NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry, and Natural Sciences

Carbonated Cement Kiln Dust (CCKD) as a partial cement substitute

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FAMA Inc.

CENE 486C Senior Design Course Spring 2017
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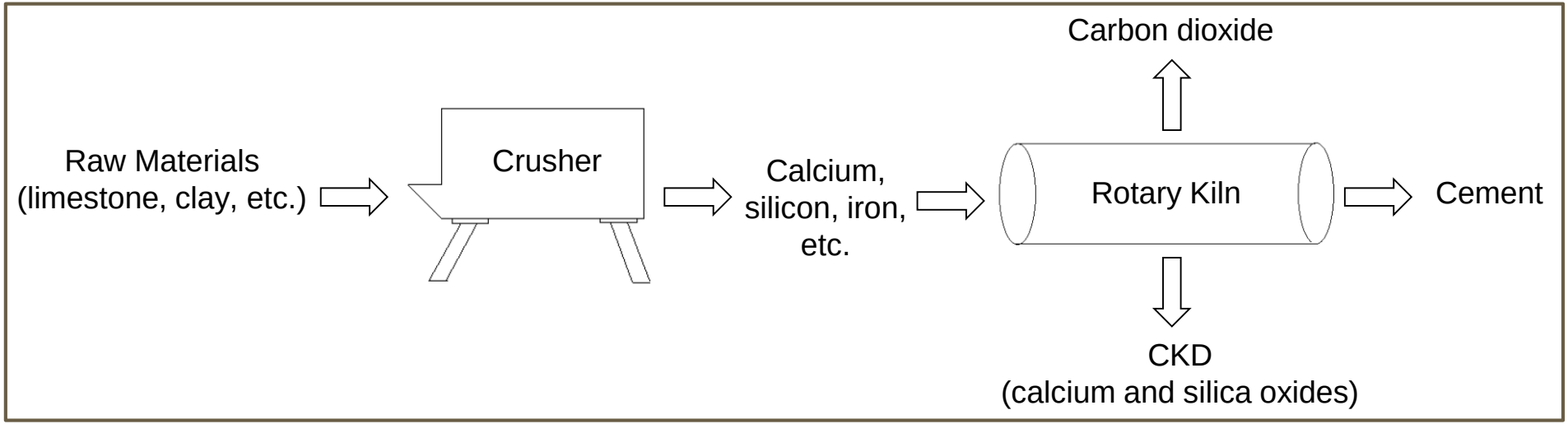
Cement Production



CKD + CO_2 = CCKD
(calcium and silica carbonates)

Figure 1: Cement Production

Purpose

- Investigate the plausibility of Carbonated Cement Kiln Dust (CCKD) as a partial cement substitute and its effect on the strength and durability of concrete to sequester carbon dioxide.
- Develop, execute and analyze an experiment to test the use of Cement Kiln Dust (CKD) and CCKD as partial cement substitutes in different concrete mixes.

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Stakeholders

- Alarick Reiboldt (Client & Technical Advisor)
- The Cement Industry
- Global Environment

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Experimental Plan for Testing

Table 1: Experimental Design Plan

	% of Cement Reduction	Water to Cement Ratio	# of Samples
Control (4000 psi)	**None**	**0.44**	**3**
CKD Substitution	**5**	**0.46**	**3**
	10	**0.49**	**3**
	15	**0.52**	**3**
CCKD Substitution	**5**	**0.46**	**3**
	10	**0.49**	**3**
	15	**0.52**	**3**
Cement reduction	**5**	**0.46**	**3**
	10	**0.49**	**3**
	15	**0.52**	**3**

Concrete Mix Design

- Sieve analysis per ASTM C136
  - Largest diameter aggregate (0.5 in)
  - Weight of water
- Water to cement ratio (0.44)
- Proportion calculations using 1:2:3 ratio (Cement:Sand:Gravel) per ASTM C150

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Concrete Mixing and Sample Prep

- Concrete mixer used for mixing strength test samples.
- 4” by 8” cylinder samples.
- Slump test conducted on all batches (0-1 inch)

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Concrete Mixing and Sample Prep

- Durability samples mixed by hand.
- 2” x 2” x 2” cubes.

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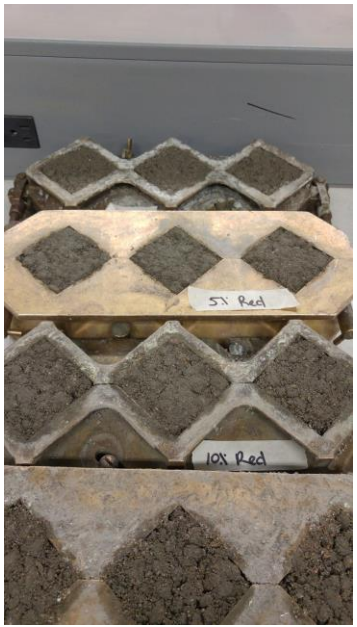

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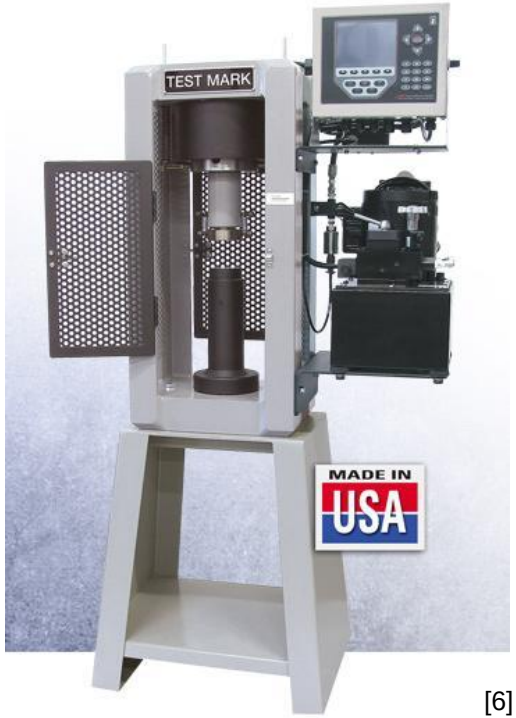
Strength and Durability Testing

- Compressive strength test per ASTM C39-16
- Freeze-Thaw test per ASTM C666/C666M-15
  - Limited space at NAU
  - Contacted other sources
- Water Absorption test per ASTM 1585-13
  - Insufficient oven capacity
- Alkali-Silica Reactivity (ASR) test per ASTM 1567-13



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Compressive Strength Test

Samples molded

Samples set for 24 hours

Placed in buckets of water to cure for 28 days

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Compression tested after curing

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Strength Test Results

Table 2: Strength Test Results

Mix	Avg. Strength (psi)
Control	4122
5% Red.	4965
10% Red.	3501
15% Red.	3868

Mix	Avg. Strength (psi)
5% CCKD	3444
10% CCKD	3953
15% CCKD	3587

Mix	Avg. Strength (psi)
5% CKD	1575
10% CKD	176
15% CKD	0

Compressive Strength Test Samples (CKD and Control)

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Strength Test Results (pH)

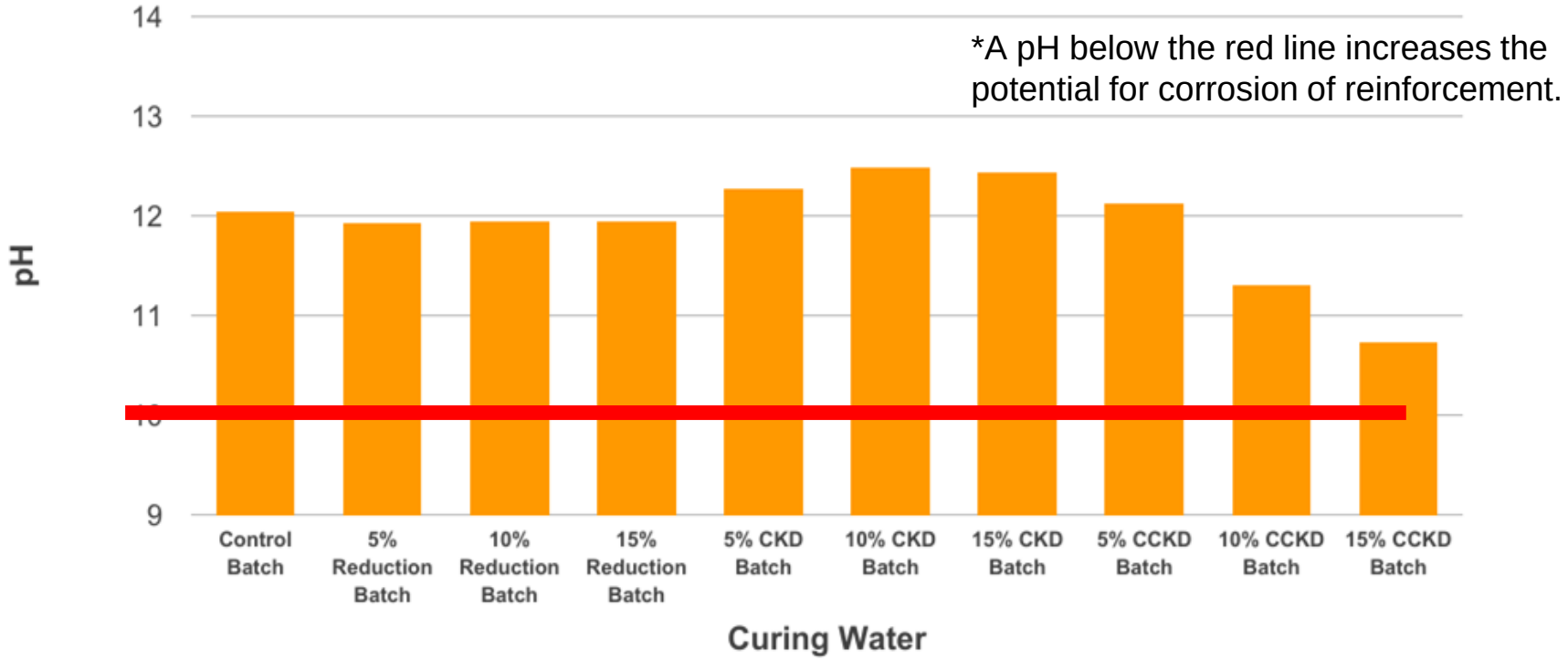


Figure 2: pH Of Curing Water For Different Mixes

Strength Test Results

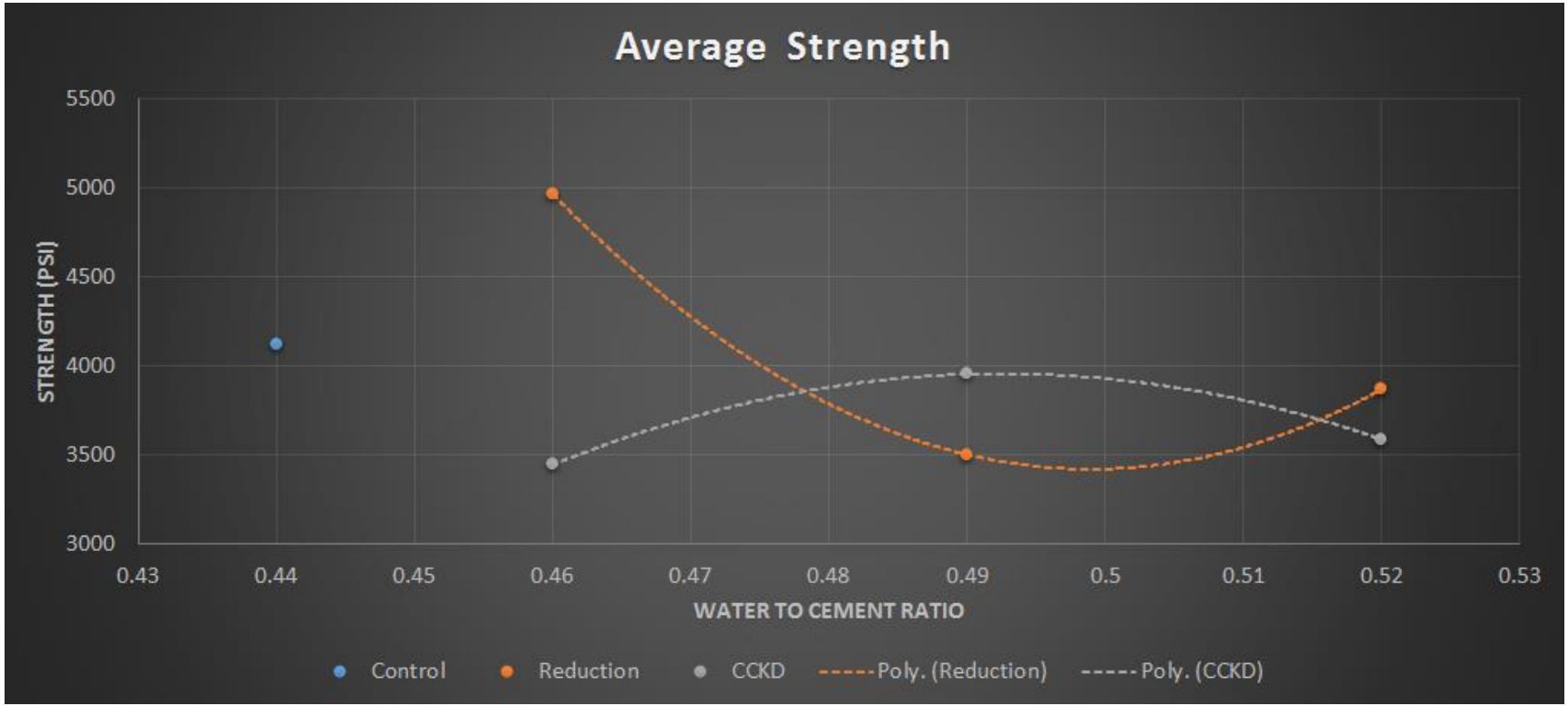
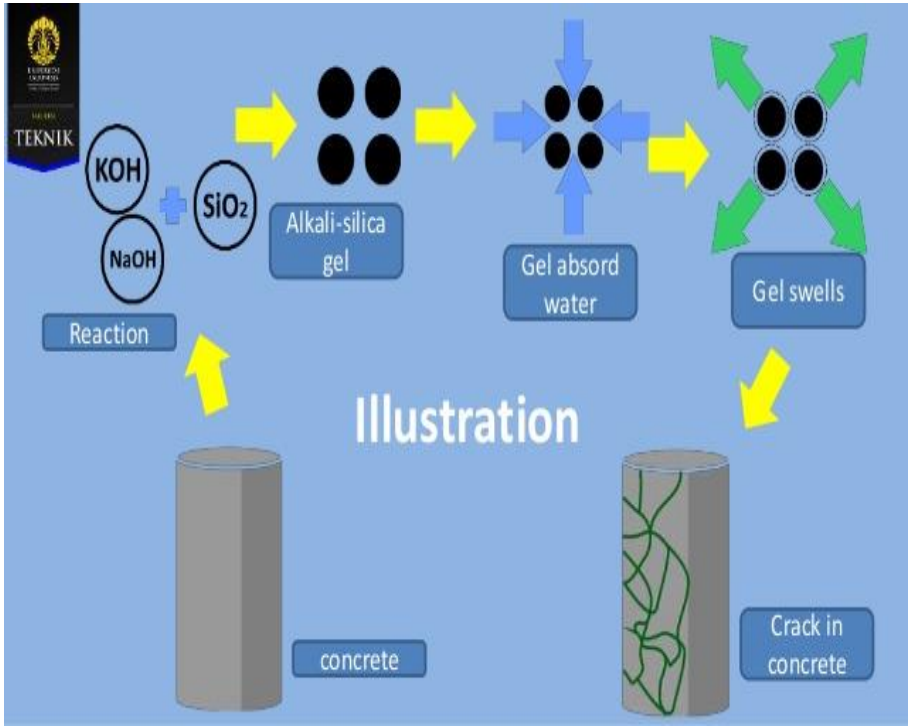


Figure 3: Average Strength

Alkali-Silica Reactivity Test



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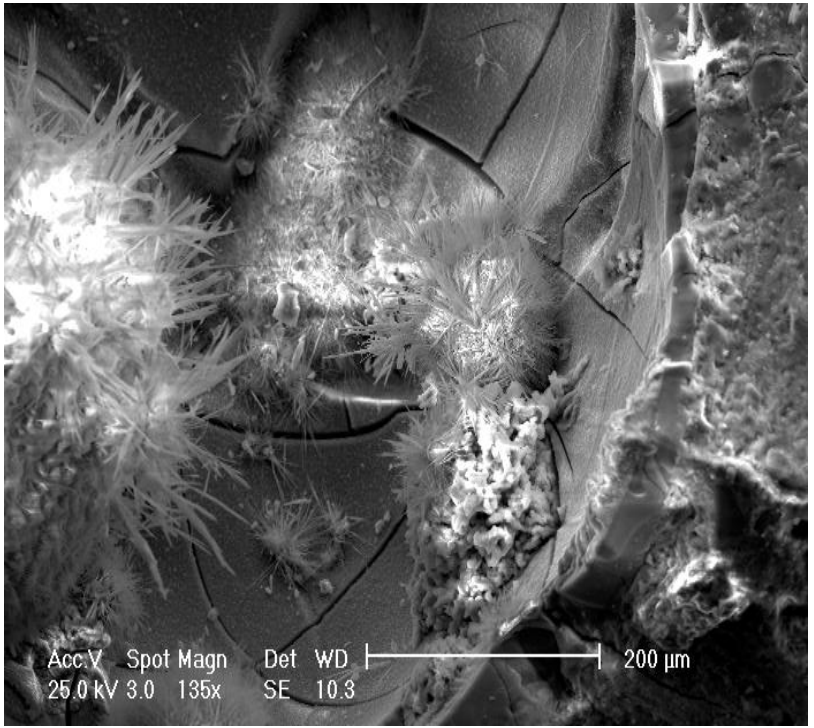

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Alkali-Silica Reactivity Test

- Molded
- Zero measurement
- Submerged in water for 24 hours
- Submerged in Sodium Hydroxide solution for 24 hours
- Subsequent measurements taken

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Alkali-Silica Reactivity Test Results by Volume

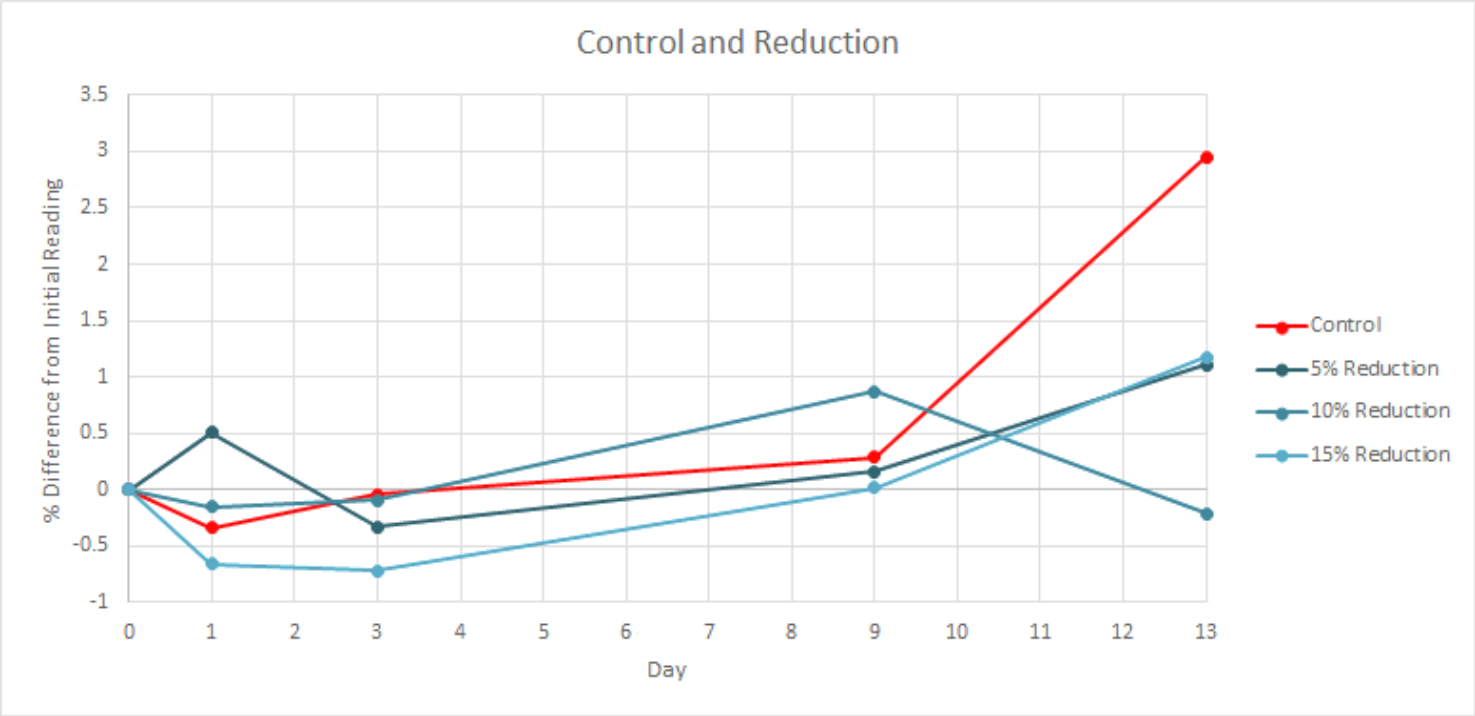

Figure 4: ASR Test Results by Volume

Alkali-Silica Reactivity Test Results by Volume

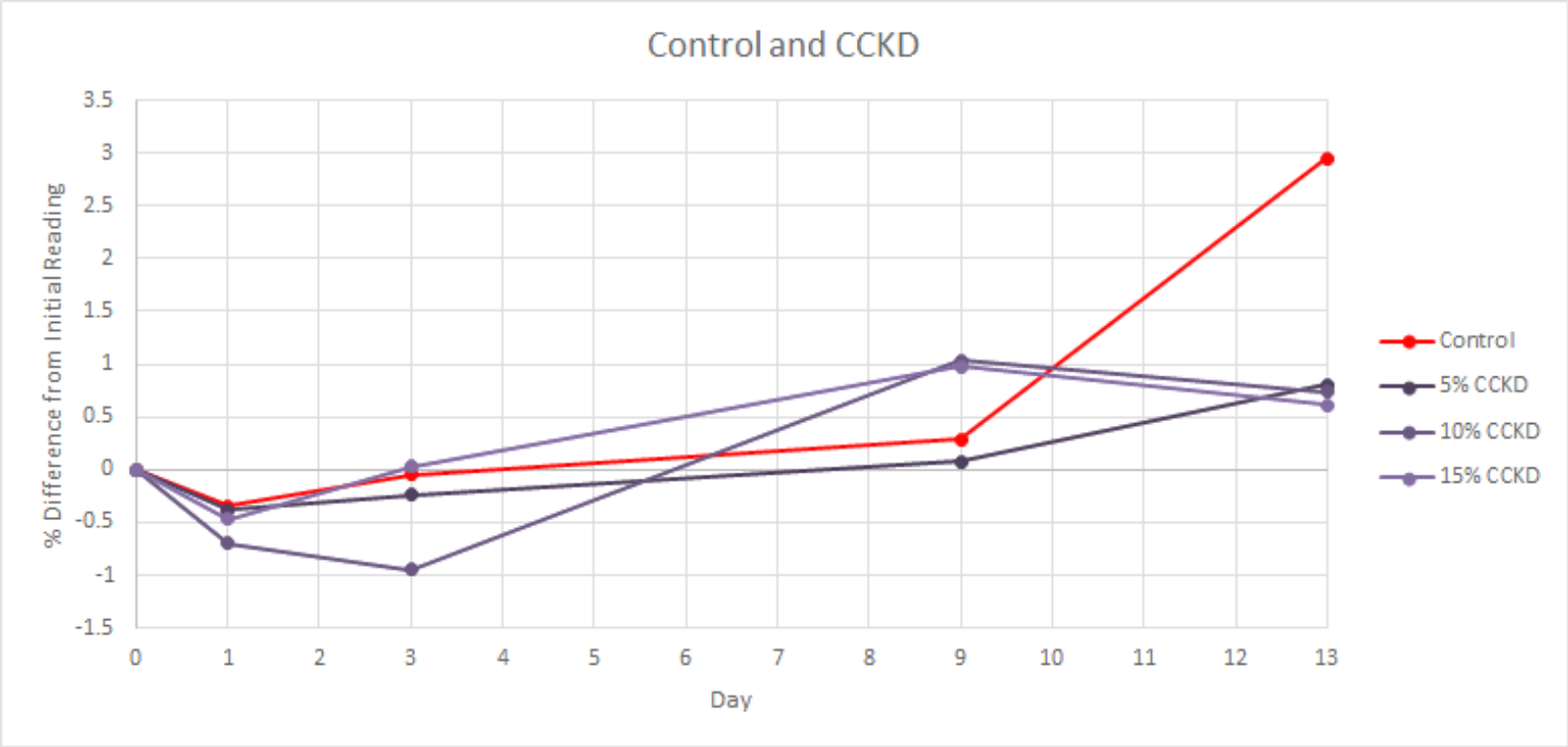

Figure 5: ASR Test Results by Volume

Alkali-Silica Reactivity Test Results by Volume

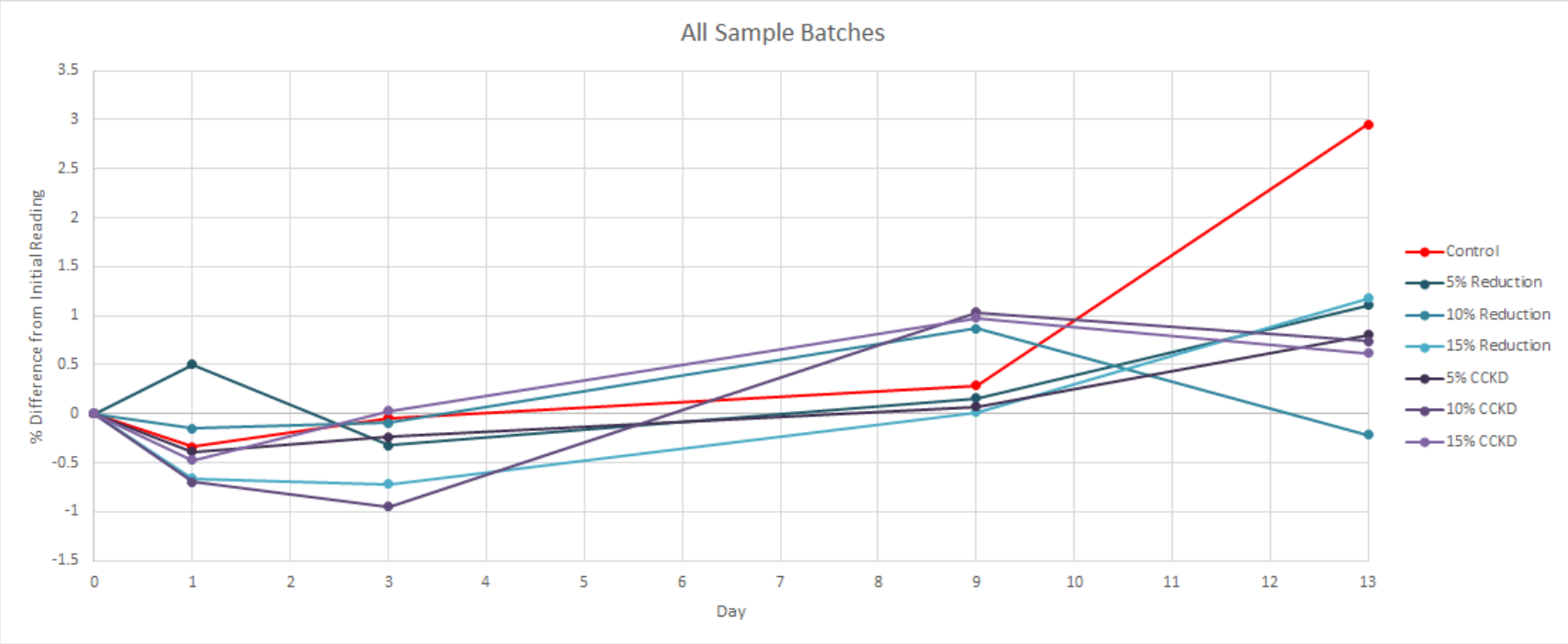

Figure 6: ASR Test Results by Volume

Schedule

Table 3: Schedule

1.0 Design of Concrete Mixes	**Scheduled End Date**	**Actual End Date**
1.1 Concrete Mixing	**02/24/17**	**03/25/17**
1.2 Sample Preparation	**02/24/17**	**03/25/17**
2.0 Testing		
2.1 Strength Testing	**03/24/17**	**03/24/17**
2.2 Durability Testing	**03/24/17**	**04/14/17**
3.0 Data Analysis	**03/31/17**	**04/23/17**

Schedule

4.0 Project Management	Scheduled End Date	Actual/Projected End Date:
4.1 Communication	**05/02/17**	**05/02/17**
4.2 Deliverables	**05/02/17**	**05/02/17**
4.2.1 50% Design Report	**03/02/17**	**03/02/17**
4.2.2 Reflection Document	**04/06/17**	**04/06/17**
4.2.3 Final Report	**05/02/17**	**05/02/17**
4.2.4 Final Presentation	**04/26/17**	**04/26/17**
4.2.5 Website	**05/02/17**	**05/02/17**

Cost of Engineering Services

Table 4: Cost of Engineering Services

Classification	Rate, $/hr	Projected Hours	Projected Cost	Actual Hours	Actual Cost
SR ENG	$207.00	68	$14,076	65.5	$13,559
2 ENG	$120.00	402	$48,240	309.5	$37,140
LAB TE	$78.00	95	$7,410	60.5	$4,719
INT	$35.00	95	$3,325	80.5	$2,818
Total personnel		660	$73,051	516	$58,235
Laboratory	$100.00	61	$6,100	97.5	$9,750
TOTAL			**$79,151**		**$67,985**

Conclusion & Recommendation

- **Conclusion**

The use of CCKD does not significantly decrease the strength or durability of concrete and has the potential to increase strength for a specific range of water to cement ratios.

- **Recommendation**

Conduct strength testing with a higher number of replicates.

Perform an ASR test for 60 days and analyze using SEM.

Conduct more research as to why the CKD samples experienced such a large strength decrease.

Acknowledgements

- Professor Alarick Reiboldt: Technical Advisor
- Gerjen Slim: Lab Manager
- Dr. Robin Tuchscherer: Assistant Professor
- Dr. CHUN-HSING (Jun) HO: Assistant Professor

[12]

References

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Questions