Dr. Medhat H. Shehata is a Professor in the Department of Civil Engineering at Ryerson University, Ontario, Canada. Dr. Shehata has 25 years of industrial and academic experience pertaining to construction material. His areas of expertise include properties, deterioration mechanisms and long-term performance of concrete, development of test methods and standards, construction sustainability and green buildings, recycling of construction and industrial wastes, and development of new construction materials. Dr. Shehata is the current Chair of the Engineering mechanics and Materials of the Canadian Society for Civil Engineering. He is also a member of various international technical committees including Canadian Standards Association, CSA A23.1 and A23.2, the Technical Subcommittee on Alkali-Aggregate Reaction of CSA, and Committee C.09, Concrete and Aggregate and subcommittee 09.26, Chemical Reaction of the American Society for Testing and Materials (ASTM).

Reclaimed Concrete Aggregate (RCA)
Reclaimed or recycled concrete aggregate is produced from processing of demolished concrete structures or returned-to-plant concrete.
Problem Definition

- In Canada, RCA has been used with success as granular base for pavements
- The use of RCA in some construction applications such as Controlled Low Strength Materials (CLSM) is under consideration
- The lack of availability of natural aggregates in some locations may push for the use of RCA in structural concrete

Reactivity of RCA and Preventive Measures

- **RCA**: a concrete block placed in 1991 with (GUPC) and highly reactive siliceous limestone coarse aggregate from Ottawa, Ontario (Spratt).
- **Virgin Reactive Aggregate**: The same aggregate used in the test block
Materials Cementing Material

- Low-Alkali GU PC, Na₂Oₑ = 0.56%
- High-Alkali GU PC, Na₂Oₑ = 0.96%
- Silica Fume
- Slag
- F-LA: CaO = 4.4%  Na₂Oₑ = 1.95%
- F-HA: CaO = 6.4%  Na₂Oₑ = 4.30%
- CI-LA: CaO = 17.0% Na₂Oₑ = 2.10%
- CH-LA: CaO = 28.7% Na₂Oₑ = 2.16%
- Lithium Nitrate

Experimental Techniques

- Concrete Prism Test
- Accelerated Mortar Bar test
- Concrete Microbar Test
- Scanning Electron Microscopy and Energy Dispersive X-ray analysis

Test Methods

<table>
<thead>
<tr>
<th>Concrete Prism Test</th>
<th>Accelerated Mortar Bar Test</th>
<th>Concrete Microbar Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>ASTM C 1293</td>
<td>ASTM C1260 and C 1567</td>
</tr>
<tr>
<td>Mixture</td>
<td>Concrete</td>
<td>Paste + Coarse aggregate</td>
</tr>
<tr>
<td>Dimension</td>
<td>75 x 75 x 285 mm</td>
<td>25 x 25 x 285 mm</td>
</tr>
<tr>
<td>Aggregate</td>
<td>19.0 – 4.75 mm + sand</td>
<td>40 x 40 x 160 (or 285) mm</td>
</tr>
<tr>
<td>Soaking solution</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Duration</td>
<td>1 or 2 years</td>
<td>14 to 28 days</td>
</tr>
<tr>
<td>Temperature</td>
<td>38 C</td>
<td>80 C</td>
</tr>
</tbody>
</table>
Aggregate Dilution: A practical Mitigation Approach

Most concrete applications would include blends of RCA and natural aggregates to reduce volume change (shrinkage) and maintain other durability aspects.

Most concrete mixtures include one of more types of SCM

Will "practical" level of SCM mitigate ASR in concrete with blends of reactive RCA and non-reactive natural aggregate?
Preventive Measures

![Graph showing Expansion (%)](image)

**Age** (Weeks)

<table>
<thead>
<tr>
<th>Expansion (%)</th>
<th>Age (Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 0.05 0.10 0.15 0.20 0.25</td>
<td>0 20 40 60 80 100 120</td>
</tr>
</tbody>
</table>

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Accelerated Testing

**Accelerated Mortar Bar Test**

*With Minor Modifications*

![Graph showing 2-Year Expansion of CPT (%)](image)

**14-Day Expansion of AMBT**

- 5% SF/30% LCFA
- 70% RCA
- 70% RCA with 25% CFA

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Sample Processing

![Sample images](image)
<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Location</th>
<th>Rock Type</th>
<th>AMBT 14d exp, %</th>
<th>CPT 1-year exp, %</th>
<th>Reactivity level</th>
<th>Block Age</th>
<th>Average Expansion %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta Gravel</td>
<td>Calgary (Canada)</td>
<td>Gravel, sandstone, limestone, quartzite and mixed volcanics</td>
<td>0.360</td>
<td>0.090</td>
<td>Moderate</td>
<td>14 years</td>
<td>0.423</td>
</tr>
<tr>
<td>Springhill Limestone</td>
<td>Fredericton (Canada)</td>
<td>Crushed greywacke</td>
<td>0.463</td>
<td>0.217</td>
<td>High</td>
<td>16 Years</td>
<td>0.563</td>
</tr>
<tr>
<td>Potsdam Sandstone</td>
<td>Montreal (Canada)</td>
<td>Siliceous sandstone</td>
<td>0.090</td>
<td>0.130</td>
<td>High</td>
<td>14 Years</td>
<td>0.193</td>
</tr>
<tr>
<td>Bernier Limestone</td>
<td>St-Jean sur-le-Richelieu(Canada)</td>
<td>Argillaceous limestone</td>
<td>0.173</td>
<td>0.069</td>
<td>Moderate</td>
<td>14 Years</td>
<td>0.092</td>
</tr>
</tbody>
</table>

Source: Adams et al. 2012
Conclusions

- Mitigating expansion in concrete containing reactive RCA could be achieved using ternary blends of silica fume and low or intermediate calcium fly ash of alkali content ≤ 2.0% Na₂Oₑ.

- Ternary blends of 20% Type F fly ash and 30% slag was also effective in mitigating the expansion in concrete with 100% RCA used as coarse aggregate.

- The use of lithium nitrate with SCM reduced the expansion of concrete; however, the levels of investigated lithium and SCM were not enough to limit the expansion to < 0.04% at 2 years.

- Blending the reactive RCA with non-reactive coarse aggregate reduced the expansion compared to concrete with 100% RCA used as the coarse aggregate.
Conclusions

- Practical levels of SCM's (25% fly ash of CaO < 20% and 50% slag) were effective in mitigating the expansion in concrete with reactive RCA blended with 30% non-reactive natural stones.

- The concrete microbar test showed promising results in terms of predicting reactivity of RCA. More work is needed to investigate the capacity of the test to evaluate preventive measures.