ROMAN CEMENT

Solutions For Making Blended Cements For Non-Engineered Concrete

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Introduction

Roman Cement

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Roman Cement Philosophy

Engineer Cement and Pozzolan to Work Together

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….But

- Cement Industry Optimizes for 100% Cement
- Industry Attempts to “Fix” the Pozzolan Fraction

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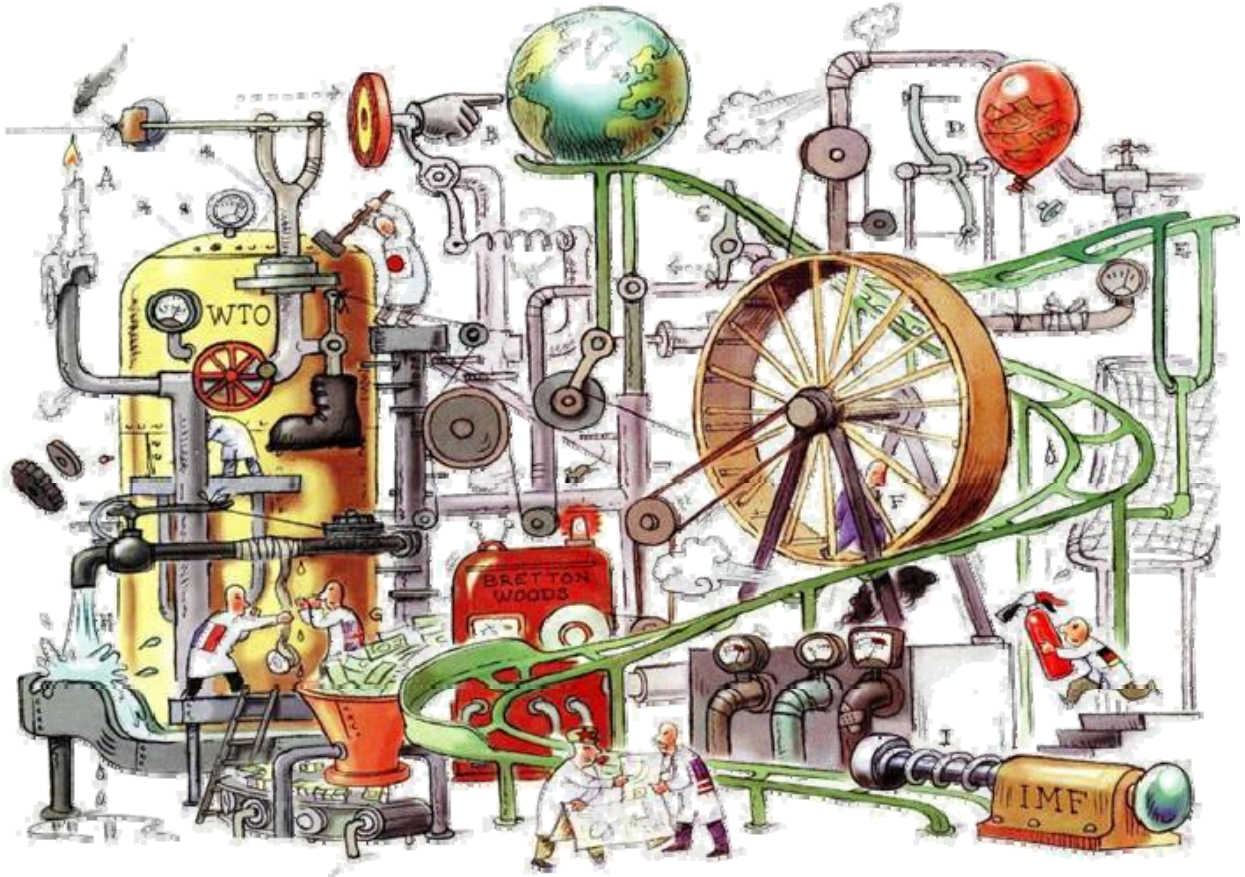
Engineered Concrete…



….But is it Suitable for the Masses?

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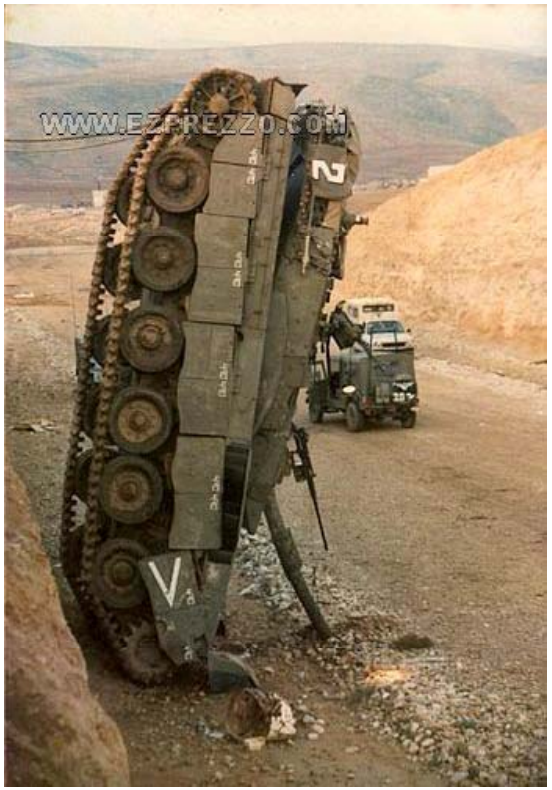
Engineered Concrete…



…When Good Mix Designs are Implemented by the Untrained

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Roman Cement: Performance Criteria

Make General Purpose "Plug and Play" Cements

- Match the Strength Curve of OPC
- Maintain similar Water Demand
- Maintain similar Set Time
- Maintain similar Autogenous Shrinkage

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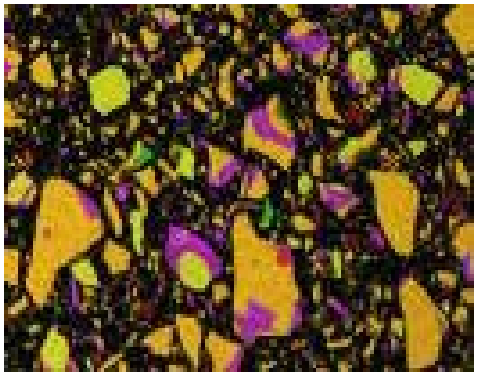
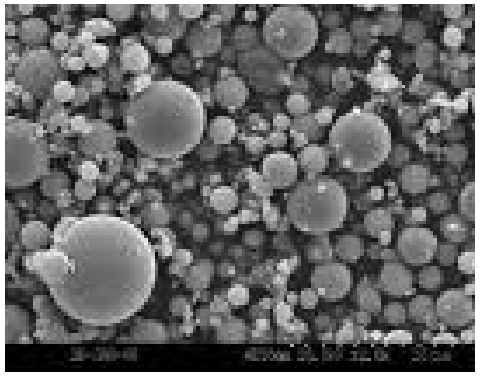
How It Works

What Should the Particle Size Distributions of the Cement and Pozzolan Be?

- Cement gives good Early Strength
- Fly Ash gives good Long Term Strength and Durability





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Predicted Outcome of Blending Fine Cement With Coarse Pozzolan

Strength Development

- Portland Cement will provide early age strength and Pozzolan will provide later age strength

Water Demand

- Coarse Ash Will Compensate For Fine Cement

Set Time

- Fine Cement Will Provide Reasonable Set Times

Autogenous Shrinkage

- Coarse Pozzolan Will Compensate For Fine Cement

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Experimental Mix Designs

Four Cements

- Targeted D90s of 5, 10, 15 and 20 microns

Four Fly Ashes

- Targeted D10s of 5, 10, 15 and 20 microns

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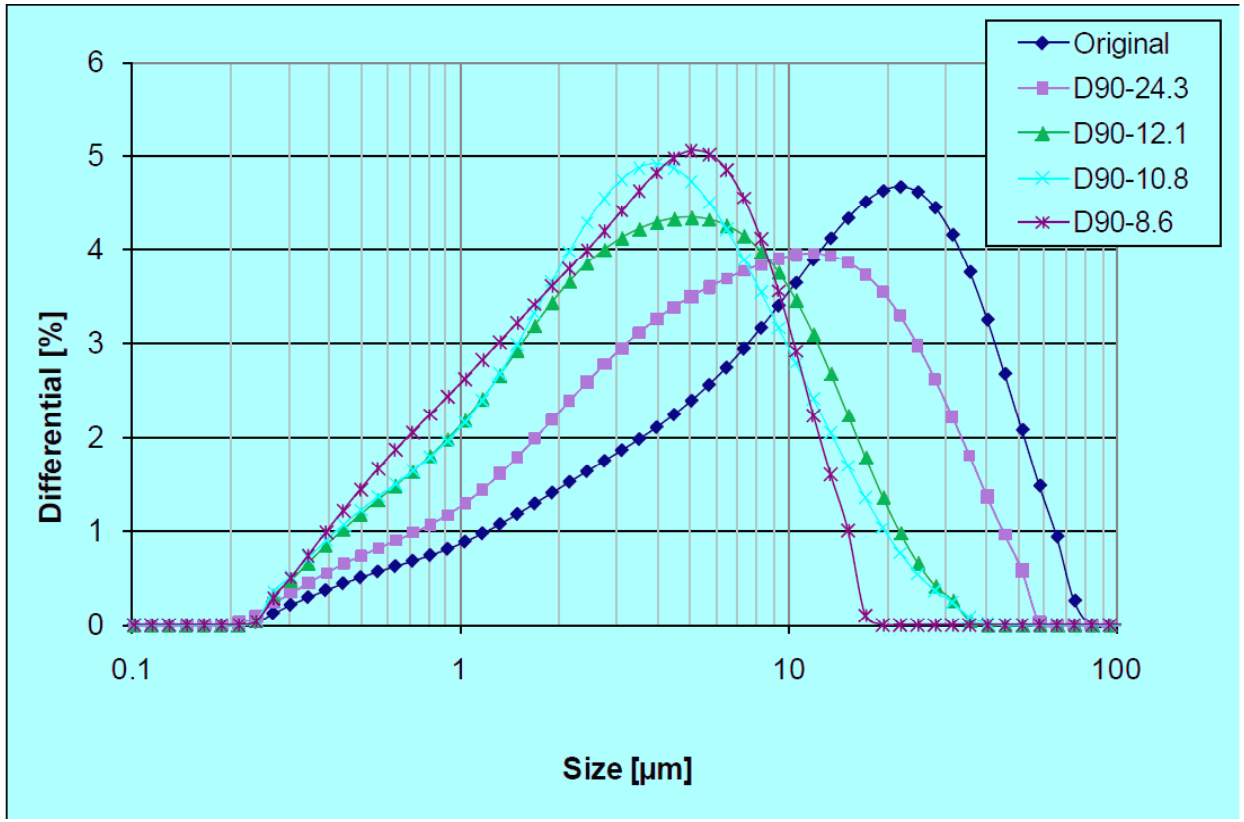
Distributions of Cement Fractions



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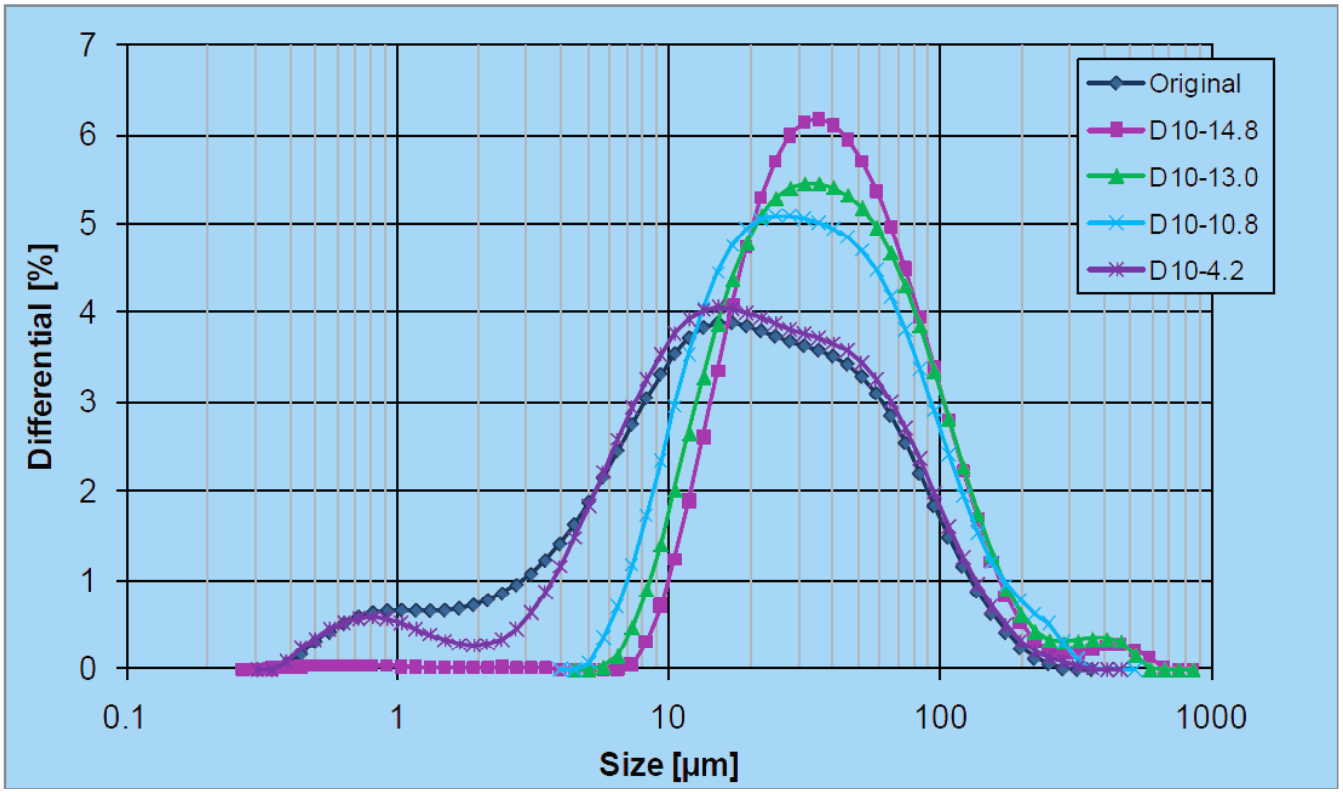
Distributions of Fly Ash Fractions



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Experimental Mix Designs

Four Substitution Levels by Volume

- 20%, 35%, 50%, 65%

Mortars Prepared With Constant Volume Fractions

- Binder, Water and Sand

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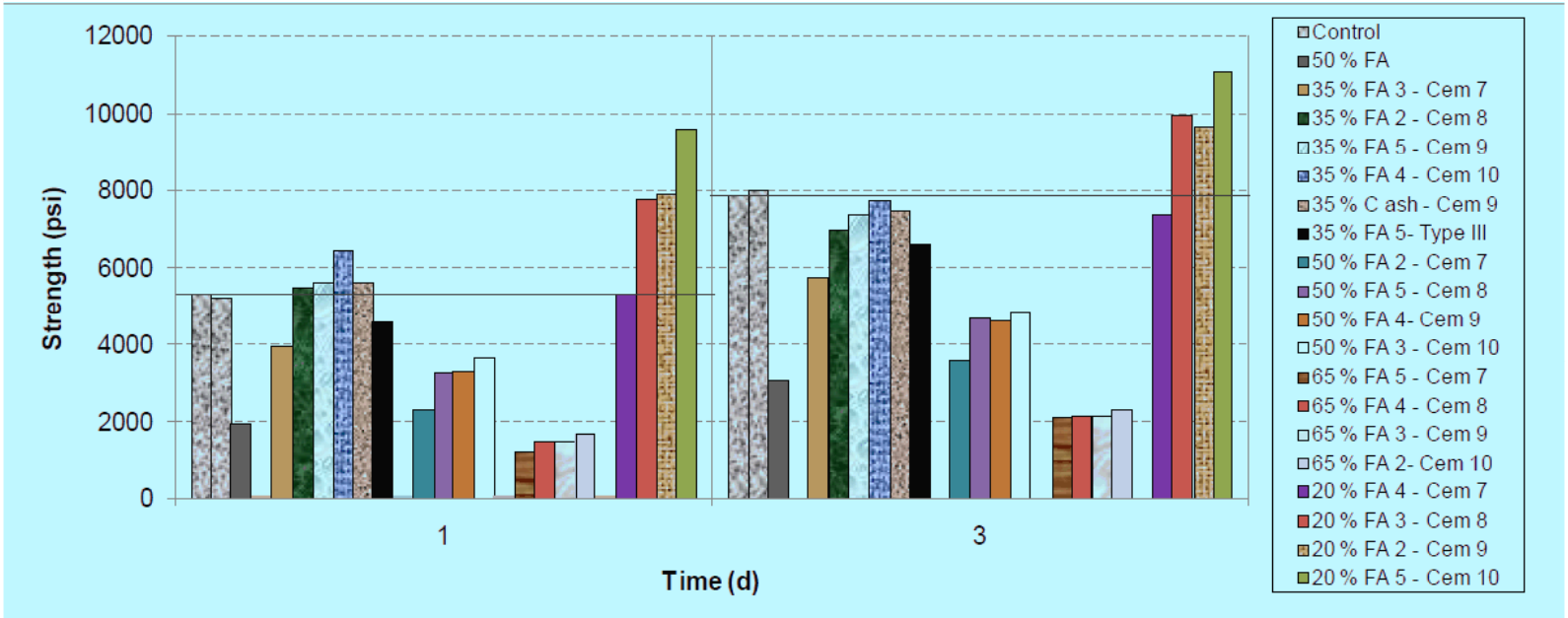
1- and 3-Day Strengths



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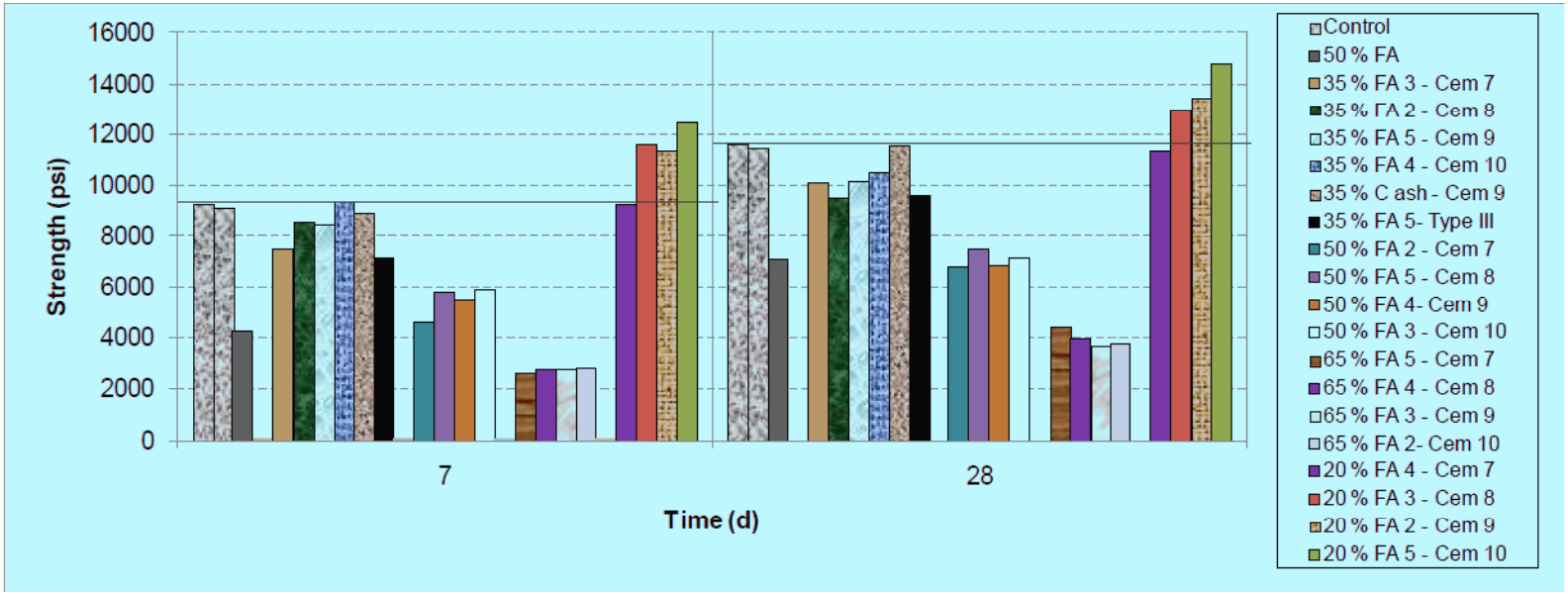
7- and 28-Day Strengths



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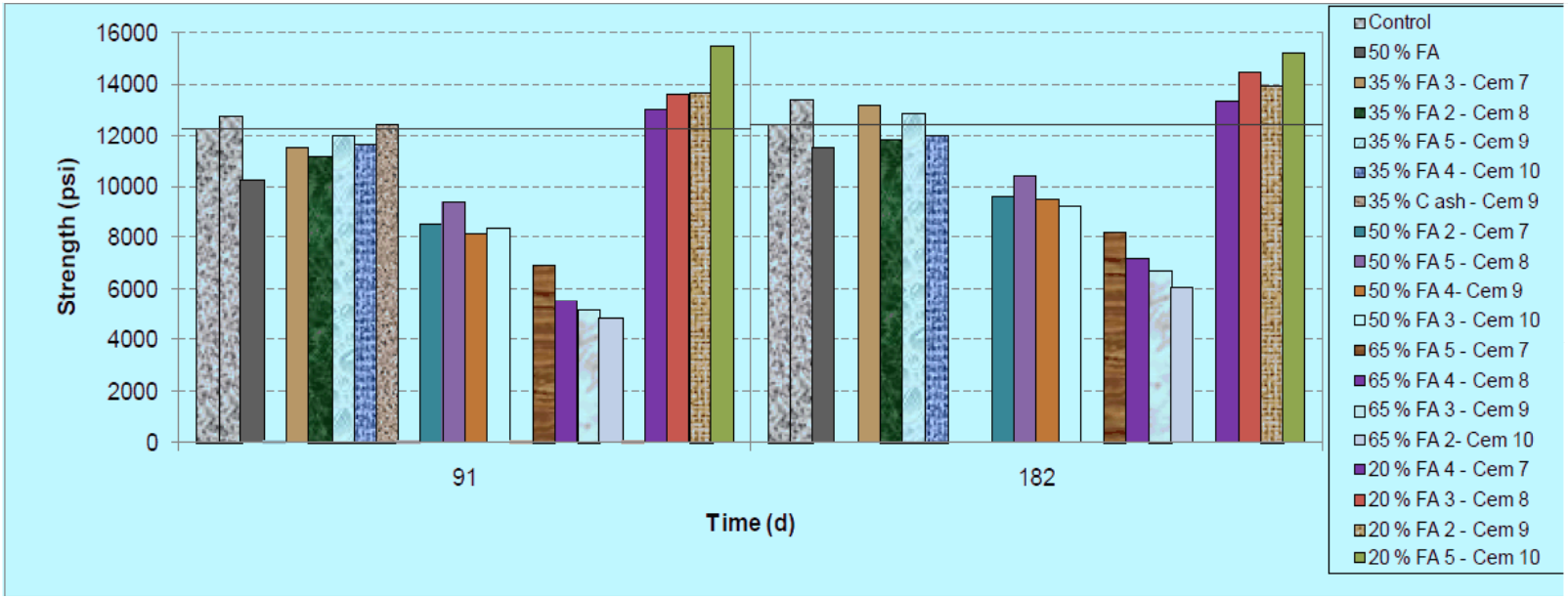
128- and 182-Day Strengths



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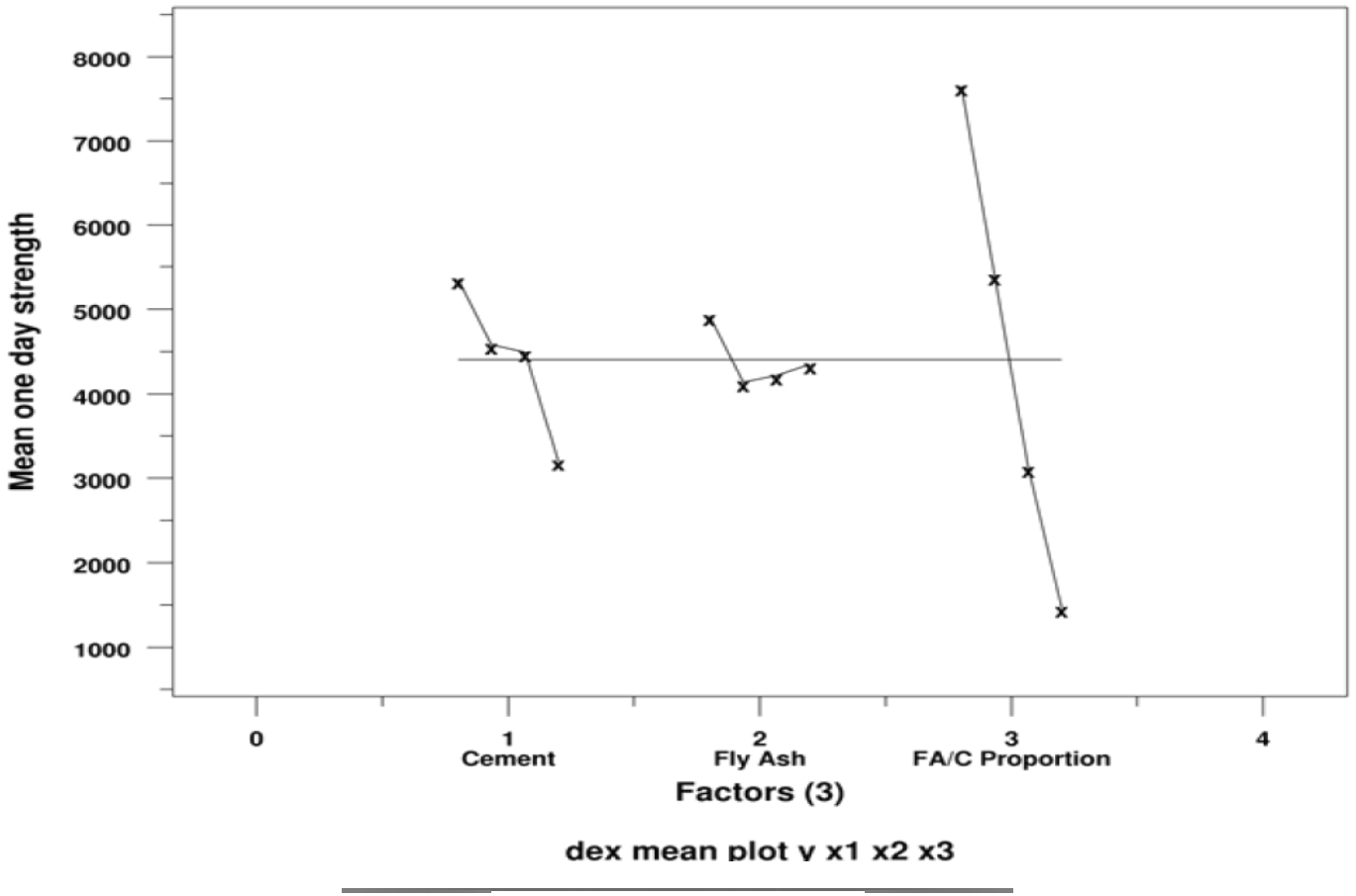
“Main Effects Plot” 1 Day Strength



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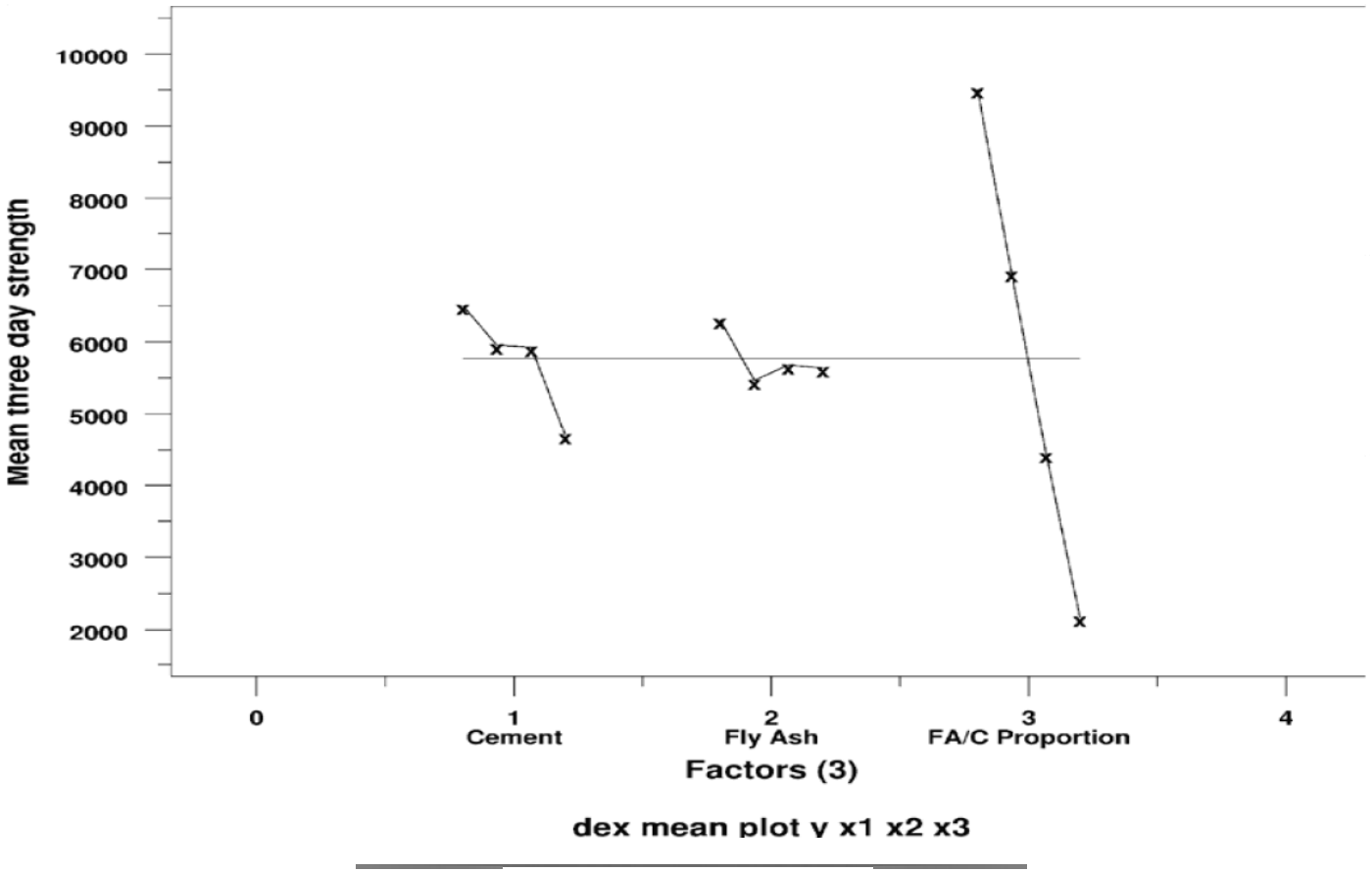
“Main Effects Plot” 3 Day Strength



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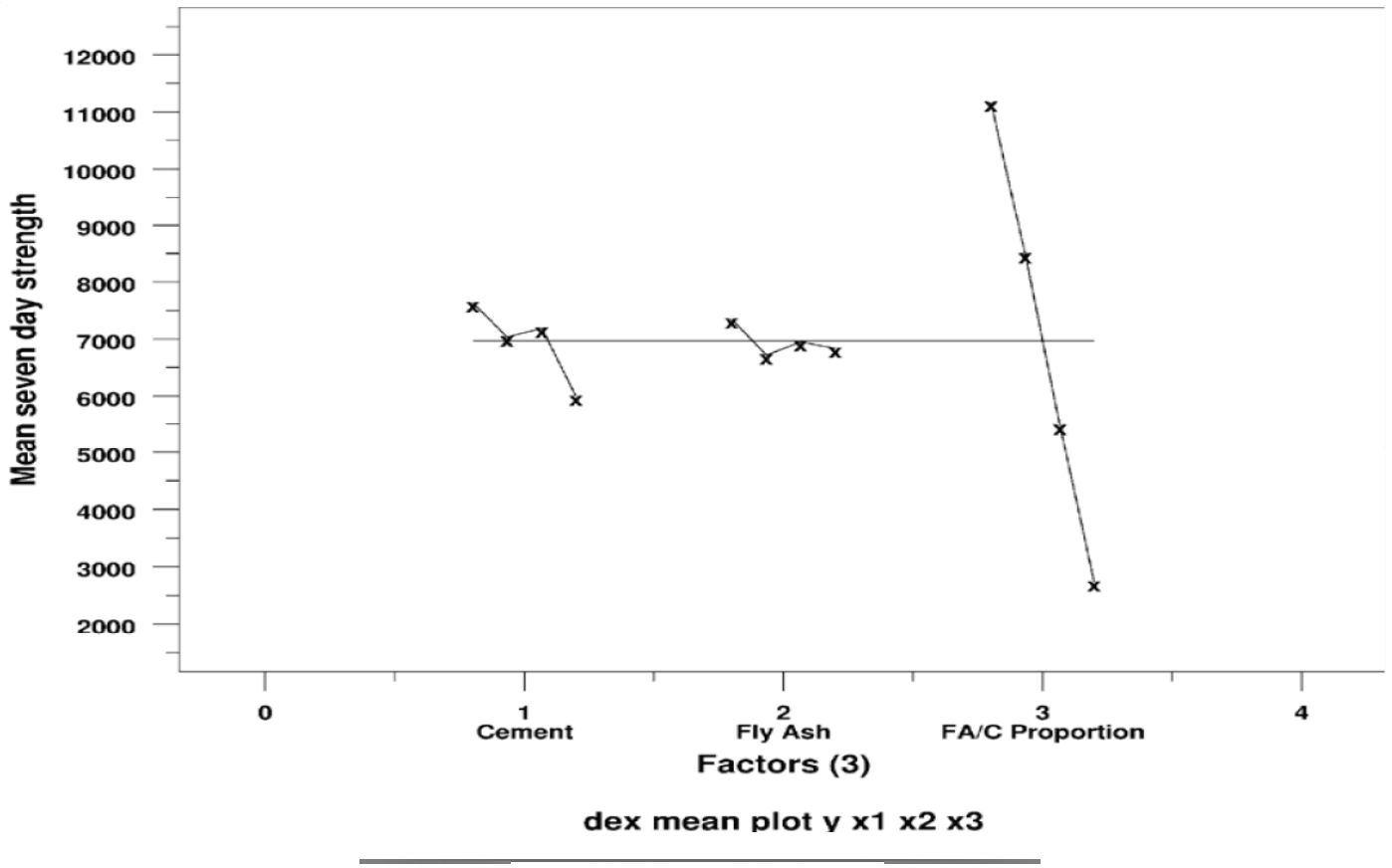
“Main Effects Plot” 7 Day Strength



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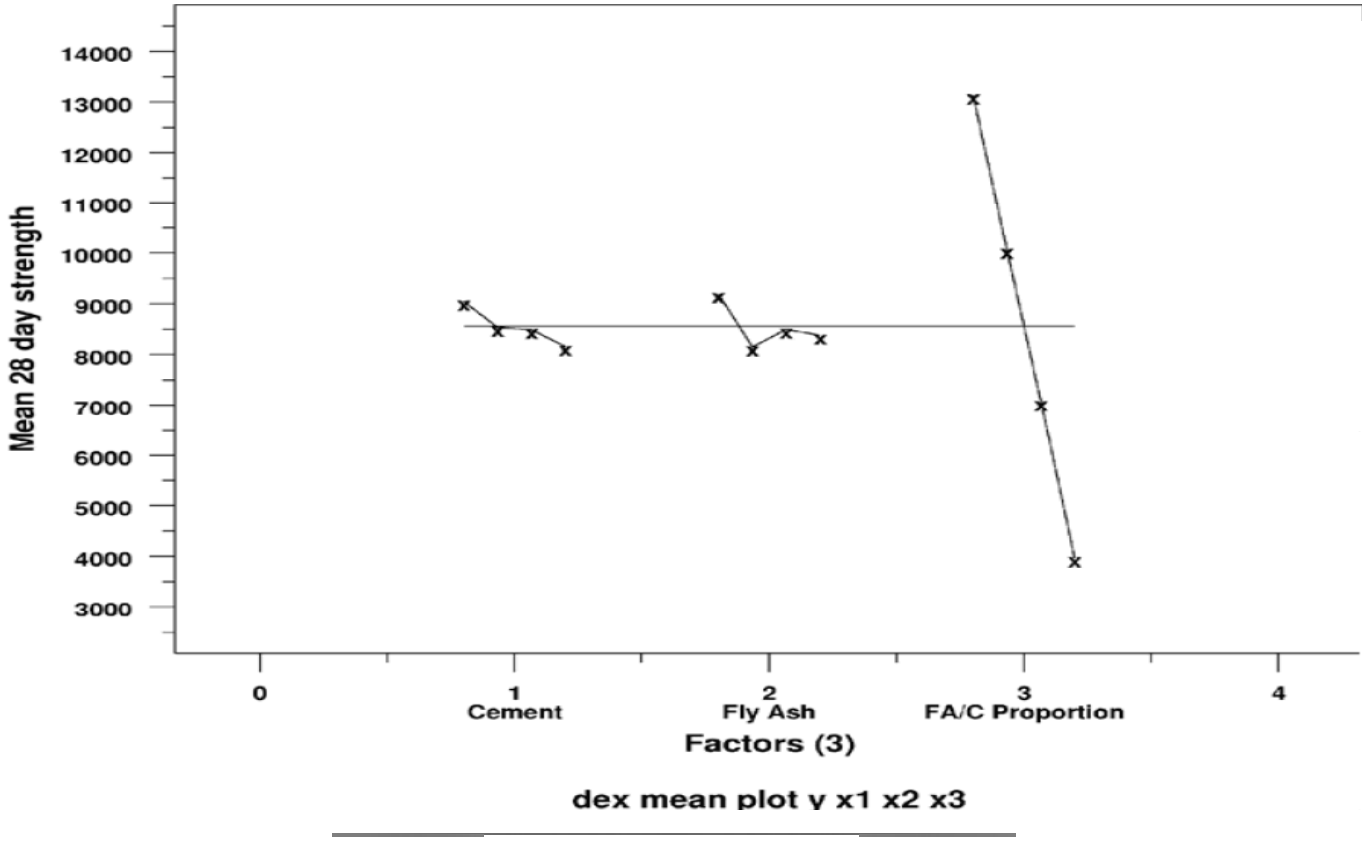
“Main Effects Plot” 28 Day Strength



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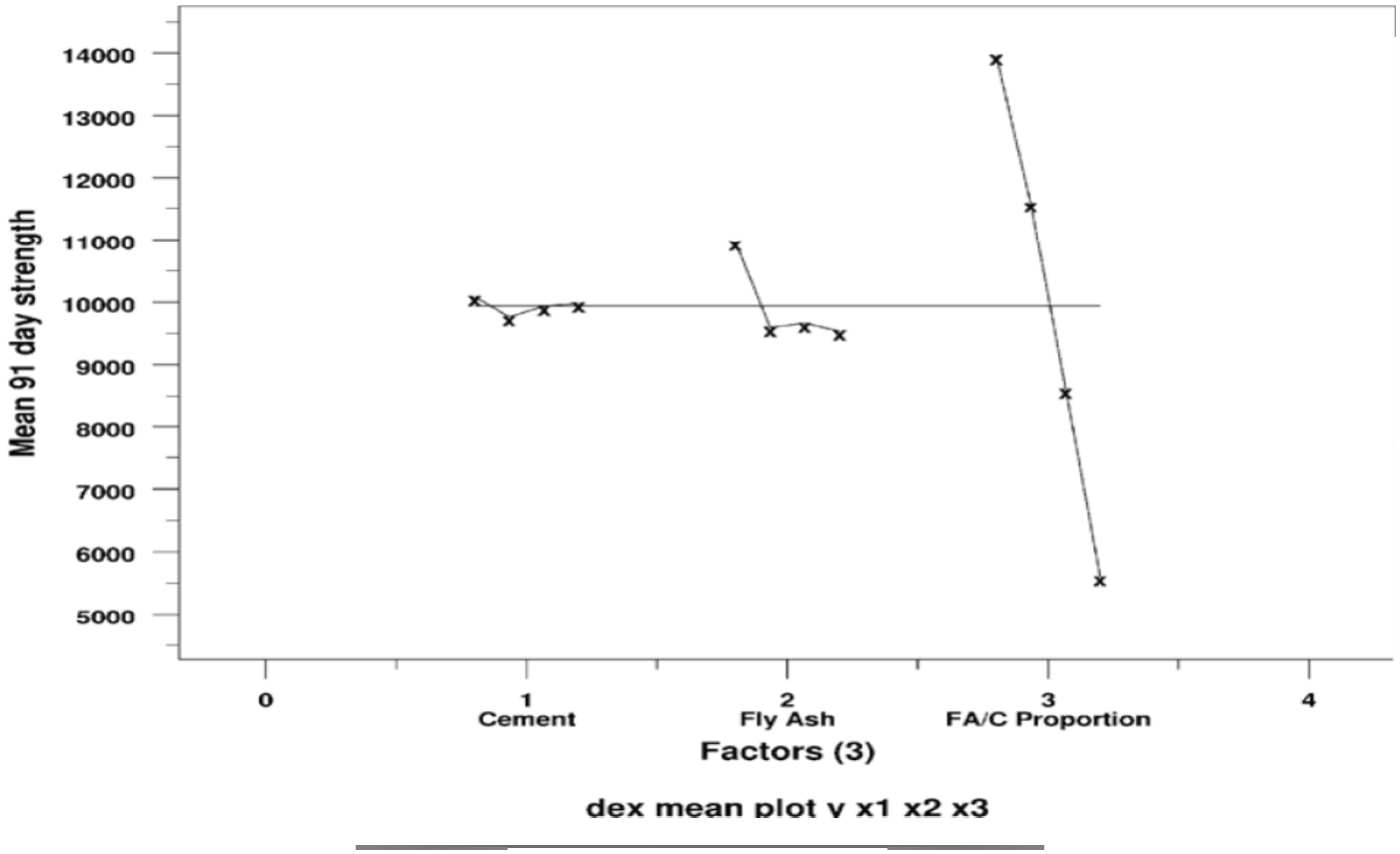
“Main Effects Plot” 91 Day Strength



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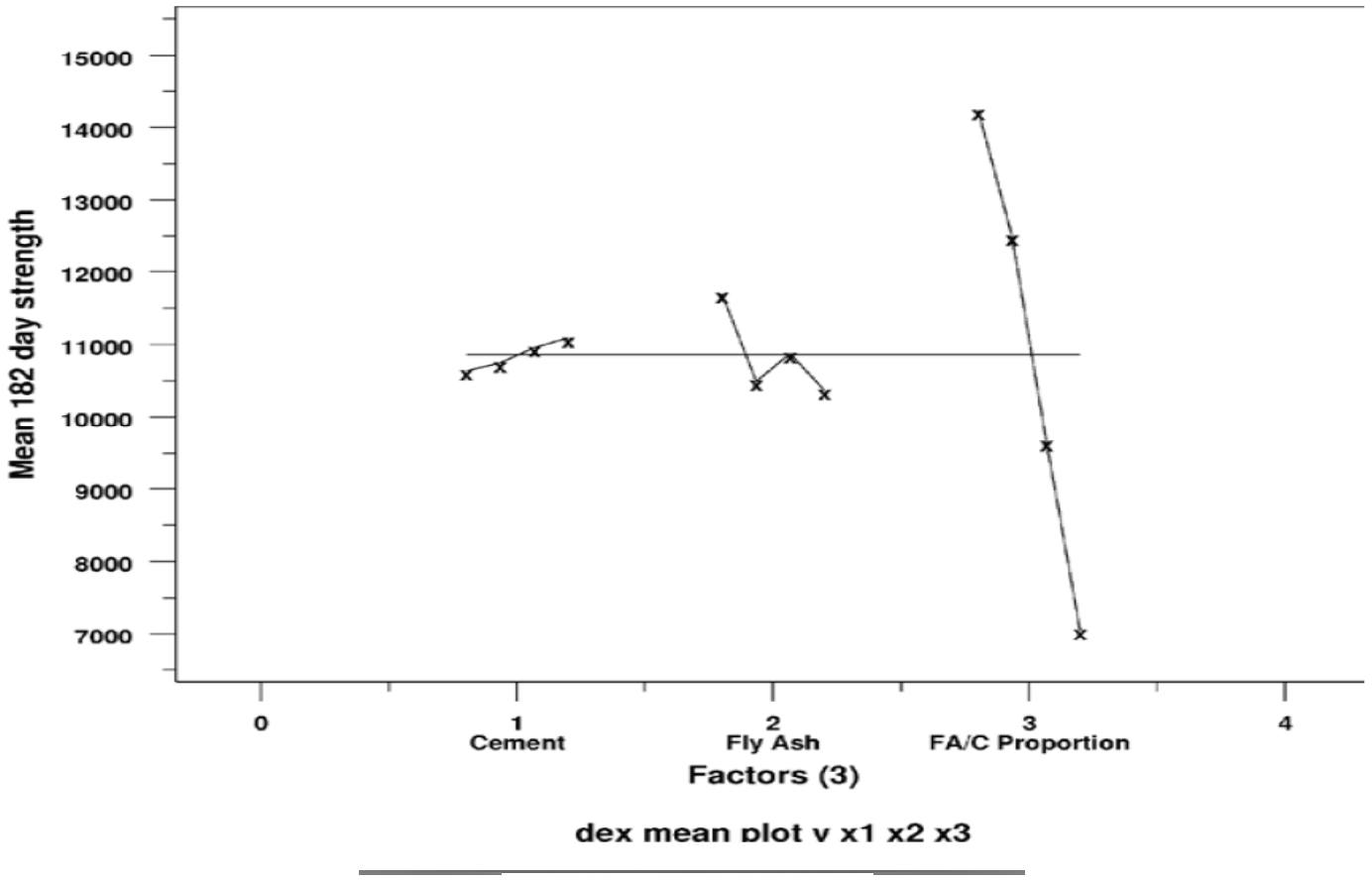
“Main Effects Plot” 128 Day Strength



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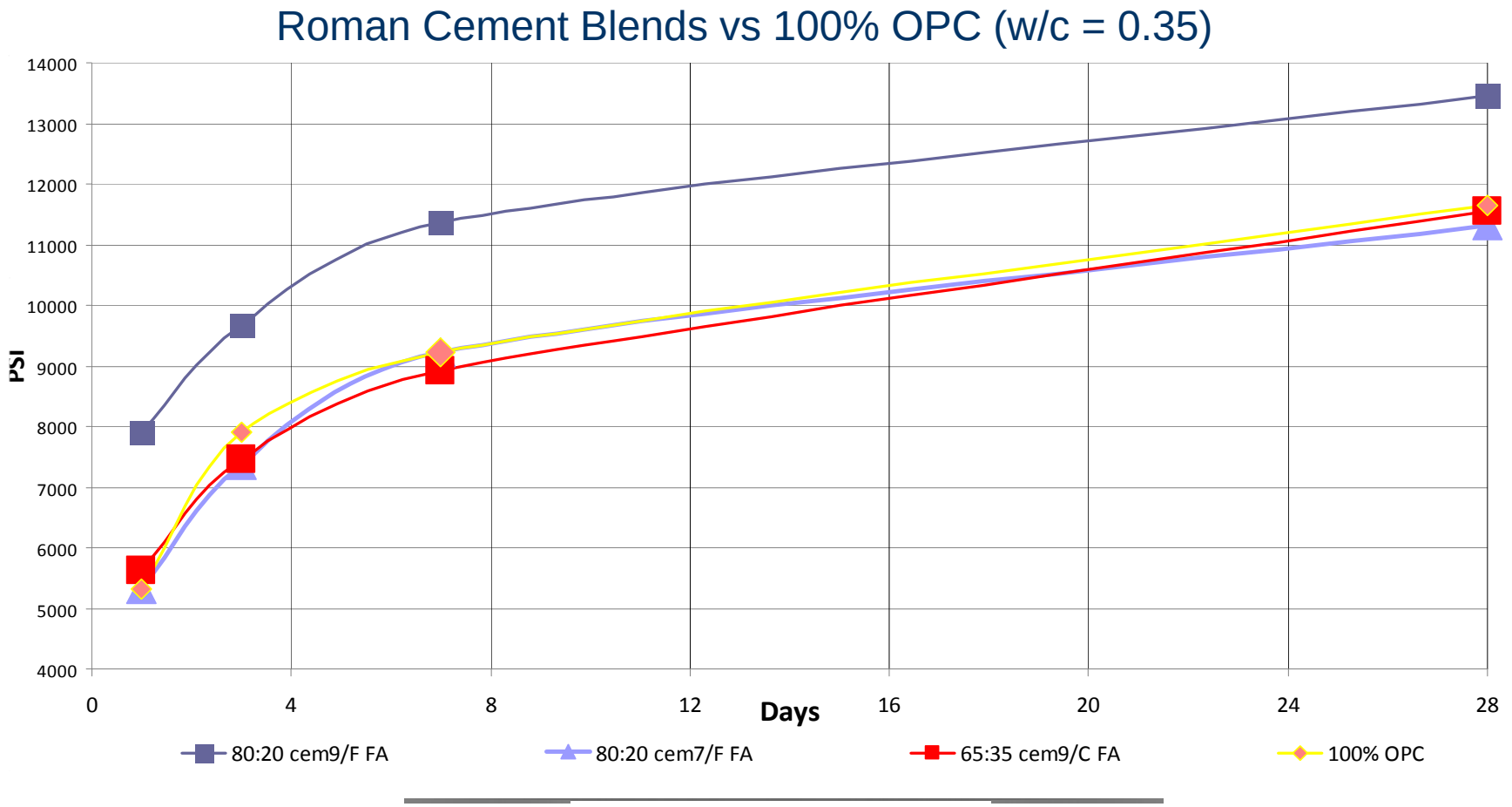
Matching the Strength Curve of OPC



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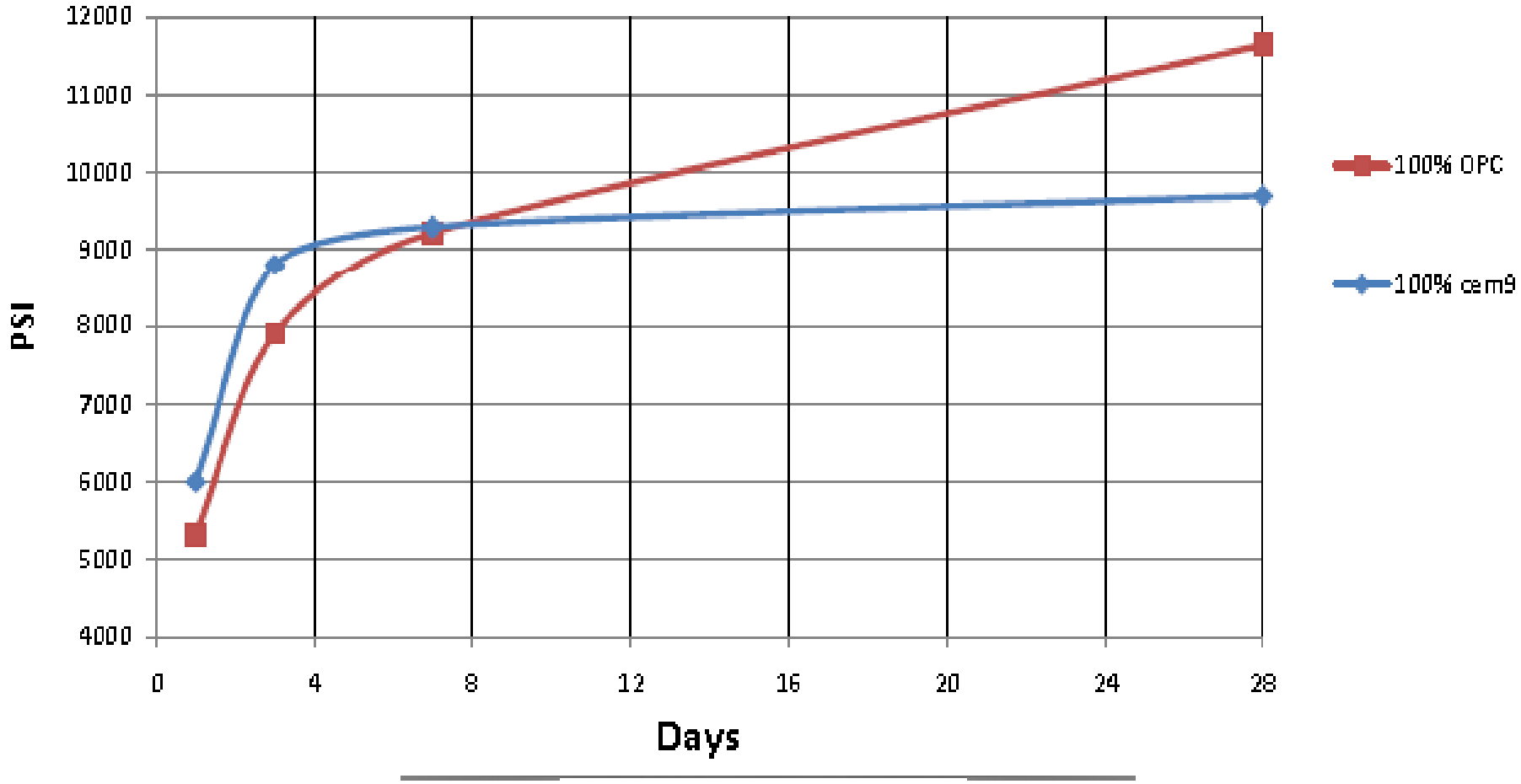
100% UltraFine Cement vs 100% OPC



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Autogenous Deformation

Mixture	Run Order ID	28-d net autogenous shrinkage (microstrain)
Control	1	247
Control repeat	1A	175
50 % fly ash	2	74
35 % FA 3–Cem 7	3	125
35 % FA 2-Cem 8	5	187
35 % FA 5-Cem 9	8	269
35 % FA 4-Cem 10	10	258
35 % C ash -Cem 9	19	348
35 % FA 5-Type III	20	Not measured
50 % FA 2-Cem 7	4	85
50 % FA 5-Cem 8	16	175
50 % FA 4-Cem 9	6	125
50 % FA 3-Cem 10	12	190
65 % FA 5-Cem 7	15	59
65 % FA 4-Cem 8	11	48
65 % FA 3-Cem 9	18	174
65 % FA 2-Cem 10	7	73
20 % FA 4-Cem 7	13	279
20 % FA 3-Cem 8	14	415
20 % FA 2-Cem 9	17	415
20 % FA 5-Cem 10	9	524

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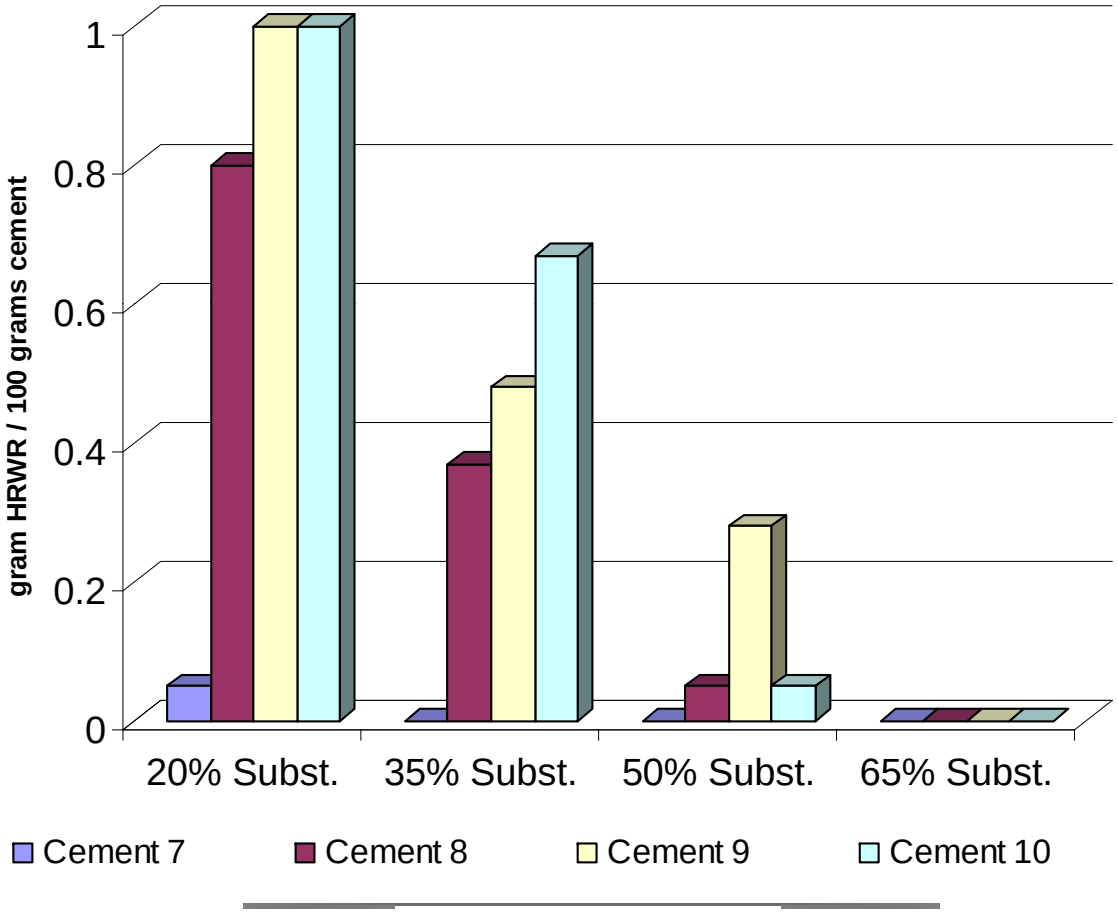
Water Demand



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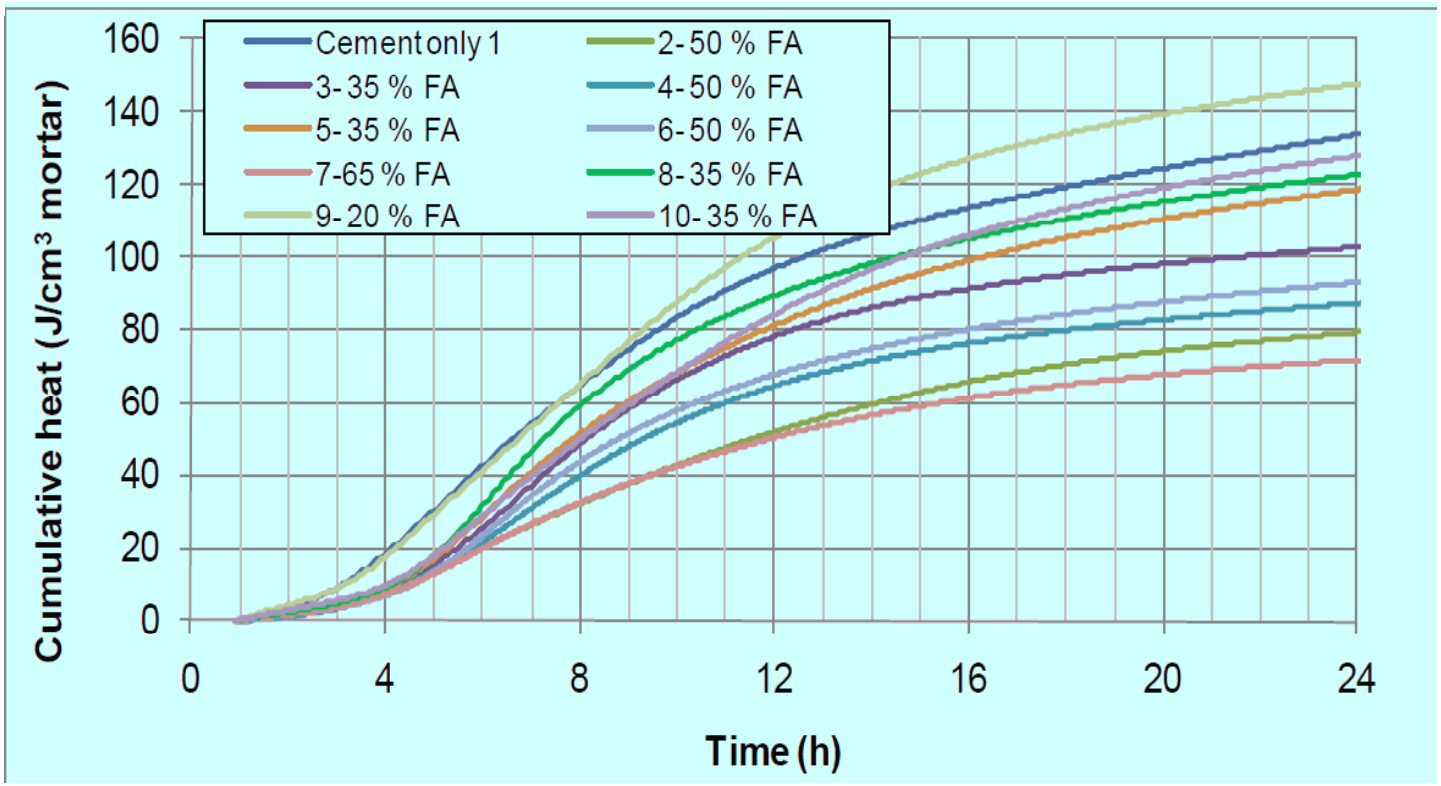
Hydration Rates: Isothermal Calorimetry



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Example Set Times

				Setting times (min)	
Paste/Mortar ID	Fly ash (%)	Cement ID	Fly ash ID	Initial set	Final set
1	0	6	--	168	214
2	50	6	1	258	318
8	35	9	5	227	267
9	20	10	5	131	168
14	20	8	3	220	255

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Conclusion

Blended Cements
at Different Substitution Levels
can be designed to match
the Strength Curve of OPC
by Optimizing the PSDs
of Cement and Pozzolan Fractions

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