Challenges and Opportunities
Recycled Materials in Ready Mixed Concrete

Concrete Sustainability Conference
April 2010
Colin Lobo, Ph.D., P.E.
NRMCA Sustainability Initiatives

Key Performance Indicators

- Potable water:
  - 10% reduction by 2020
  - 20% reduction by 2030

- Waste:
  - 30% reduction by 2020
  - 50% reduction by 2030

- Recycled content:
  - 200% increase by 2020
  - 400% increase by 2030
Recycled Content:
Where are we today?

Air: 6%
Cement: 10%
Water: 18%
Sand: 25%
Gravel: 41%

0 – 50%
20%
~30% by volume?

9% by volume?
Increase 200%

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NRMCA Sustainability Initiatives

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Cementitious Materials

Supplementary Cementitious Materials

- Improve fresh concrete properties
- Strength
- Durability
- Good history of use

- Credit in Green Rating Systems
  - Pre-consumer waste
Cementitious Materials

Challenges

- Specifications
  - Maximum limit
  - Minimum limit – reduce carbon footprint
  - Restrictions – products and properties

- Performance
  - Setting
  - Rate of strength gain
  - Compatibility

- The Fly Ash Problem!
“Waste” to “Recycled”

- Returned Concrete - estimated 2 - 10% of production
  - 8 to 12 million cubic yards
- Truck Washout
  - 50 to 200 gallons per truck
- Need to manage
  - Storm Water
  - Process Water
  - Aggregates and Cement Solids
- Comply with environmental regulations
Returned Concrete & Wash Water

1. Variable amounts surplus concrete returned to the plant **everyday**.
2. Must be disposed of or reused somehow.
3. Mixers must be flushed out at the end of each day.
4. BMPs should address both surplus concrete and mixer washout water.
5. More than one method is necessary
1950’s: This is Not New!
Water & Solids Management
Returned Concrete Options

- Top-loading: Batch on top, re-ship
- Windrow and crush
  - Sell
  - Reuse
- Settling ponds
  - Solids
  - Water
- Pave plant
- Cast blocks
- Reclaimer systems
  - Solids
  - Water
Concrete “Products”
Blocks
Blocks
Crushed Concrete Aggregate (CCA)
Crushed Returned Concrete (CCA)
CCA - Aggregate in Concrete

- Sustainability: Reduce landfill burden
  - 15 million yd³ / year (≈ 845 10’-high foot ball fields)
- Economy: $300 Million/yr
Specifications – ASTM C33

- Coarse CCA is recognized
  - May not meet all quality requirements
- Fine CCA recognized
  - ASTM C125 - manufactured sand
NRMCA Research

• CCA - 1000, 3000, 5000 psi Non AE

http://www.nrmca.org/research/eng_articles.asp
NRMCA Research

- 17 Non-AE mixtures
  - Cement = 500 pcy, slump 5-7 in., w/cm=0.57
  - CCA “as is” – 300, 600, 900 pcy
  - CCA sieved as “coarse” - 50/100% of virgin

- 4 AE mixtures
  - Cement=564 pcy, slump 6-8 in., w/cm=0.45, HRWR

- Evaluated
  - Effects on fresh concrete
  - Hardened concrete – strength, durability
Effect of CCA on Strength

Effect on Strength

Control Strength = 4200 psi
Performance Issues

- Water demand
  - Impacts strength
- Slump loss
  - Sprinkle stockpiles
- Accelerated set time
  - 30 to 60 min
- Permeability
  - Can be addressed
  - ASR – depends on old concrete
- Shrinkage
- Freeze thaw durability
Options for Concrete Producer

- No processing
  - 300 lbs/yd³ - (10% of aggregate volume)

- Manage returned loads
  - Strength > 3000 psi, crush after 14 days
  - 900 lbs/yd³ (30%)
  - Set times, higher shrinkage, F-T resistance

- Separate into coarse / fine
  - 100% Coarse CCA
  - 1600 lbs/yd³ (50%)
  - Set time, shrinkage
Proportioning mixtures

Equivalent Mortar Method
- Equivalent volume virgin agg
- Old mortar part of new mortar

- Similar performance
  - Fresh
  - Mechanical
  - Durability

Fathifazl et al, Concrete International, March 2010
Ultimate Goal

Concrete needs to meet

- Purchasers requirements
- Specifications

Challenges:

- Economic incentive
- No credit in “green” ratings
- More attention – quality control
Top-Loading
Batching on Plastic Returned

Concrete

Need to Know:

- Quantity
- Batch characteristics
  - Age
  - Cement content
  - Temperature
  - Amount of added water
- Requirements for new batch
Reusing Returned Concrete - No Admix

Effect on Strength - 28% Returned Concrete Mixed to Target Slump

<table>
<thead>
<tr>
<th>Age of Returned Concrete</th>
<th>45 min</th>
<th>90 min</th>
<th>3 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delivery Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45 min</td>
<td>5000</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>90 min</td>
<td>4500</td>
<td>4500</td>
<td>4500</td>
</tr>
<tr>
<td>3 hrs</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
</tbody>
</table>

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Reusing Returned Concrete - No Admix

Effect on Strength - 28% Returned Concrete Mixed to Target Slump

- 45 min
- 90 min
- 3 hrs

Setting Time, hr

Age of Returned Concrete

- 45 min
- 3 hrs
- Original

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Reusing Returned Concrete with Hydration Stabilizing Admixtures

Need to Know:

- Quantity
- Batch characteristics
  - Age
  - Cement content
  - Temperature
  - Amount of added water
- Time to hold
  - Admixture dosage
- Requirements for new batch
Reusing Returned Concrete – HSA

Same Day Recycling

28-day Strength, ps

Control

<table>
<thead>
<tr>
<th>Dose, oz/cwt</th>
<th>45 min</th>
<th>45 min</th>
<th>3 hr</th>
<th>3 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5000</td>
<td>5500</td>
<td>45</td>
<td>5000</td>
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<tr>
<td>6</td>
<td>5500</td>
<td>5000</td>
<td>9</td>
<td>5500</td>
</tr>
<tr>
<td>9</td>
<td>5000</td>
<td>4500</td>
<td>15</td>
<td>5000</td>
</tr>
<tr>
<td>15</td>
<td>5000</td>
<td>4500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Reusing Returned Concrete – HSA

Same Day Recycling

- **5%**
- **50%**

<table>
<thead>
<tr>
<th>Setting time, h</th>
<th>HSA Added at</th>
<th>Dose, oz/cwt</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 min</td>
<td>45 min</td>
<td>2</td>
</tr>
<tr>
<td>3 hr</td>
<td>3 hr</td>
<td>6</td>
</tr>
<tr>
<td>3 hr</td>
<td>3 hr</td>
<td>9</td>
</tr>
<tr>
<td>3 hr</td>
<td>3 hr</td>
<td>15</td>
</tr>
</tbody>
</table>

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Reusing Returned Concrete – HSA

<table>
<thead>
<tr>
<th>HSA Added at</th>
<th>45 min</th>
<th>45 min</th>
<th>3 hr</th>
<th>3 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose, oz/cwt</td>
<td>15</td>
<td>22</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>28-day Strength, ps</td>
<td>6000</td>
<td>5000</td>
<td>5500</td>
<td>4500</td>
</tr>
</tbody>
</table>

Overnight Recycling

Control

5% 50%
Challenges: Top-loading

- Standards
  - Attempts to revise ASTM C94
- Quality Control
  - Resources
  - A “real time” decision – difficult to plan
- Customer acceptance
- Credit in “green” ratings
- Economic
  - Incentives
  - Cost-benefit
Recycling Water
Recycled Water

- Reduce water usage to clean trucks and plants
- Use recycled water
  - Batch water in concrete
  - Plant and truck washing
  - Plant and yard wash down
  - Slump adjustment
  - Aggregate sprinklers

- Challenge: Disposal of solids
Water and Solids Management

Vary from simple to complex:
1. Pit or sedimentation ponds
2. Recycle clarified water
3. Basic reclaimers
4. Reclaimers - “Zero-discharge”
5. Reclaimers - “100% recycling” system w/HSAs
Typical

Truck wash, batch plant or discharge after treatment

Solids to landfill

Settling basin
Sedimentation (Washout) Basin
w/ Water Transfer Capability
Basic Reclaimer System
Drying Extracted Solids
Zero Discharge

Reclaimed Aggregates

Slurry Pit

Clear Water

Slurry Water

Recycler

Plant

Clear Water

Courtesy: Szeczy

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Reclaimers w/ Gray Water Recycling
Research – Use of wash water
Wash Water: Effect on Consistency

Target slump 3 – 5 in.

Air-entrained w/c = 0.40

Slurry Solids (kg/m³)

Control
Clarified
30 lb
60 lb

Mixing Water, lb/cu.yd.

U of Toronto

Slump (mm)

0
10
20
40

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Wash Water: Effect on Setting Time

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Constant Slump

Set Time, hrs

Control Clarified 30 lb 60 lb

0.00 1.00 2.00 3.00

Constant w/c

Air-entrained: w/c = 0.40

U of Toronto

Setting Time (hours)

0 2 4 6 8

Slurry Solids (kg/m³)

0 10 20 40

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Wash Water: Effect on Strength

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Constant Slump

Compressive Strength, psi

Control  Clarified  30 lb  60 lb

U of Toronto
Constant w/c

Strength (MPa)

Solids, kg/m³

0  10  20  40

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Zero Discharge - HSA

Courtesy: Knelson Concrete Recovery Systems
Zero Discharge - HSA

Courtesy: Knelson
Zero Discharge: w/ HSAs
Gray Water Recycling

- Monitoring gray water
  - Specific gravity
  - Temperature
  - Age
- Plumbing, back-flush
- Special water meters,
- Maintenance!
- QC buy-in
- Commitment and Training!
Wash Water/HSA: Effect on Setting Time

Slurry with 45 lb. solids to Mix

<table>
<thead>
<tr>
<th>Age of Slurry</th>
<th>Control</th>
<th>4 h</th>
<th>1d</th>
<th>7d</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Admixture</td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
</tr>
<tr>
<td>Low Dose</td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
</tr>
<tr>
<td>High Dose</td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
<td><img src="image" alt="Bar Graph" /></td>
</tr>
</tbody>
</table>
Wash Water/HSA: Effect on Strength

Slurry with 45 lb. solids to Mix

28-d Compressive Strength, psi

- Control
- No Admixture
- Low Dose
- High Dose

AGE OF SLURRY

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ASTM C1602 - Mixing Water

- Types
  - Potable
  - Non-potable
  - Water from ready mixed production

- Qualify for use
  - Strength
  - Setting time

- Optional
  - Chemistry
  - Solids

- Testing Frequency
ASTM C 1603 – Density and Solids Content

Density

Solids Content
### Gray Water Blend Chart

**Gray Water Blend Chart based on specific gravity of gray water**

<table>
<thead>
<tr>
<th>Gray Water Specific Gravity</th>
<th>% Gray Water</th>
<th>% Tap Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>1.02</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>1.03</strong></td>
<td><strong>99%</strong></td>
<td><strong>1%</strong></td>
</tr>
<tr>
<td>1.04</td>
<td>79%</td>
<td>21%</td>
</tr>
<tr>
<td>1.05</td>
<td>64%</td>
<td>36%</td>
</tr>
<tr>
<td>1.06</td>
<td>54%</td>
<td>46%</td>
</tr>
<tr>
<td>1.07</td>
<td>46%</td>
<td>54%</td>
</tr>
<tr>
<td>1.08</td>
<td>41%</td>
<td>59%</td>
</tr>
<tr>
<td>1.09</td>
<td>37%</td>
<td>63%</td>
</tr>
<tr>
<td>1.10</td>
<td>33%</td>
<td>67%</td>
</tr>
<tr>
<td>1.11</td>
<td>31%</td>
<td>69%</td>
</tr>
<tr>
<td>1.12</td>
<td>28%</td>
<td>72%</td>
</tr>
<tr>
<td><strong>1.13</strong></td>
<td><strong>26%</strong></td>
<td><strong>74%</strong></td>
</tr>
<tr>
<td>1.14</td>
<td>25%</td>
<td>75%</td>
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<tr>
<td>1.15</td>
<td>23%</td>
<td>77%</td>
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<tr>
<td>1.16</td>
<td>22%</td>
<td>78%</td>
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<tr>
<td>1.17</td>
<td>21%</td>
<td>79%</td>
</tr>
<tr>
<td>1.18</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>1.19</td>
<td>19%</td>
<td>81%</td>
</tr>
<tr>
<td><strong>1.20</strong></td>
<td><strong>18%</strong></td>
<td><strong>82%</strong></td>
</tr>
</tbody>
</table>

**Notes:**
- **Based on sp. gr. of Gray Water per ASTM C-94 Optional Table 3**
- (Limit of Total Solids in Mixing Water = 50,000 ppm)
- Chart Based on 35 gal. Water/500 lb. Cement Mix Design
Challenge: Recycle Water

- Specification clause

Mixing water for use in concrete shall be potable
Can we meet these goals???

Key Performance Indicators

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Challenges

- Performance
  - Identify Impact
  - Resolve
    - Resources
    - Technology and investment

- Standards
  - Do they restrict?

- Specifications
  - Will they permit?

- Customer Perception
And the biggest challenge

Does it make ECONOMIC sense
Challenges and Opportunities
Recycled Materials in Ready Mixed Concrete

Thank you

Questions