>
<th>Residential Buildings</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>11</td>
<td>26</td>
<td>37</td>
</tr>
<tr>
<td>Great Britain</td>
<td>11</td>
<td>28</td>
<td>39</td>
</tr>
<tr>
<td>Spain</td>
<td>8</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>Switzerland</td>
<td>19</td>
<td>29</td>
<td>48</td>
</tr>
<tr>
<td>USA</td>
<td>18</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>World</td>
<td>7</td>
<td>16</td>
<td>24</td>
</tr>
</tbody>
</table>


Challenges

- Climate Change
- Energy Supply
- Preservation and Renewal of the Built Environment

The Built Environment in Switzerland

- Current replacement value: > 2'000 bn $ (GDP ~ 120 bn $)
- Year growth ratio of living rooms: ~ 1%
- Floor space per person: ~ + 0.5 m² and year
- Yearly demolition rate: ~ 0.05%
- Expected life span: > 1000 years
**Age of Residential Buildings in Northern Europe**

- **United Kingdom:** < 1919
- **Sweden:** < 1919
- **Switzerland:** 1919-1945
- **Austria:** 1946-1970
- **France:** 1946-1970
- **Germany:** 1971-1990
- **Finland:** 1990
- **Netherlands:** 1990


**Bridges of the Swiss Highway Network**

- 25% of all bridges are older than 40 years

Source: ASTRA

**Challenges**

- Climate Change
- Energy Supply
- Preservation and Renewal of the Built Environment

"More of the same" is not enough!
Construction in the 21. Century

- Sustainable renewal and preservation of the built environment
- Reduction of the energy demand for the construction, operation, maintenance and demolition of the built environment
- Complete abandonment of fossil fuels for heating and cooling of buildings in good architecture and in recognition of the cultural heritage and the wellbeing of our society

Energy Demand of Residential Buildings in Switzerland as Function of the Year of Construction

Energy demand (kWh/m²a) in buildings from different years of construction.
Forum Chriesbach

- Office Building for 220 employees
- No active heating or cooling system

Source: 3-Plan Haustechnik

Residential Buildings as Power Plants?

Source: Erne Holzbau AG, Münchenstein

Plus-Energy House Züst, Grüsch, Switzerland
Energy demand: 15'275 kWh/y
Energy production: 31'557 kWh/y
Balance: +16'282 kWh/y
State-of-the-Art for residential and non-residential buildings

- No fossil fuels needed for the operation
- Energy demand for heating and cooling below 30 kWh/m²
- Positive energy balance over the year achievable
- Energy-efficient buildings offer more comfort and are more economic from a life cycle perspective

Energy Demand of Residential Buildings in Switzerland as Function of the Year of Construction

Goal of a sustainable renewal: 30 - 50 kWh/m²a
**Renewal Strategy for Buildings**

- Up-to-date floor plan
- Reduction of energy demand
- Efficient HVAC
- Renewable energy

Multistory residential building, Zug
Architect: Reto Miloni

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**Renewal Strategy for Buildings**

- Up-to-date floor plan
- Reduction of energy demand
- Efficient HVAC
- Renewable energy

Multistory residential building, Zürich Höngg
Architect: Beat Kämpfen

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**Energy Demand of Residential Buildings in Switzerland as Function of the Year of Construction**

<table>
<thead>
<tr>
<th>Year</th>
<th>1900</th>
<th>1925</th>
<th>1950</th>
<th>1975</th>
<th>2000</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh/m²a</td>
<td>200</td>
<td>150</td>
<td>100</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

Goal of a sustainable renewal: 30 - 50 kWh/m²a
Energy Consumption in Switzerland 2006

Industry, Services, SME’s: 24%
Agriculture: 24%
Mobility: 28%
Buildings: 48%

Quelle: BfE

Impact of the Transformation of Buildings

Industry, Services, SME’s: Agribusiness
Agriculture
Mobility
Buildings

Gain in Efficiency: 245 PJ ≈ 20% of total consumption

Source: BfE

CO₂-Emissions in Switzerland Today

Source: Bafu
Impact of the Transformation of Buildings

-50% CO₂

Energy Demand of Residential Buildings in Switzerland as Function of the Year of Construction

-25% Energy Use
-50% CO₂ Emissions
-50% Dependence on Foreign Countries regarding Energy Supply
Thousands of jobs for decades

Goal of a sustainable renewal: 30 - 50 kWh/m²a
Antoine de Saint-Exupery (1900-1944):

“We do not inherit this world from our forefathers, we borrow it from our children”

Hiroyuki Musha is a manager and head of the Ductal development team at Taisei Technology Center, a leading construction company in Japan. Ductal refers to ultra-high strength fiber reinforced concrete, which has recently been applied to various structures in Japan. Mr. Musha began his career with Taisei in 1986. He has been engaged in Ductal development for more than 10 years and has joined almost all of the Ductal projects in Japan. He holds a Master’s degree in Transportation Engineering from Purdue University.

Environmental Advantage and Applications of Ultra High-Strength Fiber Reinforced Concrete In Japan

Hiroyuki MUSHA
TAISEI CORPORATION
Contents

What is UFC?  >>>  It's a DUCTAL.

An example application and environmental aspects of DUCTAL Bridge

DUCTAL slabs applied to the new runway

Flow test

Flow value

Steel fiber: d=0.2mm, l=15mm
fraction: 157kgf/m³, 2% in vol.
Tensile strength = 2,800 N/mm²
**Definition of UFC**

**Ultra high strength Fiber reinforced Concrete**

**UFC**

**High Strength**
Compressive strength = 200N/mm²

**High Ductility**
With Steel Fiber, No rebar

**High Fluidity**
Self-leveling

**High Durability**
Design life expectancy: 100 years

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**Ductal Application**

- Torisakigawa Bridge
- Akakura Onsen Yukemuri Bridge
- Sakata Mirai Bridge
- Toyota City Gymnasium Footbridge
- Horikishi C-lamp Bridge
- Mikaneike Bridge
- Tahara Footbridge
- Haneda Airport D-runway
- GSE Bridge
- Tokyo Monorail / Showajima
- Renewal of Taisei Technology Center
- Sky corridor in Keio University
- Toyota City Gymnasium Footbridge

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**Ductal Application**

- Ductal Through Bridge
- Yokohama Cathedral
- Tsukiji Market / Tsukiji Fish Market
- Sky corridor in Kashiwa University
- Toyota City Gymnasium Footbridge

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First Example  

Sakata Mirai Bridge

The first Ductal bridge in JAPAN

Girder Height: 1.56 m (at the center of the span)
: 0.55 m (at the end of the span)
H/S ratio is 1/90.

Structural design concept

Ultimate design
Longitudinal post tensioning

Completion of Sakata-Mirai Bridge
Completion in Oct. 2002

Life cycle emissions of CO₂
(Carbon Dioxide)

PC

Ductal

27% reduction
Life cycle emissions of CO₂

- Ductal Application

- 27% reduction

PC

* cement and steel material of piers
* temporary bridge
* steel piles
* sheet piles

CO₂ emissions (t-CO₂)

0 50 100 150 200

- superstructure
- substructure
- temporary structure

CO₂ emissions of superstructure

- Ductal Application

- For 2 days at 90 degree Celsius

- Standard forms reused 300 times

Steam curing

Steel forms

Others (mainly material)

CO₂ emissions (t-CO₂)

0 20 40 60 80 100
**CO₂ emissions of superstructure**

*Case Study: Mass Production of Ductal Precast Blocks*

- **Ductal**
  - Steam curing
  - Steel forms
  - Others (mainly material)

- **PC**
  - Specific forms reused 200 times
  - Standard forms reused 300 times

---

**Life cycle emissions of NOx (Nitrogen Oxide)**

- **Ductal**
  - Super-
  - Sub-
  - Temporary

- **PC**

- 43% reduction

---

**Environmental impact**

- The Ductal Bridge
  - (in case of the Sakata Mirai bridge)

  - CO₂ and NOₓ emissions: reduced in the whole bridge

Because of the steam curing of Ductal, CO₂ emission of the superstructure has increased compared with the conventional PC bridge.

In the case of a mass production of Ductal precast blocks, CO₂ emission of the superstructure can be reduced.
Second Example

Haneda Airport D-Runway
Ductal Slab

The first Ductal Mass Production in the world

UFC slab for Haneda airport
D-runway

D-runway Project
**Ductal slab area**
- Reclaimed land area
- Jacket area
- Runway
- Taxiway
- Ductal slab 171,800m²
- Ductal volume 21,000m³

Applied to the outside area of Runway (Blue area)

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**Ductal slab and PC slab**

**PC slab**
- Conventional Technology
- 0.32m
- V=9.8 m³; W=24 ton
- Less durability

**Ductal slab**
- State of the art Technology
- 0.25m
- V=3.9 m³; W=10 ton
- Light and 100 year durability

- 56% weight reduction

Averaged thickness = 0.13m

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**Ductal slab**

- Upper side
- Weight = 10 ton
- Thickness = 25cm
- 3.6m
- 7.8m

---
Ductal Application

①仮設製作ヤード上屋 (45m×200m)
設
・プレテンションヤード
⑪場周道路
プラントヤード
倉庫
5K×4K
試験室
5K×6K
駐車場
物揚げ場
A
A
75000
23600
2059
UFC
床版
⑥仮設プレテンションアバット
③仮設試験室
④仮設倉庫
⑦仮設プラント設備
⑩仮設排水処理槽
⑪場周道路
⑨仮設養生槽 (1ライン当たり3箇所)
80tクローラクレーン
積出し岸壁までの一般道
走行距離900m程度
出入口 (床版搬出)
一般道路
⑫床版仮置きヤード
一般道路
富津船溜り
物揚げ場エプロン
出入口 (資材搬入)
一般道路
20000
392600
20000
7000
7000
278000
317600
事務所・休憩所 5K×10K (1F)
5K×10K (2F)
トイレ 5K×2K
浄化槽
外階段
庇 (外廊下)
365600
78500
⑬仮囲い
58500
20000
2021
2185
2233
⑧仮設門型クレーン (1ライン当たり3基)
②仮設事務所
⑤仮設ボイラー室
Erection

Thank you

Fuminori Tomosawa is Professor Emeritus in the Department of Architecture at the University of Tokyo. He began his career with the Building Research Institute in 1970 and became a professor at the University of Tokyo in 1987. He has also been a professor at Hokkaido University and Nihon University. He served as President of the Japan Concrete Institute from 2006 to 2008. His most notable research accomplishments are the establishment of a computer simulated model of cement hydration, comprehensive research works on durability design and maintenance/repair strategy of concrete structures, and development of high-strength concrete and recycling.
An Advanced Concrete Recycling Plant and Completely Recyclable Concrete Products come into Market

- The recent development of recycling concrete in Japan -

7 November 2009
New Orleans, Louisiana

F. TOMOSAWA
Department of Architectural Engineering
Nihon University

CONTENTS
1. Concept and Practice of Sustainability of Concrete
2. Brief History of Research and Development on Recycling of Concrete
3. Innovative Approaches for New Methods of Concrete Recycling
4. Standardization of Recycled Aggregate and Concrete
5. Recent Progress of Application
6. Concluding Remarks

Concept and Practice for Sustainability of Concrete
What is the Sustainability of Concrete and How can we achieve it in Practice?
Sustainability of Concrete

Long Life Concrete Structures:
Durable Concrete, High Seismic Resistibility

Low CO₂ Gas Emission:
Use of Decarbonated Raw Materials for Cement

High Resources Saving:
Use of Byproduct, Recycling of Concrete

Innovative Approaches for New Methods of Concrete Recycling

Completely Recyclable Concrete

Complete Decomposition of Demolished Concrete

Completely Recyclable Concrete

Completely recyclable concrete is a concrete or Mortar 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 or recycled aggregate after hardening.

Concrete containing recycled aggregate from a completely recyclable concrete is also a completely recyclable concrete.

In this way, such a concrete can be recycled endlessly. This was invented by the author in 1994.
Concept of Completely Recyclable Concrete

**Completely Recyclable Concrete (CRC)**

1. Production and Placing of CRC
2. Demolishing of Structures
3. Fractionation of Waste Concrete into Cement Materials or Recycled Aggregate
4. Production and Utilization of Recycled Concrete

### Materials

- **Cement**: Portland cement, etc.
- **Coarse Aggregate**: Limestone, Quartzite, etc.
- **Fine Aggregate**: Limestone, Quartzite, etc.
- **Additions**: Blast-furnace slag, Fly ash, etc.
- **Admixtures**: Superplasticizer, AE agent, etc.

### Examples of Mix proportion for CRC of cement like composition (kg/m³)

<table>
<thead>
<tr>
<th>CRC (cement type)</th>
<th>Cement</th>
<th>Fly Ash</th>
<th>Coarse Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRC-1 (NPC)</td>
<td>317</td>
<td>203</td>
<td>115</td>
</tr>
<tr>
<td>CRC-2 (NPC)</td>
<td>317</td>
<td>199</td>
<td>112</td>
</tr>
<tr>
<td>CRC-3 (NPC)</td>
<td>315</td>
<td>666</td>
<td>60</td>
</tr>
<tr>
<td>CRC-4 (NPC)</td>
<td>317</td>
<td>603</td>
<td>118</td>
</tr>
<tr>
<td>CRC-5 (NPC)</td>
<td>172</td>
<td>276</td>
<td>122</td>
</tr>
<tr>
<td>CRC-6 (HPC)</td>
<td>317</td>
<td>616</td>
<td>111</td>
</tr>
<tr>
<td>CRC-7 (BPC)</td>
<td>317</td>
<td>286</td>
<td>188</td>
</tr>
</tbody>
</table>

### The First Application of CRC

**Precast CRC Foundations of Experimental Perfect Recycling House Project By Waseda Univ.**

**CRC (cement type)**

- **Crush adjustment**: Portland cement
Complete Decomposition of Demolished Concrete

Technologies for Concrete Recycling have been developed in the R&D Project “New Technologies of Recycling Concrete for Nuclear Power Plant Renovation” conducted by Nuclear Power Engineering Corporation (NUPEC) in 1996-2003. Developed Technologies are applied to Recycling of Demolished Concrete from Ordinary Concrete Structures.

Proposed Technologies

- Improved Mechanical Grinding Method
  (Developed by Takenaka Corporation)
- Selective Heating and Grinding Method
  (Developed by Mitsubishi Heavy Industries Ltd.)
- Heating and Rubbing Method
  (Developed by Mitsubishi Materials Corporation)

Among them, Heating and Rubbing Method proved to be effective, producing High Quality Recycled Aggregate and Hydrated Cement Powder. Improved Mechanical Grinding Method is also applied to Ordinary Demolishing Site.

Heating and rubbing method
(Developed by Mitsubishi Heavy Industries Ltd.)

High Quality Aggregate Recovering Process

Heating treatment
Rubbing treatment

Concrete rubble

Deintegration of cement paste by dehydration
Selective separation of cement paste

ACI WEB SESSIONS
Heating Temperature and Quality of Recycled Coarse Aggregate

- **JASO B-Standard**: Oven-dry Density: 2.5 or more
- **Absorption**: 2.0% or less

<table>
<thead>
<tr>
<th>Heating Temperature (℃)</th>
<th>Oven-dry Density</th>
<th>Absorption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>100</td>
<td>2.6</td>
<td>2.0</td>
</tr>
<tr>
<td>200</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td>300</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>400</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>500</td>
<td>4.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Gravity of Original Aggregate: 2.74

Heating and Rubbing Plant

- **Capacity**: 3t/h
- **Plant size**: 27mL × 15mW × 15mH
- **Features**: Recover high quality coarse and fine aggregates

Recovered Aggregate and Cement Rich Powder

- **Heating and Rubbing Plant**
- **Coarse Aggregates**
- **Pulverized Materials**
- **Fine Aggregates**
**Recovered ratio of aggregate by air heating and non-heating methods**

<table>
<thead>
<tr>
<th>Powder</th>
<th>Fine aggregate</th>
<th>Coarse aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original mix</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Heating</td>
<td>25</td>
<td>31</td>
</tr>
<tr>
<td>Non-heating</td>
<td>44</td>
<td>34</td>
</tr>
</tbody>
</table>

**Closed-Loop Concrete System**

**An Example of Closed-Loop Concrete System**

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

Facility B:
- Place: Kitakyushu city
- Year of completion: 1988
An Example of Closed-Loop Concrete System

T- Project completed in 2003

- Storehouse
  - Upper structure: SRC 6-storey
  - Basement structure: RC 1-storey
- Building area: 12,600m²
- Total floor area: 62,100m²

Total volume of recycled concrete: 25,000m³

Construction Process

- April/02
- May/02
- August/02
- November/02
- February/03
- August/03
F- Project completed in 2003

Laboratory:
- Structure: Steel structure (7 Stories)
- Building area: 9,800m²
- Total floor area: 51,000m²

Total volume of recycled concrete: 10,000m³

Construction Process

A Practical Application of Completely Recyclable Concrete: “Eco-Pole”

Practical application of the completely recyclable concrete is now on the way of being materialized as a telecommunication concrete pole.

Eco-pole is a trade name of a centrifugally compacted prestressed concrete pole made of completely recyclable concrete, using limestone aggregate.
Closed Recycle Loop of Eco-Pole

ACI WEB SESSIONS

CRC Slump test
Placing of concrete
Centrifugal Compaction
Steam cured

ACI WEB SESSIONS

Removal of form
Inspection
Bending test
Installation and Operation of Marketable Recycle Plant for High Quality Recycled Aggregate

The first marketable concrete recycling plant equipped with heating and rubbing method for production of high quality recycled aggregate, Type "H", has been installed and operated in June 2009 in Super-Ecotown in Tokyo Bay Area near Haneda A.P. by Seiyu-Kogyo Corporation. The capacity of treatment of concrete debris is 4,080 ton/day, 34 times larger than the pilot plant shown in 3.2.
Rotary Kiln for Drying and Heating

Length \( L = 9,000 \text{mm} \)
Diameter \( \phi = 2,000 \text{mm} \)
Heating Temp. = 300 °C
Staying Time = Around 5 – 7 min.
Staying Quantity = Around 2 ton

Rubbing Machine

Quality of recycled aggregate is controlled by staying time of materials in the rubbing machine, which depends on the rotation rate and inclination.

Heating Process in Rotary Kiln
Recycled Coarse Aggregate  20 ~ 05㎜

JIS A 5021 : Grade H
Absorption :  3.0% or less
Dry Density:  2.5g/cm³ or more

Recycled Fine Aggregate : 05㎜ under

JIS A 5021 : Grade H
Absorption :  3.5% or less
Dry Density:  2.5g/cm³ or more

Completely Recyclable Concrete of Aggregate-recovery Type by using Microwave Heating Technology

This is another inventive example of completely recyclable concrete being developed. Aggregate is coated before mixing of concrete by dielectric materials, basically a mixture of ferrous oxide and epoxy resin, in order to obtain easiness of recovering aggregate when the concrete is demolished and recycled.

Coating material is heated selectively when radiated by microwave, and demolished concrete is easily decomposed and aggregate is almost fully recovered.
Concluding Remarks

In this presentation, a brief history of the development of recycling concrete conducted in Japan as well as innovative methods of recycling concrete and new concepts of complete recycling or closed loop recycle methods are introduced.

Standards for recycled aggregate are also established and it leads new business of concrete recycling.

Demolished concrete is now becoming a new materials for next generation of concrete structures instead of being a troublesome burden.

It is essential to utilize once decarbonated limestone, namely hydrated cement from demolished concrete, in order to decrease carbon dioxide gas emission in the cement, concrete and construction industry. Completely recyclable concrete and complete decomposition of demolished concrete will pave the way to this end.

The installation and operation of an advanced concrete recycling plant and the development of marketable completely recyclable concrete product are expected to be the dawn of a new age.
Thank you for your attention.

Dr. Takafumi Noguchi is known internationally for his work in concrete and environmental engineering. He graduated and qualified as Doctor of Engineering at the University of Tokyo. He is a secretary for ISO/TC71/SC8, which is establishing international standards for environmental aspects of concrete and concrete structures, and for fib Commission 3, which deals with environmental aspects of concrete. Dr. Noguchi is also a member of ACI’s board advisory committee on sustainable development and a leading member of the Building Material committee at the Architectural Institute of Japan.

International Standard for Environmentally-Conscious Specification of Concrete Materials, Production, and Structures

Takafumi Noguchi
The University of Tokyo
Background

- Environmental problems on a global scale due to development of material civilization and industrialization since the Industrial Revolution
  - Global warming
  - Ecosystem disruption
  - Resources depletion
  - Waste accumulation
- Kyoto Protocol
  - Reduction of CO₂ emission
  - Crucial task for all industries

Building Related CO₂ Emission

- CO₂ Emission in 1990 in Japan: 1.2 billion t
- Housing Construction: 5%
- Building Renovation: 1%
- Office Construction: 6%
- Energy for Housing: 12%
- Energy for Office: 13%
- Other Industries: 16%

Waste from Construction Industries

<table>
<thead>
<tr>
<th>Industrial Waste</th>
<th>Construction Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total: 412 (million t/year)</td>
<td>Total: 75 (million t/year)</td>
</tr>
<tr>
<td>Concrete (75 million t/year) 32%</td>
<td>Concrete (32 million t/year) 41%</td>
</tr>
<tr>
<td>Wood (18 million t/year) 4%</td>
<td>Wood (18 million t/year) 4%</td>
</tr>
<tr>
<td>Steel (5 million t/year) 1%</td>
<td>Steel (5 million t/year) 1%</td>
</tr>
<tr>
<td>Pulp (4 million t/year) 1%</td>
<td>Pulp (4 million t/year) 1%</td>
</tr>
<tr>
<td>Chemical (2.5 million t/year) 1%</td>
<td>Chemical (2.5 million t/year) 1%</td>
</tr>
<tr>
<td>Others (2 million t/year) 1%</td>
<td>Others (2 million t/year) 1%</td>
</tr>
</tbody>
</table>
Recycling Ratio of Concrete

<table>
<thead>
<tr>
<th>Year</th>
<th>Recycle</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Emission of Concrete Lumps (million t)

- For road bottoming materials
- For mechanical stabilization materials
- Decrease in the demand for road bottoming

International Standard

ISO 13315 (Environmental management for concrete and concrete structures)
- Part 1: General principles
- Part 2: System boundary and inventory data
- Part 3: Constituents and concrete production
- Part 4: Environmental design of concrete structures
- Part 5: Execution of concrete structures
- Part 6: Use of concrete structures
- Part 7: End of life phase including recycling of concrete structures
- Part 8: Labels and declaration

Publication by AIJ (Architectural Institute of Japan) in 2008

"Recommendations for Environmentally Conscious Practice of Reinforced Concrete Buildings"

Chap. 1 Purpose and scope
Chap. 2 Classification and application methods of environmental consideration
Chap. 3 Design of members and structural framing
Chap. 4 Selection of concrete materials
Chap. 5 Concrete proportioning
Chap. 6 Order placement/production/acceptance of concrete
Chap. 7 Concreting work
Chap. 8 Reinforcing bars and bar placement
Chap. 9 Formwork and form construction
Appendix 1 to 5 Application examples
Purpose and Scope of the Recommendations

- It provides items of environmental consideration related to reinforced concrete work primarily on the jobsite.
- It should be used when incorporating environmental consideration in the design drawings and specifications and execution plans for reinforced concrete buildings.
- It provides basic concepts to be referred to through various activities throughout the lifecycle.

Lifecycle of Reinforced Concrete Structures

- Design
- Execution
- Production
- Disposal
- Demolition
- Operation

Potential Chance to Influence Degree of Environmental Impact

- Design
- Execution
- Operation
- Disposal
- Recycling

Life Cycle Phases of Concrete Structure
Occasions Using Recommendations

• When a design engineer formulates the design drawings and specifications
• When a contractor makes environment-friendly technical proposals to the design engineer and construction supervisor
• When a contractor provides subcontractors and material producers with items of environmental consideration
• When a material producer plans specific environmental measures for the production phase

Four Types of Environmental Consideration

• Resource-saving type (RS)
  – Reducing the amounts of natural resources used
  – Use of recycled materials or materials that are recyclable after use
  – Reduction of the cross-sectional areas of members by increasing the strength of materials
• Energy-saving type (ES)
  – Using materials, equipment, or systems that would reduce the energy required for the production and transportation of materials and the construction, use, and demolition of buildings, and the disposal of demolished waste

Four Types of Environmental Consideration

• Environmental impact substance-reducing type (IR)
  – Reducing hazardous substances (CO₂, NOₓ, SO₂, etc.) causing global warming, ozone depletion, acid rain, disruption of ecosystems, neighbour environment pollution (air, soil and water pollution, etc.), heat-island effect, interior hygienic environment pollution, etc.
• Long service life type (LL)
  – Contributing to the improvement of the durability of buildings and their component materials
Design of Members and Structural Framing

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete strength</td>
<td>LL</td>
<td>Increase the design strength of concrete in the range of not impairing the qualities of fresh and hardened concrete while not excessively increasing the emission of Environmental impact substances.</td>
</tr>
<tr>
<td>Cover depth</td>
<td>LL</td>
<td>Appropriately design the concrete cover depth.</td>
</tr>
<tr>
<td>Use of precast products</td>
<td>RS</td>
<td>Investigate the use of precast or half-precast concrete products instead of cast-in-place concrete. If this can improve the environment, then incorporate it in the design.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td></td>
</tr>
</tbody>
</table>

Selection of Concrete Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>RS</td>
<td>Use blast-furnace slag cement or fly ash cement. Investigate the use of eco-cement if it is readily available.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Use blast-furnace slag cement or fly ash cement.</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>Use portland cement.</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>Use portland cement.</td>
</tr>
<tr>
<td>Aggregate</td>
<td>RS</td>
<td>Use recycled aggregate, various slag aggregates, and artificial aggregates made from industrial byproducts while exercising care to ensure the quality of concrete.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Use gravel or crushed stone for coarse aggregate. Use sand or crushed sand for fine aggregate.</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>Use gravel or crushed stone for coarse aggregate. Use sand or crushed sand for fine aggregate.</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>Use gravel or crushed stone for coarse aggregate. Use sand or crushed sand for fine aggregate.</td>
</tr>
</tbody>
</table>

Selection of Concrete Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing water</td>
<td>RS</td>
<td>Use recovered water</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>Use tap water.</td>
</tr>
<tr>
<td>Admixtures and addition</td>
<td>RS</td>
<td>Reduce the cement content by using AE admixture, AE and water-reducing admixture, high-range water-reducing admixture, AE and high-range water-reducing admixture, or superplasticizer.</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>Reduce the cement content by using an expansive admixture or shrinkage-reducing admixture while ensuring the quality of concrete. When the effect of seawater is of concern, use ground granulated blast-furnace slag or silica fume.</td>
</tr>
<tr>
<td></td>
<td>RS</td>
<td>Use ground granulated blast-furnace slag or fly ash while ensuring the quality of concrete.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Use ground granulated blast-furnace slag or fly ash while ensuring the quality of concrete.</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>Use ground granulated blast-furnace slag or fly ash while ensuring the quality of concrete.</td>
</tr>
<tr>
<td></td>
<td>LL</td>
<td>Use ground granulated blast-furnace slag or fly ash while ensuring the quality of concrete.</td>
</tr>
</tbody>
</table>
### Concrete Proportioning

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-binder ratio</td>
<td>IR</td>
<td>Reduce the water-binder ratio in the range of not adversely affecting the quality of structural framing</td>
</tr>
<tr>
<td>Cement content</td>
<td>RS</td>
<td>Reduce the cement content</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Replace part of cement with a supplementary cementing material</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td></td>
</tr>
</tbody>
</table>

**RB**: Resource-saving type  
**IR**: Impact-reducing type  
**ES**: Energy-saving type  
**LL**: Long-service-life type

### Order Placing, Production and Acceptance of Concrete

*(to be contd.)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of plant</td>
<td>RS</td>
<td>Select a plant that is furnished with equipment capable of accepting recycled materials and where materials are appropriately stirred and controlled.</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>Select a plant accredited by ISO 14001 or a plant making efforts to protect the environment by taking measures against noise/vibration for the community, measures against dusting and water pollution, as well as measures to reduce waste.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Select a plant close to the jobsite.</td>
</tr>
<tr>
<td>Order placing</td>
<td>RS</td>
<td>Place orders so as to eliminate excess concrete.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Mix concrete appropriately using an efficient mixer with an adequate batch capacity in consideration of the mixing efficiency, avoiding an excessive batch size.</td>
</tr>
<tr>
<td>Production</td>
<td>RS</td>
<td>Recycle the materials reclaimed from the production process to minimize waste.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td></td>
</tr>
</tbody>
</table>

**RB**: Resource-saving type  
**IR**: Impact-reducing type  
**ES**: Energy-saving type  
**LL**: Long-service-life type

### Order Placing, Production and Acceptance of Concrete

*(contd.)*

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>IR</td>
<td>For conveying concrete, use vehicles with noise/emission control</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Drive vehicles for conveying concrete with due consideration to noise and fuel consumption.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>For conveying concrete, take a route that allows smooth and quick hauling to the jobsite.</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>Select vehicles suitable for the loads to achieve efficient transportation.</td>
</tr>
<tr>
<td></td>
<td>IR</td>
<td>After unloading concrete, wash the concrete remaining on the hopper openings and chutes at the jobsite or in the plant. Use the agitating drum for carrying the waste washing water back to the plant where it should be discharged.</td>
</tr>
<tr>
<td>Acceptance</td>
<td>RS</td>
<td>When the slump of concrete conveyed is found to have decreased at the time of unloading, judge if the concrete is usable for the concreting work, and use it as much as possible after restoring the slump by e.g., using a superplasticizer.</td>
</tr>
</tbody>
</table>

**RB**: Resource-saving type  
**IR**: Impact-reducing type  
**ES**: Energy-saving type  
**LL**: Long-service-life type
Concreting Work

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL</td>
<td>Make efforts to <strong>enhance the quality of concrete</strong> as structural framing by taking special measures for the transportation, placement, construction joint treatment, and curing of concrete.</td>
<td></td>
</tr>
<tr>
<td>IR</td>
<td>Make efforts to protect the neighboring and work environments by giving due consideration to the working areas and working hours, while giving priority to construction vehicles/machines that contribute to suppression of noise/vibration and gas emission resulting from the work. Appropriately treat/dispose of the sludge and waste washing water generated on the jobsite.</td>
<td></td>
</tr>
<tr>
<td>RS</td>
<td>Give priority to methods and materials/equipment that contribute to the protection of natural resources. Concrete and mortar that cannot be used anyhow for the structural framing should be recycled for temporary blocks, road bottoming, etc.</td>
<td></td>
</tr>
<tr>
<td>ES</td>
<td>Appropriately select methods and materials/equipment that contribute to the reduction of CO&lt;sub&gt;2&lt;/sub&gt; emission in the range of not impairing the quality of concrete and not causing increases in the amounts of Environmental impact substances.</td>
<td></td>
</tr>
</tbody>
</table>

Rebar Work and Form Work

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>For anchorages of densely reinforced members, select a method with a reduced amount of rebars. For bar joints, select a jointing method requiring small gas consumption.</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>In areas prone to severe chloride attack, consider the use of rustproof rebars while ensuring the design cover depth.</td>
<td></td>
</tr>
<tr>
<td>ES</td>
<td>Select the form type and formulate a construction plan appropriately so that forms can be reused for an increased number of times. Give priority to forms for which a recycling system has been established.</td>
<td></td>
</tr>
<tr>
<td>RS</td>
<td>Give priority to system forms or stay-in-place forms, which can shorten the construction period and working hours.</td>
<td></td>
</tr>
<tr>
<td>ES</td>
<td>Give priority to recyclable forms or stay-in-place forms, which require no waste disposal after use.</td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td>Give priority to a method whereby permeable/dewaterable forms densify the concrete surfaces or a method using precast concrete products which have a strong effect of protecting the structural framing.</td>
<td></td>
</tr>
</tbody>
</table>

Concluding Remarks

- Environmental consideration will inevitably be required more strongly for the design and execution of reinforced concrete structures in the future.
- AIJ Recommendations hopefully serves as a reference for formulating the ISO standards which will be established by ISO/TC71/SC8.
- The Recommendations also helps design engineers, material producers, and contractors exercise environmental consideration when they formulate reinforced concrete work specifications, produce material products, and carry out execution work.
Koji Sakai is a Professor at Kagawa University, Japan. He chairs ISO/TC 71/SC 8 on environmental management for concrete and concrete structures, the fib Commission 3 on environmental aspects of design and construction, and the Japan Concrete Institute Technical Committee TC081A on Minimization of Global Warming Substances and Wastes in Concrete Sector.

Standardization for Sustainability in ISO/TC71/SC8

Koji Sakai (Kagawa University)
Chair, ISO/TC71/SC8

Sustainability (ISO 15392*)

“state in which components of the ecosystem** and other functions are maintained for the present and future generations”

*Sustainability in building construction – General principles
**plants and animals, as well as humans*** and their physical environment
***Key elements of human needs: the economic, environmental, social and cultural conditions for societies’ existence
Sustainability (Cont’d)

- Sustainability is the goal of sustainable development and can result from the application of the concept of sustainable development.
- In building construction, it related to how all construction aspects contribute to the maintenance of ecosystem components and functions for the future generations.

Warning by IPCC Report

“CO₂ emissions must be reduced by 85 - 50% by 2050 compared with the 2000 level to limit CO₂ to 350 -400 ppm. Even if we could do it, a temperature rise of 2.0 – 2.4 ºC will be inevitable.”

CO₂ Observation in Hawaii

[Graph showing CO₂ levels over time with a Keeling Curve trendline]
Global Warming Gas Reduction Targets (1990 level) until 2050

- EU: 60~80%
- UK: 60~80%
- France: 75% (with the 2000 level)
- Germany: 80%
- Norway: 100%
- USA (Obama): 80%
- Japan: 60~80% (with the present level)
  (25% until 2020 with the 1990 level)

L’Aquila G8 Summit (2009)

- The developed countries reduce GHG emissions by 80% by 2050.
- Leaders’ communiqué of the Major Economics Forum (MEF)
  “The increase in global average temperature above pre-industrial levels should not exceed 2°C.”

UN Climate Change Conference

- The global warming measurements (Post-Kyoto Protocol) will be determined in COP15 in Copenhagen on December 7-18, 2009.

LET’S SEE WHAT HAPPENS !!!
A System to Reduce Environmental Impact

ISO STANDARDS

Benefits of Standardization as Concrete Sector
- Social accountability
- Clarification of environmental benefits (positive impacts)
- Stimulation of the potential for decision-maker or market-driven continuous environmental improvement

Existing ISO Environmental Standards
- ISO 14000 series (Environmental management)
- ISO 21930: Sustainability in Building Construction - Environmental declarations of building products
ISO/TC71/SC8
-Environmental Management for Concrete and Concrete Structures-

- Ratification of SC8 on Feb., 2008
- First meeting at Los Angels on Mar., 2008
- Second meeting at Cairo on Feb., 2009
- The first draft of Part 1 document is now under development.

Basic Framework of ISO/TC71/SC8 EMCC Standards

- Part 1 - General Principles
- Part 2 - System boundary and inventory data
- Part 3 - Constituents and concrete production
- Part 4 - Environmental design of concrete structures
- Part 5 - Execution
- Part 6 - Use
- Part 7 - End phase
- Part 8 - Labels and declaration

Basic Framework of EMCC Standard Group
Basic Flow of EMCC

Framework of ISO EMCC: Part 1

1. Scope
2. Normative references
3. Terms and definitions
4. General framework: General; Phases in lifecycle; Environmental impacts; Analysis (general/system boundary/inventory data/indicators); Design; Production/execution; Use; End phase; Labels and declarations (Appendix)

Phases in Lifecycle

- Design
- Production/execution
- Use phase
- End phase
Environmental Impacts

- Global warming
- Natural resources depletion
- Acidification
- Air pollution
- Water pollution
- Soil contamination
- Waste
- Noise/vibration
- Dust
- Hazardous substances

Analysis-General

- Determination or confirmation of the system boundaries and indicators
- Preparation of data corresponding to the indicators
- Calculation of environmental performance

Design

[Diagram showing the process of design with steps such as project initiation, client's brief, laws and regulations, performance requirements, design, estimation of performance, retained performance, verification, and documentation.]
Production/execution

- Formulation of production plan and execution plan
- Calculation of environmental impact including transportation
- Verification of performance requirements
- Conservation of documents related to all procedure

Front cover of EMCC: Part 1
ISO/WD 13315-1

Membership of ISO/TC71/SC8 as of July, 2009

- **P-member** (11 countries)
  Australia, Brazil, Egypt, France, Israel, Japan, Korea, Norway, Saudi Arabia, USA, United Kingdom
- **O-member** (4 countries)
  Belgium, Hong Kong/China, Namibia, Sudan
Concluding Remarks

- “Sustainable development” is the most important concept in the 21st century.
- The ISO EMCC standards and a new framework creation for design of concrete structures, which includes sustainability, will accelerate the development of innovative technologies for concrete and concrete structures.

Additional Resources

Pervious Concrete
- ACI 522R-06: Pervious Concrete
- ACI 522.1-08: Specification for Pervious Concrete Pavement

Recycled Cementitious Materials
- ACI 232.2R-03: Use of Fly Ash in Concrete
- ACI 233R-03: Slag Cement in Concrete and Mortar
- ACI 234R-06: Guide for the Use of Silica Fume in Concrete
- ACI SP-202: Third CANMET/ACI International Symposium: Sustainable Development of Cement and Concrete
- ACI SP-221: Eighth CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete
- ACI SP-242 Ninth CANMET/ACI Fly Ash Conference
Additional Resources

Recycled Concrete
- ACI 550R-01: Removal and Reuse of Hardened Concrete
- ACI SP-219: Recycling Concrete and Other Materials for Sustainable Development

Thermal Mass/Minimizing Energy Use
- ACI 122R-02: Guide to Thermal Properties of Concrete and Masonry Systems

Sustainability of Concrete
- The Sustainable Concrete Guide: Strategies and Examples by Andrea Schokker

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