Role of Minimum Cement Contents in Concrete Specifications and Mixture Proportioning

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Introduction

- Should Minimum CM content be specified?
- Mixture proportioning with low CM content

Research Objective

Examine influence of CM content on concrete performance at specific *w/cm*

Parallel tests at Iowa State University

Experimental Variables

w/cm: 0.40, 0.47, 0.55

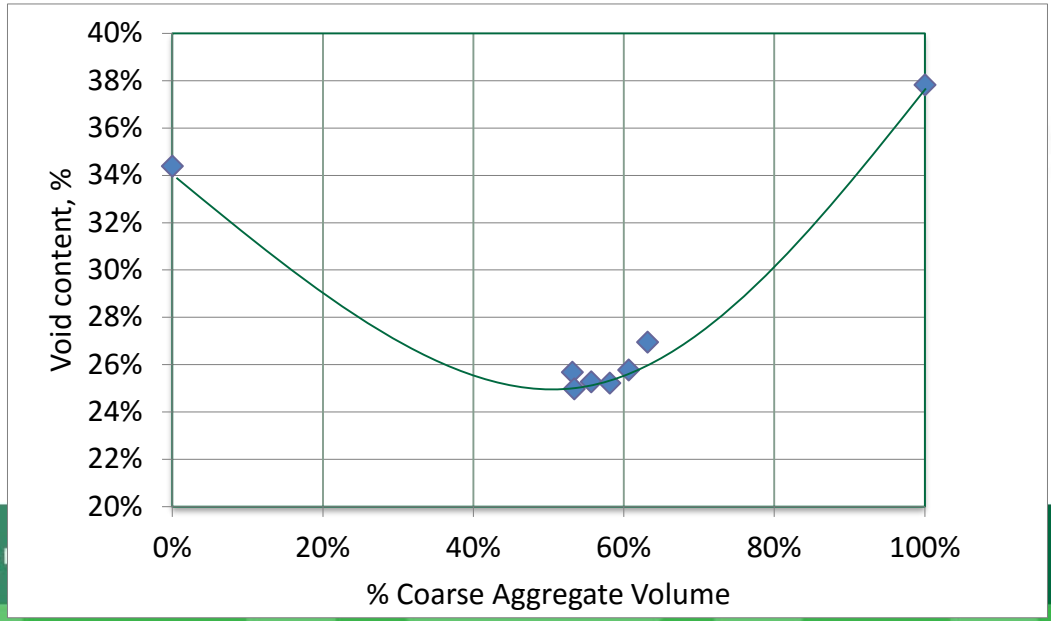
CM – 417 to 720 lb/yd^3

Paste: 22%, 24%, 27%, 31% at same CA/FA

Total of 20 non-air concrete mixtures

40% slag cement, 100% OPC, 25% Class F

Aggregate Voids Testing (ASTM C29)



Concrete Tests Conducted

Slump – add Type F HRWR if slump<1 in.

Air content, density, temperature, setting time

Compressive strength

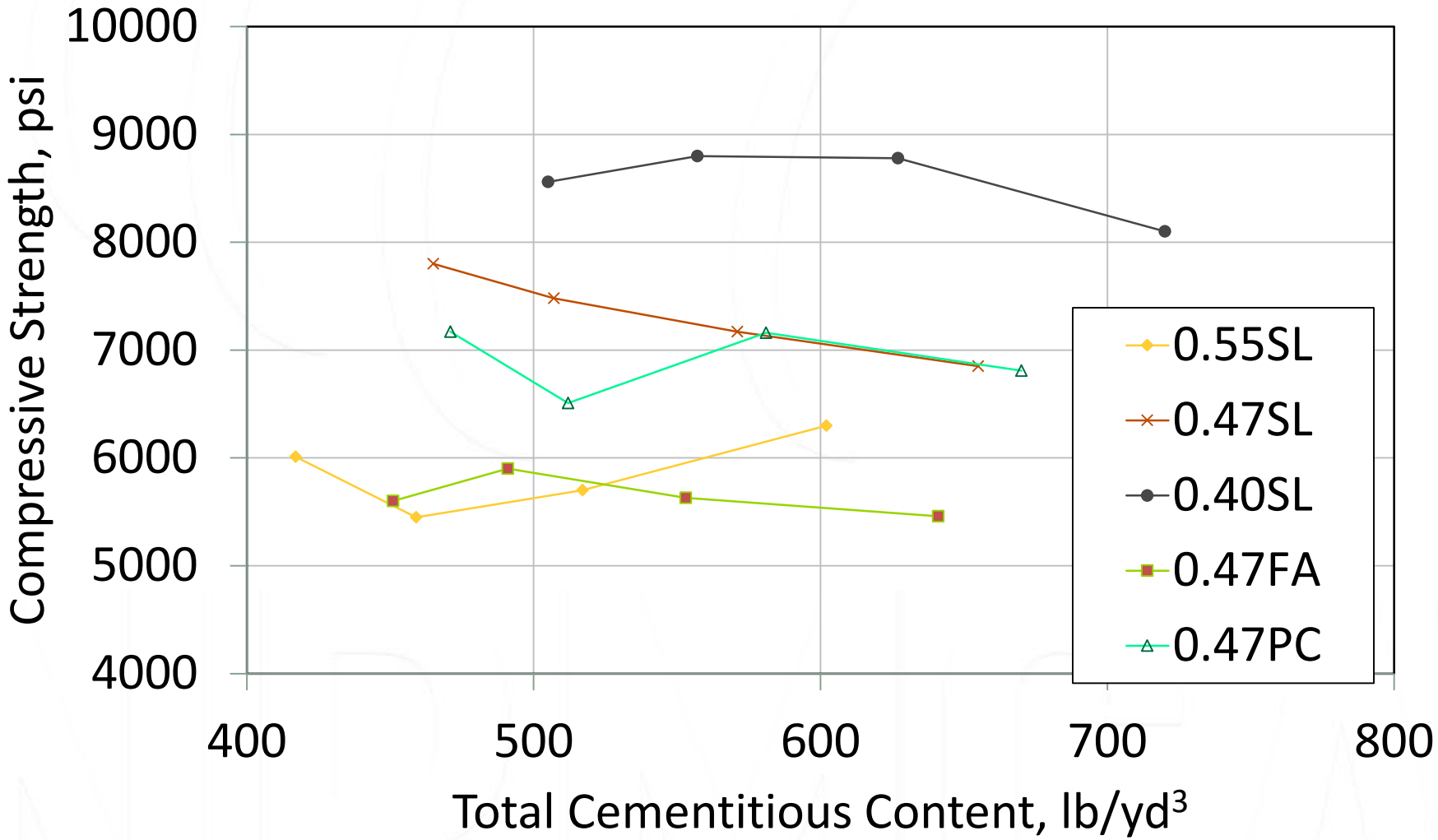
RCPT (ASTM C1202)

RMT (AASHTO TP64)

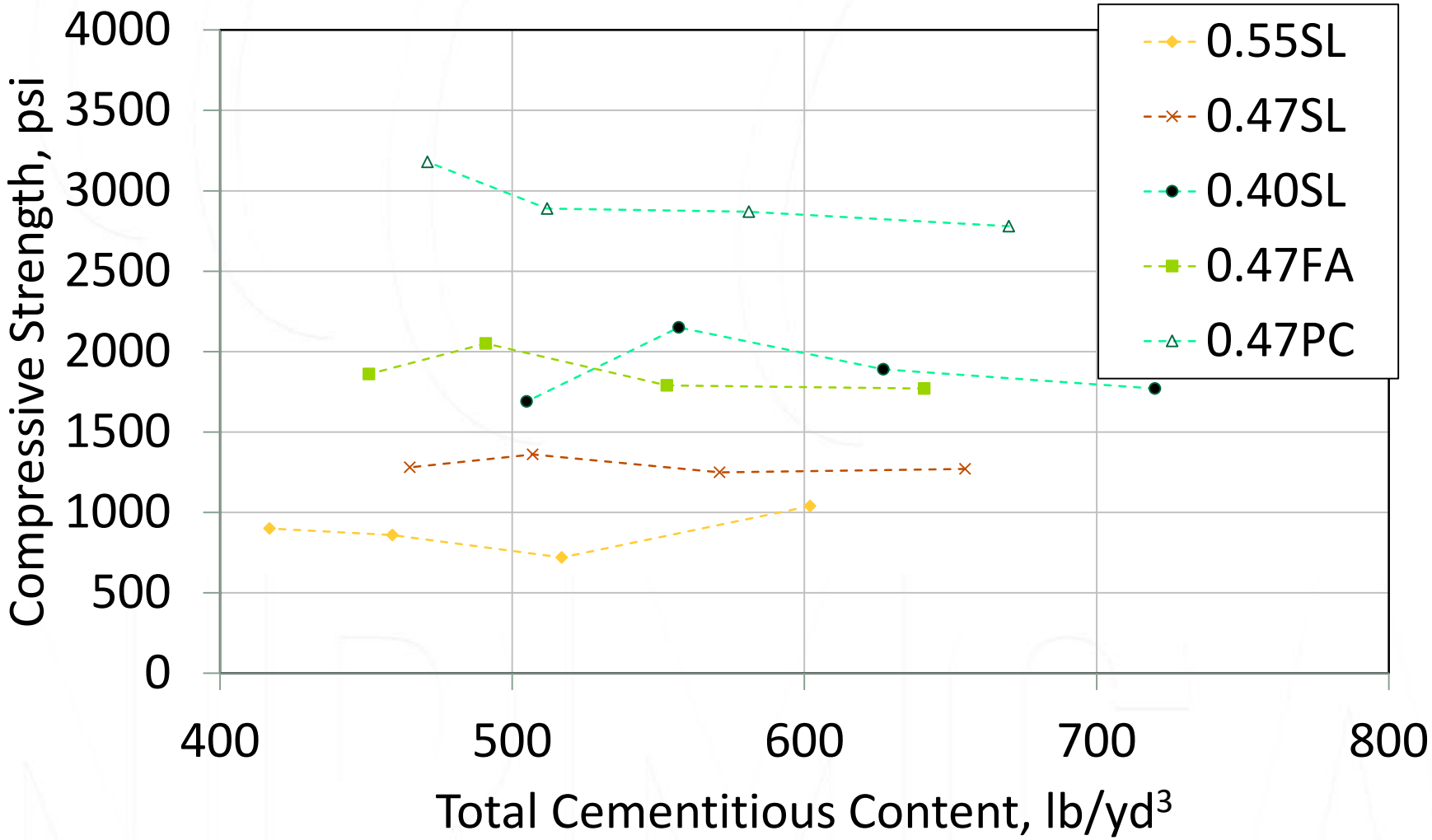
Sorptivity (C1585)

Shrinkage (C157)

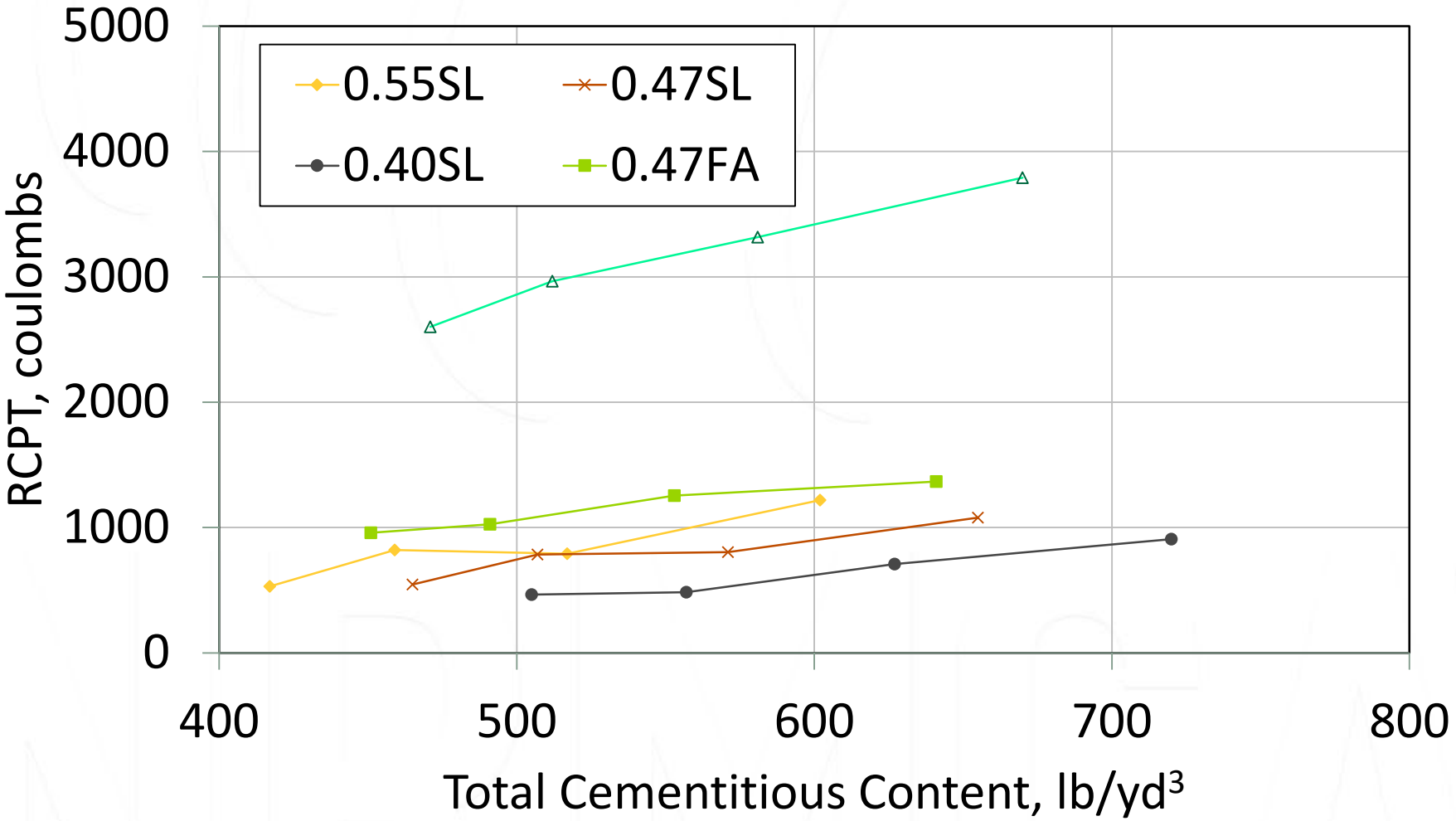
Compressive Strength – 28 days



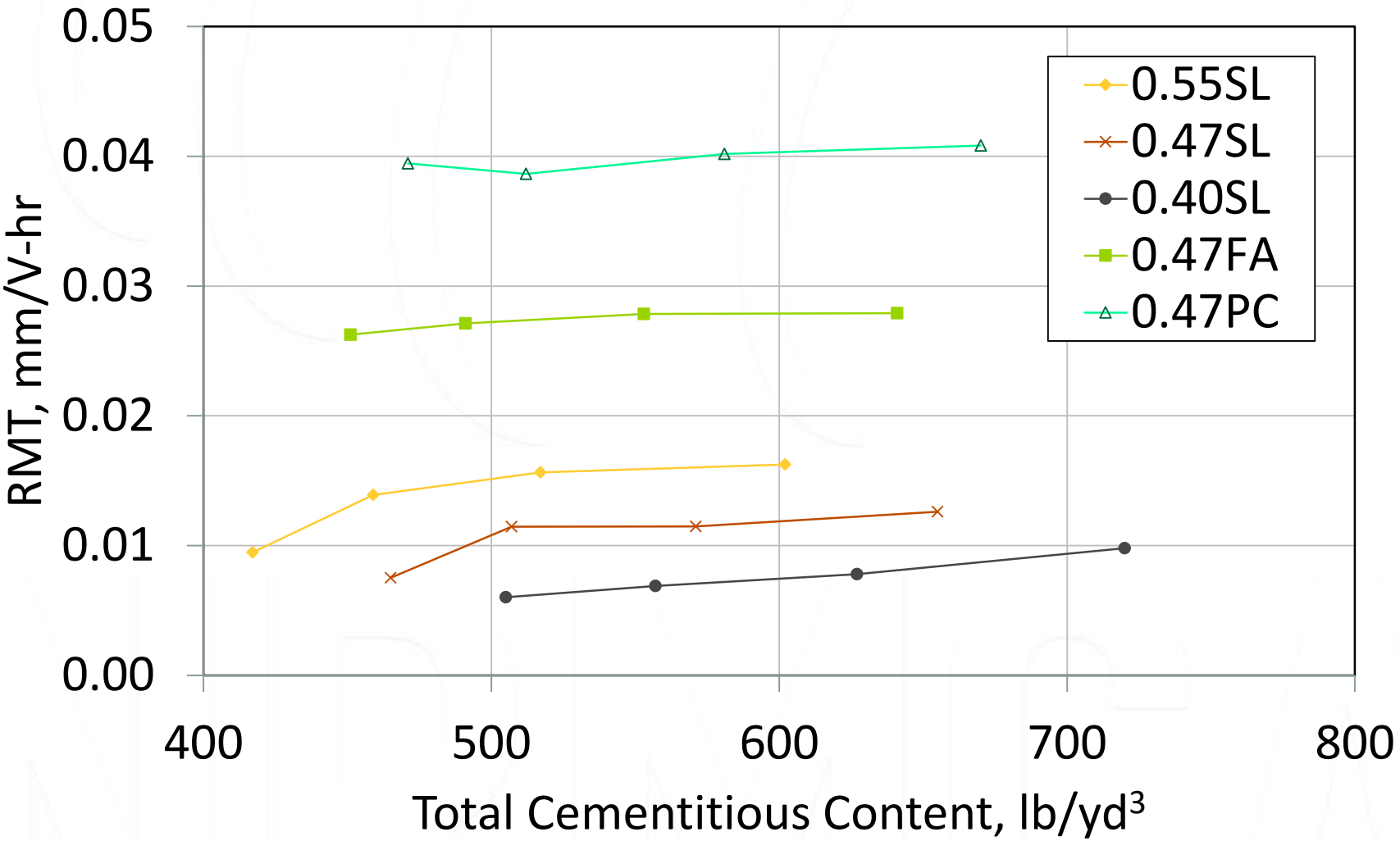
Compressive Strength – 1 day



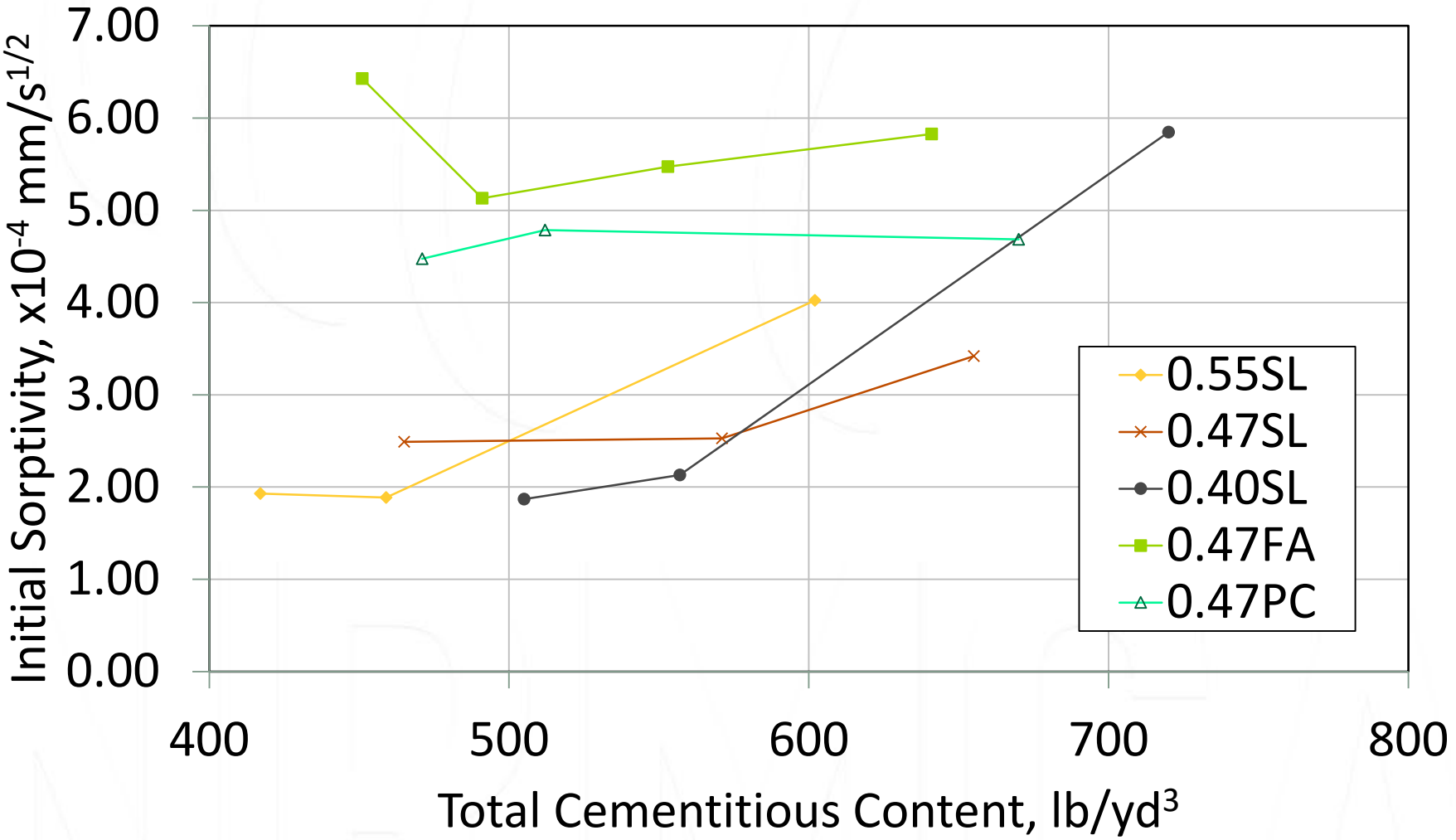
RCPT – 28 day AC



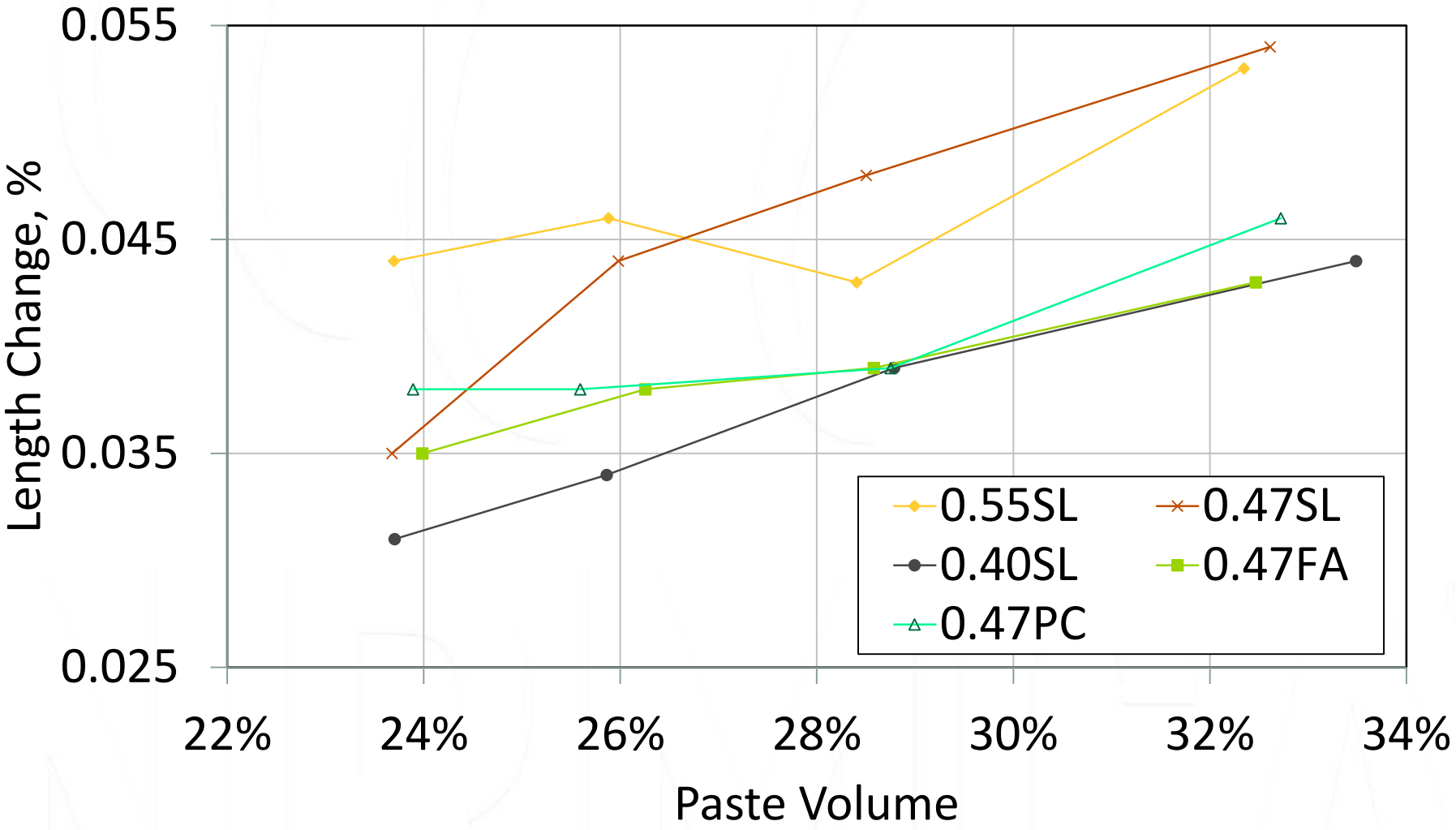
RMT – 28 day AC


0.05
0.04
0.03
0.02
0.01
0.00
RMT, mm/V-hr
400
500
600
700
800
Total Cementitious Content, lb/yd³
0.55SL
0.47SL
0.40SL
0.47FA
0.47PC

Initial Sorptivity



Drying Shrinkage – 90 days



Summary

Higher CM contents increase mixing water demand

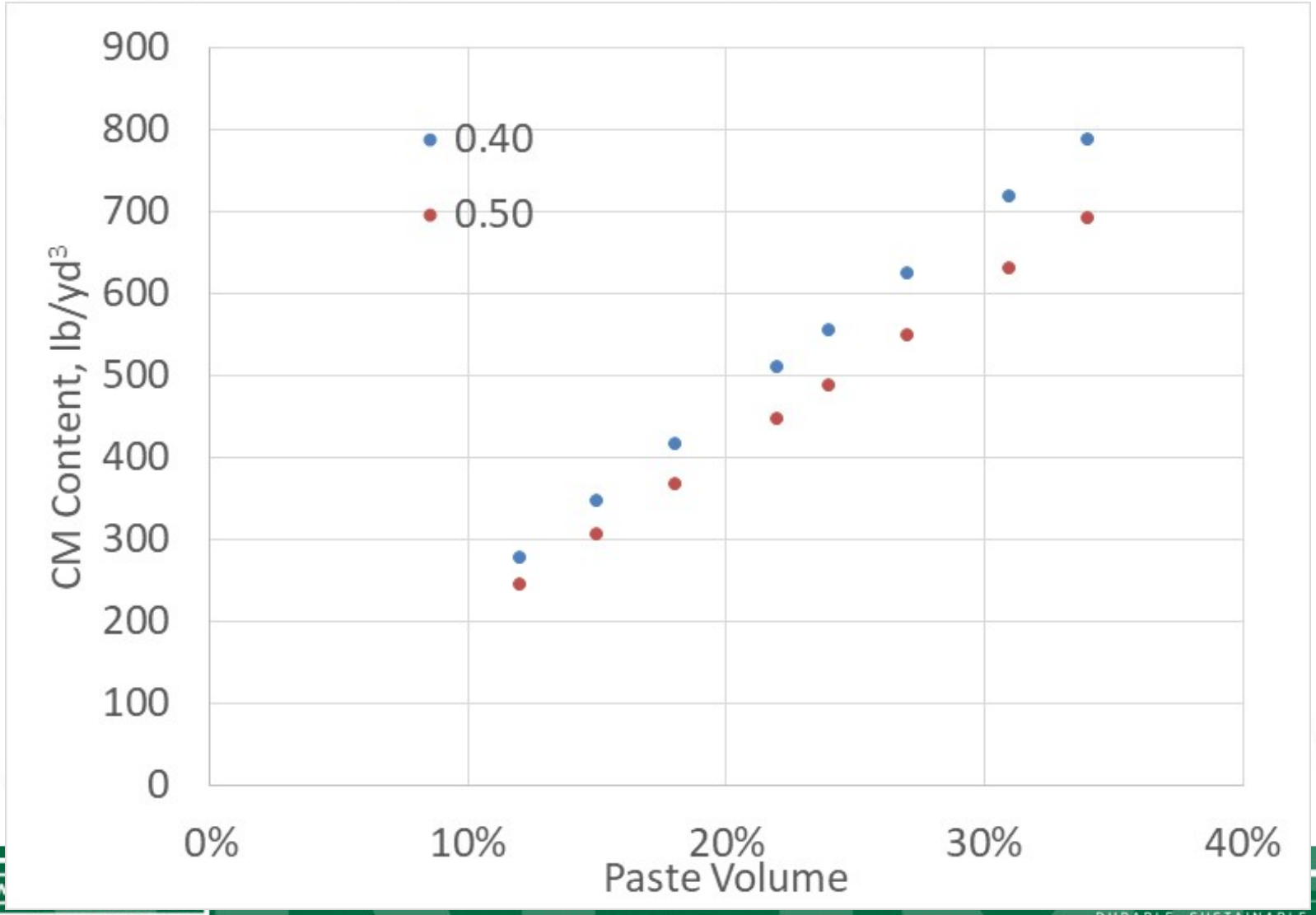
For given *w/cm* increasing CM content:

- Same strength
- Increased chloride penetrability, sorptivity, shrinkage

Does not appear to be a technical basis for specifying minimum CM content or a maximum *w/cm* when not needed

Mixtures with Low CM content

How low can you go?



Mixtures with Low CM content

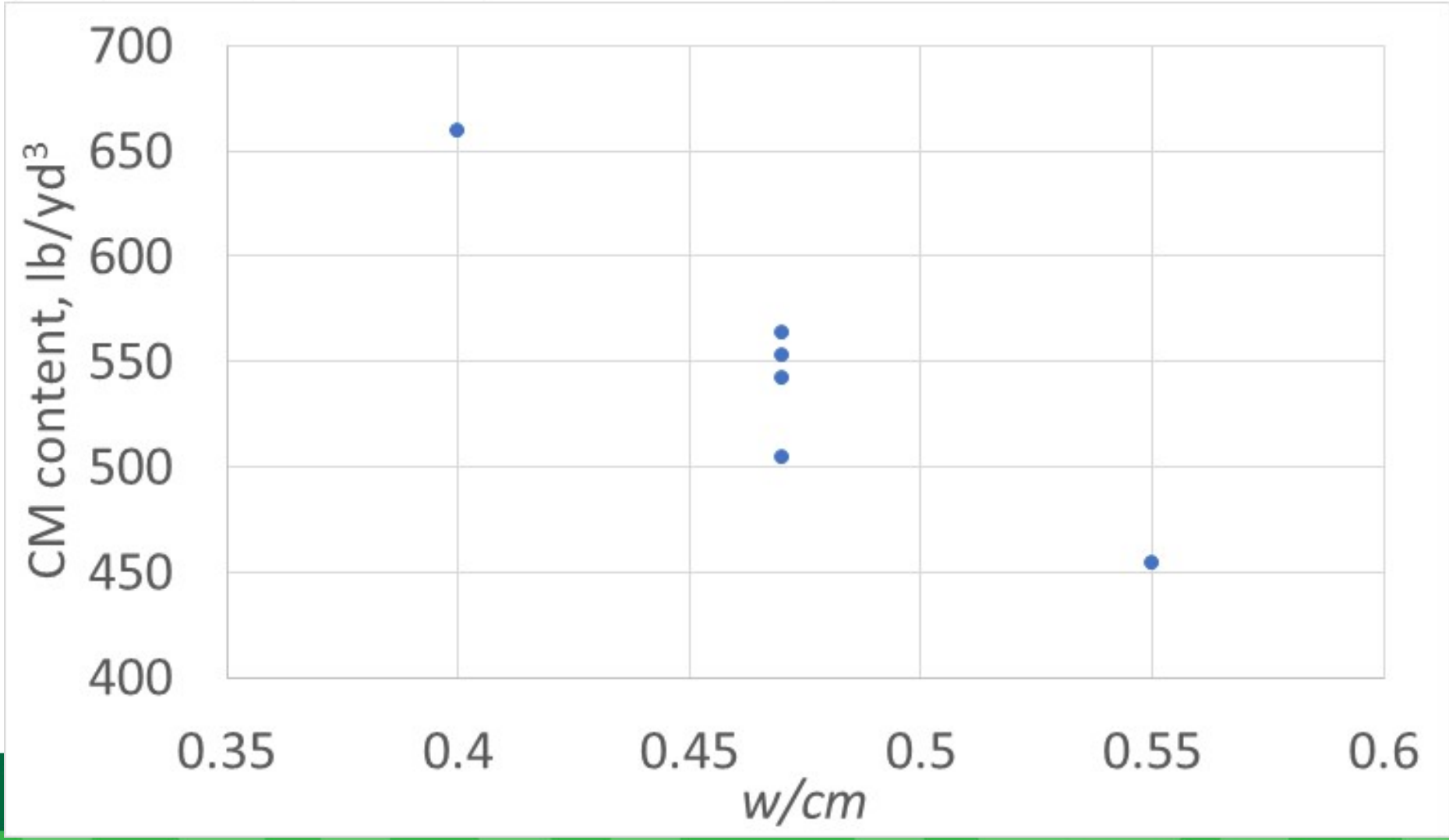
How low can you go?

- Impact of air entrainment?
- Impact of SCMs and WRA

Cast 12 more mixtures

Minimum CM content for acceptable performance – Effect of *w/cm*

For water slump of 1 in. before WR addition



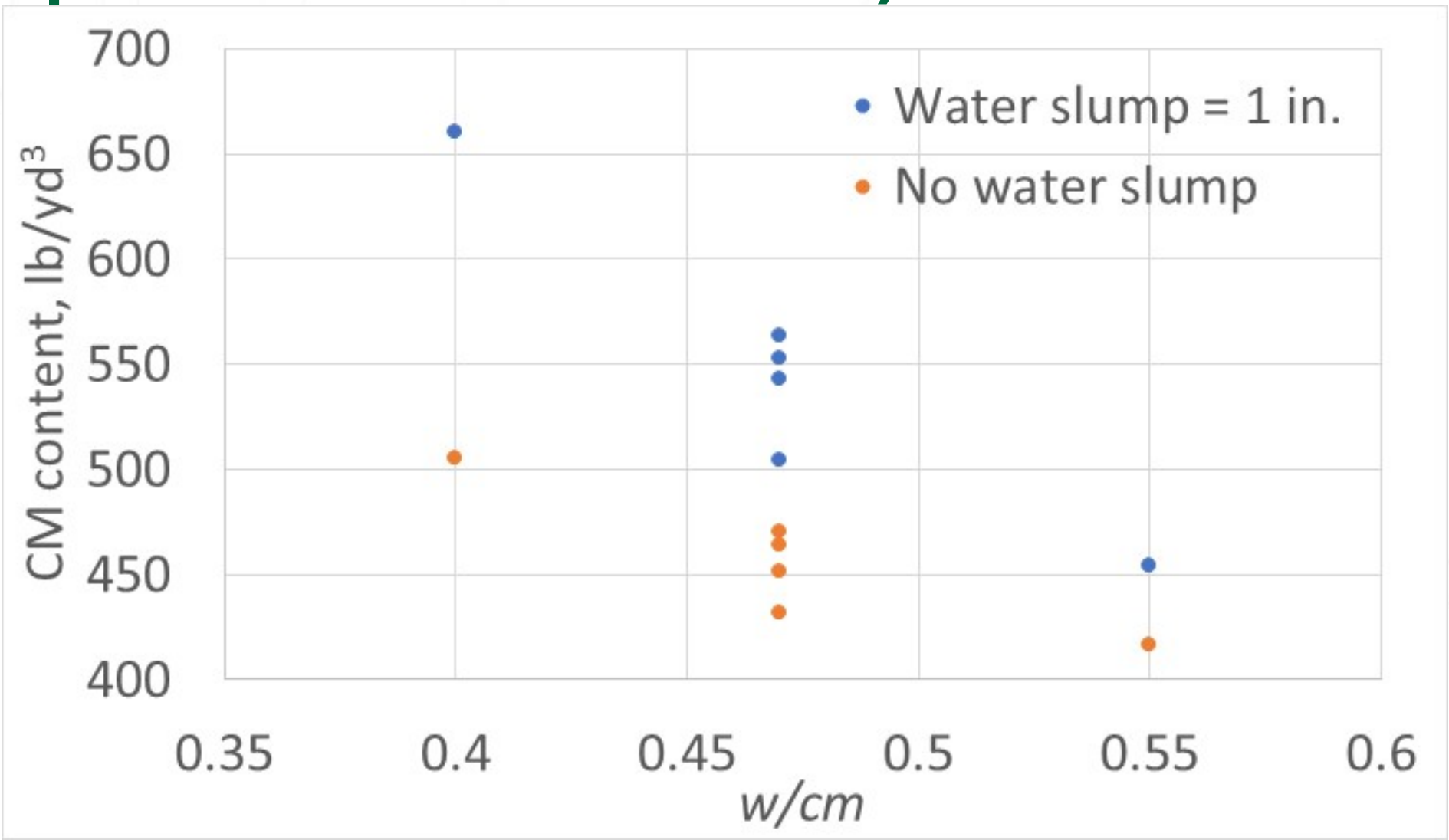
Minimum water, paste volume – Effect of *w/cm*

For water slump of 1 in. before WR addition

	0.40	0.47	0.55
40% SL	265/28%	260/26%	250/24%
PC		265/26%	
25% FA		255/26%	
40% SL A		240/24%	

But what if WRA can be added earlier?

Minimum CM content for acceptable performance – Effect of *w/cm*



Minimum water, paste volume – Effect of *w/cm*

For no measurable water slump (use of WRA)

	0.40	**0.47**	**0.55**
40% SL	202/22%	218/22%	230/22%
PC	207/22%	221/22%	235/22%
25% FA	199/22%	212/22%	225/22%
40% SL A		203/20%	

Minimum CM content for acceptable performance

0.47 w/cm 40% slag mix

Condition	Water	CM	PV, %
Control	300	640	30%
Water slump=1 in.	260	550	26%
No water slump (NWS)	218	460	22%
NWS - air entrained	203	430	20%

Benefits of not specifying minimum CM

- Better concrete performance
- Optimized mixtures
- Sustainable construction
- Incentive to lower variability, i.e. improve quality
- Knowledgeable producers

How to specify to get low CM content concrete?

What if producers reduce CM contents too low?

What if we state a maximum CM content?

What if we state a maximum paste volume?

What if we state a strength range?

Reasonable performance specs – best solution!

Thank you

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