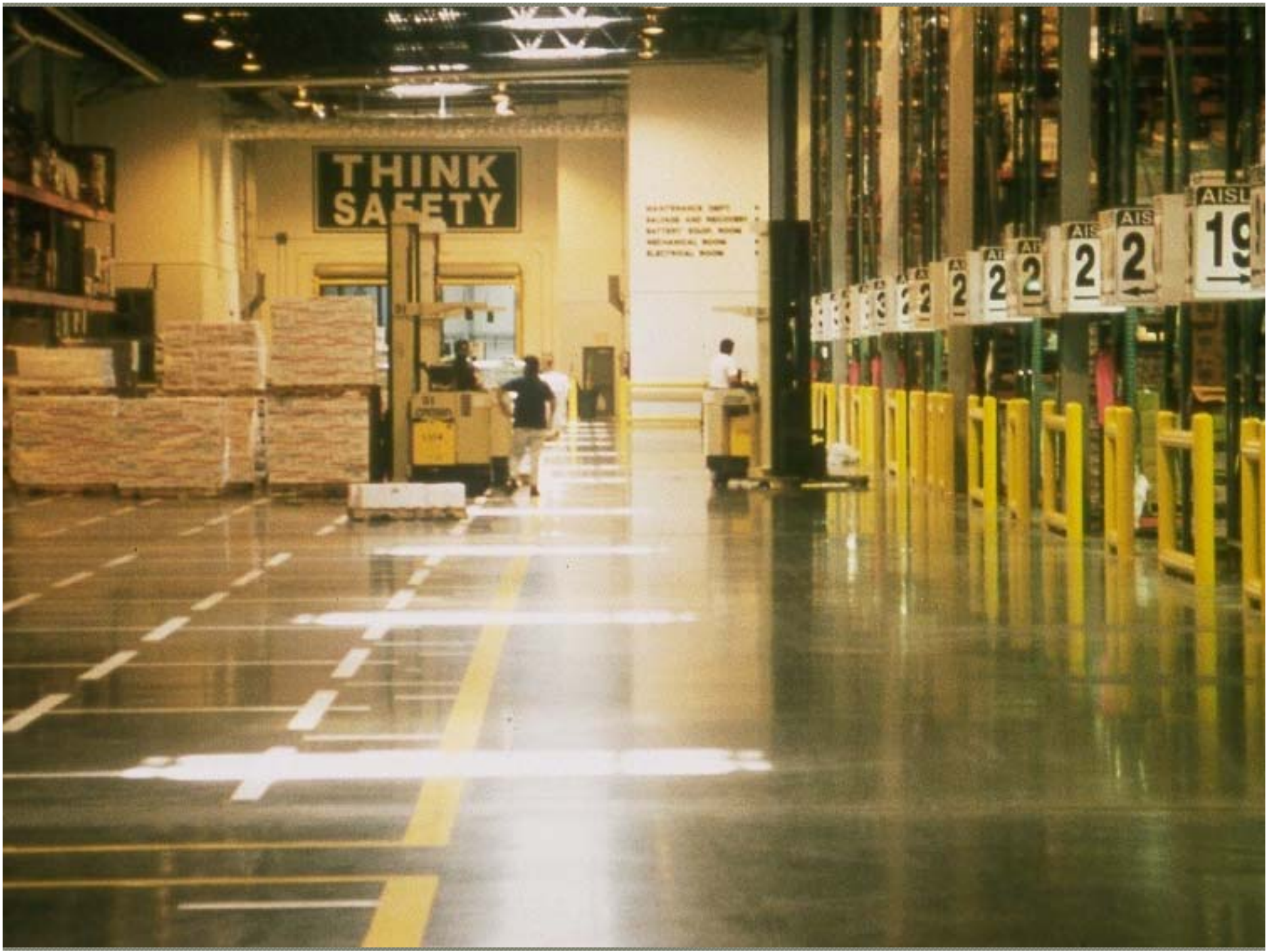
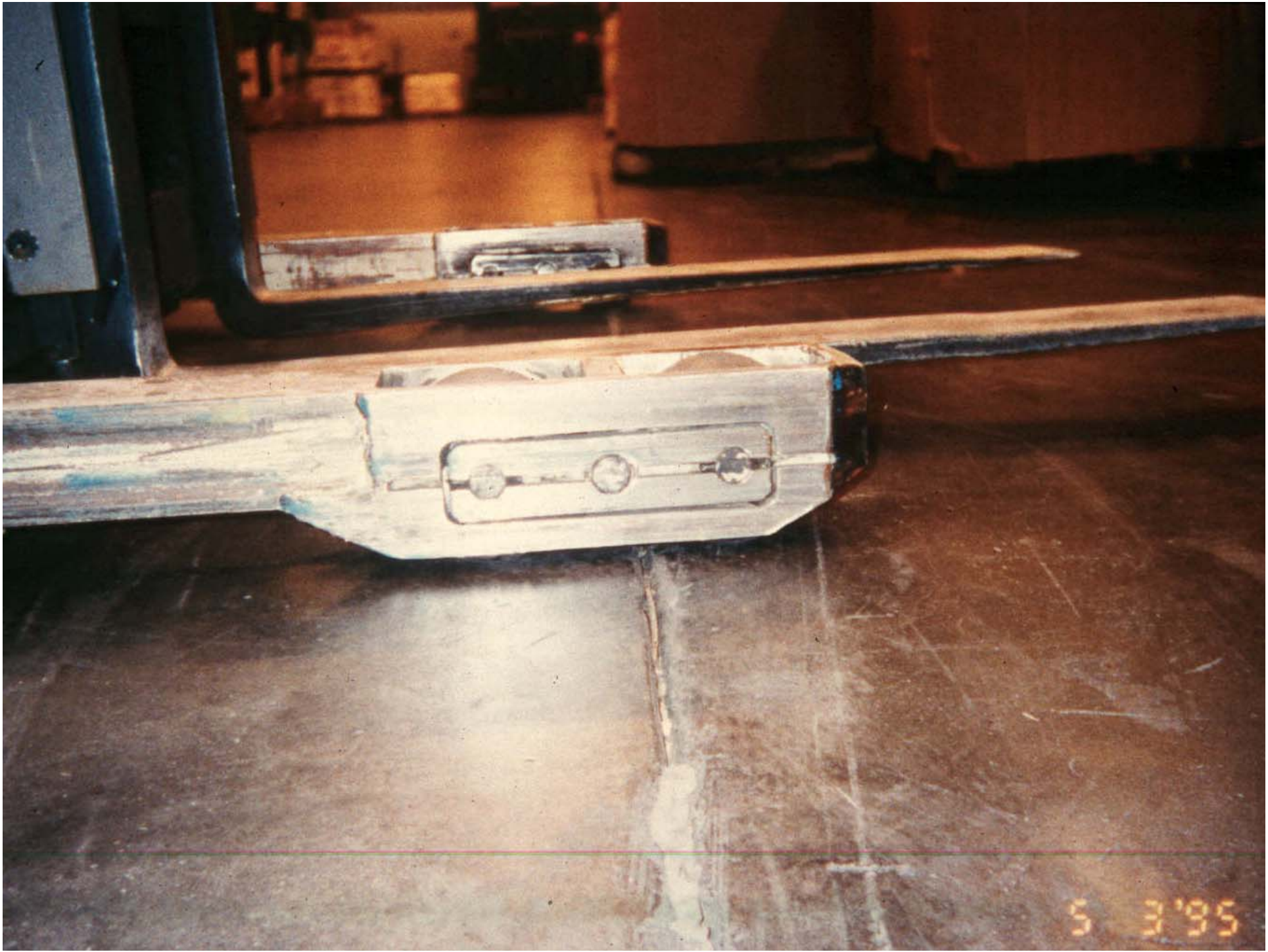
Concrete Slab Mix Proportioning

Beyond Water-Cement Ratio and Strength

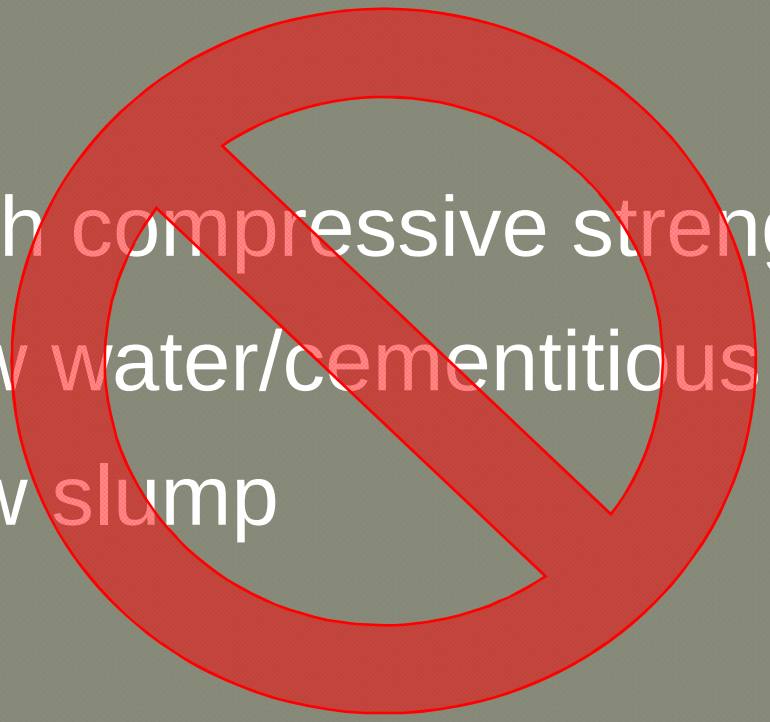
Patrick Harrison
Vice President
Structural Services, Inc.


THINK
SAFETY
AISL
19

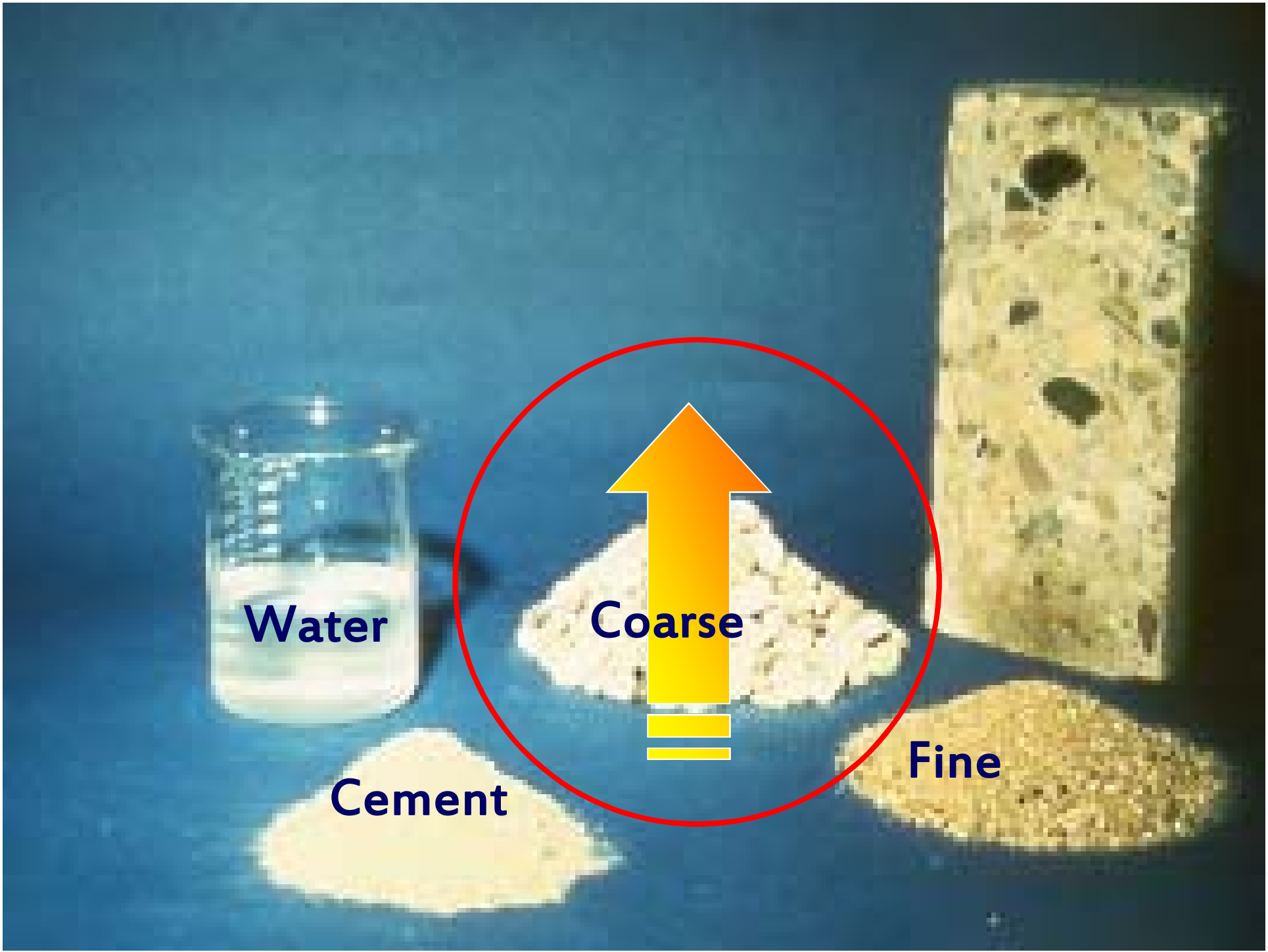

5 3'95


Low Prices

Define Quality Concrete



- High compressive strengths
- Low water/cementitious ratios
- Low slump


Water
Coarse
Cement
Fine

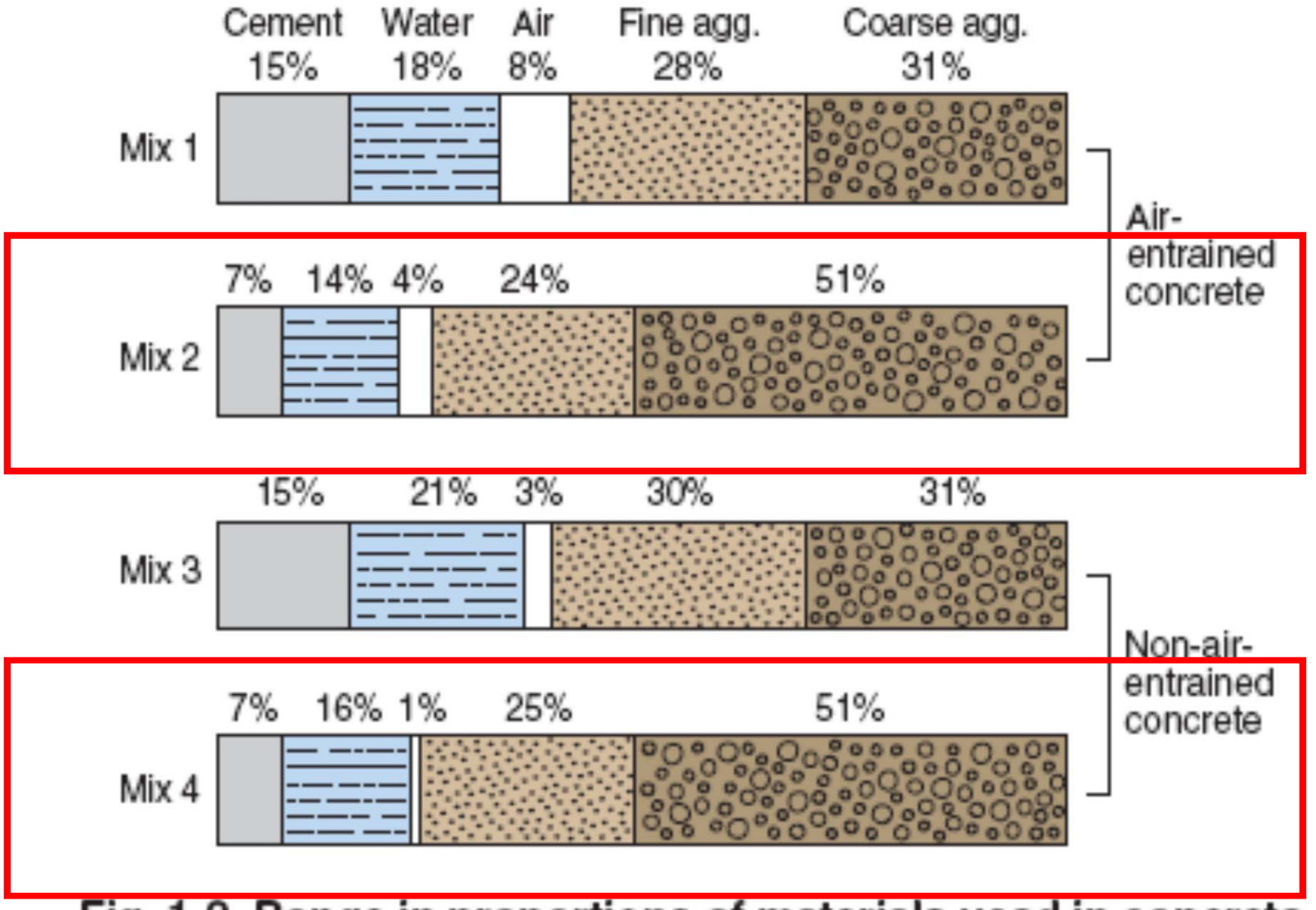


Fig. 1-2. Range in proportions of materials used in concrete, by absolute volume. Bars 1 and 3 represent rich mixes with small size aggregates. Bars 2 and 4 represent lean mixes with large size aggregates.

ACI 302-2004 (Section 6.2.2)

"Concrete for floors should have other desirable characteristics in addition to strength. There should be sufficient mortar content to allow the finisher to completely "close" the surface and to achieve the required surface tolerances, hardness, and durability."

ACI 302.1R-04

Table 6.1—Recommended strength and maximum slump at placement for concrete floors

Floor class*	Specified compressive strength f'_c on 28-day tests, psi (MPa)	Maximum slump at placement†, in. (mm)
1, 2, and 3	3000 (21)	5 (125)
4, 5, and 6	3500 (24)	5 (125)
7 base	3500 (24)	5 (125)
7 bonded topping‡	5000 (35)	3 (75)
8 unbonded topping§	4000 (28)	3 (75)
9 superflat	4000 (28)	5 (125)

*Refer to Table 2.1 for floor class definitions.

†Maximum slump is assumed to be achieved using a Type A water-reducing admixture.

‡The strength specified will depend on the severity of usage.

§Maximum aggregate size not greater than 1/4 the thickness of unbonded topping.

Cement Types (ASTM C 150)

- Type I – normal
- Type II – moderate sulfate resistance
- ~~Type III – high early strength~~
- ~~Type IV – low heat of hydration~~
- Type V – high sulfate resistance
- Type K – expansive cement (SCC)

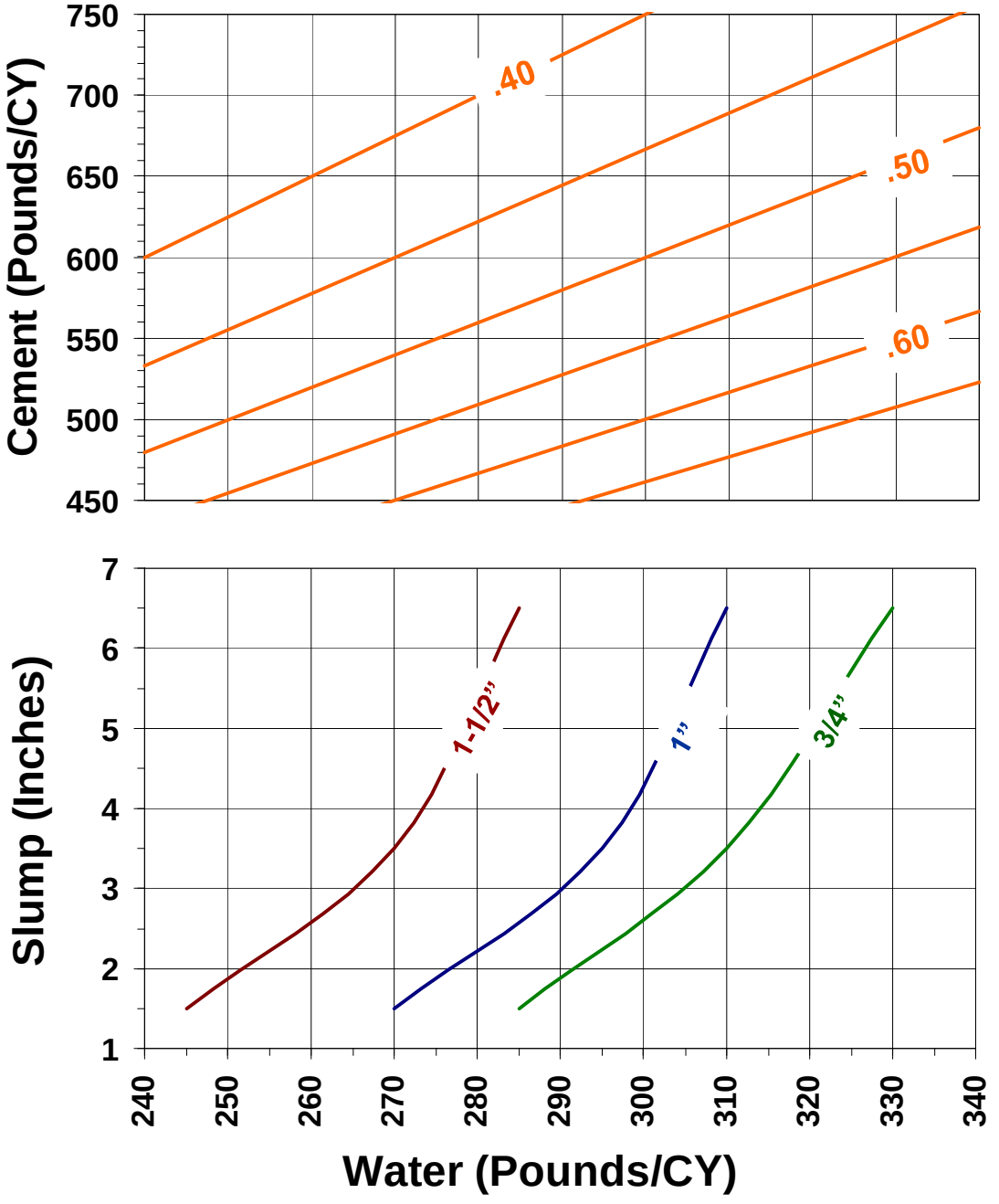
ACI 302.1R-04 (Section 6.1)

". . . For steel-trowelled, slab-on-ground concrete, a minimum amount of water is required to produce a workable, finishable mixture with predictable, uniform setting characteristics. Currently available water-reducing admixtures perform best when they are mixed with concrete that has enough water to produce a slump of 2" to 3" if no admixture was added."

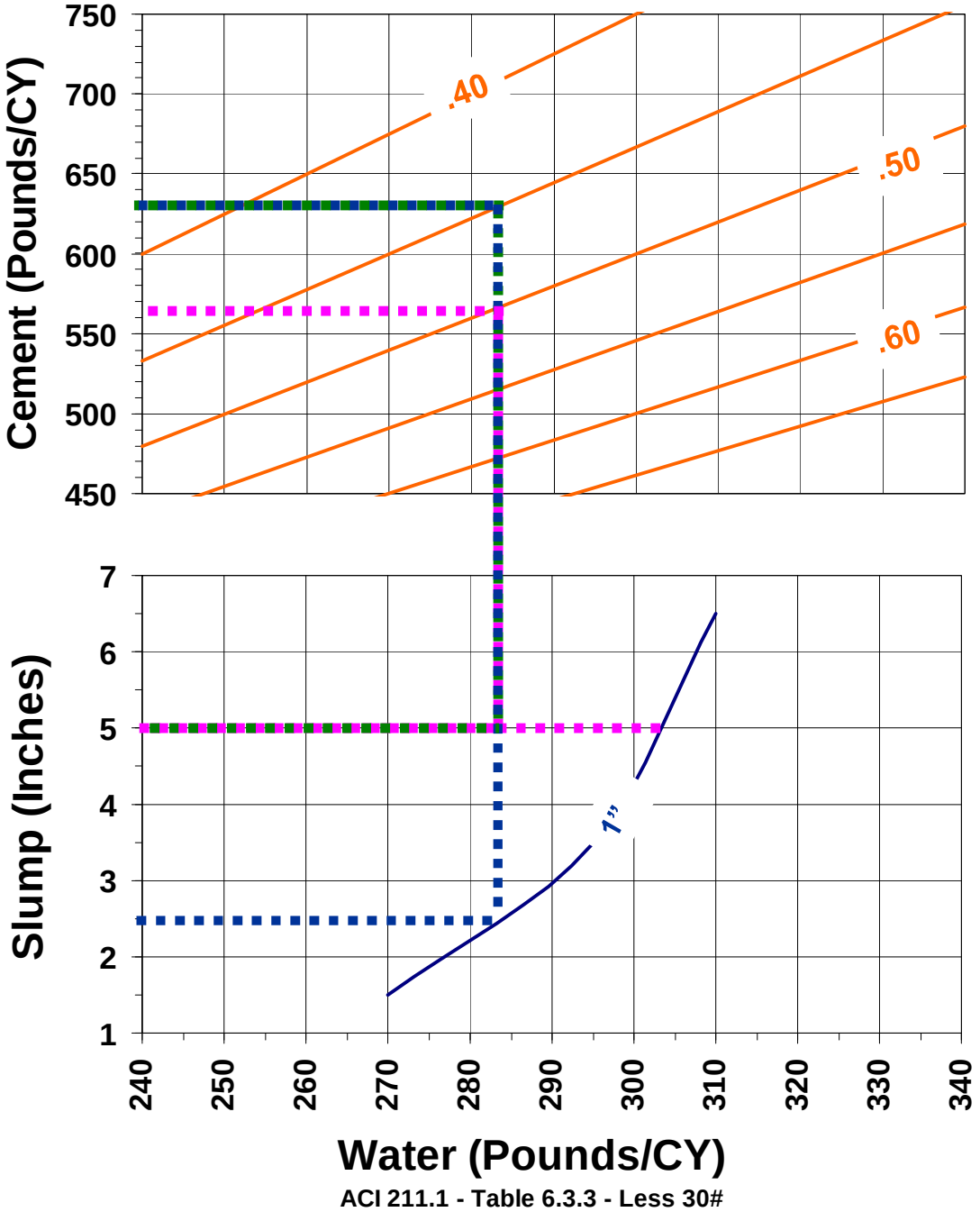
ACI 302-2004 (Section 6.2.4)

The amount of water needed to produce a workable mixture is generally determined by the characteristics of the combined aggregate materials used in the mixture and is not effectively controlled by specifying w/cm. If w/cm is specified, w/cm in the range of 0.47 to 0.55 are common for most interior floors of Classes 4 to 9.


DON'T GET MIXED UP WITH



ACI 211.1 - Table 6.3.3 - Less 30#



4-5” Final Slump
Type A WR
284# Water
564# Cement
0.50 w/c Ratio

4-5” Final Slump
Type A WR
284# Water
0.45 w/c Ratio
631# Cement

2-3” Water Slump
6-7” Final Slump
284# Water
Type F HRWR 0.45 w/c Ratio 631# Cement

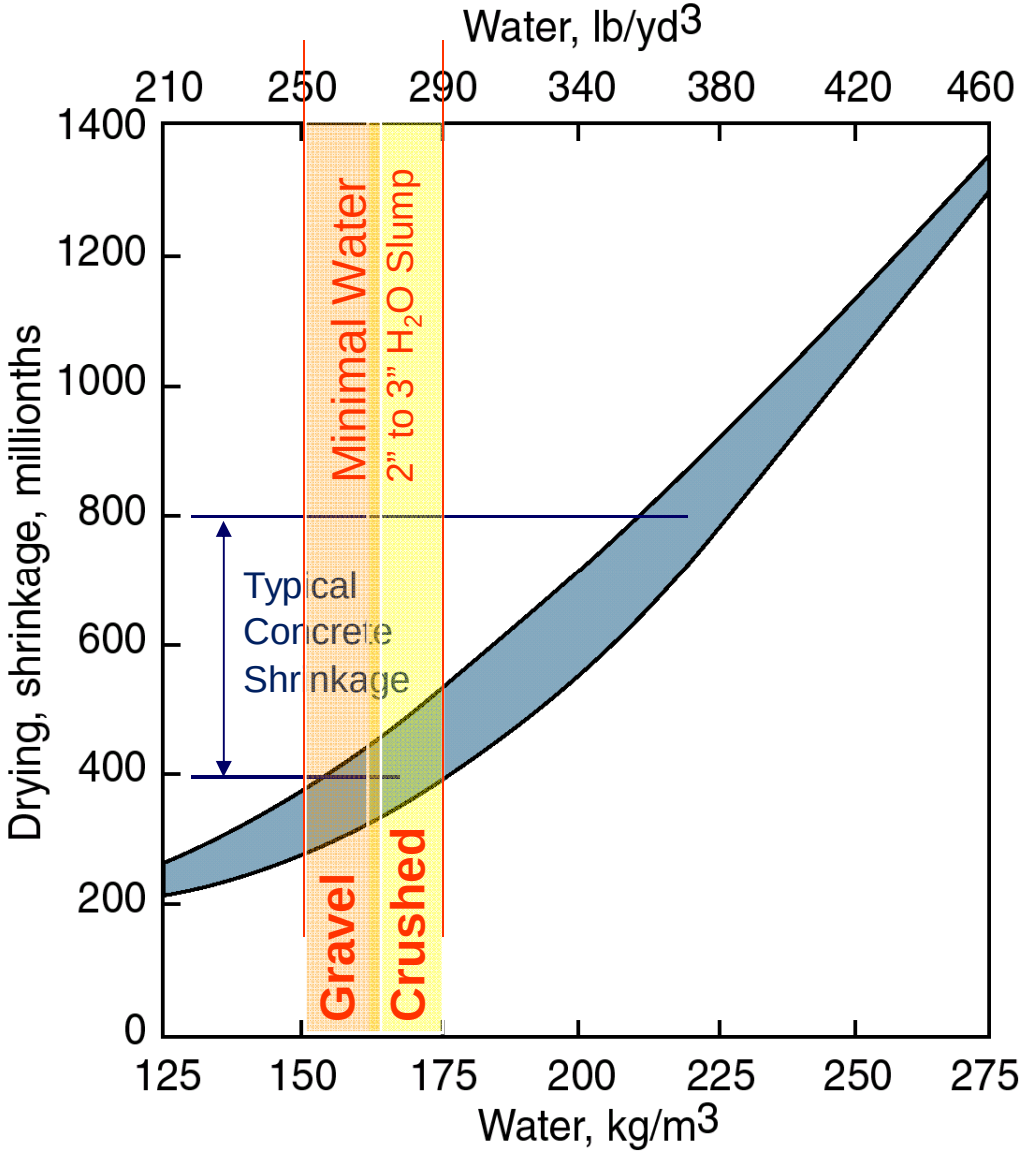
When low w/cm ratios needed

- Freeze-thaw exposure (≤ 0.50)
- Deicing chemical exposure (≤ 0.45)
- High sulfate exposure (0.45 to 0.40)
- Aggressive materials exposure (≤ 0.40)
  - Brackish water
  - Seawater
- Water of convenience (0.40 to 0.50)
  - Dissipation can causes adhesive failure

Table 1. Drying Time, in Days, at 73°F and 50% Relative Humidity For a 4-Inch-Thick Specimen to Reach 3 lbs/1,000 sq ft/24 hrs

Water-Cement Ratio	Bottom Sealed	Bottom Exposed To Water Vapor	Bottom In Contact With Water
0.4	46	52	54
0.5	82	144	199
0.6	117	365	>> 365
0.7	130	>> 365	>> 365
0.8	148	>> 365	>> 365
0.9	166	>> 365	>> 365
1.0	190	>> 365	>> 365

Shrinkage & Water Content



Normal Concrete

400 to 800 millionths

(0.000400 inch per inch)

Crushed Aggregate
275 to 290 lbs/cy
(33 to 35 gal/cy)

Gravel
250 to 275 lbs/cy
(30 to 33 gal/cy)

PCA
Portland Cement Association

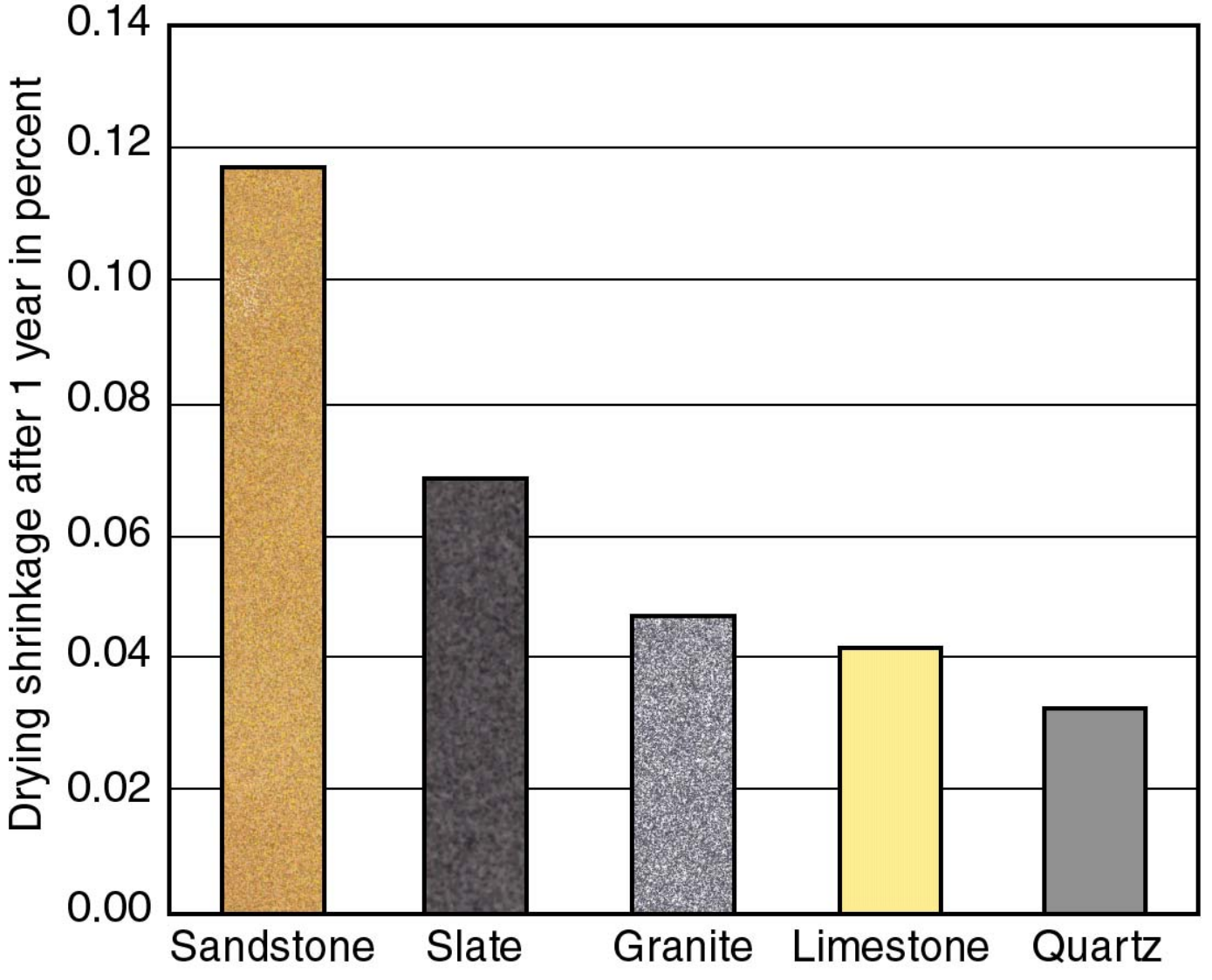
Good Interior Slab Mix

- Low shrinkage
- Good placeability / finishability
- Timely and uniform set characteristics
- Required flexural strength
  - Modulus of rupture (MOR)

Minimizing Shrinkage

- Use lowest shrinkage aggregate available
- Minimize paste quantity
  - Increase aggregates size (surface area)
  - Optimize total aggregate gradations (voids)
    - Packing
  - Minimize cement content
- Maximize paste quality
  - Reasonable water/cement ratio
  - Enough water for workable slump

Aggregate Type affects Shrinkage



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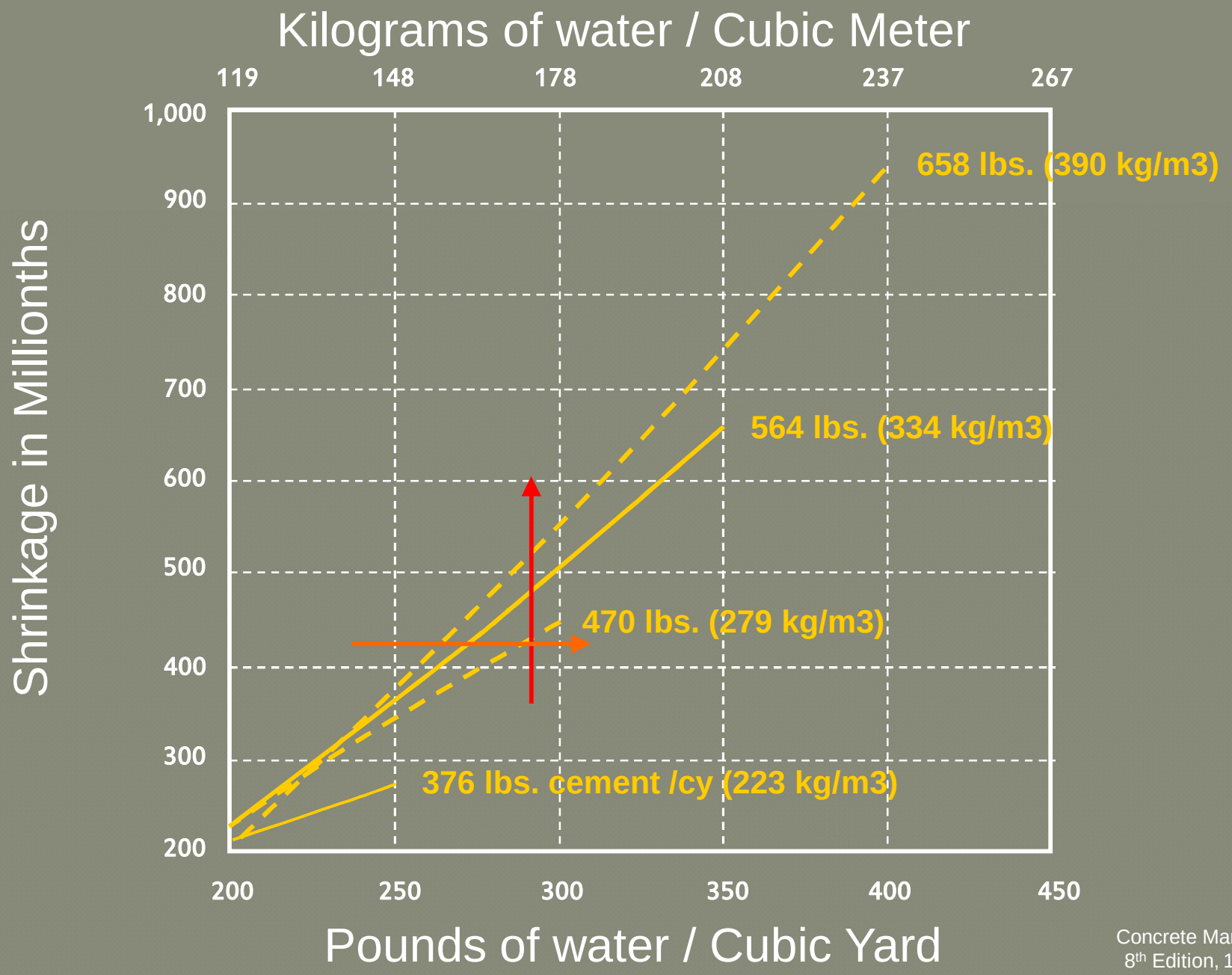

Concrete Manual
8th Edition, 1981
U.S. Bureau of Reclamation

Aggregates

- Characteristics
  - Round, crushed, flat, elongated
  - Low modulus of elasticity
- Coarse aggregates
  - ASTM C-33 standards
  - Clean
- Fine aggregates (sand)
  - Prefer natural over manufactured
  - ACI 302-96 gradation recommendations
    - Fineness Modulus between 2.60 and 3.30


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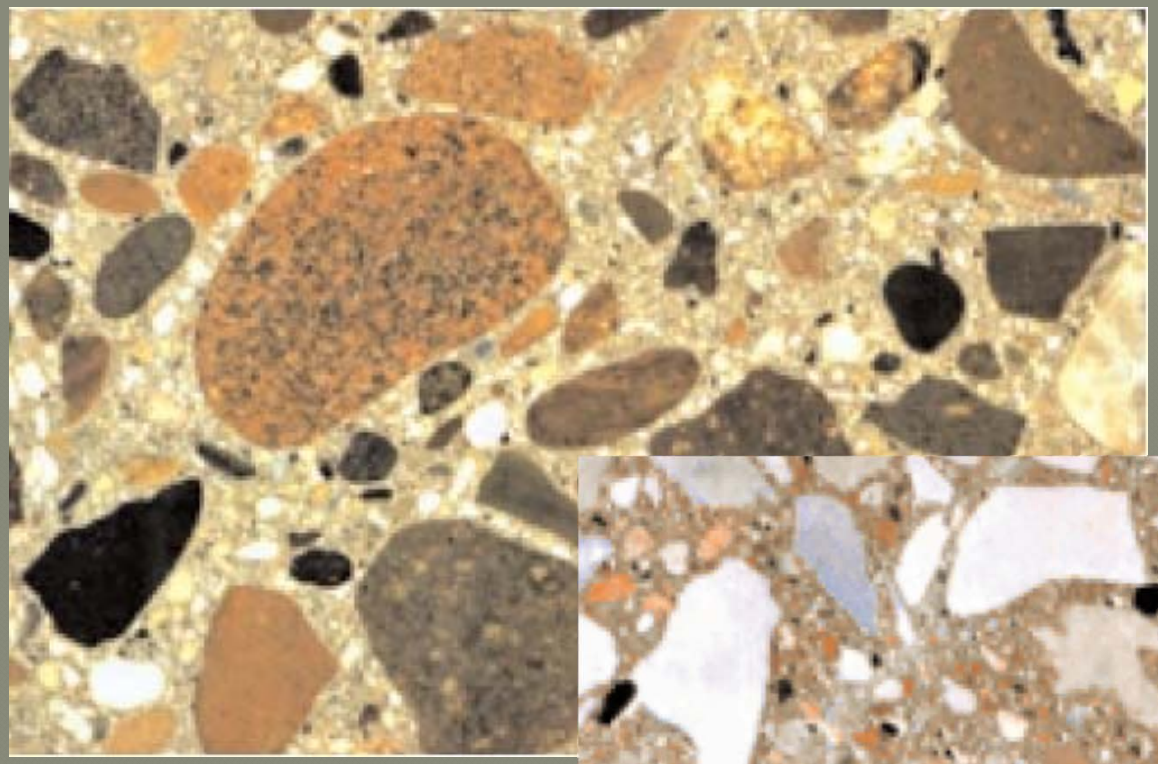
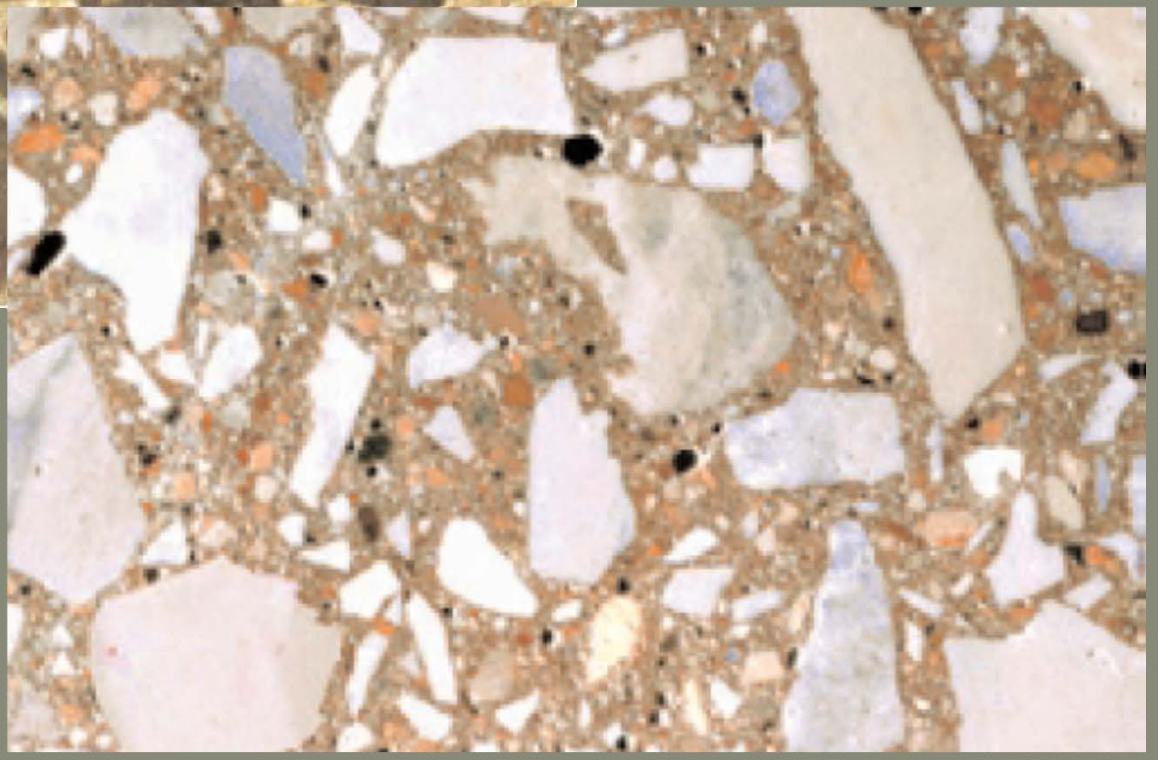
Natural Gravel
Crushed Stone

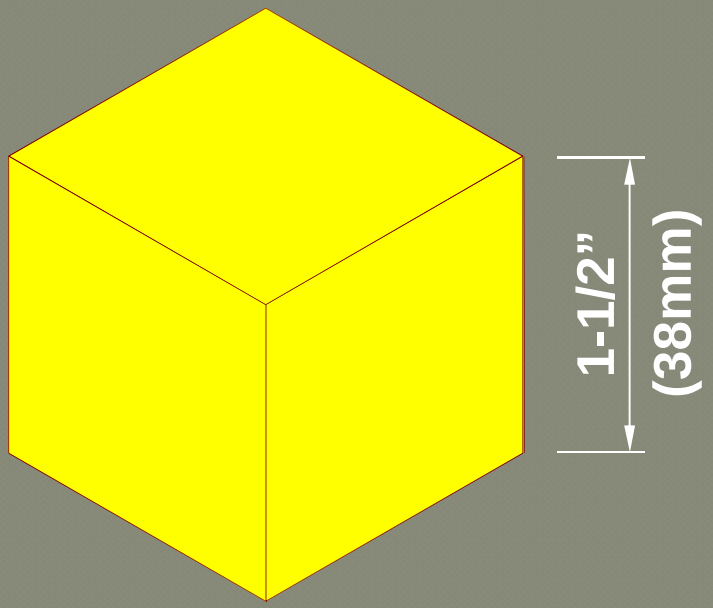


rounded siliceous gravel

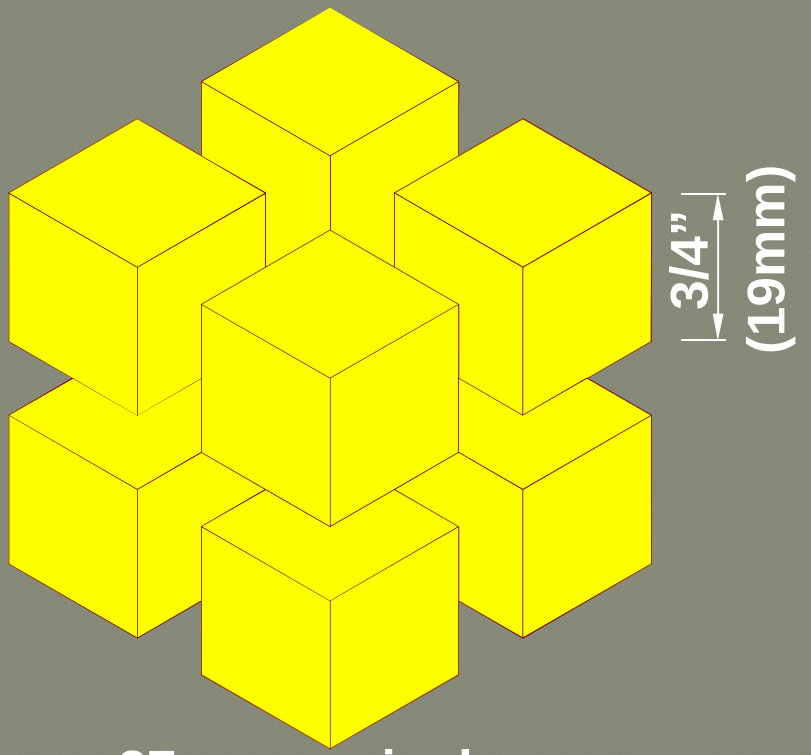


crushed limestone

Aggregate Surface Area

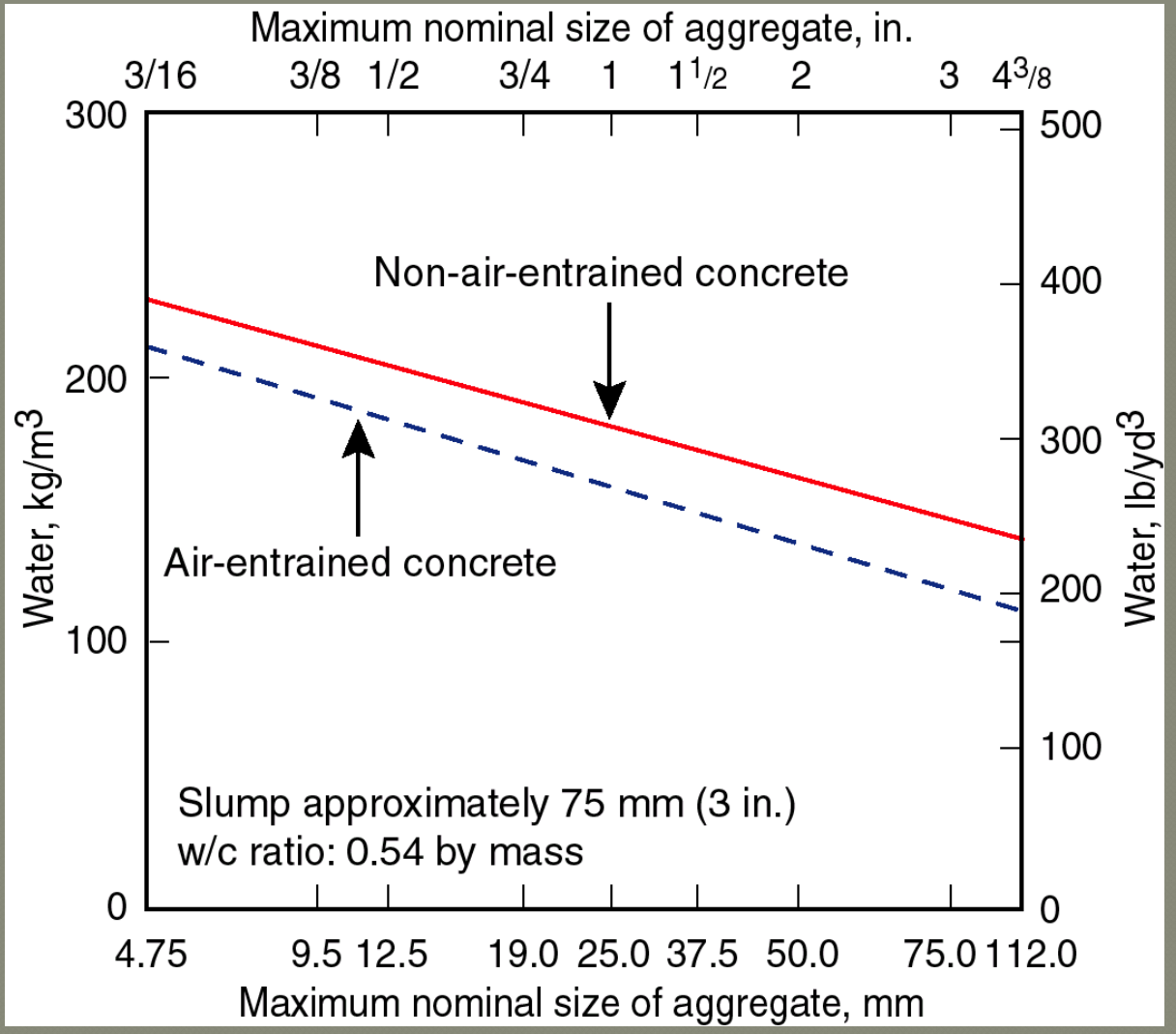


13.5 square inches
(866 square mm)

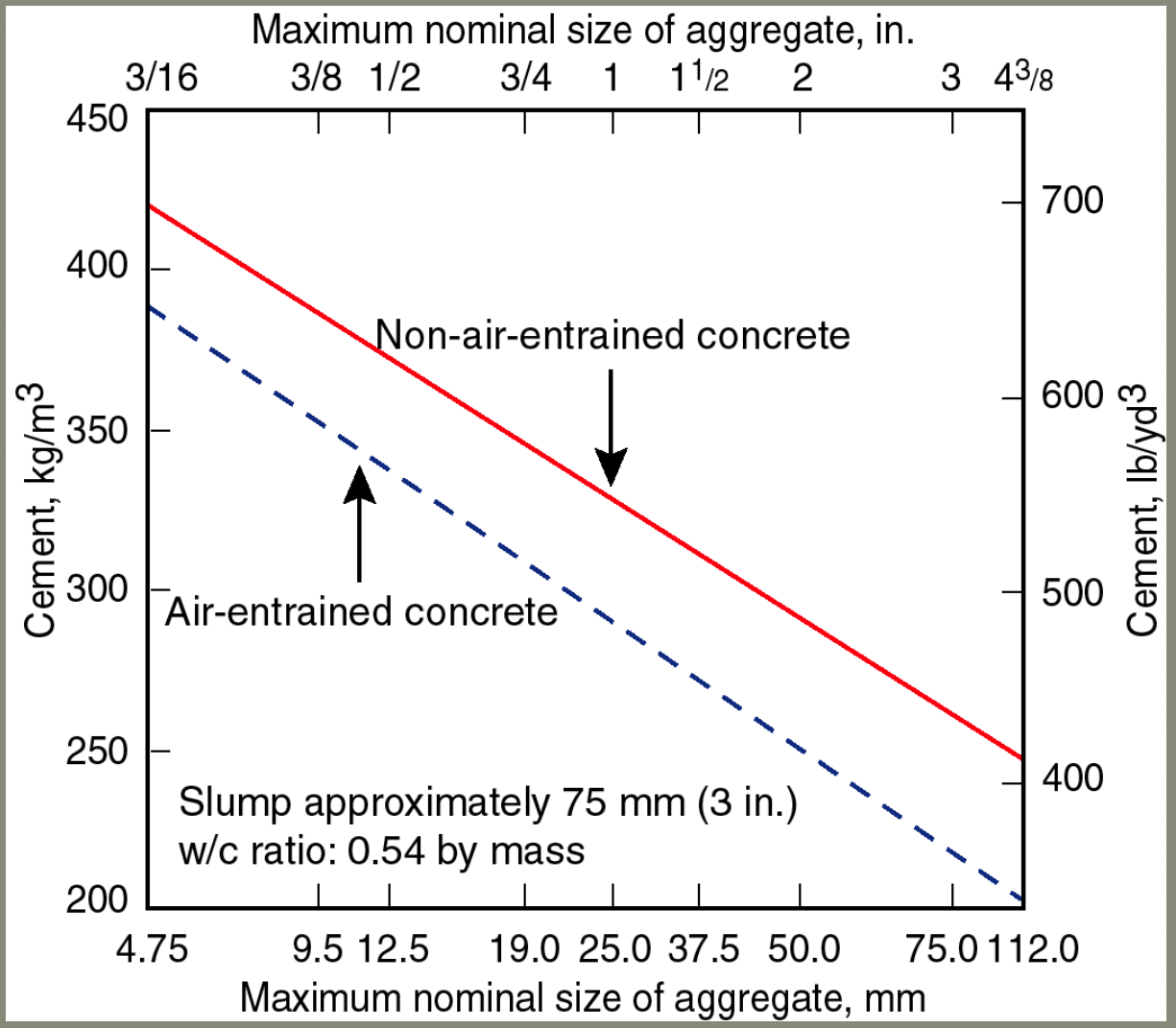


27 square inches
(1732 square mm)

Aggregate Size and Water Required



Aggregate Size and Cement Required



Nominal Maximum Size

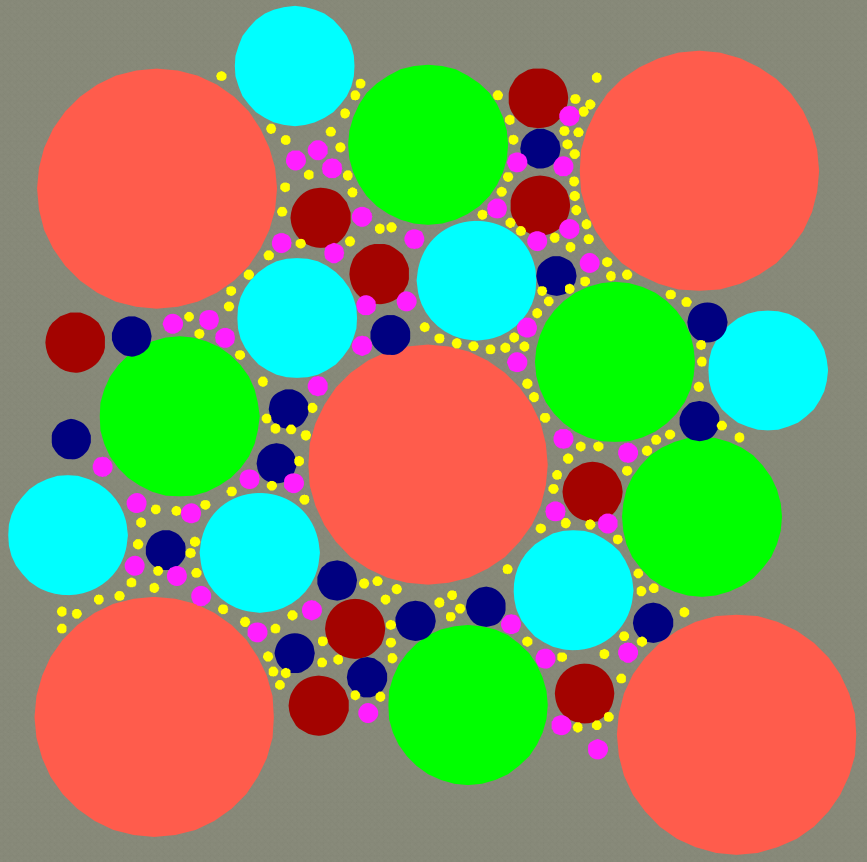
- Maximum size
  - is the smallest sieve that all of a particular aggregate must pass through
- Nominal maximum size
  - is the standard sieve opening immediately smaller than the smallest through which all of the aggregate must pass

Consider Particle Shape

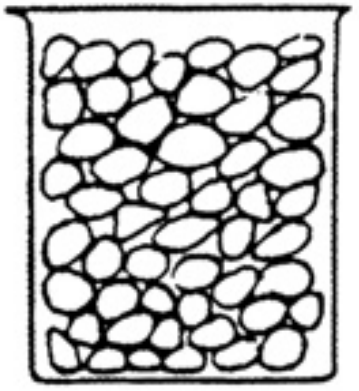
Aggregate Shadowing

Aggregate Void Space

Aggregate Void Space

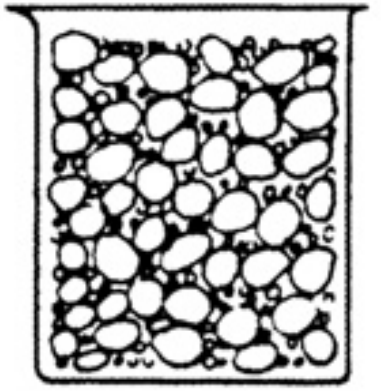


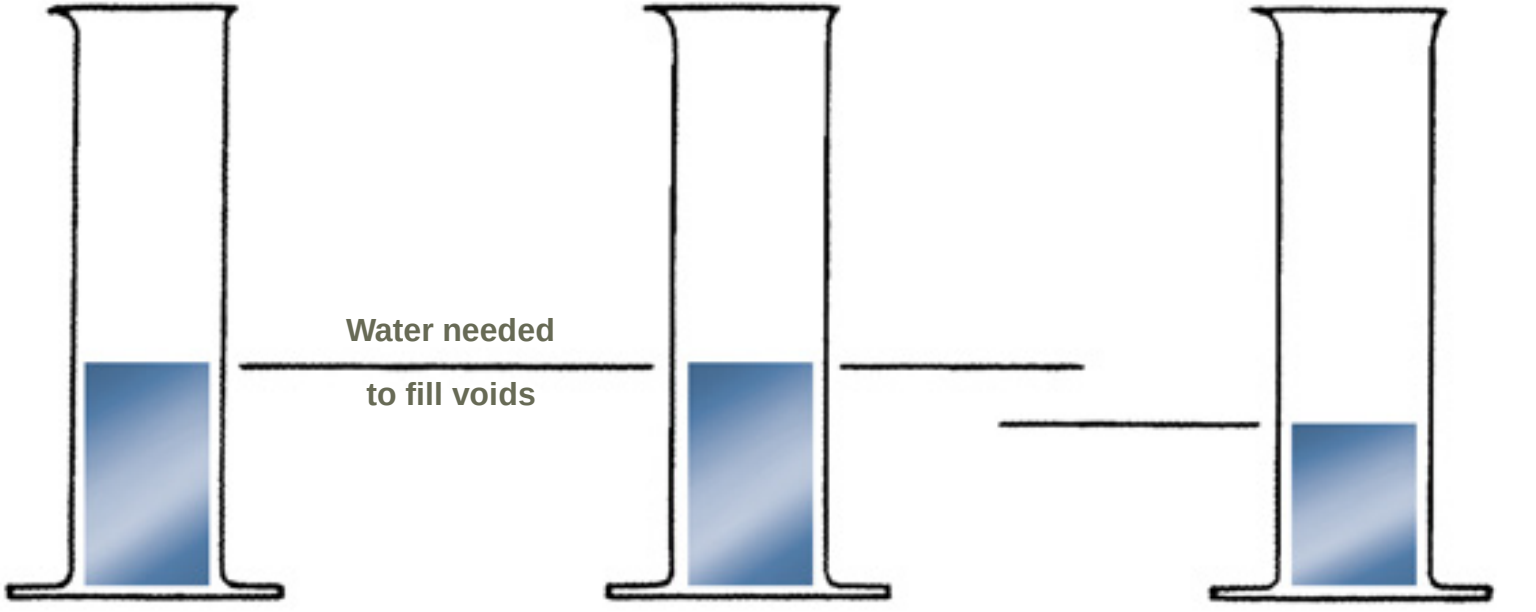
1” Aggregate



3/8” Aggregate

Combined





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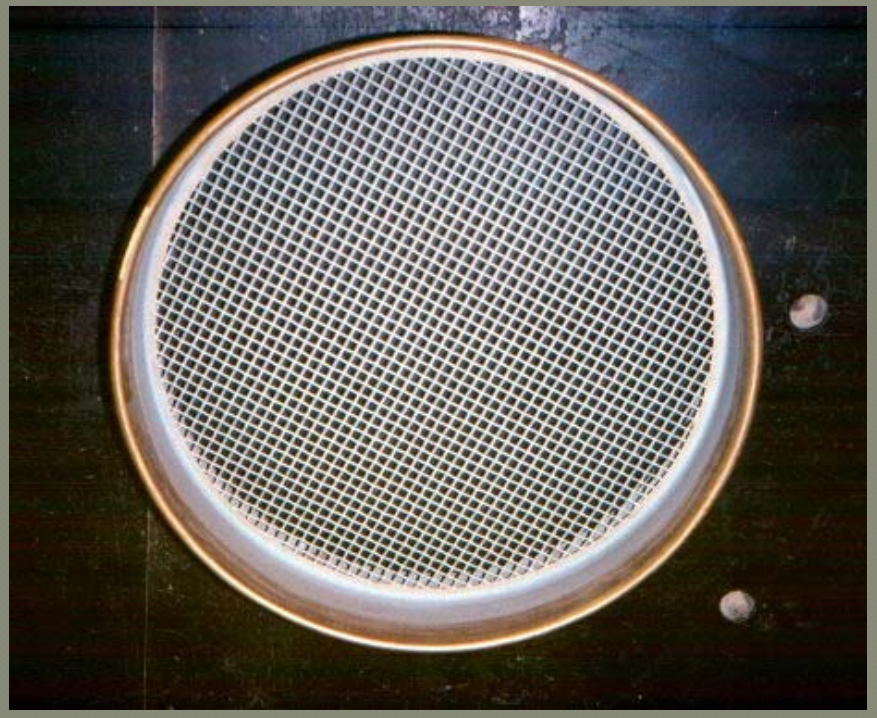
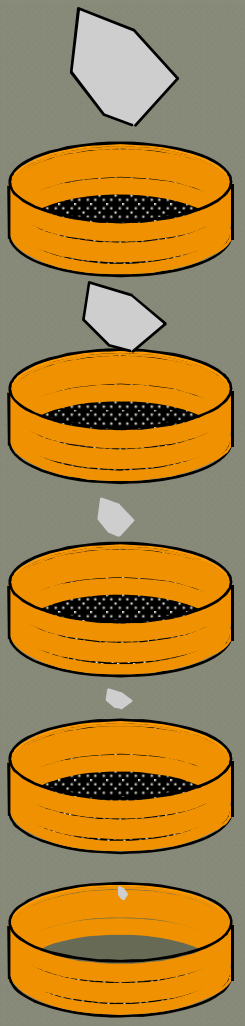
Mechanical Sieve



Individual Sieve

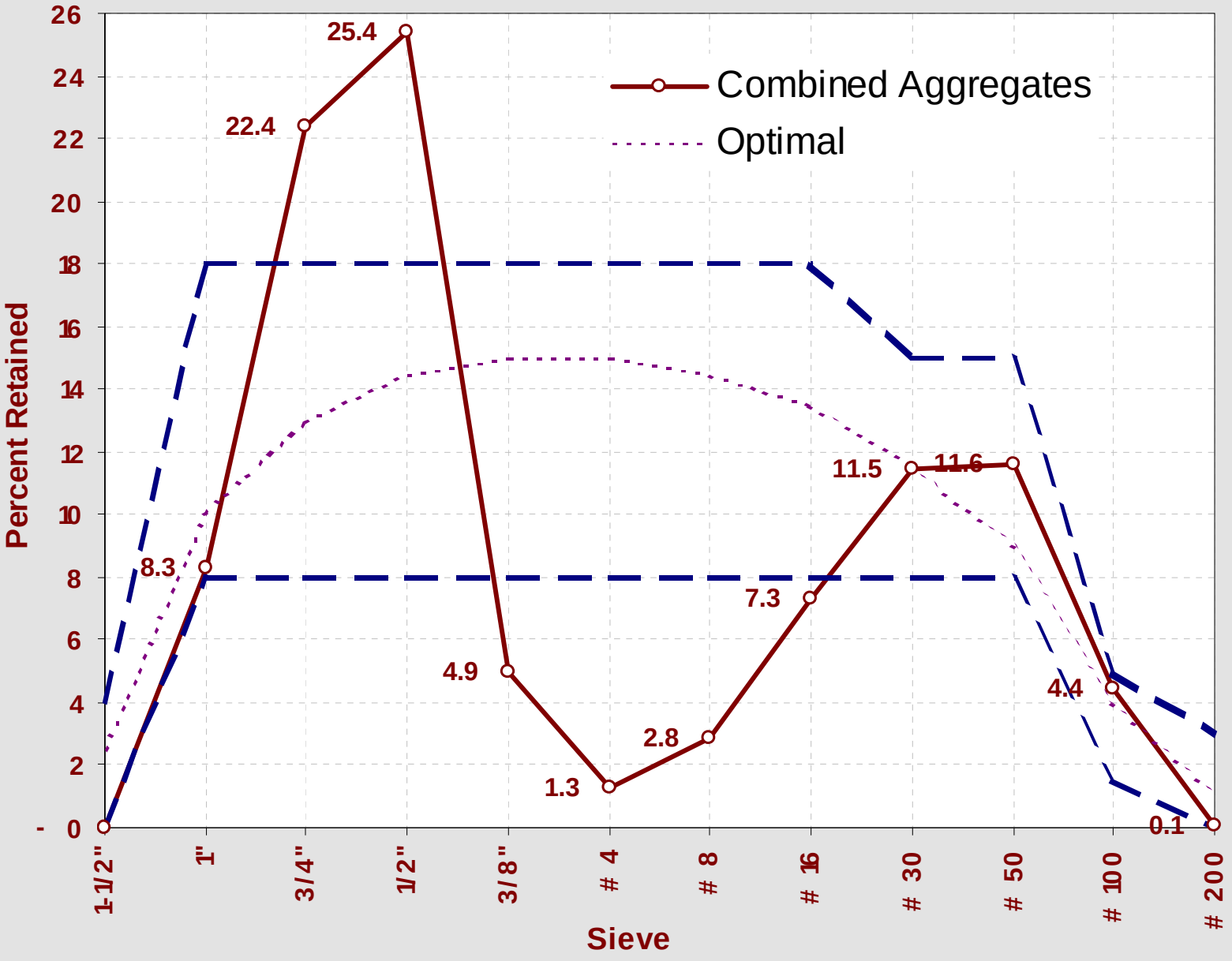
Stack of Sieves

Mechanical Sieve



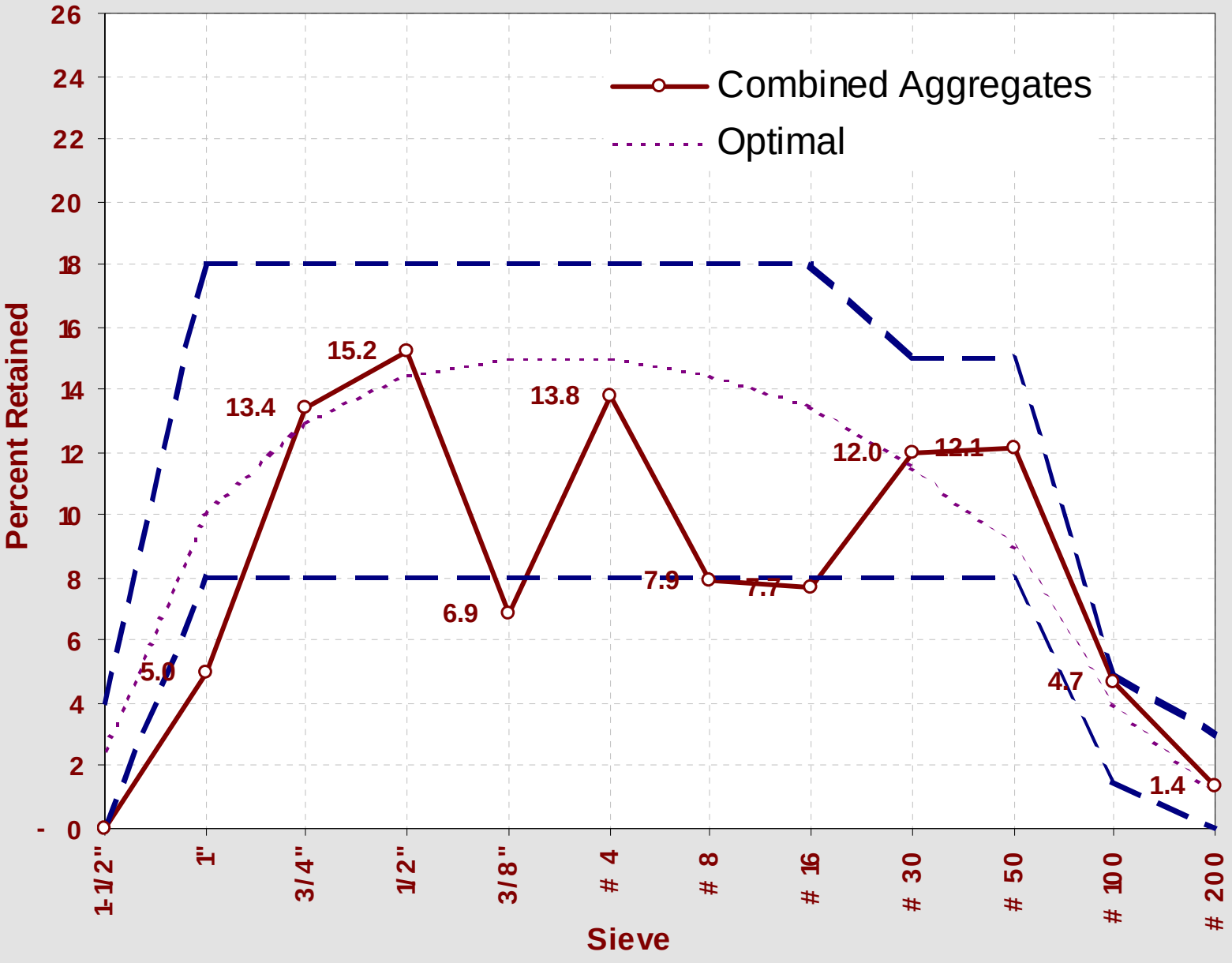
MATERIAL DISTRIBUTION CHART BY SIEVE

8%-18%



MATERIAL DISTRIBUTION CHART BY SIEVE

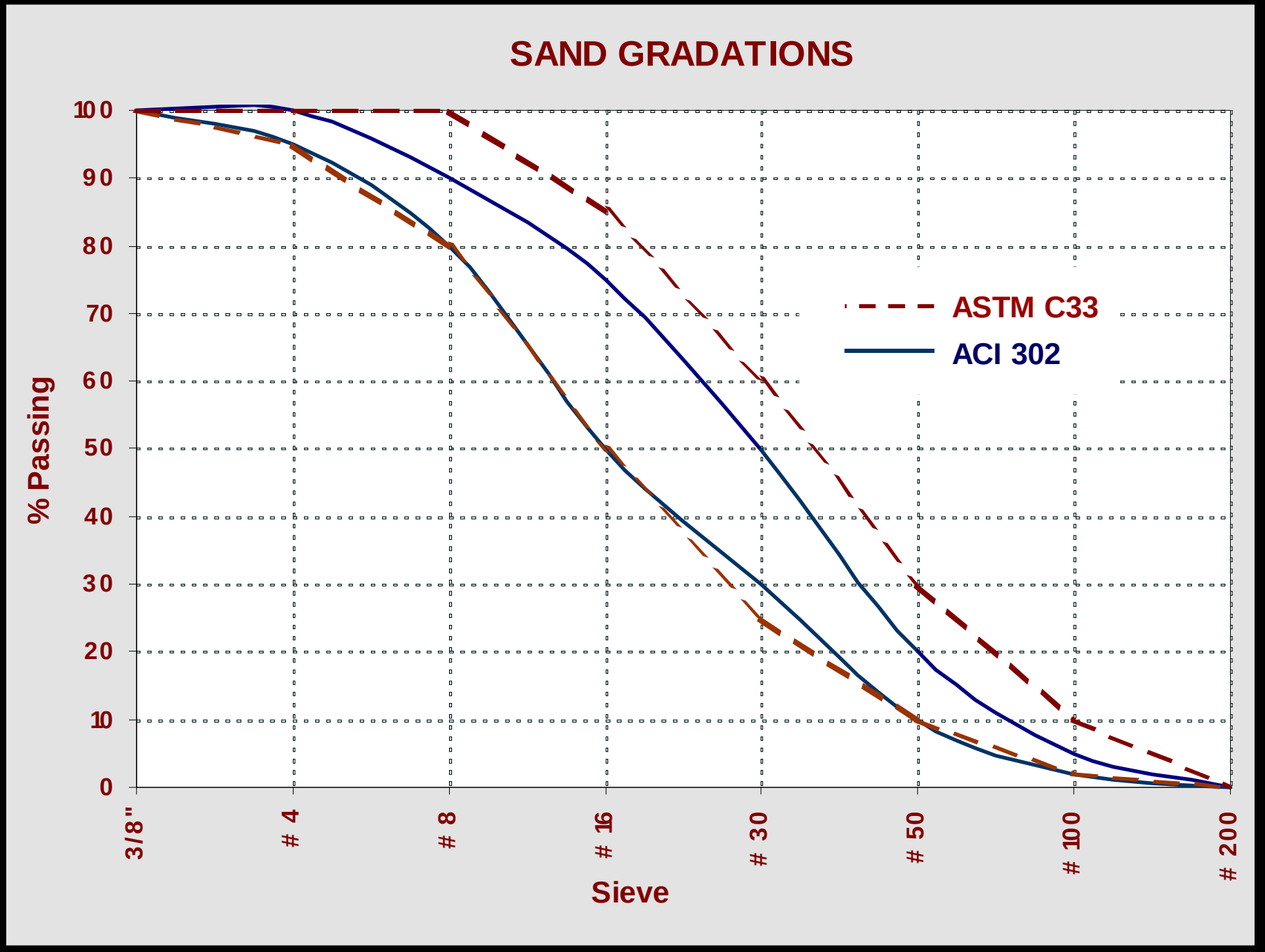
8%-18%



Sand Gradations (ACI 302)

for Normal Weight Concrete

Sieve (Imperial)	ACI 302	ASTM C33	Sieve (Metric)
3/8”	100	100	10 mm
#4	85-100	95-100	5 mm
#8	80-90	80-100	23.6 mm
#16	50-75	50-85	1.18 mm
#30	30-50	25-60	600 um
#50	10-20	10-30	300 um
#100	2-5	2-10	150 um


SAND GRADATIONS
% Passing
100
90
80
70
60
50
40
30
20
10
0
3/8"
4
8
16
30
50
100
200
Sieve
ASTM C33
ACI 302

Combined Aggregates

- Q (coarse) > 3/8” (10 mm)
- I (intermediate) < 3/8” (10 mm)
  and > #8 (2.36 mm)
- W (fine) < #8 (2.36 mm)

Coarseness Factor

$$\frac{\text{Coarse (Q)}}{\text{Coarse (Q) + Intermediate (I)}}$$

Workability Factor

$$\frac{\text{Fines (W)}}{\text{Total Aggregates (Q + I +W)}}$$

* Based on 564 lbs/cy cement content

Adjusted Workability Factor

(W-Adj) =

$$WF + \left[\left(\frac{\text{Cementitious Materials} - 564\ (\text{lbs})}{94}\right) \times 2.5\right]$$

Balance CF / Adj-W

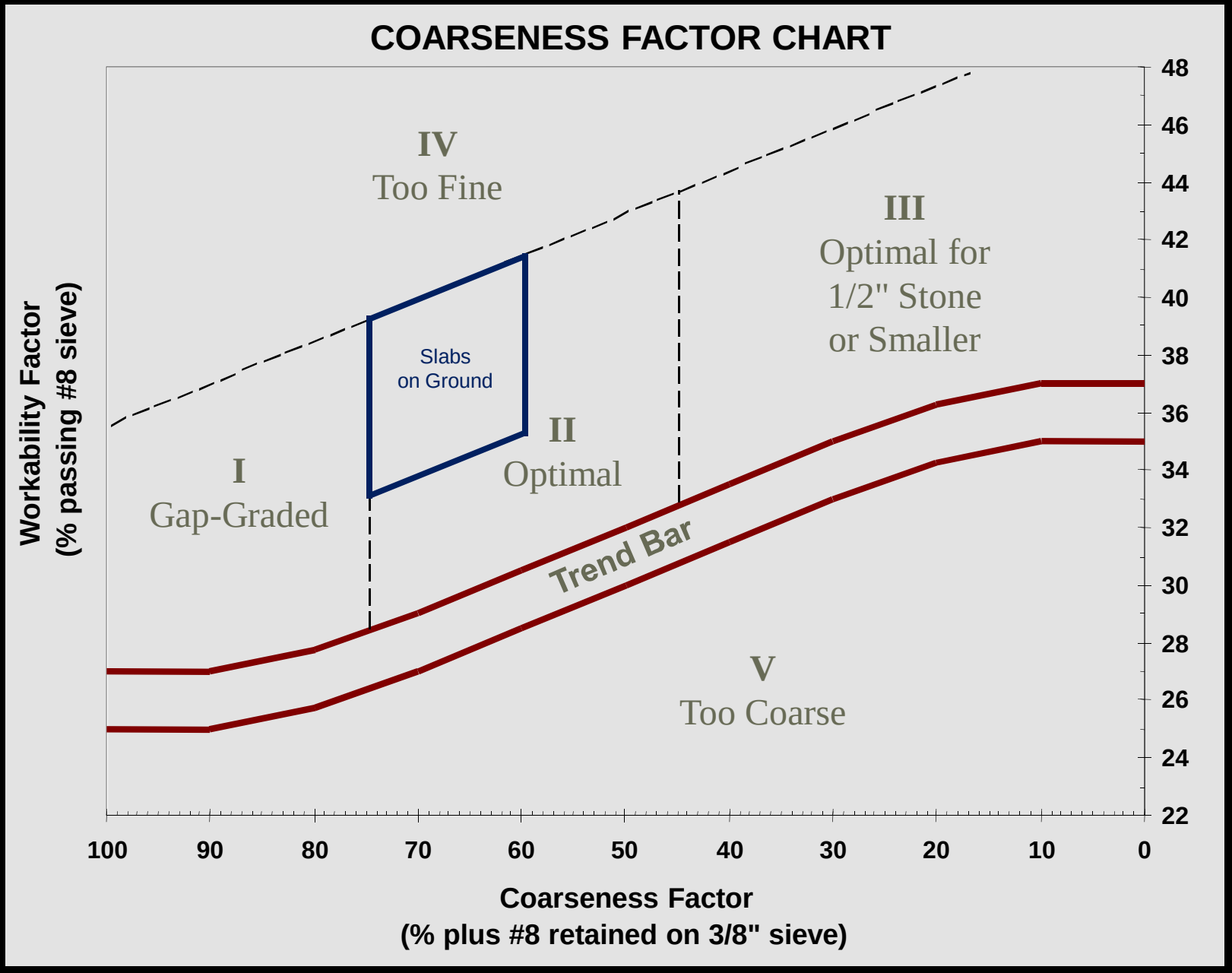
(W-Adj) =

$$\left[\frac{(75 - CF)}{6.67} + 36\right] \pm 3$$

CF = Coarseness Factor

W-Adj = Adjusted Water Ratio

33% to 41%


COARSENESS FACTOR CHART
IV
Too Fine
III
Optimal for
1/2" Stone
or Smaller
Slabs
on Ground
II
Optimal
I
Gap-Graded
Trend Bar
V
Too Coarse
Workability Factor
(% passing #8 sieve)
48
46
44
42
40
38
36
34
32
30
28
26
24
22
100
90
80
70
60
50
40
30
20
10
0
Coarseness Factor
(% plus #8 retained on 3/8" sieve)

Mortar Fraction (Volume)

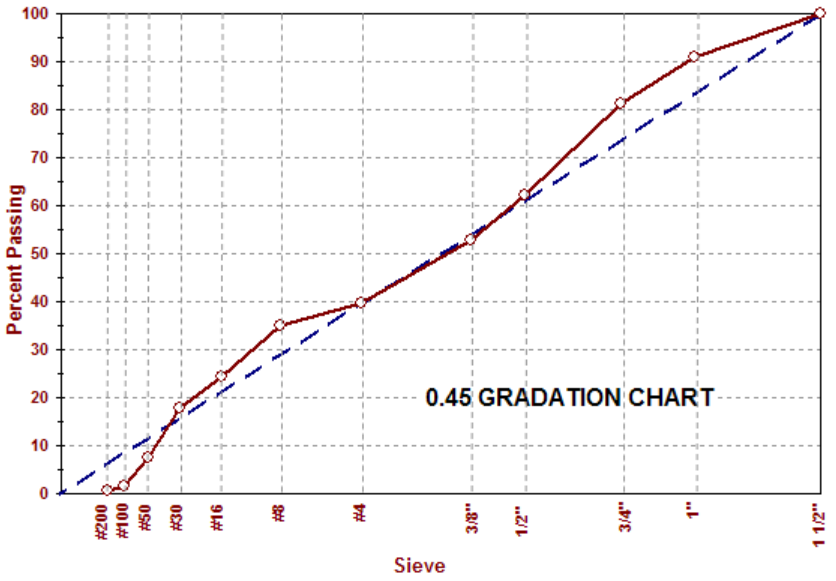
$$\frac{\text{(Paste + Air + Fines)}}{\text{Total Mix}}$$

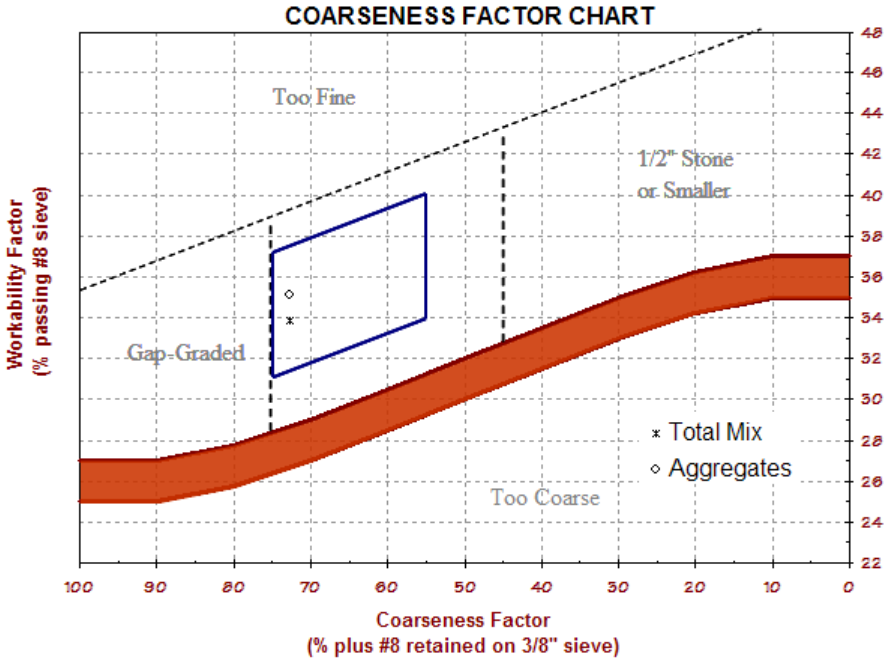
	Density	Weight	Volume	
Cement	3.150	517	2.63	(5.5 sks)
Pozzolan	2.350	-	-	0%
467 Blend	2.650	1,978	11.96	
Stone 2	-	-	-	
Stone 3	-	-	-	(11.96 cf)
Sand	2.580	1,237	7.68	
Sand 2	-	-	-	
Water	8.345	260	4.17	(31.2 gal)
Total Air	2.00%		0.54	
Fibers	0.910	1	0.02	
Total		3,993	27.00	

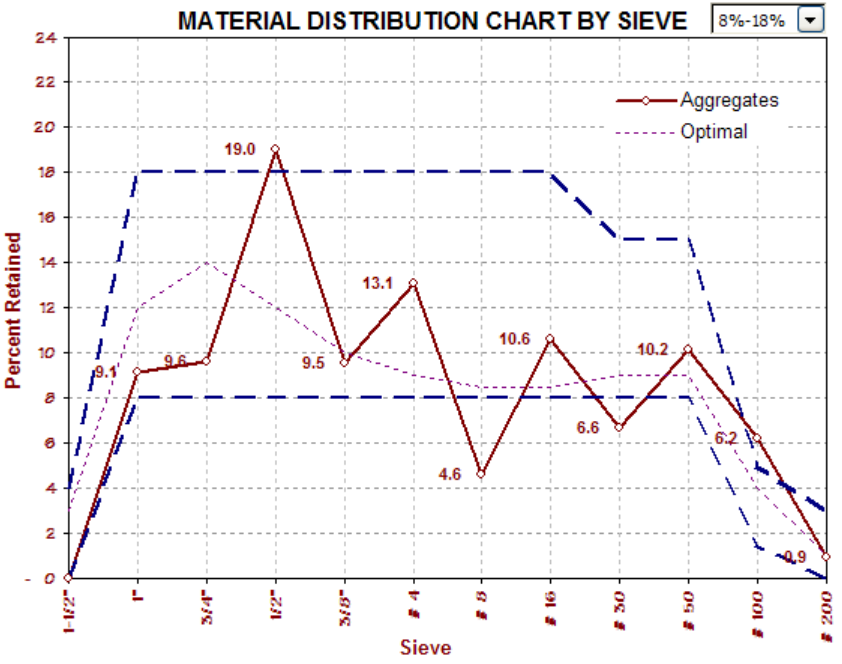
Analysis		
Design Strength	4,000	psi
W/C Ratio	0.503	
Slump	5.0	inches
Unit Weight	147.9	lbs/cu ft
Total Stone	1,978.0	lbs
Coarseness	72.8%	
Workability	35.1%	6.5%
W-Adjusted	33.8%	5.2%
Mortar Fraction	52.7%	
Paste Fraction	25.2%	
Total Finess Modulus	5.40	

Admixture(s) 6 oz/cwt Mid Range WRA 10% **water reduction** Max Size Aggregate 1-1/2"

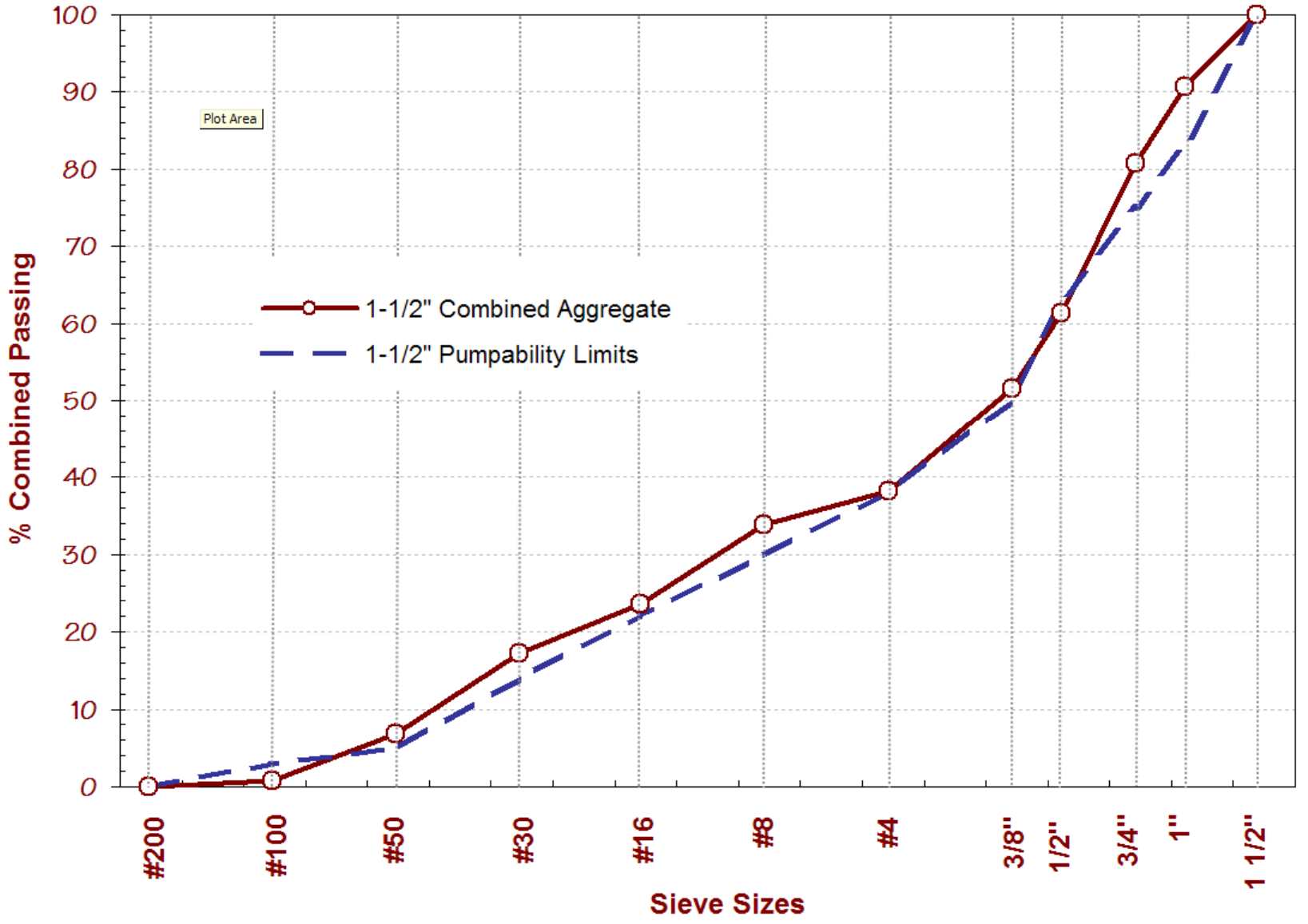
	467 Blend	Stone 2	Stone 3	Sand	Sand 2	% of Total Mix	
% Passing 3/8" Sieve	22.4	-	-	100.0	-	467 Blend	44.3%
% Passing #8 Sieve	1.1	-	-	88.0	-	Stone 2	0.0%
Fineness Modulus	7.02	-	-	2.88	-	Stone 3	0.0%
% Total Aggregate	60.9%	0.0%	0.0%	39.1%	0.0%	Sand	28.4%
Blend	100.0%	0.0%	0.0%	100.0%	0.0%	Sand 2	0.0%
Rock/Sand			60.9%		39.1%	Paste+Air	27.2%
						Fiber	0.1%
							100.0%







ACI 304 PUMPABILITY LIMITS



CONCRETE SLAB MIX DESIGN SUBM
(Section 03312 – Cast-in-Place Concre

☐ DISCOUNT STORE ☐ SUPERCE

SUBMITTED MIX DESIGN

 # 03312-1 ☐ **Interior Building Sla**

A) Natural Concrete (grey

B) Integrally Colored Con

C) Vestibule Stamped Co

 # 03312-2 ☐ **Exterior Building Sl**

A) Garden Center Slab

A. CONCRETE INFORMATION

Supplier Mix Design # _____

Design Strength (f'c) _____

Water / Cementitious Ratio _____

Total Air Content _____

Mix Developed From

☐ Trial Mix Test Data (*attach test*

☐ Field Experience

Density

Wet _____ pcf Dry ____

Slump

_____" (± 1") **WITHOUT** WR Admi

_____" (± 1") **WITH** WR Admixture

B. ADMIXTURE INFORMATION

	ASTM Designation (ASTM designation)
Water Reducing	
Air Entraining	
Accelerating	
Retarding	
Liquid Color	

C. MIX DESIGN

	Identi (Type,
Cement	
Fly Ash	
Slag	
Coarse Aggregate # 1	
# 2	
# 3	
Fine Aggregate # 1	
# 2	
Water	
Air Content	
Liquid Color	

Co

Sieve Size	% Pa (All Sieve	
	Coarse Agg. # 1	Coarse Agg. # 2
1-1/2"		
1"		
3/4"		
1/2"		
3/8"		
# 4		
# 8		
# 16		
# 30		
# 50		
# 100		
# 200		
% of Volume		

Coarseness Factor =	Com
	Com
Workability Factor =	Com
Adj-Workability Factor =	WF
Allowable Adj-WF=	Adj-V

D. REQUIRED CURRENT ATTACHMENTS

- ☐ NRMCA plant certification documentation
- ☐ State Department of Transportation plant certification documentation
- ☐ Coarse aggregate gradation reports for each size group (all sieves)
- ☐ Fine aggregate gradation reports for each size group
- ☐ Combined coarse and fine aggregate gradation report and graph
- ☐ Possible reactivity of aggregate, based on tests or past service
- ☐ Possible aggregate pop-outs or their disruptions, based on tests or past service
- ☐ Cement mill test reports
- ☐ Fly ash mill test reports (If required to resist aggregate ASR or soluble sulfates in soils)
- ☐ Slag mill test reports (If required to resist aggregate ASR or soluble sulfates in soils)
- ☐ Concrete compressive strength data used for standard deviation calculations
- ☐ Chloride ion data and related calculations
- ☐ Liquid color admixture product data sheet

E. CONCRETE SUPPLIER INFORMATION

Company Name _____ **Tel. #** ( )_____

Address _____

City, ST Zip _____

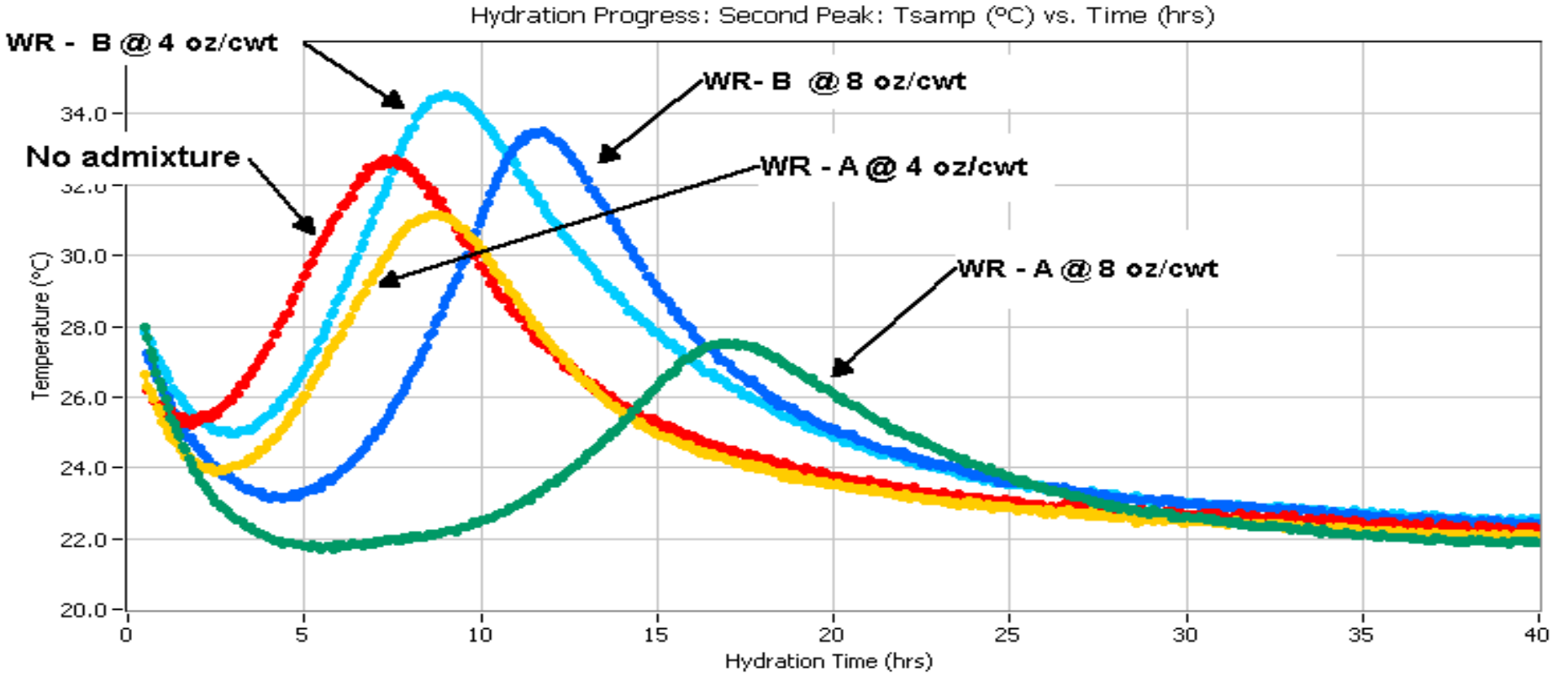
Technical Contact **Tel. #** ( )_____

e-mail _____

Sales Contact _____ **Tel. #** ( )_____

	PRIMARY PLANT	SECONDARY PLANT
Plant Location:		
Miles from Site:		
Travel Time to Site:		
NRMCA Certified:	☐ YES ☐ NO	☐ YES ☐ NO
State DOT Certified:	☐ YES ☐ NO	☐ YES ☐ NO
Batch Mixing Type:	☐ DRY ☐ CENTRAL MIX	☐ DRY ☐ CENTRAL MIX

Admixture affect on setting time



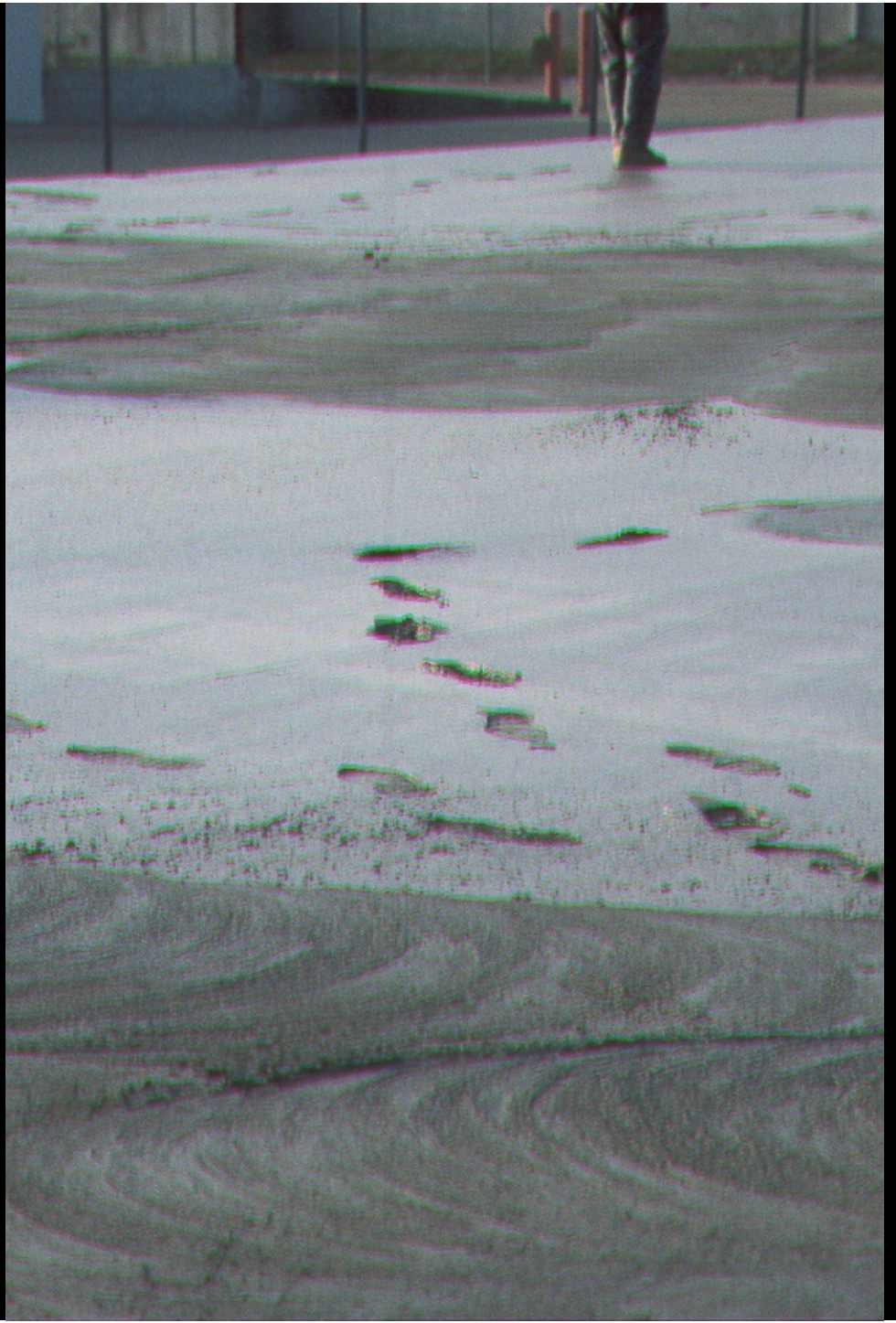
1 Theodore (500) : WR A @ 8 oz-cwt
2 Theodore (500) : WR A @ 4 oz-cwt
3 Theodore (500) : No Admixture
4 Theodore (500) : WR B @ 8 oz-cwt
5 Theodore (500) : WR B @ 4 oz-cwt

Supplementary Cementitious Materials

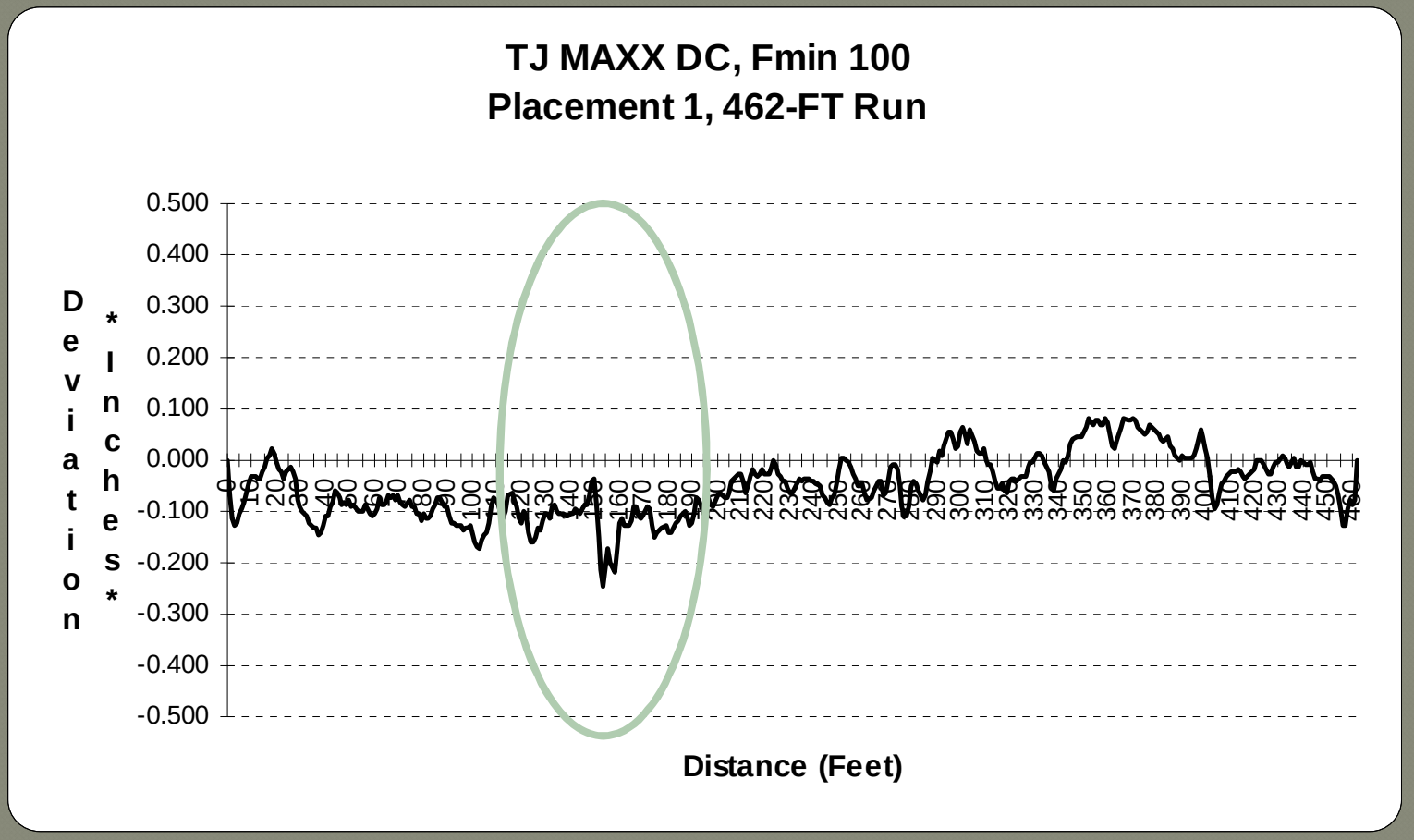
- Fly ash
  - Class F
  - Class C (cementitious properties)
- Granulated blast furnace slag

Other Admixtures

- Air entrainment
  - Do not use for steel trowel finished floors
  - Test first truck and periodically thereafter
- Retarding
  - Included in many water-reducers
- Accelerating
  - Including some with calcium chloride
- Shrinkage Reducers



Delivered Concrete Consistency



ACI 302-04 (Section 6.2.7)

"It is recommended that an air entraining agent not be specified or used for concrete to be given a smooth, dense, hard-troweled finish since blistering or delimitation may occur. These troublesome finishing problems can develop any time the total air (both entrained and entrapped) content is in excess of 3 percent. This is particularly true when monolithic surface treatments are used."

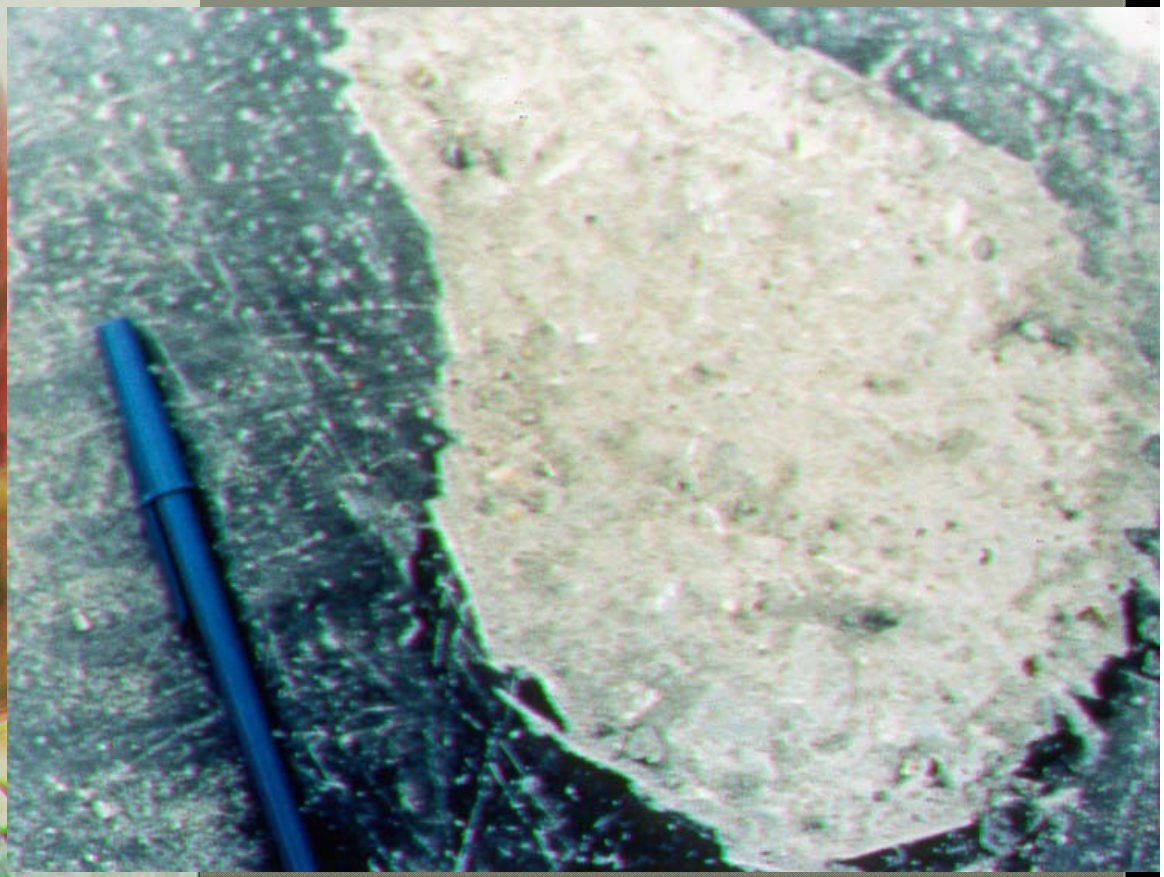
ACI 306.1-90 (Section 2.2)

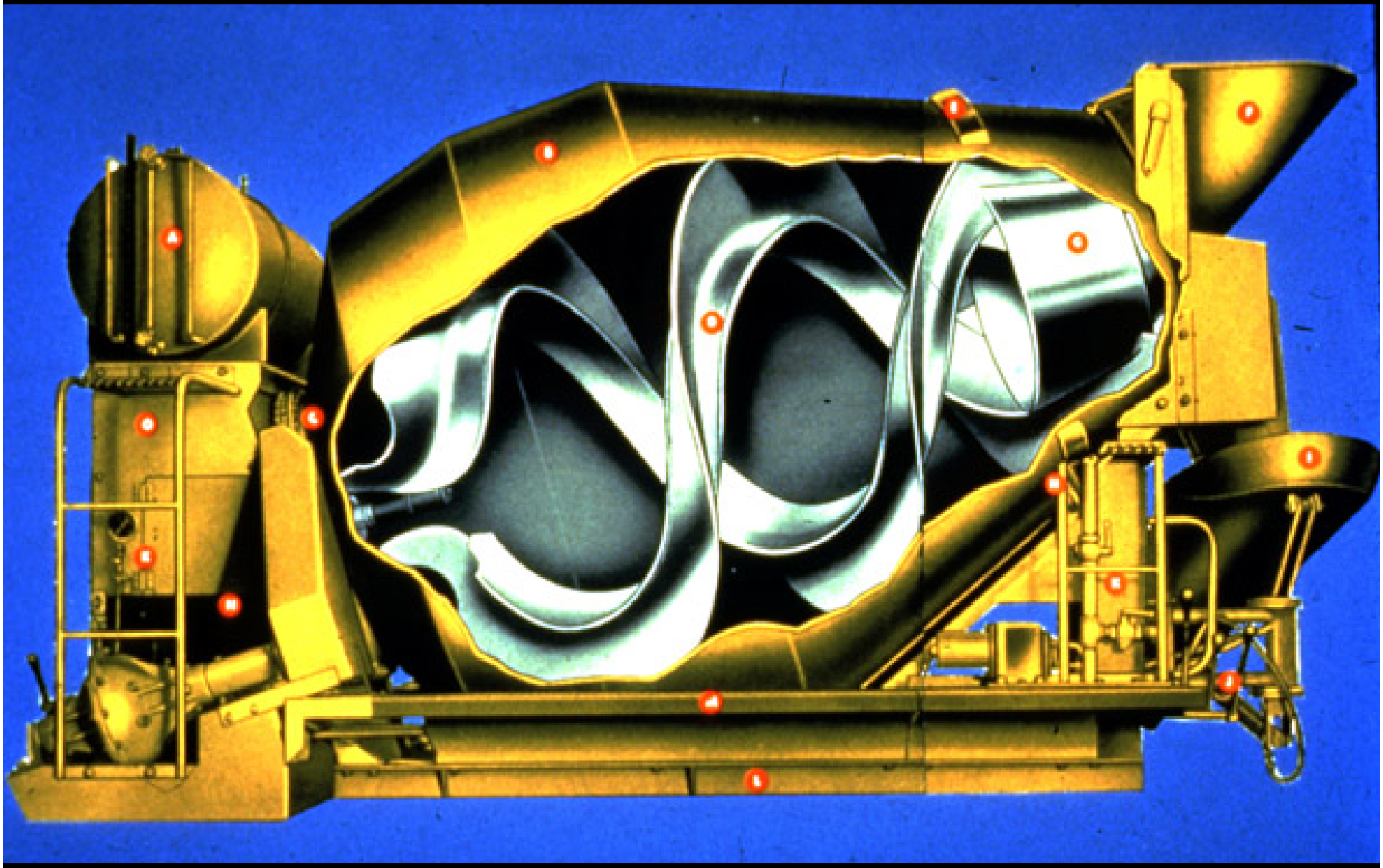
"Concrete for slabs and other flatwork exposed to cycles of freezing and thawing in a wet condition during the construction period shall be air entrained as specified in ACI 301 even though the concrete may not be exposed to freezing in service."

Fresh Concrete Air Content Tests

- Air content can be measured directly by the pressure method or volumetric method
- Air content can be estimated by using the unit weight test

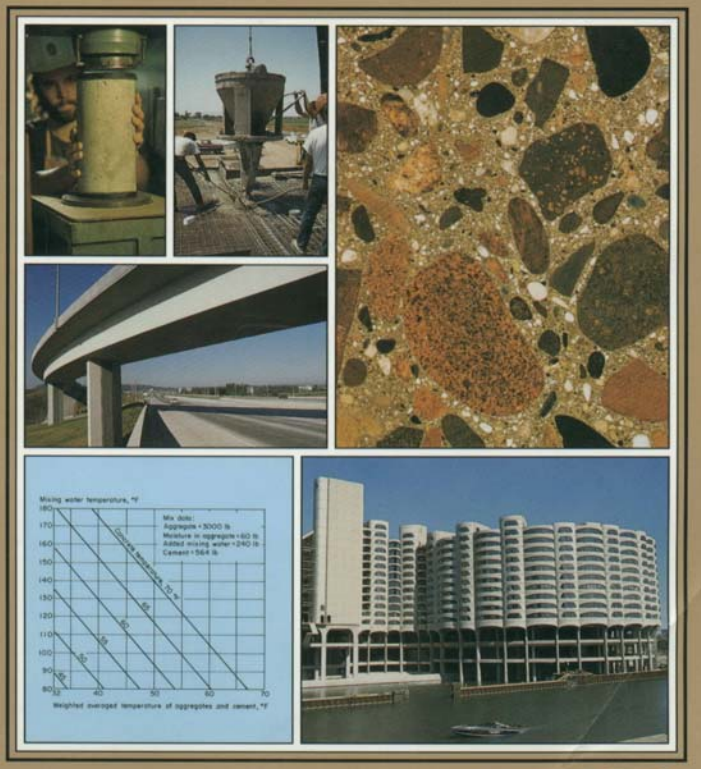

JLG





PORTLAND CEMENT ASSOCIATION

Design and Control of Concrete Mixtures



THIRTEENTH EDITION

Define Quality Concrete

- High compressive strengths
- Low water/cementitious ratios
- Low slump

- Low Shrinkage
- Good placeability / finishability
- Timely and uniform set characteristics
- Required Flexural Strength (MOR)

Concrete Slab Mix Proportioning

Water-Cement Ratio & Strength

Patrick Harrison
Vice President
Structural Services, Inc.