Building Materials Reclamation Program

Construction and Demolition Waste Used as Recycled Aggregates in Concrete:

Solutions for Increasing the Marketability of Recycled Aggregate Concrete

Brett Tempest, Tara Cavalline, Janos Gergely, and David Weggel
UNC Charlotte
Building Materials Reclamation Program

**UNC Charlotte Building Materials Reclamation Program Overview**

- Grant from the US Department of Energy
- **Purpose:**
  - Develop innovative and cost-effective ways of diverting construction and demolition (C&D) waste from landfills through recycling and reuse
  - Possibly develop strategies that create small business opportunities
- **Ongoing research as part of this grant:**
  - Reclamation and reuse of structural steel members
  - Use of gypsum wallboard as a soil amendment
  - Use of concrete and masonry rubble as recycled aggregate in concrete materials
Building Materials Reclamation Program

**UNC Charlotte Building Materials Reclamation Program Overview**
Building Materials Reclamation Program

Introduction

• Most RA used in ready-mixed concrete applications consists of crushed returned concrete.

• Some components of C&D waste, particularly concrete slabs, beams, columns, and masonry walls can be crushed and graded into RA material.

• Use of C&D waste as RA in concrete has been successfully demonstrated.

• Acceptance and use have not become widespread, particularly in Charlotte and Mecklenburg County, North Carolina.
Building Materials Reclamtion Program

**Goal of this Study:**

From a local/regional perspective, show that use of RA, produced from C&D waste, in concrete is

- Technically feasible
- Economically viable

- Investigate the feasibility of developing a substantial supply of concrete-grade RA from C&D waste
- Identify a range of potential concrete products that could potentially incorporate the RA from C&D waste
- Synthesize feedback from those involved in the industry regarding
  - impediments to more widespread use of RA from C&D waste in concrete applications
  - incentives that could promote acceptance and use
Building Materials Reclamation Program

**Current endpoint for RA comprised of C&D waste**

- **Worldwide:**
  - Europe has excelled at reusing high proportions of C&D Waste in new construction
  - RILEM and BRE have made strides towards a standard for recycled aggregate use in Portland Cement Concrete

- **In Mecklenburg County, North Carolina:**
  - Low-grade uses
    - Fill material
    - Surfacing material for temporary roads
    - Some roadbed material
  - Temporary roads at the Landfill
Building Materials Reclamation Program

**NCDOT Recycled Aggregate Usage**

- **Allowed**
  - Base course for roadway construction
  - Projects with special permission to include recycled material

- **Not Allowed**
  - Hot mix asphalt
  - Portland cement concrete
  - Miscellaneous

Division 1 – General Requirements
Section 104-13 Recycled Products or Solid Waste Materials

“It is the policy of the Department of Transportation to aid in reduction of materials that have become a part of our solid waste stream. To that extent the Department encourages contractors to initiate develop, and utilize products and/or construction methods that incorporate the use of recycled or solid waste products…”
### Building Materials Reclamation Program

#### NCDOT Recycled Aggregate Usage

**NCDOT Specifications Section 104-13**

Subsequently outlines:

- Procedure for submitting a Recycled Products or Solid Waste Materials Proposal for approval.

- Price adjustment provisions
  - Net savings can be shared with contractor under similar provisions to other Value Engineering Proposals
  - In the case of a new, innovative use not utilized by NCDOT, will award a bonus payment ($500 to $2,500) to the Contractor even if there is no net cost savings on the particular project.
Building Materials Reclamation Program

**RA in Mecklenburg County, North Carolina**

- **2005 statistics:**
  - Concrete and other hardscape rubble comprised 8% of the C&D waste produced
  - Approximately 28,000 tonnes

- Recent economic downturn has resulted in a reduced intake of rubble materials (and overall C&D waste volume)

- Currently, the C&D landfill has more internal demand for RA produced from C&D waste (for haul roads) than that which is being provided
Case Study – Idlewild Elementary School

- Demolished portion of school was built in 1953.
  - Concrete slab-on-grade
  - Reinforced and unreinforced masonry walls
  - Steel framed roof, some prestressed concrete double-tees
Building Materials Reclamation Program

Case Study – Idlewild Elementary School
On-Site Testing Prior to Demolition

- Concrete slab-on-grade
  - Documented location of portion of slab to be crushed, graded, and returned to laboratory
  - Cores removed
  - Rebound hammer testing

- Masonry walls
  - Documented location of walls to be crushed, graded, and returned to laboratory
  - Whole brick and whole clay tile samples removed
Building Materials Reclamation Program

**Top-Down Demolition Strategy**

- From demolition contractor’s standpoint, advantageous for several reasons:
  - Concrete slab-on-grade remains in place until remainder of building is cleared from site
    - Ensures that equipment has a sound surface to traverse
  - Concrete slab is used as a sorting pad for other materials
Building Materials Reclamation Program

**Top-Down Demolition Sequence**

1. Removal of hazardous materials such as asbestos
2. Removal of valuable metals (copper, non-critical steel structures)
3. Demolition of non-masonry partition walls, drop ceilings, and fenestration
4. Collection and disposal of materials listed in #3
5. Demolition and removal of roof framing, decking and covering
6. Demolition and removal of masonry partition and exterior walls
7. Demolition and removal of concrete slab
Building Materials Reclamation Program
Building Materials Reclamations Program
Building Materials Reclamation Program
Building Materials Reclamation Program
Building Materials Reclamation Program
Building Materials Reclamration Program
Building Materials Reclamation Program
Building Materials Reclamation Program

**Crushing Operations**

- Portions of concrete slab and masonry walls were transported (separately) to demolition contractor’s crushing operations.
- Crushed and graded
  - Minimal additional work was required to ensure that the material stayed “clean.”
  - No additional equipment was added and no operational changes made prior to crushing and grading of the material.
Building Materials Reclamation Program
Building Materials Reclamation Program
Building Materials Reclamation Program
Building Materials Reclamation Program
Building Materials Reclamation Program
### Characteristics of RA

Gradation of RA and Recycled Brick Masonry Aggregates Produced from Idlewild Elementary School Demolition Rubble

<table>
<thead>
<tr>
<th>Sieve Opening [mm]</th>
<th>Recycled Concrete Aggregate</th>
<th>Recycled Brick Masonry Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td>100</td>
<td>99.8</td>
</tr>
<tr>
<td>9.5</td>
<td>85.0</td>
<td>85.1</td>
</tr>
<tr>
<td>4.75</td>
<td>14.0</td>
<td>19.5</td>
</tr>
<tr>
<td>2.36</td>
<td>3.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Pan</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Building Materials Reclamation Program

**Characteristics of RA**

Characteristics of RA and Recycled Brick Masonry Aggregates Produced from Idlewild Elementary School Demolition Rubble

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Recycled Concrete Aggregate</th>
<th>Recycled Brick Masonry Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density (kg/m³)</td>
<td>1,281</td>
<td>975.5 (ASTM C29 shoveling procedure)</td>
</tr>
<tr>
<td>Absorption (%)</td>
<td>7.6</td>
<td>12.2</td>
</tr>
<tr>
<td>Abrasion Resistance (% lost)</td>
<td>TBD</td>
<td>43.1</td>
</tr>
</tbody>
</table>
### Building Materials Reclamation Program

#### Characteristics of RBMA

Composition of Recycled Brick Masonry Aggregate

<table>
<thead>
<tr>
<th>Material</th>
<th>% by weight</th>
<th>% by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay brick</td>
<td>64.5</td>
<td>63.9</td>
</tr>
<tr>
<td>Clay tile</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Mortar</td>
<td>30.1</td>
<td>31.6</td>
</tr>
<tr>
<td>Other (rock, porcelain, lightweight debris)</td>
<td>3.3</td>
<td>2.6</td>
</tr>
</tbody>
</table>
Building Materials Reclamation Program

*Development of Concrete Applications*

- Ongoing research
- Portland Cement Concrete
  - Recycled concrete aggregate (slab-on-grade)
  - Recycled brick masonry aggregate (brick masonry walls)
    - Development of concrete mixture designs, mechanical properties
- Geopolymer Concrete
  - Recycled concrete aggregate (slab-on-grade)
Building Materials Reclamation Program

Geopolymer Concrete Beams
with Recycled Aggregates
Building Materials Reclamation Program

Geopolymer Concrete Beams
with Recycled Aggregates
Building Materials Reclamation Program

**Development of Concrete Applications**

- **Overall:**
  - Careful source separation of reasonable quality C&D waste materials has resulted in production of a relatively consistent RA.

  - Concrete incorporating RA (up to 100% replacement) produced from C&D waste obtained at the case study site has exhibited acceptable fresh properties and mechanical properties.

- Findings to be presented in subsequent publications
Local and Regional Market for RA – Input from Those Involved in the Industry

- Demolition Contractors
- Aggregate Producers
- Concrete Producers

- Impediments preventing widespread acceptance and use of RA in concrete
- Possible incentives that could be used to promote use of RA in concrete
  - Particularly RA from C&D waste
Building Materials Reclamation Program

**Impediments to Use of RA in Concrete – Perspective of Aggregate Producers**

- Existence of on-site and low-grade uses for RA
- Potential for unsteady supply of source material
- No examples of large scale use
- Conflict with other cost centers within a company
- Equipment costs
- Limited awareness of crushing as a disposal option
- Availability of illicit dump sites
- Quarries have a political advantage in large projects
Building Materials Reclamation Program

**Impediments to Use of RA in Concrete – Perspective of Concrete Producers**

- Ready supply of virgin aggregates in the Mecklenburg County, NC area
- Preference for returned material, if RA is used
  - Known composition enhances comfort level
- Storage space and handling requirements
  - Space at a premium at many facilities
  - Cost to up-fit existing facilities with storage and conveying systems can be significant
- Lack of experience with recycled materials
  - Additional training and guidance, grounded in research and field study is needed
Building Materials Reclamation Program

Incentives and Tactics to Promote the Use of RA – Input from Aggregate Producers

- Waive tipping fees for higher quality rubble at crushing operations
  - Offset cost of hauling
- Provide income tax credits
  - Identified as perhaps the incentive of most interest
- Create demand from project owners
  - Tax credits for use or other incentives to encourage selection over virgin aggregates
- Create more stationary/permanent crushers
  - Capable of producing more consistently graded material
Building Materials Reclamation Program

**Incentives and Tactics to Promote the Use of RA – Input from Concrete Producers**

- Explore potential products and markets
  - Lower-strength uses such as footings
- Consolidate operations
  - If a single facility could receive and crush C&D waste, quarry virgin aggregates, and batch concrete, development of mixtures containing appropriate quantities of RA would be more feasible.
- Engineers submit their own quality control plan
  - For use on niche projects (such as buildings seeking LEED certification), specifications from engineer regarding source material handling, prequalification tests for mixtures, and additional testing requirements.
Conclusions

• In Mecklenburg County, North Carolina, RA produced from the existing stream of C&D waste is currently directed to non-concrete low-grade applications.

• Shortage of field experience with RAC in North Carolina has delayed interest in and acceptance of the material by engineers, contractors, and suppliers.
  – Much research and guidance on RAC has been centered on RA produced from returned concrete.
  – Additional research focusing on performance of RA from C&D waste sources needs to be performed.
Building Materials Reclamation Program

Conclusions

- Apprehension regarding use of C&D waste as RA based upon:
  - Potential for contamination of source material with other debris
  - Inconsistent physical properties

- “Top-down” demolition approach has been shown to address these concerns
  - Already routinely utilized by many demolition contractors
  - Has been shown to produce relatively clean and uniform sources of RA with satisfactory characteristics for PCC applications.
Building Materials Reclamation Program

Conclusions

- Concrete incorporating up to 100% RA produced from the case study site has been shown to exhibit acceptable performance.
  - Findings to be presented in subsequent publications

- Concrete producers can realize cost savings with RA
  - If supply and consistency of C&D waste increases, improved market interest in RA should follow.
  - Remaining impediments include:
    - Equipment and operational cost barriers
    - Other economic issues such as tipping fees, hauling costs, and increased product development expenses
Acknowledgements

- United States Department of Energy
- DH Griffin Wrecking Company
- DH Griffin Grading & Crushing
- Concrete Supply Company
- Vulcan Materials
- Argos USA
- National Ready Mixed Concrete Association
Building Materials Reclamation Program

Thank you...  Questions?