Coarseness - Workability - Consolidation
A New Approach

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Acknowledgements

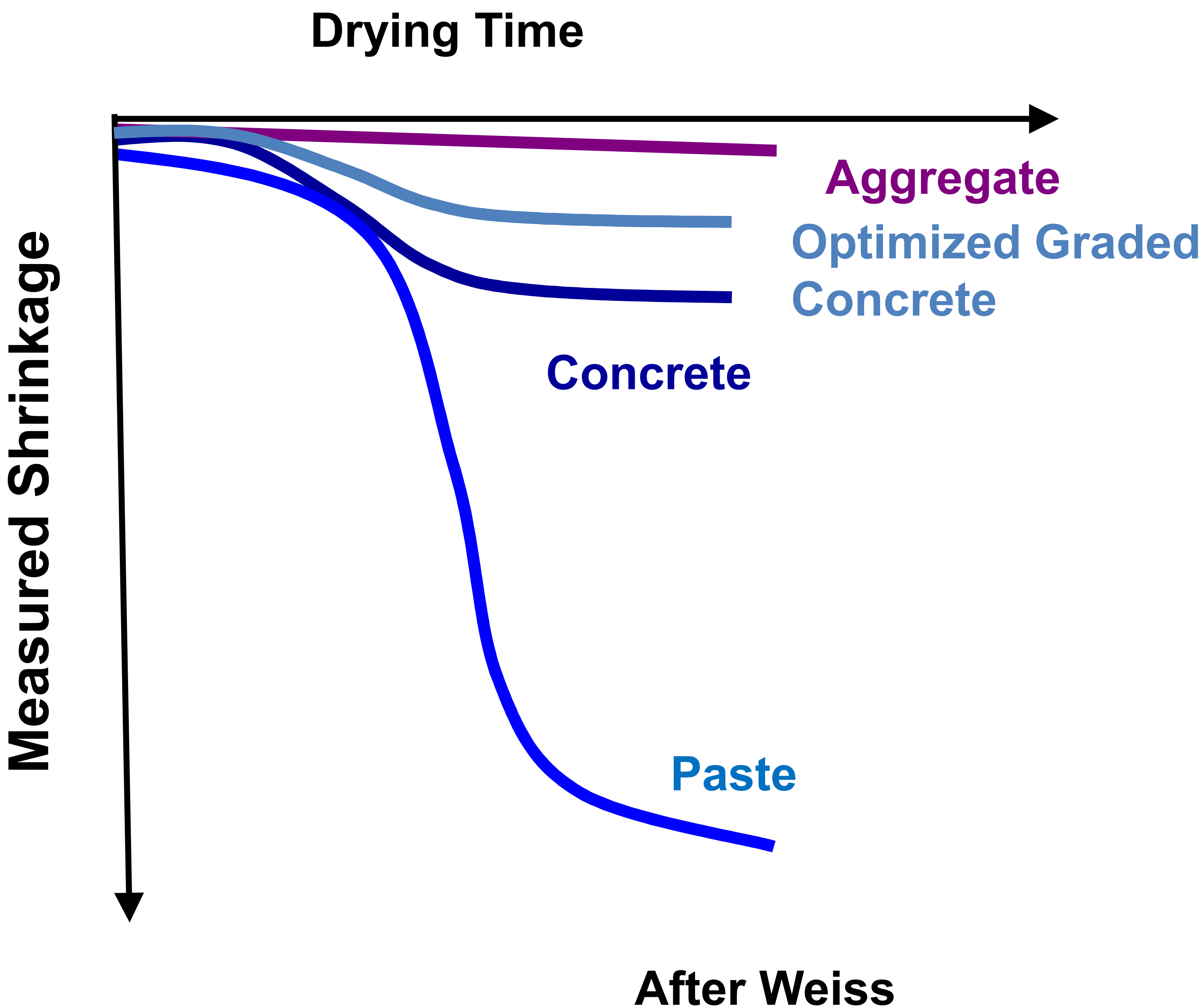
- Oklahoma Department of Transportation (ODOT)
- Oklahoma Transportation Center
- CP Tech Center
- FHWA hfl
- Trinity Construction
- Dolese Bros Company
- Martin- Marietta
- Arkhola Sand and Gravel
- Lafarge

Outline

- Introduction of OG concrete
- The Box Test
- A new path forward

What is OG concrete all about?

- The goal of OG concrete is to **increase** the volume of **aggregate** and **decrease** the volume of **paste**
- paste = binder + water + air
- The paste is the most costly, least sustainable concrete ingredient and has the biggest impact on the durability



Drying Time
Measured Shrinkage
Aggregate
Optimized Graded Concrete
Concrete
Paste
After Weiss

How do you design optimized graded concrete?

- Find your aggregate gradation
- Find out the volume and consistency of the paste that you need for your application
- Check strength and durability

after Koehler and Fowler

How do you find your gradation?

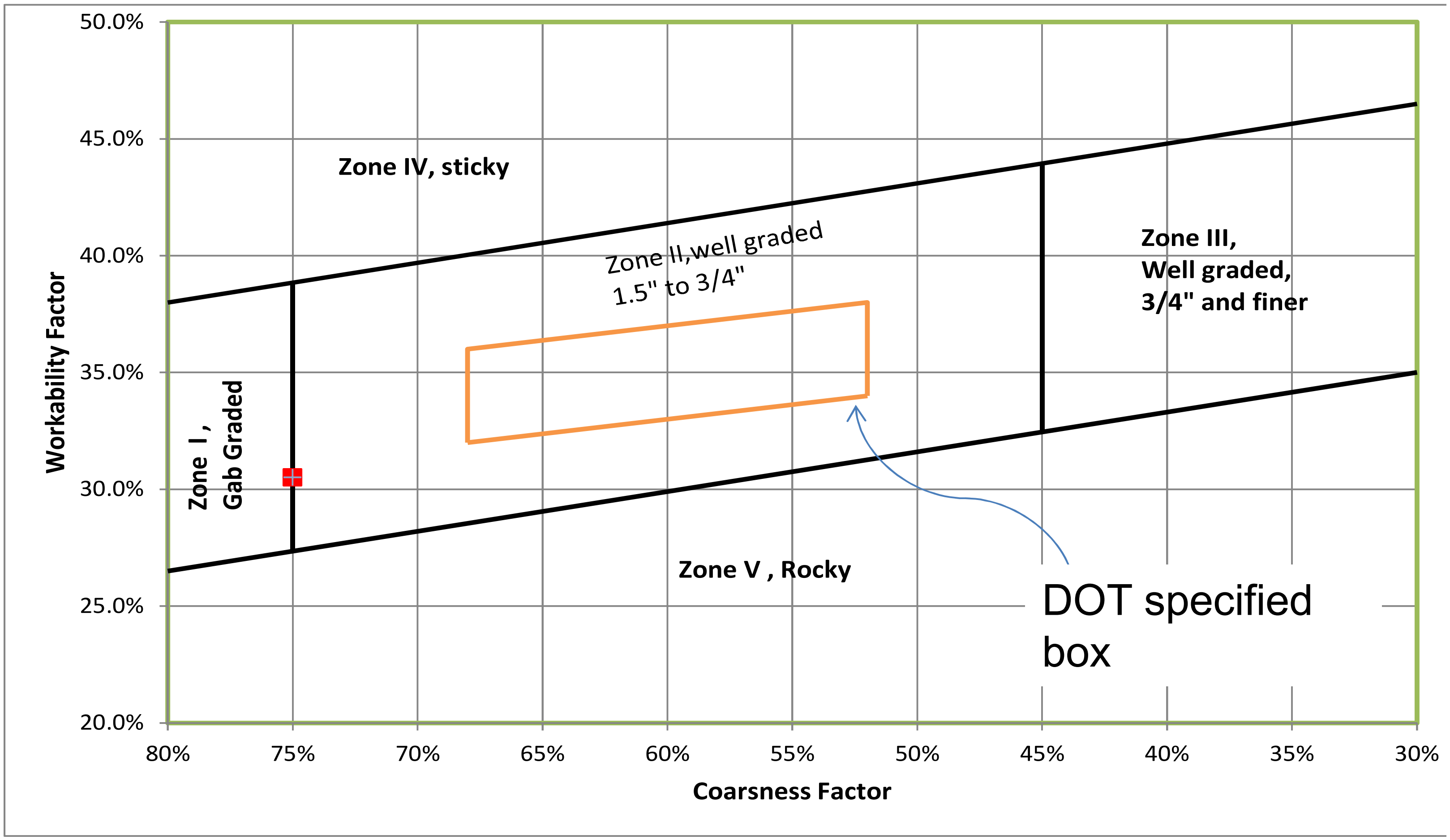
- Shilstone
- 8-18 curves
- Power 45

Which one is right?

What do these tools tell you?

Is one better than the other?

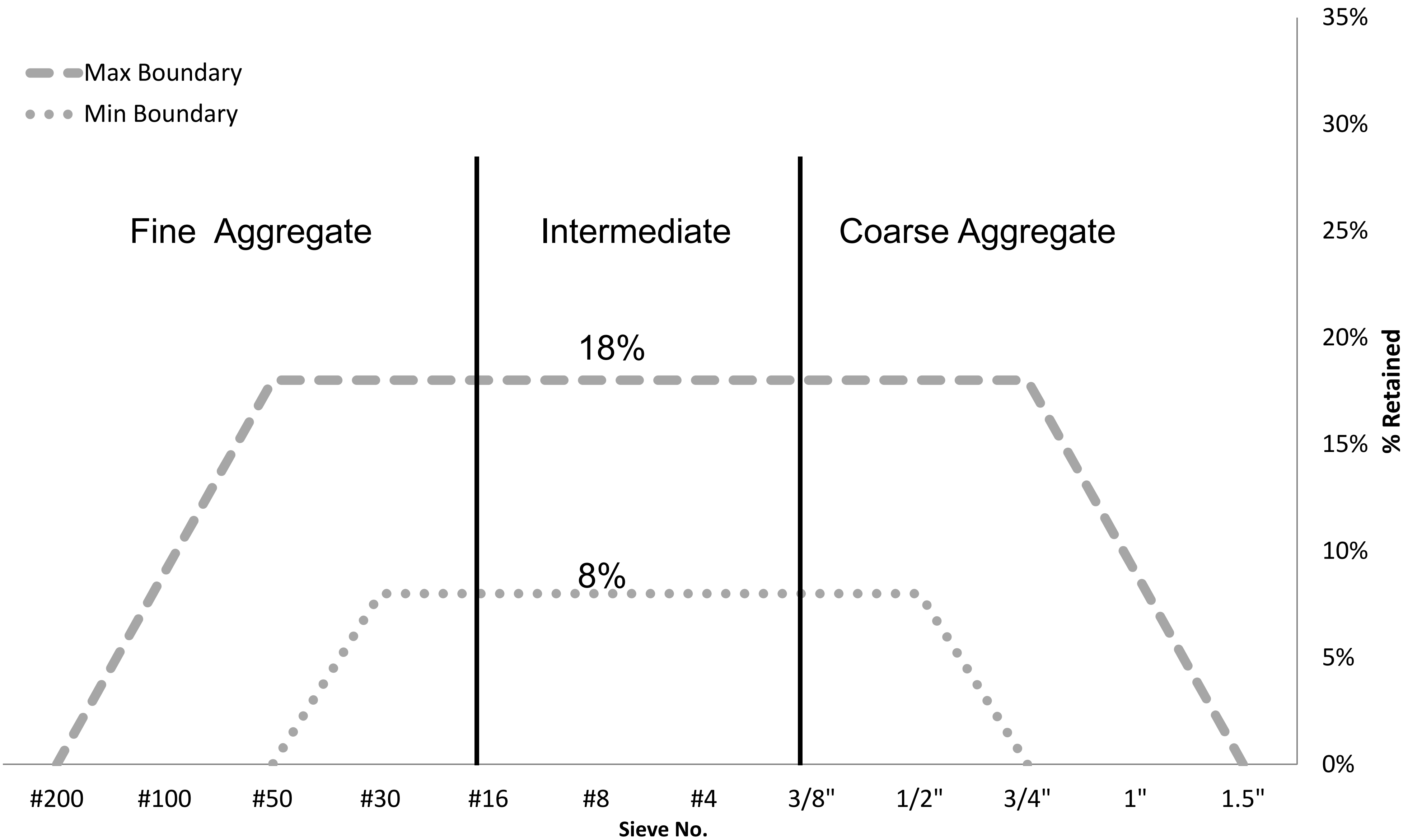
Shilstone



WF = % passing #8 + 2.5x powder above 6 sacks

$$CF = \frac{\text{\% cumulative retained 3/8''}}{\text{\% cumulative retained \#8}}$$

Typical Individual Percent Retained

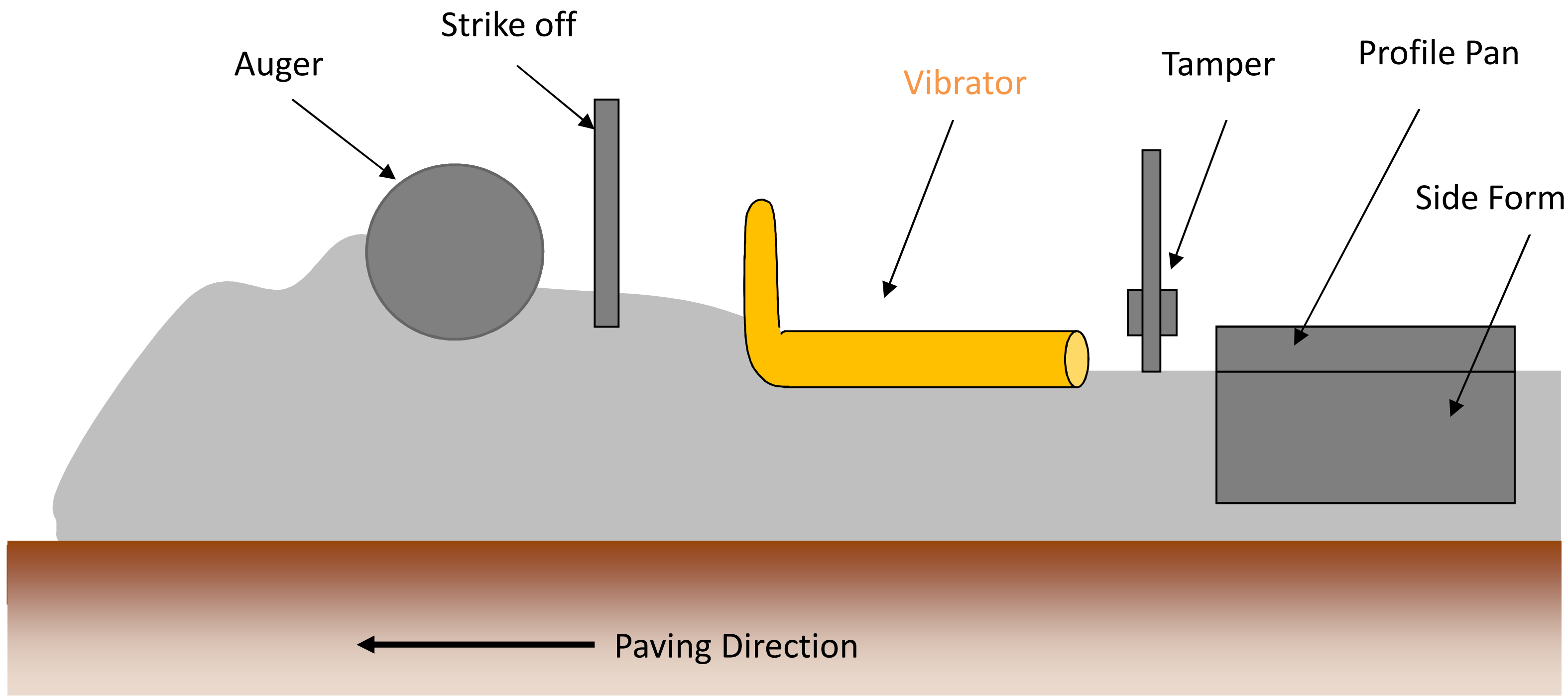


Research Goals

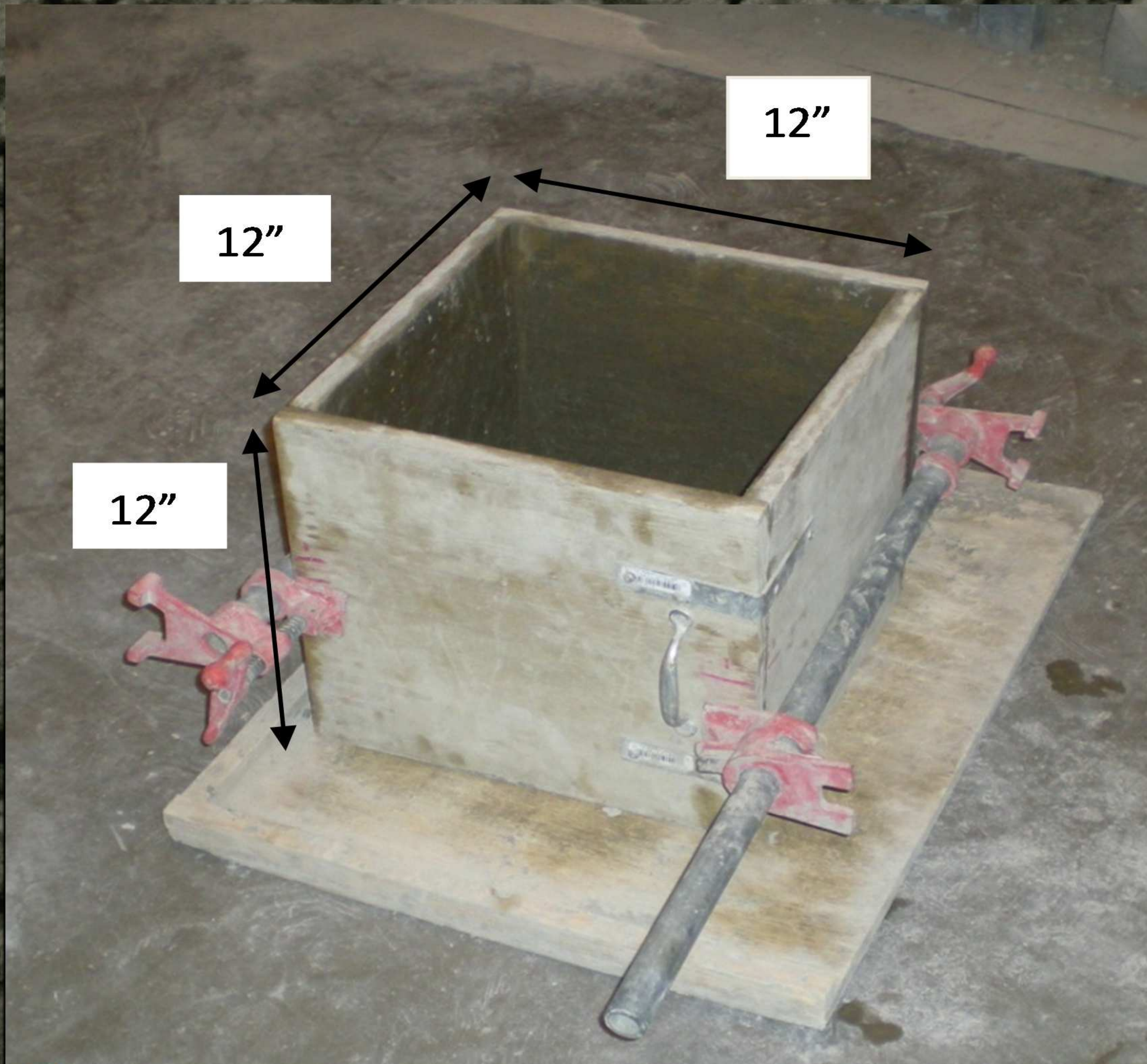
- Find gradations that allow reduced paste content while still providing sufficiently workable concrete for paving.
- We need "enough" workability to make the concrete place able by the paver but not too much that it doesn't hold an edge.
- <u>The slump cone can not tell us this</u>

Slip Formed Paver

What part of a paver is the most critical for concrete consolidation?



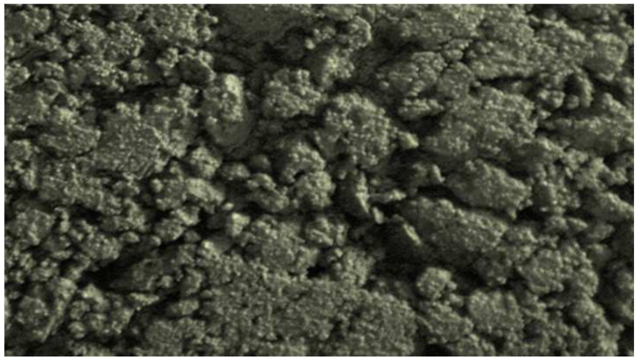
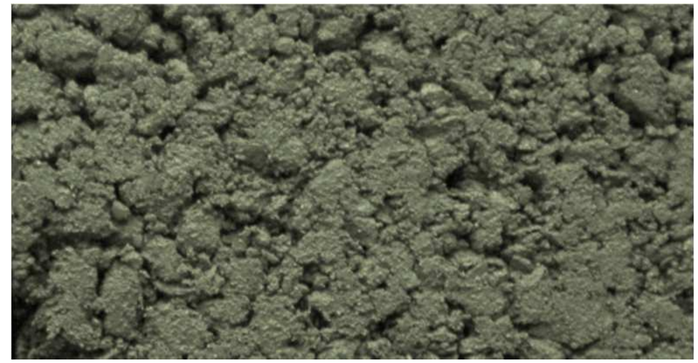
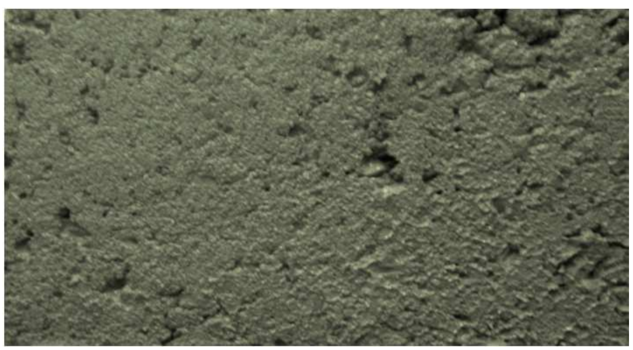
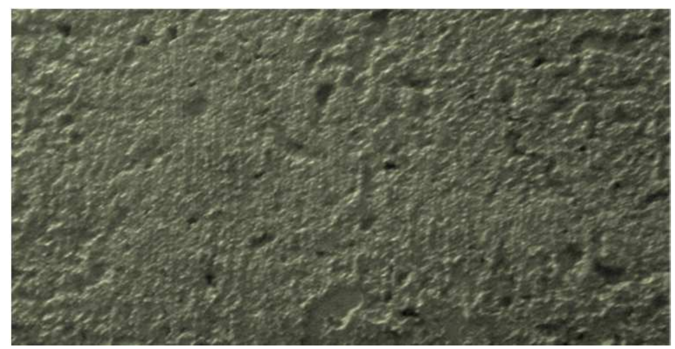
- We want a test that is simple and can examine:
  - Response to vibration
  - Filling ability of the grout (avoid internal voids)
  - Ability of the slip formed concrete to hold a sharp edge (cohesiveness)


12”
12”
12”

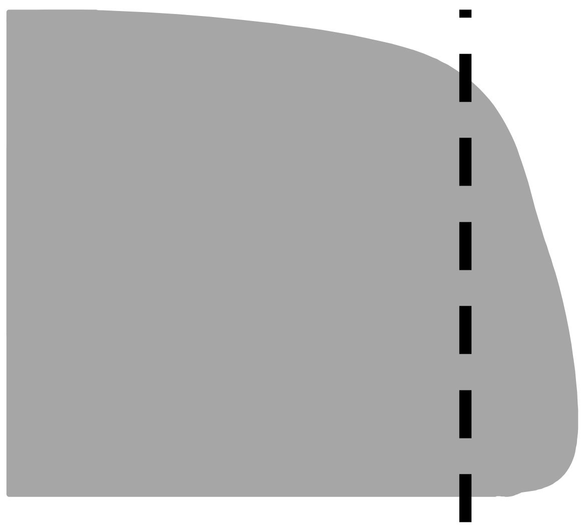
Box Test

- Add 9.5” of unconsolidated concrete to the box
- A 1” diameter stinger vibrator is inserted into the center of the box over a three count and then removed over a three count
- The edges of the box are then removed and inspected for honey combing or edge slumping

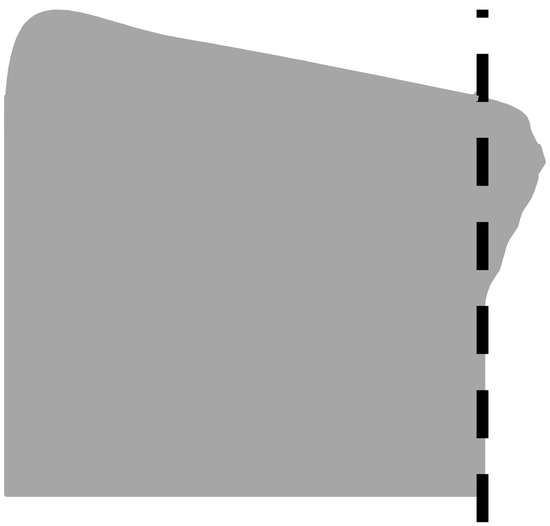
Box Test Ranking Scale

	
4	**3**
Over 50% overall surface voids.	30-50% overall surface voids.
	
2	**1**
10-30% overall surface voids.	Less than 10% overall surface voids.

Edge Slumping



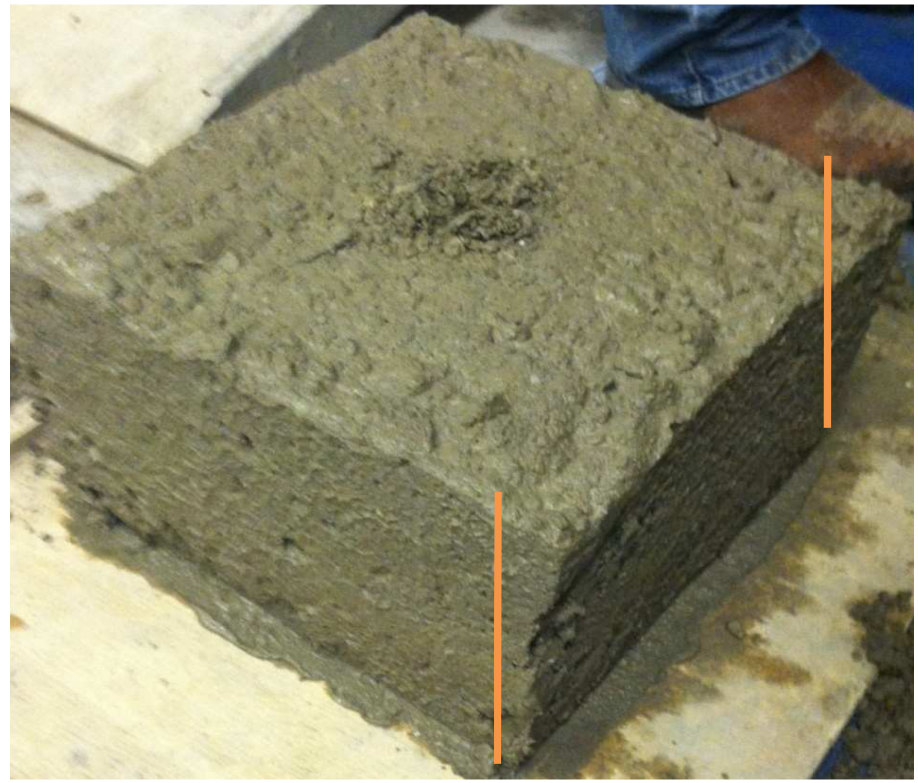
Bottom Edge Slumping



Top Edge Slumping

No Edge Slump

Edge Slump



Question:

Why does a mixture fail the box test?

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Answer: it either needs more paste or more lubrication (plastic yield stress is too large)

Question:

What if we found out how much water reducer it took to pass the box test without changing the paste content?

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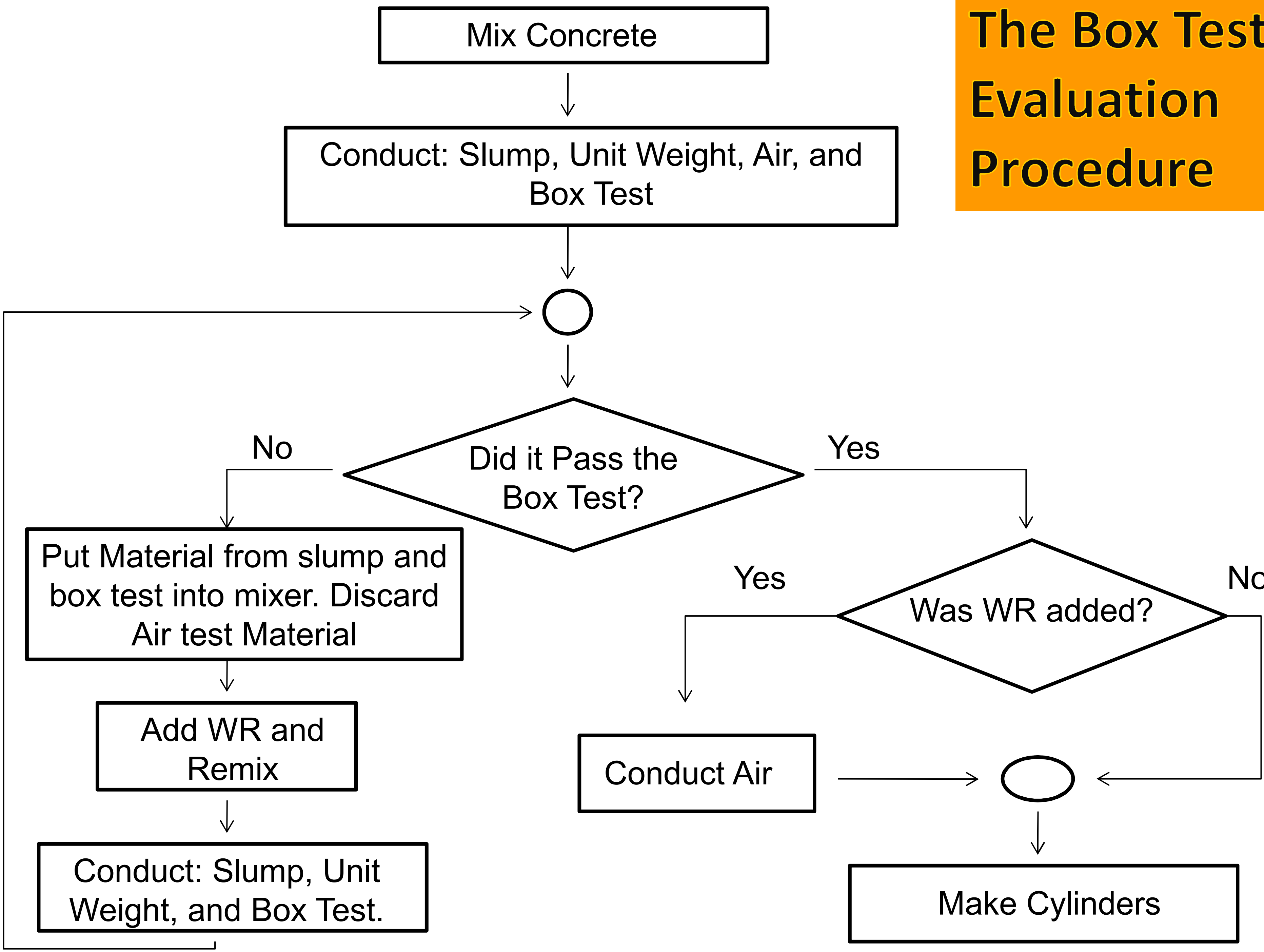
Answer: This would allow us to measure how aggregate gradation impacts the workability of a mixture.

The Box Test Evaluation Procedure



Validation

- Test was found to be accurate to +/- 2 oz/cwt with a single operator.
- Same box test performance was found if the WR was added up front or if added in small dosages
- If the sample did not pass the box test within one hour it was discarded
- The box test has correlated well with field paving mixes
- Work is ongoing with multiple operators

Summary of the Box Test

- The box test evaluates the response of a concrete mixture to vibration.
- We did this because no other test exists that can tell us this information.

Use of the Box Test to Evaluate Shilstone

- .45 w/cm
- 20 percent fly ash replacement
- A single sand source-Sand A
- Used 3 crushed limestones
  - Limestone A
  - Limestone B
  - Limestone C

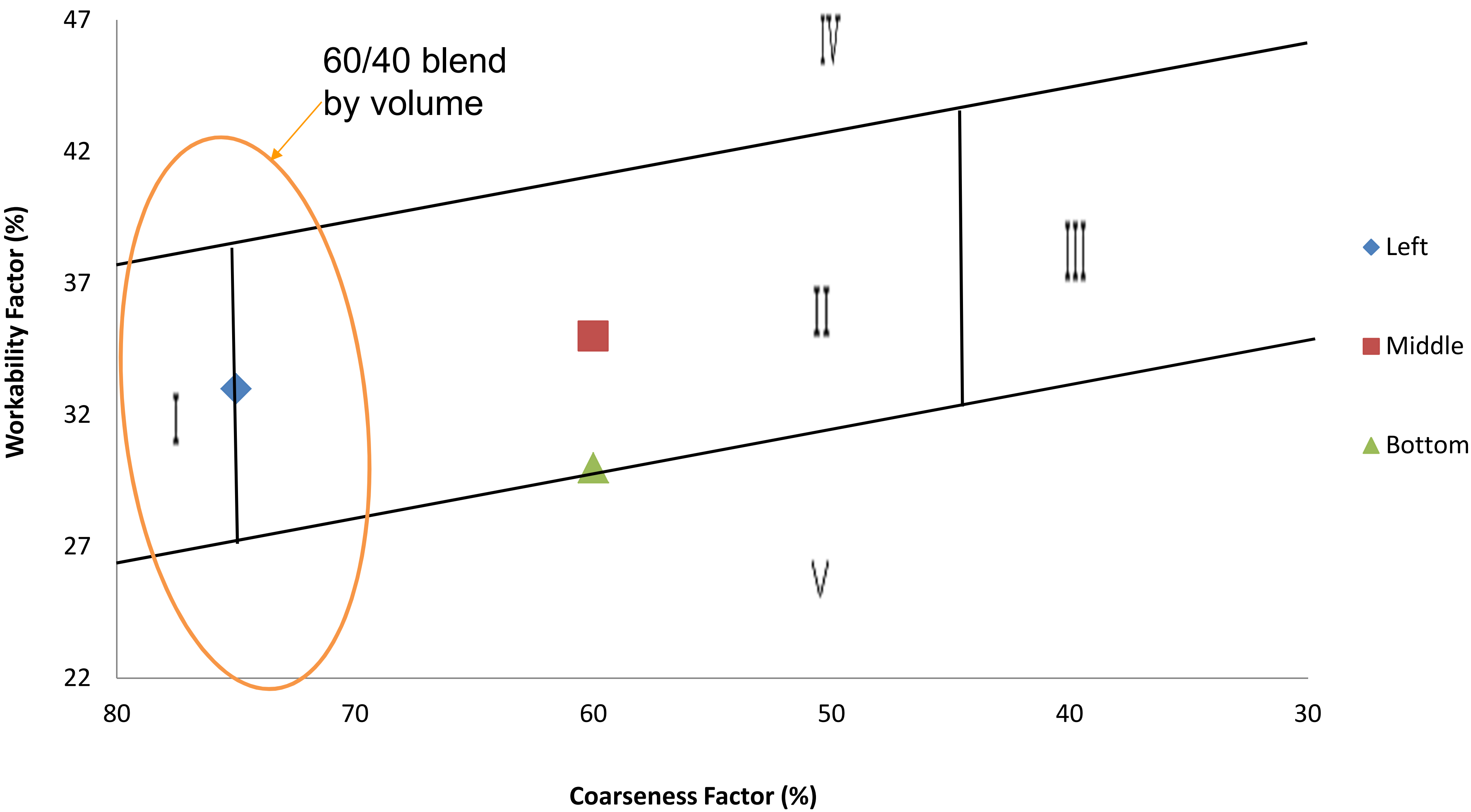
Aggregate Summary

Limestone A

Limestone B

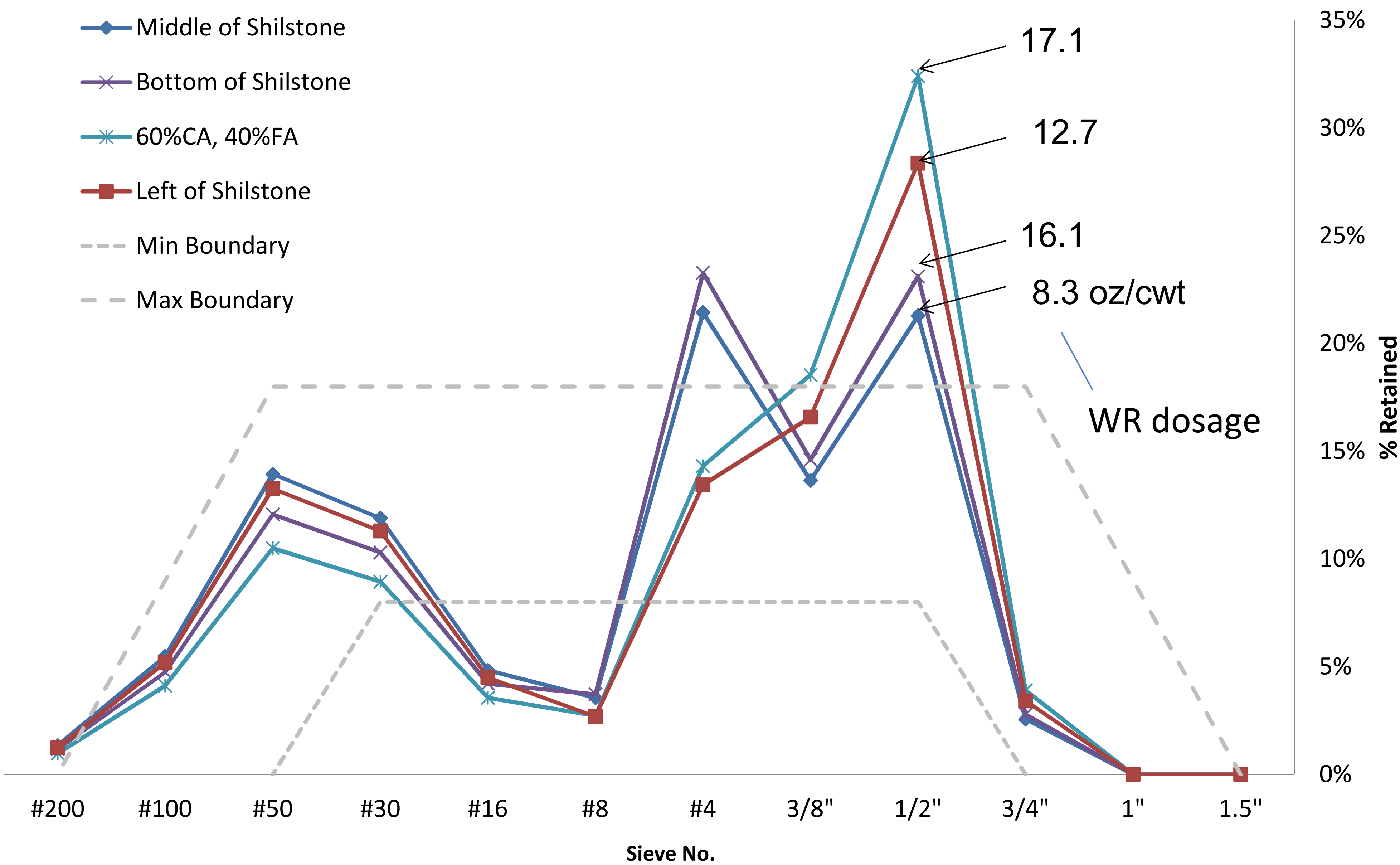
Limestone C

Sand A

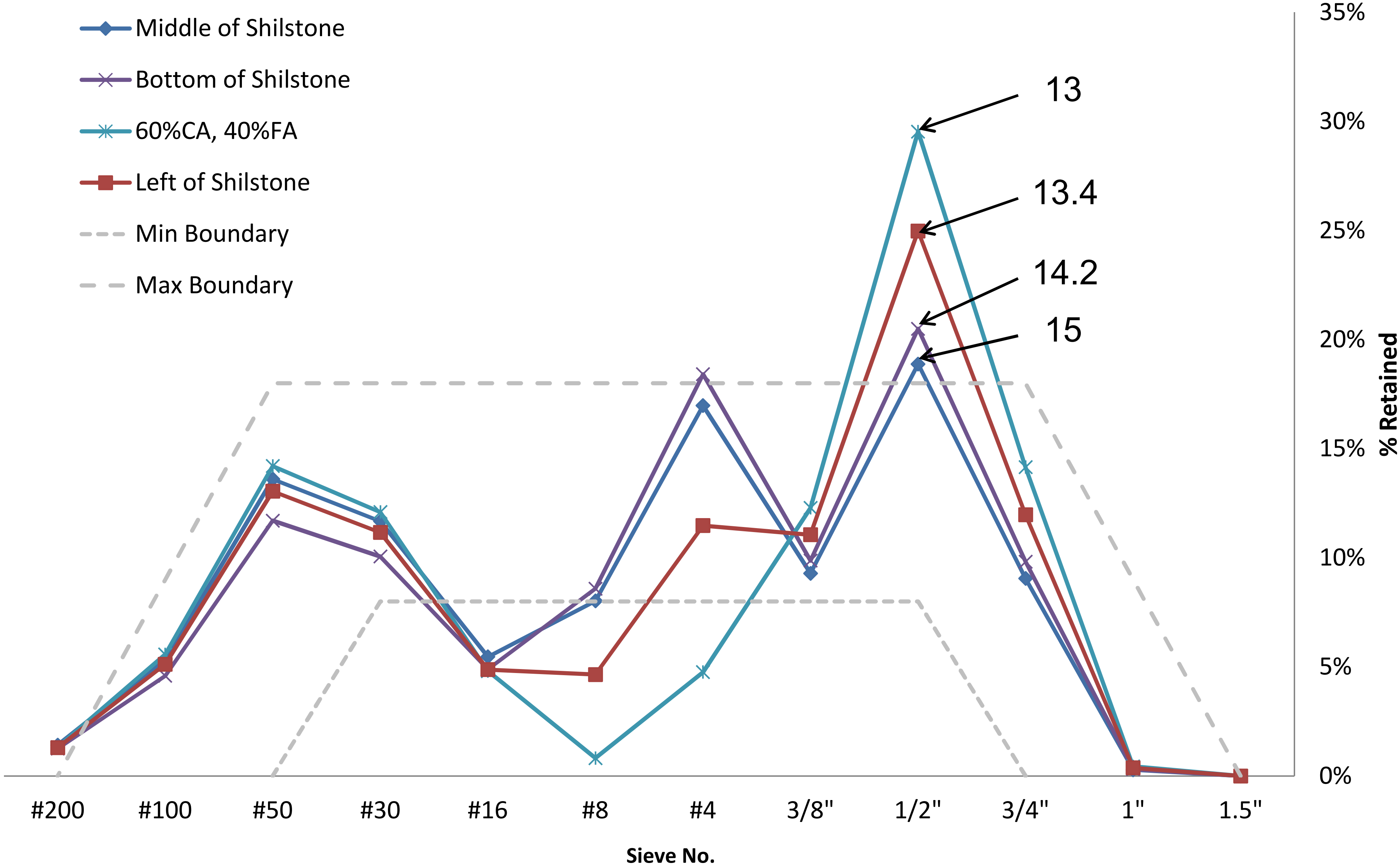


60/40 blend
by volume
Workability Factor (%)
47
42
37
32
27
22
80
70
60
50
40
30
Coarseness Factor (%)
I
II
III
IV
V
Left
Middle
Bottom

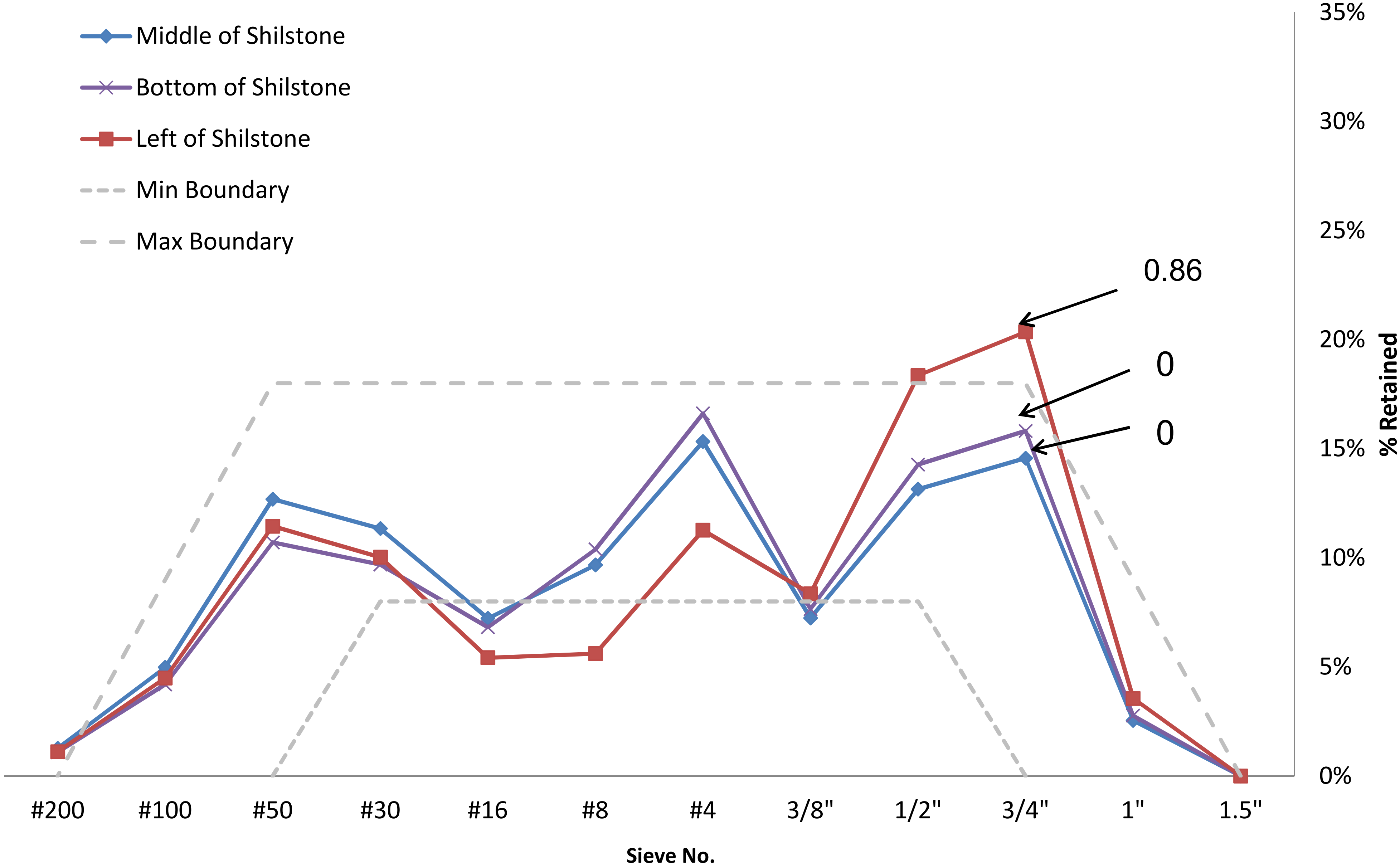
5 Sack Limestone A & Sand A

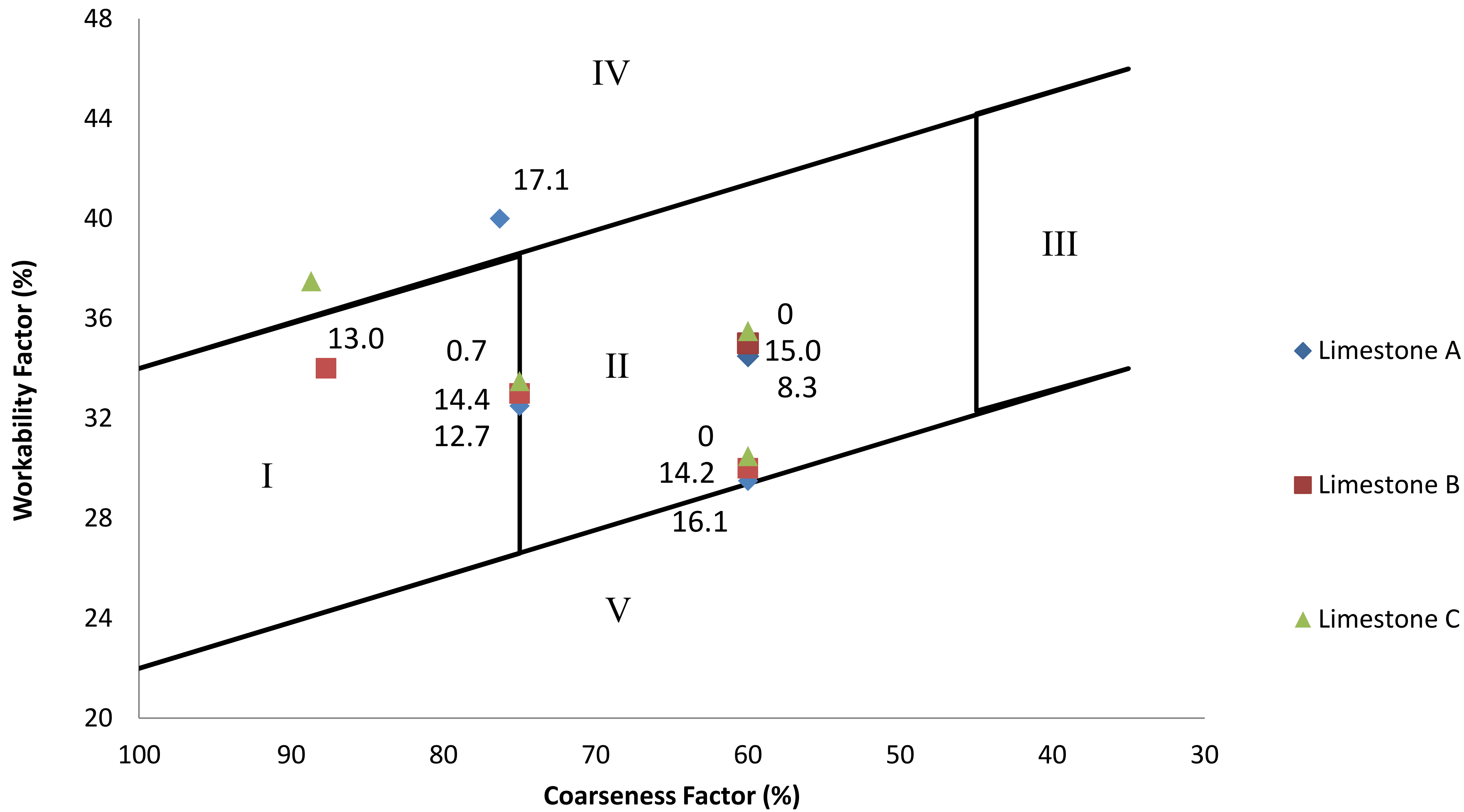


5 Sack Limestone B & Sand A



5 Sack Limestone C & Sand A



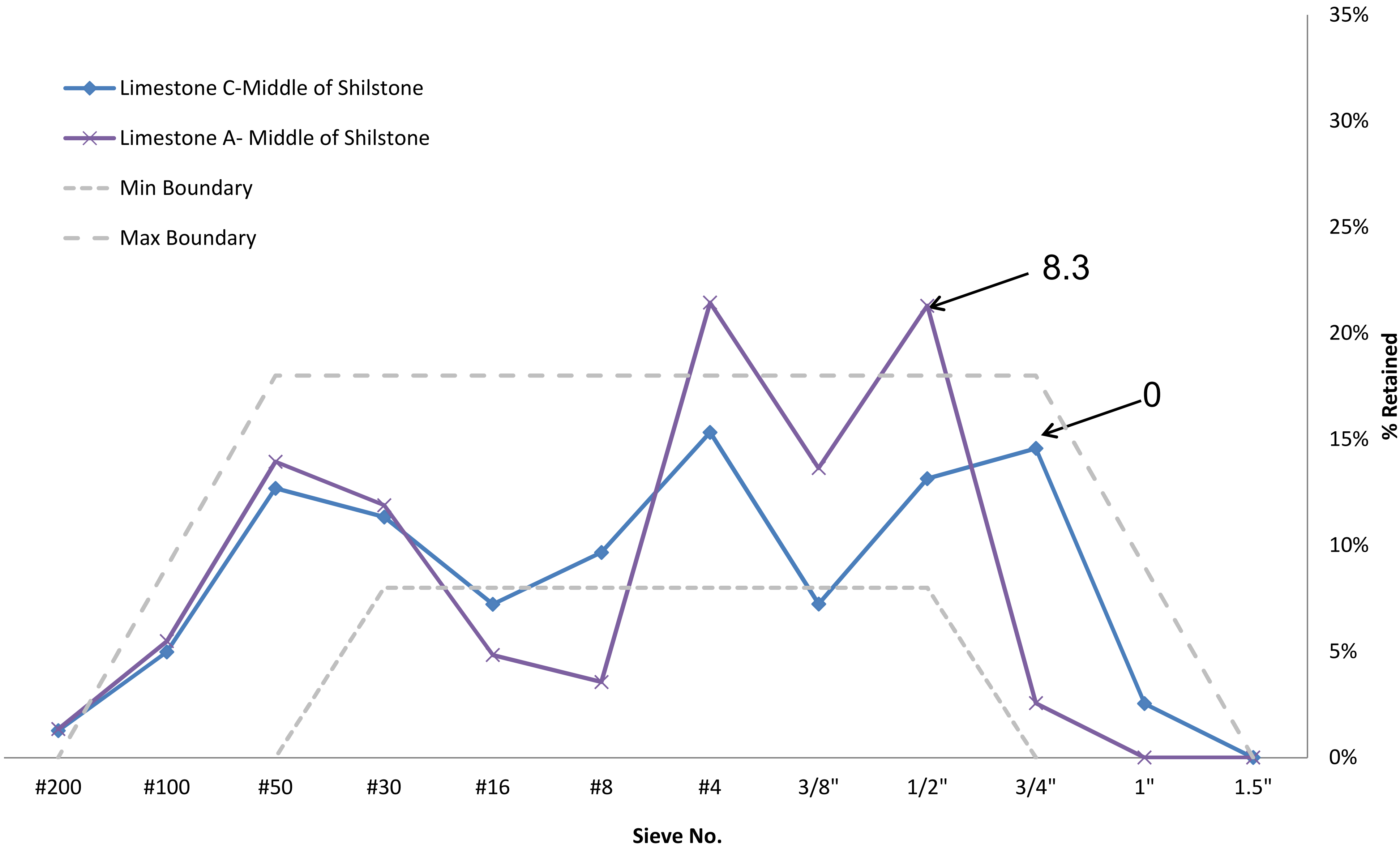


48
44
40
36
32
28
24
20
100
90
80
70
60
50
40
30
Workability Factor (%)
Coarseness Factor (%)
IV
III
II
I
V
17.1
13.0
0.7
14.4
12.7
0
15.0
8.3
0
14.2
16.1
Limestone A
Limestone B
Limestone C

Using the Shilstone Chart alone to proportion your aggregates does not influence performance with these materials.

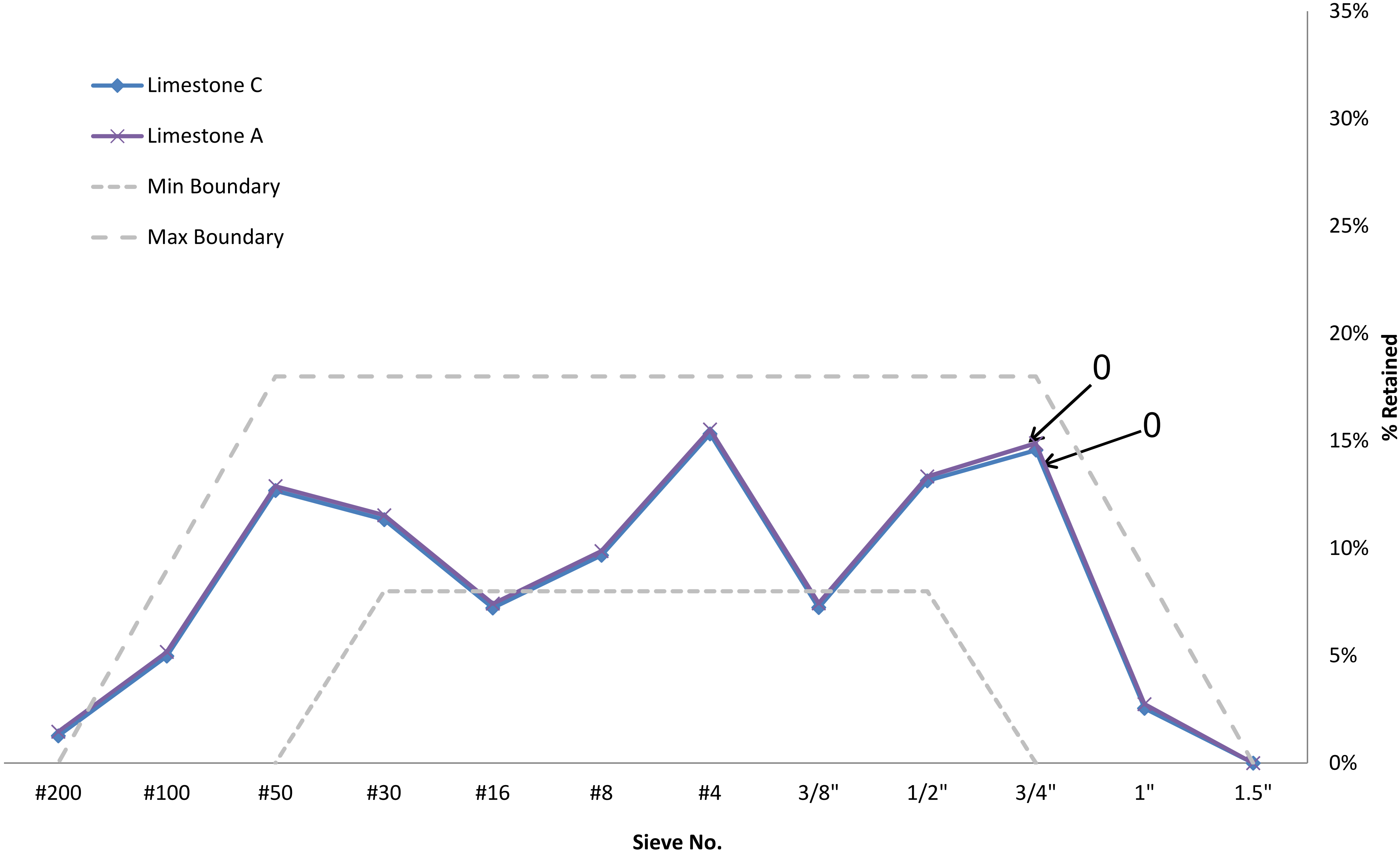
The 8-18 chart seems to provide better guidance.

Does Distribution Really Matter?



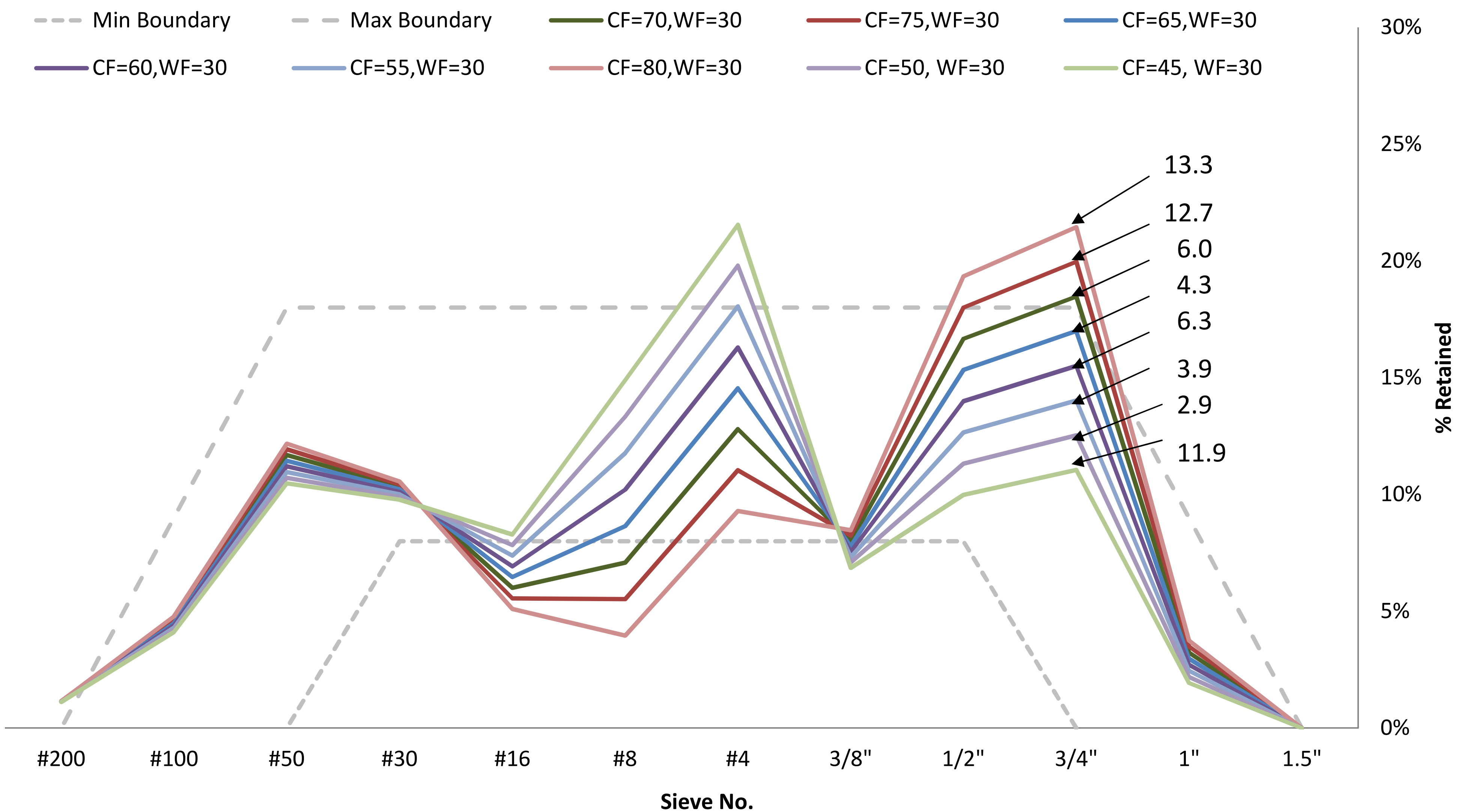
We sieved Limestone A to have the exact same gradation as Limestone B.

Yes, Distribution Matters!

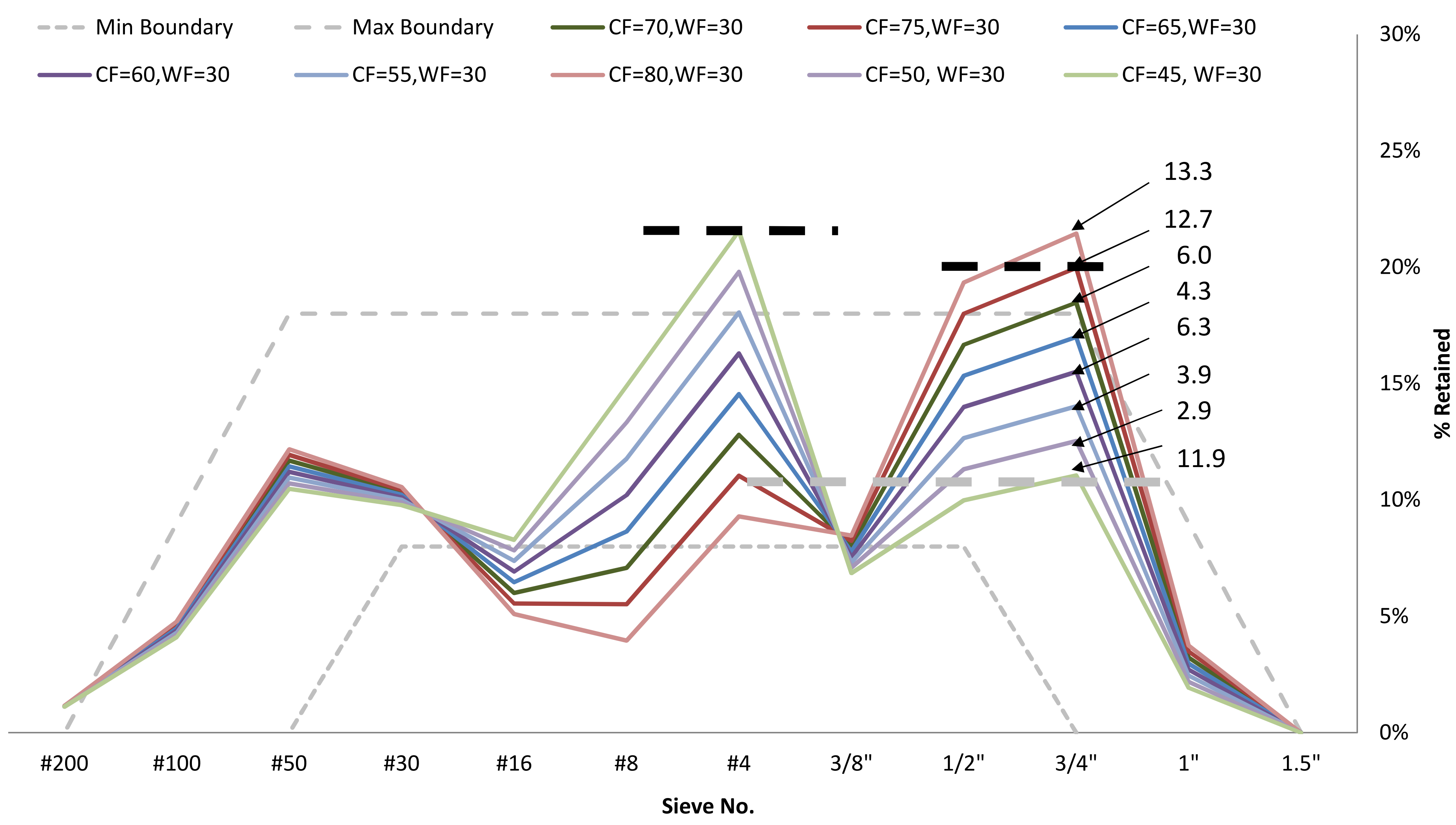


By changing the distribution of aggregates, it changes the workability of the mixture. However the Shilstone method did not accurately predict this (at least for these aggregate combinations).

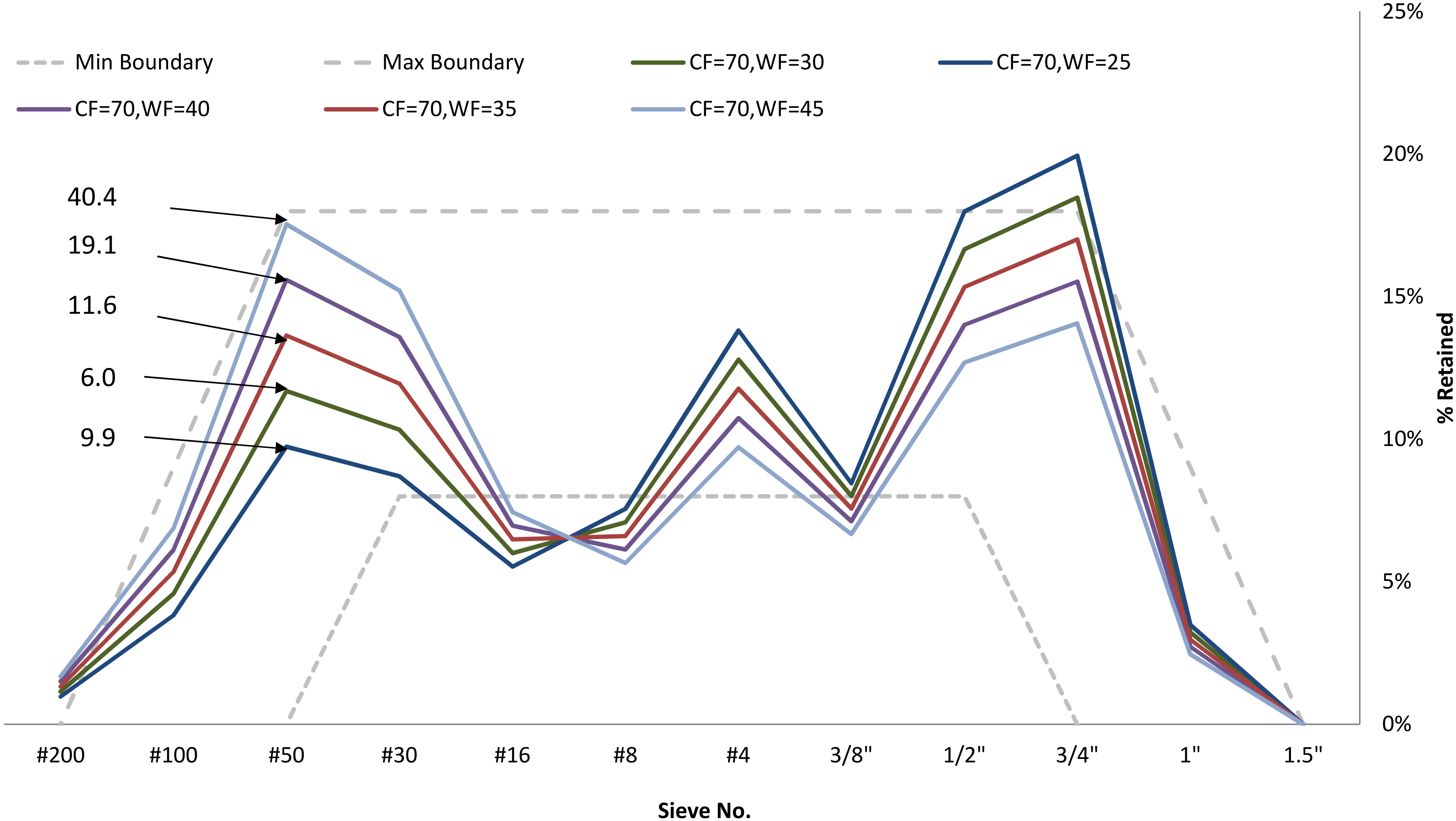
Proportioning of Coarse to Intermediate



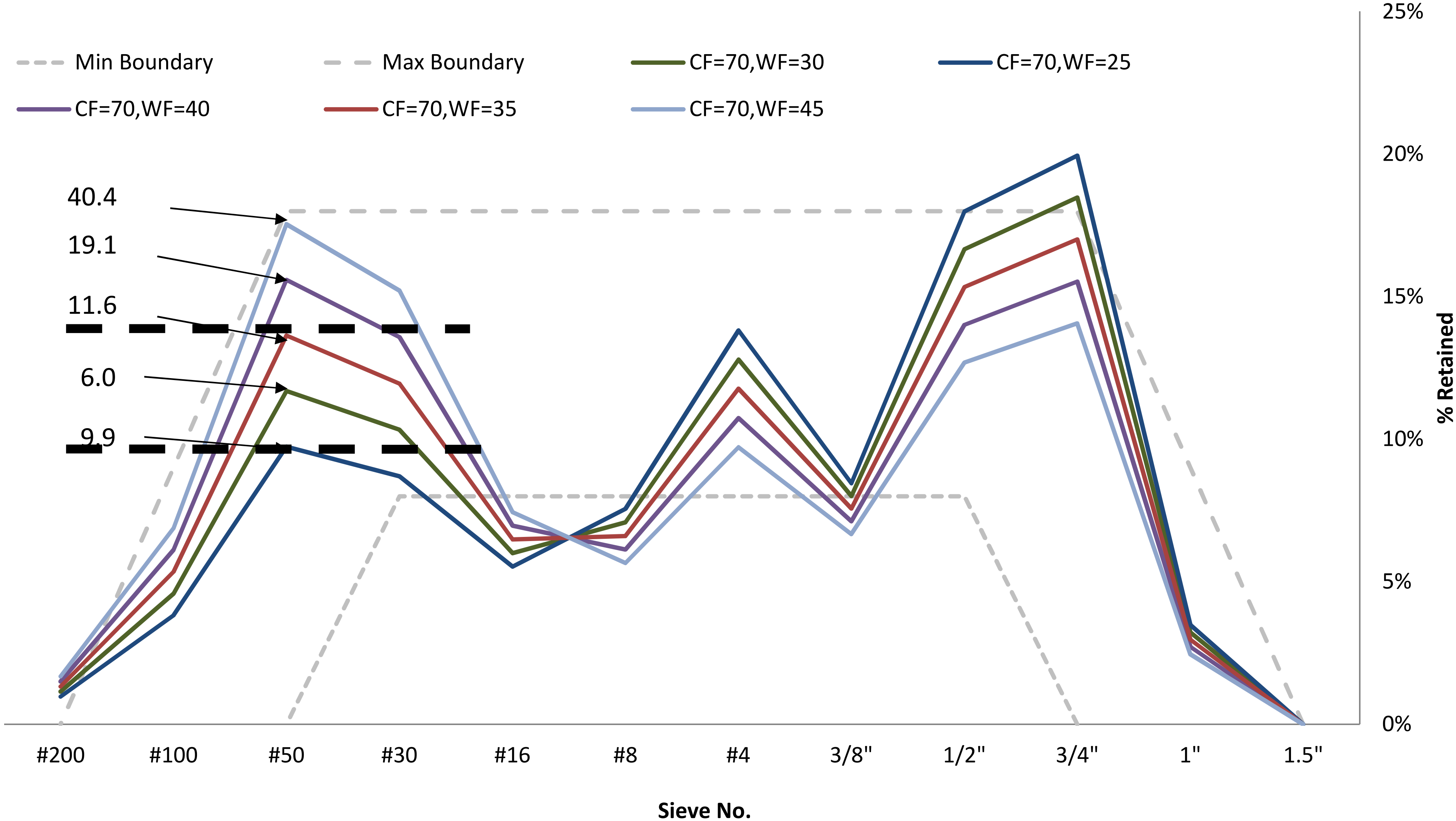
Proportioning of Coarse to Intermediate



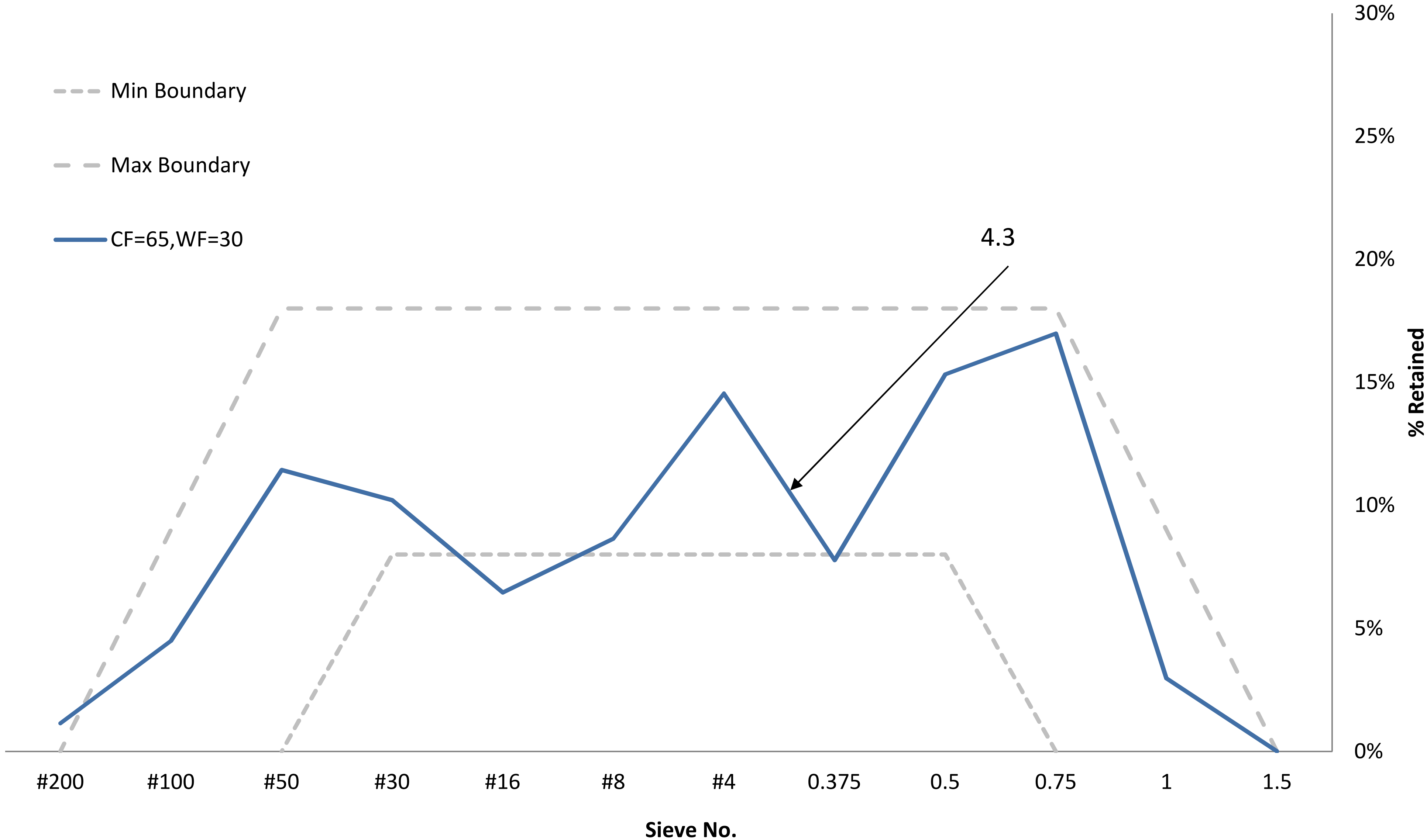
Proportioning of Sand



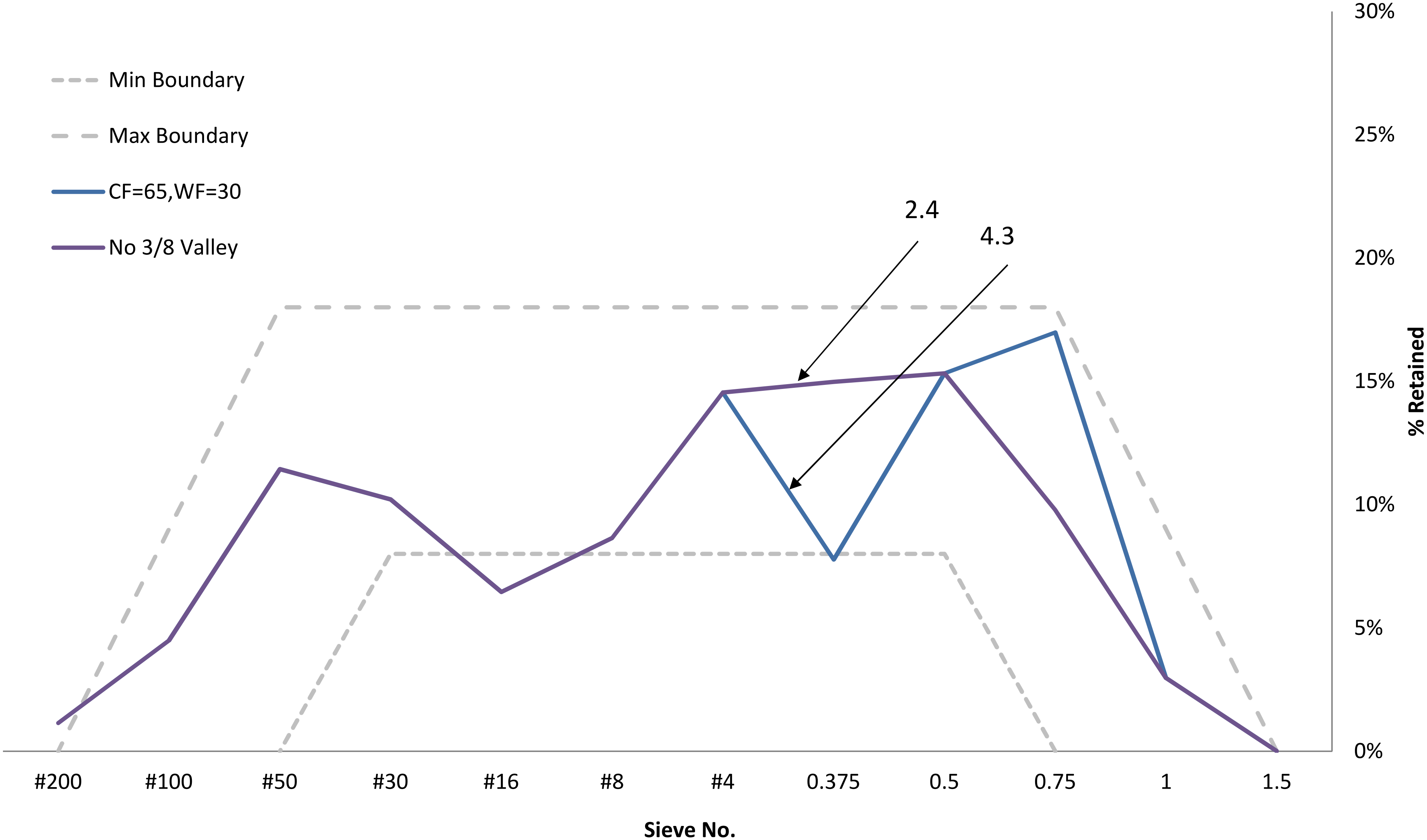
Proportioning of Sand



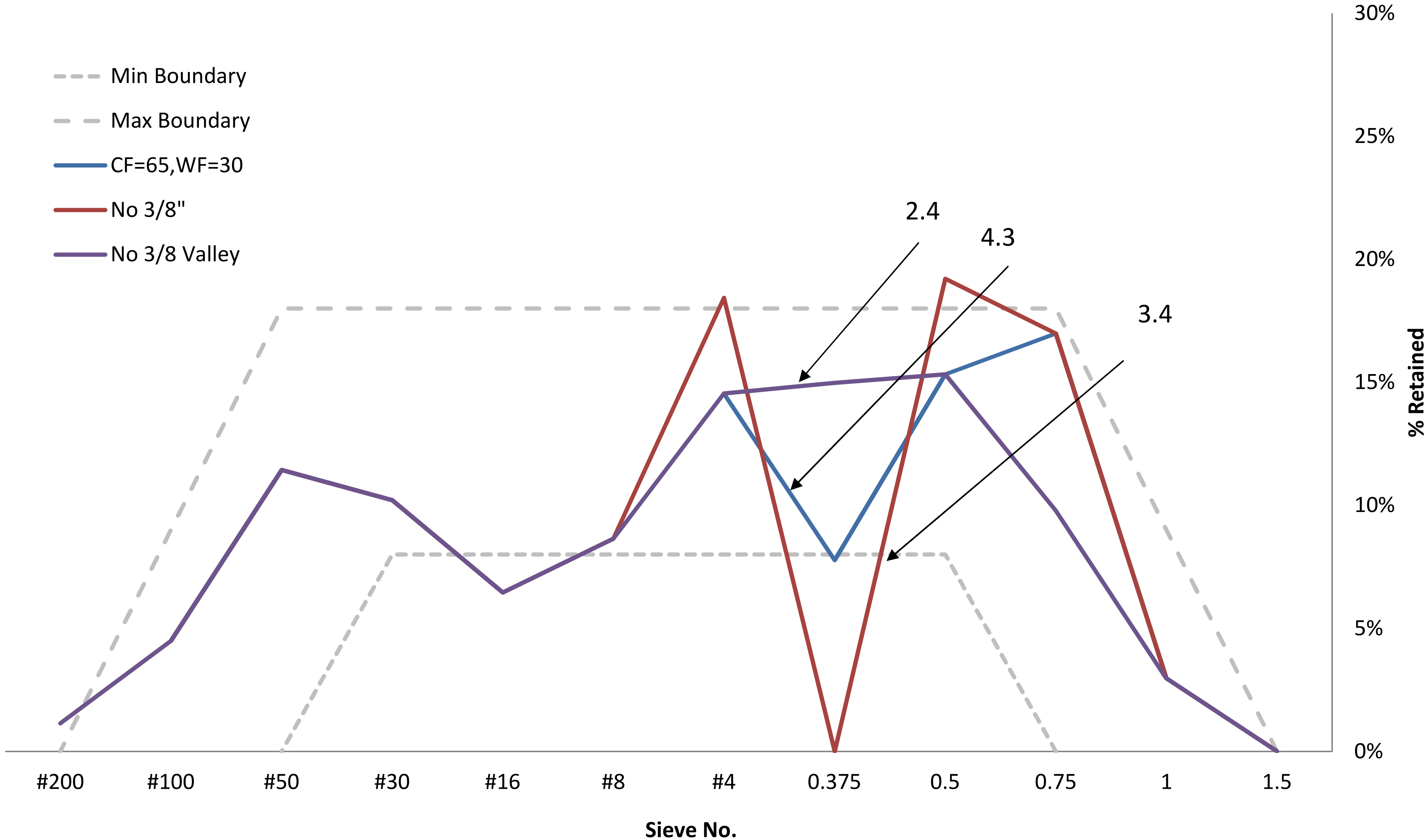
Impacts of a Single Valley

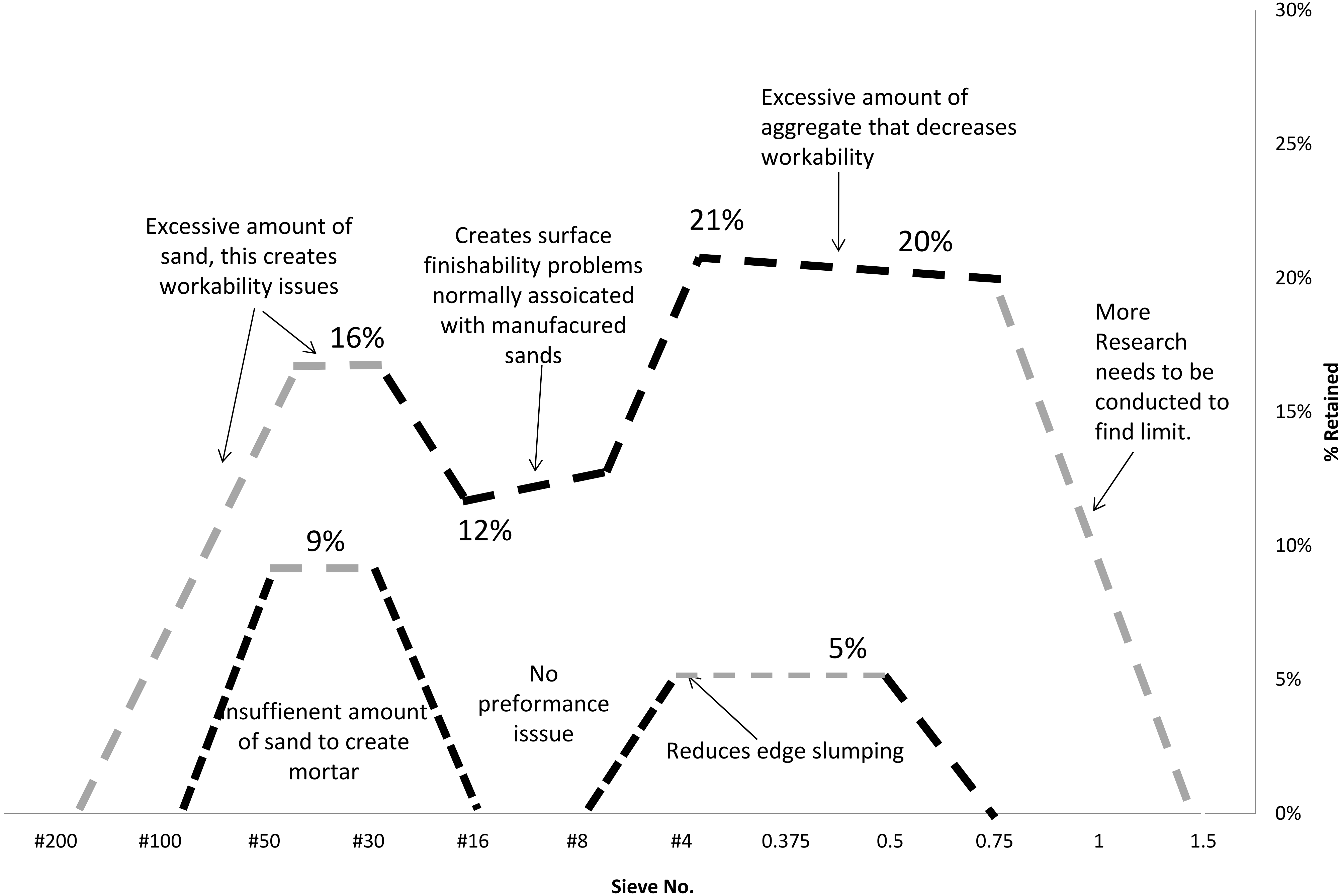


Impacts of a Single Valley



Impacts of a Single Valley




30%
25%
20%
15%
10%
5%
0%
% Retained
Excessive amount of aggregate that decreases workability
Excessive amount of sand, this creates workability issues
Creates surface finishability problems normally assoicated with manufacured sands
21%
20%
16%
More Research needs to be conducted to find limit.
12%
9%
5%
No preformance isssue
Insuffienent amount of sand to create mortar
Reduces edge slumping
#200
#100
#50
#30
#16
#8
#4
0.375
0.5
0.75
1
1.5
Sieve No.

Conclusion

- The box test has shown to be a useful tool to understand the impact of gradation on the workability of mixtures for concrete pavements
- The Shilstone box was not shown to be a useful method for the materials investigated

Conclusion

- A modified version of the 8-18 graph was shown to better predict performance
- The box test has been used to evaluate the performance of pavement concrete mixtures and a recommended gradation limit has been produced

Questions?

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