Using Limestone Cement to build the future for a 100 year old cement plant using Sustainable Cements

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Lehigh Hanson
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Before we get started, a review of cement standards

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Designation: C150/C150M – 12

Standard Specification for Portland Cement[1]

Type I, Type II, Type III, Type IV, Type V

Prescriptive

Designation: C595/C595M – 12ε1

Standard Specification for Blended Hydraulic Cements[1]

Type IP Type IS, Type IT, **Type IL** (Total 26 Types)

Prescriptive

Designation: C1157/C1157M – 11

Standard Performance Specification for Hydraulic Cement[1]

Types: GU, HS, MS, HE LH

Performance

Leeds Cement Plant (Leeds Alabama)

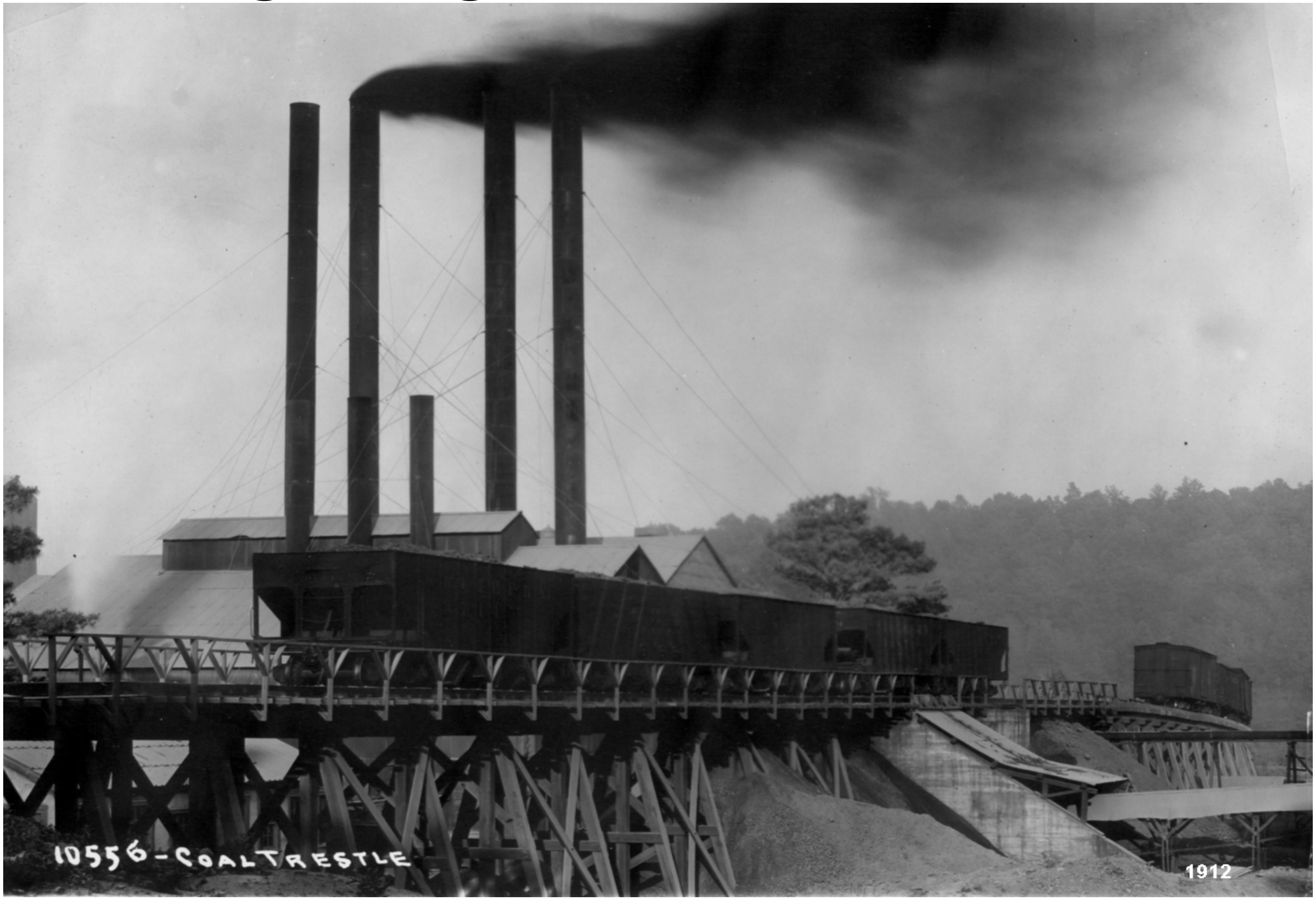
Updating a 100 year old cement plant using Sustainable cements

1906-1919	Standard Portland Cement Plant
1919-1930	Atlas Portland Cement
1930-1980	Universal Atlas Cement Company
	❖ *United States Steel Corporation*
1980-2002	Lehigh Portland Cement Company
	❖ *Heidelberg Cement*
2002-2007	Lehigh Cement Company
2007-present	Lehigh Hanson

1977, Lehigh was acquired by Heidelberger Zement AG

In the beginning…

In the beginning…



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1914 - 2000 barrels of cement /day
1916 - 3000 barrels of cement /day

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Leeds Plant
1938 rebuild
2 kilns 10ft x 300ft
new "wet process - closed circuit grinding"
9-27-38

2008

2008 Plan to update the 1976 Lehigh Leeds

- Extend Quarry by relocating local creek
- Three (3) chamber silo with total of 20,000 MT capacity
- Install Truck Self Loading

Updated in 1976 to current layout

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The Proposal

Use Limestone cement to construct the <u>Creek</u> and <u>Silo</u> Projects
C595 IL / C1157 HE… Design concrete for durability

Designation: C595/C595M – 12ε1

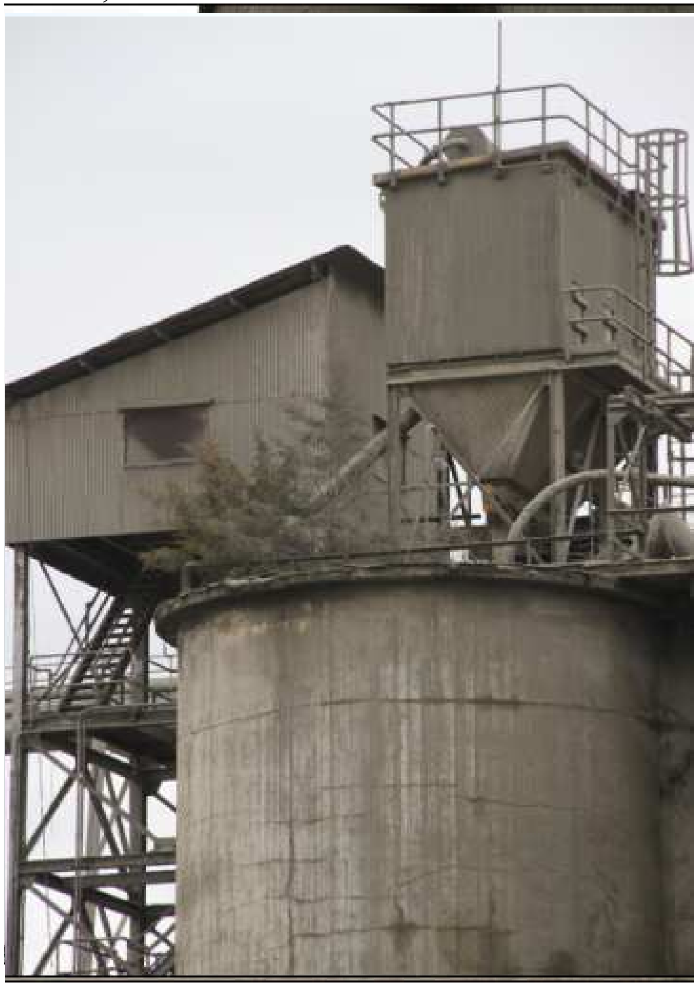
TABLE 3 Physical Requirements

Cement Type[A]	Applicable Test Method	IP, IS(<70), IL, IT(P≥S), IT(P>L), IT(L≥S), IT(L≥P), IT(P<S<70), IT(L<S<70)	IP(MS), IS(<70)(MS), IT(P≥S)(MS), IT(P<S<70)(MS)	IP(HS), IS(<70)(HS), IT(P≥S)(HS), IT(P<S<70)(HS)	IS(≥70), IT(S≥70)	IP(LH),[B] IL(LH),[B] IT(P≥S)(LH),[B] IT(L<S<70)(LH),[B] IT(P>L)(LH),[B] IT(L≥S)(LH),[B] IT(L≥P)(LH),[B]
Fineness	C204, C430	[C]	[C]	[C]	[C]	[C]
Autoclave expansion, max, %	C151	0.80	0.80	0.80	0.80	0.80
Autoclave contraction, max, %[D]	C151	0.20	0.20	0.20	0.20	0.20
Time of setting, Vicat test:[E]	C191					
Set, minutes, not less than		45	45	45	45	45
Set, hours, not more than		7	7	7	7	7
Air content of mortar, volume %, max[A]	C185	12	12	12	12	12
Compressive strength, min[A], MPa [psi]:	C109/C109M					
3 days		13.0 [1890]	11.0 [1600]	11.0 [1600]	...	...
7 days		20.0 [2900]	18.0 [2610]	18.0 [2610]	5.0 [720]	11.0 [1600]
28 days		25.0 [3620]	25.0 [3620]	25.0 [3620]	11.0 [1600]	21.0 [3050]
Heat of hydration, max, kJ/kg [cal/g]:	C186					
7 days		290 [70][F]	290 [70][F]	290 [70][F]	...	250 [60]
28 days		330 [80][F]	330 [80][F]	330 [80][F]	...	290 [70]
Water requirement, max weight % of cement	C109/C109M	...	...	...	...	64
Drying shrinkage, max, %	C157/C157M	...	...	...	...	0.15
Mortar expansion, max, %:[G]	C227					
14 days		0.020	0.020	0.020	0.020	0.020
8 weeks		0.060	0.060	0.060	0.060	0.060
Sulfate resistance, max, %:[H]	C1012					
Expansion at 180 days		...	0.10	0.05	...	...[I]
Expansion at 1 year		...	...	0.10	...	...[I]

The Proposal

Use Limestone cement to construct the Creek and Silo Projects
C595 IL / C1157 HE… Design concrete for durability

5,153 Yards … Silo and Foundation



26,781 Yards … Creek Shell and Ground Stabilization

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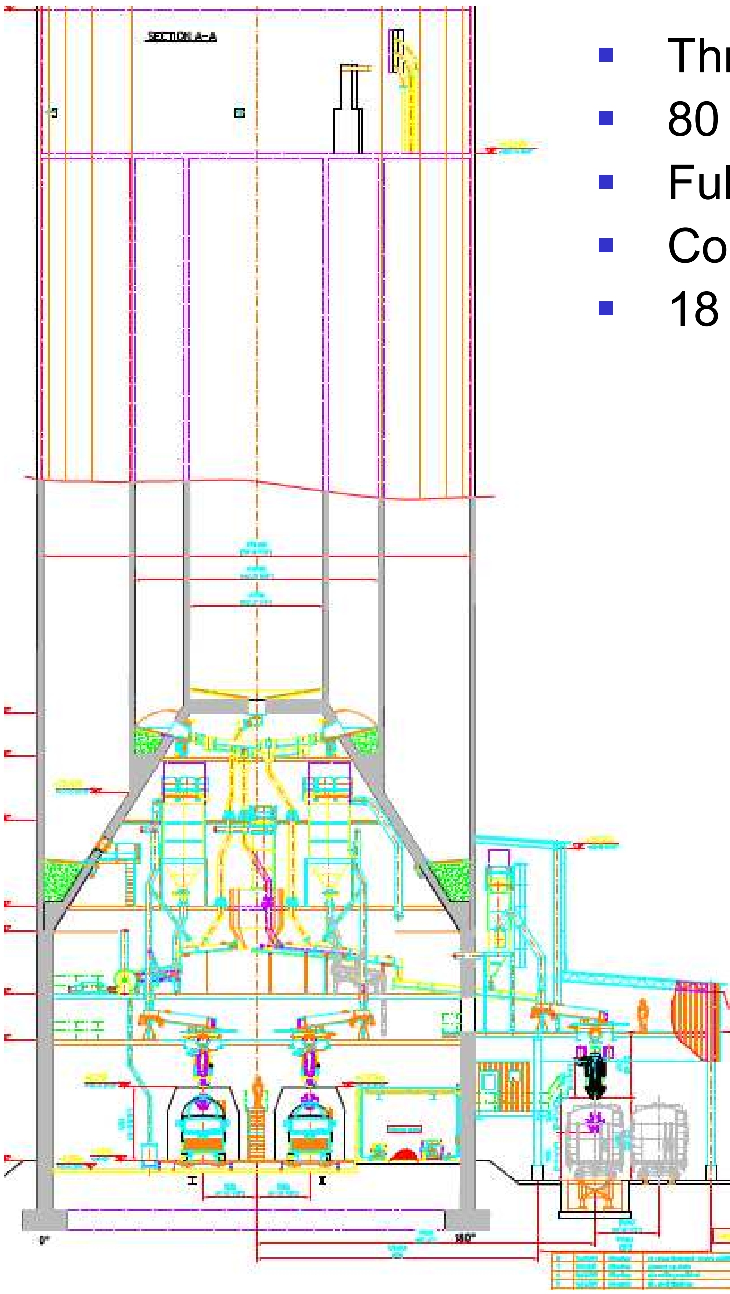
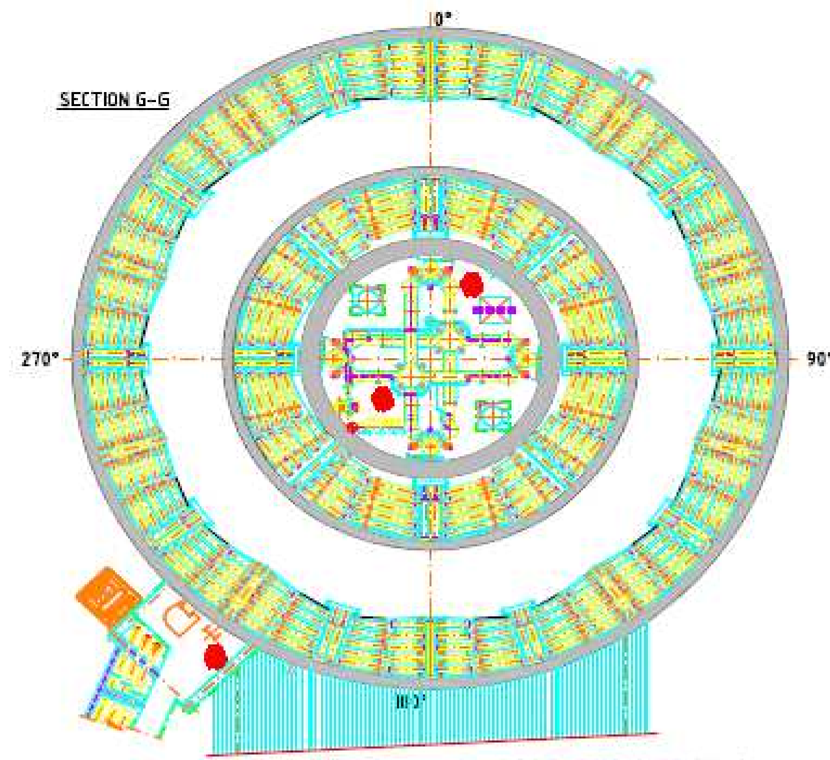
The SILO

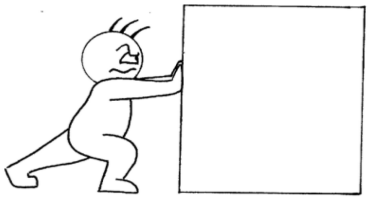


- Three (3) chamber silo with total of 20,000 MT capacity
- 80 feet diameter, 240 feet tall
- Fully automated truck loading facility
- Construction cost $20.5 million
- 18 months construction time



LEHIGH PORTLAND CEMENT Co.
LEEDS, ALABAMA
COM.NO.: 20.18055

Situation contractor push back



- Shortage of time for mix design development
- Slip forms require specific properties
- Contractor concerned about “experimental mix design”
- Lack of acceptance for Limestone Cement specification (before C595IL)
- Lab Data vs. field test (“real world”)

  -> field test “box”
- Major concern: “setting time” control

  -> 1157HE *“perceived spike” (C595 IL fine grind)*

  Admixture -> Retarder?

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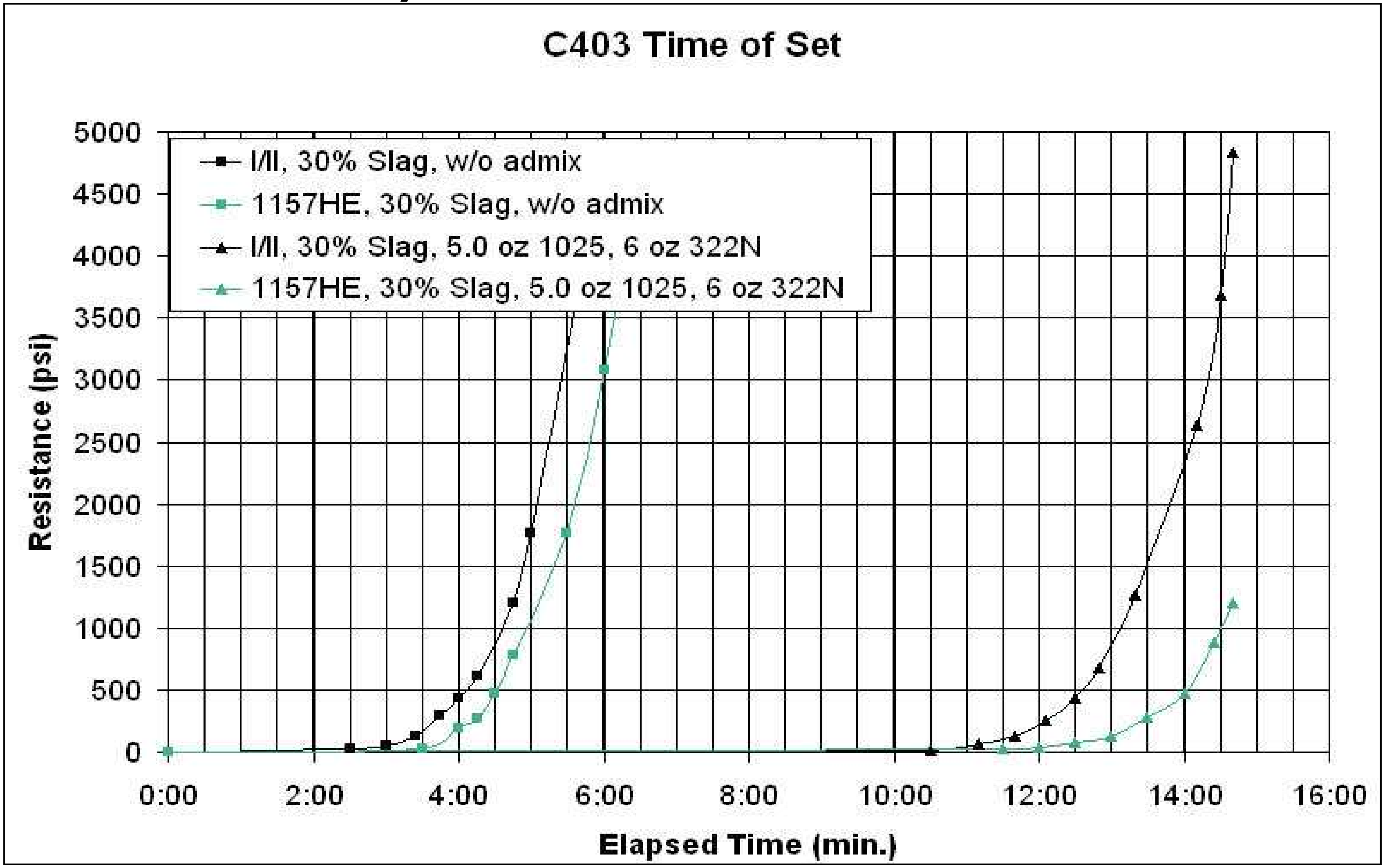
Situation

- ASTM C595 IL / ASTM C1157HE cement (12% limestone)
- Slag as SCM
- Admixture to control “setting time”
- Contractor experience only with Type I/II and none with Slag cement
- 28d strength 6000psi

Proving our case… in the lab

Lab Data – I) Time of Set



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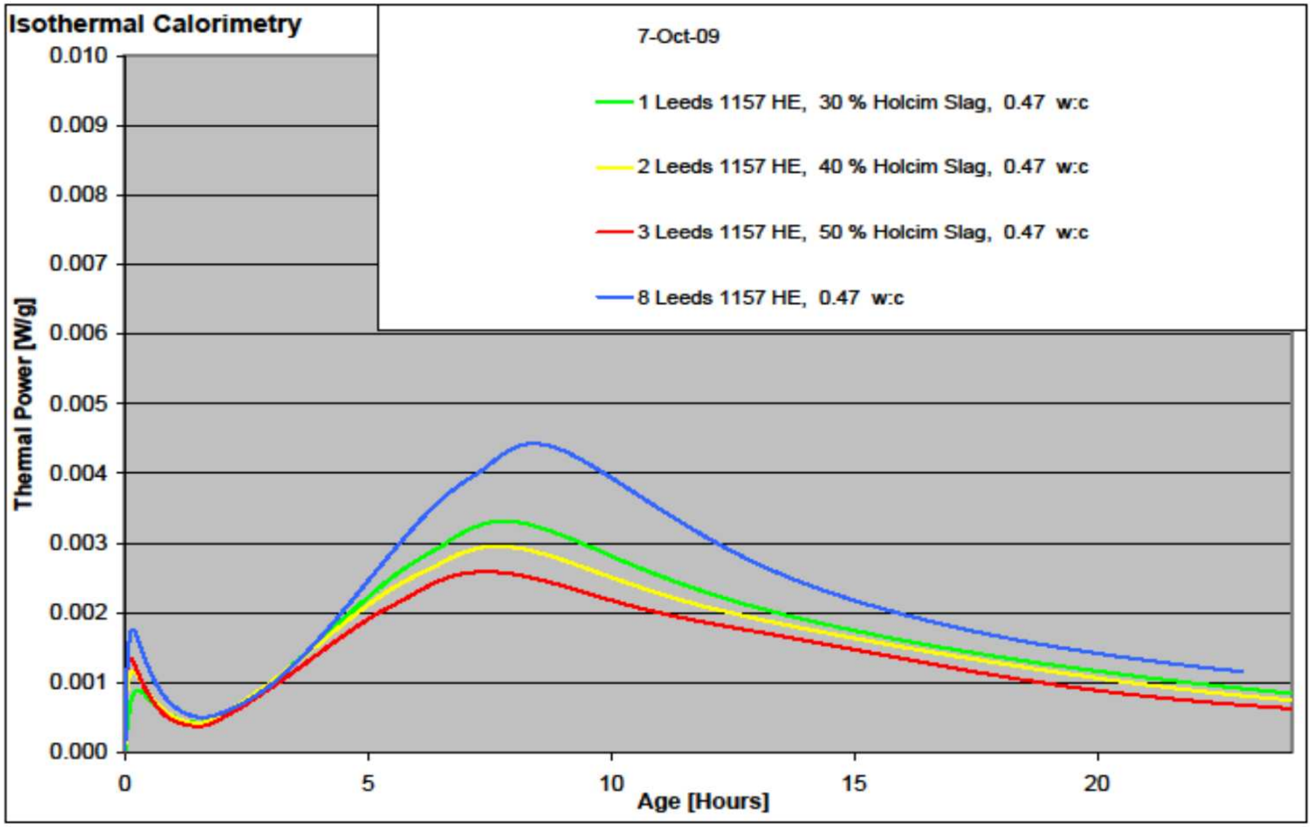
Lab Data – II) Calorimeter – 0%, 30%, 40%, 50% slag



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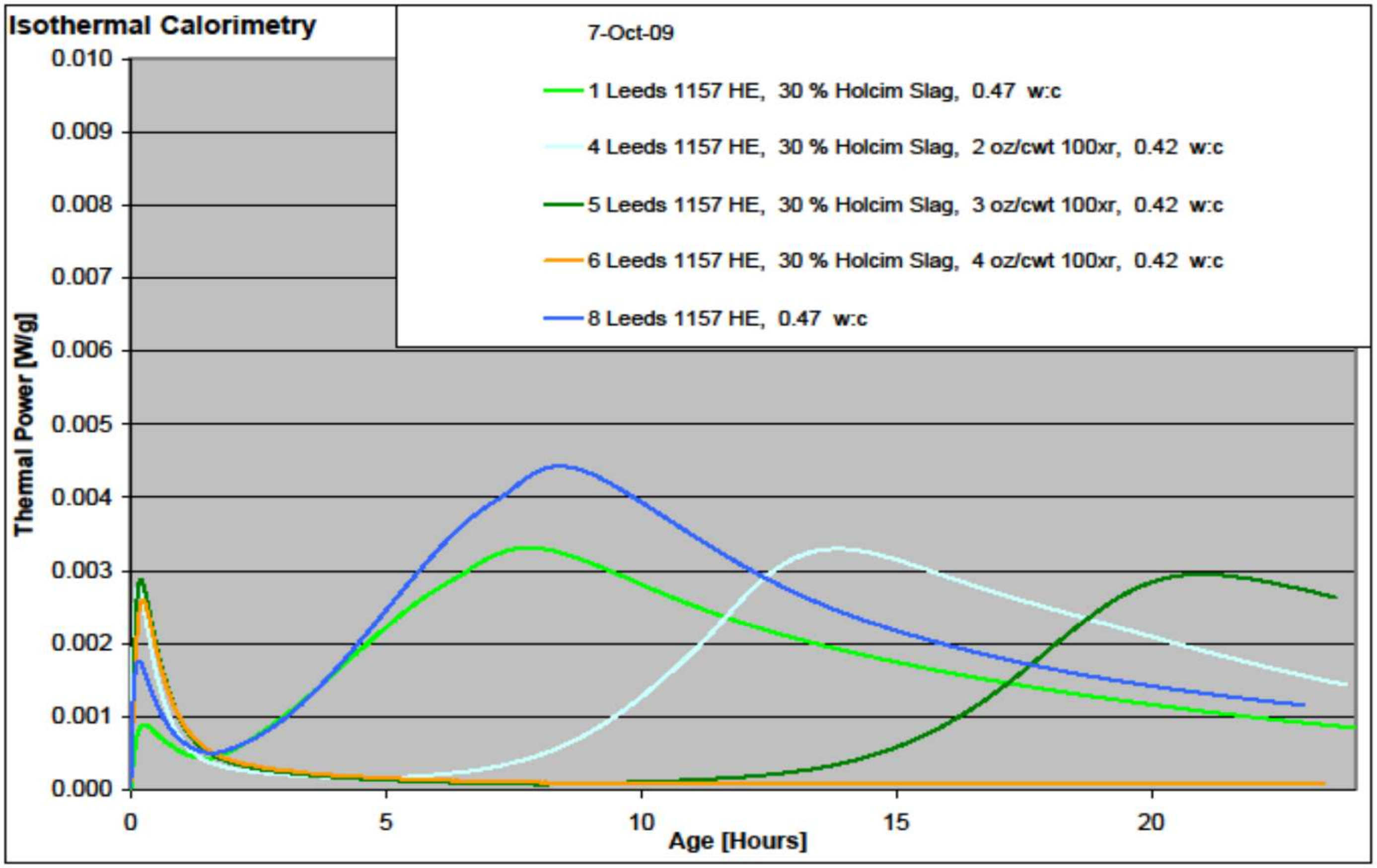
Lab Data – II) Calorimeter 30% Slag, changing WR dose



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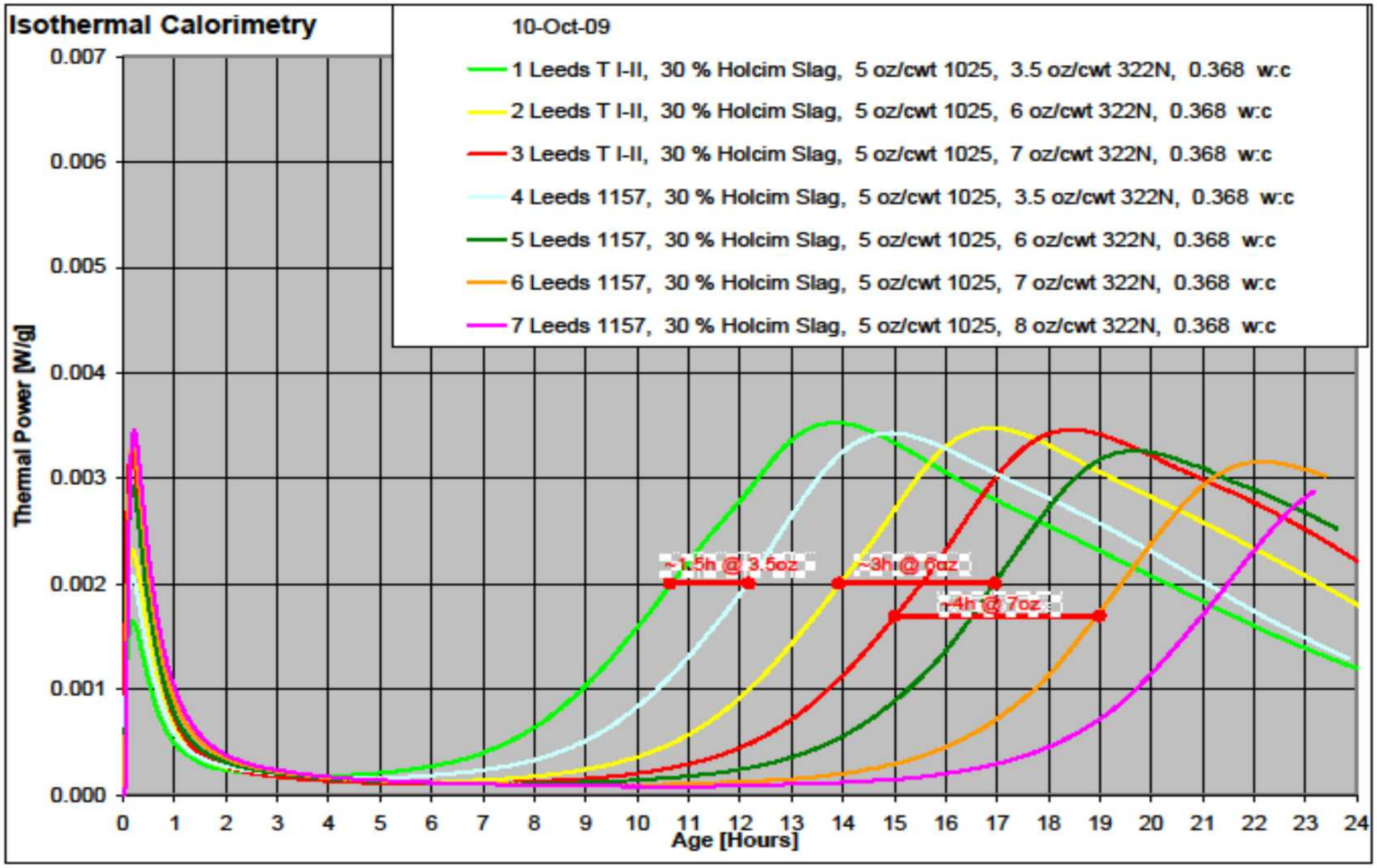
Lab Data – II) Calorimeter

Admixture dosage rate controlling set time (3.5 / 6.0 / 8.0 oz/cwt



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Lab Data – III) Consistometer

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Lab Data – III) Consistometer

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The contractor would not except any of our testing….

What could we do to persuade the contractor?

Convince "Shawne"

Field Trial – “Box” test

- 3 layer of concrete
- 16” each layer
- 30min between each filling with new load of concrete
- Rebar test as measurement

←Shawne

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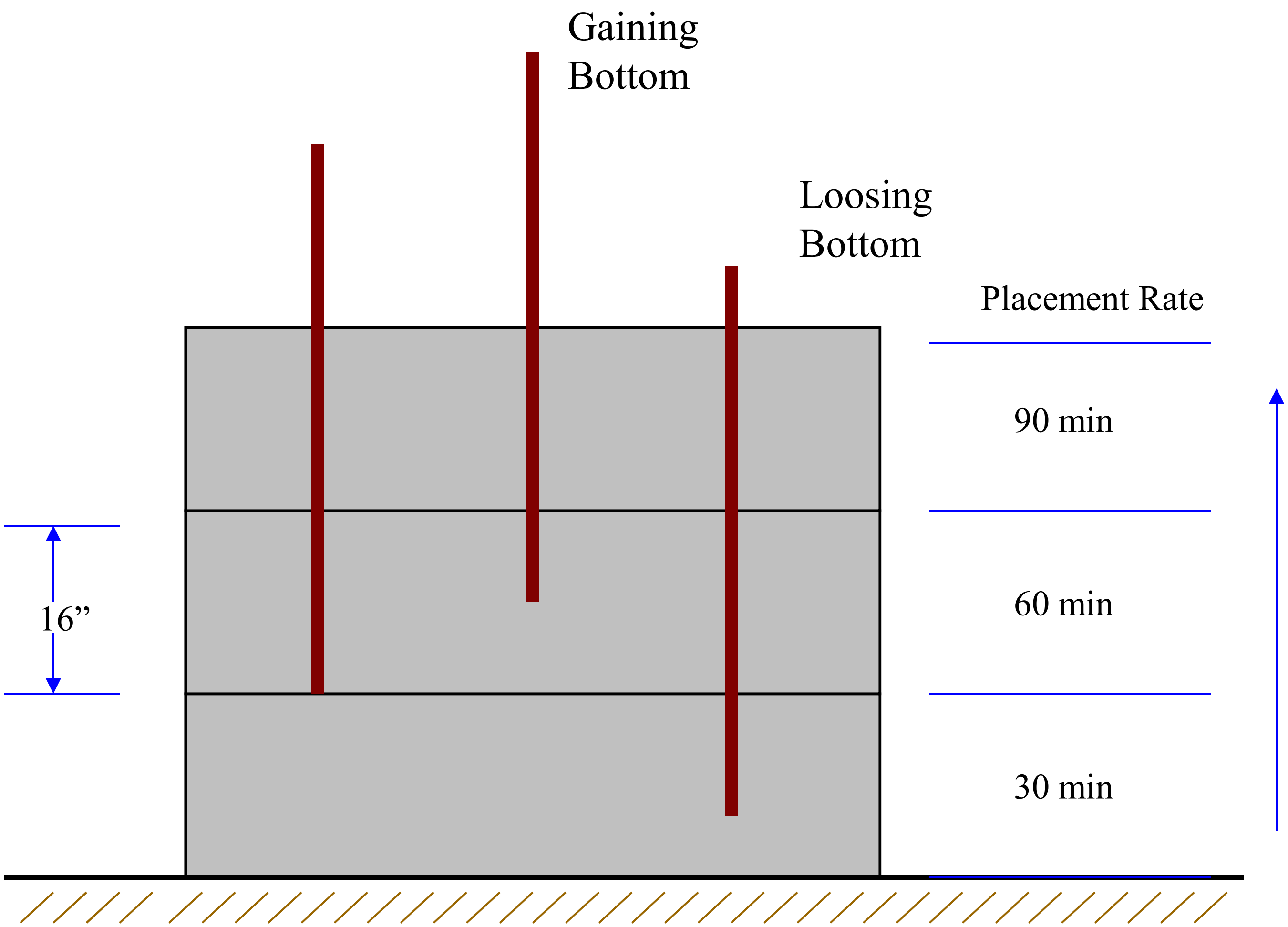
Gaining & Loosing Bottom



Each tier represents a new load of concrete

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Field Trial – “Box” test

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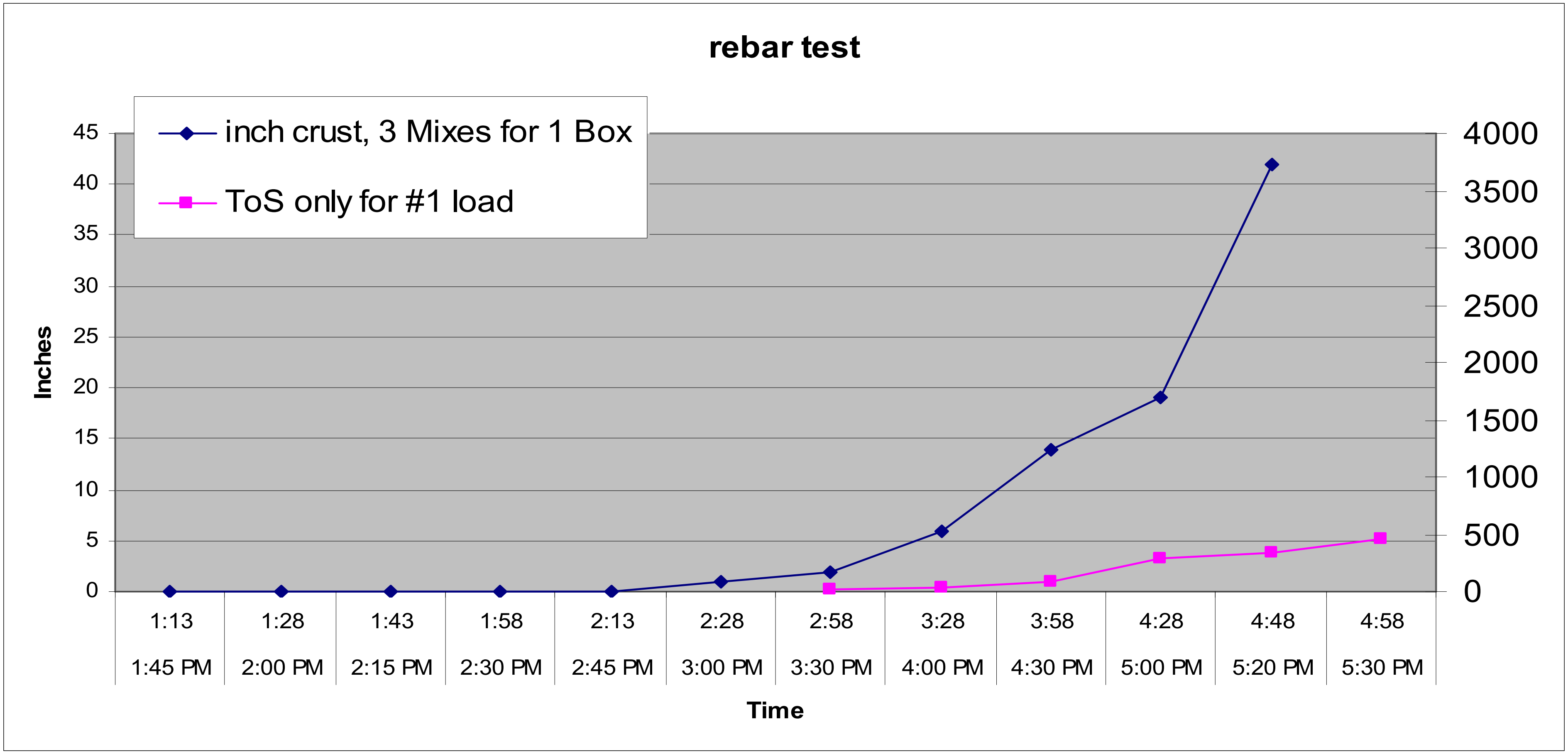
Field Trial – "Box" test



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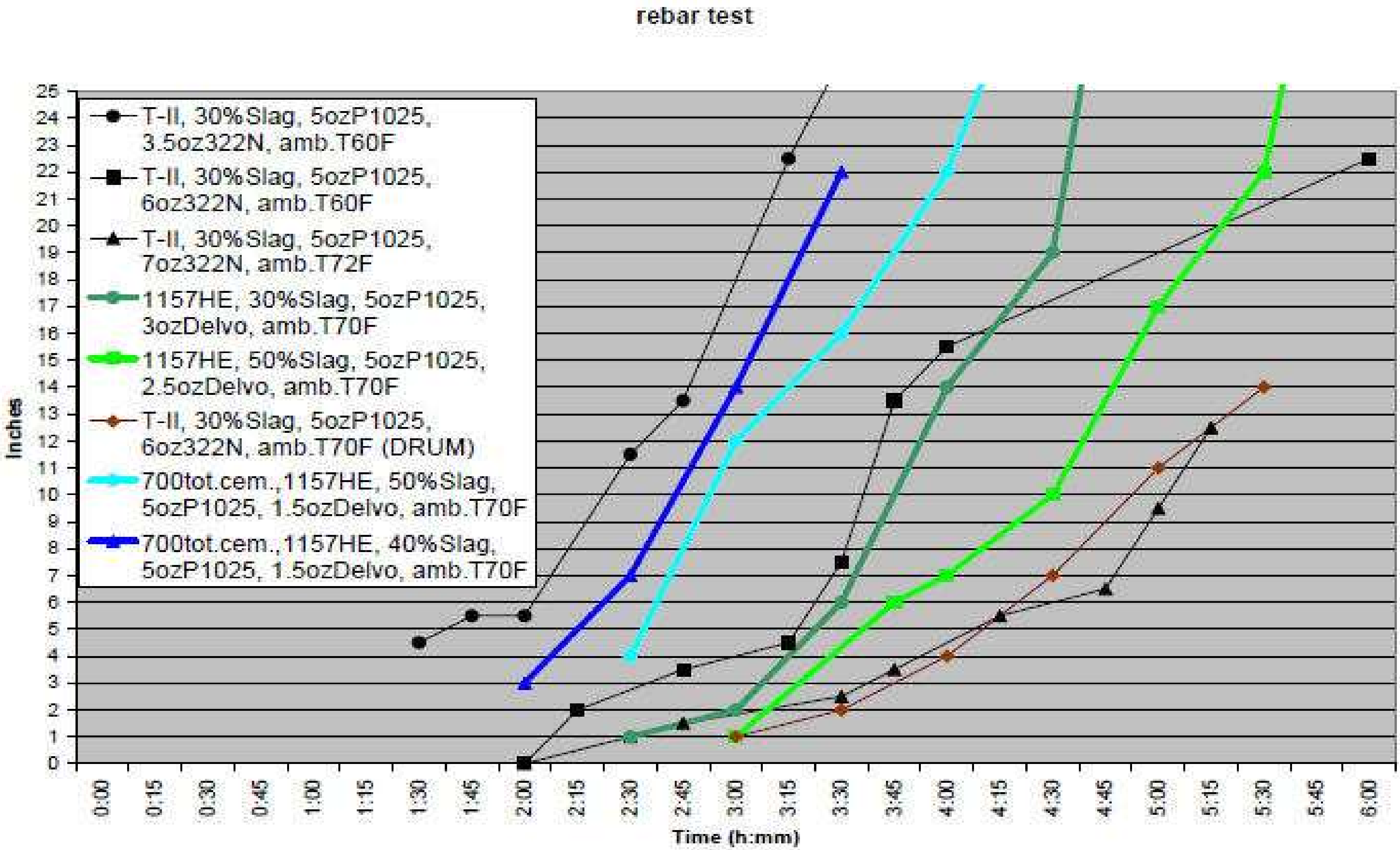
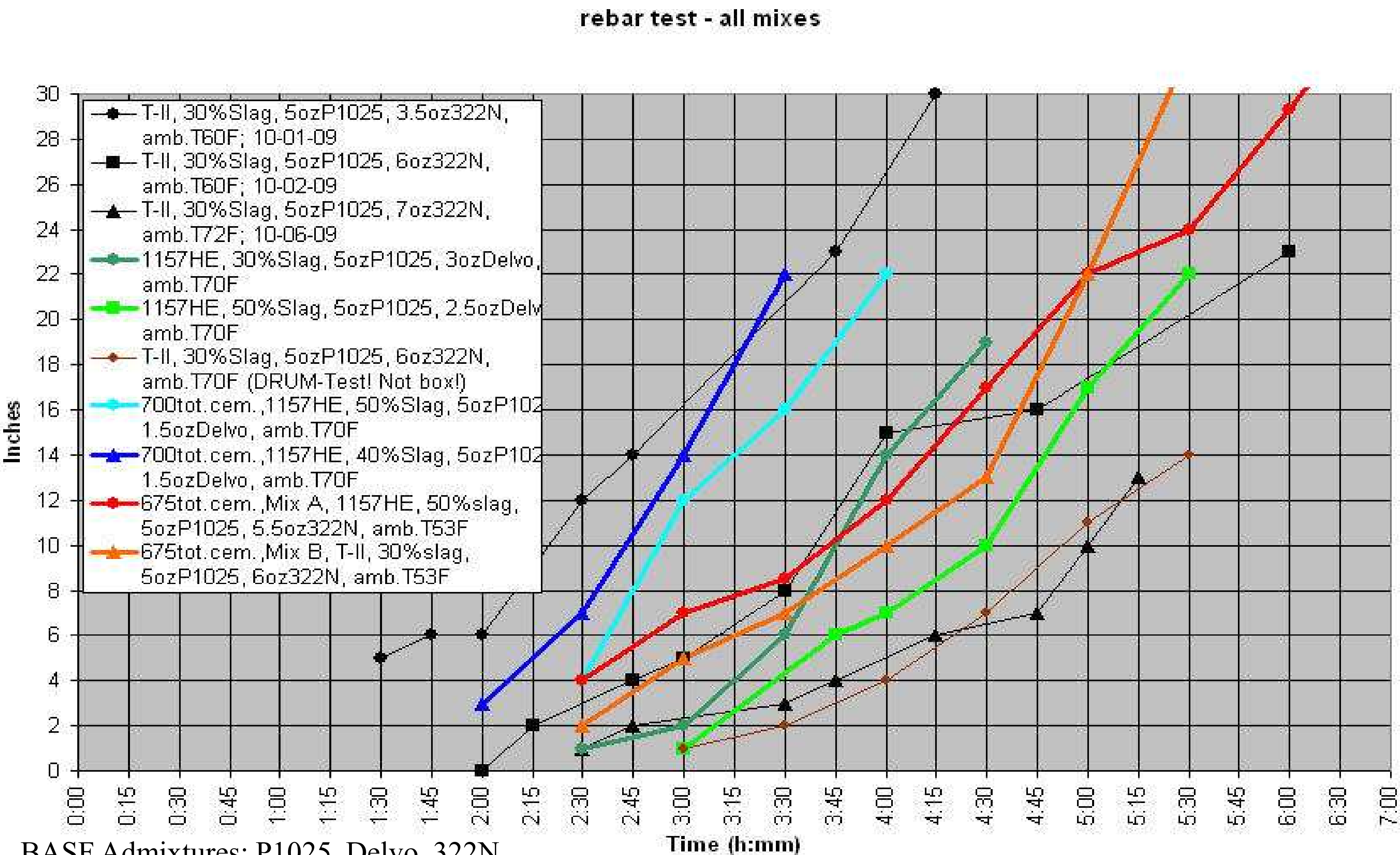
Field Trial – "Box" test



Field Trial – "Box" test



BASF Admixtures: P1025, Delvo, 322N

Water Reducer / Hydration stabilizer

Slope / Time

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Variable set time mix design

MATERIALS	STANDARD	TYPE		SOURCE	SPECIFIC GRAVITY
Cement 1	ASTM C-1157	1157		LEHIGH	3.15
Cement 4	ASTM C-989	GGBF. SLAG		HOLCIM	2.85
Sand 1	ASTM C-33	NATURAL		SUPERIOR/JEMISON	2.60
Coarse Agg 1	ASTM C-33	#78 LIMESTONE		LAFARGE	2.74
Admix 2 -	ASTM C-494	POZZ 322N	Type A or D	BASF - MB	
Admix 3 -	ASTM C-494	POLY 1025	Type A or F	BASF - MB	

Mix ID No.	SILO6040	Mix ID No.	SILO6041	Mix ID No.	SILO6042	Mix ID No.	SILO6043	Mix ID No.	SILO6044
Set Rate:	Faster		→→→		→→→		→→→		Slow
STRENGTH :	6000	STRENGTH :	6000	STRENGTH :	6000	STRENGTH :	6000	STRENGTH :	6000
% AIR:	1.5 - 3.0	% AIR:	1.5 - 3.0	% AIR:	1.5 - 3.0	% AIR:	1.5 - 3.0	% AIR:	1.5 - 3.0
SLUMP :	5 - 7"	SLUMP :	5 - 7"	SLUMP :	5 - 7"	SLUMP :	5 - 7"	SLUMP :	5 - 7"
WET- lb/ft3 : **	149.70	WET- lb/ft3 : **	149.70	WET- lb/ft3 : **	149.70	WET- lb/ft3 : **	149.70	WET- lb/ft3 : **	149.70
MATERIALS	**UNITS**	**MATERIALS**	**UNITS**	**MATERIALS**	**UNITS**	**MATERIALS**	**UNITS**	**MATERIALS**	**UNITS**
1157	420	1157	420	1157	420	1157	420	1157	420
GGBF. SLAG	280	GGBF. SLAG	280	GGBF. SLAG	280	GGBF. SLAG	280	GGBF. SLAG	280
NATURAL	1202	NATURAL	1202	NATURAL	1202	NATURAL	1202	NATURAL	1202
#78 LIMESTONE	1865	#78 LIMESTONE	1865	#78 LIMESTONE	1865	#78 LIMESTONE	1865	#78 LIMESTONE	1865
Water (lbs)	275	Water (lbs)	275	Water (lbs)	275	Water (lbs)	275	Water (lbs)	275
Admix 2	15.4	Admix 2	22.4	Admix 2	29.4	Admix 2	36.4	Admix 2	43.4
Admix 3	35.0	Admix 3	35.0	Admix 3	35.0	Admix 3	35.0	Admix 3	35.0
W/C ratio	0.39	W/C ratio	0.39	W/C ratio	0.39	W/C ratio	0.39	W/C ratio	0.39

Faster Set ⟷ Slower Set

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Day 1 – Tuesday: 0–20ft, 10.8in/h

Day 2

Day 3

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Day 4

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Interior Ring Silo Slip

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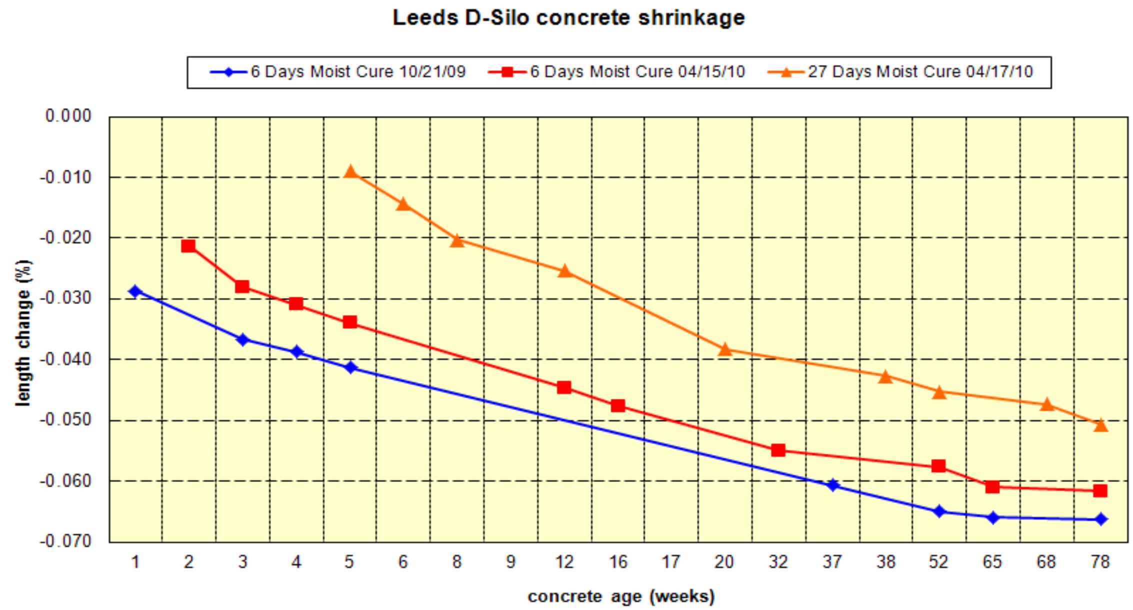
Testing and Specifications

ASTM C157 Shrinkage

D Silo shrinkage	6 Days Moist Cure	6 Days Moist Cure	27 Days Moist Cure
cast date:	10/21/09	04/15/10	04/17/10
concrete age (weeks)	length change (%)	length change (%)	length change (%)
1	-0.029	#N/A	#N/A
2	#N/A	-0.021	#N/A
3	-0.037	-0.028	#N/A
4	-0.039	-0.031	#N/A
5	-0.041	-0.034	-0.009
6	#N/A	#N/A	-0.014
8	#N/A	#N/A	-0.020
9	#N/A	#N/A	#N/A
12	#N/A	-0.045	-0.025
16	#N/A	-0.048	#N/A
17	#N/A	#N/A	#N/A
20	#N/A	#N/A	-0.038
32	#N/A	-0.055	#N/A
37	-0.061	#N/A	#N/A
38	#N/A	#N/A	-0.043
52	-0.065	-0.058	-0.045
65	-0.066	-0.061	#N/A
68	#N/A	#N/A	-0.047
78	-0.066	-0.062	-0.051



C1202 RCP Testing for Creek Project

Leeds Silo - Creek Project						
Lab Mixes						
Sherman Concrete Data						
HTC RCP Testing						
MIXTURE I.D.			Mix 1LS	Mix 2 LS	Mix 3 LS	Mix 4 LS
PERCENT CEMENT			60%	70%	60%	70%
PERCENT SLAG			40%	30%	40%	30%
TOTAL CEMENTITIOUS			564	564	564	564
Lehigh Type C1157			338	395	338	395
GGBF SLAG (LBS)			226	169	226	169
SILICA FUME (LBS)			0	0	50	50
CONCRETE SAND (LBS)			1247	1252	1187	1192
#67 LIMESTONE (LBS)			1880	1880	1880	1880
Water			267	267	267	267
MASTERBUILDERS POLY1025 (oz/cwt)			5	5	8	8
MASTERBUILDERS AIR-ENTRAINING MBAE-90 (oz/cwt)			0.4	0.4	0.5	0.5
Water / Cement			0.47	0.47	0.47	0.47
Slump	[in]		4.5	4	5.5	4.5
Air	[%]		5.3	5.2	5.5	5
Unit Wt	[lb/cuft]		146	144.8	143.2	145.6
28d Rapid Cl		**HTC**	**651**	**1163**	**433**	**500**
56d Rapid Cl		**HTC**	**606**	**878**	**301**	**369**

C595 IL Material Certificate

Fine Grind High Early (HE) ~Type III Alternative

Used in Silo / Creek project

Chemical				Physical			
Item	**ASTM**	**Limit**	**Result**	**Item**	**ASTM**	**Limit**	**Result**
SiO_2	C 114	-	18.51	Fineness:	C 204		
Al_2O_3	C 114	-	3.84	% Passing 45 µm (No. 325) Sieve (%)	C 430	-	99.1
Fe_2O_3	C 114	-	3.11	Blaine Fineness (m^2/kg)	C 204	-	581
CaO	C 114	-	63.59	Autoclave Expansion (%)	C 151	0.80 max	0.06
MgO	C 114	-	3.38	C-1038 Expansion (%)	C 1038	0.020 max	0.013
SO3	C 114	3.0	3.23	Vicat Setting Time:	C 191		
LOI	C 114	10.0	5.88	Initial Vicat (minutes)	C 191	45 - 420	111
				Final Vicat (minutes)	C 191	-	208
Limestone Content	C 114		11.85	Air Content (%)	C 185	12.0	7
CaCO3	C 114	70 min	96.59				
				Compressive Strength MPa:	C 109/C 109M		
Methylene Blue Index, max, g/100 g	C114.A2	1.2	0.005	1 Day	C 109/C 109M	-	22.13
Total Organic Carbon, max, % by mass	C114.A3	0.5	0.0	3 Day	C 109/C 109M	13.0 min	33.84
				7 Day	C 109/C 109M	20.0 min	37.88
				28 Day	C 109/C 109M	25.0 min	-
				Compressive Strength PSI:	C 109/C 109M		
				1 Day	C 109/C 109M	-	3209
				3 Day	C 109/C 109M	1890 min	4907
				7 Day	C 109/C 109M	2900 min	5493
				28 Day	C 109/C 109M	3620 min	5800

Notes

ASTM C595 IL (Normal Grind) ~Type I Alternative

Tests Data on ASTM "Standard" Requirements							
Chemical				Physical			
Item	ASTM	Limit	Result	Item	ASTM	Limit	Result
SiO_2	C 114	-	18.30	Fineness:	C 204		
Al_2O_3	C 114	-	4.06	% Passing 45 µm (No. 325) Sieve (%)	C 430	-	97.2
Fe_2O_3	C 114	-	3.06	Blaine Fineness (m^2/kg)	C 204	-	477
CaO	C 114	-	63.69	Autoclave Expansion (%)	C 151	0.80 max	0.07
MgO	C 114	-	2.95	C-1038 Expansion (%)	C 1038	0.020 max	
SO3	C 114	-	3.24	Vicat Setting Time:	C 191		
				Initial Vicat (minutes)	C 191	45 - 420	104
Insol	C 114		0.64	Final Vicat (minutes)	C 191	-	202
				Air Content (%)	C 185	12	8
LOI	C114	10.00	5.76				
				Compressive Strength MPa:	C 109/C 109M		
				1 Day	C 109/C 109M	-	16.97
				3 Day	C 109/C 109M	13 min	27.56
				7 Day	C 109/C 109M	20 min	32.86
				28 Day	C 109/C 109M	25 min	-
				Compressive Strength PSI:	C 109/C 109M		
				1 Day	C 109/C 109M	-	2461
				3 Day	C 109/C 109M	1890 min	3997
				7 Day	C 109/C 109M	2900 min	4765
				28 Day	C 109/C 109M	3620 min	-

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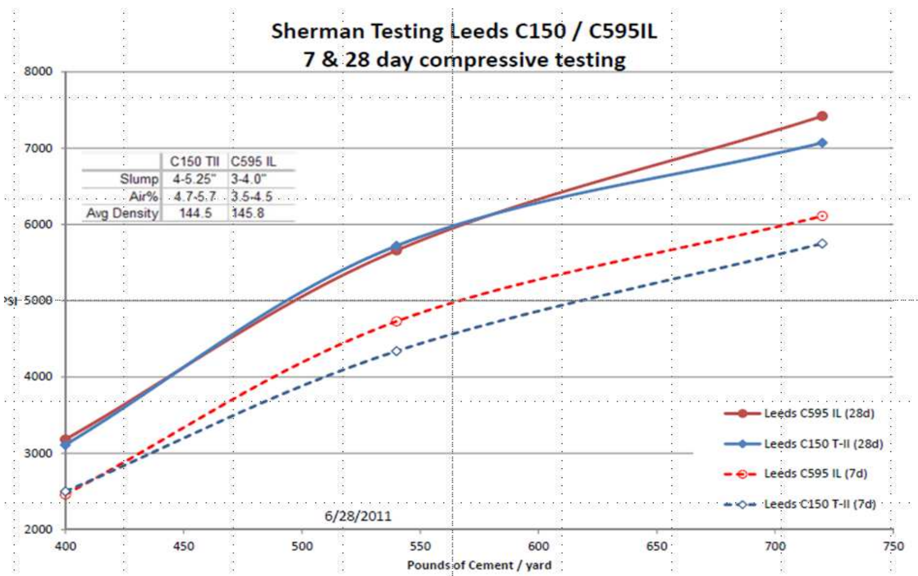
Conclusions

- C595 IL (Limestone Cements)
  - ❖ Can be substituted for Portland Type I cements
  - ❖ Works very well with C618 Fly Ash and C989 Slag Cements
  - ❖ Works very well with current commercial admixtures
  - ❖ Works very well in complex concrete Applications
  - ❖ Can produce durable concrete



52% reduction in clinker factor

Other Concerns

Other Concerns… sink holes

1938c Building of the original Leeds Silos

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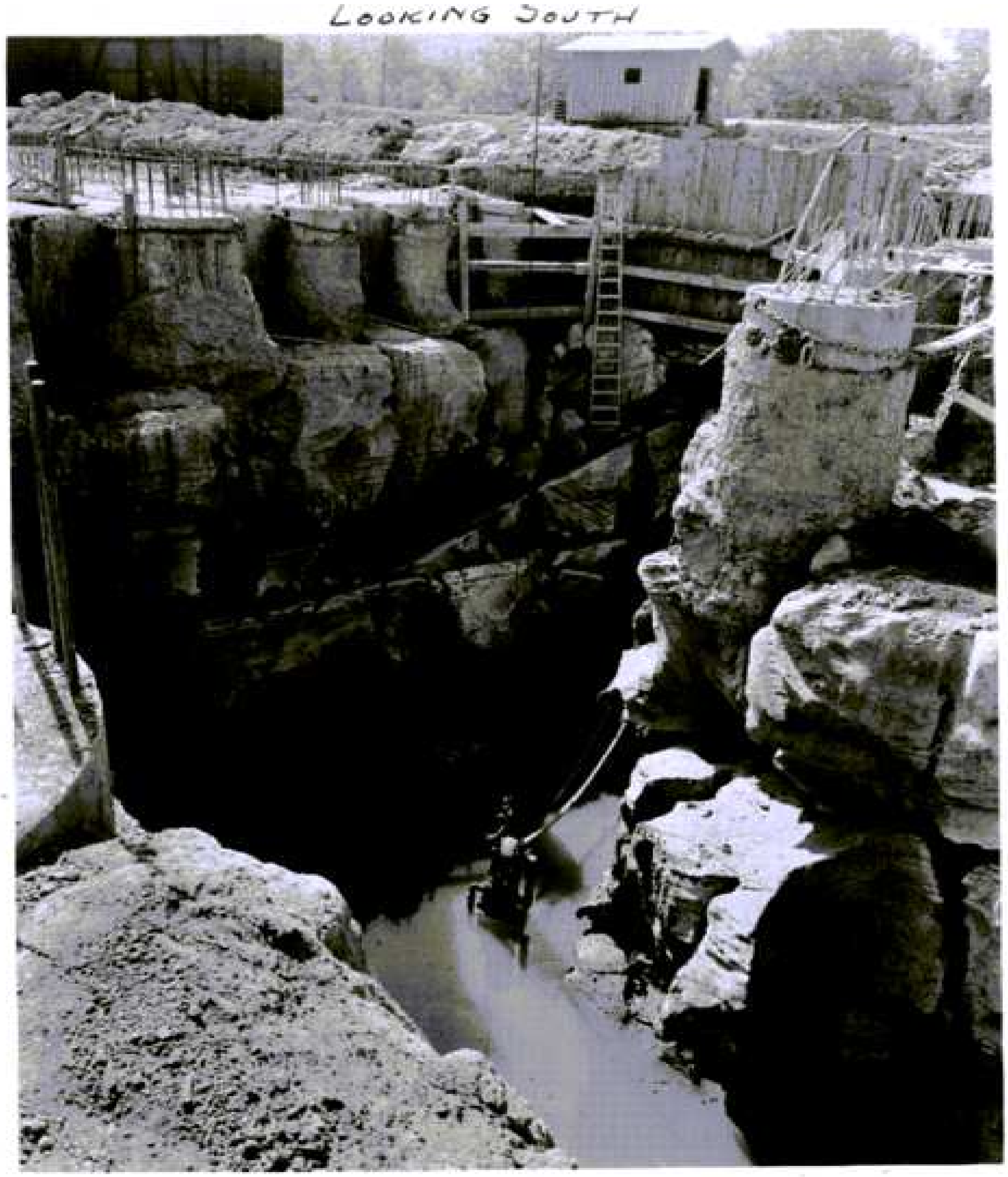
1938c Building of the original Leeds Silos



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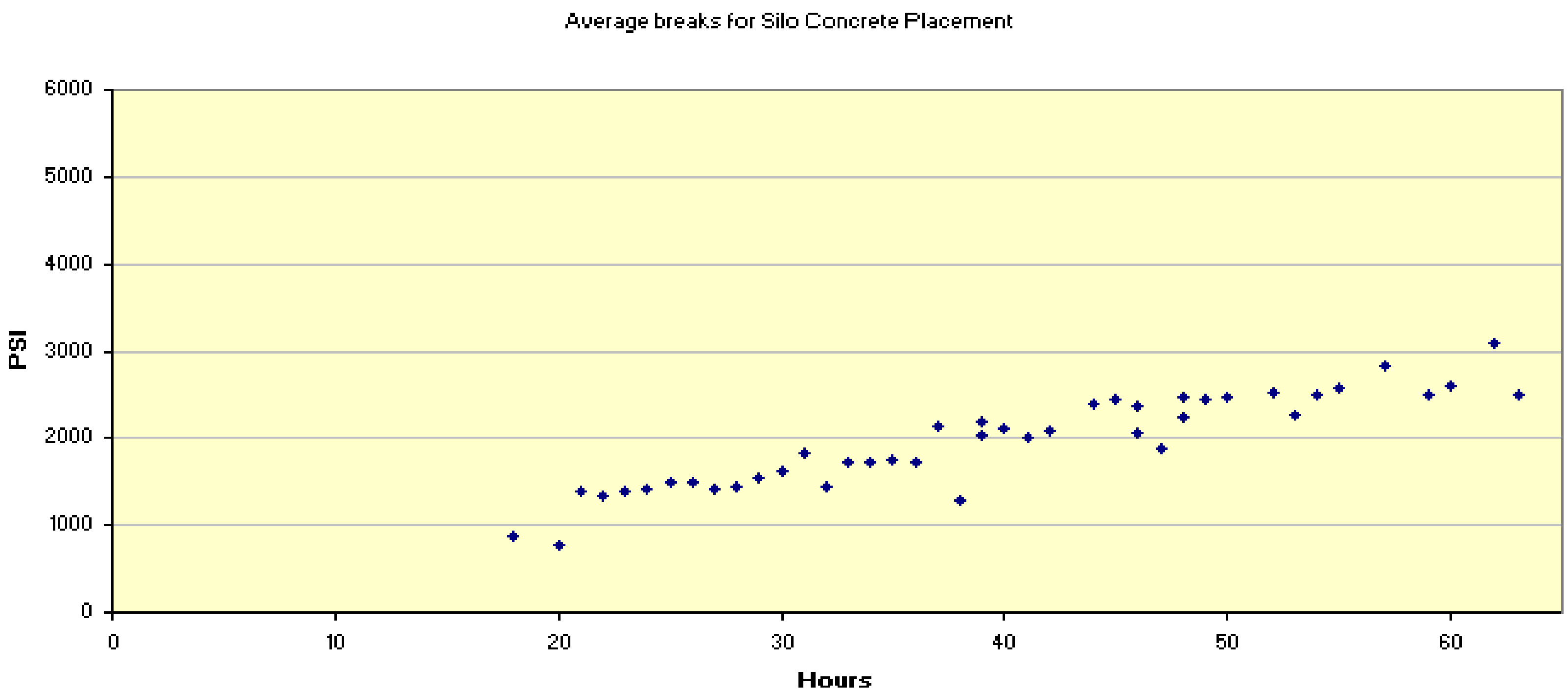
1938c Building of the original Leeds Silos

Questions? ………………….the end

Working together for success with performance material

12% Limestone Cement

C989 Ground Granulated Slag



244 Breaks - 60hrs