Airfield Concrete Mixture Optimization

SWIFT Conference

Calgary, Alberta

Gary L. Mitchell, P.E.

Director of Airports and Pavement Technology

Count on Concrete PAVEMENT

Aknowledgement

John R. Anderson, Ph.D., P.E.
4 Lawn Street
Oviedo, FL 32765
407-365-7229
jranderson@tigerbrain.com

TIGERBRAIN ENGINEERING, INC.

Concrete Optimization

- Why?
- What?
- How?

TIGERBRAIN ENGINEERING, INC.

Why?

Avoid Sliver Spalls!

- Within 1 inch of joint
- Max Depth = Seal Reservoir

TIGERBRAIN ENGINEERING, INC.

What is Mix Optimization?

Combined Gradation

- Dense graded aggregates
- Concrete 85% Aggregate
- Aggregates control Concrete
- Similar in concept to
  - Granular Base
  - Hot Mix Asphalt

Tigerbrain Engineering, Inc.

Quality Concrete

- Quality is not about Strength
- Quality is not about proper air content
- Quality is not about concrete slump
- Quality is not about 100% Inspection

Quality Concrete Is:

- Durable Concrete
  - No sliver spalls
  - No scaling, surface spalls
  - No reactivity / aggregate durability issues

Quality Airfields Are:

- Functional
- Proper Drainage
- Slab size/thickness/layer strengths
  - If incorrect = cracked slabs

PCC Mix History

- Dense-graded prior to WWII
- After WWII began asphalt industry;
  - intermediate aggregates for aspahlt
  - PCC became gap graded
  - Admixture use increases
- Shilstone Mixes
- USAF Combined Gradation 1997

TIGERBRAIN ENGINEERING, INC.

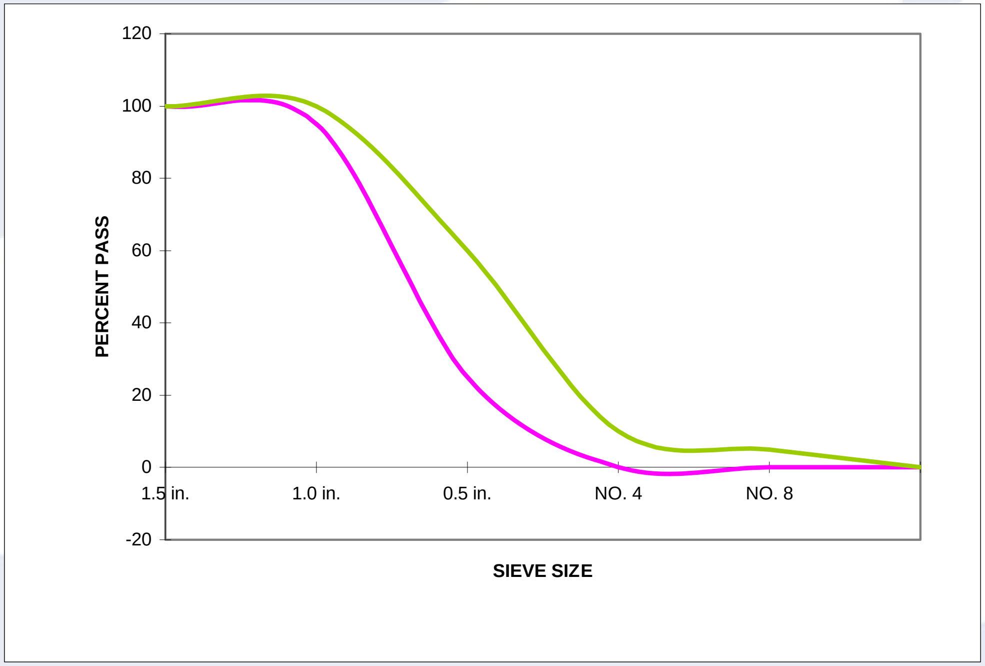
Gap-Graded PCC Mixes

- Common Specifications - ACI
  - No. 57 or No. 67 Stone
  - ASTM C33 Sand
- Produce gap-graded mix
  - Large aggregate + sand
  - High paste demand to fill voids between large aggregate

TIGERBRAIN ENGINEERING, INC.

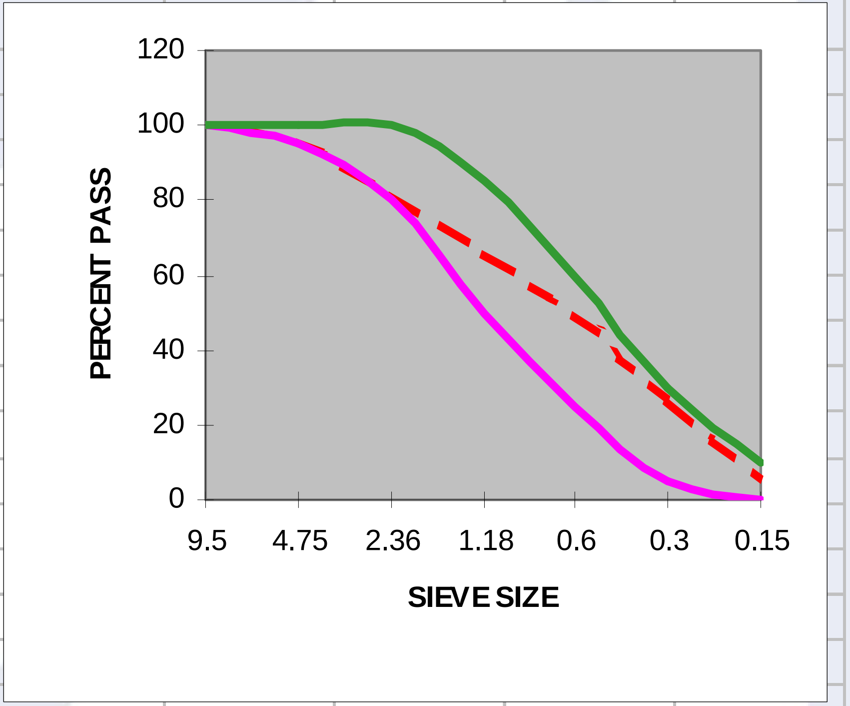
ASTM C33 No. 57 Stone Gradation

SIEVE SIZE		ASTM MIN	ASTM MAX
1.5 in.	37.5 mm	100	100
1.0 in.	25.0 mm	95	100
0.5 in.	12.5 mm	25	60
NO. 4	4.75 mm	0	10
NO. 8	2.36 mm	0	5



Typical Sand Gradation

FINENESS MODULAS CALCULATION				
MODIFIED LOWER LIMITS FOR HIGH CEMENT FACTOR		400 lbs		
SIEVE SIZE		**% PASSING**		
3/8 9.5 MM	9.5	100	100	100
NO. 4 4.75 MM	4.8	96	95	100
NO. 8 2.36 MM	2.4	82	80	100
NO. 16 1.18 MM	1.2	66	50	85
NO. 30 600 mm	0.6	50	25	60
NO. 50 300 mm	0.3	27	5	30
NO.100 150 mm	0.2	6	0	10
TOTAL		427		
FINENESS MODULAS		2.73		
ASTM C-33 LIMITS				
FM 2.3 TO 3.1 45% MAX BETWEEN SIEVES				

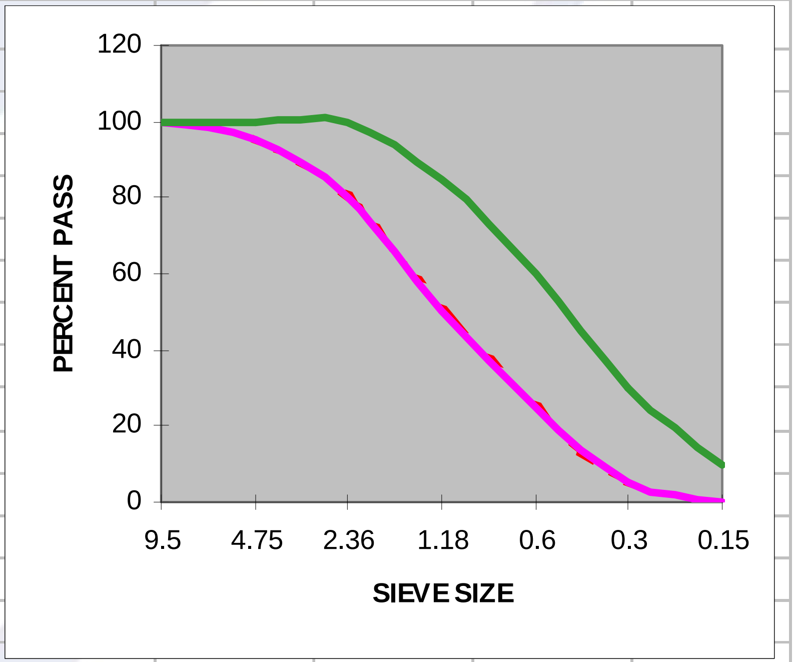


Can Coarse Sand be Specified?

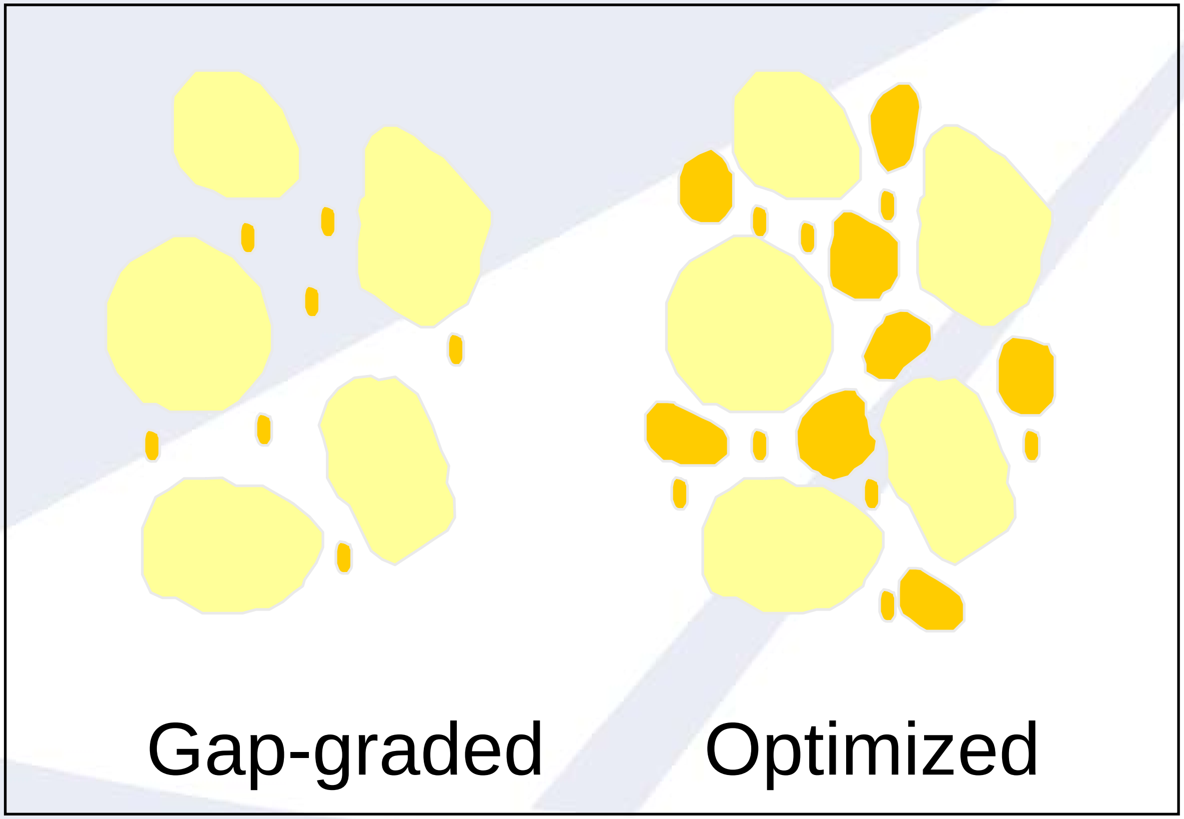
FINENESS MODULAS CALCULATION				
MODIFIED LOWER LIMITS FOR HIGH CEMENT FACTOR				400 lbs
SIEVE SIZE		**% PASSING**		
3/8 9.5 MM	9.5	100	100	100
NO. 4 4.75 MM	4.8	95	95	100
NO. 8 2.36 MM	2.4	80	80	100
NO. 16 1.18 MM	1.2	50	50	85
NO. 30 600 mm	0.6	25	25	60
NO. 50 300 mm	0.3	5	5	30
NO.100 150 mm	0.2	0	0	10
TOTAL		355		
FINENESS MODULAS		**3.45**		

ASTM C-33 LIMITS

FM 2.3 TO 3.1 45% MAX BETWEEN SIEVES



Aggregate Grading



Gap Continued

- Large aggregate Issues
  - Harsh, difficult to place and finish
  - Desire to add water, sand, superplasticizers
    - All bad for airfield paving
- Paste and mortar required to fill voids
  - Work concrete to finish, paste/mortar at edges

TIGERBRAIN ENGINEERING, INC.

Gap Mixes

- Paste and mortar required to fill voids
  - Work concrete to finish
  - Paste/mortar collect at edges; create weak pockets to spall
  - Slipform edges slump; rebuild by hand, paste/mortar pockets and spalling

Tigerbrain Engineering, Inc.

How Do I Optimize?

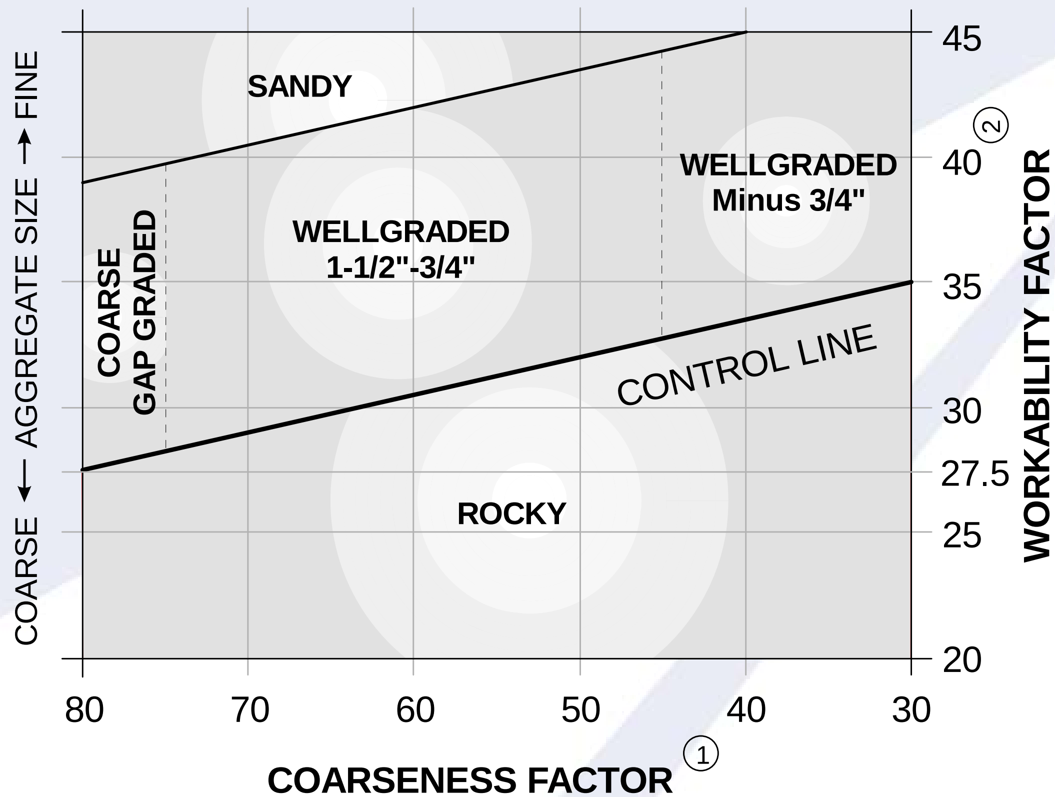
- 1997 USAF ETL 97-5
- UFGS 32 13 11
- P-501 Allowable
- P-50X
- Shilstone

Tigerbrain Engineering, Inc.

Optimization Guidelines

- Use Combined Materials
- Workability and Coarseness Factors
  - WF: Percent Pass No. 8 Sieve
  - CF: 3/8 Retained % / No. 8 Retained %
- Percent Aggregate Retained
- 0.45 Power Curve

USAF Constructability Chart

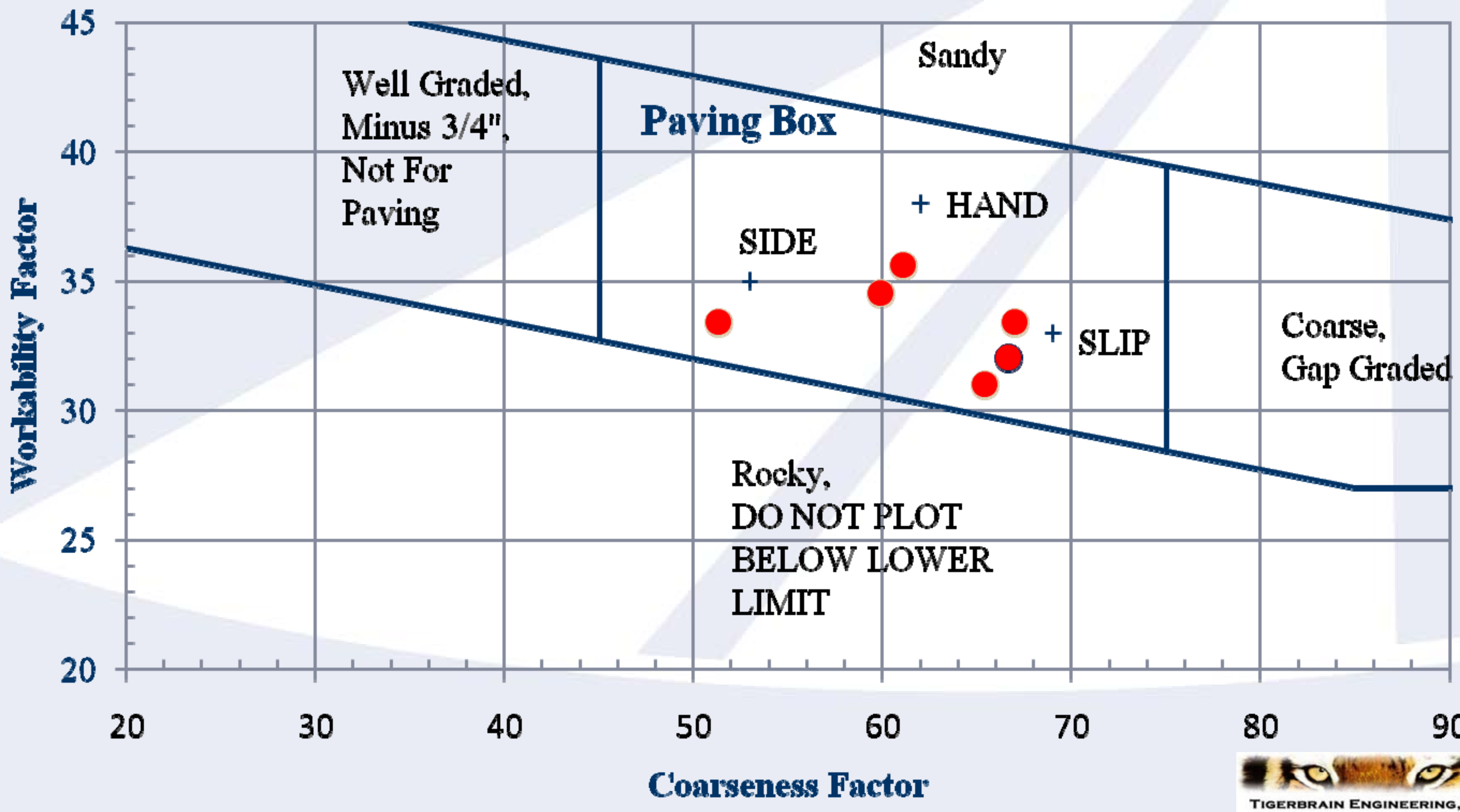


NOTES:

① **COARSENESS FACTOR =** $\frac{\text{\% RETAINED ABOVE 9.5mm SIEVE}}{\text{\% RETAINED ABOVE \#8 SIEVE}} \times 100$

② **WORKABILITY FACTOR =** % PASSING #8

WF & CF



45
40
35
30
25
20
Workability Factor
20
30
40
50
60
70
80
90
Coarseness Factor
Well Graded,
Minus 3/4",
Not For
Paving
Paving Box
Sandy
HAND
SIDE
SLIP
Coarse,
Gap Graded
Rocky,
DO NOT PLOT
BELOW LOWER
LIMIT
TIGERBRAIN ENGINEERING, INC.

Aggregate Proportioning Guide

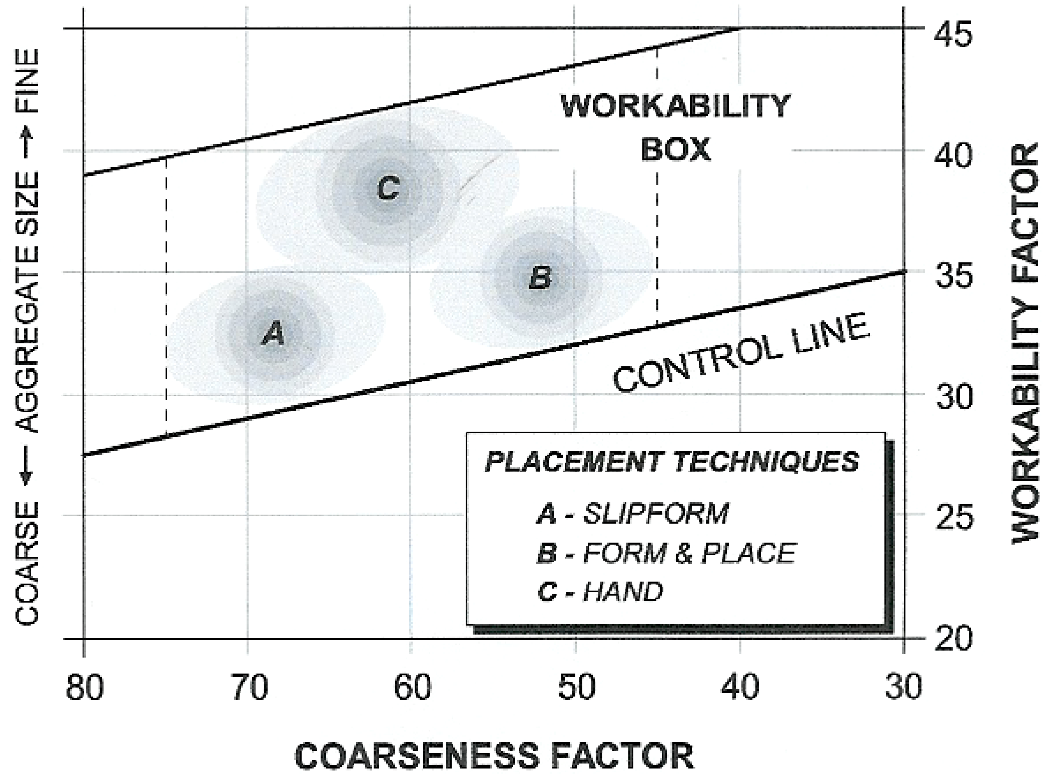


Figure 3.3 Workability Box Within Aggregate Proportioning Guide

WF & CF = “Big Box”

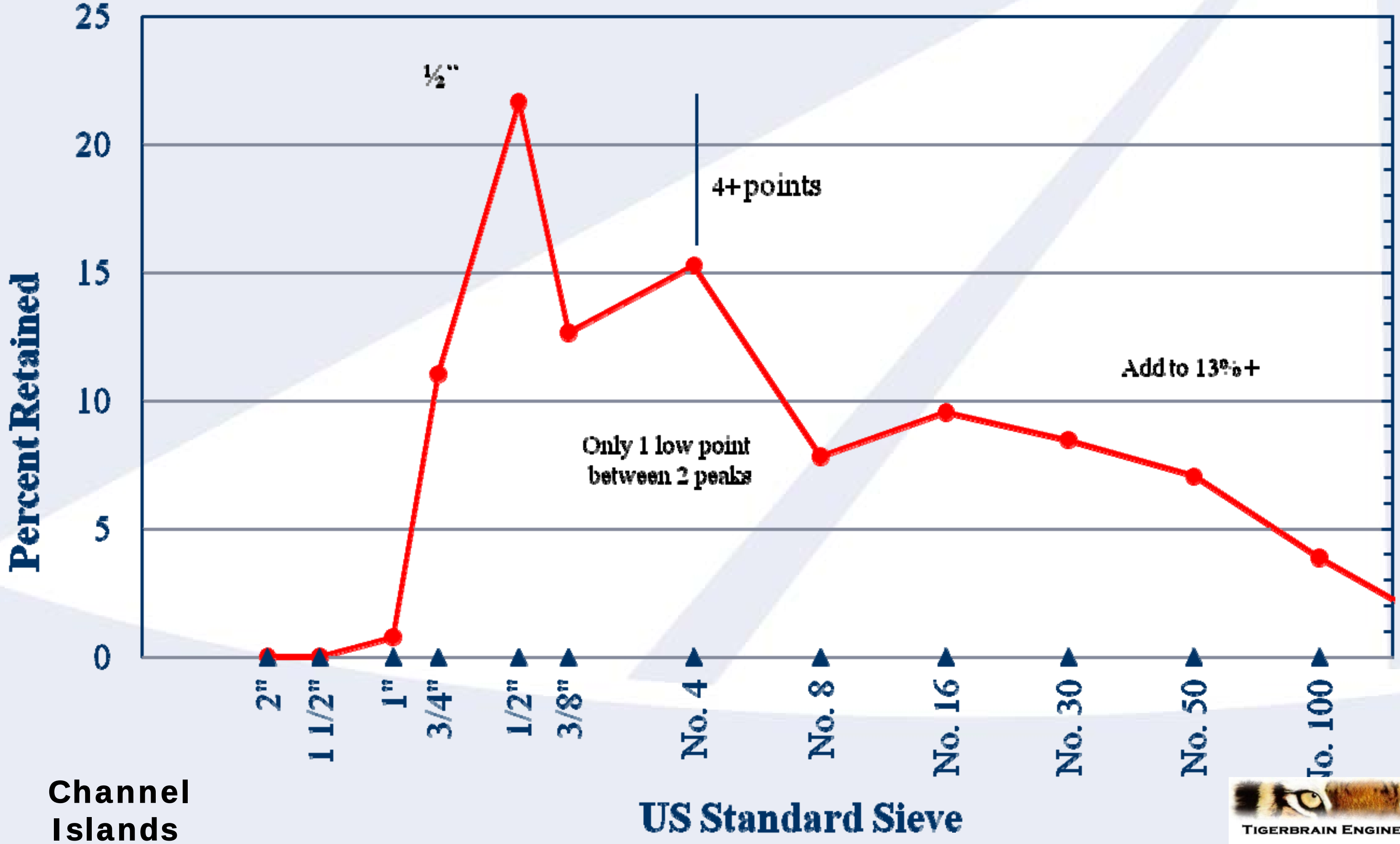
- Big Box is mandatory
- Outside, mix will not work
- Inside, mix occasionally has issues
- Percent Retained & 0.45 Power Curve help refine

Tigerbrain Engineering, Inc.

Percent Retained

- Highest Peak on 1/2 inch sieve or larger
- At least 4 points difference between peaks
- Sum of two adjacent points is 13% or more, except for maximum size, No. 100 and No. 200 sieves
- No more than 2 low points between 2 peaks

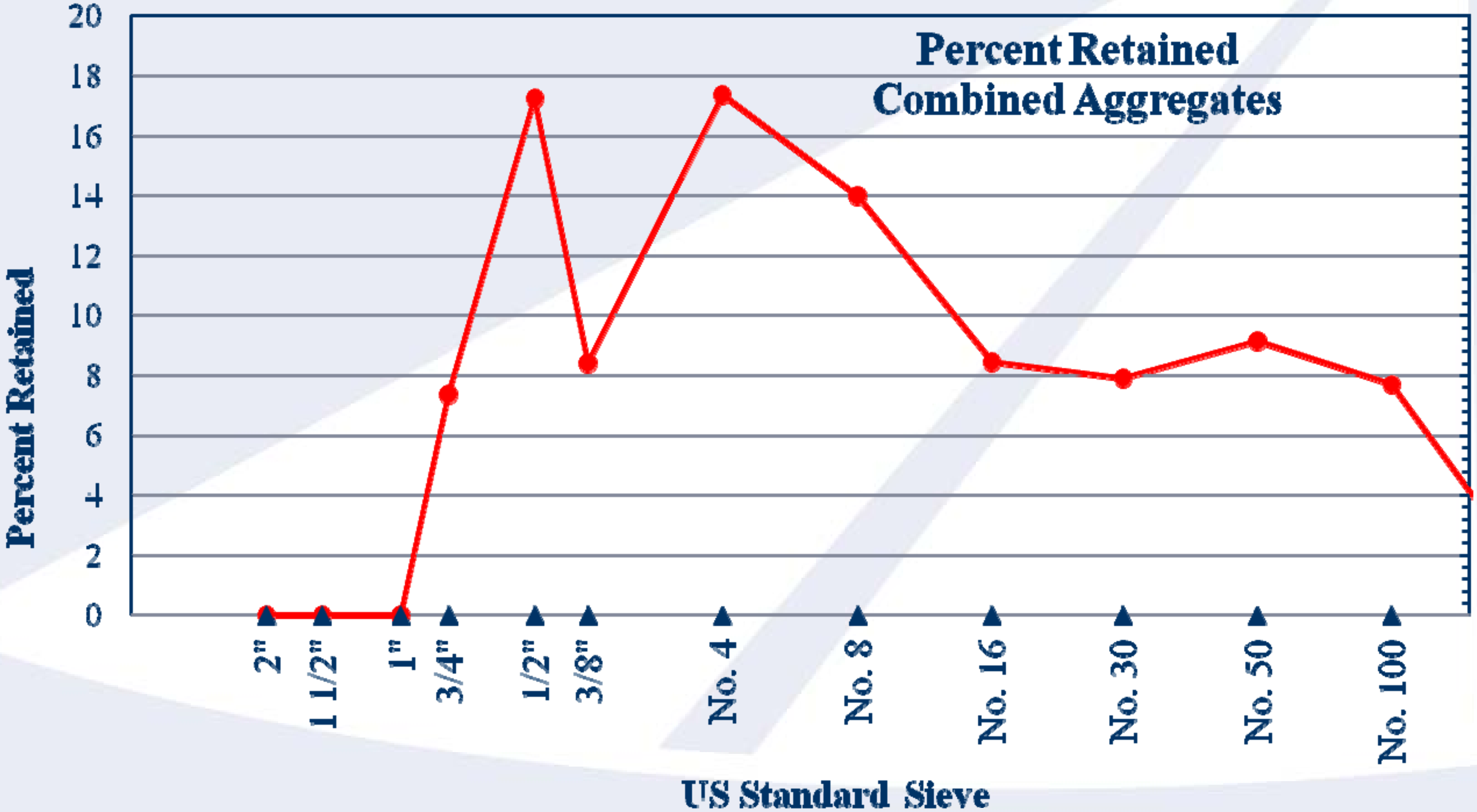
Percent Retained



Channel Islands

TIGERBRAIN ENGINEERING, INC.

Percent Retained – Equal Peaks



Base X Highly sensitive to water—too hard to pave

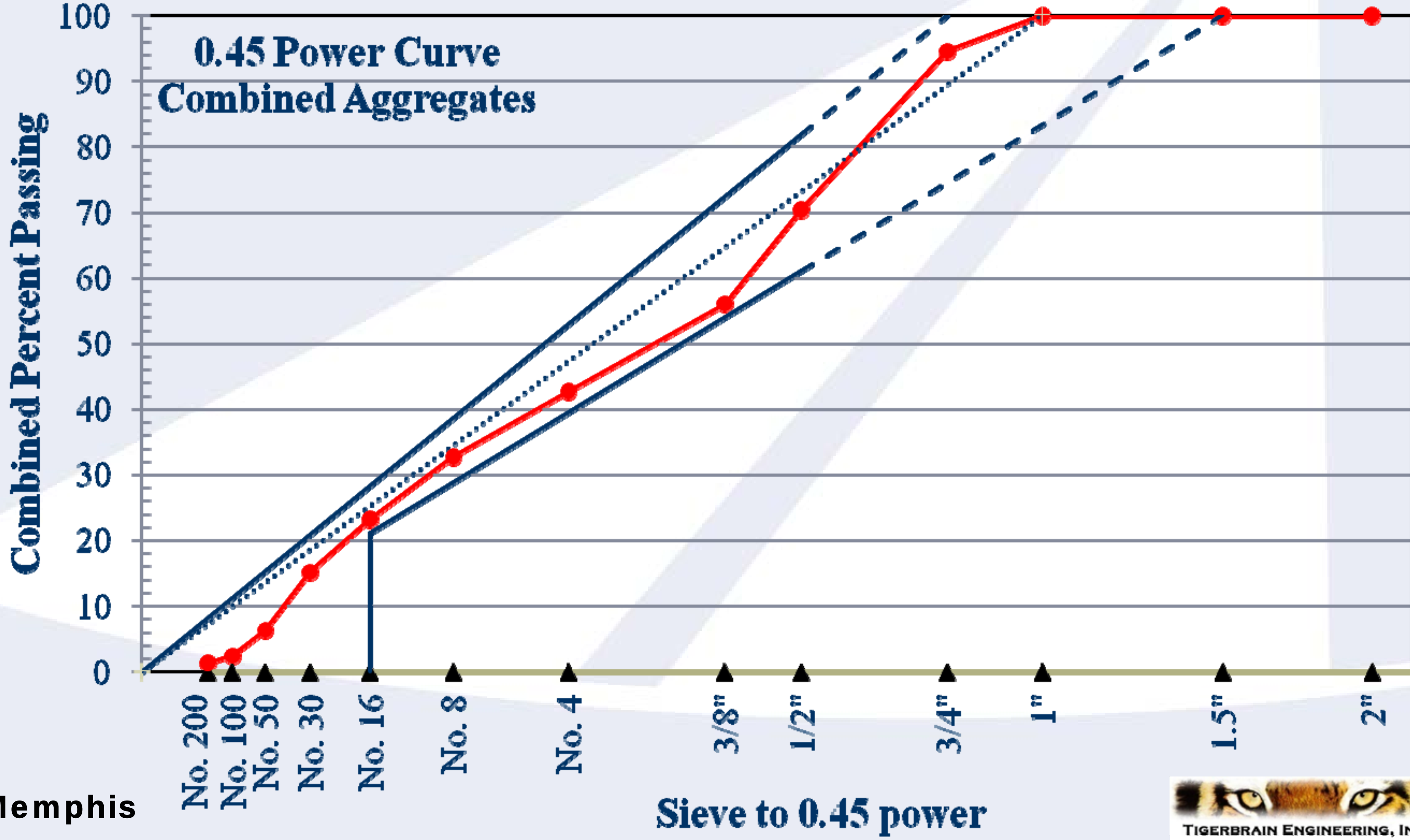
Two Peaks -Water Sensitivity

TIGERBRAIN ENGINEERING, INC.

Two Peaks

TIGERBRAIN ENGINEERING, INC.

0.45 Power Curve



Memphis

TIGERBRAIN ENGINEERING, INC.

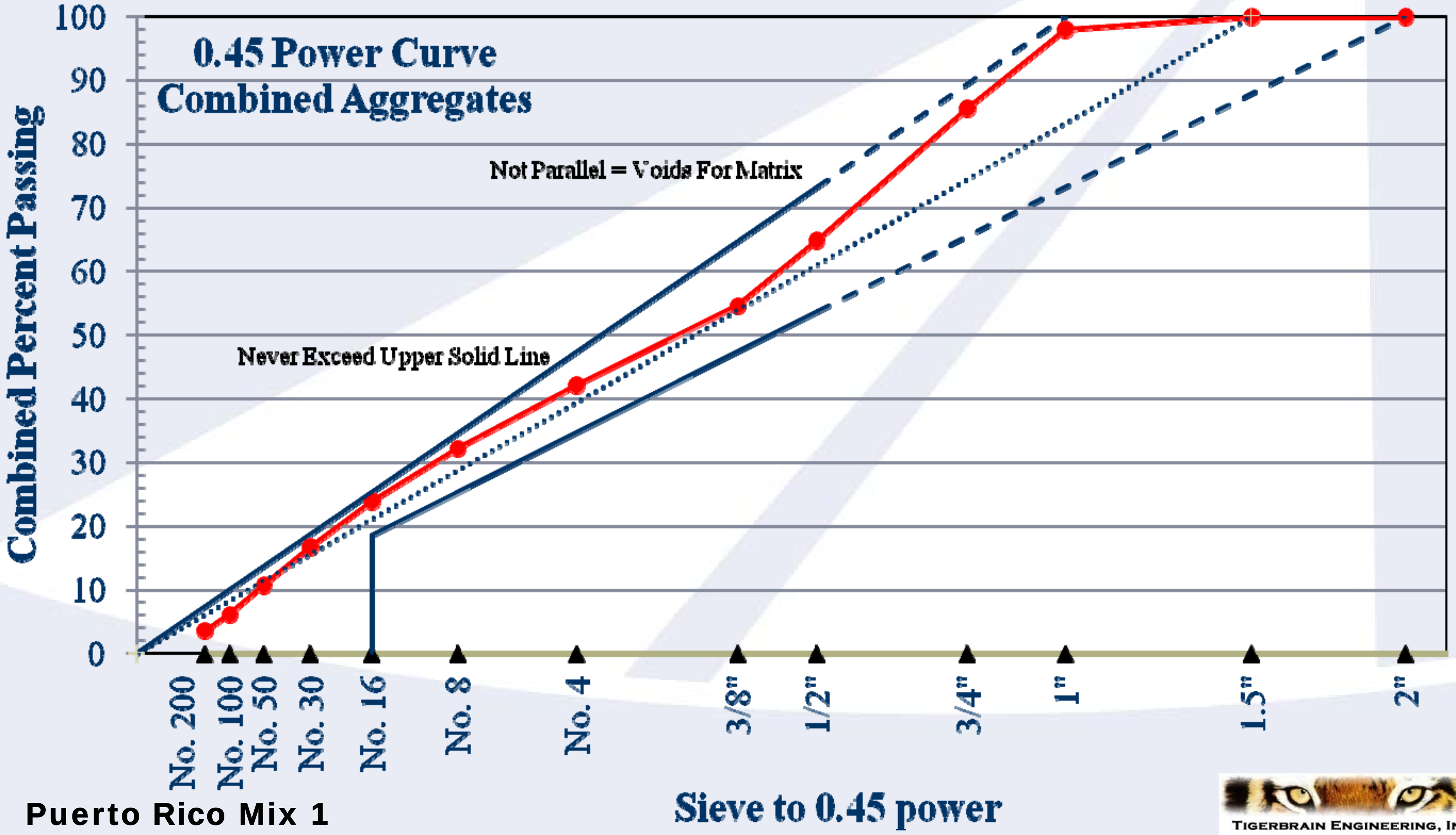
0.45 Power Curve

- Never exceed upper solid line
- Never consider exceeding upper solid line
- Avoid exceeding upper solid line
- Do not parallel the maximum density line

-Upper Solid Line Controls Sliver Spalls
-Especially in the No. 16 to No. 100 Sieves
-Parallel Contributes to Sliver Spalls, difficult to work

TIGERBRAIN ENGINEERING, INC.

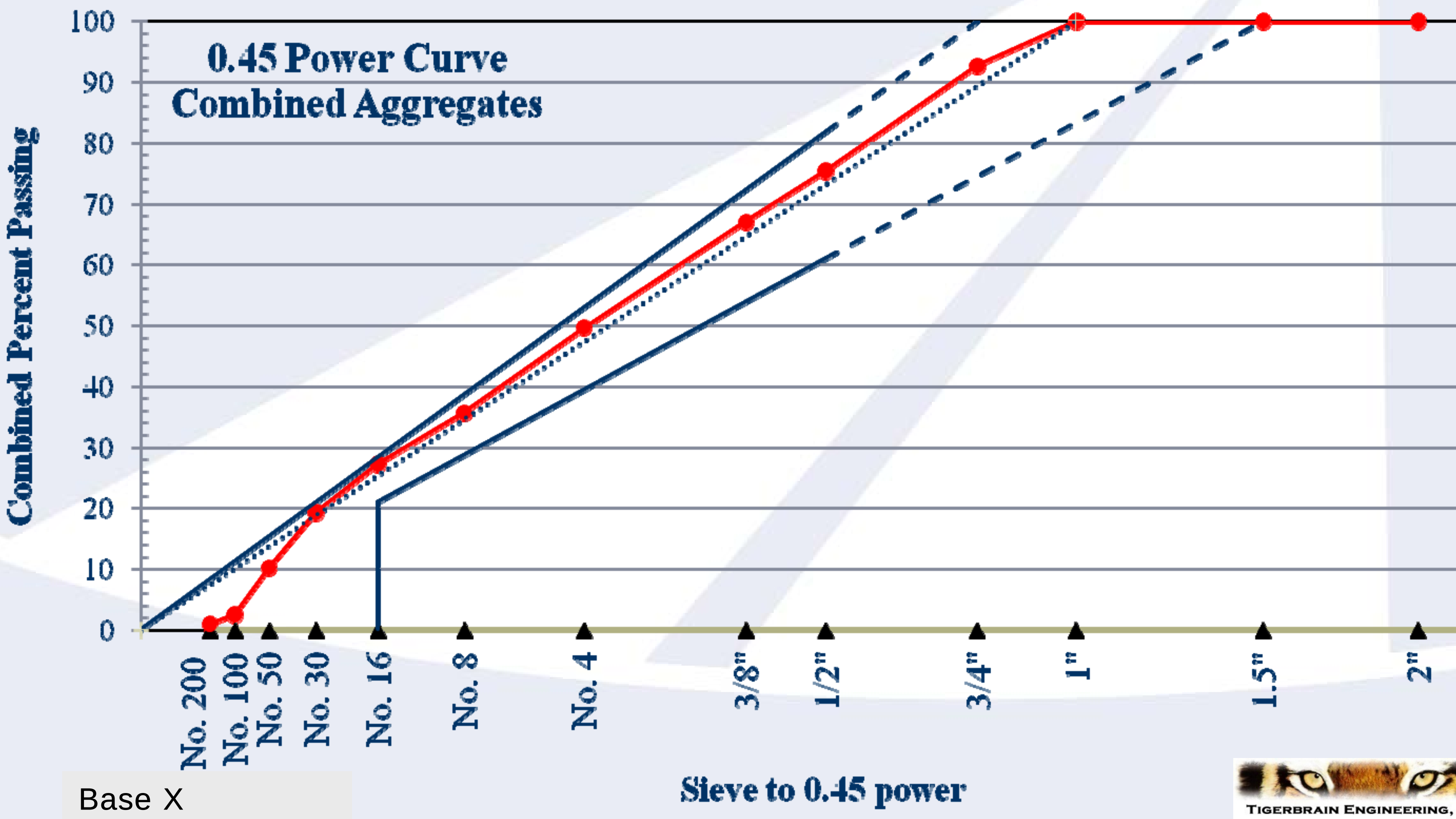
0.45 Power Curve - Good



Puerto Rico Mix 1

TIGERBRAIN ENGINEERING, INC.

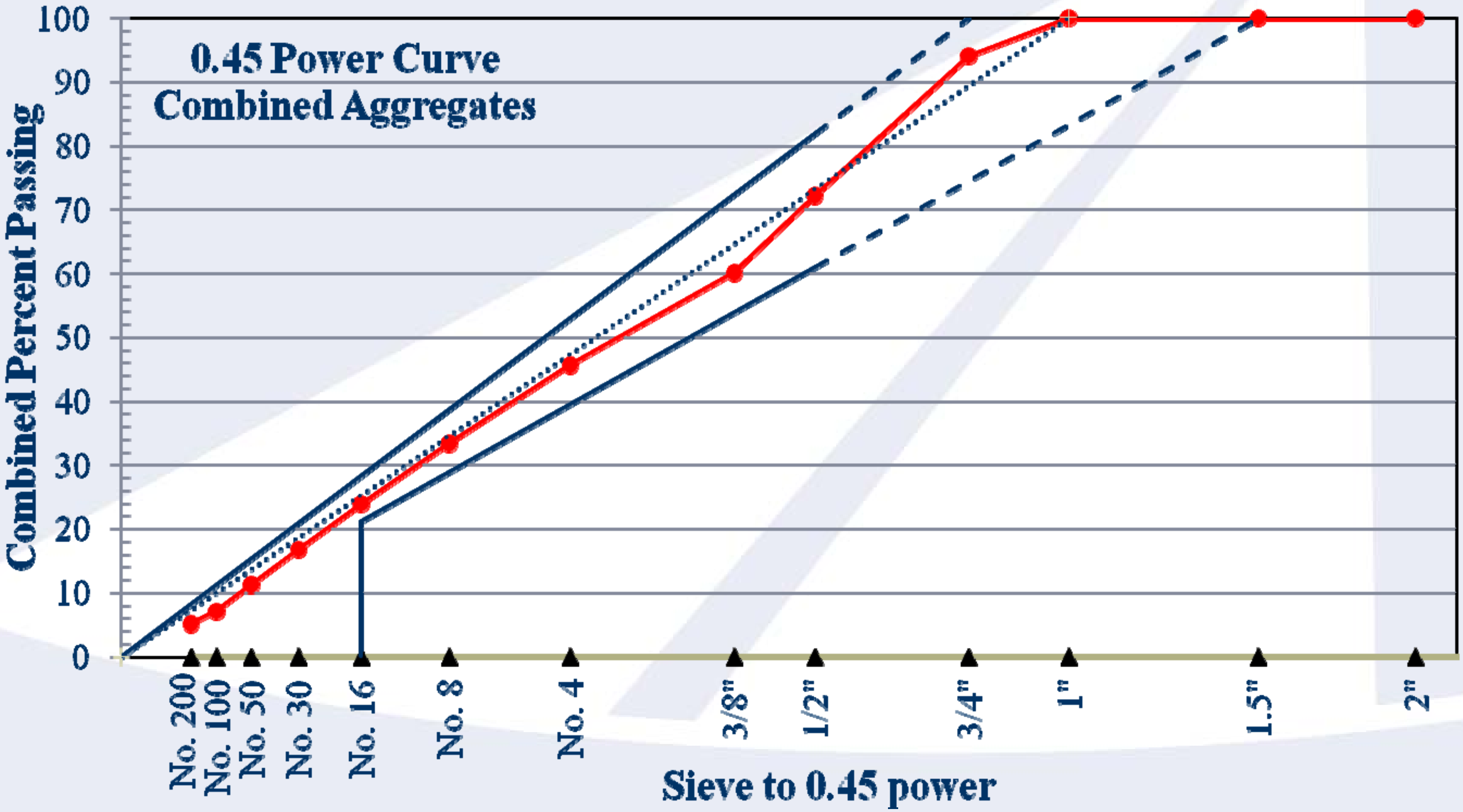
Do Not Parallel Max Density



Base X

TIGERBRAIN ENGINEERING, INC.

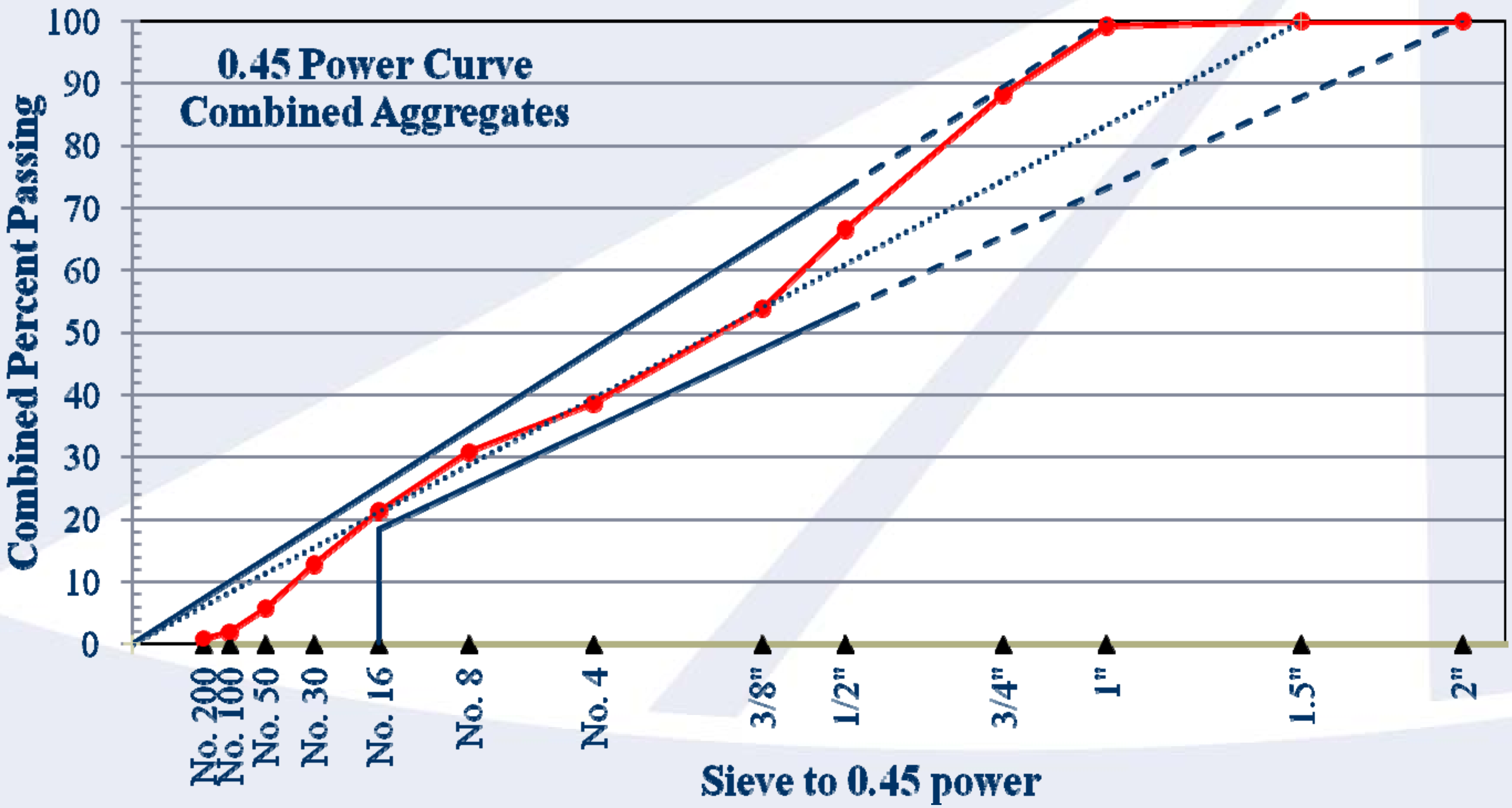
0.45 Power Curve - Good



Puerto Rico Mix 2

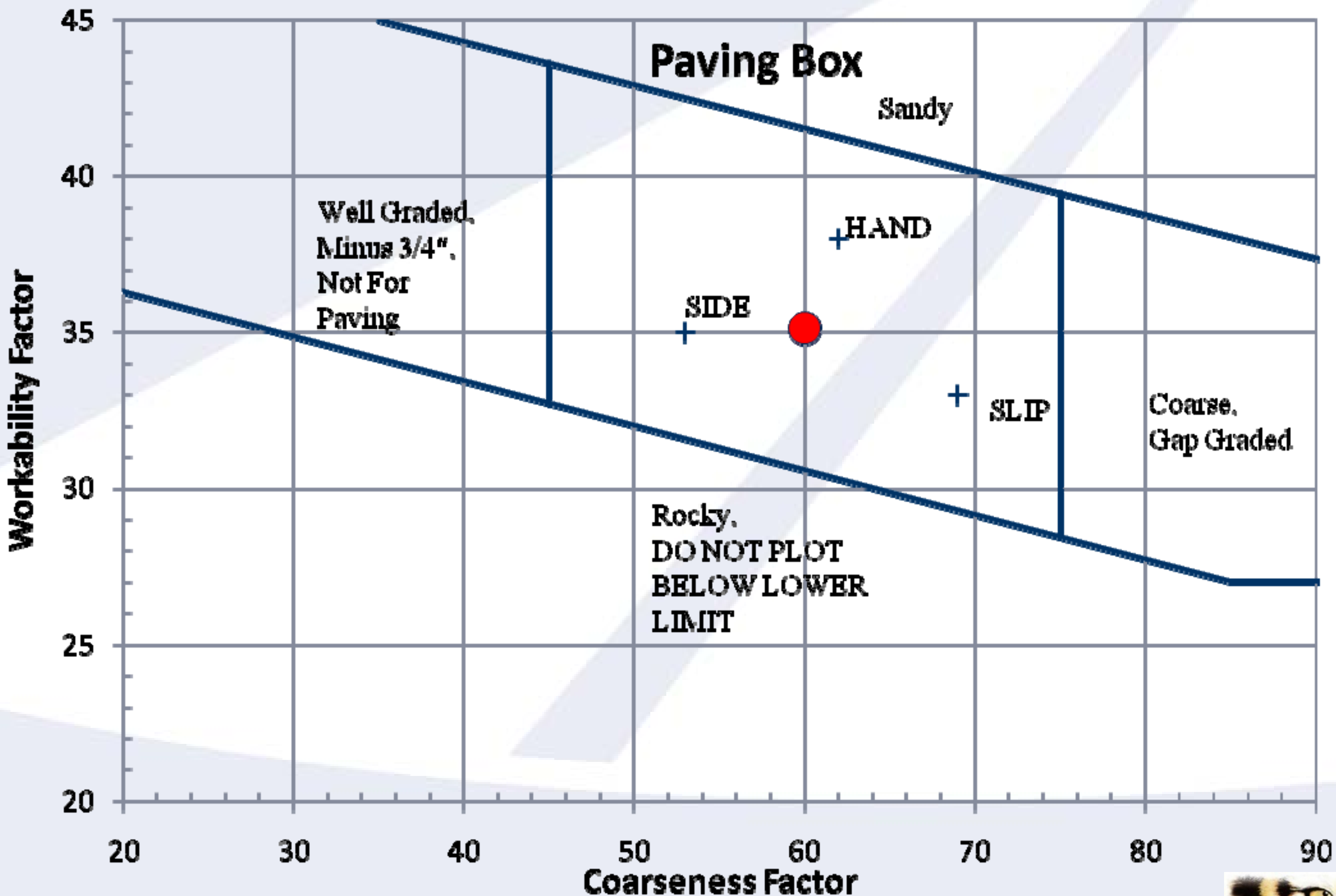
TIGERBRAIN ENGINEERING, INC.

0.45 Power Curve - Good



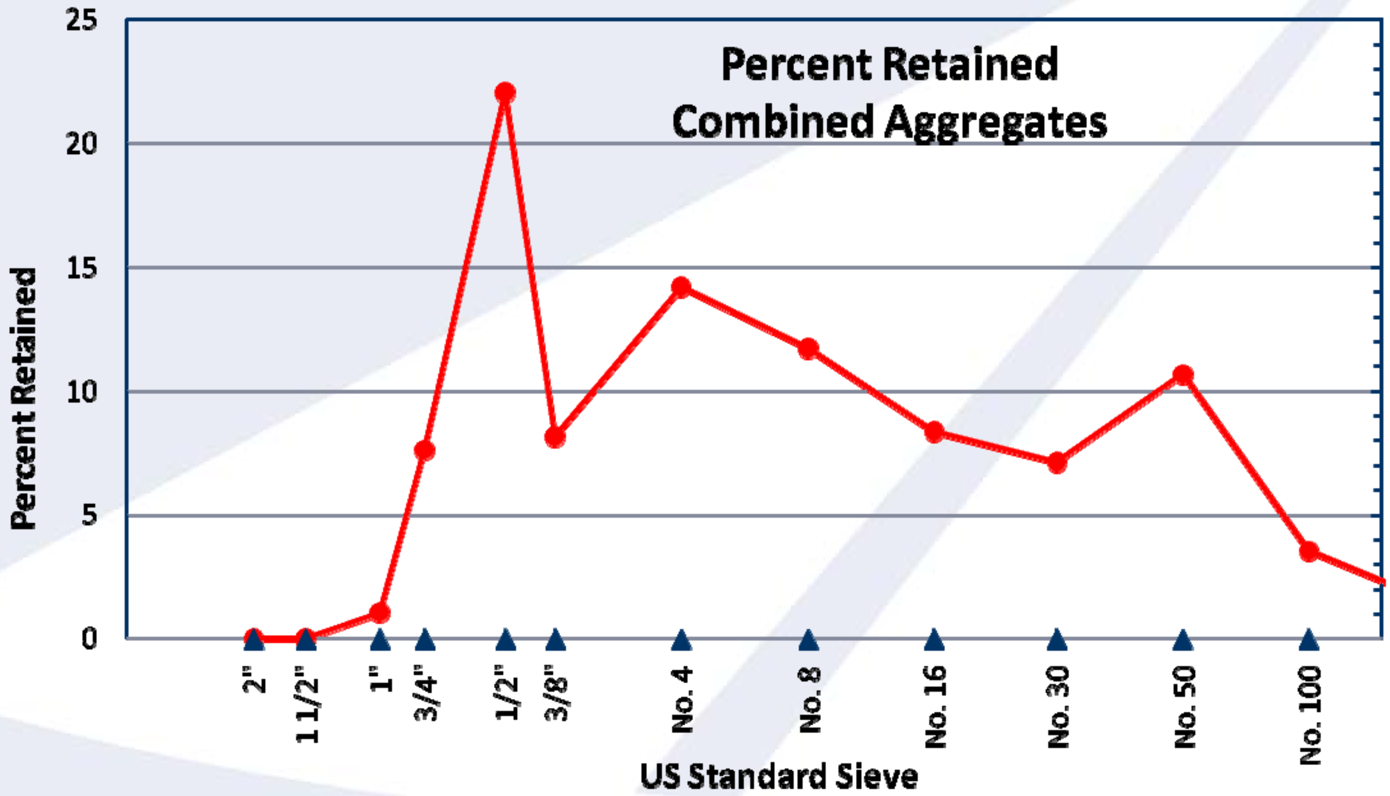
Channel

Memphis R/W 9-27



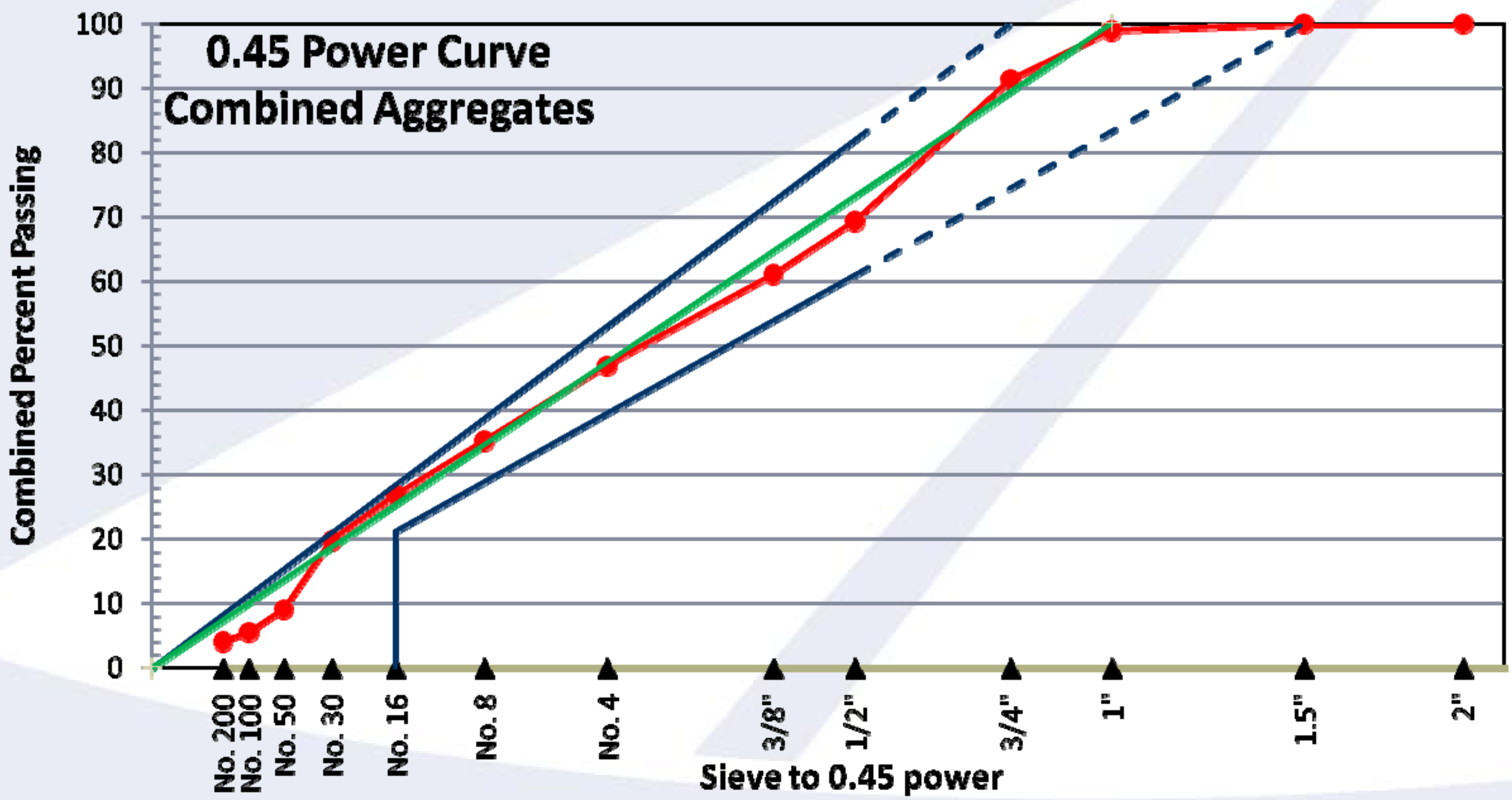
TIGERBRAIN ENGINEERING, INC.

Memphis R/W 9-27



Tigerbrain Engineering, Inc.

Memphis R/W 9-27



TIGERBRAIN ENGINEERING, INC.

Aggregate Shape & Size

- Slipform needs crushed aggregate
- Sideform may use gravels or crushed
- Maximum size –
  - let the contractor choose ¾ inch or larger
  - Larger max size requires more intermediate sizes
  - 1.5” rock is not available everywhere

TIGERBRAIN ENGINEERING, INC.

To Be Wise

- This is all “paper” analysis
- Must make trial batches with batch plant
- Must adjust proportions to optimize mix
  - do it with the contractor
- Must pave and adjust proportions to paver and site
- *Combined* proportions are the approved mix

Daily Paving

- Gradation of each stockpile prior to paving
- Mathematically check combined gradation
- Adjust individual batch weights to achieve target combined gradation
- If WF is ± 3pts and CF ± 5 pts,
  - May see placement workability changes
  - No measurable strength changes

Tigerbrain Engineering, Inc.

How Do you Know its Right?

Tigerbrain Engineering, Inc.

Not Quite There

TIGERBRAIN ENGINEERING, INC.

But it looks good?

But after fixing the plant...

Memphis ANG

TIGERBRAIN ENGINEERING, INC.

Memphis ANG

Tigerbrain Engineering, Inc.

Memphis R/W 9-27

TIGERBRAIN ENGINEERING, INC.

Memphis R/W 9-27

San Juan R/W 10-28

Not Quite...

San Juan R/W 10-28

Got it!

Mineral Admixture

- Fly Ash
  - Class F - >15% and < 25%
  - Class C – be careful (chemical analysis)

Chemical Admixture

- Air entraining
- Set-retarding
- Accelerating
- Water reducing
- Must be compatible with other components

Mineral Admixtures

- Flyash
  - Improves Durability
  - Increases Water Demand
  - Increases AEA
  - Sand Reduction
  - Class C contains calcium
  - Hot ↑ Cold ↓
- GGBFS
  - Cementitious
  - Improves Durability
  - Improves Workability
  - No Bleed Water
  - Stiff Mix
  - Sensitive to Vibration
  - Saw Cutting Critical

Basic Cement Reaction

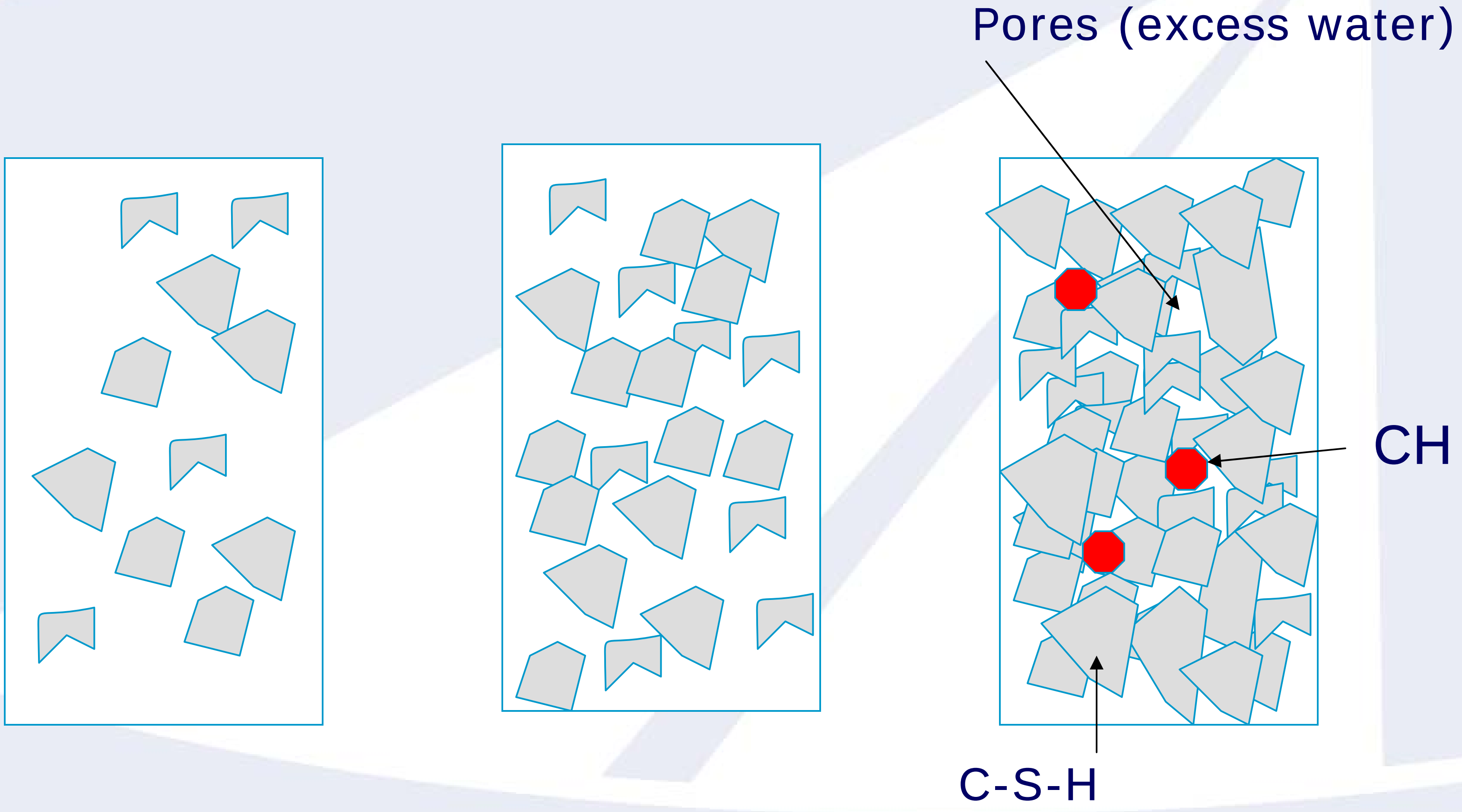
$2\ C_3S + 6H = C_3S_2H_3 + 6\ CH + heat$

Additional Water yields no additional C-S-H

$2\ C_3S + 8\ H = C_3S_2H_3 + 6\ CH + 2H + heat$

Min w/c for full hydration < 0.32

Age Effects



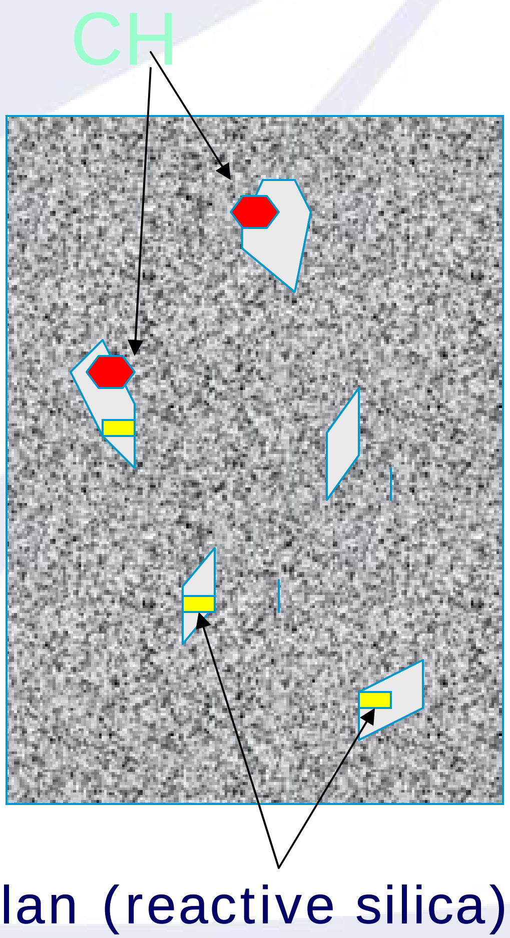
Pozzolans

- Reactive Silica from Ash, Slag, Fume
- Bonds Chemically with CH formed by cement reaction
- Slower Strength Gain
    - Takes time to get started
    - No heat early
    - Doesn't retard but does dilute
- Improves Durability
    - Fills existing pores
    - Removes reactive components

Pozzolanic Reaction

CH + S = C-S-H

- Additional Curing Time
- Lower early strengths
- Higher ultimate strengths
- Reduced permeability



Pozzolans: Typical Quantities

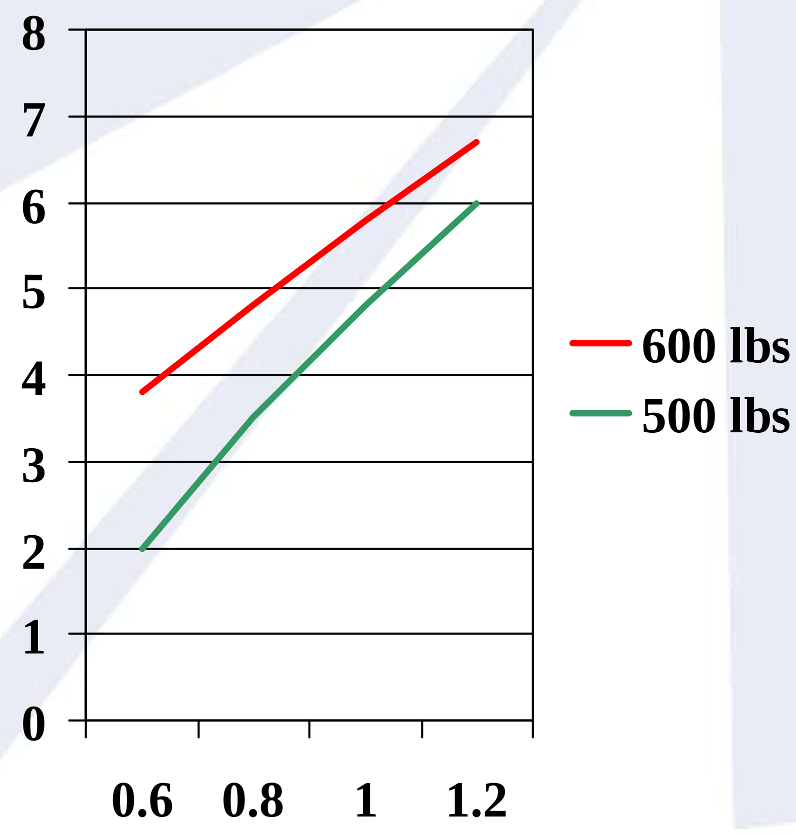
- Fly Ash: 15 – 25 %
  - 25 % max if deicing salt exposure
  - Help mitigate ASR??
- Slag: 40 – 60 %
- Silica Fume: 5 – 12 %
  - Cost
  - High water demand (HRWR typically)

Pozzolans: Effect of Replacement

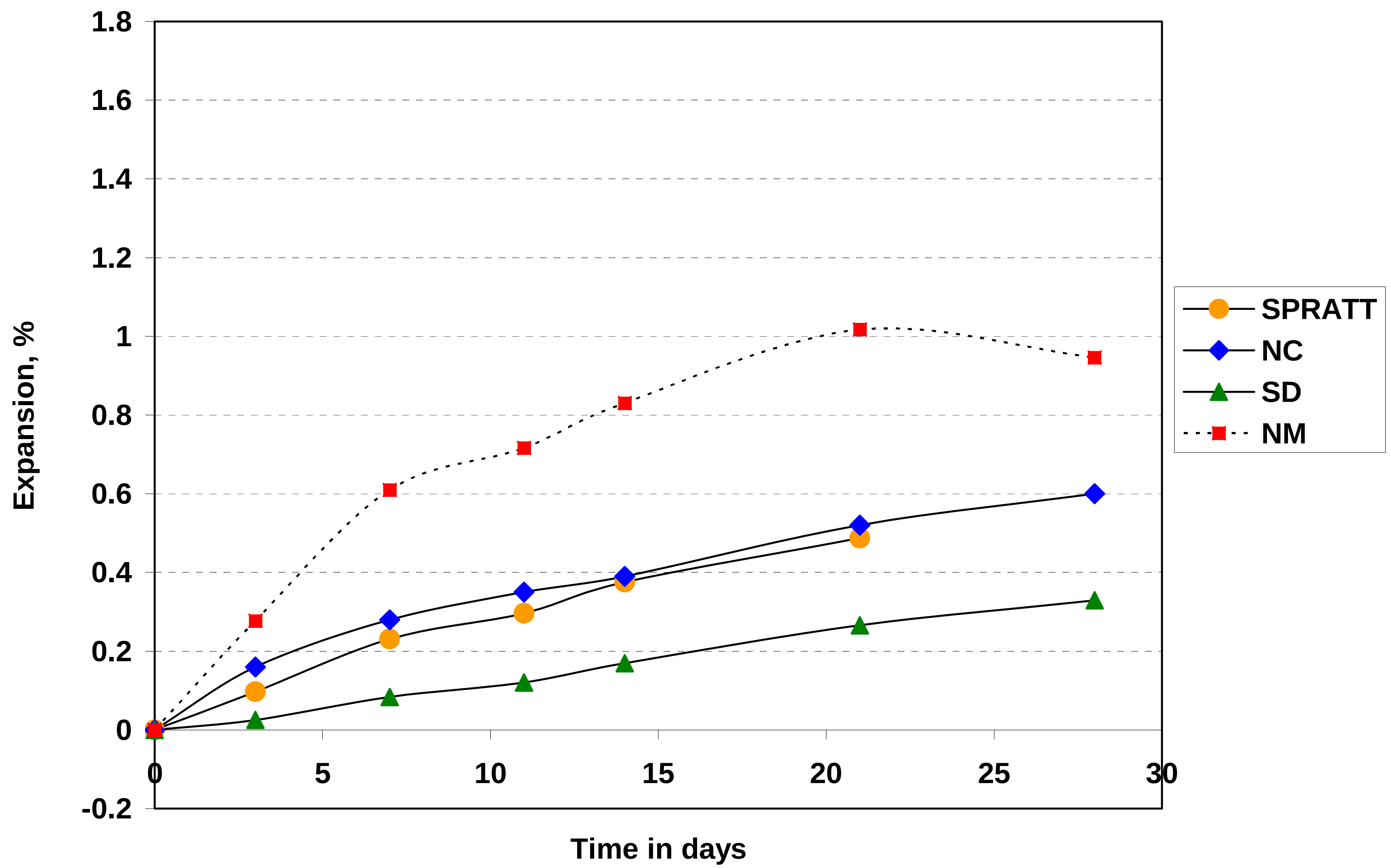
- Fly Ash: 20%
  - 1.2 to 1.3 to 1 (or higher)
  - 130 PCY to replace 100 PCY of cement
- Slag: 50%
  - 1 to 1 replacement
- Silica Fume: 7%
  - Very high cost
  - High strength and durable

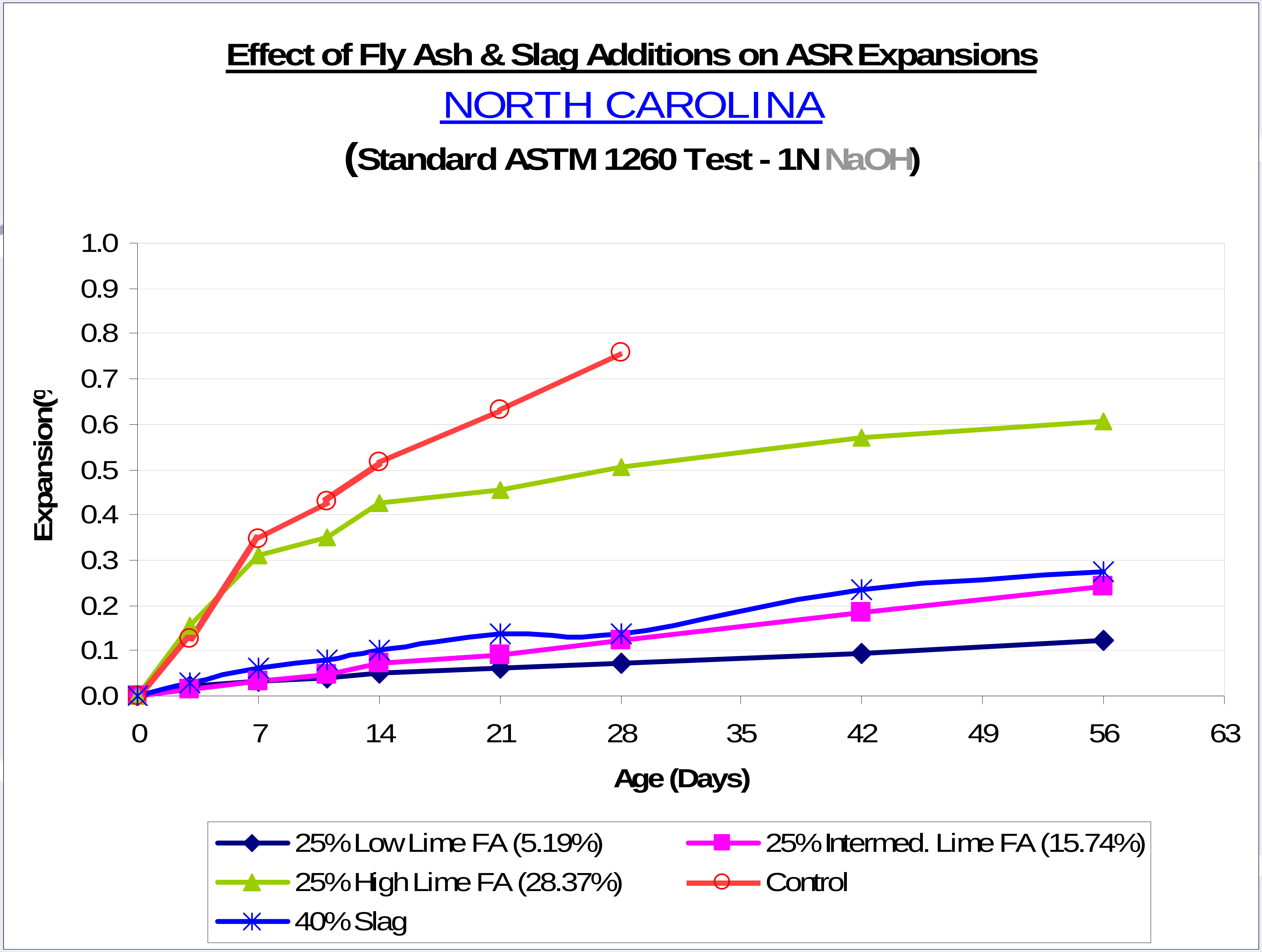
What is ASR Potential?

- Potential Exists When
  - >5 lbs/cu yd alkali
  - Moisture
  - Reactive Aggregate
- Concentrated Alkali's
  - ASR Potential



Control (1 N NaOH Soak Solution)



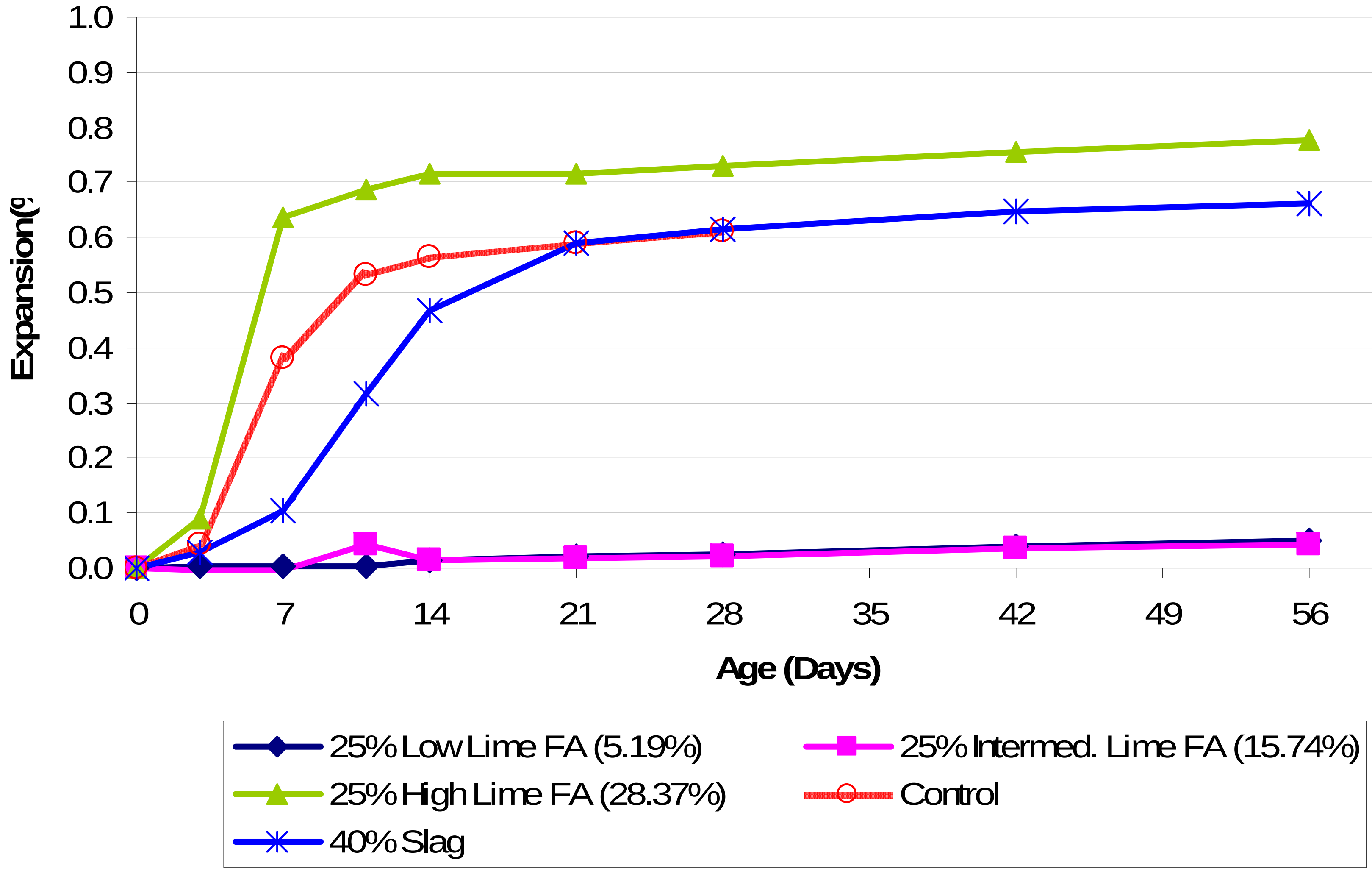


Effect of Fly Ash & Slag Additions on ASR Expansions
NORTH CAROLINA
(Standard ASTM 1260 Test - 1N NaOH)
Expansion(%
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
7
14
21
28
35
42
49
56
63
Age (Days)
25% Low Lime FA (5.19%)
25% Intermed. Lime FA (15.74%)
25% High Lime FA (28.37%)
Control
40% Slag

Effect of Fly Ash & Slag Additions on ASR Expansions

NORTH CAROLINA

(Modified ASTM 1260 Test - 50% conc. Potassium Acetate)



Optimize Concrete Mixtures coupled with SCM can lead to longer lasting – more durable airfields Pavements.

TIGERBRAIN ENGINEERING, INC.

Questions?