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

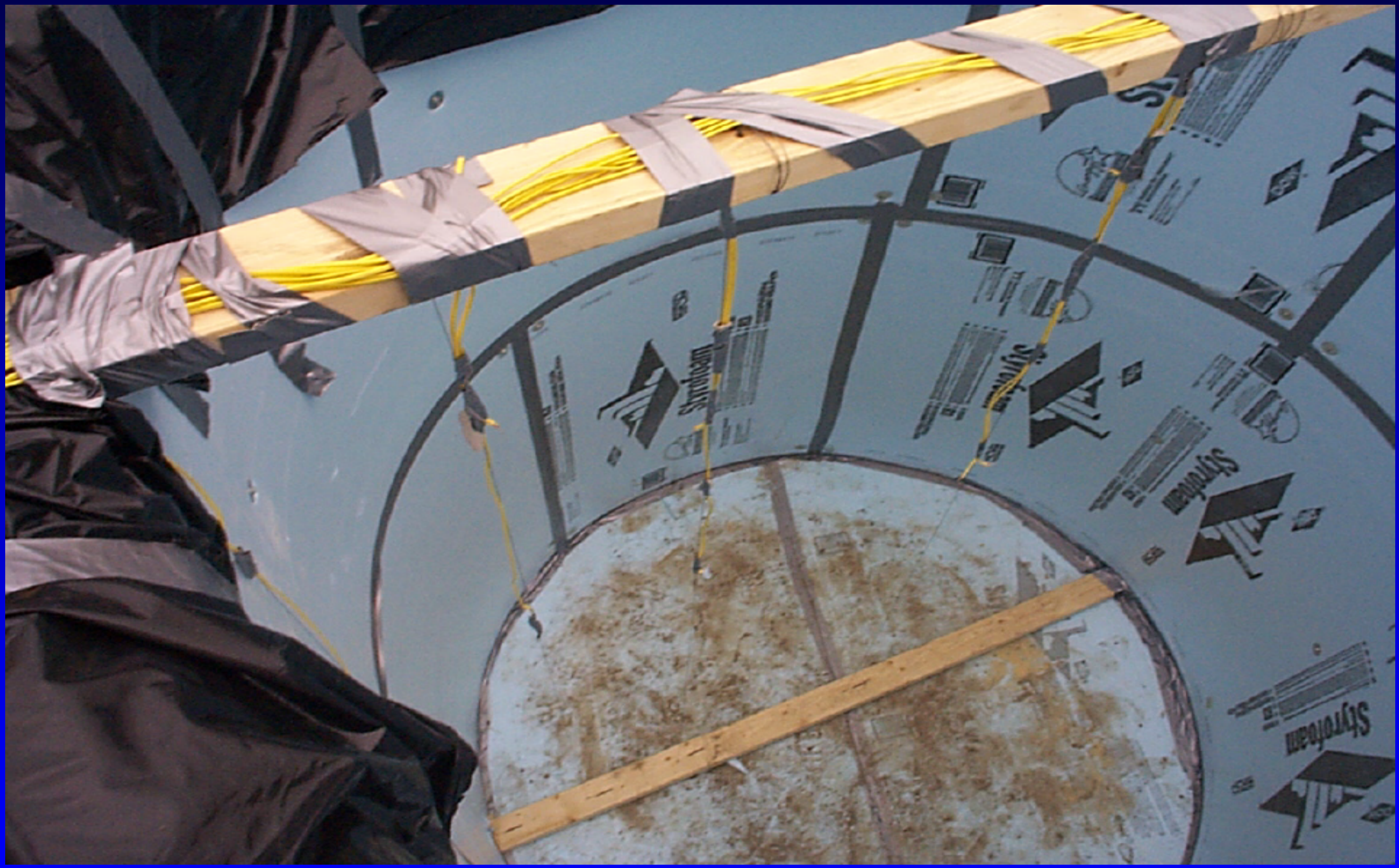
- Huntington to coordinate efforts between Kokosing / Fru-Con and ERDC
- Huntington to make final decision to use of type II portland cement, without the HH restriction, or to terminate concrete placements until type II, HH available again

Test Cells

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



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Test Cell

Test Cell

Test Cell

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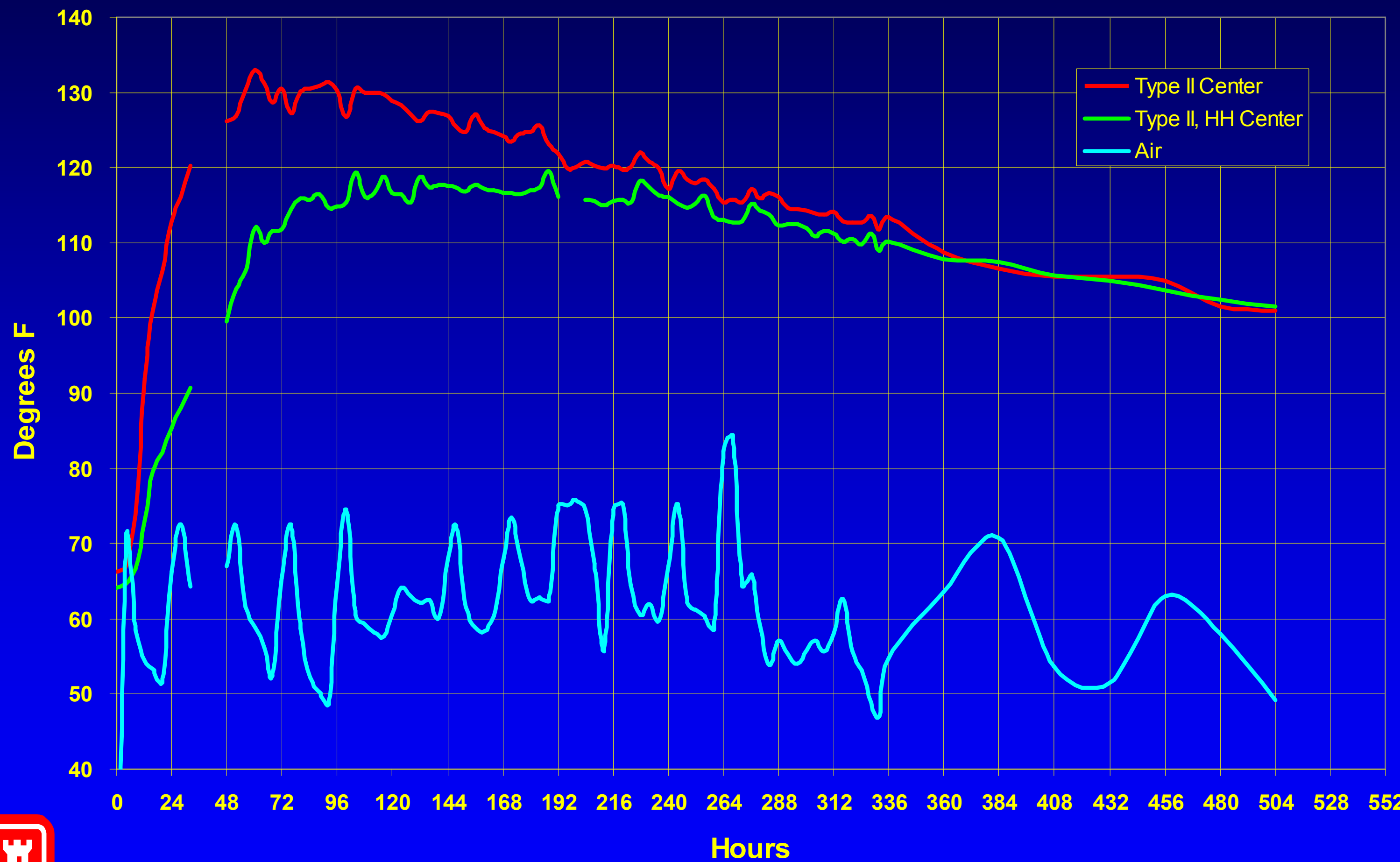
Test Cell Temperatures



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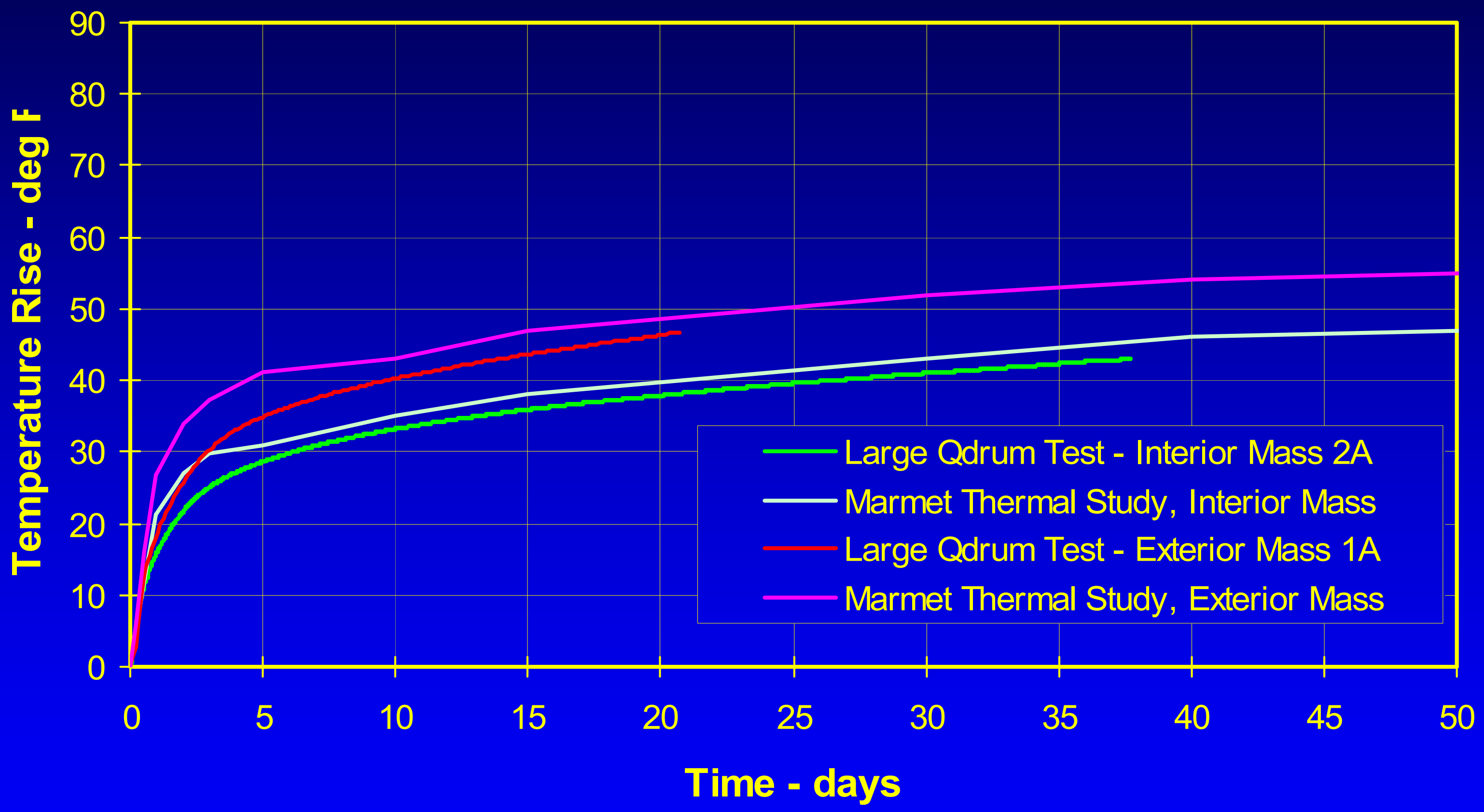
Baseline Mass Mixtures with Type II, HH



Test Cells

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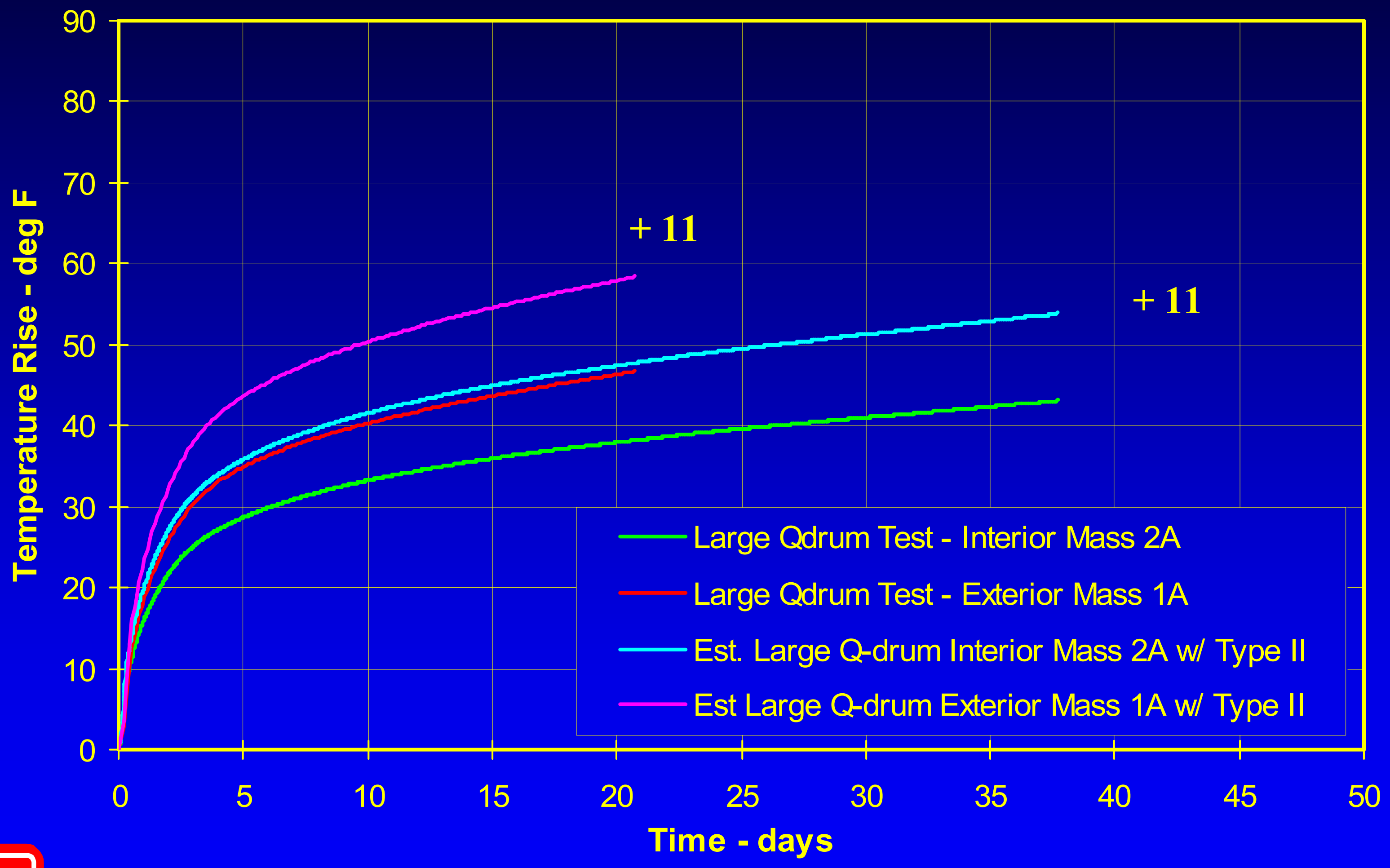
Type II, HH versus Type II



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Analysis of Mixture Proportions

			Quantity per cubic yd, lb				Estimated maximum temp rise	Estimated maximum temp rise	Estimated increase in temp
Mix No.	w/(c+m)	Fly Ash %	PC	Total Cementitious	FA	Water	w/ LH cement	w/ MH cement	w/ MH ceme
1A	0.49	20	281	329	48	171	51	60	9
1B	0.49	25	263	323	60	172	49	58	9
1C	0.49	30	243	315	72	170	47	55	8
1D	0.46	25	286	351	65	175	52	61	9
2A	0.55	30	223	289	66	175	45	52	7
2B	0.60	30	199	257	58	170	43	50	6
2C	0.60	25	215	264	49	172	44	51	7
2D	0.65	25	202	248	46	175	43	49	7
348	0.435	30	461	596	135	286	66	81	15
347	0.495	30	392	507	115	277	60	73	13

Heat of Hydration Analysis

- Thesis
  - Temperature rise = $\dfrac{\text{HH of cement} \times \text{cement fraction}}{\text{heat capacity of concrete}}$
  - Adjust cement fraction for % fly ash
  - $dT = \dfrac{(1.3\ HH + ((1.3 – 0.51(\%\ \text{fly ash}))) \times \%\ \text{cement}}{\text{heat capacity of concrete}}$

Heat of Hydration Analysis

- Example calculations

$$dT = \frac{(1.3\ HH + (1.3 - 0.51(\%\ fly\ ash)))\ x\ \%\ cement}{heat\ capacity\ of\ concrete}$$

$$dT = \frac{((1.3)(79) + (1.3 - (0.51)(30)))\ x\ 0.1231}{0.24} = \mathbf{45° C} = \mathbf{82° F}$$

$$dT = \frac{((1.3)(68) + (1.3 - (0.51)(30)))\ x\ 0.1231}{0.24} = \mathbf{38° C} = \mathbf{69° F}$$

Heat of Hydration Analysis

- Example calculations

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

$$dT = \frac{((1.3)(79) + (1.3 - (0.51)(30))) \times 0.1231}{0.24} = 45°\ C = 82°\ F$$

$$dT = \frac{((1.3)(79) + (1.3 - (0.51)(45))) \times 0.1231}{0.24} = 42°\ C = 75°\ F$$

38° C
69° 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

	7-day	28-day	90-day
30% ash + HH	1,300	4,000	5,500
60% ash + reg II	1,300	3,000	4,800

- 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?