Alaska Department of Transportation & Public Facilities

ATM 530, Concrete Mix Designs by ACI & Packing Density Methods

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1. Scope

- Gradation optimization for Flowable (traditional) Concrete
- Volumetric Mix Design procedure for flowable ready-mix concrete often used for sidewalks, floor slabs, fixed formed pavements, parking lots, walls, and pumpable concrete applications. (A fully detailed, ACI 301 and ACI 211 compliant, example mix design with spreadsheets and graphs is given in Appendix D)
- Gradation optimization for Slip-Formed Concrete
- Gradation optimization for Self-Consolidating Concrete

2. Significance

- Concrete proportions, properties and performance are determined by the aggregate that forms most of the matrix of this composite material.
- For each sieve size the Tarantula Curve provides a recommended maximum retention limit and a suggested minimum retention limit.
- An adequate amount of coarse sand (#8 to #30) provides the cohesion properties of the concrete and reduces segregation.
- An adequate amount of fine sand (#30 to #200) provides the finishability, consolidation, and richness of a mixture.
- This method includes historic ACI 211 and newer Packing Density proportioning procedures.

3. Apparatus

- Ovens and hot plates thermostatically controlled to maintain the various required temperatures within ± 3°C (5°F).
- Fresh Concrete Testing equipment for Slump, Air, Unit Weight, and Temperature, AASHTO T 119, T 152, T 121, and T 309 respectively.
- Water tank with temperature at 23.0 ± 1.7°C (73.4 ± 3.0°F) per AASHTO T 85.
- Balance or scale: Capacity sufficient for the principal sample mass, readable to 0.1 g or 0.1 percent of the total sample mass and meeting the requirements of AASHTO M 231.
- Sieve shaker meeting the requirements of WAQTC FOP for AASHTO T 27/T 11.
- Specimen molds with lids, either 4x8" or 6x12" that conform to ASTM C470.
- Compression testing machine meeting the requirements of ASTM C39 and referenced documents.
- Surface Resistivity testing apparatus meeting the requirements of AASHTO T 358.
- Shrinkage testing apparatus meeting the requirements of ASTM C157.
- Air-entrained concrete maximum bubble spacing factor of 0.008 inch by ASTM C457 or AASHTO T 395, Sequential Air Method (SAM) number ≤ 0.20 on fresh concrete.

4. Aggregates

4.1. Perform gradations in accordance with AASHTO T 11 and T 27

- Combined Aggregate gradations must be within the Tarantula Curve boundary limits for each sieve size in each of the following mix types:
  1. Flowable
  2. Slip-Formed
  3. Self-Consolidating

4.1.1. Flowable 2 Aggregate Mix Design

-Sieve Analysis -

Coarse Aggregate (AASHTO Gr.# 67)			Intermediate Aggregate (AASHTO Gr.# 8)			Fine Aggregate (AASHTO Gr.# M6)		
Sieve	% Pass	Specs	Sieve	% Pass	Specs	Sieve	% Pass	Specs
1 1/2"	100					3/8"		100
1"	100	100	1"		100	#4	100	95-100
3/4"	95	90-100	3/4"		100	#8	95	80-100
1/2"	60		1/2"		100	#16	75	50-85
3/8"	39	20-55	3/8"		85-100	#30	43	25-60
#4	4	0-10	#4		10-30	#50	15	10-30
#8	0.7	0-5	#8		0-10	#100	4	2-10
#200	0.04		#200			#200	1.3	0-3
SSD Specific Gravity:		2.728	SSD Specific Gravity:			SSD Specific Gravity:		2.706
Absorption %:		0.60	Absorption %:			Absorption %:		1.30
Dry-Rodded Unit Wt:			Dry-Rodded Unit Wt:			Fineness Modulus:		2.68

Component	Batch Weights - Pounds or Ounces Per: Sack weights no longer used	Cubic Yard		Batch Volumes: Ft³ per Cubic Yard	Admixture SpG
Cement	"	600.0		3.053	
Mixing Water	"	247.0		3.958	
Coarse Aggregate	"	1820.0	SSD	10.692	
Inter. Aggregate	"	0.0	SSD	0	
Fine Aggregate	"	1290.0	SSD	7.640	
Master Polyheed 997	"	40.00	fl oz	0.042	1.28
MasterAir AE 90	"	2.00	fl oz	0.002	1.01
	"		fl oz		
	"		fl oz		
Air %: 6.0	"			1.620	Theoretical Max SpG
Totals:	"	3960.5	lbs.	27.006	156.01

4.1.1. Flowable - Two Aggregate Blend

Mix Design (or batch) ID: Flowable Class AA Mix **Date:** 6/1/2023

Enter Aggregate SSD Weights under BLEND SUPPLIED below.

Note: **Blue font is data entry**, **Red font indicates a calculation cell**

	BLEND SUPPLIED						
Aggregate Sizes:	1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals
SSD Weights (lbs)	0	0	1,820	0	1,290	0	3,110
Mass % Each Size	0.0%	0.0%	58.5%	0.0%	41.5%	0.0%	100.0%

SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	(mm)	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
2"	50	100	100	100	100	100	100	100.0	0.0
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	95	100	100	100	97.1	2.9
1/2"	12.5	0	0	60	100	100	100	76.6	20.5
3/8"	9.5	*	0	39	0	100	100	64.3	12.3
#4	4.75	*	0	4	0	100	0	43.8	20.5
#8	2.36	*	0	0.7	0	95	0	39.8	4.0
#16	1.18	*	*	0.3	0	75	0	31.3	8.5
#30	0.3	*	*	*	0	43	0	17.8	13.4
#50	0.3	*	*	*	*	15	0	6.2	11.6
#100	0.15	*	*	*	*	4	0	1.7	4.6
#200	0.075	0	0	0.04	0	1.3	0	0.6	1.1
Pan	0.000								0.6
								Total:	100.0

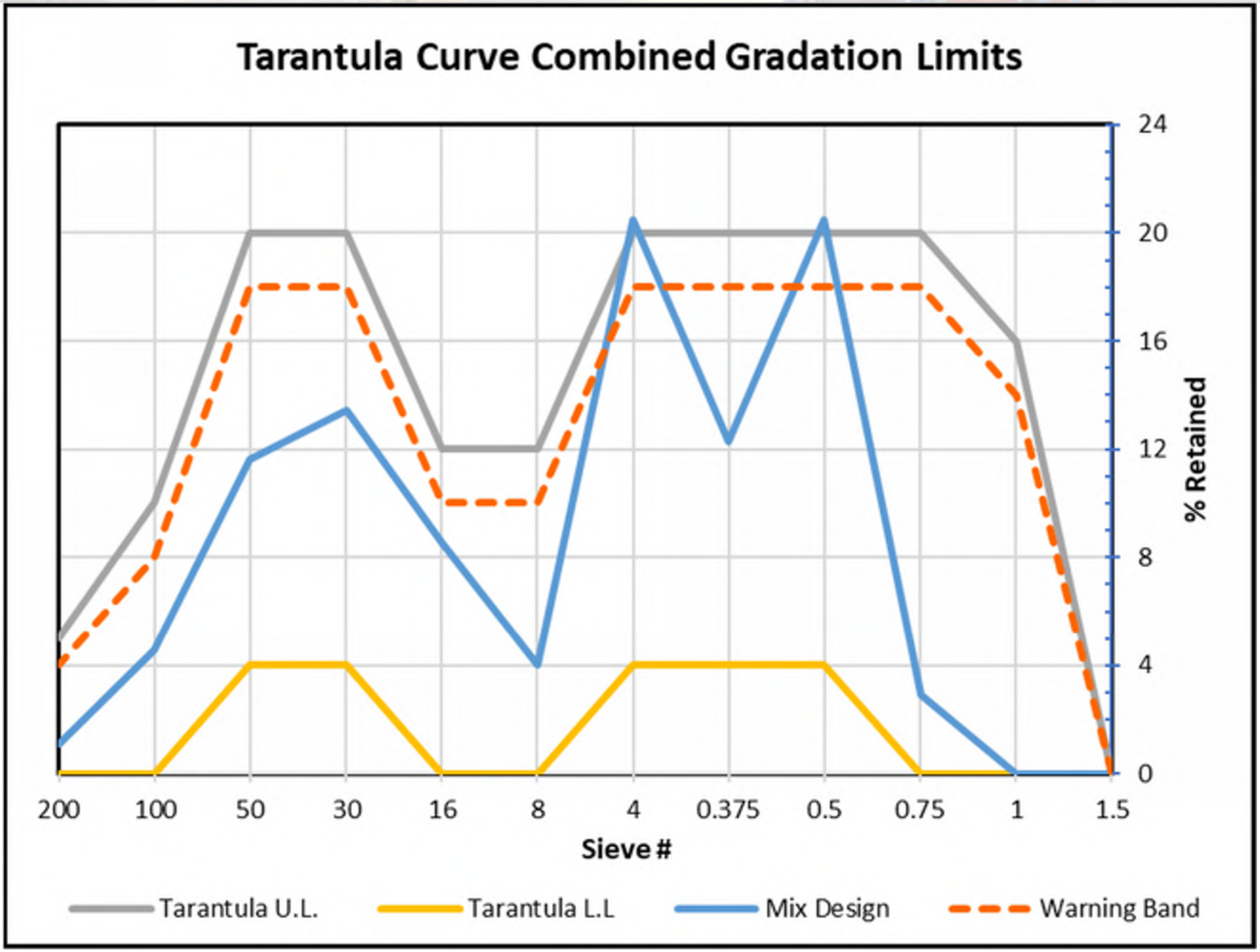
4.1.1. Flowable Tarantula & Sand Limits

Tarantula Limits - Flowable

Sieve Sizes	Tarantula U.L.	Tarantula L.L	Warning Band	Combined % Passing	Combined % Retained
1.5"	0	0	0	100.0	0.0
1"	16	0	14	100.0	0.0
3/4"	20	0	18	97.1	2.9
1/2"	20	4	18	76.6	20.5
3/8"	20	4	18	64.3	12.3
#4	20	4	18	43.8	20.5
#8	12	0	10	39.8	4.0
#16	12	0	10	31.3	8.5
#30	20	4	18	17.8	13.4
#50	20	4	18	6.2	11.6
#100	10	0	8	1.7	4.6
#200	2	0	2	0.6	1.1

Concrete Sand Limits - Flowable	Coarse/Fine Percentage	Within Limits?
Coarse Sand % (#8-30) = *Minimum is 20%*	**26.0**	**Yes**
Fine Sand % (#30-200) = *Allowable range is 25-40%*	**30.7**	**Yes**

Flowable Tarantula Curve w/Limits



4.1.2. Paving - Six Aggregate Blend

Mix Design or batch ID: Paving Example xyz **Date:** 6/1/2023

Enter Aggregate SSD Weights under BLEND SUPPLIED below.

Note: **Blue font is data entry**, **Red font indicates a calculation cell**

	BLEND SUPPLIED						
Aggregate Sizes:	1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals
SSD Weights (lbs)	1,000	1,200	11,360	4,060	5,410	4,250	27,280
Mass % Each Size	3.7%	4.4%	41.6%	14.9%	19.8%	15.6%	100.0%

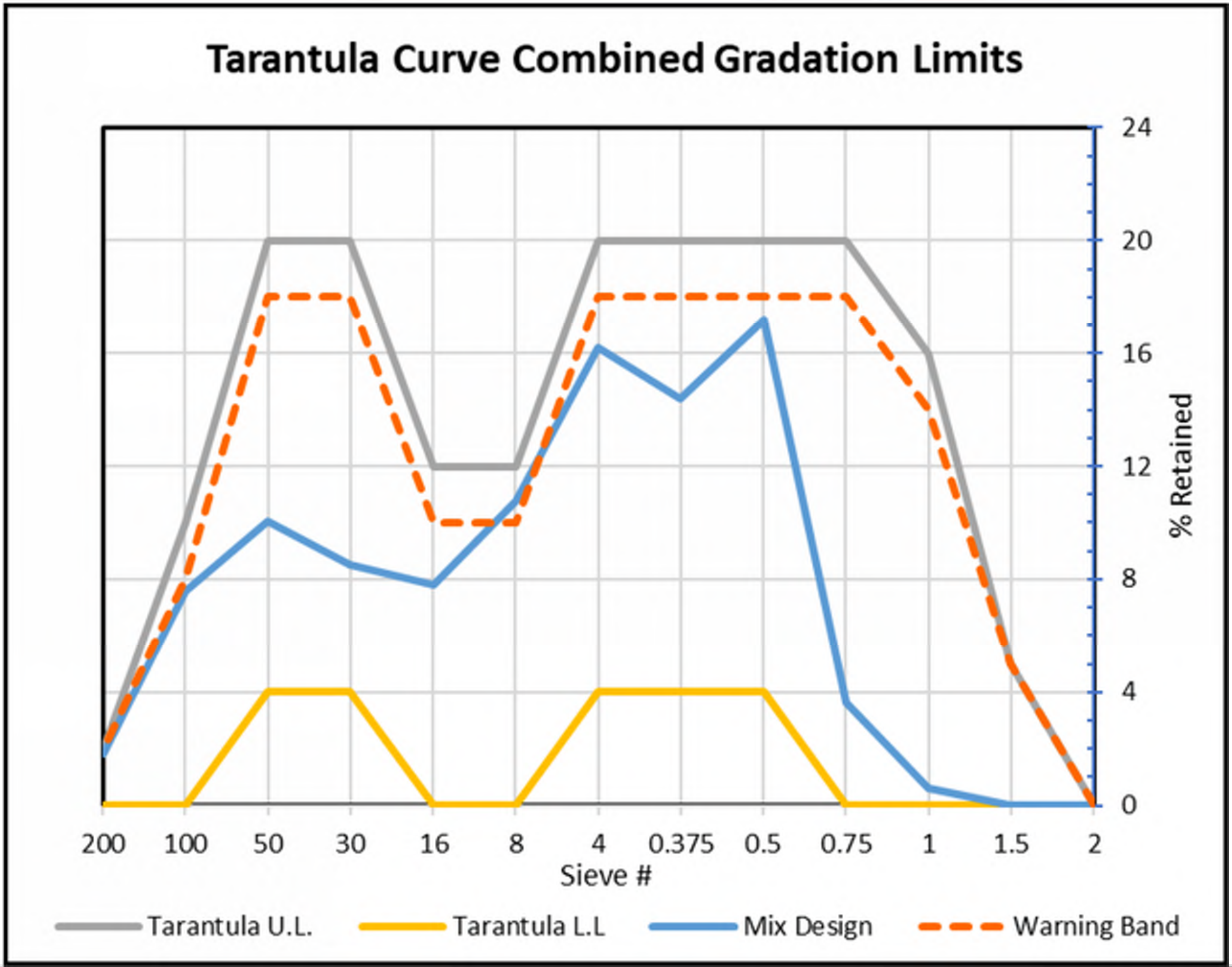
SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	(mm)	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
2"	50	100	100	100	100	100	100	100.0	0.0
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1"	25	85	99	100	100	100	100	99.4	0.6
3/4"	19	50	84	96	100	100	100	95.8	3.6
1/2"	12.5	10	48	62	100	100	100	78.6	17.2
3/8"	9.5	*	30	32	95	100	100	64.2	14.4
#4	4.75	*	5	12	52	99	99	48.0	16.2
#8	2.36	*	2	3	12	95	98	37.2	10.8
#16	1.18	*	*	2	2	72	90	29.4	7.8
#30	0.3	*	*	*	1	45	76	20.9	8.5
#50	0.3	*	*	*	*	14	52	10.9	10.0
#100	0.15	*	*	*	*	4	16	3.3	7.6
#200	0.075	0	0.2	0.5	0.7	1.1	6	1.5	1.8
Pan	0.000								1.5
								Total:	100.0

4.1.2. Slip-Formed (Paving) Concrete Tarantula & Sand Limits

Tarantula Limits: Paving Concrete					
Sieve Sizes	Tarantula U.L.	Tarantula L.L	Warning Band	Combined % Passing	Combined % Retained
2"	0	0	0	100.0	0.0
1.5"	5	0	5	100.0	0.0
1"	16	0	14	99.4	0.6
3/4"	20	0	18	95.8	3.6
1/2"	20	4	18	78.6	17.2
3/8"	20	4	18	64.2	14.4
#4	20	4	18	48.0	16.2
#8	12	0	10	37.2	10.8
#16	12	0	10	29.4	7.8
#30	20	4	18	20.9	8.5
#50	20	4	18	10.9	10.0
#100	10	0	8	3.3	7.6
#200	2	0	2	1.5	1.8

Concrete Sand Limits - Paving	Coarse/Fine Percentage	Within Limits?
Coarse Sand % (#8-30) =	**27.1**	**Yes**
Minimum is 15%		
Fine Sand % (#30-200) =	**28.0**	**Yes**
Allowable range is 24-34%		

4.1.2 Paving - Tarantula Gradation Limits



4.1.3. SCC - Three Aggregate Blend

	BLEND SUPPLIED						
Aggregate Sizes:	1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals
SSD Weights (lbs)	0	0	1,462	485	1,071	0	3,018
Mass % Each Size	0.0%	0.0%	48.4%	16.1%	35.5%	0.0%	100.0%

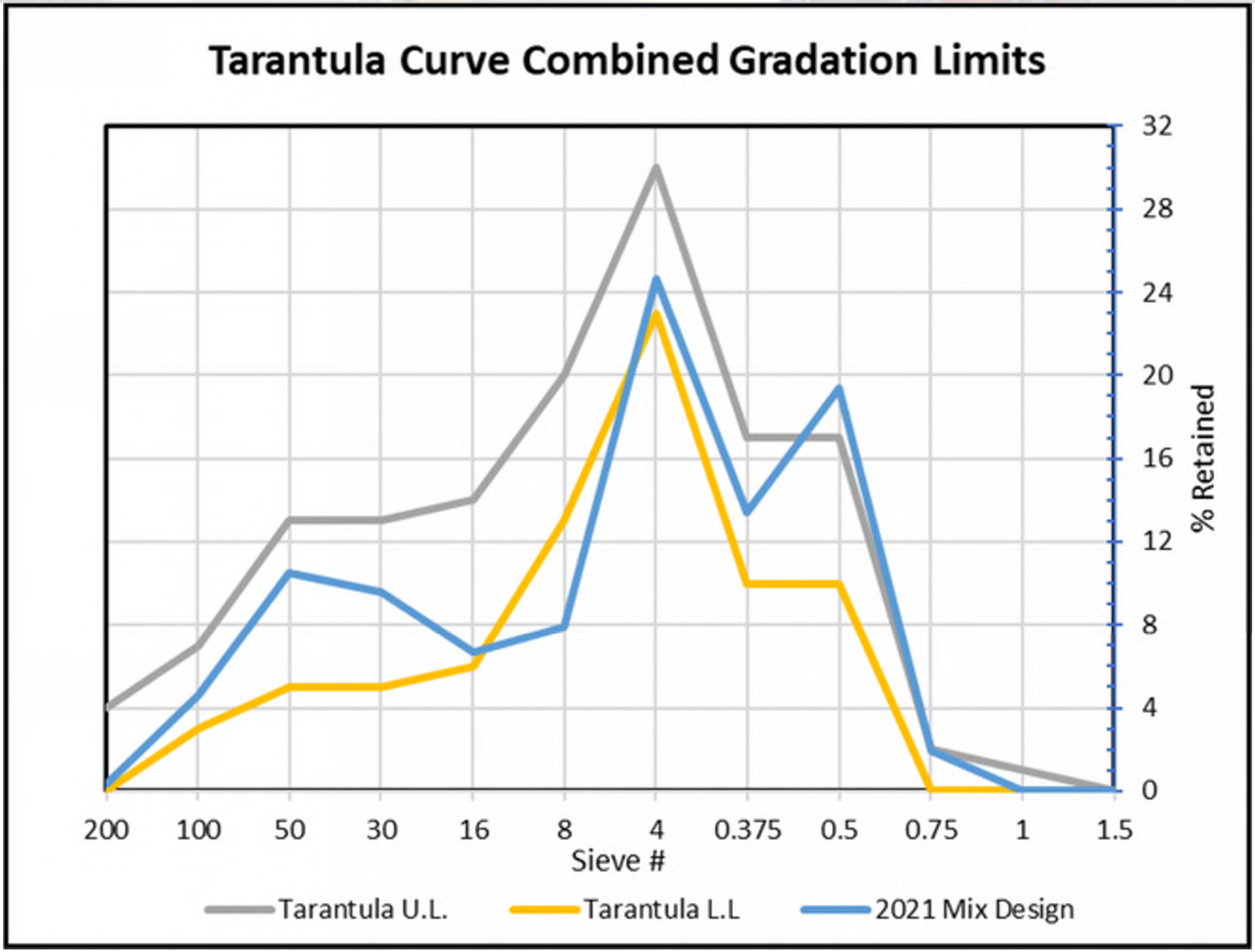
SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	(mm)	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	96	100	100	100	98.1	1.9
1/2"	12.5	0	0	56	100	100	100	78.7	19.4
3/8"	9.5	*	0	29	98	100	100	65.3	13.4
#4	4.75	*	0	4	20	100	0	40.6	24.6
#8	2.36	*	0	1.7	2.1	89	0	32.7	7.9
#16	1.18	*	*	1.3	1.5	71	0	26.1	6.7
#30	0.3	*	*	*	1.1	46	0	16.5	9.6
#50	0.3	*	*	*	*	17	0	6.0	10.5
#100	0.15	*	*	*	*	4	0	1.4	4.6
#200	0.075	0	0	0.9	0.7	1.5	0	1.1	0.3
Pan	0.000								1.1
								Total:	100.0

4.1.3. SCC Tarantula & Sand Limits

Tarantula Limits: Self-Consolidating Concrete				
Sieve Size	Tarantula U.L.	Tarantula L.L	Combined % Passing	Combined % Retained
1.5"	0	0	100.0	0.0
1"	1	0	100.0	0.0
3/4"	2	0	98.1	1.9
1/2"	17	10	78.7	19.4
3/8"	17	10	65.3	13.4
#4	30	23	40.6	24.6
#8	20	13	32.7	7.9
#16	14	6	26.1	6.7
#30	13	5	16.5	9.6
#50	13	5	6.0	10.5
#100	7	3	1.4	4.6
#200	4	0	1.1	0.3

SCC Concrete Sand Limits:	Coarse/Fine Percentage	Within Limits?
Coarse Sand % (#8-30) =	**24.1**	**Yes**
Minimum is 20%		
Fine Sand % (#30-200) =	**24.99**	**No**
Allowable range is 25-40%		

Self-Consolidating Tarantula Limits



4.1.3. SCC - Four Aggregate Blend

		BLEND SUPPLIED						
Aggregate Sizes:		1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals
SSD Weights (lbs)		0	0	1,162	386	755	715	3,018
Mass % Each Size		0.0%	0.0%	38.5%	12.8%	25.0%	23.7%	100.0%

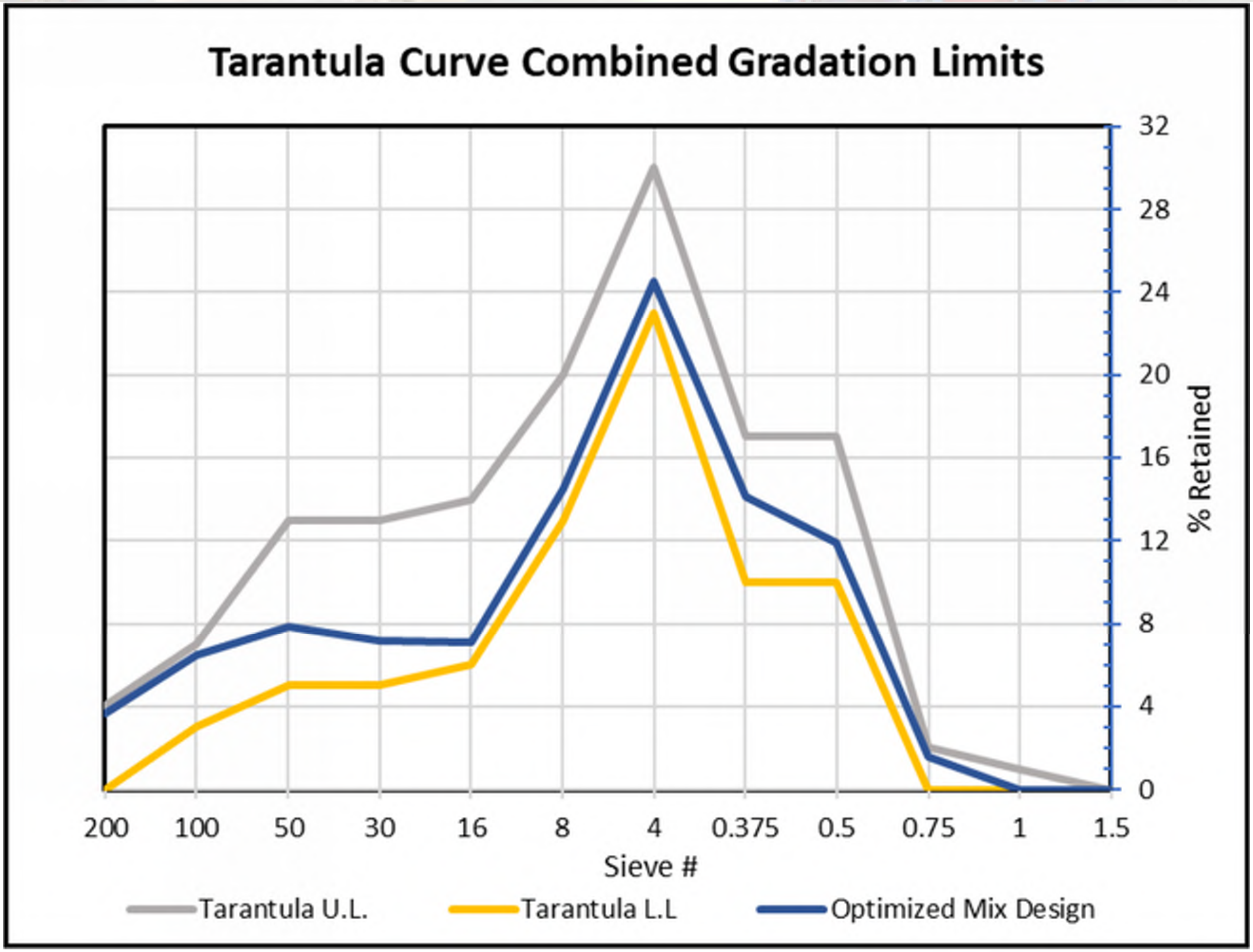
SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	(mm)	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	96	100	100	100	98.5	1.5
1/2"	12.5	0	0	65	100	100	100	86.5	11.9
3/8"	9.5	*	0	29	98	100	100	72.4	14.1
#4	4.75	*	0	4	20	85	95	47.9	24.5
#8	2.36	*	0	1.7	2.1	54	80	33.4	14.5
#16	1.18	*	*	1.3	1.5	38	68	26.3	7.1
#30	0.3	*	*	*	1.1	24	55	19.2	7.1
#50	0.3	*	*	*	*	12	35	11.3	7.9
#100	0.15	*	*	*	*	5	15	4.8	6.5
#200	0.075	0	0	0.9	0.7	1.1	2	1.2	3.6
Pan	0.000								1.2
								Total:	100.0

4.1.3. SCC Tarantula & Sand Limits

Tarantula Limits - SCC				
Sieve Size	Tarantula U.L.	Tarantula L.L	Combined % Passing	Combined % Retained
1.5"	0	0	100.0	0.0
1"	1	0	100.0	0.0
3/4"	2	0	98.5	1.5
1/2"	17	10	86.5	11.9
3/8"	17	10	72.4	14.1
#4	30	23	47.9	24.5
#8	20	13	33.4	14.5
#16	14	6	26.3	7.1
#30	13	5	19.2	7.1
#50	13	5	11.3	7.9
#100	7	3	4.8	6.5
#200	4	0	1.2	3.6

Concrete Sand Limits - SCC	Coarse/Fine Percentage	Within Limits?
Coarse Sand % (#8-30) =	**28.7**	**Yes**
Minimum is 20%		
Fine Sand % (#30-200) =	**25.1**	**Yes**
Allowable range is 25-40%		

Self-Consolidating Tarantula Limits



Additional Aggregate Tests

4.2. Determine duplicate specific gravities (bulk, bulk SSD, apparent) and absorption values of each fine & coarse aggregate in accordance with AASHTO T 84 and T 85 respectively. Perform additional testing if duplicate values do not agree within 1s Single operator precision. The average of the duplicate test values shall be used in the mix design. (For "Example Calculations" see Appendix D worksheets for *"Duplicate Coarse Aggregate Specific Gravities and Absorption"* and *"Duplicate Fine Aggregate Specific Gravities and Absorption"*)

4.3. Perform Sodium Sulfate Soundness testing on both coarse (retained on #4 sieve) and fine (passing #4 sieve) aggregates or on coarse and fine fractions of the combined aggregate in accordance with AASHTO T 104. Maximum loss for coarse aggregate is 12% for sodium sulfate and 18% for magnesium sulfate. Maximum allowable loss for fine aggregate is 10% for sodium sulfate and 12% for magnesium sulfate.

4.4. Limit flat or elongated coarse aggregate to a maximum of 15% at a ratio of 1:3 according to ASTM 4791.

4.5. Limits for deleterious materials must conform to AASHTO M 80, Table 2, Class A, for coarse aggregates and AASHTO M 6, Table 2, Class A, for fine aggregates.

Duplicate CA SpG

AASHTO T 85 (ASTM C127) Duplicate Relative Density, (SpG) and Absorption of Coarse Aggregate

Sample Preparation:

Use AASHTO T 85, Section 7.3. table for sample size. If more than 15% retained on 1-1/2" sieve, test this portion separately from the smaller material. Multiple fractions may be used. Sieve the reduced sample over a #4 sieve and wash all dust from the sample.

Procedure:

1. Dry to constant mass at 110 ± 5°C. Cool at room temperature for 1-3 hrs. or until sample can be handled comfortably.
2. Completely submerge sample in water at room temperature and soak for 15-19 hrs. (ASTM 24 ± 4 hrs.)

   Note: *AASHTO allows initial drying to be eliminated if aggregate will be used in concrete mixtures in it's naturally wet condition. The 15 hour soaking period may be eliminated if surfaces of the sample have been kept continuously wet until the test was begun.*

Note: Report Sp.G results to 0.001 (AASHTO) 0.01 (ASTM). Check that SSD SpG of Trials 1 & 2 agree within 1s, 0.007

Formulas:	**Description:**	Trial 1	Trial 2	**Average**
A	Oven dry mass in air (g)	2869.0	2892.6	
B	SSD mass in air (g)	2907.8	2933.5	
C	Mass in water (g)	1820.8	1836.2	
T	Temperature ©	23.4	23	
A/(B-C)	Bulk Sp.G (oven dry)	2.639	2.636	2.638
B/(B-C)	SSD Sp.G	2.675	2.673	2.674
A/(A-C)	Apparent Sp.G	2.737	2.738	2.738
100[(B-A)/A]	% Absorption	1.35%	1.41%	1.38%

Duplicate FA SpG

AASHTO T 84 (ASTM C128) Duplicate Relative Density, (SpG) and Absorption of Fine Aggregate				
Sample Preparation:				
1. Obtain 2 each, 1kg samples in accordance with T 2 (D 75) and T 248 (C 702) for duplicate tests.				
2. Dry to constant mass then add a minimum of 6% moisture after cooling. Allow sample to stand 15-19 hrs.				
(24 ± 4 hrs. for ASTM).				
a) Initial drying is optional if aggregates will be used for concrete mixtures, and are still in their moist states				
Note: Report Sp.G results to 0.001 (AASHTO) 0.01 (ASTM). Check that SSD SpG of Trials 1 & 2 agree within 1s, 0.0095				
Formulas:	**Description of data or calculation:**	Trial 1	Trial 2	**Average**
B	Pyc+ Distilled Water	660.7	660.7	
	(from calib) Ave M pw, c (g)			
S	SSD Soil Mass	500.1	500.8	
C	Pyc + Distilled Water + Agg	973.7	974.5	
T	Temperature (23.0 ± 2.0°C)	23.0	22.7	
A	Oven Dry Mass	493.4	495.3	
A/(B+S-C)	Bulk Sp.G. (Oven Dry)	2.637	2.649	2.643
S/(B+S-C)	SSD Sp.G.	2.673	2.678	2.675
A/(B+A-C)	Apparent Sp.G.	2.735	2.729	2.732
100(S-A)/A	Absorption	1.36%	1.11%	1.23%

5. Cementitious Materials

- Cementitious materials acceptable for concrete include, but are not limited to; Portland Cement, Calcium Sulfoaluminate Cement, Class C and F fly ash, micro-silica, nano-silica, natural pozzolans, ground granulated blast furnace slag (GGBF), silica fume, and meta-kaolin.

6. Admixtures

- Admixture materials acceptable for concrete include, but are not limited to water-reducers, surfactants, viscosity modifiers, air-entrainment agents, crack reducers, shrinkage reducers, accelerators, retarders, surface sealers, hardeners and finishing aides.

7. Fibers

- Fiber materials acceptable for reinforcement, shrinkage and crack control in concrete include, but are not limited to; steel, stainless steel, synthetic, and alkali-resistant cellulose fibers.

8. Internal Curing

- Internal curing may be used to increase tensile and compressive strength, reduce internal stresses and reduce shrinkage in concrete. Internal curing materials include, but are not limited to; expanded shale, clay or slate fine aggregates, alkali-resistant cellulose, super-absorbent polymers, multi-crystalline enhancer, specialty admixtures, and naturally occurring aggregates of volcanic origin meeting ASTM C1761.

9. Concrete Proportions by ACI 211.1 Chapter 6 – Procedure, 6.3.1 - 6.3.9

1. Select slump appropriate for the type of construction.
2. Select maximum size of aggregate so concrete can be placed without excessive segregation or voids.
   2b. (Not in ACI) Blend available aggregates to optimize the combined gradation as evaluated by gradation guidelines in section 4.1.1., 4.1.2 or section 4.1.3 for flowable, slip-formed, or self-consolidating concrete, respectively.
3. Estimate mixing water and entrained-air content for exposure class, selected slump and maximum aggregate size.
4. Select water-cementitious materials ratio needed to provide required durability and compressive strength.
5. Calculate the cementitious materials content based on steps 3-4 above.
6. Estimate coarse aggregate content using ACI 211.1 Table 6.3.6 - Volume of coarse aggregate per volume of concrete.
7. Calculate fine aggregate content. At the end of step 7 all ingredients of the concrete have been estimated except the fine aggregate. The fine aggregate content is calculated by difference.
8. Adjust for aggregate moisture.
9. Trial batch adjustments for air content, workability, freedom from segregation, finishing properties.

Example ACI Mix Design

- Goal: New Mix Design
  - 3-4” slump
  - 6% Entrained-air for Extreme Exposure
  - f'_c = 4000psi, (f'_{cr} = 5200psi)

1. Recommended Slump = 3-4”

Table 6.3.1 — Recommended slumps for various types of construction*

Types of construction	Slump, in.	
	Maximum†	Minimum
Reinforced foundation walls and footings	3	1
Plain footings, caissons, and substructure walls	3	1
Beams and reinforced walls	4	1
Building columns	4	1
Pavements and slabs	3	1
Mass concrete	2	1

2. Nominal Maximum Aggregate Size = 3/4 in.

1. Slump = 3-4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Moderate exposure, Air = 5% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement content = 305/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference

   $27.0\ ft^3$ – (all other volumes) = Sand volume (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9)

3. Estimate of Mixing Water & Air

Table 6.3.3 — Approximate mixing water and air content requirements for different slumps and nominal maximum sizes of aggregates

	Water, lb/yd³ of concrete for indicated nominal maximum sizes of aggregate							
Slump, in.	⅜ in.*	½ in.*	¾ in.*	1 in.*	1-½ in.*	2 in.*[†]	3 in.[†‡]	6 in.[†‡]
Non-air-entrained concrete								
1 to 2	350	335	315	300	275	260	220	190
3 to 4	385	365	340	325	300	285	245	210
6 to 7	410	385	360	340	315	300	270	—
More than 7*	—	—	—	—	—	—	—	—
Approximate amount of entrapped air in non-air-entrained concrete, percent	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-entrained concrete								
1 to 2	305	295	280	270	250	240	205	180
3 to 4	340	325	305	295	275	265	225	200
6 to 7	365	345	325	310	290	280	260	—
More than 7*	—	—	—	—	—	—	—	—
Recommended averages[§] total air content, percent for level of exposure:								
Mild exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5**,[††]	1.0**,[††]
Moderate exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5**,[††]	3.0**,[††]
Severe exposure[‡‡]	7.5	7.0	6.0	6.0	5.5	5.0	4.5**,[††]	4.0**,[††]

3. Mixing Water = 305#, Air = 6%

1. Slump = 4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Severe exposure, Air = 6% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement content = 305/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference
   27.0 ft^3 – (all other volumes) = Sand volume (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9)

4. Select w/c Ratio for 4000 psi w/ Air

Table 6.3.4(a) — Relationship between water-cement or water-cementitious materials ratio and compressive strength of concrete

Compressive strength at 28 days, psi*	Water-cement ratio, by weight	
	Non-air-entrained concrete	Air-entrained concrete
6000	0.41	—
5000	0.48	0.40
4000	0.57	0.48
3000	0.68	0.59
2000	0.82	0.74

4. Select w/c Ratio = 0.48

1. Slump = 4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Moderate exposure, Air = 5% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement content = 305/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference

   27.0 ft^3 – (all other volumes) = Sand volume (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9)

5. Calculate Cement Weight = 635 lbs

1. Slump = 4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Moderate exposure, Air = 5% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement weight = 305 lbs. water/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference
   27.0 ft^3 – (all other volumes) = Sand volume (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9)

6. Estimate Coarse Aggregate Content

1. Slump = 4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Moderate exposure, Air = 5% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement weight = 305 lbs. water/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9)

Fine Aggregate Gradation

AASHTO Gr.#		M6
Fine Aggregate		
Sieve	% Pass	Specs
3/8"	100	100
#4	100	95-100
#8	84	80-100
#16	60	50-85
#30	38	25-60
#50	18	10-30
#100	6	2-10
#200	2.8	0-3

Fineness Modulus Calculation

Fineness Modulus (FM) – An empirical factor obtained by adding the total percentages of a sample of fine aggregate retained on each of the following sieves, that sum divided by 100.

Sieve numbers 4, 8, 16, 30, 50, 100

For example:

Sieve Size	% Passing	% Retained
#4	100	0
#8	84	16
#16	60	40
#30	38	62
#50	18	82
#100	6	94
		Sum = 294

Fineness Modulus calculation: 294 / 100 = **2.94**

6a. Bulk Volume of dry CA/yd^3 Concrete

Table 6.3.6 — Volume of coarse aggregate per unit of volume of concrete

Nominal maximum size of aggregate, in.	Volume of oven-dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli of fine aggregate†			
	2.40	2.60	2.80	3.00
⅜	0.50	0.48	0.46	0.44
½	0.59	0.57	0.55	0.53
¾	0.66	0.64	0.62	0.60
1	0.71	0.69	0.67	0.65
1½	0.75	0.73	0.71	0.69
2	0.78	0.76	0.74	0.72
3	0.82	0.80	0.78	0.76
6	0.87	0.85	0.83	0.81

2.94

0.61

6b. Bulk Density and Voids in Aggregate

Formula:	Description:	1
G	Wt. of Agg. + T (lb)	32.984
T	Wt. Tare (lb):	7.718
V	Volume(ft^3):	0.248
M = (G-T)/V	Bulk Density Dry (lb/ft^3) **(M)** =25.266 lb / 0.248 ft^3=	**102**
A	% Absorption	1.38
M[1+(A/100)]	Bulk Density at SSD (lb/ft^3) **(Mssd)**	103
S	Bulk SpG (dry basis)	2.754
W	Water density 62.3 lb/ft^3)	62.3
100[(S*W)-M)/(S*W)]	% Void Content	40.6%

6. CA Bulk Volume Calculation

- Coarse Aggregate Unit volume is 0.61 yd^3
- 0.61 yd^3 (27 ft^3/yd^3) = 16.47 ft^3 Coarse Aggregate Bulk Volume

  16.47 ft^3 (102 lbs/ft^3) = 1680 lbs Dry CA.

- 1680 lbs Dry CA is 37.8% of the concrete volume.

  1680 lb / 2.638 / 62.4 pcf = 10.21 ft^3 (or 0.378 cy)

7. Calculate Sand Content by difference

1. Slump = 4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Moderate exposure, Air = 5% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement content = 305/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference
   27.0 ft^3 – (all other volumes) = Sand volume (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9)

7. Calculate Sand Content by difference

- Volume of water = 305 lb / 62.4 lb/ft^3 = 4.89 ft^3
- Volume of cement = 635 lb / (3.15 x 62.4 lb/ft^3) = 3.23 ft^3
- Volume of Dry CA = 1680 lb / 2.638 / 62.4 pcf = 10.21 ft^3
- Volume of Air = 6% x 27 ft^3 = 1.62 ft^3
- Subtotal = 19.95 ft^3
- Sand Volume = 27.00 – 19.95 = **7.05 ft^3**
- Required weight of Dry sand:

  7.05 ft^3 (2.643)(62.4 pcf) = 1163 lb

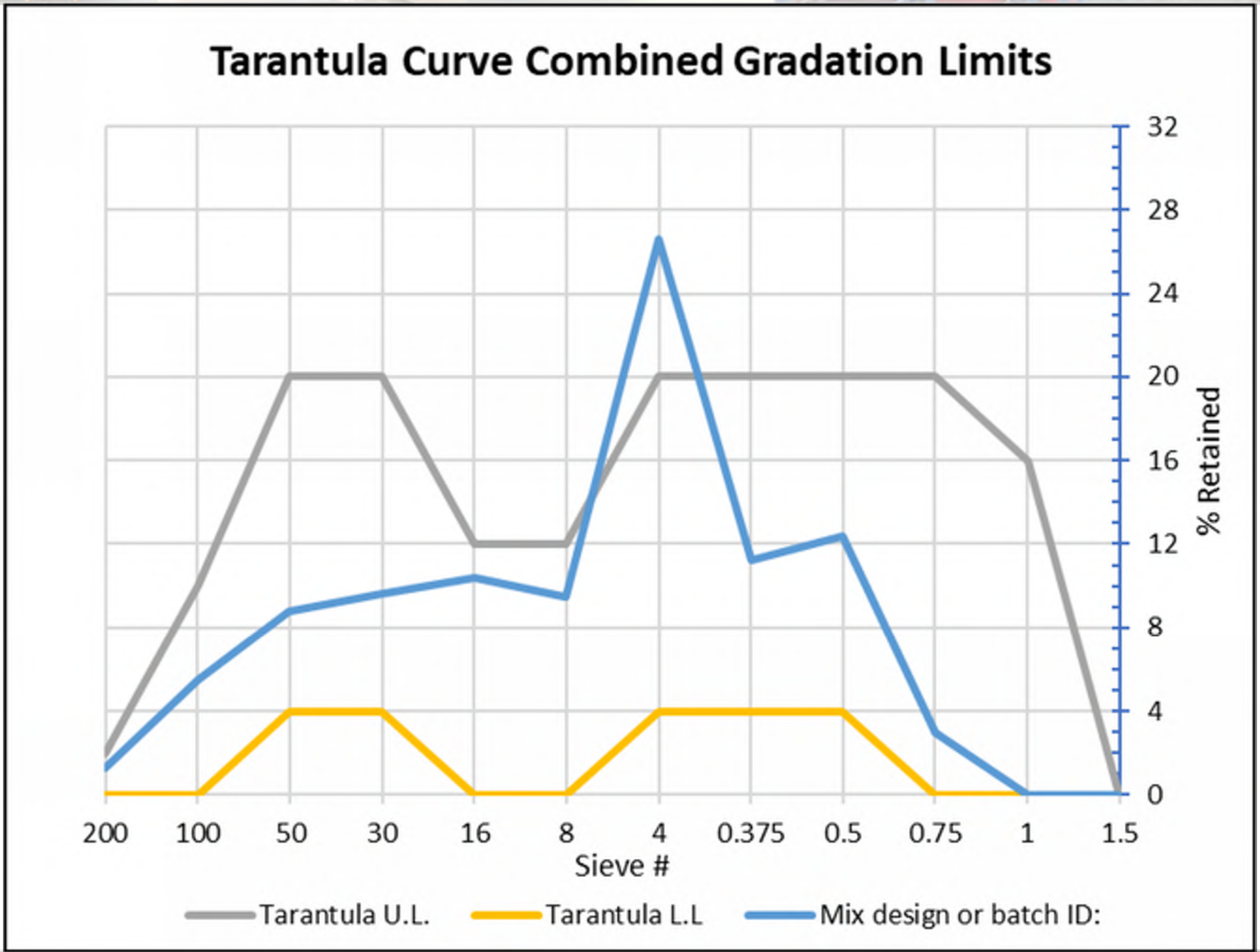
Flowable Combined Gradation

		BLEND SUPPLIED							
Aggregate Sizes:		1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals	
SSD Weights (lbs)		0	0	1,680	0	0	1,164	2,844	
Mass % Each Size		0.0%	0.0%	59.1%	0.0%	0.0%	40.9%	100.0%	

Enter Aggregate Gradations:

SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	(mm)	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1.0"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	95	100	100	100	97.0	3.0
1/2"	12.5	0	0	74	100	100	100	84.6	12.4
3/8"	9.5	*	0	55	0	100	100	73.4	11.2
#4	4.75	*	0	10	0	0	100	46.8	**26.6**
#8	2.36	*	0	5	0	0	84	37.3	9.5
#16	1.18	*	*	4	0	0	60	26.9	10.4
#30	0.60	*	*	3	0	0	38	17.3	9.6
#50	0.30	*	*	2	0	0	18	8.5	8.8
#100	0.15	*	*	1	0	0	6	3.0	5.5
#200	0.075	0	0	1.0	0	0	2.8	1.7	1.3
Pan	0.000								1.7
								Total:	100.0

ACI Class A Tarantula Plot



7. Re-Calculate Sand Content-12% CA

- Volume of water = 305 lb / 62.4 lb/ft^3 = 4.89 ft^3
- Volume of cement = 635 lb / (3.15 x 62.4 lb/ft^3) = 3.23 ft^3
- Volume of dry CA = 1478 lb / 2.638 / 62.4 pcf = 8.98 ft^3
- Volume of Air = 6% x 27 ft^3 = 1.62 ft^3
- Subtotal = 18.72 ft^3
- Sand Volume = 27.00 – 18.72 = **8.28 ft^3**
- Required weight of dry sand:

  8.28 ft^3 (2.643)(62.4 pcf) = 1366 lb

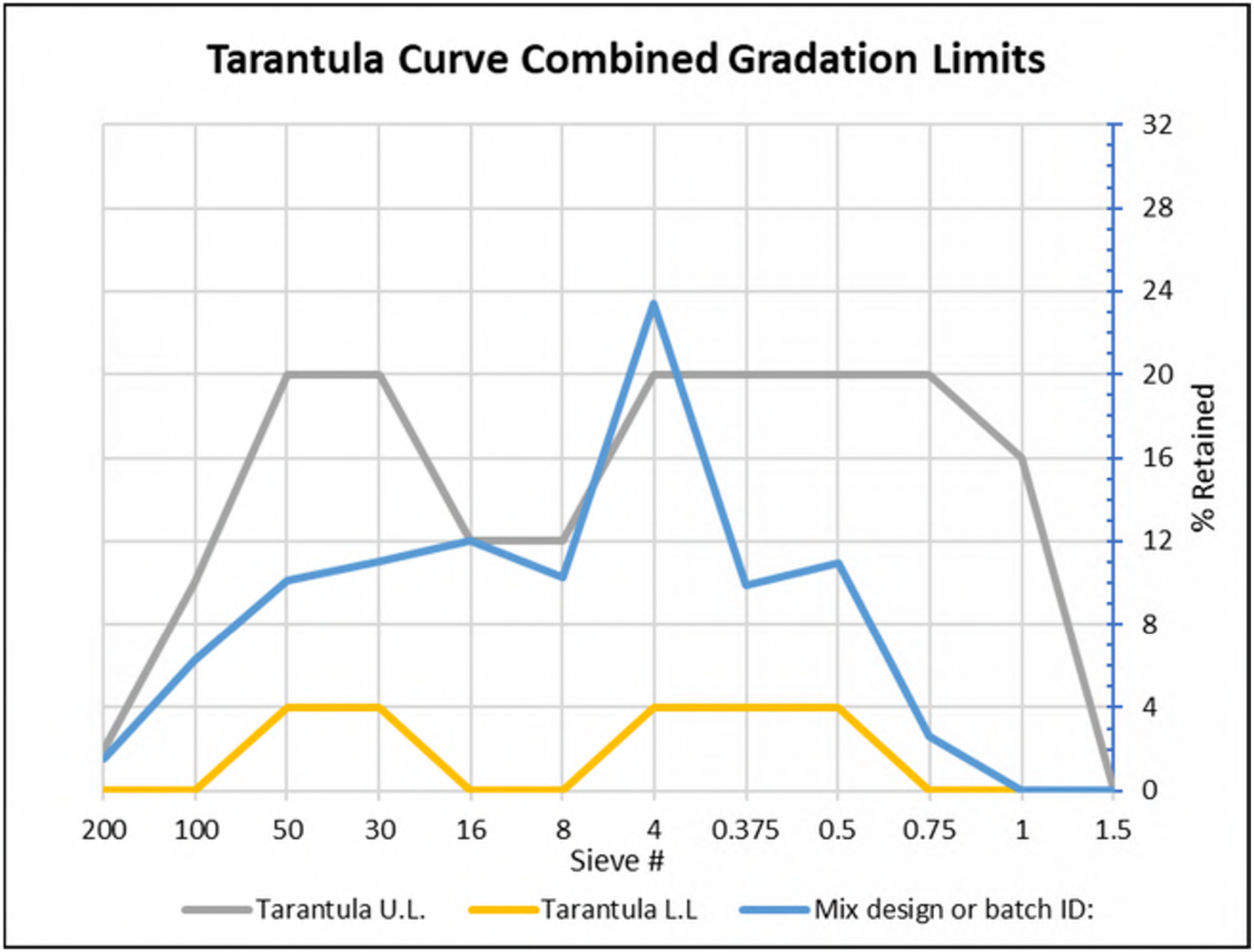
Flowable Combined Gradation

		BLEND SUPPLIED							
Aggregate Sizes:		1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals	
SSD Weights (lbs)		0	0	1,478	0	0	1,366	2,844	
Mass % Each Size		0.0%	0.0%	52.0%	0.0%	0.0%	48.0%	100.0%	

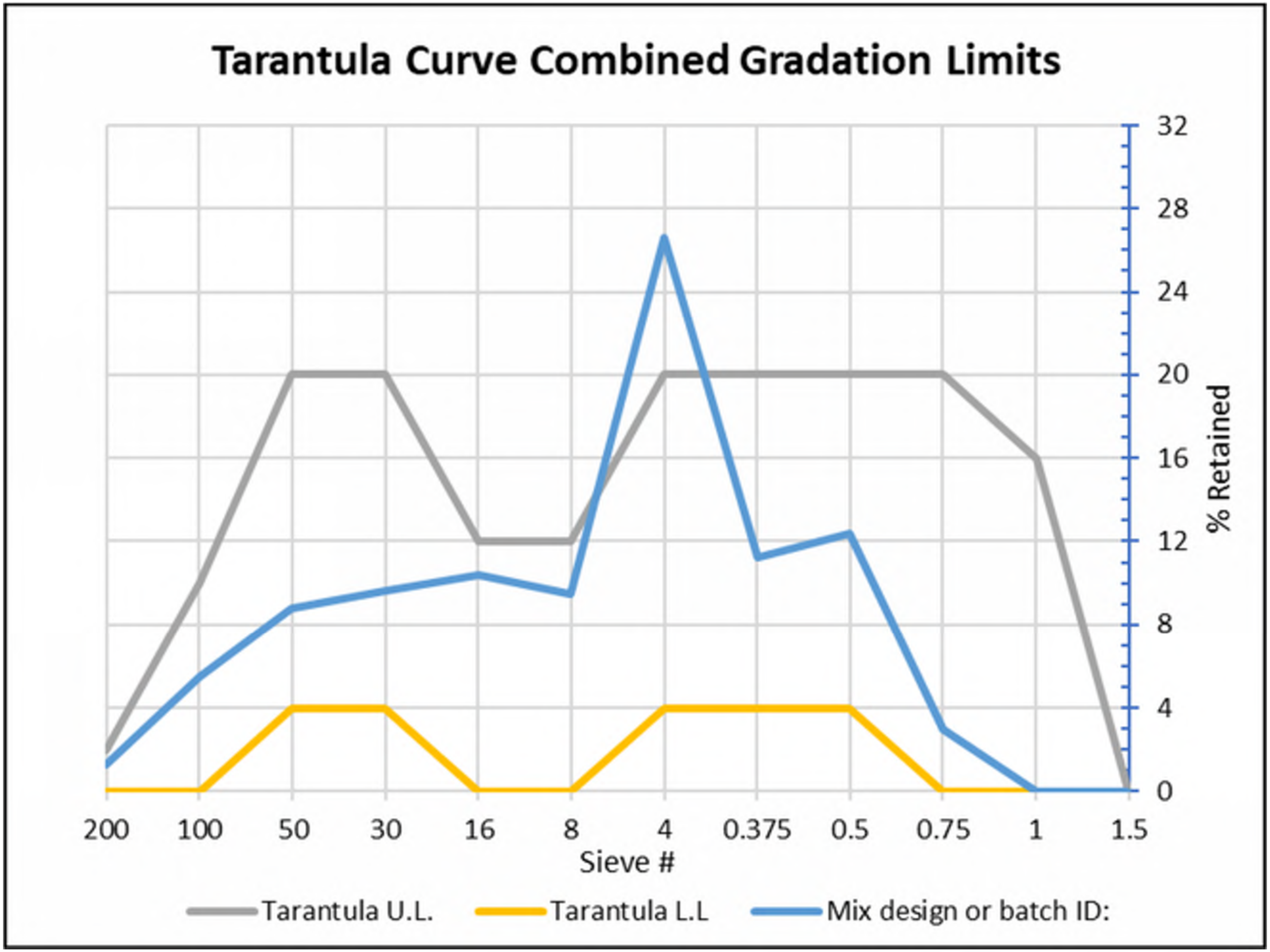
Enter Aggregate Gradations:

SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	**(mm)**	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1.0"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	95	100	100	100	97.4	2.6
1/2"	12.5	0	0	74	100	100	100	86.5	10.9
3/8"	9.5	*	0	55	0	100	100	76.6	9.9
#4	4.75	*	0	10	0	0	100	53.2	**23.4**
#8	2.36	*	0	5	0	0	84	42.9	10.3
#16	1.18	*	*	4	0	0	60	30.9	12.0
#30	0.60	*	*	3	0	0	38	19.8	11.1
#50	0.30	*	*	2	0	0	18	9.7	10.1
#100	0.15	*	*	1	0	0	6	3.4	6.3
#200	0.075	0	0	1.0	0	0	2.8	1.9	1.5
Pan	0.000								1.9
								Total:	100.0

ACI Tarantula Plot -12% CA



ACI Tarantula Plot



8. Adjustments for aggregate moisture

1. Slump = 4” (ACI Table 6.3.1)
2. Maximum Aggregate Size = ¾” (6.3.2)
3. Estimate Mixing Water = 305 lbs./cu. yd., and Air, Moderate exposure, Air = 5% (Table 6.3.3)
4. Select w/c ratio for 4000 psi compressive strength, air entrained, w/c = 0.48 from Table 6.3.4(a)
5. Calculate cement content = 305/0.48 = 635 lbs. (6.3.5)
6. Estimate CA content (Sand FM 2.94) = 0.61 (Table 6.3.6)
7. Calculate Sand content by difference
   27.0 ft^3 – (all other volumes) = Sand volume (6.3.7)
8. Adjustments for aggregate moisture (6.3.8)
9. Trial batch adjustments (6.3.9 to 7.3.10)

Mix Design Spreadsheet

Mix Design Volumetric Data - 6.0 sk Trial (1)

Note: Blue Font = Data Entry, Red Font = Calculation

Type of Concrete:	4000 psi	6.0% Air	6.0 sack	Calculated by:	
Project Name:	Slabs - Exposed to Freeze/Thaw			Checked by:	
				Date:	

Mix Design Criteria:

Maximum Nominal Aggregate Size (inches):	3/4
Cement (Minimum weight per cubic yard):	520 lbs
Cement Mfg / Type:	Type I/II
Max Water/Cementitious Materials Ratio (lbs/l	0.48
28 day Design Strength, (f'c):	4000 psi
28 day Required Strength, (f'cr):	5200 psi
Slump Range (inches):	4 ± 1.5"
Entrained Air Content (% by Volume):	6 ± 1.5%
Mix Ratio by weight (Cementitious:Sand:Grave	1:2.47:3.07
Sand Content (% by Weight of SSD Agg):	42.8%

FA, CA Mix Ratios

2.22

2.97

Aggregate Moisture (As Received):

	CA	FA
Tare	1012.1	1238.8
T + Wet	2498.4	2534.0
T + Dry	2470.0	2471.3
Water	28.4	62.7
Dry	1457.9	1232.5
%M	1.95%	5.09%

Reference Data:

Type I cement, Sp G:	3.15
Water, unit weight at 20^0 C (pcf):	62.4

Aggregate Characteristics:

Moisture	Size	AASHTO	Bulk Sp G	SSD Sp G	App Sp G	Absorption	Free water
1.95%	Coarse Agg	M-43 #67	2.638	2.674	2.738	1.38%	0.57%
5.09%	Fine Agg	M-6	2.643	2.675	2.732	1.23%	3.86%

Mix Design Spreadsheet (2)

Admixtures:	Enter Dose	Trial Batch Amounts			Cubic Yard Amounts		Admixture
	fl oz/100#	fl oz	ml	lbs	fl oz / yd^3	lbs / yd^3	SpG
Polyheed 997	2.00	0.638	**18.9**	0.053	11.5	0.950	1.27
MasterAir AE 200	0.60	0.191	**5.66**	0.0126	3.4	0.227	1.01
	0.00	0.000	0.0	0.000	0.0	0.000	1

Dry Batch weights for 1.0 yd^3	Dry Weight (lbs.)	Volume (ft^3)	SSD Batch Weights (lbs.)	Field Moist Batch Wts (lbs.)	Aggregate Free Water (lbs.)
w/c ratio	0.500				
Total free water	287				
Cement	574	2.92	574	**574**	
Mixing water	287	4.60	287	**229**	
Coarse Aggregate	1681	10.21	1704	**1714**	10
Polyheed 997	0.950	0.01	1.0	**1.0**	
MasterAir AE 200	0.227	0.00	0.2	**0.2**	
	0.000	0.00	0.0	**0.0**	
Air 6.0%		1.62			
Volume Subtotal =		19.37			
Fine Aggregate	1259	7.63	1274	**1323**	49
Totals	3802	27.00	3841	3841	58
Unit Weight (pcf)	140.8		142.2	142.2	

Cement:

94 lbs / sack

6 sack = 564.0 lbs

Total Cementitious = 574.0 lbs

Paste Volume (ft^3) = 7.520

Extra Water Record:

Tare

Start T+W

End T+W

Water added

9. Trial Batch Adjustments

- For no-air mix design you need to make at least three trial batches at different cement contents and different water/cement ratios. (ACI 301, Sec. 4.2.3.4.b, 3rd bullet)
- For air-entrained concrete you will need to make at least two addition batches to cover the entire specified air content range.
- (e.g. 6.0% Air has a ±1.5% air tolerance so you need a trial batch below 4.5% air, one within 0.5% of 6.0%, and one exceeding 7.5%.

9. Trial Batch Adjustments (2)

	Mass (lb)	Vol. (ft^3)				
w/c ratio	0.500		Cement:			
Total free water	282		94	lbs / sack		
Cement, Cell B26>	564	2.87	6.0	sack =	564.0 lbs	
Silica Fume			Total Cementitious =		564.0 lbs	
Mixing water	282	4.52	Total Paste Volume (ft^3) =		7.389	← Steps 5-8, with cursor on this cell use Goal Seek to change Cement mass in Cell B26 until paste volume = 7.515

	Mass (lb)	Vol. (ft^3)				
w/c ratio	0.450		Cement:			
Total free water	275		94	lbs / sack		
Cement	611	3.11	6.5	sack =	611.0 lbs	
Silica Fume			Total Cementitious =		611.0 lbs	
Mixing water	275	4.41	Total Paste Volume (ft^3) =		7.515	← Step 4 is Goal for all three w/c ratios

	Mass (lb)	Vol. (ft^3)				
w/c ratio	0.400		Cement:			
Total free water	263		94	lbs / sack		
Cement, Cell B40>	658	3.35	7.0	sack =	658.0 lbs	
Silica Fume			Total Cementitious =		658.0 lbs	
Mixing water	263	4.22	Total Paste Volume (ft^3) =		7.566	← Step 9, with cursor on this cell use Goal Seek to change Cement mass in Cell B40 until paste volume = 7.515

Reference Data:

Type I cement, Sp G:	3.15
Silica Fume, Sp G:	2.2
Water, unit weight at 20^0 C (pcf):	62.4

9. Trial batch adjustments (3)

	Mass (lb)	Vol. (ft^3)			
w/c ratio	0.500		Cement:		
Total free water	287		94	lbs / sack	
Cement, Cell B26>	574	2.92	6.0	sack =	564.0 lbs
Silica Fume			Total Cementitious =		573.6 lbs
Mixing water	287	4.60	Total Paste Volume (ft^3) =		7.515

← Steps 5-8, with cursor on this cell use Goal Seek to change Cement mass in Cell B26 until paste volume = 7.515

	Mass (lb)	Vol. (ft^3)			
w/c ratio	0.450		Cement:		
Total free water	275		94	lbs / sack	
Cement	611	3.11	6.5	sack =	611.0 lbs
Silica Fume			Total Cementitious =		611.0 lbs
Mixing water	275	4.41	Total Paste Volume (ft^3) =		7.515

← Step 4 is Goal for all three w/c ratios

	Mass (lb)	Vol. (ft^3)			
w/c ratio	0.400		Cement:		
Total free water	261		94	lbs / sack	
Cement, Cell B40>	654	3.33	7.0	sack =	658.0 lbs
Silica Fume			Total Cementitious =		653.6 lbs
Mixing water	261	4.19	Total Paste Volume (ft^3) =		7.515

← Step 9, with cursor on this cell use Goal Seek to change Cement mass in Cell B40 until paste volume = 7.515

Reference Data:

Type I cement, Sp G:	3.15
Silica Fume, Sp G:	2.2
Water, unit weight at 20^0 C (pcf):	62.4

End of ACI Mix Design

- In summary, an ACI 301 and ACI 211 compliant no-air concrete mix design will require at least three trial batches.
- An air entrained mix will need at least 5 trial batches, 3 no-air batches to establish strength vs. water/cement ratio and then at least two more batches at medium and high air contents to establish the strength variation with change in air content.

10. Proportions by Packing Density

1. Select maximum size of aggregate so concrete can be placed without excessive segregation or voids. Blend available aggregates to optimize the combined gradation as evaluated by gradation guidelines in section 4.1.1., 4.1.2 or section 4.1.3
2. Determine the volume of voids in the combined aggregate. (AASHTO T 19 / ASTM C29)
3. Estimate the amount of excess paste required to provide desired workability.
4. Calculate volume of paste required to fill the aggregate voids.
5. Calculate volumes of each aggregate.
6. Calculate weights of each aggregate.
7. Select w/c ratio based on compressive strength requirements
8. Calculate cement content.
9. Calculate water content.
10. Determine required entrained air content for exposure conditions and maximum aggregate size.
11. Trial batch adjustments.

11. Full Mix Design - Appendix D

- Mix Design Procedure is outlined in ATM 530, Section 11, with Appendix D containing a full set of the required data, calculations, and graphs, in sequential spreadsheets.

11. Required data, calcs, & graphs

The following mix design data is arranged in developmental sequence.

11. Required Trial Batch Data

1. Aggregate structure is the starting point for good concrete proportions, properties, and performance. Perform gradations on representative samples of each aggregate (or use the average gradation from screening plant control charts). The following 7 worksheets contain required data for mix designs. (First 5 already shown in earlier slides)
   a. Use worksheet 1-*Combined Aggregate Worksheet, Calcs, Graph*, to develop aggregate blend within the Tarantula Curve limits.
   b. Use worksheet 2-*Duplicate Coarse Aggregate Specific Gravities & Absorption* for these tests.
   c. Use worksheet 3-*Duplicate Fine Aggregate Specific Gravities & Absorption* for these tests.
   d. Use worksheet 4-*Bulk Density and Voids in Aggregate* for these tests.
   e. Use worksheet 5-*Constant Paste Volume Calculations* for three no-air batches to establish Compressive Strength vs. w/c Ratio
   f. Use worksheet 6-*MD Volumetric Data* for each trial batch
   g. Use worksheet 7-*MD Compresssive Strength, Unit Wt Data* for each trial batch

Worksheet 1a

Tarantula Curve Data Entry & Graphical Plot: Flowable Concrete

Mix design or batch ID: Flowable Example xyz **Date:** 4/3/2023

Enter Aggregate SSD Weights under BLEND SUPPLIED below.

Note: **Blue font is data entry**, **Red font indicates a calculation cell**

	BLEND SUPPLIED						
Aggregate Sizes:	1.5"	1"	3/4"	Pea	Pea - Sand	F. Sand	Totals
SSD Weights (lbs)	0	0	1,762	0	0	1,417	3,179
Mass % Each Size	0.0%	0.0%	55.4%	0.0%	0.0%	44.6%	100.0%

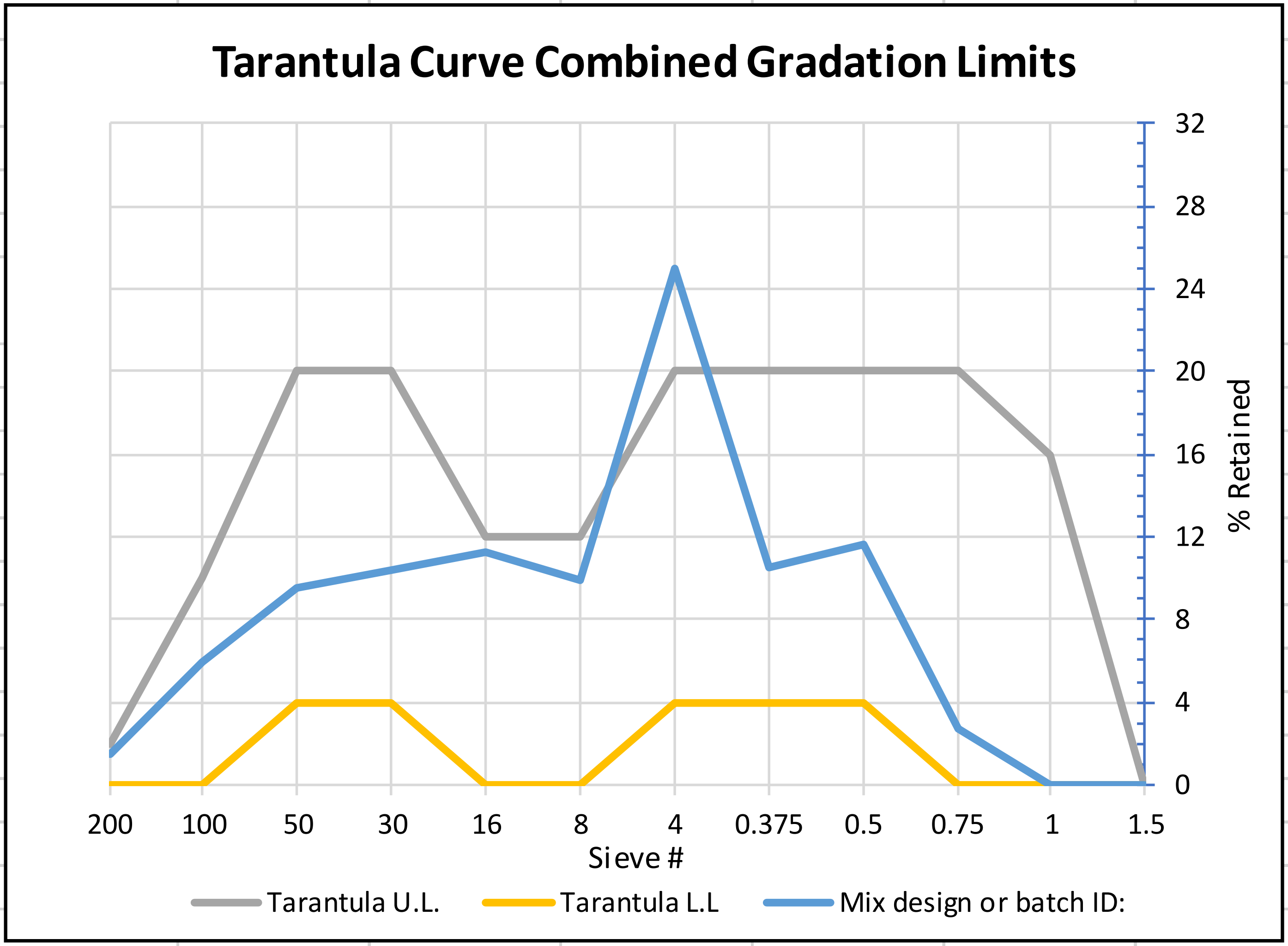
Enter Aggregate Gradations:

SIEVE SIZE		CURRENT GRADATIONS, PERCENT PASSING						Combined	Combined
(us)	**(mm)**	1.5"	1"	3/4"	Pea	C. Sand	F. Sand	% Passing	% Retained
1.5"	37.5	100	100	100	100	100	100	100.0	0.0
1.0"	25	0	0	100	100	100	100	100.0	0.0
3/4"	19	0	0	95	100	100	100	97.2	2.8
1/2"	12.5	0	0	74	100	100	100	85.6	11.6
3/8"	9.5	*	0	55	0	100	100	75.1	10.5
#4	4.75	*	0	10	0	0	100	50.1	24.9
#8	2.36	*	0	5	0	0	84	40.2	9.9
#16	1.18	*	*	4	0	0	60	29.0	11.3
#30	0.60	*	*	3	0	0	38	18.6	10.4
#50	0.30	*	*	2	0	0	18	9.1	9.5
#100	0.15	*	*	1	0	0	6	3.2	5.9
#200	0.075	0	0	1.0	0	0	2.8	1.8	1.4
Pan	0.000								1.8
								Total:	100.0

Worksheet 1b

Concrete Sand Limits - Flowable	Coarse/Fine Percentage	Within Limits?
Coarse Sand % (#8-30) =	**31.5**	**Yes**
Minimum is 20%		
Fine Sand % (#30-200) =	**27.2**	**Yes**
Allowable range is 25-40%		

Tarantula Limits - Flowable		
Sieve #	Tarantula U.L.	Tarantula L.L
1.5	0	0
1	16	0
0.75	20	0
0.5	20	4
0.375	20	4
4	20	4
8	12	0
16	12	0
30	20	4
50	20	4
100	10	0
200	2	0



2. Duplicate Coarse Aggregate Specific Gravities & Absorption

Formulas:	Description:	Trial 1	Trial 2	Average
A	Oven dry mass in air (g)	2869.0	2892.6	
B	SSD mass in air (g)	2907.8	2933.5	
C	Mass in water (g)	1820.8	1836.2	
T	Temperature ©	23.4	23.0	
A/(B-C)	Bulk Sp.G (oven dry)	2.639	2.636	**2.638**
B/(B-C)	SSD Sp.G	2.675	2.673	**2.674**
A/(A-C)	Apparent Sp.G	2.737	2.738	**2.738**
100[(B-A)/A]	% Absorption	1.35%	1.41%	**1.38%**

3. Duplicate Fine Aggregate Specific Gravities & Absorption

Formulas:	Description of data or calculation:	Trial 1	Trial 2	Average
B	Pyc+ Distilled Water	660.7	660.7	
	(from calib) Ave M pw, c (g)			
S	SSD Soil Mass	500.1	500.8	
C	Pyc + Distilled Water + Agg	973.7	974.5	
T	Temperature (23.0 ± 2.0°C)	23.0	22.7	
A	Oven Dry Mass	493.4	495.3	
A/(B+S-C)	Bulk Sp.G. (Oven Dry)	2.637	2.649	**2.643**
S/(B+S-C)	SSD Sp.G.	2.673	2.678	**2.675**
A/(B+A-C)	Apparent Sp.G.	2.735	2.729	**2.732**
100(S-A)/A	Absorption	1.36%	1.11%	**1.23%**

4. Bulk Density and Voids in Aggregate

Method Used:	A		Trial Number:			
Formula:	**Description:**		1	2	3	Avg.
G	Wt. of Agg. + T (lb)		32.984			-
T	Wt. Tare (lb):		7.718			-
V	Volume(ft^3):		0.248			-
M = (G-T)/V	Bulk Density (lb/ft^3) **(M)**		102			**102**
A	% Absorption		1.38			-
M[1+(A/100)]	Bulk Density at SSD (lb/ft^3) **(Mssd)**		103			**103**
S	Bulk SpG (dry basis)		2.754			-
W	Water density 62.3 lb/ft^3)		62.3			-
100[(S*W)-M)/(S*W)]	% Void Content		40.6%			**40.6%**

5-Constant Paste Volume Calculations

	Mass (lb)	Vol. (ft^3)				
w/c ratio	0.500		Cement:			
Total free water	287		94	lbs / sack		
Cement, Cell B26>	574	2.92	6.0	sack =	564.0 lbs	
Silica Fume			Total Cementitious =		573.6 lbs	
Mixing water	287	4.60	Total Paste Volume (ft^3) =		7.515	← Steps 5-8, with cursor on this cell use Goal Seek to change Cement mass in Cell B26 until paste volume = 7.515

	Mass (lb)	Vol. (ft^3)				
w/c ratio	0.450		Cement:			
Total free water	275		94	lbs / sack		
Cement	611	3.11	6.5	sack =	611.0 lbs	
Silica Fume			Total Cementitious =		611.0 lbs	
Mixing water	275	4.41	Total Paste Volume (ft^3) =		7.515	← Step 4 is Goal for all three w/c ratios

	Mass (lb)	Vol. (ft^3)				
w/c ratio	0.400		Cement:			
Total free water	261		94	lbs / sack		
Cement, Cell B40>	654	3.33	7.0	sack =	658.0 lbs	
Silica Fume			Total Cementitious =		653.6 lbs	
Mixing water	261	4.19	Total Paste Volume (ft^3) =		7.515	← Step 9, with cursor on this cell use Goal Seek to change Cement mass in Cell B40 until paste volume = 7.515

6a-MD Volumetric Data

Mix Design Volumetric Data - 6.0 sk, No Air, Trial (1)

Note: Blue Font = Data Entry, Red Font = Calculation

Type of Concrete:	5000 psi	Calculated by:	
Project Name:	Slabs - Not exposed to Freeze/Thaw	Checked by:	
		Date:	

Mix Design Criteria:

Maximum Nominal Aggregate Size (inches):	3/4		
Cement (Minimum weight per cubic yard):	520 lbs		
Cement Mfg / Type:	Type I/II		
Max Water/Cementitious Materials Ratio (lbs/l	0.46		
28 day Design Strength, (f'c):	5000 psi		
28 day Required Strength, (f'cr):	6200 psi		
Slump Range (inches):	4 ± 1.5"	FA, CA Mix Ratios	
Entrained Air Content (% by Volume):	1.5 ± 1%	2.47	
Mix Ratio by weight (Cementitious:Sand:Grave	1:2.47:3.07	3.07	
Sand Content (% by Weight of SSD Agg):	44.6%		

Agg. Moisture (As Rec'd):

	CA	FA
Tare	1012.1	1238.8
T + Wet	2498.4	2534.0
T + Dry	2470.0	2471.3
Water	28.4	62.7
Dry	1457.9	1232.5
%M	1.95%	5.09%

Reference Data:

Type I cement, Sp G:	3.15
Water, unit weight at 20⁰ C (pcf):	62.4

Aggregate Characteristics:

Moisture	Size	AASHTO	Bulk Sp G	SSD Sp G	App Sp G	Absorption	Free water
1.95%	Coarse Agg	M-43 #67	2.638	2.674	2.738	1.38%	0.57%
5.09%	Fine Agg	M-6	2.643	2.675	2.732	1.23%	3.86%

Units:	1 gallon =	128 fl oz =	3785.3 milliliter	1 pound =	453.59 grams
		1 fl oz =	29.57 ml		

Admixtures:	Enter Dose	Trial Batch Amounts			Cubic Yard Amt.		Admixture
	fl oz/100#	fl oz	ml	lbs	fl oz / yd^3	lbs / yd^3	SpG
Polyheed 997	2.00	0.638	18.9	0.053	11.5	0.950	1.27
Micro-Air	0.00	0.000	0.00	0.0000	0.0	0.000	1.01
	0.00	0.000	0.0	0.000	0.0	0.000	1

6b-MD Volumetric Data

Dry Batch weights for		Weight	Volume	SSD Batch	Field Moist	Aggregate			
1.0 yd^3		(lbs.)	(ft^3)	Weights	Batch Wts	Free Water			
	W/C Ratio	0.500		(lbs.)	(lbs.)	(lbs.)	Cement:		
	Total free water	287					94	lbs / sack	
	Cement	574	2.92	574	**574**		6	sack =	564.0 lbs
							Total Cementitious =		574.0 lbs
	Mixing water	287	4.60	287	**223**				
Coarse Aggregate (Dry)		1738	10.56	1762	**1772**	10	Paste Volume (ft^3) =		7.520
Polyheed 997 Admixture		2.376	0.03	2.4	**2.4**				
Micro-Air Admixture		0.000	0.00	0.0	**0.0**				
		0.000	0.00	0.0	**0.0**				
Air	1.5%		0.41						
	Volume Subtotal =		18.51					Extra Water Record:	
Fine Aggregate (Dry)		1400	8.49	1417	**1471**	54		Tare	
	Totals	4001	27.00	4042	4042	64		Start T+W	
	Unit Weight (pcf)	148.2		149.7	149.7			End T+W	
								Water added	
T = Theoretical Maximum Unit Weight (pcf) =				**152.00**					

6c-MD Volumetric Data

Mix Design Volumetric Data - 6.0 sk Trial (1) - Continued

Trial Batch Volumetrics		Weight	Volume
Size (ft^3)	1.5	(lbs.)	(ft^3)
Cement		**31.889**	0.162
		0.000	
Mixing water		**12.386**	0.198
Dry Coarse Aggregate		96.556	0.587
CA Absorption		1.332	
CA Free Water		0.550	0.009
Total Weight Wet CA =		**98.438**	
Polyheed 997 Admixtu		0.053	0.001
Micro-Air Admixture		0.000	0.000
		0.000	0.000
Air	1.5%	0.00	0.023
Dry Fine Aggregate		77.928	0.473
FA Absorption		0.959	
FA Free Water		3.008	0.048
Total Weight Wet FA =		**81.895**	
	Totals	**224.661**	**1.500**
Calculated Unit Wt w/Admixtures			149.8 pcf

Added water (lbs)	
Total Mixing Water in Trial batch	15.944
Final W/C Ratio	0.500

For Sizing Trial Batch:

Note:	6x12 cyl =	0.196	ft^3
	4x8 cyl =	0.058	ft^3
	Slump cone =	0.204	ft^3
	Unit wt bucket =	0.25	ft^3
	16 ea 4x8 cyl =	0.93	ft^3
	Min Trial batch =	1.38	ft^3

6d-MD Volumetric Data

Trial Batch Data:

Temperature	48	^{0}F	Weight of Tare	7.920	lbs
Slump	5.5	inches	Wt of Tare & Concrete	44.725	lbs
Air	2.0%		Weight of Concrete	36.805	lbs
Unit Weight	147.2	pcf	Volume of Tare	0.2500	ft^3
Yield (ft^3/sk)	4.498		Weight of all ingredients as batched	224.661	lbs

(*ASTM C138, Sec 7.6, Equation (7)*)

To calculate % Air from Unit Weight:

A = [(T - D)/T] x 100

Where: A = % Air

D = Wet Unit Weight

T = Theoretical Maximum Unit Weight = 152.1

Calculate % Air (x) from Unit Weight (y)		
For D =	**147.2**	pcf
A =	**3.2**	% Air

or

To calculate Unit Weight from % Air:

Solve: A = [(T - D)/T] x 100 for D

A/100 = (T - D)/T

AT/100 = T - D

D = T - AT/100

Calculate Unit Weight (y) from % Air (x)		
For A =	**1.5**	% Air
D =	**149.8**	pcf

7a-MD Compressive Strength Data

Mix Design Compressive Strength & Unit Weight Data - 6sk Trial 1, No Air, f'c = 5000 psi									
Note: Blue Font = Data Entry, Red Font = Calculation				1.00 psi =	6.894761	kPa			
Date & Age Data			Cylinder Compressive Strength Data					Compressive Strength	
Cast	Tested	Age (Days)	Cyl ID	Diameter 1 (Inches)	Diameter 2 (Inches)	XC Area (Sq Inch)	Peak Load (Pounds)	f'c (psi)	f'c (kPa)
5/3/2013	5/6/2013	3	181	4.00	4.00	12.57	34,085	2710	18700
5/3/2013	5/6/2013	3	182	4.00	4.01	12.60	34,040	2700	18600
5/3/2013	5/6/2013	3	183	3.99	4.00	12.53	34,020	2710	18700
5/3/2013	5/6/2013	3	184	4.00	3.99	12.53	33,765	2690	18500
5/3/2013	5/10/2013	7	185	4.000	4.000	12.57	58,015	4620	31900
5/3/2013	5/10/2013	7	186	4.020	3.990	12.60	58,565	4650	32100
5/3/2013	5/10/2013	7	187	4.020	4.010	12.66	57,115	4510	31100
5/3/2013	5/10/2013	7	188	4.020	4.010	12.66	58,175	4590	31600
5/3/2013	5/17/2013	14	189	4.000	4.010	12.60	71,855	5700	39300
5/3/2013	5/17/2013	14	190	3.990	4.010	12.57	71,350	5680	39200
5/3/2013	5/17/2013	14	191	3.990	4.000	12.53	69,875	5570	38400
5/3/2013	5/17/2013	14	192	4.010	4.000	12.60	70,755	5620	38700
5/3/2013	5/31/2013	28	193	3.990	4.000	12.53	78,255	6240	43000
5/3/2013	5/31/2013	28	194	4.000	3.980	12.50	75,930	6070	41900
5/3/2013	5/31/2013	28	195	3.980	3.980	12.44	76,835	6180	42600
5/3/2013	5/31/2013	28	196	3.980	3.980	12.44	75,110	6040	41600
						Average 3 day f'c=		2703	
						Average 7 day f'c=		4593	
						Average 14 day f'c=		5643	
						Average 28 day f'c=		6133	

7b-MD Unit Weight Data

Note: Use cylinder unit weight to check wet unit weight and mix design value. Find root cause if Δ > 1.85 pcf

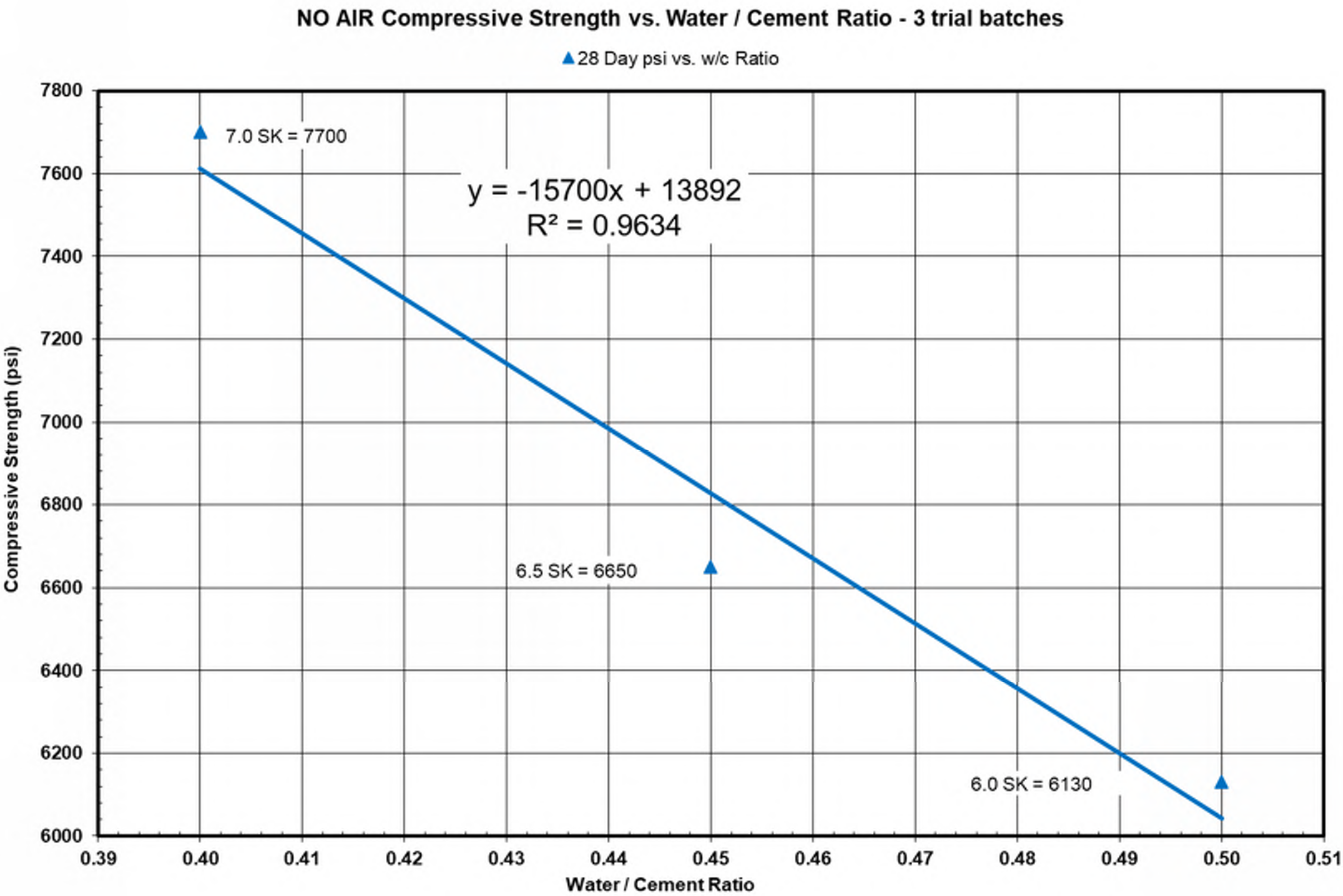
Cylinder Unit Weight Data							Unit Weight	
Cyl ID Number	Wt in Air (grams)	Wt in H_2O (grams)	H_2O Temp (^0C)	H_20 Density (g/cm^3)	Cyl Volume (cm^3)	Cyl Density (g/cm^3)	(lbs/ft^3)	(kg/m^3)
181	3944.5	2298.1	22.8	0.99759	1650.4	2.3901	149.1	2390
182	3960.2	2315.3	22.8	0.99759	1648.9	2.4018	149.9	2402
183	3926.3	2285.1	22.8	0.99759	1645.2	2.3866	148.9	2387
184	3938.1	2295.2	22.8	0.99759	1646.9	2.3913	149.2	2391
185	3948.9	2304.1	23.9	0.99732	1649.2	2.3944	149.4	2394
186	3973.4	2328.2	23.9	0.99732	1649.6	2.4087	150.3	2409
187	3975.1	2325.2	23.9	0.99732	1654.3	2.4028	149.9	2403
188	3949.9	2305.6	23.9	0.99732	1648.7	2.3957	149.5	2396
189	3981.8	2338.5	20.6	0.99808	1646.5	2.4184	150.9	2418
190	3971.2	2320.1	20.6	0.99808	1654.3	2.4006	149.8	2401
191	3990.2	2349.6	20.6	0.99808	1643.8	2.4275	151.5	2427
192	3989.5	2348.3	20.6	0.99808	1644.4	2.4262	151.4	2426
193	3970.1	2322.7	20.5	0.99810	1650.5	2.4053	150.1	2405
194	3956.0	2312.4	20.5	0.99810	1646.7	2.4023	149.9	2402
195	3967.5	2322.8	20.5	0.99810	1647.8	2.4077	150.2	2408
196	3977.4	2332.9	20.5	0.99810	1647.6	2.4140	150.6	2414
				Average Unit Weight =			**150.0**	
			3-day cylinder average unit weight =				**149.3**	
		14 & 28-day cylinder average unit weight =					**150.6**	

One batch done, How many more?

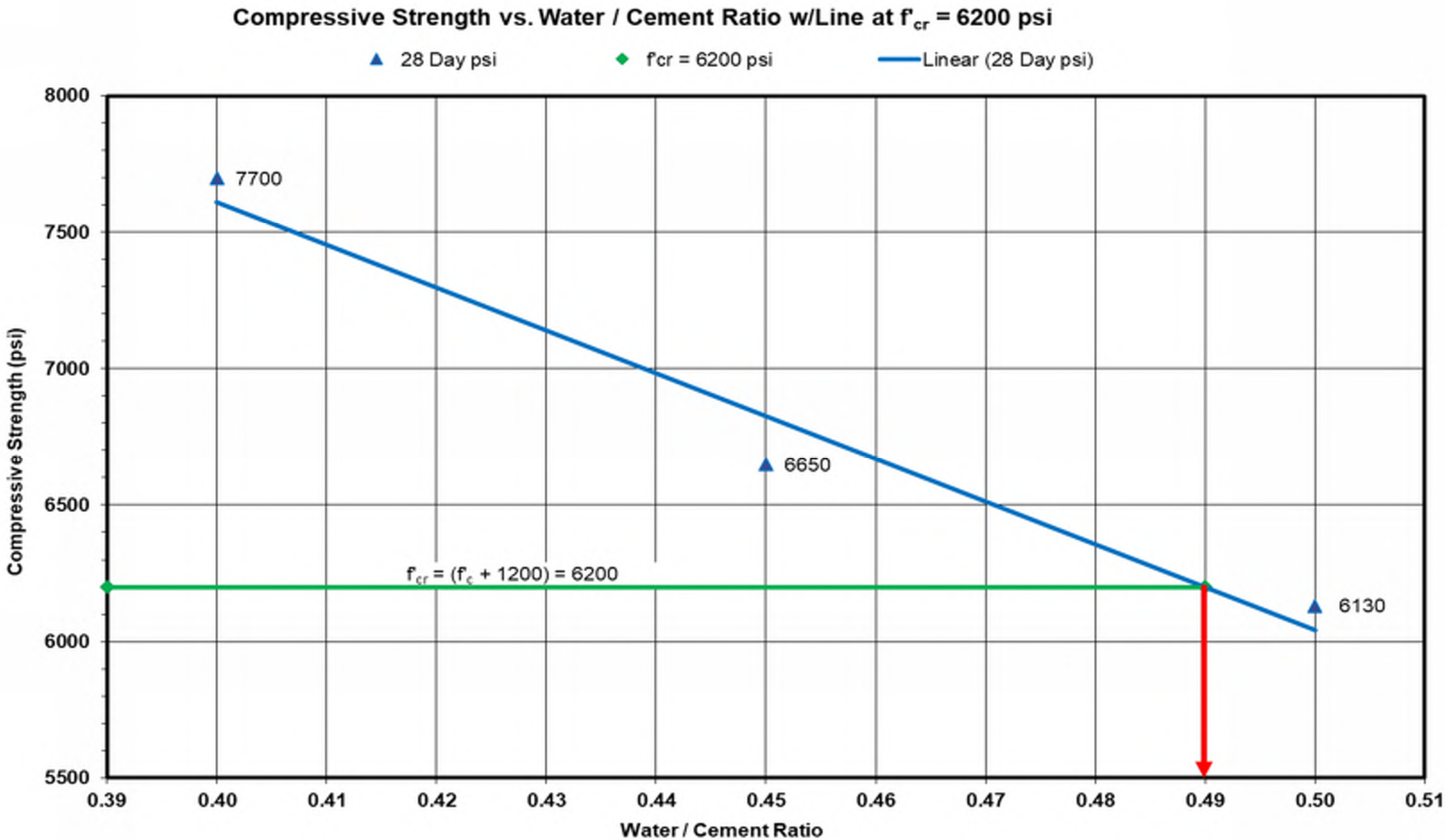
- Two more No Air trial batches were done at 6.5 & 7.0 sack to define the no-air strength to w/c ratio.
- Summary of No Air Batches:

Sack	w/c	Pres./Grav. % Air	Compressive Strength
6.0sk	0.50	2.0 / 0.9	6130psi
6.5sk	0.45	1.4 / 1.3	6650psi
7.0sk	0.40	1.5 / 1.7	7700psi

Graph 1a, NO AIR psi vs. w/c



Graph 1b, NO AIR psi vs. w/c Ratio w/Line at f'_{cr} = 6200 psi



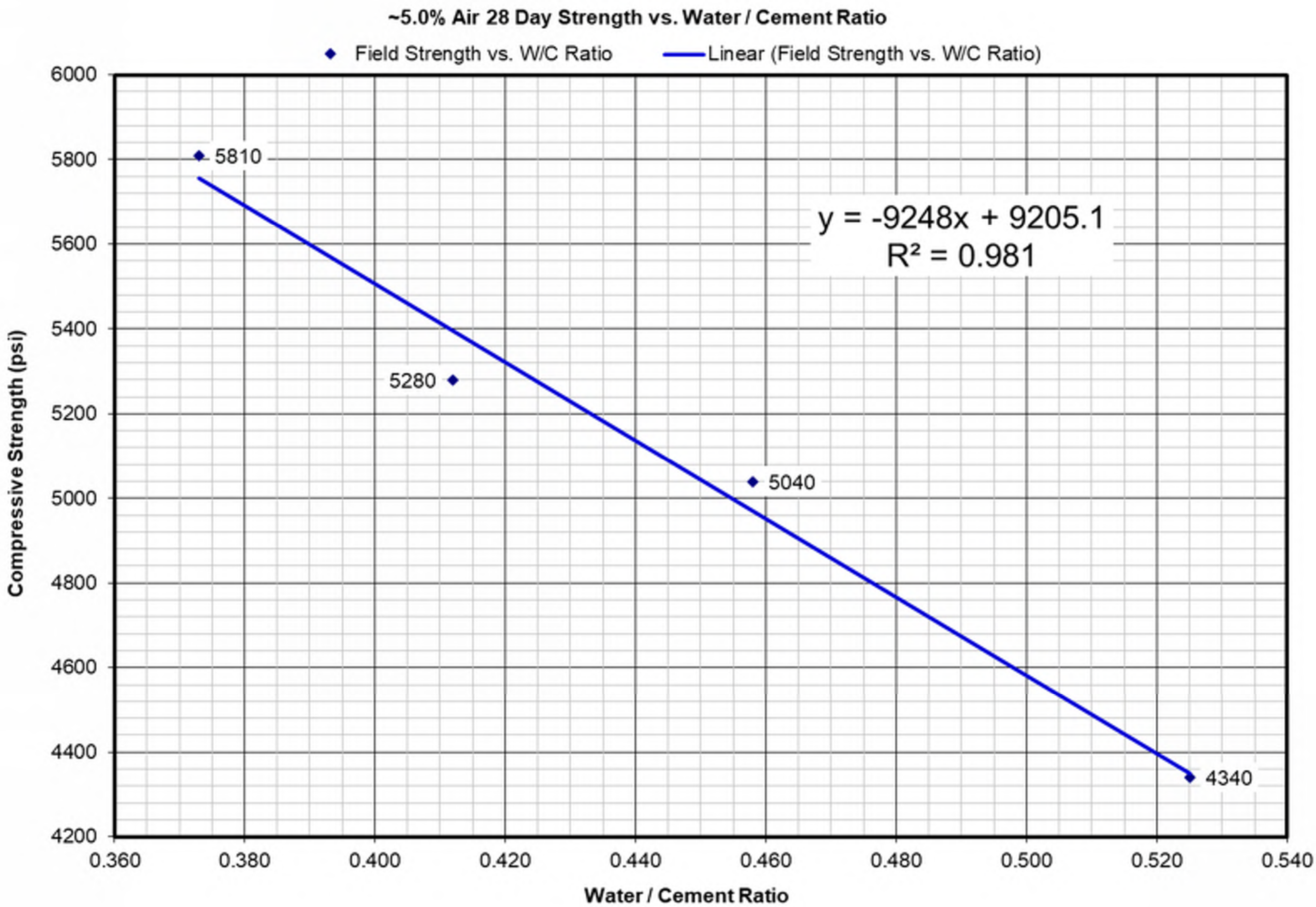
For 5000 psi No Air concrete final proportions: Maximum w/c = 0.49

One trial batch done, ? More to go

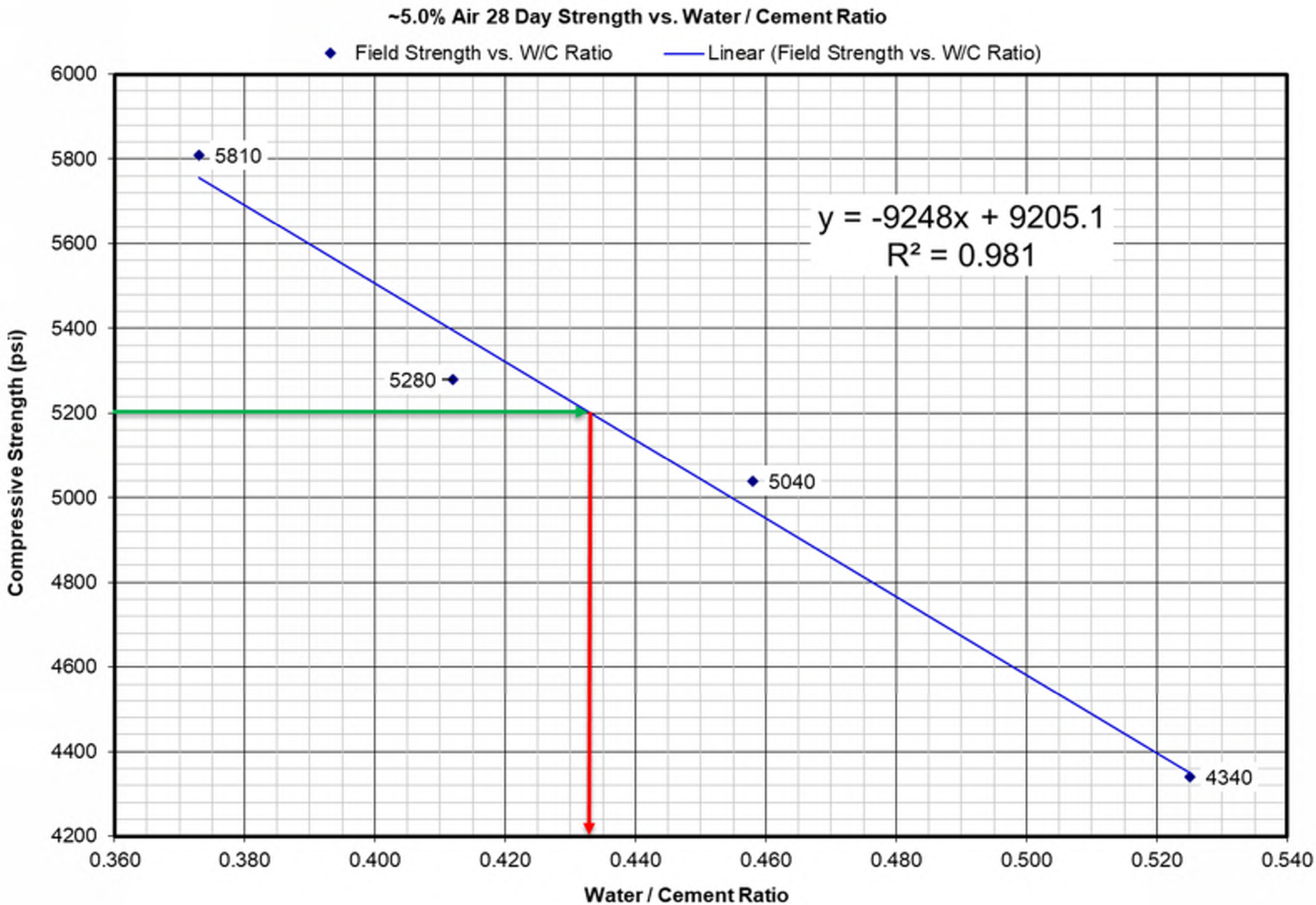
- Four ~5% Air batches were needed to define the % Air to Compressive strength relationship through the range of cement contents and w/c ratios:

Sack	w/c	Press.% Air	Compressive Strength
6.0sk	0.532	4.5	4340psi
6.5sk	0.467	4.8	5040psi
7.0sk	0.411	4.5	5280psi
7.5sk	0.362	3.5	5810psi

Graph 2a ~5.0% Air 28 Day psi vs. w/c



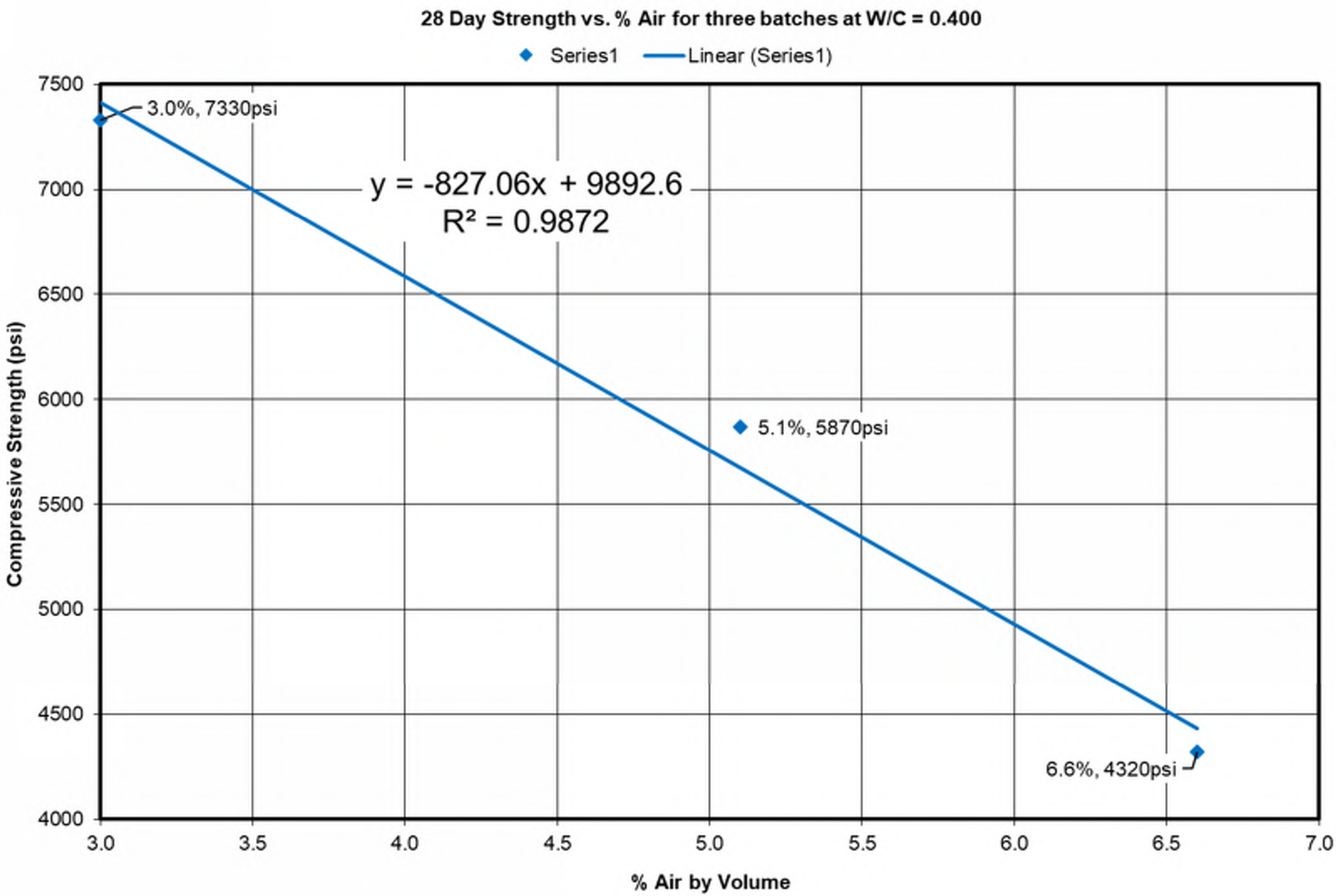
Graph 2b ~5.0% Air 28 Day psi vs. w/c



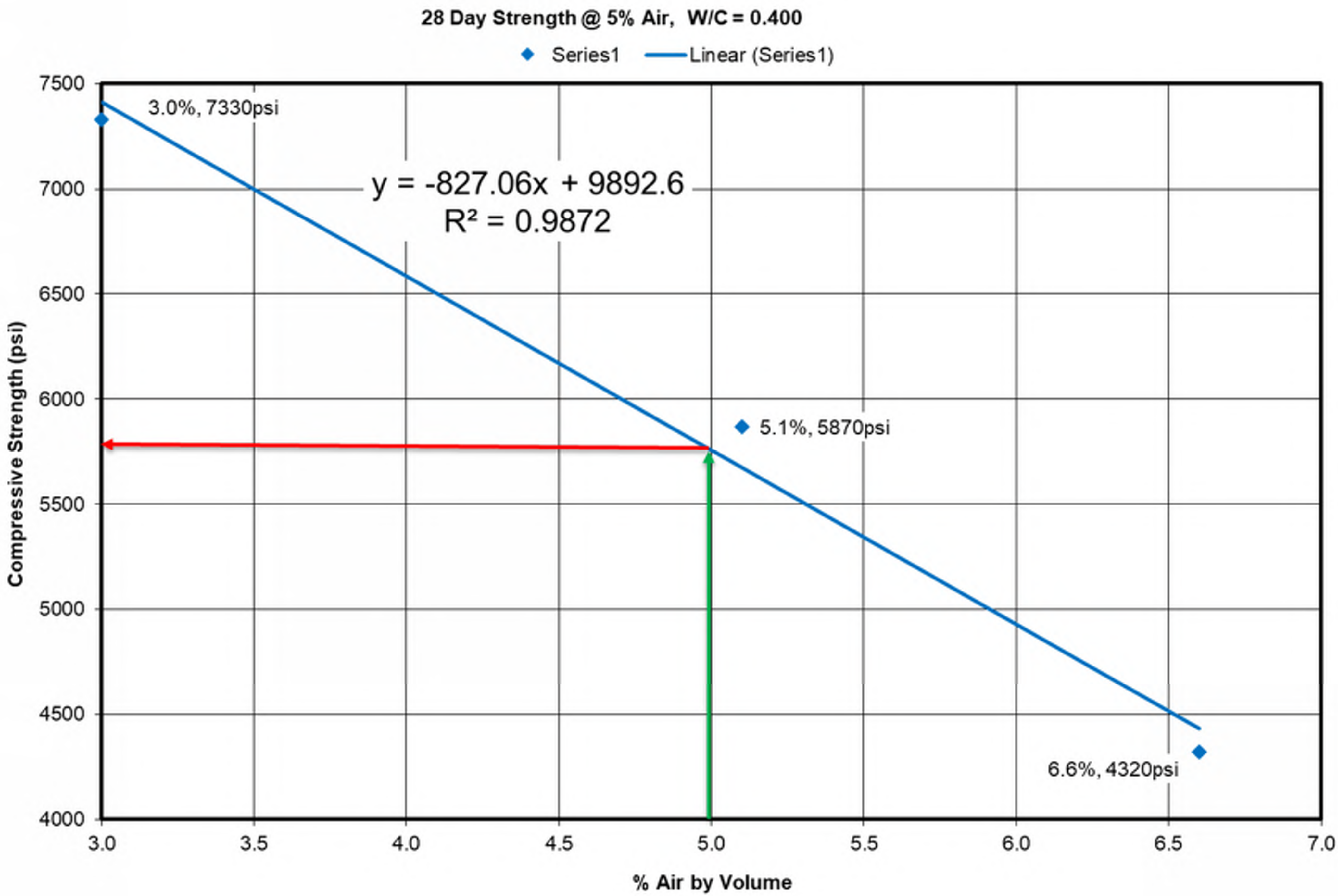
Getting close to our goal

- Make three batches at 0.400 w/c ratio at low, optimum and high air contents to define the variation of strength throughout the 5.0±1.5% Air range.

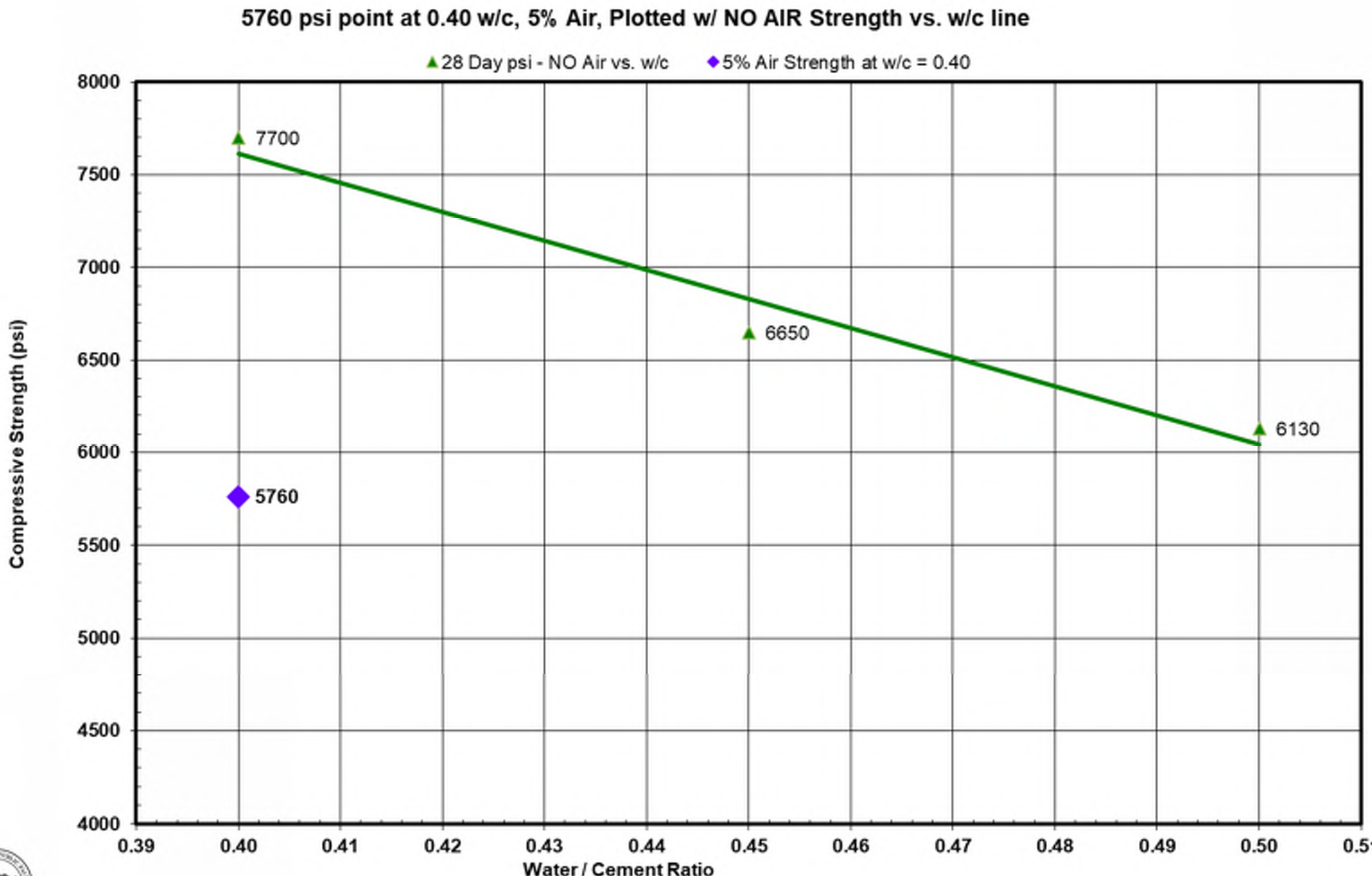
Graph 3a, 28-Day psi vs. % Air



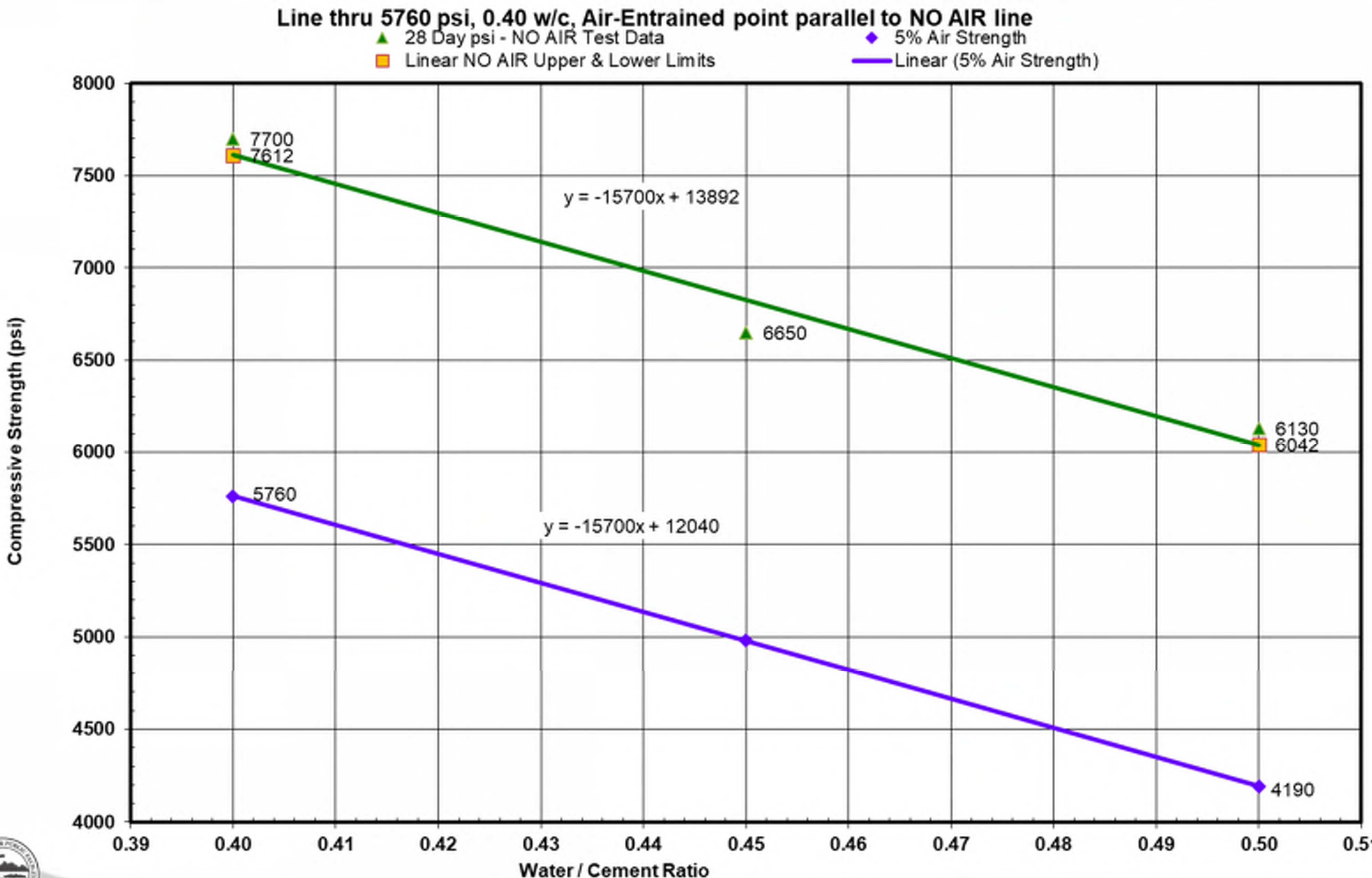
Graph 3b, psi at 5.0% Air



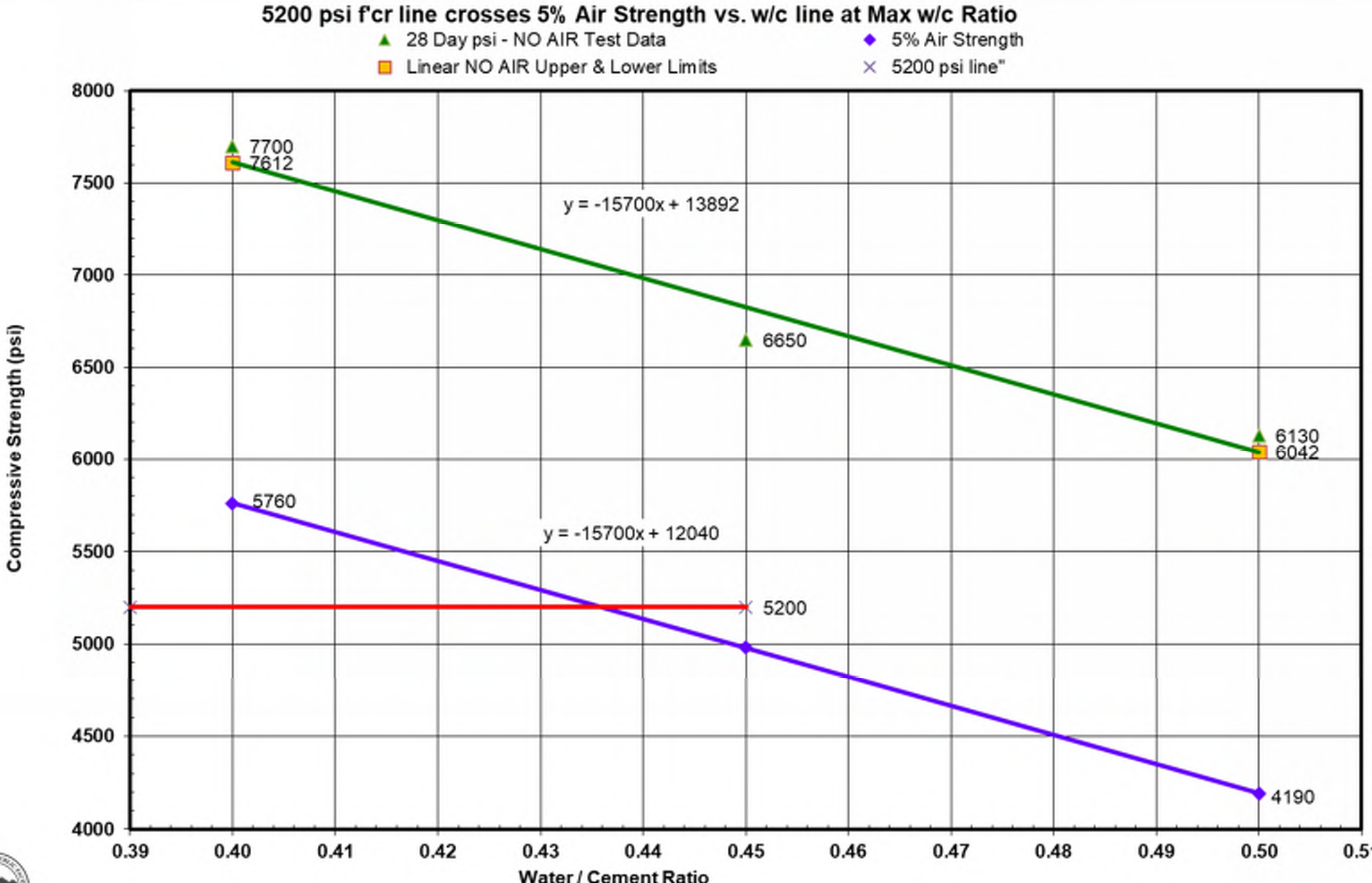
Graph 4a, 5760 psi point at 0.40 w/c, 5% Air, and NO AIR Strength vs. w/c line



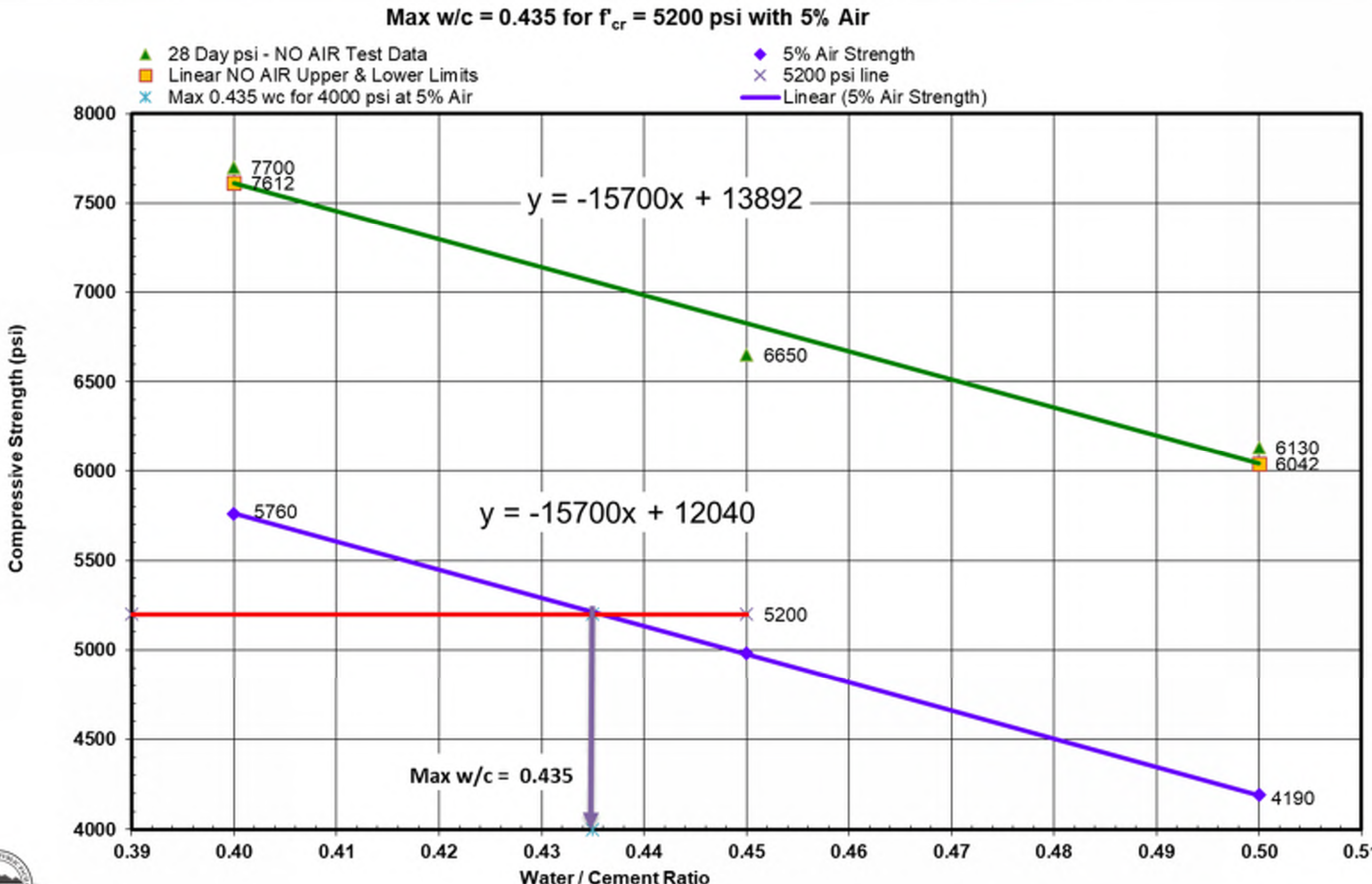
Graph 4b, Draw line thru 5760 psi point parallel to NO AIR line



Graph 4c, Draw 5200 psi f'cr line to intercept 5% Air Strength vs wc



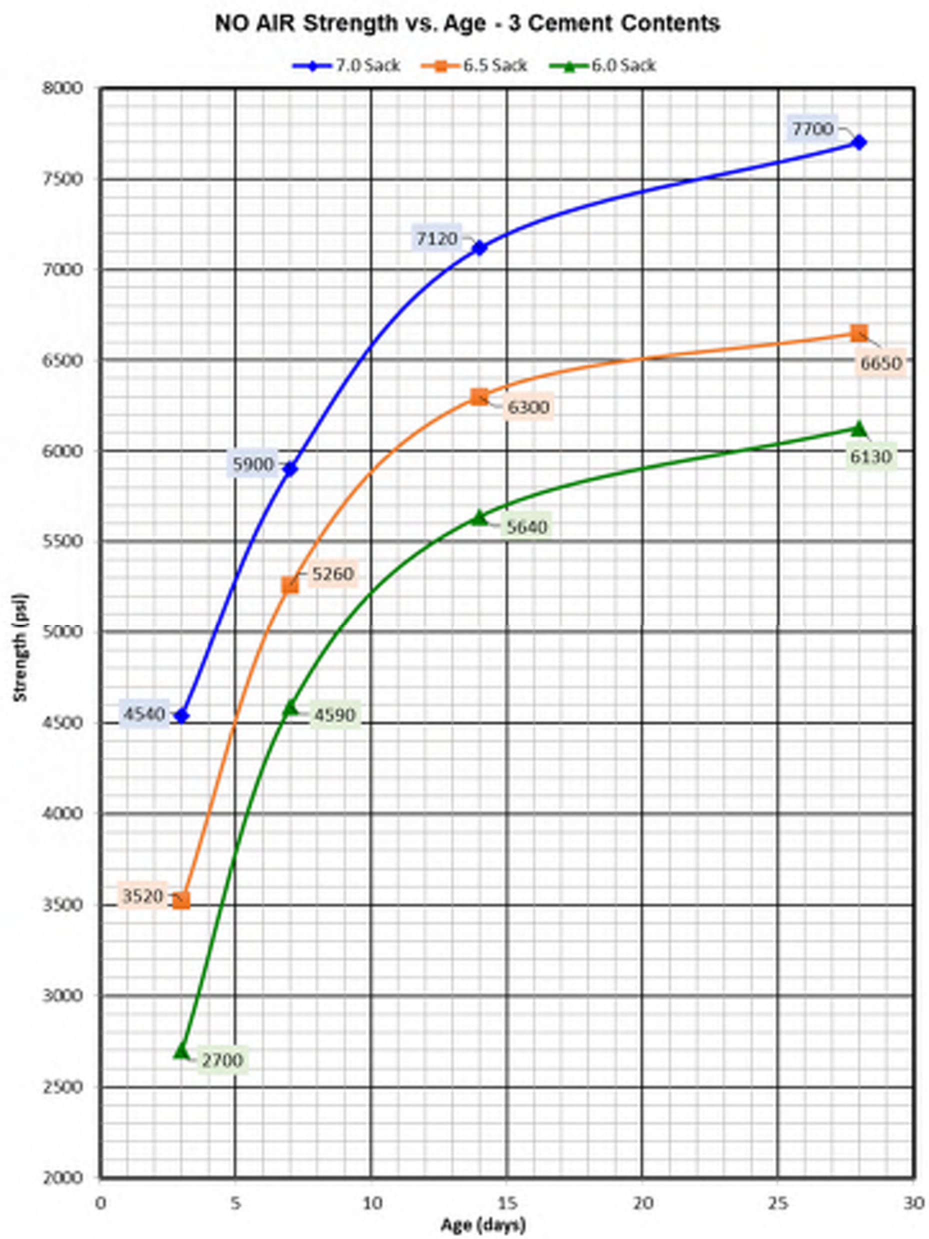
Graph 4d, Max w/c Ratio = 0.435 for f'cr = 5200 psi w 5% Air



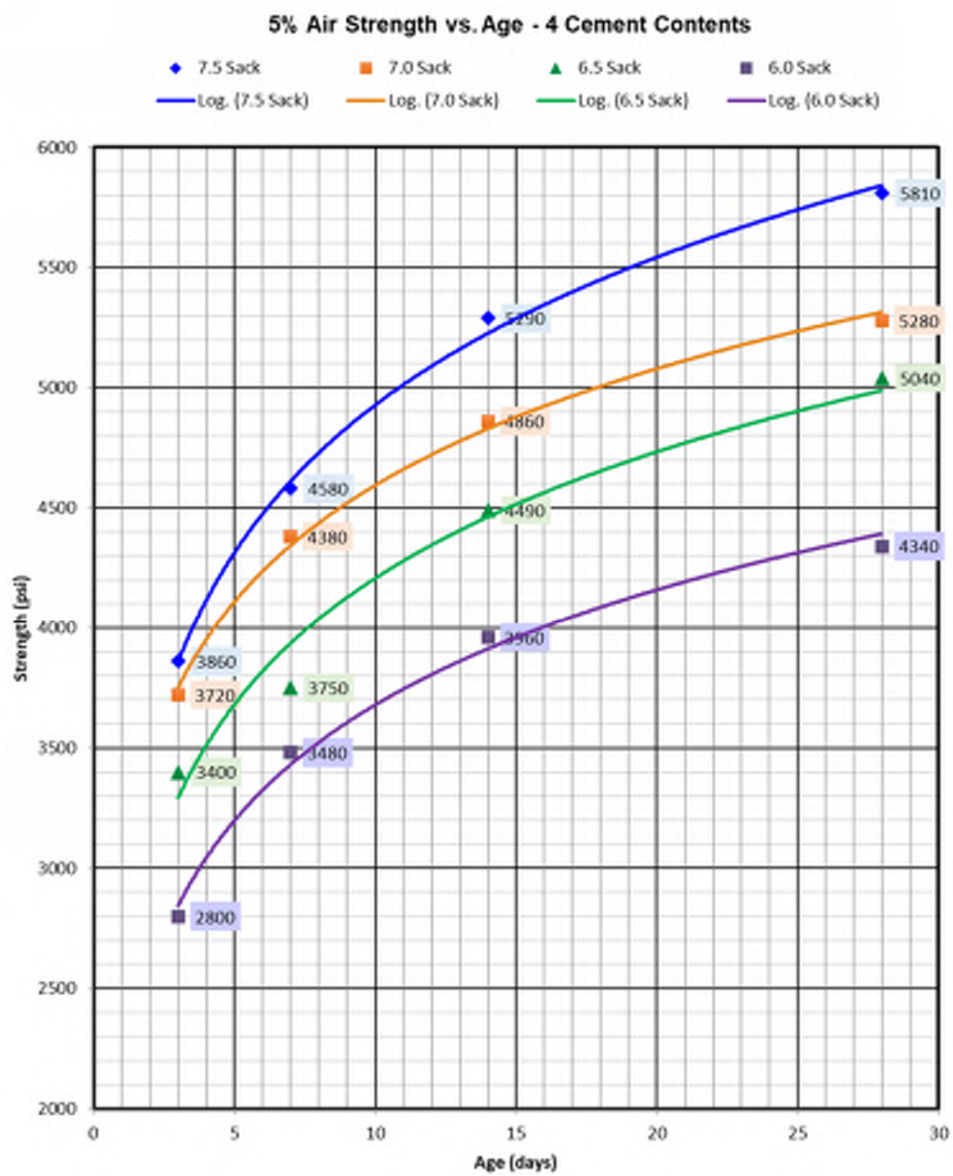
Batching Summary

- We made a total of 10 trial batches.
- The following graphs summarize the essential data from trial batches.

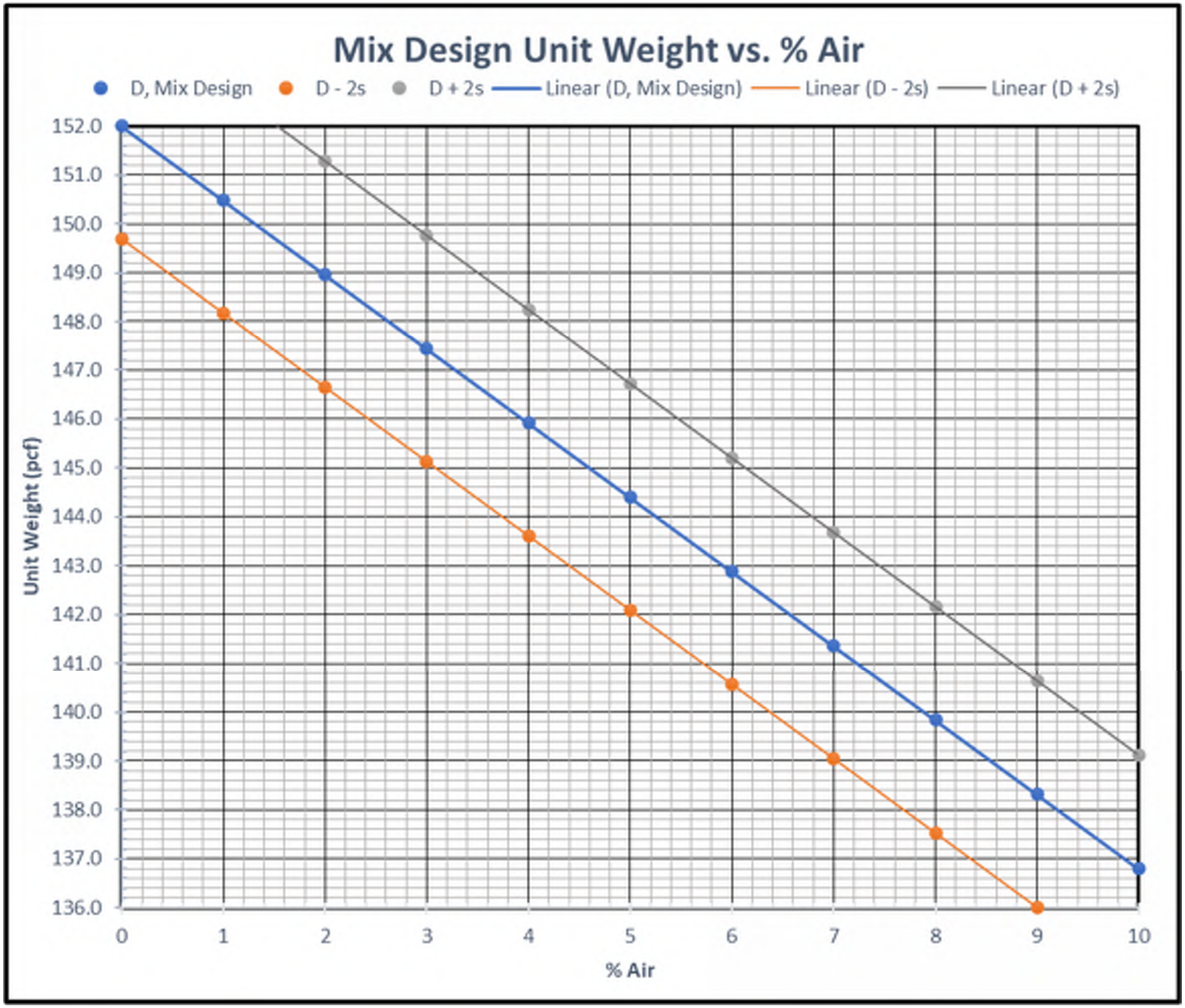
Graph 5, NO AIR Strength vs. Age for 3 Cement Contents



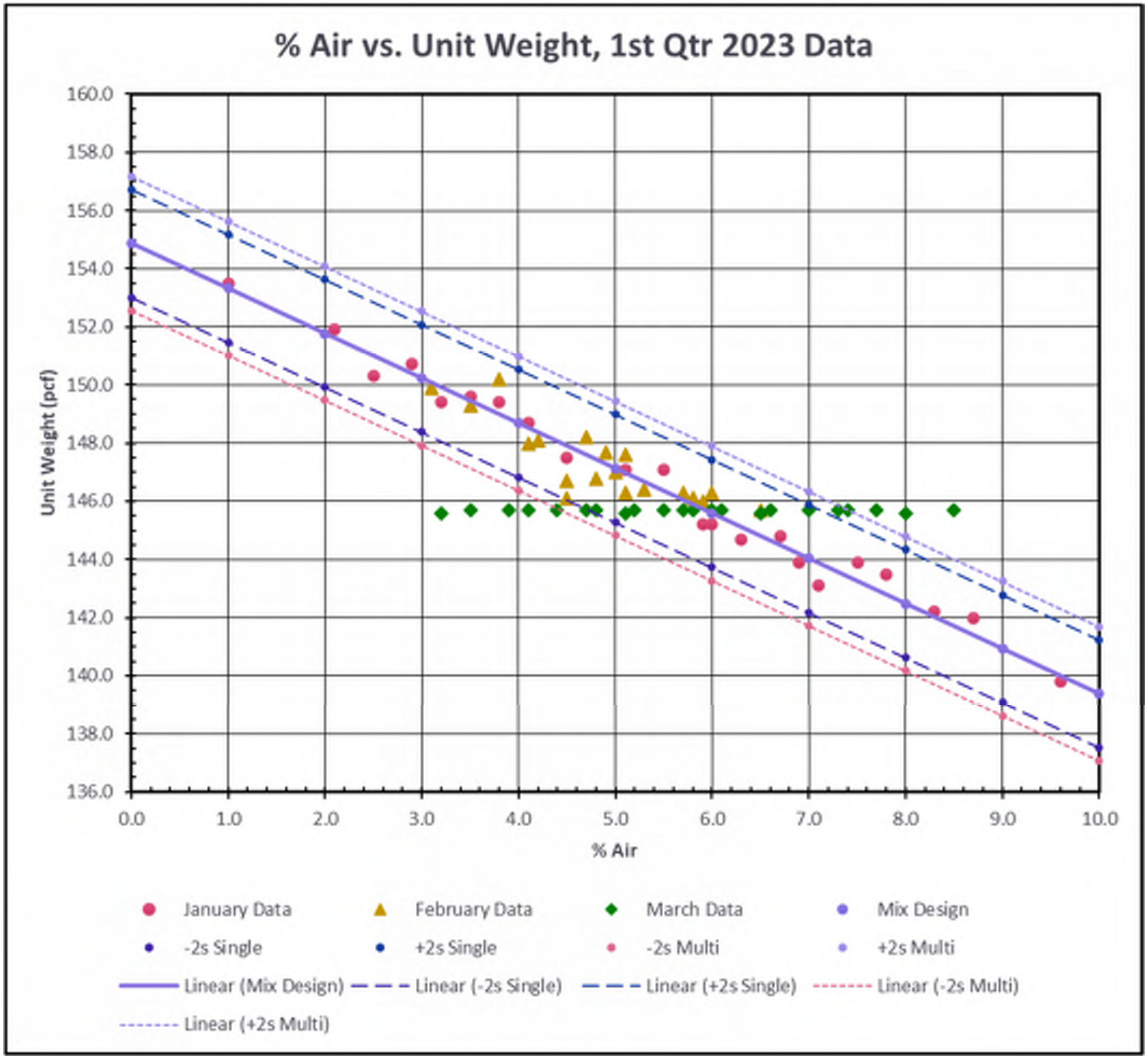
Graph 6, 5% Air Strength vs. Age for 4 Cement Contents



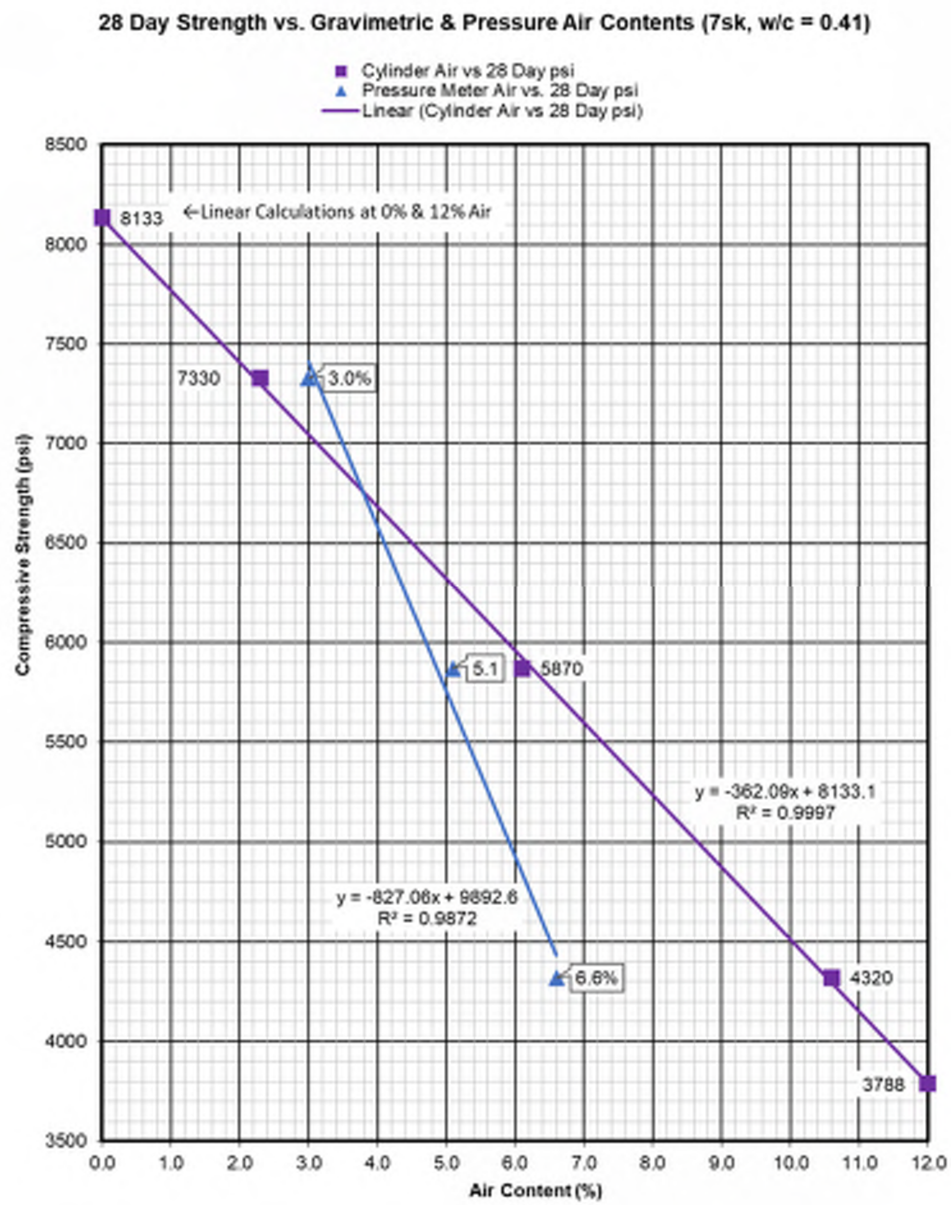
Graph 7, Mix Design Unit Weight vs % Air w 2s Limits



Example, Unit Weight vs % Air



Graph 8, 28 Day Strength vs. Gravimetric & Pressure Air Contents



Why Measure Unit Weight and %Air?

MasterAir AE 200

Air Content Determination: The total air content of normal weight concrete should be measured in strict accordance with ASTM C 231, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method” or ASTM C 173/C173M, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.”

The air content of lightweight concrete should only be determined using the Volumetric Method. The air content should be verified by calculating the gravimetric air content in accordance with ASTM C 138/C 138M, “Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.” If the total air content, as measured by the Pressure Method or Volumetric Method and as verified by the Gravimetric Method, deviates by more than 1.5%, the cause should be determined and corrected through equipment calibration or by whatever process is deemed necessary.

In a trial mixture, use 0.125 to 1.5 fl oz/cwt (8-98 mL/100 kg) of cement.

Using Graphs for acceptance/rejection decisions

Graphs of w/c vs. compressive strength and entrained-air vs. compressive strength provide design and construction personnel with valuable strength information for acceptance/rejection decisions should concrete arrive at the job site that is outside w/c or entrained-air limits.

A theoretical percent air vs. unit weight graph provides a good check of pressure type air meter readings.

12. Final mix Design Report

Include the following:

1. Project identification, Source/Supplier of mix and name of the general contractor when mix design is specific for a single project.
2. Aggregate source(s), quality identification(s), target gradation of each aggregate, blend ratio of individual stockpiles, individual aggregate absorption values, apparent, bulk SSD, and bulk specific gravities. For blended Aggregate sources, screen and test Coarse and Fine Fractions. Other properties that may be specified such as; Unit Weight of dry-rodded coarse aggregate, fineness modulus of the blended fine aggregate, percent flat and elongated; sodium sulfate soundness of coarse and fine aggregate fractions, or aggregate-silica reactivity (ASR).
3. Gradation for each aggregate stockpile with graphical representation on Tarantula Curve of the combined aggregate gradation. AASHTO M 6 and M 43gradations for ACI 211.1 mixes. Include Lower Specification Limit (LSL) and Upper Specification Limit (USL) data with both combined and ACI gradations.

12. Final mix Design Report (2)

Include the following:

4. An orderly presentation of all trial batch data including; type(s) and source certificate with chemical oxide analysis for all cementitious materials, trial batch proportions, complete test cylinder data with unit weight of all cylinders determined immediately after initial curing period and removal from molds, surface resistivity (when required) of test cylinders, with nominal cylinder size indicated, just before compressive testing, compressive strength and average compressive strength at each age.
   - Include graphs of Compressive strength vs. w/c Ratio and Compressive strength vs. Air content (for air-entrained mixes). Plot trial batch data points on graph(s) along with best-fit linear trend line. For trial batch nearest to selected mix design proportions plot Strength vs. Age points and the best-fit smoothed curve through the data points.
   - Plot the wet unit weight (D) versus air contents of 0% to 10% from the theoretical unit weight (T) using ASTM C138, Sec 7.6, Equation (7), $A = [(T - D)/T] \times 100$, Where: A = % Air, D = Wet Unit Weight, and T = Theoretical Maximum Unit Weight.
5. Identification and address of the laboratory that performed the mix design, mix design identification number, and the signed seal of the professional engineer who reviewed and approved the mix design.

State of Alaska
Department of Transportation
& Public Facilities

Supplier Submitted Concrete Proportions (Form 25D-203)

Note: Adjust this form as needed to meet project and mixture requirements.

Project No **Example** Project Name: **Example**

Supplier: **XYZ** Plant Location: **Anytown** Mix ID No. **123**

Aggregate Materials Source(s): **Big Pit** Cement Brand/Type: Type I/II

Note: Shaded areas automatically compute values.

Class **A** Concrete **Minimum Compressive Strength (psi):** 4000

Specifications: **Use: Precast Products** **Cement Content (sacks/cy):** 6.75

-Sieve Analysis -

AASHTO Gr.#	67	
Coarse Aggregate		
Sieve	% Pass	Specs
1 1/2"	100	
1"	100	100
3/4"	95	90-100
1/2"	74	
3/8"	55	20-55
#4	10	0-10
#8	5	0-5
#200	1	

SSD Specific Gravity 2.674
Absorption %: 1.38
Dry-Rodded Unit Wt: 102

AASHTO Gr.#	8	
Intermediate Aggregate		
Sieve	% Pass	Specs
1"		100
3/4"		100
1/2"		100
3/8"		85-100
#4		10-30
#8		0-10
#200		

SSD Specific Gravity:
Absorption %:
Dry-Rodded Unit Wt:

AASHTO Gr.#	M6	
Fine Aggregate		
Sieve	% Pass	Specs
3/8"		100
#4	100	95-100
#8	84	80-100
#16	60	50-85
#30	38	25-60
#50	18	10-30
#100	6	2-10
#200	2.8	0-3

SSD Specific Gravity: 2.675
Absorption %: 1.23
Fineness Modulus: 2.94

		Batch Weights - Pounds or Ounces Per		Batch Volumes	
Component	Sack weights no longer used	**Cubic Yard**		Ft^3 per Cubic Yard	
Cement	"	635.0		3.231	
Mixing Water	"	305.0		4.888	
Coarse Aggregate	"	1680.0	SSD	10.068	
Inter. Aggregate	"	0.0	SSD	0	
Fine Aggregate	"	1200.0	SSD	7.189	**Admixture SpG**
AE 200	"	4.00	fl oz	0.004	1.010
MasterGlenium 1466	"	12.00	fl oz	0.013	1.109
	"	0.00	fl oz	0.000	1.000
	"	0.00	fl oz	0.000	1.399
Air %: 6.0	"			1.620	Theoretical Max SpG
Totals:	"	3821.1	lbs.	27.013	150.48

Compressive Strength

Spec. No.	Size	Age	PSI

		Specifications
Probable 28-day Strength (psi):	5200	4000
Slump or Slump Flow (in):	4	4
Air content (%):	5.7	4.5-7.5
Water/Cement Ratio (lb / lb):	0.48	0.33 Max
Wet Density (pcf):	141.5	
Nom. Max. aggregate size:	0.75"	
Volume of coarse aggregate per unit volume of concrete (cf/cf):	0.37	
Chloride Ion Content (%)		
SAM Number for Class P		≤0.25

Submitted By: ____________________ Date: ________
(Supplier's Representative) Name/Title

Approved By: ____________________ Date: ________
Materials Engineer or Quality Assurance Engineer

State of Alaska
Department of Transportation
& Public Facilities

Supplier Submitted Concrete Proportions (Form 25D-203)

Admixture, Required Attachment Checklist, Remarks and Engineer Seal

Supplier: XYZ **Project:** Example

Admixture	Mfg. Recommended	Mix Design dosage range

Required for:	Attachments	Check box if attached	Check box if the material is not used in this mix design
501	NRMCA plant and delivery system certification		
501, 550	Mix Design computations per Contract requirements		
501	Chloride ion content testing report per AASHTO T 260		
501, 550	Plant manager's certification of weighing and measuring devices		
501, 550	Cementitious materials certifications per AASHTO M 85		
501, 550	Mixing water and ice test results or certifications per Subsection 712-2.01		
501, 550	Coarse aggregate quality test results per Subsection 703-2.02		
501, 550	Coarse aggregate gradtion test results per Subsection 703-2.02 or ATM 530		
501, 550	Fine aggregate quality test results per Subsection 703-2.01		
501, 550	Fine aggregate gradation test results per Subsection 703-2.01 or ATM 530		
501, 550	Other aggregate quality test results per Subsection 703-2.01 or 703-2.02		
501, 550	Other agg. gradation test results per Subsection 703-2.01 or 703-2.02 or ATM 530		
501, 550	Chemical admixture certifications per Subsection 711-2.02		
501, 550	Admixture manufacturer's certification of compatibility for adding simultaneously*		
501, 550	Compressive strength test data		
501, 550	Test data of mixture temperature, slump, unit weight and air content		
501, 550	Graph of theoretical unit weight vs. % air (for air-entrained concrete)		
501, 550	Graph of compressive strength vs. % air (for air-entrained concrete)		

* Either manufacturer's letter or as shown in admixture certifications of compatibility

Supplier Remarks: ______________________

AK P.E. Stamp (501)

Approving Engineer's Remarks: ______________________

Form 25D_203 Required Attachments

Required for:	Attachments	Check box if attached	Check box if the material is not used in this mix design
501	NRMCA plant and delivery system certification		
501, 550	Mix Design computations per Contract requirements		
501	Chloride ion content testing report per AASHTO T 260		
501, 550	Plant manager's certification of weighing and measuring devices		
501, 550	Cementitious materials certifications per AASHTO M 85		
501, 550	Mixing water and ice test results or certifications per Subsection 712-2.01		
501, 550	Coarse aggregate quality test results per Subsection 703-2.02		
501, 550	Coarse aggregate gradtion test results per Subsection 703-2.02 or ATM 530		
501, 550	Fine aggregate quality test results per Subsection 703-2.01		
501, 550	Fine aggregate gradation test results per Subsection 703-2.01 or ATM 530		
501, 550	Other aggregate quality test results per Subsection 703-2.01 or 703-2.02		
501, 550	Other agg. gradation test results per Subsection 703-2.01 or 703-2.02 or ATM 530		
501, 550	Chemical admixture certifications per Subsection 711-2.02		
501, 550	Admixture manufacturer's certification of compatibility for adding simultaneously*		
501, 550	Compressive strength test data		
501, 550	Test data of mixture temperature, slump, unit weight and air content		
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501, 550	Graph of compressive strength vs. % air (for air-entrained concrete)		

* Either manufacturer's letter or as shown in admixture certifications of compatibility

Memorial: Victims of Stalin Repression

Questions?

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