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The Economics, Performance, and Sustainability of Internally Cured Concrete, Part 3

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WEB SESSIONS

Erik Holck, P.E. is the Materials Laboratory Manager at Denver Water, Denver, CO. Erik has 15 years of experience in the design and construction of water facilities including pipe lines, post-tensioned tanks, vaults, pump stations and dams. Erik currently is a voting member of ACI 306, ACI 308, and Chair of ACI 308/213 Joint Subcommittee on Internal Curing. Erik is Secretary/Treasurer of the Rocky Mountain Chapter of ACI.

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Design and Construction of a 10-Million Gallon Internally-Cured Post-Tensioned Tank

DENVER WATER

Acknowledgements

- Bates Engineering
- Aggregate Industries
- TXI Expanded Clay and Shale
- Garney Construction
- Denver Water Engineering Division

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Project Description

- Construct a new 10 million gallon storage tank for the Lone Tree service area
- Site was laid out for 2 – 10 MG tanks
- First tank constructed in 1984
- Continued commercial and residential development drove the need for the second tank

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Project Timeline

- Preliminary Design – Feb 2010
- Trial Slabs – Aug 2010
- Construction – Jul 2011 – Jul 2012
- Base Slab Placement – Oct 10, 2011
- Roof Slab Placement – Mar 4, 2012
- Tank online – July 1, 2012

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Post-Tension Tank Construction

- Monolithically place floor and roof slabs
- 61,000 sf (140 ft radius)
- 5” thick base
- 8” thick roof
- No joints
- Shrinkage cracking is key problem

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Lessons Learned Discussions

- Lone Tree #2 is the 8th Denver Water tank designed by Bates Engineering
- Lessons learned from other tanks
  - Weather (wind, heat, and humidity)
  - Need to minimizing shrinkage
  - Finishing issues
- Continually looking for ways to reduce shrinkage cracking

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Shrinkage Cracking

- Bates and Denver Water decided to investigate emerging technologies to reduce shrinkage cracking
- Traditionally, we moved toward lower and lower w/cm ratio concrete
  - This can lead to finishing problems
  - Peak temp of hydration can be high

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New Idea, Internal Curing

- Reduced shrinkage cracking
- Decreased permeability
- Reduced warping and curling
- More complete hydration of cement
- Control the peak temperature of hydration

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Trial Mix Selection

- AI ran 3 different trial mixes
- Chose the 0.40 w/cm mix for further testing
- Shrinkage values were great for all 3
- 0.40 w/cm is in a comfortable range

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Field Study

- Decided to place 2 slabs at the project site, side by side
- 1 traditional mix, and 1 ICC mix
- Reasoning was to test:
  - Workability
  - Pumpability
  - Finishability
  - More testing

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Test Slabs

- 10 feet x 40 feet
- 4 inches thick
- Unreinforced
- No surface curing
- Check for cracks at 1 month
- Harshest conditions possible
  - No cure, no rebar, hot weather
- Slabs placed on Aug 25, 2010

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ICC Test Slab

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ICC Slab Finished

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Conventional Concrete Slab

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Slabs at 2-days after placement

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Test Slab Conclusions

- Contractor reported that the ICC was easier to finish
- No issues pumping
- At 35-days, ICC had minimal cracking compared to control slab
- Estimated to be about 60% reduction in size and number

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Test Results

ICC Mix	Age	Comp. Strength	MOE (psi)
A, B	1-day	3350 psi	-
C, D	3.5-day	4950 psi	3,500,000
E, F	7.5-day	5380 psi	3,730,000
G, H, I	28-day	6700 psi	3,590,000
J, K	56-day	7650 psi	-

Traditional Mix	Age	Comp. Strength	MOE (psi)
A, B	1-day	4060 psi	-
C, D	3.5-day	5460 psi	3,350,000
E, F	7.5-day	6160 psi	3,710,000
G, H, I	28-day	7140 psi	3.810,000
J, K	56-day	7890 psi	-

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Final Design

- Design Team decided to specify ICC for both slabs on tank
- 0.40 w/cm mix with no fly ash

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Construction of Tank

- Contractor decided to use ICC on the sump pits (first concrete on project)
- Wanted to see how it performed
- 2-day strength of 5055 psi
- 7-day strength of 6250 psi
- 28-day strength of 7230 psi

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Construction of Tank

- Tank was designed for 28-day strength of 4500 psi
- Bates and DW decided to relax the w/cm ratio to 0.42
- Comparable shrinkage values
- Try to slow the mix down
- Contractor used the 0.42 mix on sump pit walls (2nd project placement)
- Used 2 mixes, 0% and 10% fly ash

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Test Results from Sump Walls

Age	0% Fly Ash strength	10% Fly Ash Strength
3-day	4600 psi	4580 psi
5-day	4990 psi	5220 psi
7-day	5200 psi	5200 psi
28-day	6340 psi	6890 psi

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Final Decision

- Based on experience and performance, the 0.42 ICC mix with no fly ash was selected for the slabs
- No hot weather placement
- In the past, we have had some difficulty with fly ash mixes
- Problem with differential set

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Base Slab Construction

- Placed on October 10, 2011
- 1300 CY of ICC
- 2 central mix plants used
- 150-200 CY/hr delivery rate
- Eight set of four cylinders cast
- 7-day strength of 5980 psi
- 28-day strength of 7130 psi

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Roof Slab Construction

- Placed on March 4, 2012
- 1800 CY of ICC
- 2 central mix plants used
- 150-200 CY/hr delivery rate
- Nine sets of 4 cylinders
- 7-day strength of 5720 psi
- 28-day strength of 6830 psi

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Heat of Hydration Temperature

- Heat of hydration was measured
- Determine max temp during hydration
- Determine if rapid strength gain was causing temperature spikes

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Heat of Hydration

Structure	Average Peak Temp	Time to Peak
Floor Slab (5" thick)	77.0 F	5 hours
Ring Girder (24" thick)	112.6 F	10 hours
Walls (13" thick)	86.7 F	12 hours
Roof Slab (8" thick)	92.1 F	12 hours

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Summary of All Strength Data

- Mix was very consistent
- 41 sets of 4 cylinders taken in all
- Average 7-day strength of 5360 psi
- Average 28-day strength of 6520 psi
- Standard deviation of all data 626 psi

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Ready to Go

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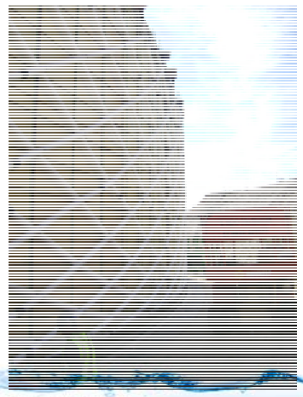

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Conclusions

- Denver Water believes that ICC is superior to conventional concrete
- Denver Water intends to use ICC on all future storage tanks
- Denver Water believes that ICC will have better performance, less leakage, and less maintenance
- Resulting in a longer service life

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Questions?

Erik Holck, P.E.
Construction Engineering Manager – Infrastructure
erik.holck@denverwater.org

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