Portugues Dam

RCC Materials Investigation
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• **Outline**
  – Goals
  – Mix Design Parameters
  – Materials
  – Test Program
  – Tests on Laboratory Simulated Lift Joints
  – Conclusions
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RCC Materials Investigation

• **Goals**
  – Determine behavior/characteristics of potential project materials
  – Determine properties for use in design analysis
  – Determine mix proportions for use in test fill placement(s)
  – Provide information for use in adjusting mixtures during production
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- **Mix Design Parameters**
  - **Workability**
    - Vebe Consistency 14 to 20 seconds
    - Entrapped Air Content 1.0%
    - Coarse aggregate proportions and aggregate grading:
      - EM 1110-2-2006, “Roller Compacted Concrete”
      - Sand aggregate volume selected to limit segregation
    - Fine aggregate content:
      - Selected by trial mixes to limit segregation
  - **Strength**
    - Compressive Strength Range 3000 to 5000 psi
    - Tensile Strength 300 psi +/-
      (Design based on potential of materials!)
  - **Pozzolan**
    - Targeted 40% cement replacement by volume based on previous experience and “comfort” level of designers.
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- **Materials**
  - Aggregates: Crushed diorite from government-owned quarry
  - Cement:
    - San Juan Cement Co., Type I, San Juan
    - Puerto Rican Cement Co., Type I, Ponce
    - Antilles Cement Co., Type I/II, Aalborg (Denmark)
    - Lone Star Cement Co., Type I/II, (Control)
  - Pozzolan:
    - Dolet Hills, Class F
    - Martin Lake, Class F
  - Slag:
    - Holnam GGBS, Grade 100, Chicago
  - Admixtures:
    - Master Builders WRA, Pozzolith 220N and 100-XR
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- **Materials Investigation Program**
  - **Phase I**
    - Establish baseline proportions for RCC mixtures
    - Proportion series of mixes to span 1-year compressive strength of 2000 to 5000 psi (including modulus of elasticity)
    - Proportion series of mixes to evaluate effect of cement and pozzolan type
    - Proportion series of mixes to evaluate use of slag
    - Proportion series of mixes to investigate effect of pozzolan content
    - Proportion series of bedding mortar mixes
    - Perform direct tensile strength tests on “jointed” 6x12-inch cylinders
    - Select “design” mix
Compressive Strength vs W/C (w/40% Dolet Hills Ash)

Puerto Rican
Aalborg
Essroc Cement
Lone Star

W/C by weight equivalent cement
Compressive Strength vs W/C
(Aalborg Cement with varying Ash %)

Test set age 90-days

W/C by weight equivalent cement
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- **Materials Investigation Program**
  - **Phase I Supplemental**
    - Perform dry rodded unit weight tests to verify coarse aggregate proportions
    - Proportion series of mixes at varying sand contents to verify sand aggregate content
    - Proportion series of mixes to further investigate use of higher pozzolan contents (60 and 75-percent cement replacement by volume)
    - Proportion series of mixes with varying WRA/Retarding admixture dosage to evaluate effect on time of set
    - Perform sand degradation tests to investigate sand balling anomaly
    - Proportion mix with “clean” sand to evaluate effect on compressive strength and workability (water content)
    - Perform “modified” accelerated cure strength tests to evaluate compressive strength gain of high pozzolan content mixes
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- **Materials Investigation Program**
  - **Phase IIa**
    - Construct series of panels to investigate direct and splitting tensile strength and biaxial direct shear strength of lift joints
  - **Phase II**
    - Modulus of Elasticity and Poisson’s Ratio Tests
    - Creep and Autogenous Volume Change Tests
    - Adiabatic Temperature Rise Tests (Including Q-drum)
    - Thermal Diffusivity
    - Coefficient of Thermal Expansion
    - Specific Heat
    - Tensile Strain Capacity
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Standard Procedures
Simulated Lift Joints

- Nominal 46 x 72 x 12-inch thick panels
- Constructed in two lifts using varying lift joint treatments
- RCC consolidated using walk-behind vibratory roller
- Core and sawn block samples for direct and indirect tensile strength, bi-axial direct shear strength
- Results intended for use in evaluating effect of fly ash, retardation, joint maturity, fines content
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2000 °F-hr Joint Maturity with Bedding Mortar

Normal Stress = 100 psi

Shear Stress, psi vs. Shear Displacement, in.
Portugues Dam RCC
Panel D/B6
Mixture 6d (40% Fly Ash); 2,000 deg F-hr Joint Maturity; With Bedding Mortar
Nominal Normal Stress = 400 psi
Portugues Dam RCC
Panel D/B6
Mixture 6d (40% Fly Ash); 2,000 deg F-hr Joint Maturity: With Bedding Mortar
Nominal Normal Stress = 400 psi
# Selected Results: BiAxial Direct Shear

<table>
<thead>
<tr>
<th>Joint Treatment</th>
<th>Cohesion, psi</th>
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<tbody>
<tr>
<td>Design Mix, 500°F-Hr</td>
<td>266</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr</td>
<td>275</td>
</tr>
<tr>
<td>75% Ash, 2000°F-Hr</td>
<td>139</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr w/bedding</td>
<td>448</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr Retarded</td>
<td>408</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr Clean Sand</td>
<td>316</td>
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</tbody>
</table>

*Tests at age 90-days
Selected Results: Direct Tensile Strength Tests

<table>
<thead>
<tr>
<th>Joint Treatment</th>
<th>Direct Tensile*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Mix, 500°F-Hr</td>
<td>385</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr</td>
<td>220</td>
</tr>
<tr>
<td>75% Ash, 2000°F-Hr</td>
<td>180</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr w/bedding</td>
<td>345</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr Retarded</td>
<td>275</td>
</tr>
<tr>
<td>Design Mix, 2000°F-Hr Clean Sand</td>
<td>285</td>
</tr>
</tbody>
</table>

*Tests at age 365-days
Conclusions

- The comprehensive test program conducted for the Portugues Dam Project has provided invaluable insight on the behavior and characteristics of RCC and other concreting materials.
- The COE has significant expertise in the design, evaluation and use of RCC. This expertise is readily accessible through the RCC DX and Materials CoP.
Questions?

(Thank You!)