Construction and Demolition Waste Used as Recycled Aggregates in Concrete:

Solutions for Increasing the Marketability of Recycled Aggregate Concrete

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UNC Charlotte
Building Materials Reclamation Program

Introduction
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**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
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.
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
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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
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**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

- **Current economic conditions have 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**
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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
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 hammer testing

- **Masonry walls**
  - Documented location of walls to be crushed, graded, and returned to laboratory
  - Whole brick and whole clay tile samples removed
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
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**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
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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.
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## 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>% Finer</th>
<th>Recycled Brick Masonry Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td>100</td>
<td>99.8</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>85.0</td>
<td>85.1</td>
<td></td>
</tr>
<tr>
<td>4.75</td>
<td>14.0</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>2.36</td>
<td>3.0</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Pan</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>
# 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>
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>
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**Development of Concrete Applications**

- Ongoing research – findings in future presentations
- 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)
- 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.
Reclaimed Aggregates within Portland Cement Concrete

Mixed Demolition RCA – 28 Day Compression

Source Separated (Idlewild Elementary School) RCA - 28 Day Compression

Aggregates provided by D.H.Giffin Wrecking Co.
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Reclaimed Aggregates within Geopolymer Cement Concrete

- Recycled aggregates were mixed into the geopolymer concrete by replacing 10, 20, 30, 40, 50, 80, and 100% of the virgin aggregate volume.
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Geopolymer Concrete Beams with Recycled Aggregates
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Geopolymer Concrete Beams with Recycled Aggregates
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
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**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
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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
  - 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
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
Incentives and Tactics to Promote the Use of RA – Input from Concrete Producers

• Explore potential products
  – 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.
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.
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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
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Questions?
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**NCDOT Recycled Aggregate Usage**

- **Yes**
  - Base Course
  - Projects with Special Permission to include Recycled Material

- **No**
  - Hot Mix Asphalt
  - Portland Cement Concrete
  - Miscellaneous