Effective Partnering to Overcome an Interruption in the Supply of Portland Cement During Construction at Marmet Lock and Dam

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We have a problem!
The Problem

- A full silo of type II, HH portland cement at the Armstrong Cement facility in Cabot, PA was ruined by rising flood waters in October 2004.

- The loss occurred approximately 1 to 2 weeks before the cement was scheduled to be delivered to the Marmet construction site.
The Time Crunch

- The supply of type II, HH cement remaining at the construction site would be exhausted within 2 weeks, or less.

- Armstrong Cement would require approximately 4 to 5 weeks to produce and deliver another shipment of type II, HH cement.

- Concrete placements would be halted within approximately 2 weeks unless a suitable alternative could be found.
The Challenge

- Find an acceptable solution within less than 2 weeks that would allow concrete placements to continue uninterrupted, while maintaining the integrity and quality of the concrete construction.
The Team

- Huntington District
- Kokosing / Fru-Con
- ERDC
Available Options

- Use type II portland cement, without the HH restrictions, from Armstrong (proposed by Kokosing / Fru-Con; preferred by ERDC)

- Procure type II, HH portland cement from another source

- Discontinue concrete placements until a new shipment of type II, HH portland cement could be delivered from Armstrong (last resort)
The BIG Question

- Determine whether a mixture with type II portland cement, without the heat of hydration restriction, and a modest increase in fly ash content will have an acceptably low adiabatic temperature rise comparable to a similar mixture using type II, HH portland cement and a lower amount of fly ash
The Dilemma

- Ongoing placements were guide-wall cells being filled with a high-slump tremie mixture for which no temperature rise data existed.

- Temperature rise data existed only on two 3-in. NMSA mass mixtures with type II HH cement.

- Not enough time to measure actual temperature rise in the laboratory on any mixtures using type II cement without the HH restriction.
A Multi-Pronged Approach

- Kokosing / Fru-Con to cast 2 well-insulated and instrumented test cells of concrete, with the portland cement being the only variable
  - Armstrong type II, HH
  - Armstrong type II

- Kokosing / Fru-Con to review construction schedule looking for ways to
  - Slow demand for concrete, and
  - Move less critical placements forward without severely hindering overall schedule
A Multi-Pronged Approach

❖ ERDC to conduct a review of literature to estimate potential temperature difference based upon heat of hydration of cement and fly ash content

❖ ERDC to conduct a review of available project data to estimate potential temperature difference based upon mixture proportions

❖ ERDC to analyze all available data and make final recommendation on mixtures
A Multi-Pronged Approach

- Huntington to coordinate efforts between Kokosing / Fru-Con and ERDC

- Huntington to make final decision to use of type II portland cement, without the HH restriction, or to terminate concrete placements until type II, HH available again
Mixture 348 Used in Test Cells

- Portland cement – 70% by volume
- Fly ash – 30% by volume
- w/(c+m) – 0.485
- Type portland cement
  - Type II, HH
  - Type II
Test Cell
Test Cell
Test Cell
Test Cell Temperatures

Type II Center
Type II, HH Center
Air

Degrees F

Hours

0 24 48 72 96 120 144 192 216 240 264 288 312 336 360 384 408 432 456 480 504 528 552
Baseline Mass Mixtures with Type II, HH

Temperature Rise - deg F

Time - days
Test Cells

Time - days

Temperature Rise - deg F

Large Qdrum Test - Interior Mass 2A
Large Qdrum Test - Exterior Mass 1A
Marmet Field Experiment - Type II HH_est Adiabatic
Marmet Field Experiment - Type II HH curve fit
Marmet Field Experiment - Type II_est Adiabatic
Marmet Field Experiment - Type II curve fit
Type II, HH versus Type II

Temperature Rise - deg F

Time - days

Large Qdrum Test - Interior Mass 2A
Large Qdrum Test - Exterior Mass 1A
Est. Large Q-drum Interior Mass 2A w/ Type II
Est. Large Q-drum Exterior Mass 1A w/ Type II

+ 11

US Army Corps of Engineers
Engineer Research and Development Center
## Analysis of Mixture Proportions

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>w/(c+m)</th>
<th>Fly Ash</th>
<th>PC</th>
<th>Total</th>
<th>FA</th>
<th>Water</th>
<th>temp rise</th>
<th>Estimated maximum</th>
<th>Estimated temp rise</th>
<th>Estimated increase in temp</th>
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<td>0.49</td>
<td>20</td>
<td>281</td>
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<td>351</td>
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<td>175</td>
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<td>61</td>
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<tr>
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<td>30</td>
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<td>269</td>
<td>66</td>
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<td>46</td>
<td>175</td>
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<td>277</td>
<td>60</td>
<td>73</td>
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</table>
Heat of Hydration Analysis

 Thesis

- Temperature rise = \( HH \text{ of cement} \times \text{cement fraction} \) \( \frac{\text{heat capacity of concrete}}{\text{heat capacity of concrete}} \)

- Adjust cement fraction for \% fly ash

- \( dT = (1.3 \times HH + ((1.3 - 0.51(\% \text{ fly ash}))) \times \% \text{ cement} \) \( \frac{\text{heat capacity of concrete}}{\text{heat capacity of concrete}} \)
Heat of Hydration Analysis

Example calculations

\[ dT = (1.3 \times HH + (1.3 - 0.51(\% \text{ fly ash}))) \times \% \text{ cement} \]

heat capacity of concrete

\[ dT = ((1.3)(79) + (1.3 - (0.51)(30))) \times 0.1231 = 45^\circ C \]

\[ 0.24 = 82^\circ F \]

\[ dT = ((1.3)(68) + (1.3 - (0.51)(30))) \times 0.1231 = 38^\circ C \]

\[ 0.24 = 69^\circ F \]
Heat of Hydration Analysis

Example calculations

\[ dT = (1.3 \text{ HH} + (1.3 - 0.51(\% \text{ fly ash}))) \times \% \text{ cement} \]

heat capacity of concrete

\[ dT = ((1.3)(79) + (1.3 - (0.51)(30))) \times 0.1231 = 45^\circ \text{ C} \]
\[ 0.24 = 82^\circ \text{ F} \]

\[ dT = ((1.3)(79) + (1.3 - (0.51)(45))) \times 0.1231 = 42^\circ \text{ C} \]
\[ 0.24 = 75^\circ \text{ F} \]

\[ dT = ((1.3)(79) + (1.3 - (0.51)(45))) \times 0.1231 = 42^\circ \text{ C} \]
\[ 0.24 = 38^\circ \text{ C} \]

\[ dT = ((1.3)(79) + (1.3 - (0.51)(45))) \times 0.1231 = 38^\circ \text{ C} \]
\[ 0.24 = 69^\circ \text{ F} \]
The Conclusion

- Mixtures comprised of type II portland cement, without the HH restriction, combined with a modest increase in fly ash to 40 to 45% will result in a mixture that has a significantly higher temperature rise than the mixture it would be replacing.

- A significantly higher fly ash content will be required to adequately reduce the temperature rise.

- The required fly ash content would be higher than anything the Corps had a ready history of using.
What’s the Bottom Line?

- The required fly ash content appeared to be approximately 60%, by volume

  - Would Huntington District be willing to use mixtures with 60% fly ash?

  - Would Kokosing / Fru-Con be willing to use mixtures with 60% fly ash?
Brave Souls
(or was it desperation)

- Huntington District said YES
- Kokosing / Fruj-Con said YES
- ERDC provided a tentative substitute for use in the guide-wall cells
The Result

- Starting on 6 Nov 2004, the mixture with 60% fly ash was used to fill 2-1/2 cells

<table>
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<th></th>
<th>7-day</th>
<th>28-day</th>
<th>90-day</th>
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<tr>
<td>30% ash + HH</td>
<td>1,300</td>
<td>4,000</td>
<td>5,500</td>
</tr>
<tr>
<td>60% ash + reg II</td>
<td>1,300</td>
<td>3,000</td>
<td>4,800</td>
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</table>

- Fewer cracks noted on these 2 cells than on previous cells cast with the original mixture

- Armstrong Cement delivered a new shipment of HH portland cement on 13 Nov 04
Summary

- A bizarre problem developed out of the blue that was completely out of everyone’s control

- Effective and cooperative partnering was key to finding a workable solution in a very short period of time

- Even though a degree of estimating was involved, the solution was based upon sound engineering principles
Summary

- The interim solution was successful
- You can do it, ERDC can help!
Questions?