MnDOT CONCRETE DELIVERY TIME STUDY

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NCC Meeting – Rapid City, SD

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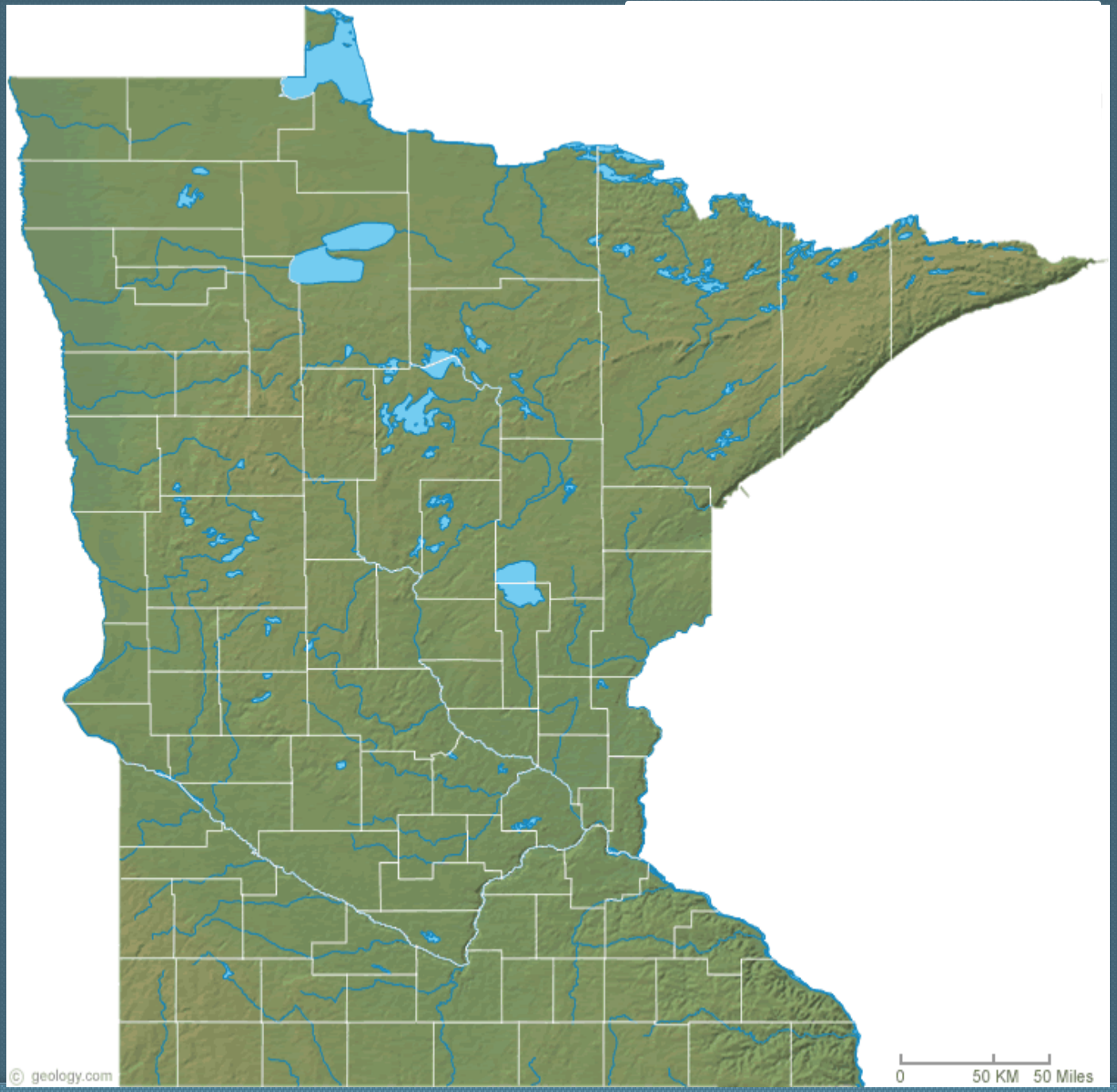
Background

- Industry has been asking Mn/DOT to lengthen the time allowed to deliver concrete
- Mn/DOT is planning on constructing many small bridge projects that are difficult to reach within the existing 60 minute time limit for air-entrained concrete
- Need to verify what many other state DOT's already allow (ie. Longer transit times with the use of retarding admixtures)
- There are no known studies to verify whether the longer hauling time is not detrimental to concrete performance.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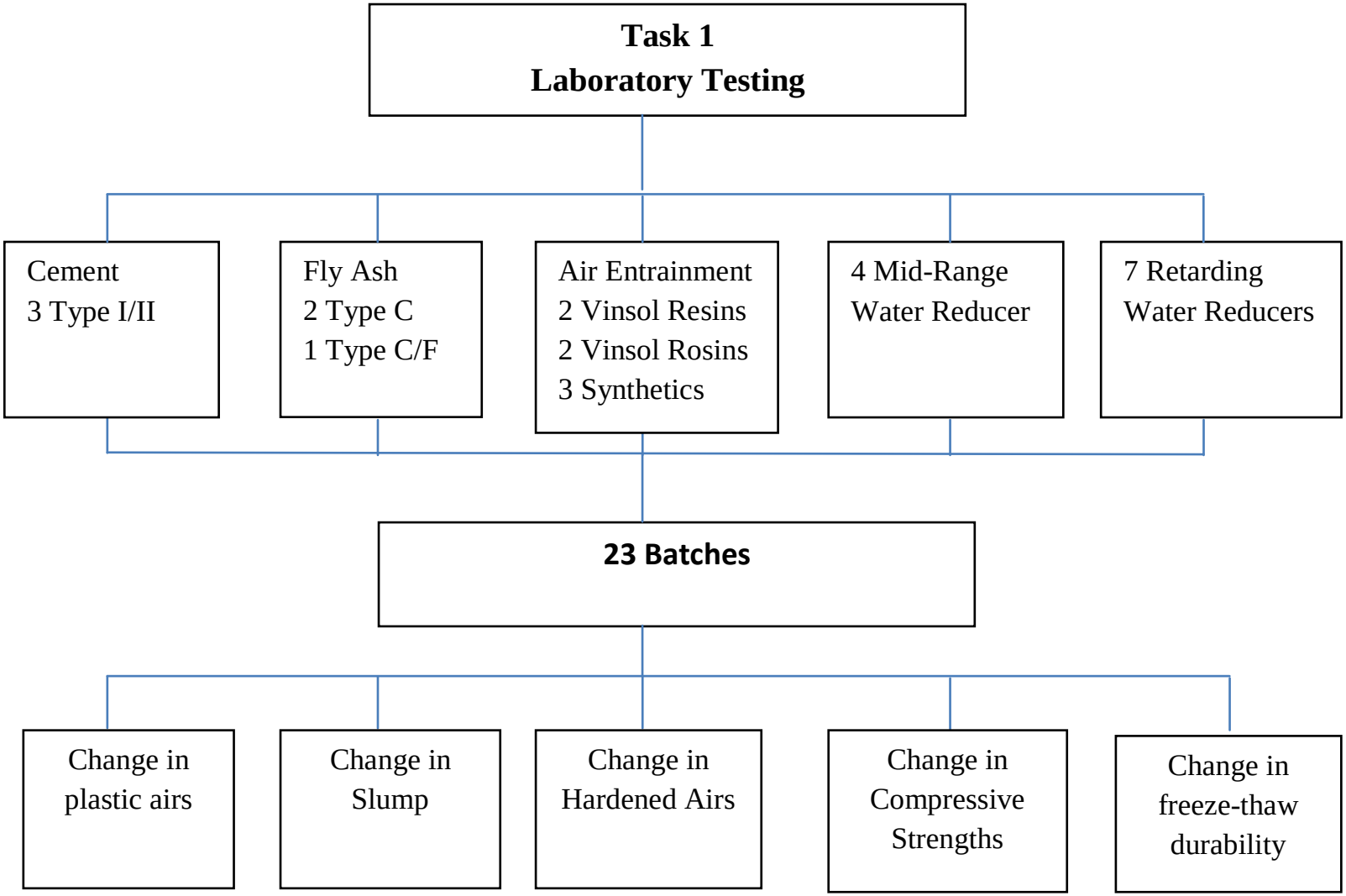
0
50 KM
50 Miles

Background

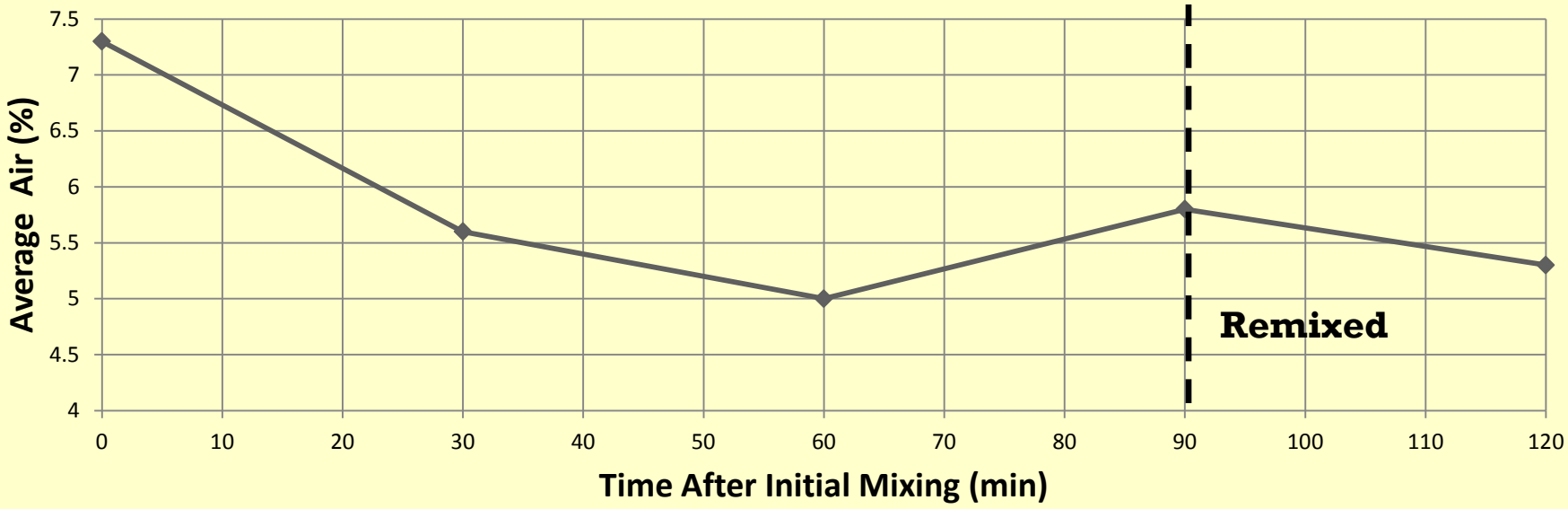
- The goal of this project was to utilize the results of the testing programs and develop specification guidelines that allow the implementation of chemical admixtures to extend transport and delivery time from the current 60 minutes for air-entrained concrete up to 120 minutes.
- MnDOT contracted with American Engineering and Testing (AET) to conduct this study

Task 1 – Lab Testing

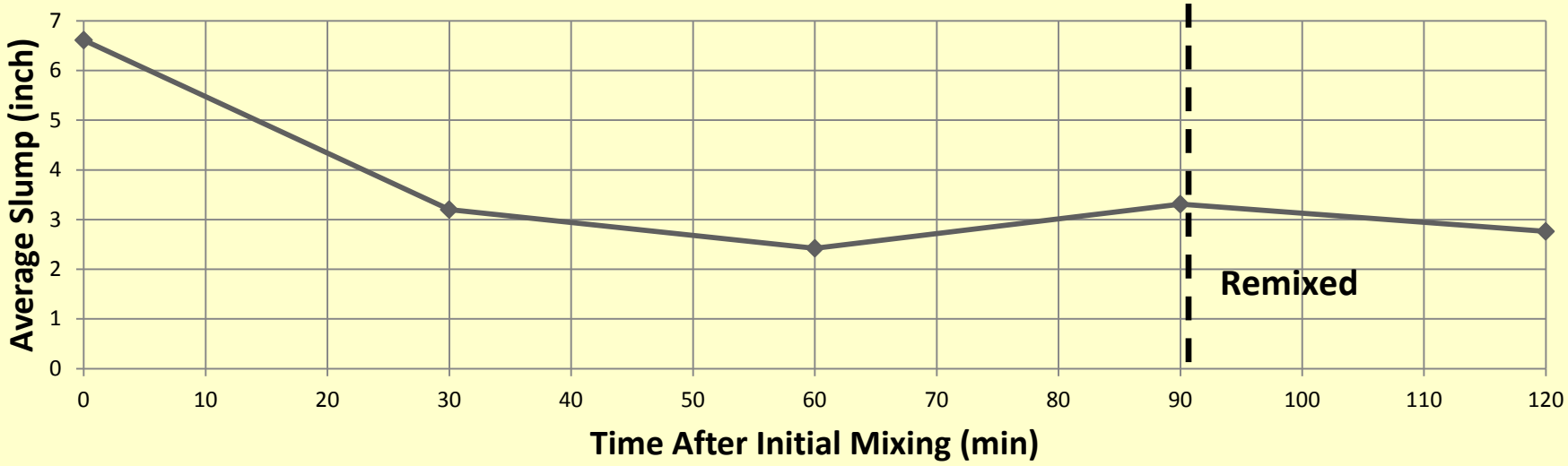
- Batched 23 concrete mixes using the same mix design
  - Used various kinds and combinations of cement, fly ash, water reducer, water-reducing retarder, hydration stabilizer, and air entrainment admixtures.
  - The plastic concrete properties were tested initially and then after 30, 60, 90, and 120 minutes.
  - Hardened concrete proportions such as compressive strength, freeze-thaw, and hardened airs were also performed on concrete that was cast after initial mixing and at 120 minutes.


Task 1
Laboratory Testing
Cement
3 Type I/II
Fly Ash
2 Type C
1 Type C/F
Air Entrainment
2 Vinsol Resins
2 Vinsol Rosins
3 Synthetics
4 Mid-Range
Water Reducer
7 Retarding
Water Reducers
23 Batches
Change in
plastic airs
Change in
Slump
Change in
Hardened Airs
Change in
Compressive
Strengths
Change in
freeze-thaw
durability

Task #1: Average Air Versus Time Since Mixing



Task #1: Average Slump Versus Time Since Mixing



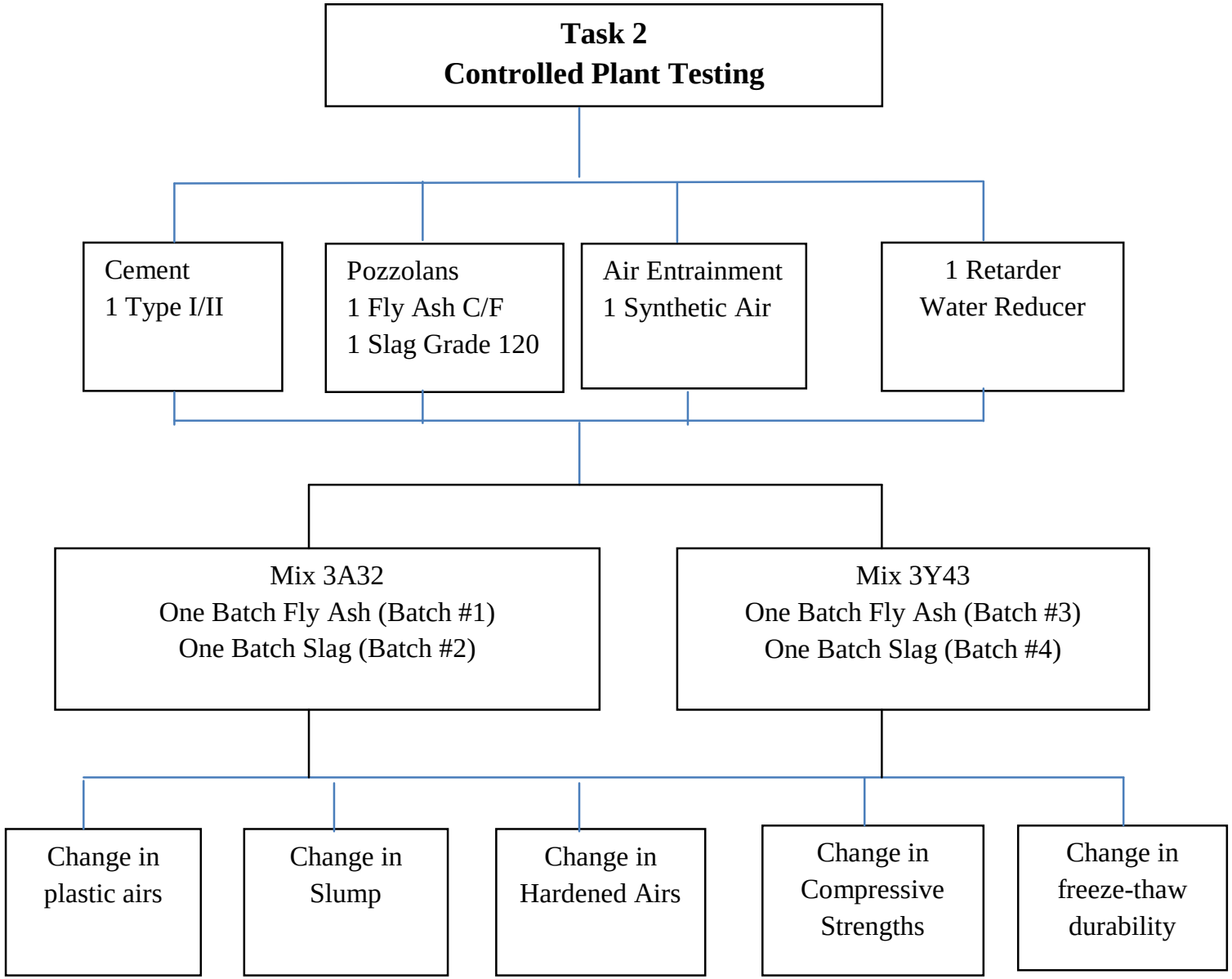
Task 2
Controlled Plant Testing

- Mn/DOT considered which mixes generally sit in the truck the longest due to placement operations

Table 7 – Mix Design Specifications

Mix Design	Mix Design Use	Minimum Cementitious Content (pounds per cubic yard)	Anticipated Compressive Strength at 28 days (psi)	Maximum Allowed Slump with a Water Reducer (in)
3A32	Hand Placed and Formed Sidewalk and Curb and Gutter	560	3900	4
3Y43	Structures	640	4300	5

- Single ready mix concrete plant
- All had partial replacement with either fly ash or slag.
- Each had a combination of chemical admixtures.

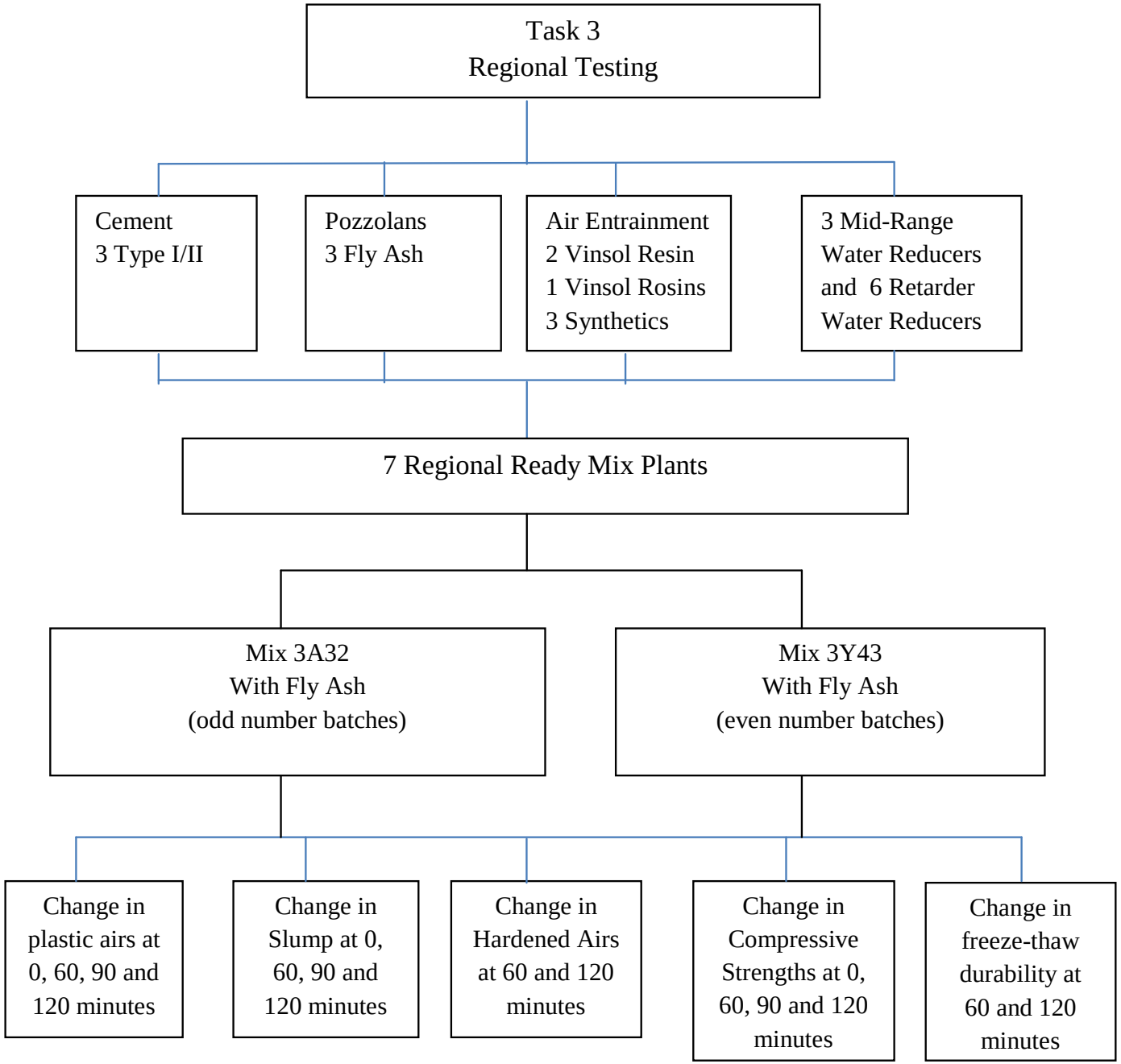

Task 2
Controlled Plant Testing
Cement
1 Type I/II
Pozzolans
1 Fly Ash C/F
1 Slag Grade 120
Air Entrainment
1 Synthetic Air
1 Retarder
Water Reducer
Mix 3A32
One Batch Fly Ash (Batch #1)
One Batch Slag (Batch #2)
Mix 3Y43
One Batch Fly Ash (Batch #3)
One Batch Slag (Batch #4)
Change in plastic airs
Change in Slump
Change in Hardened Airs
Change in Compressive Strengths
Change in freeze-thaw durability

Task 2
Controlled Plant Mixing

- Air temperature during the sampling and testing was 78^{O}F.
- Plastic concrete properties were tested initially and then after 30, 60, 90, and 120 minutes.
- Hardened concrete properties such as compressive strength, freeze-thaw, and hardened airs were also performed on concrete that was originally cast at 60 and 120 minutes after initial mixing.

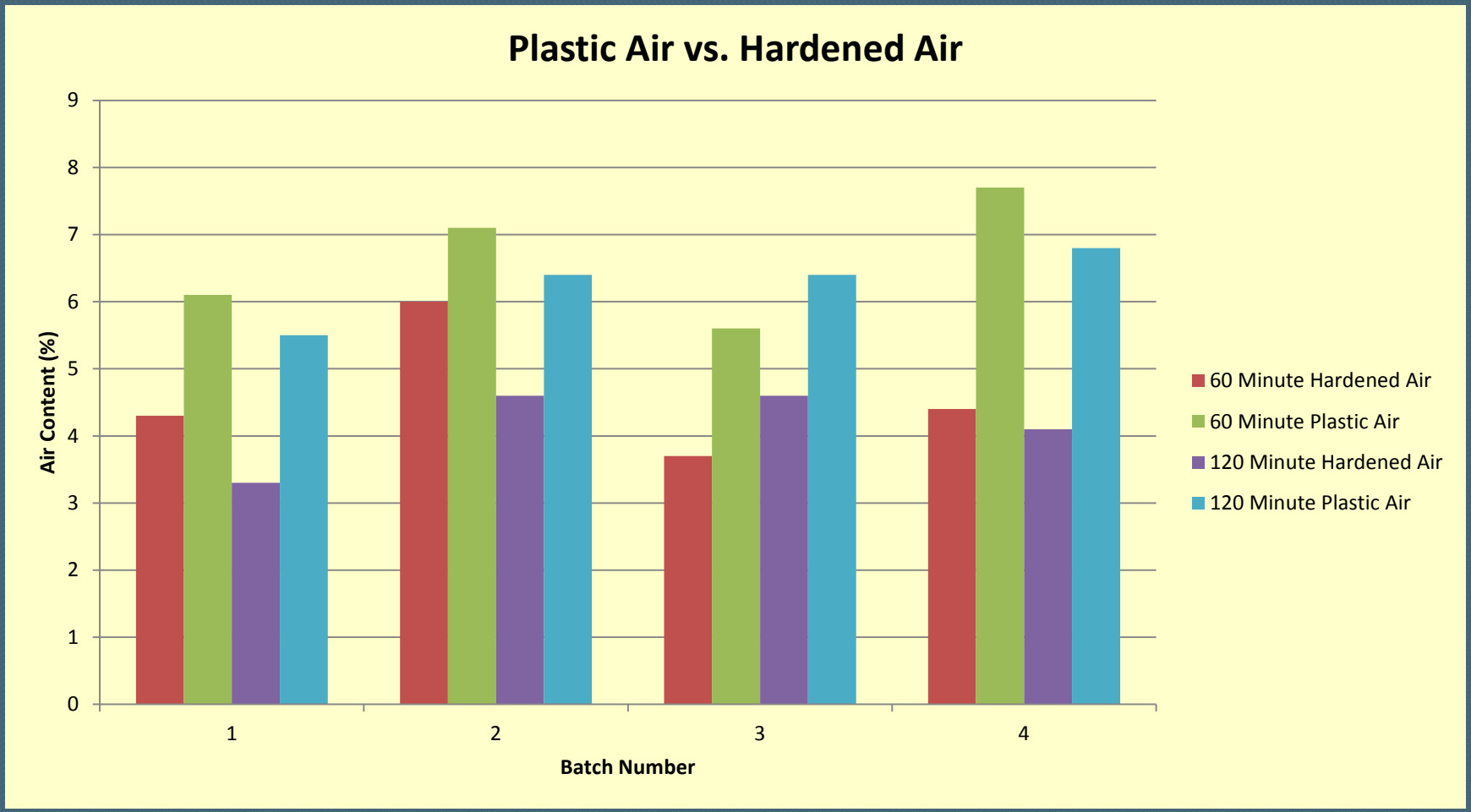
Task 3 - Regional Testing Program

- 7 ready mix plants located throughout Minnesota.
- The mixes consisted of a 3A32 and a 3Y43, each with partial replacement of cement with 15% to 20% fly ash
- Air temperature during the sampling and testing ranged from 50°F to 77°F.
- Once mixed, nothing additional was allowed to be added


Task 3
Regional Testing
Cement
3 Type I/II
Pozzolans
3 Fly Ash
Air Entrainment
2 Vinsol Resin
1 Vinsol Rosins
3 Synthetics
3 Mid-Range
Water Reducers
and 6 Retarder
Water Reducers
7 Regional Ready Mix Plants
Mix 3A32
With Fly Ash
(odd number batches)
Mix 3Y43
With Fly Ash
(even number batches)
Change in plastic airs at 0, 60, 90 and 120 minutes
Change in Slump at 0, 60, 90 and 120 minutes
Change in Hardened Airs at 60 and 120 minutes
Change in Compressive Strengths at 0, 60, 90 and 120 minutes
Change in freeze-thaw durability at 60 and 120 minutes

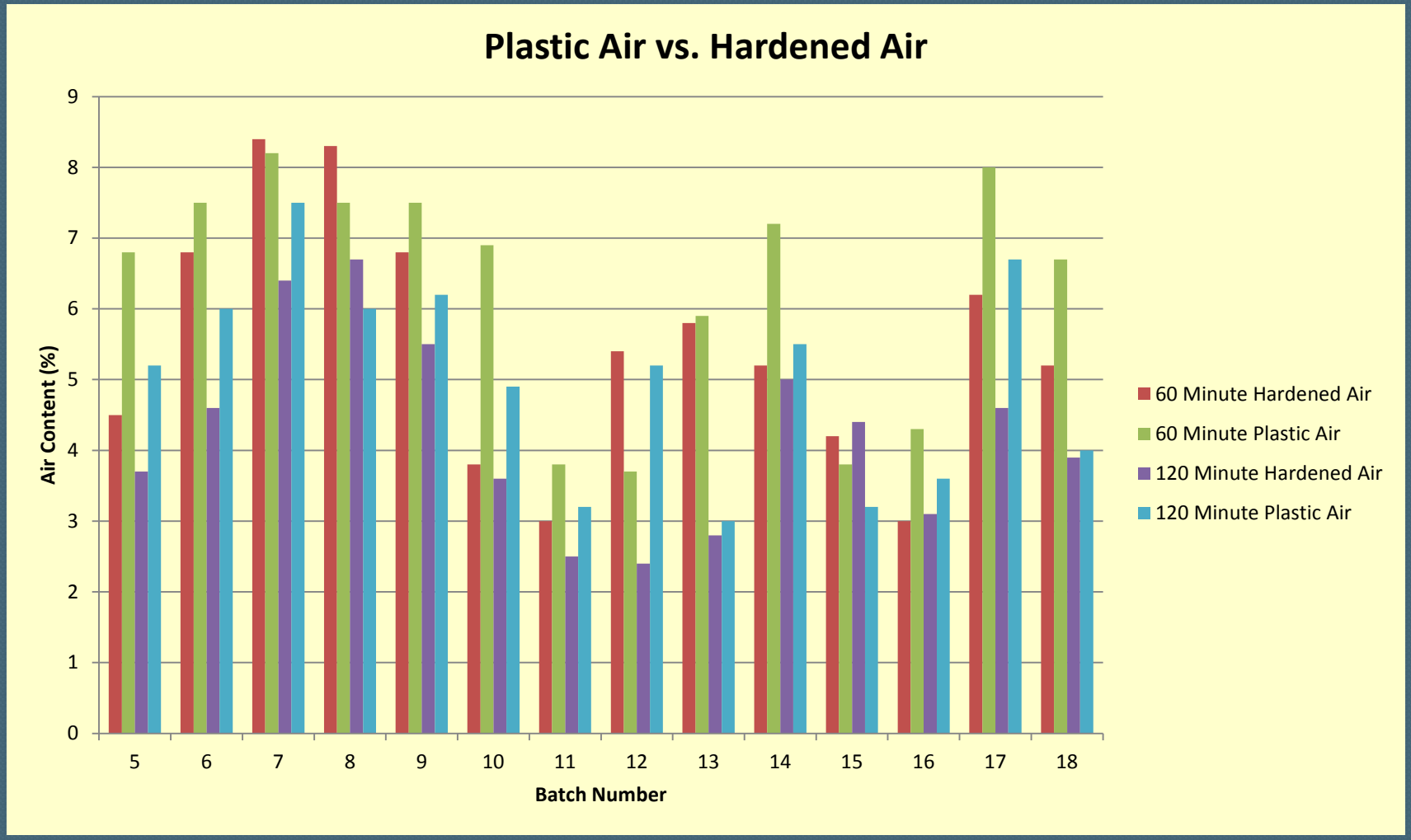
Task 2

Plastic vs. Hardened Air Contents



Task 3

Plastic vs. Hardened Air Contents



Freeze-Thaw Results

- Samples were cast at 60 minutes and 120 minutes after batching.

		Initial Mixing	120 minutes
Relative Dynamic Modulus after 300 cycles	Task 1	88 to 92%	87 to 90%
	Task 2	82 to 88%	82 to 87%.
	Task 3	83 to 93%	86 to 94%

- All of the concrete tests results indicate that the concrete is freeze-thaw durable.

Statistics

- Looked at the effect of the mix design variations
  - (e.g., changes in cement content, changes in admixture type, etc.) had on the air, slump, compressive strength, and durability at each of the points in time.

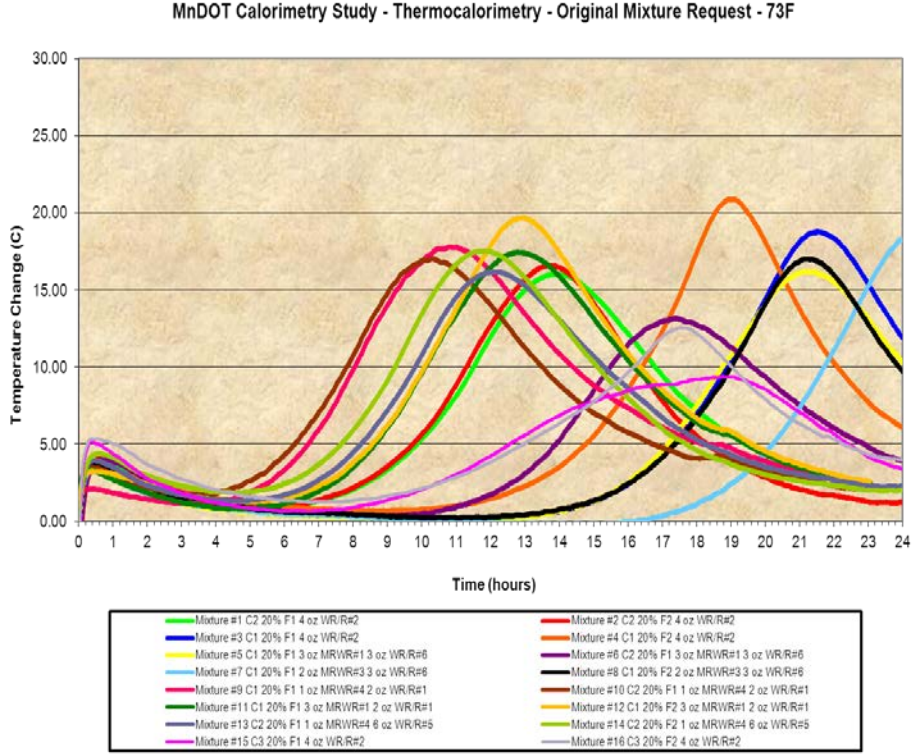
The statistical evaluations showed the following:

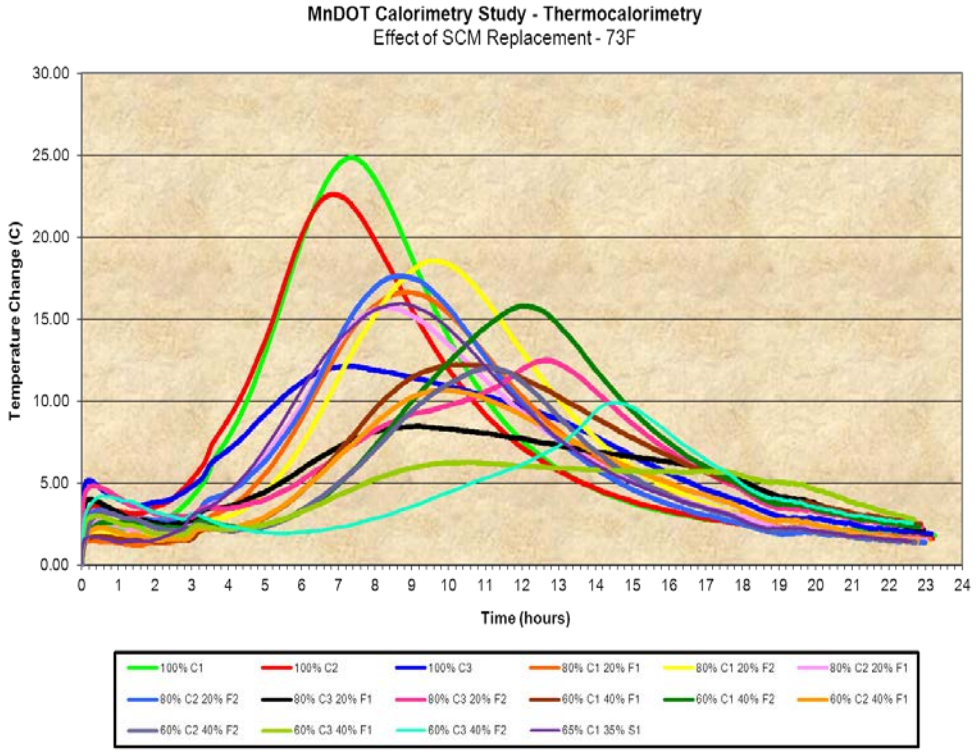
- There is a drop in plastic and hardened air content when extending the transit time from 60 minutes to 120 minutes; 1.3 percent and 1.2 percent, respectively.
- There is a significant loss of slump with an average loss of 1.7 inches.
- There was not a significant effect on concrete compressive strength by extending the transit time.
- There was not a significant effect on freeze-thaw durability by extending the transit time.

Calorimetry Testing

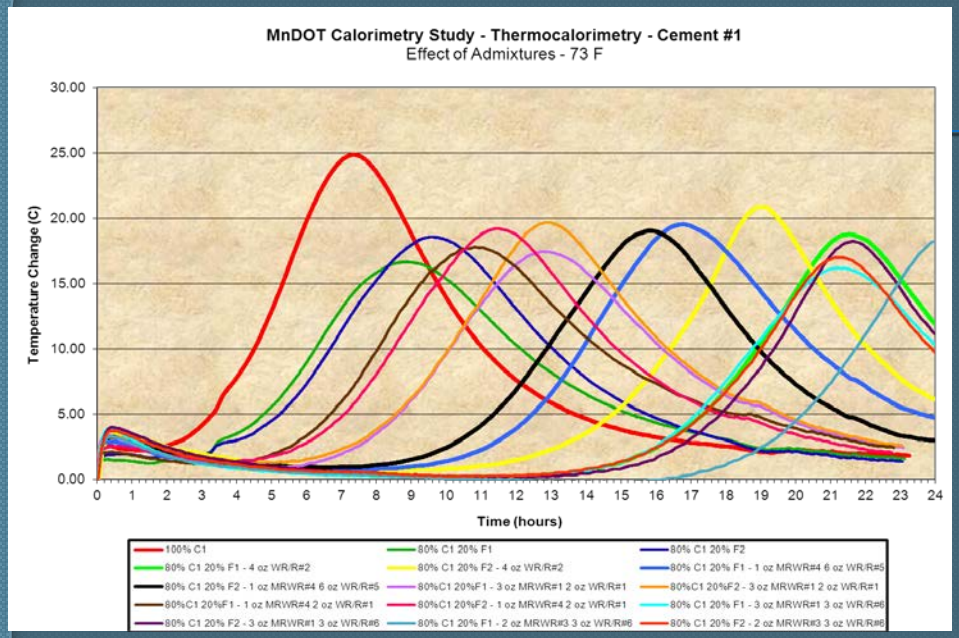
- Method 1
  - Semi-adiabatic calorimetry using a 16 channel ThermoCal system from Solidus Integration, which uses probes to monitor changes in temperature over time as well as ambient temperature.
- Method 2
  - Isothermal calorimetry system Adiacal TC, which monitors the amount of energy required to maintain a constant temperature of the sample.

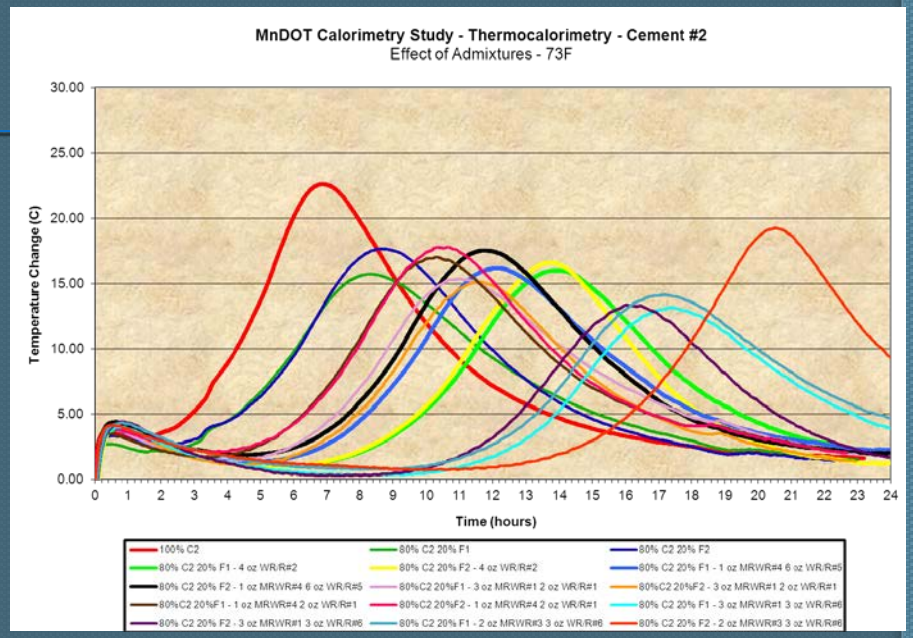
Original Lab Mixes vs. Effect of SCM Replacement

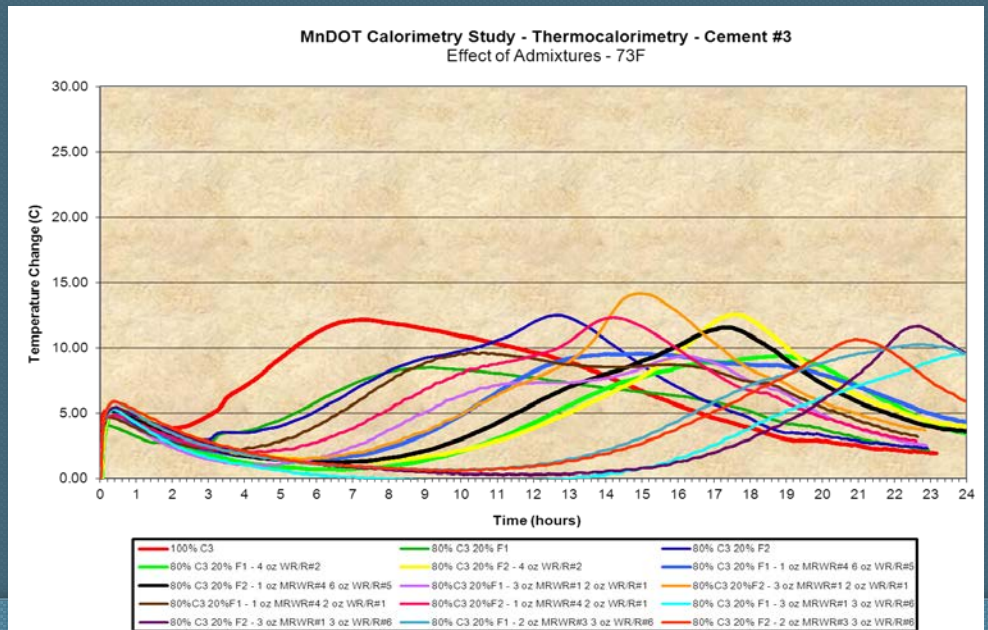




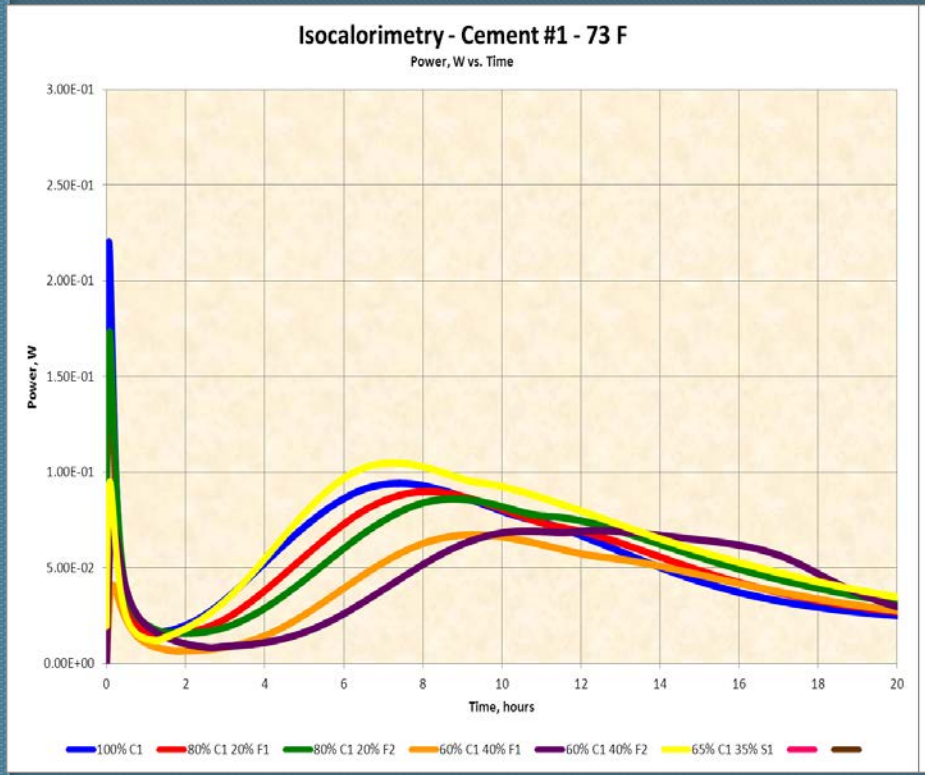
Effect of Admixtures

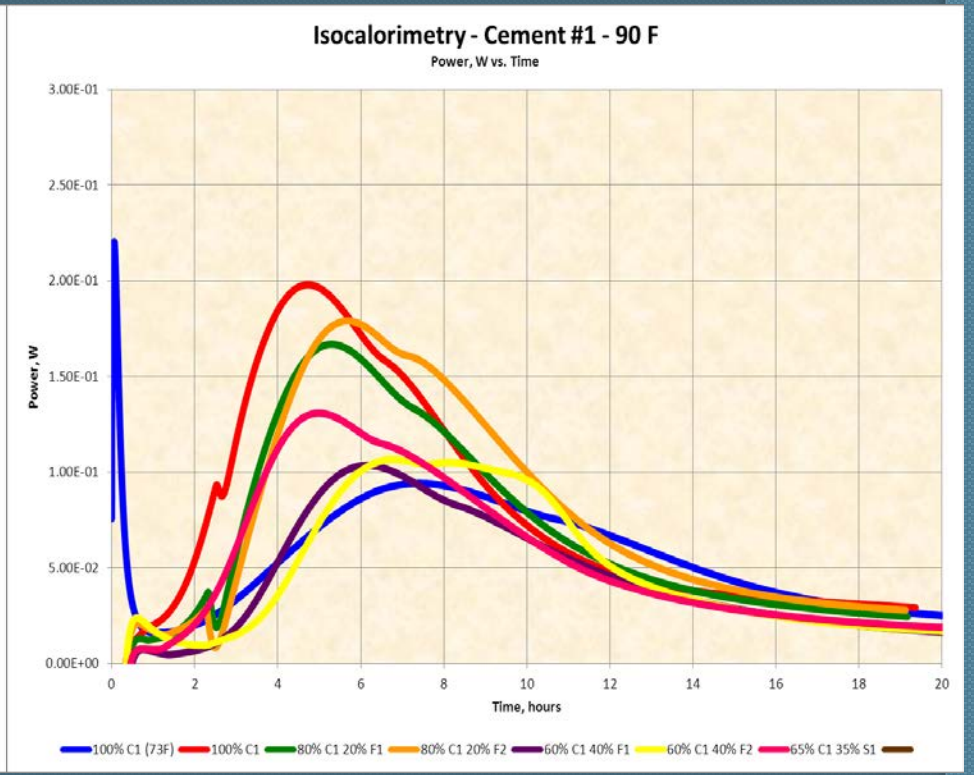




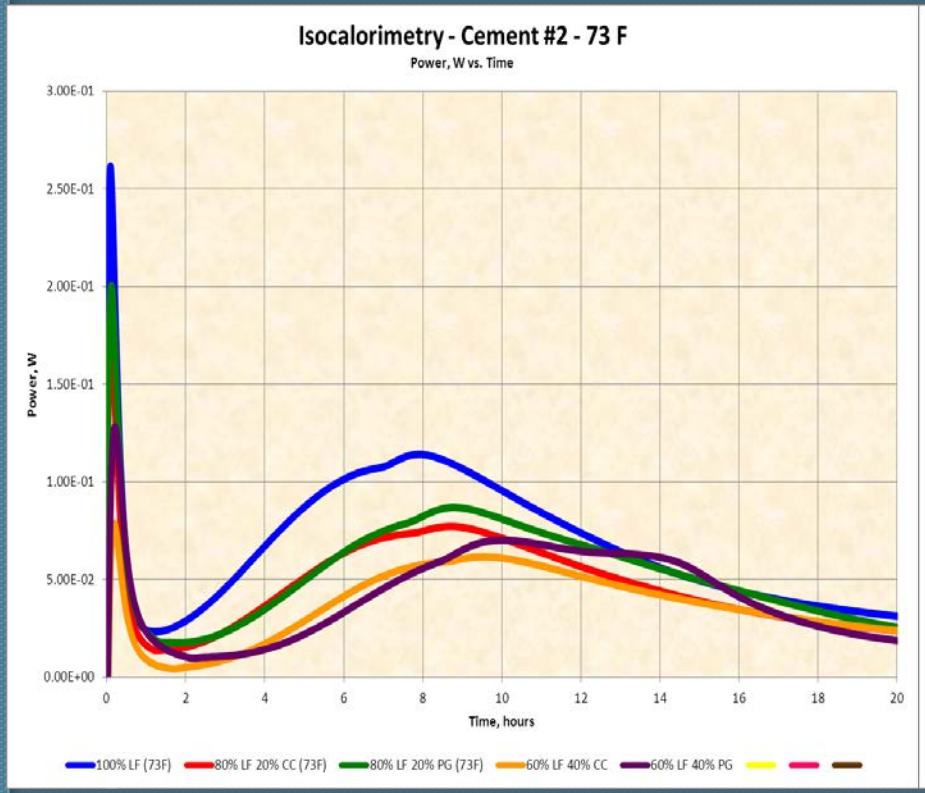


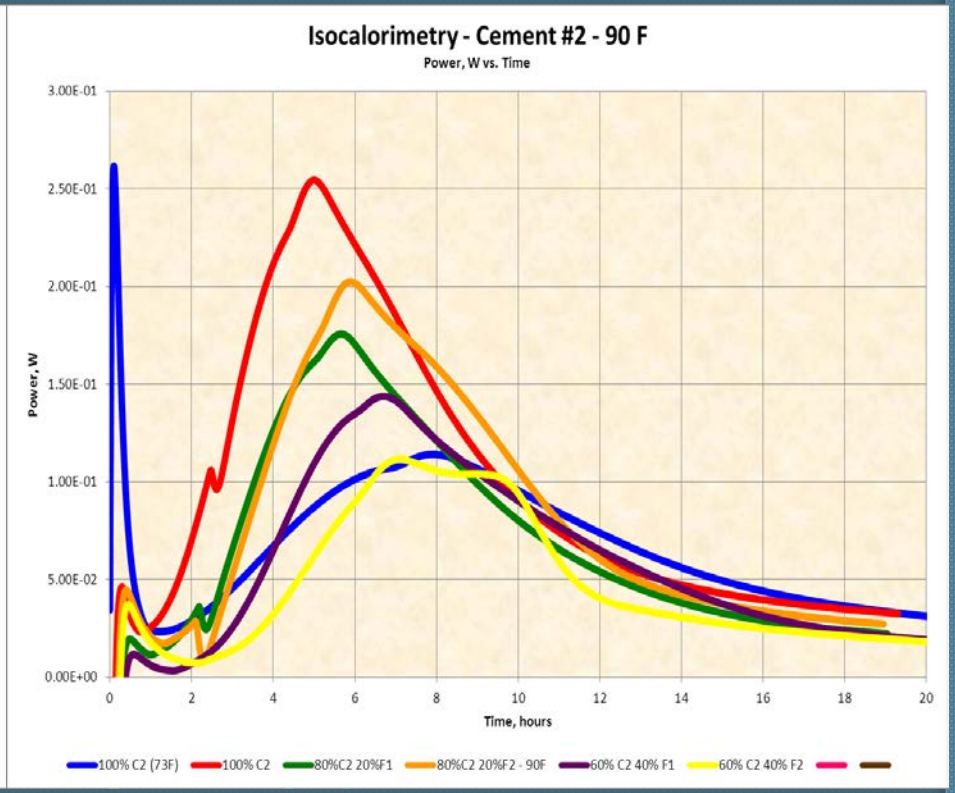
Temperature Variation – Cement #1



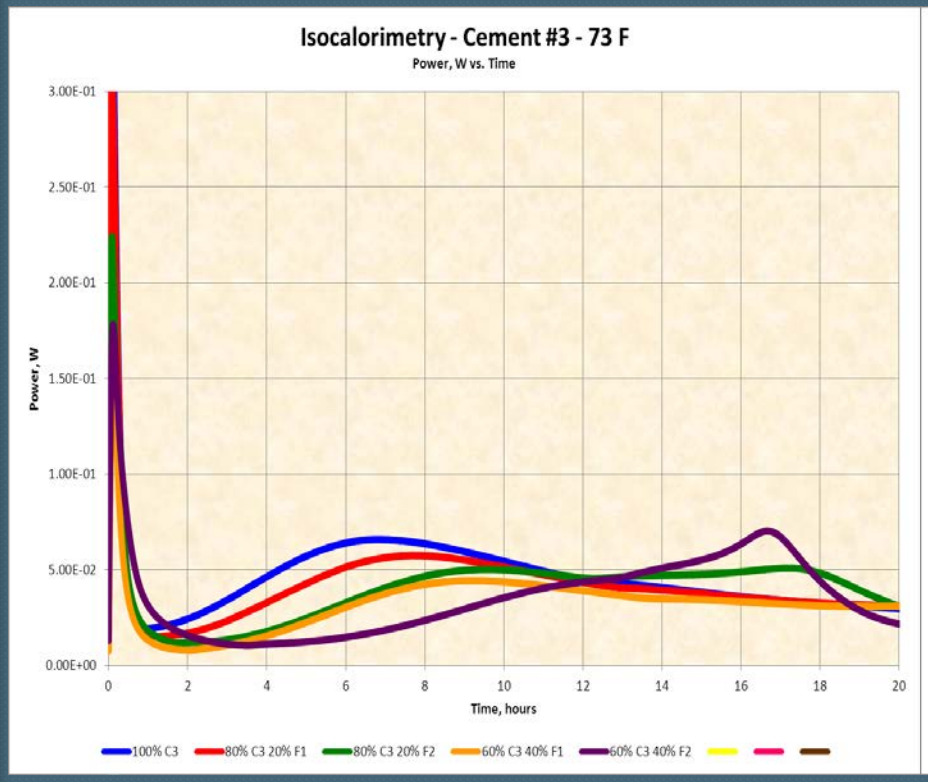


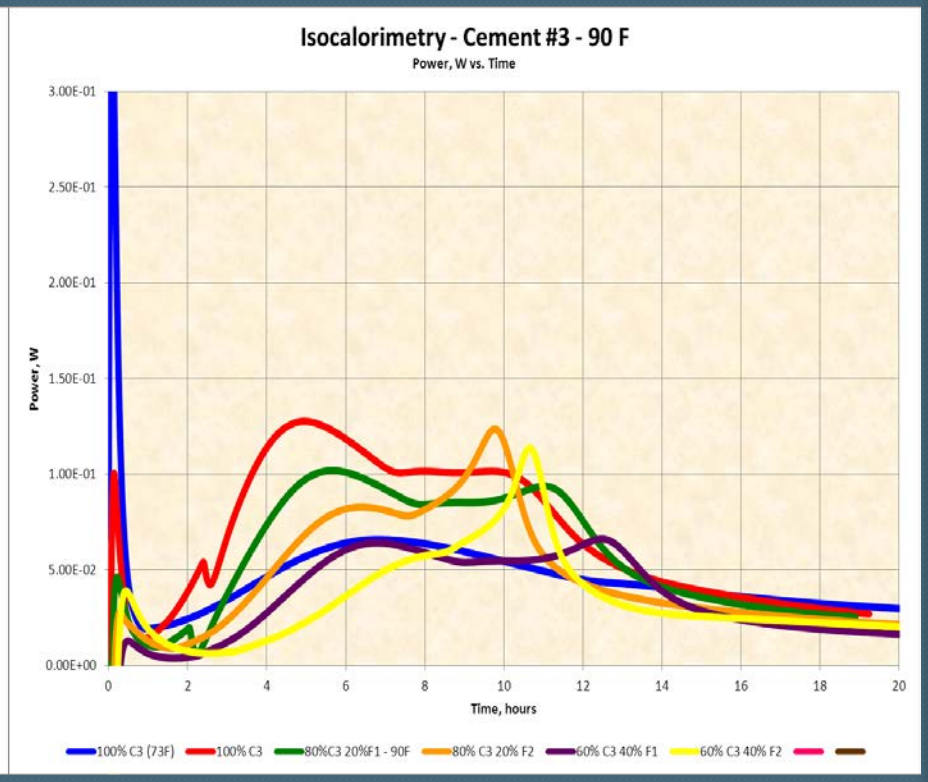
Temperature Variation – Cement #2





Temperature Variation – Cement #3





Conclusions

- Based upon the test results, it is apparent that there are no performance related issues directly related to the use of retarding and water reducer admixtures, beyond the loss of slump and air content.

Recommendations for 60 and 90 minutes

- In any case, do not add additional mixing water once the concrete is 60 minutes old.
- Only provide admixture additions at the job site that are the same products as originally incorporated into the mix.
- Mix the load a minimum of 5 minutes or 50 revolutions at mixing speed after addition of the admixture.
- To extend the delivery time to 90 minutes allow the Contractor to use a retarding admixture at the manufacturer's recommended dosage rates provided all admixtures are initially mixed into the concrete at the plant.

Recommendations for 120 minutes

- To extend the delivery time to 120 minutes, the Contractor shall provide the following once per each mix per each combination of materials:
  - Contractor mix design allowing up to 20% fly ash replacement for cement and use of any admixtures as recommended by the admixture manufacturer in order to meet required compressive strength for Grade of concrete.
  - Field trial batching on the proposed mix (minimum of 5 cubic yard batch size) utilizing the same materials, mixing and transporting procedures as will be used for supplying the concrete.

Recommendations for 120 minutes (cont.)

- Ready mix truck drum should maintain a minimum 6 revolution spin between sampling for the entire 120 minutes.
- Testing of slump, air content, unit weight and temperature immediately after batching and at 90 and 120 minutes.
- Compressive strength at 90 and 120 minutes (sets of 3).
- Hardened air content (ASTM C457) at a minimum of 7 days (5 samples). The Contractor is required to test at least 1 sample and provide Mn/DOT with the other 4 samples for informational testing at their discretion.

- Final Report expected December 2011