Update on Air Entrained Grout Enriched RCC Research

Jeremy Young, PE / November 5, 2018
Acknowledgements

• Dave Campbell and Preston Frey
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• Gary Horninger and Doug Fairchild

• Dr. Eric Musselman, Robert Flynn, George Zimmer, Sean Pousley and Villanova University

• John Bowen and ASI Constructors
Roller Compacted Concrete
RCC Gravity Dams
Hickory Log Creek Dam (GA)
RCC Stepped Spillways
Monksville Dam (NJ)
Facing Systems – Geomembrane Liners

Photo courtesy of Carpi
Facing Systems –
Grout Enriched RCC (GERCC)
**ADVANTAGES**

- Durable
- Relatively Impermeable
- Attractive Facing
- Seamless Transition
- Simplified Construction
  - Elimination of Separate Batching, Mixing, etc.
  - Concurrent Placement
- Less Costly

**LIMITATIONS**

- Limited Use in US
- Lack of Understanding of Grout Consistency
  - ‘Dry’ US RCC Mixes
  - Stiff Grout Mixes
  - Dosage Rates
- Concern w/ Freeze-Thaw (F-T) Durability
- Limited Success with Prior Attempts to Entrain Air
Research Collaboration

- Stipend
- RCC Expertise
- Field Testing Equipment

- Laboratory Facility
- Graduate Assistants
- Concrete/Grout Expertise
Research Goals

Evaluate Grout Formulations w/ Air Entraining and Supportive Admixtures

Experiment w/ GERCC Construction Techniques

Promote Cost Effective GERCC Construction in Climates Subject to F-T

Improve GERCC F-T Resistance
Phased Approach to Research (2015-2016)

Phase 1
• Evaluate Various Grout Mixes to Produce Stable Air Void Matrix

Phase 2
• Small Scale Lab AE GERCC Production to Identify Optimal Grout Mix and Evaluate F-T Resistance

Phase 3
• Large Scale Lab AE GERCC Production to Evaluate Construction Techniques and F-T Resistance

Phase 4
• Field Trials
Determine admixture dosage rates that will produce a grout with 15%-25% air content

Evaluate stability of air void matrix through simulated vibration

Examine effect of combining AE admixtures with other admixtures

Identify most promising admixtures combo for use in future phases
Phase 1 Results
Flynn, 2015

• 37 Unique Grout Mixes

• Higher and More Stable Air Content w/ Synthetic AEA

• Latex Based Water Repelling Admix may Increase Air Content and Improve Stability

• Negative Impact w/ WRA and Powder Water Resisting Admix
• Evaluated 6 RCC mix designs developed per ACI 211.3

• 375 lbs/cy Cement

• No Pozzolan Content

• Vebe Times: 30 secs (179 lbs free water/cy)

• Evaluated Grout with 7 Different Admixture Combinations
Phase 2 - Small Scale Lab GERCC Production
Flynn, 2015
Phase 3 - Large Scale Lab GERCC Production
Flynn, 2015

- Grout on Top
- Grout on Bottom
- Grout by Injection
Phase 3 – Grout Penetration
Flynn, 2015

Grout on Top

Grout on Bottom

Grout Injected
• Found that synthetic air entrainer provided most stable air void system in grout

• Latex Based Water Repelling Admixture also helped to improve air void stability and improved F-T resistance by reducing permeability
• When grout and RCC are combined in a drum mixer, excellent F-T resistance is achieved

• When grout and RCC are combined using field techniques simulated in lab, F-T resistance is improved some

• Injection of grout showed good performance in lab trials
Developing an Optimal Grout Formulation for Air-Entrained Grout-Enriched Roller-Compacted Concrete

Robert J. Flynn
&
Dr. Eric Musselman

Department of Civil and Environmental Engineering
Villanova University
Field Trial – October 2015

- Conducted at Duck River Dam (AL) by ASI Constructors

- Validate Simulated Construction Processes and Material Formulations Developed in Lab

- Evaluate Various Levels of Vibration and Grout Dosage on F-T Resistance

- Placed two 12” thick lifts of RCC (18’ X 50’)
  - 190 lbs/cy Cement
  - 129 lbs/cy Flyash
  - 15 sec Vebe Time
2015 Field Trial – Duck River Dam
• Evaluated 3 Different Placement Techniques:
  - Grout on top of RCC (GT)
  - Grout on bottom of RCC (GT)
  - Grout injected into RCC

• Evaluated 3 Grout Dosage Rates (per ft of facing)
  - 1 gal/ft (Low), 1.5 gal/ft (Med) and 2 gal/ft (High)

• Evaluated 4 Levels of Internal Vibration
  - None, Low, Med and High
Grout Injector
• Grout on Bottom Placement Method Not Considered Viable
  - Unable to Apply Sufficient Vibration/Energy to Move Grout Up Through RCC

• Injection Method was Preferred to Grout on Top
  - Appeared to Result in Better Mixing and Allowed Better Control of Grout Distribution
  - Preferred by Contractor
2015 Field Trial – Grout Coverage
Zimmer, 2016
Effects of Grout Coverage
Zimmer, 2016

• Sample Before Testing
• Sample After Testing
Conclusions from Phases 1-4
Zimmer, 2016

- Grout can maintain a high level of air entrainment with good stability under reasonable vibration

- Higher levels of vibration is beneficial because it increases both consolidation and mixing for improved freeze thaw performance

- Higher dosage improves mixing and freeze thaw performance

- The grout injection technique is the superior method in both grout penetration and freeze thaw performance. It can speed construction which can save cost
Recommendations for Future Research
Zimmer, 2016

• Develop Method with Improved Vibration Energy
• Evaluate options to mechanically mix grout and RCC in the field
  - Improved Grout Injectors
  - Mini ‘Jet Grouter’?
  - Roto-tiller?
  - Augers?
• Potential Development of Mechanize Tools
• Investigate Effects of Entraining Air in RCC
• Evaluate Admixtures to Improve Grout Penetration/ Weaken RCC Paste Around Coarse Aggregate?
2017 Research

Phase 1 • Evaluate Various Factors Related to Grout Injection on Grout Distribution

Phase 2 • Field Trial

Phase 3 • Lab AE GERCC Production to Evaluate Alternate Construction Techniques

Phase 4 • F-T Testing of Phase 2 and 3 Specimens
Phase 1 – Grout Injection Evaluation
Pousley, 2017

- 2 nozzle configurations, 4 trials each
- Varying pressure (12.5 psi – 100 psi)
- RCC mix design:
  - 300 lb/yd³ cement
  - 100 lb/yd³ Fly Ash
  - w:c = 0.65
- Grout penetration and coverage inconclusive in laboratory setting
Phase 2 – 2017 Field Trial
Pousley, 2017

• Test section at Lunga Dam, Quantico MCB by ASI Constructors

• RCC mix design:
  - 300 lb/yd\(^3\) cement and 100 lb/yd\(^3\) Fly Ash
  - w:c = 0.60
  - Single aggregate

• 3 construction methods:
  - Grout injection w/ vibration during
  - Grout injection w/ vibration after
  - Trench?
Trench Method (or GEVR-ish?)

- Trenches dug with backhoe
- Grout poured via hose, RCC shoveled by hand
- GERCC consolidated and compacted using 2” vibrator and plate compactor
Phase 3 – Lab Evaluation of Alternate Construction Techniques

- **Trench**

- **Auger**
  - Grout placed on surface of RCC
  - Auger drill raised and lowered vertically into RCC to mix grout
  - 2” vibrator used to consolidate GERCC

- **Rototiller**
  - Grout placed on surface of RCC
  - Rototiller “driven” back and forth across surface of RCC to mix grout
  - 2” vibrator used to consolidate GERCC
Phase 3 – Grout Distribution
Pousley, 2017

Auger

Rototiller
Phase 3 – Improved Grout Penetration

Typical Injection Specimen 2016

Typical Auger Specimen 2017
## Phase 2 - 2017 Field Trial

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### Phase 4 – Freeze-Thaw Testing

**Pousley, 2017**

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### Phase 3 – Auger and Rototiller

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In terms of grout injection (and air entrainment?), grout distribution is highly dependent on the workability of the RCC.

Compared to traditional methods, the trench method leads to better performance along the front formed face.

Overall, mechanical mixing is the best method for producing AE GERCC resistant to freeze-thaw.
• Effects of grout dosage and RCC mix proportions on mechanical mixing methods should be investigated

• A mechanical mixing apparatus should be designed and fabricated for use in the field

• Field trials should be conducted to determine the effectiveness of mechanical mixing under full-scale conditions