Utilization of Recyclable Materials for Construction

By

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Presented at the Yamaguchi University, Ube City, Japan, October 20, 2008.
UWM Center for By-Products Utilization

Reduce, reuse, and recycle for sustainable developments.
Minimize use of manufactured materials.
Basic Approach

WASTE is wasted if you waste it, otherwise it is a resource.

Recycle. Recycle as is.

Recycle without additional processing, (i.e., without adding any cost to it).
Introduction

• Over 5 billion tonnes of non-hazardous by-product materials are produced each year in USA (2000). At an average cost of $30. per tonne, it would cost B$150. to throw it all away.

• They consist of by-products from agricultural sources, domestic/post-consumer sources, industrial sources, and materials processing sources.
Progression: Solid Waste Management

Town Dump, Landfill, Recycling, Durable Construction Materials, Sustainable Infrastructures, Sustainable Management of Resources (SMR), Reduced GHGs, Global Climate Change, Improved Air Quality, CO2 Sequestration.
Solid Waste Management (cont’d)

Landfills contributes to global warming because it releases GHGs (Water Vapor, Methane, and CO2).

Alternatives: Increase recycling rates, MSW to energy, and composting.
CLEAN AIR
CLEAN WATER
and
RESOURCE CONSERVATION

“The earth, the sea (water), and the air are the concern of every nation.” President John F. Kennedy, fall 1963, in a speech to the U.N. General Assembly.
Coal Ash

Fly ash & Bottom ash

Cyclone boiler slag, Cenospheres

FGD Materials (dry or wet/sludge)

AFBC & PFBC Materials

Clean-coal ash

Co-generation ash (coal, wood, petroleum coke, etc.)
Figure 2. Examples of Class C and Class F fly ash.
Fly ash particles (Magnification, 1000 X)
Bottom Ash, 20 X Magnification
Coal Ash (CCPs)

• Over 120 million-tonnes of non-hazardous coal combustion products (CCPs) are produced each year in USA (2007). At an average disposal cost of $30 per tonne, it would cost $3.6 billion to throw it all away.

• These by-products generally can be used as a partial substitution of cement and many other everyday construction needs.
Portland Cement + Water

Free Lime, Ca(OH)₂ + Fly Ash

Cementitious Material
SEM Images of BCN60, 7 days
Foundry By-Products

• About 15 million tonnes of non-hazardous by-product materials are produced each year in USA (2003) by the cast-metals industry (foundries). At an average cost of $30. per ton, it would cost 450 million USD to throw it all away.

• They consist of by-products from sand molds (used foundry sand - UFS), broken or rejected core butts, slag, furnace-refractory, dust-collector fines, floor-sweepings, abrasives, materials processing sources, and other similar materials.
• Cores are used for making desired/defined cavity/shapes in a sand mold in which molten metal is cast/poured.

• Molds are primarily composed of silica sand with small percentages of either organic or inorganic binders.
• The organic binders include oil, synthetics, cereal proteins, etc.

• The inorganic binders include portland cement, coal fly ash, sodium silicate, etc.
Foundry By-Products

(steel, iron, brass, aluminum)

- Used Foundry Sand
- Core butts, abrasives, etc.
- Cupola Slag
- Bauxite processing and aluminum & brass foundries by-products
# Physical Properties of Used Foundry Sand

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.39</td>
<td>ASTM D 854</td>
</tr>
<tr>
<td>Unit Weight, kg/m³</td>
<td>2590</td>
<td>ASTM C 48</td>
</tr>
<tr>
<td>SSD Absorption, %</td>
<td>0.45</td>
<td>ASTM C 128</td>
</tr>
<tr>
<td>Coefficient of Permeability, cm/sec</td>
<td>$10^{-3}$</td>
<td>ASTM D 2434</td>
</tr>
</tbody>
</table>
Applications of Used Foundry Sand

- Foundry sand can be used as a replacement of regular sand up to 45% by weight, to meet various requirements of structural-grade concrete (1991).

- Use of foundry sand in concrete may result in some loss of concrete strength due to increased water demand. However, this can be compensated by proper mixture proportioning.
Applications of Used Foundry Sand (Cont’d)

• Concrete of compressive strength over 50 MPa can be produced with the inclusion of foundry sand with up to 45% replacement of regular sand.

• Flowable slurry (CLSM), incorporating used foundry sand as a replacement of fly ash up to 85% has been produced (1996).
Applications of Used Foundry Sand (Cont’d)

- Up to 15% used foundry sand can be used as replacement of fine aggregate in Hot Mix Asphalt (HMA).

- Bricks, blocks, and paving stones made with up to 35% used foundry sand passed ASTM requirements for compressive strength, absorption, and bulk density.
Manufacturing of bricks with used foundry sand
Applications of Foundry Slag

- Foundry (cupola) slag is appropriate for use as a coarse semi-lightweight aggregate in cement-based materials.

- Foundry slag has been used as replacement of aggregate in manufacturing of structural-grade concrete.
Post-Consumer Glass
• Approximately 10 million tonnes of post-consumer glass is produced each year in USA.

• About 3.4 million tonnes is used primarily as cullet for glass manufacturing.

• There are three types of glass: borosilicate, soda-lime, and lead glass.
Applications of Post-Consumer Glass

- Crushed glass is highly reactive with cement (alkali-silica reaction). But Class F fly ash was used as a replacement of cement by mass of 45% or more, which helped in controlling alkali-silica reaction (1999).
Applications of Post-Consumer Glass (Cont’d)

• Mixed colored glass can be utilized in flowable self-compacting concrete (1998). Addition of mixed colored glass increased impermeability of concrete as the age increased.

• It can be used as partial replacement of sand in other cement-based materials.
Wood waste from (forest products industry)saw mills, pulp mills, wood processing industries, etc. to pins, chips, and bundled fibers.
Wood ash
Wood ash is the residue generated due to combustion of bark, wood, and scraps from manufacturing operations (pulp mills, saw mills, and wood products manufacturing plants) and from CDW (construction and demolition wastes).

Wood ash is composed of both inorganic and organic compounds.

Yield of wood ash decreases with increase in combustion temperature.
Physical and chemical properties of wood ash are influenced by:

1. Species of trees.
2. Method and manner of combustion.
3. Efficiency of boiler.
4. Other supplementary fuel used with wood.
Typical SEM picture of wood fly ash
Applications of Wood Ash

• Approximately 70% of the wood ash generated in the USA is landfilled.

• 20% is applied on land as soil supplement.

• Remaining 10% has been used for miscellaneous applications, e.g., construction materials, metal recovery, and pollution control.
Applications of Wood Ash (Cont’d)

• Wood fly ash has substantial potential for use as a pozzolanic mineral admixture and as an activator in cement-based materials.

• Wood ash has been used in the making of structural-grade concrete, bricks/blocks/paving stones, flowable slurry, and blended cements (1997-2002).
Applications of Wood Ash (Cont’d)

• Air-entrained concrete can be achieved by using wood fly ash up to 35%.

• Structural-grade concrete can be made using wood fly ash and its blends with Class C fly ash to achieve a compressive strength of 50 MPa or higher.
Micro-fibers from Pulp and Paper Mill Wastewater Treatment Residuals

- Solid residue removed from mill wastewater before the water is discharged or reused.
- Removed via a two-step (gravity/primary and biological/secondary).
- Usually, dewatered before disposal or beneficial use.
Paper Mill Wastewater Treatment Process

- Mill Wastewater
  - Primary Clarifier
    - Dewatering
      - Primary Residual
        - Recovered Water
    - Secondary Clarifier
      - Secondary Residual
        - Dewatered Residual
  - Clarified Water

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Pulp and Paper Mill Residual Solids in Concrete

• Approximately 60% of the residual solids generated in the USA is either landfilled or burned.

• Because of cellulose fibers in the residual solids, the residual solids could become an economical source of fibers for use in concrete.
As-received fibrous residual C1
Pulp Mill Primary Sludge Solids

Center for By-Products Utilization
Scanning electron micrograph of Residual S
### Characteristics of Residuals

<table>
<thead>
<tr>
<th>Type of Residual</th>
<th>6 Primary, 1 Fiber reclaim</th>
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<tbody>
<tr>
<td>Fiber Origin</td>
<td>5 Virgin, 1 Recycled, 1 Mixed</td>
</tr>
<tr>
<td>Moisture Content (%)*</td>
<td>153 (84-230)</td>
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<tr>
<td>Wood Fiber (%)*</td>
<td>57 (35-94)</td>
</tr>
<tr>
<td>LOI at 590°C (%)*</td>
<td>65.9 (43.6-99.6)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.83 (1.56-2.17)</td>
</tr>
<tr>
<td>Avg. Fiber Length, $L_L$ (mm)</td>
<td>1.27 (0.85-1.68)</td>
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</tbody>
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* % of oven-dry mass.
Pulp and Paper Mill Residual Solids in Concrete

- There have been very few investigations.
- Best performance of concrete seems to be achieved if the residual solids were collected prior to chemical conditioning and solidification.
Residual Fiber Reinforcing a Micro-crack in Concrete
CONCLUSIONS

When compared to a reference concrete containing no residuals, concrete containing residuals exhibited:

• Slightly lower compressive strength
• higher average residual-strength
• Equivalent drying-shrinkage
• Improved resistance to freezing and thawing
• Equivalent or lower chloride-ion penetration resistance and abrasion resistance.
Brown Fields Soils

In-situ brown field remediation, excavated soils re-use, engineered fills & structural embankments with high-volume industrial by-products.
Blast furnace slag, Scrap-iron slag, Electric-arc Furnace slag.
CKD and LKD
Used Tires
Dredged Materials
Post-Consumer Plastics

Hard plastics & Styrofoam
Mining tailings, spoilage, and dust.
Textiles and carpet fibers
New construction and CDW scrap woods to pins, chips, and bundled fibers.
CDW painted and treated woods to pins, chips, and bundled fibers.
CDW – clay bricks to SCM, and concrete blocks and other concrete to SCM and pozzolanic aggregates.
Scrap wallboards (gypsum drywalls) from new construction and CDW.
MSW for Cement

Residues from incineration facilities, with or without sewage sludge.
Biodegradable-MSW for Composting with vermicomposting

Anaerobic decomposition followed by mixing with wastewater sludge, wood ash, coal ash, and/or cement- or lime-kiln dust.
Saving of Resources by Recycling (per tonne):

- Paper – 20 Grown trees, 30,000 Lts. water, and 4,500 kw of electricity;
- Plastics – Petroleum, natural gas, 40,000 Lts, water, and 5,500 kw of electricity;
- Aluminum – 4 tonnes of bauxite and 100,000 Lts. of water;
- Glass - 1.2 tonnes of silica sand, 50% less water, and 2,500 kw of electricity.
Time for Degradation in Landfills at ambient condition (years):

- Periodicals – one;
- Paint cans – 13;
- Plastic bags – 100;
- Steel cans – 100; Aluminum cans – 200 to 500;
- Plastic bottles – 450; and,
- Glass – more than one million.
Spaceship Earth – La Bella Terra

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Arigatou Gozaimasu. Thank you very much for your interest.
Aabhar Tamaro, Afcharisto Poly, Arigatou Gozaimas, Grazie Molto, Maraming Salamat, Merci Beaucoup, Muchas Gracias, Muito Obrigado, Salamat, Shukriya, Spasibo, Thank you, Toda Raba.
LECTURE

Civil Infrastructure Management Div.

Research Center for Environmental Safety (RCES)
Yamaguchi University

Special Lecture

Utilization of Wastes as Construction Materials

by
Prof. Tarun R. NAIK

(Research Professor of University of Wisconsin-Milwaukee, USA)

Date: Oct. 20th (Mon), 10:30-12:00
Place: A105 Lecture Room

Everybody interested is welcome

2008.10.10

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