Uses of Red Mud as a Construction Material

By:

Mohamed Abdel-Raheem, PhD, PMP, LEED GA, LSSGB, CM-BIM, CM-Lean
Assistant Professor
Department of Civil Engineering

Lizeth G. Santana, Miguel Piñeiro Cordova, Bilkis O. Martinez
Undergraduate Student
Department of Civil Engineering
Agenda

- Red Mud: An Overview
- Waste Management and Disposal Practices of RM
- Chemical Characterization
- Previous Studies
  - Raw Material in Cement Production
  - Red Mud as a Construction Material
  - Partial Cement Replacement
  - Other Applications
- Objective
- Methodology
- Preliminary Findings
- Conclusions
Red Mud: An Overview

- Caustic waste from alumina refining industry.
- Classified as hazardous by EPA prior to 1990 and a regular waste thereafter.
- Disposal has raised concerned of impact on environment and economy.
- RM characteristics qualify it as a versatile construction material.

Aerial view of red mud landfills in the U.S.
Current Waste Management and Disposal Practices of RM

1. **Sea Water Discharge**
   RM is transported to sea via pipes.

2. **Lagooning**
   RM is left in clay-lined landfills.

3. **Dry Stacking**
   RM is dewatered and dried in layers.

4. **Dry Disposal**
   RM is washed, some components removed and dried.
Chemical Characterization

- Major compounds in RM:
  - SiO$_2$ (2-20%)
  - Al$_2$O$_3$ (15-30%)
  - Fe$_2$O$_3$ (25-55%)
- Low on CaO
- RM Composition varies by:
  - Bauxite origin
  - Refinement process
  - Country of refining
  - Method of disposal

<table>
<thead>
<tr>
<th>Composition by wt. %</th>
<th>Red Mud</th>
<th>Portland Cement</th>
<th>Hydrated Lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO</td>
<td>17</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>AlO</td>
<td>20</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>FeO</td>
<td>36</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>CaO</td>
<td>4</td>
<td>64</td>
<td>90</td>
</tr>
</tbody>
</table>
Previous Studies

1. Raw Material in Cement Production
2. Partial Cement Replacement
3. RM in Brick Manufacturing
4. RM as a Corrosion Inhibitor
Previous Studies

1- Raw Material in Cement Production

1. Iron rich cements: lime, gypsum, red mud and bauxite.
   - Results: new cements have higher strengths than ordinary Portland cement when they were heated up to 1250°C for 1.5 hours

2. Cement produced: using lime, red mud, bauxite, gypsum and fly ash.
   - Results: (1) lime, red mud and bauxite and (2) lime gypsum, red mud and bauxite gave 28-day compressive strengths comparable to those obtained using ordinary OPC.
   - Cement mixtures made with fly ash were not as successful
Studies show discrepancies in optimum replacements percentages:
- 2% (Kushwaha et al. 2013)
- 10% (Rana et al. 2015),
- 20% (Bishetti et al. 2014)
- 25% (Rathod et al. 2012)

Several studies: agree increasing replacement beyond 15% would reduce compressive strength.
Previous Studies

2- Partial Cement Replacement (cont’d)

- RM concrete:
  - 15% RM & 5% hydrated lime
  - Comparable Compressive strength to OPC concrete

- RM in mortar reached optimal strengths:
  - 10% RM, 4% lime & 20% silica fume
  - Comparable Compressive strength to OPC concrete

- Discrepancies may be attributed to:
  - Alumina refining process
  - Origin of red mud and/or alumina
  - Unreported mix proportions
Previous Studies

3- RM in Bricks

• Several studies explored the use of red mud as a component in clay bricks
• Bricks made of fly ash and red mud: had a maximum compressive strength between 5 and 6 MPa
• Bricks were made using clay wastes and fine wastes from boron and red mud: fired at 700, 800 and 900°C.
• In general, the compressive strength of the bricks increased with a higher firing temperature
• Light weight red mud bricks: red mud + fly ash + foaming agent
Previous Studies

4- RM as a Corrosion Inhibitor

• Steel immersed in NaOH and RM solution differed in corrosion potential.
  ▫ RM solution showed lower corrosion potential.
Objective

1. Provide a comprehensive literature review for the uses of Red Mud to serve as a foundation for future research.

2. Assess the feasibility of utilizing red mud produced in the United States for incorporation into concrete.

3. Reduce environmental impact by effectively utilizing the red mud waste.
Methodology

1. Literature Review
2. Material Procurement
3. Material Processing
   • Mixing (ASTM C305-14)
4. Testing Samples
5. Observations
Preliminary Findings: Cement Replacement

- Mortar’s compressive strength **decrease** with higher % cement replacements

<table>
<thead>
<tr>
<th>Replacement %</th>
<th>Compressive Strength, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>30.3</td>
</tr>
<tr>
<td>5%</td>
<td>25.3</td>
</tr>
<tr>
<td>10%</td>
<td>25.0</td>
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<tr>
<td>15%</td>
<td>21.6</td>
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<tr>
<td>20%</td>
<td>27.0</td>
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<td>30%</td>
<td>28.9</td>
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<tr>
<td>40%</td>
<td>17.5</td>
</tr>
<tr>
<td>50%</td>
<td>11.2</td>
</tr>
</tbody>
</table>
Preliminary Findings: Sand Replacement

- Compressive strength **increases up to 30% replacement of sand.**

<table>
<thead>
<tr>
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<th>Compressive Strength, Mpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>28.3</td>
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<td>5%</td>
<td>44.2</td>
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<td>10%</td>
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<td>20%</td>
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<td>30%</td>
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<tr>
<td>40%</td>
<td>4.6</td>
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<tr>
<td>50%</td>
<td>8.4</td>
</tr>
</tbody>
</table>
Conclusions

• RM as cement replacement negatively affects mortar compressive strength.

• RM as sand (up to 30% ) replacement improves mortar strength.
References


Thank You