

Designing Concrete Mixtures for Constructible Slip Formed Pavements



Tyler Ley, PE, PhD

Dan Cook, PhD

Michael Dickey

Acknowledgements

Oklahoma Department of Transportation

Oklahoma Transportation Center

Overview

Why

How to measure response to vibration

How to measure finishing

What can you do with this?

What is the most important property of concrete?

1. Workable
2. Durable
3. Economical
4. Strength

- Every project has a different set of requirements!!!

What is the most important property of concrete?

1. Workable

2. Durable

3. Economical

4. Strength

- Every project has a different set of requirements!!!

How do you design for workability?

slip formed
truck placed
pumped
flat work



Each mixture requires a different level of workability.

How do you design for workability?

Paste content (water + binder)

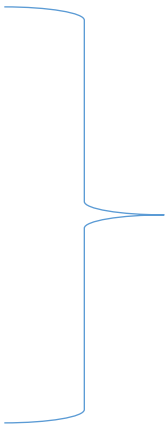
Admixtures

Aggregates

Overview of tests

- We need workability tests that measure practices in the field, such as:

- Can we **place** it?
- Can we **drag** it?
- Can we **pump** it?
- How does it **vibrate**?
- Can we **finish** it?



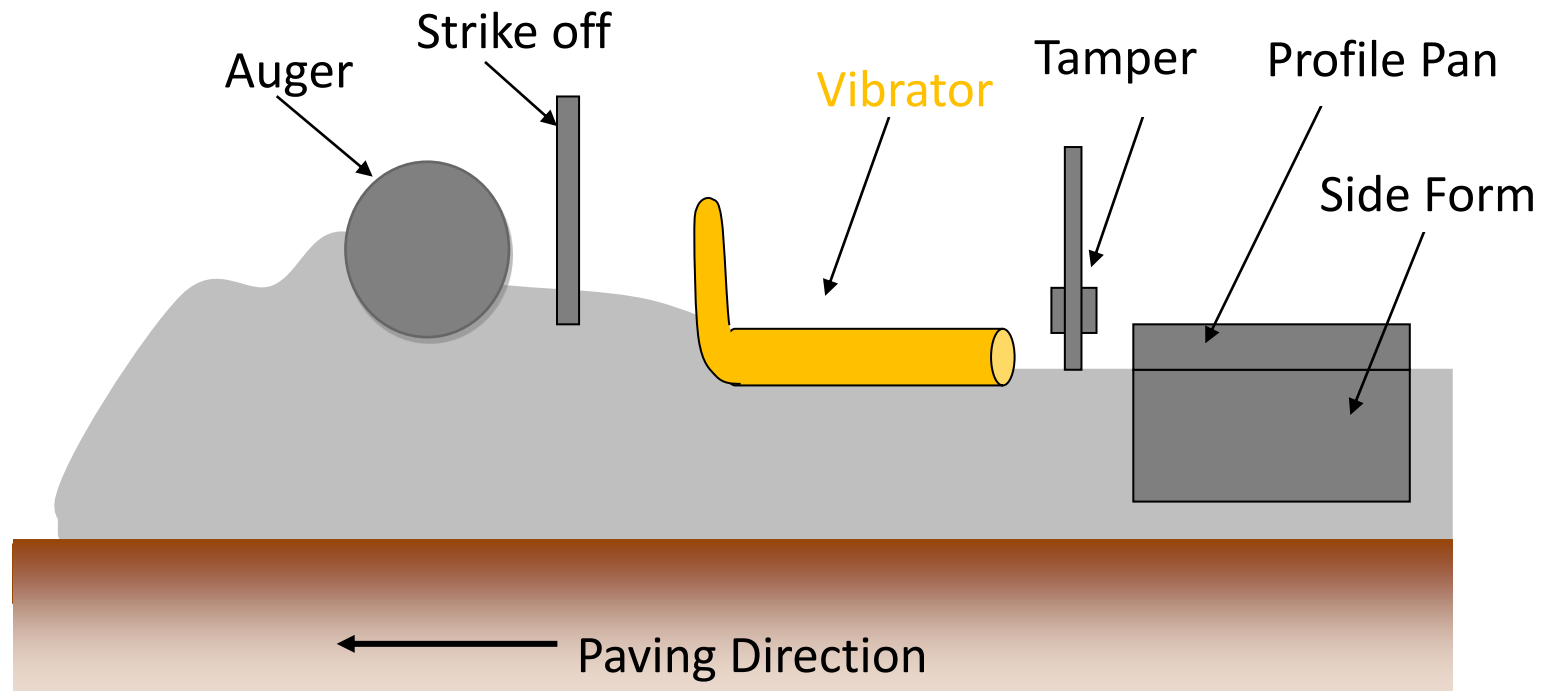
Can it be
used in the
field?





Slip Formed Paver

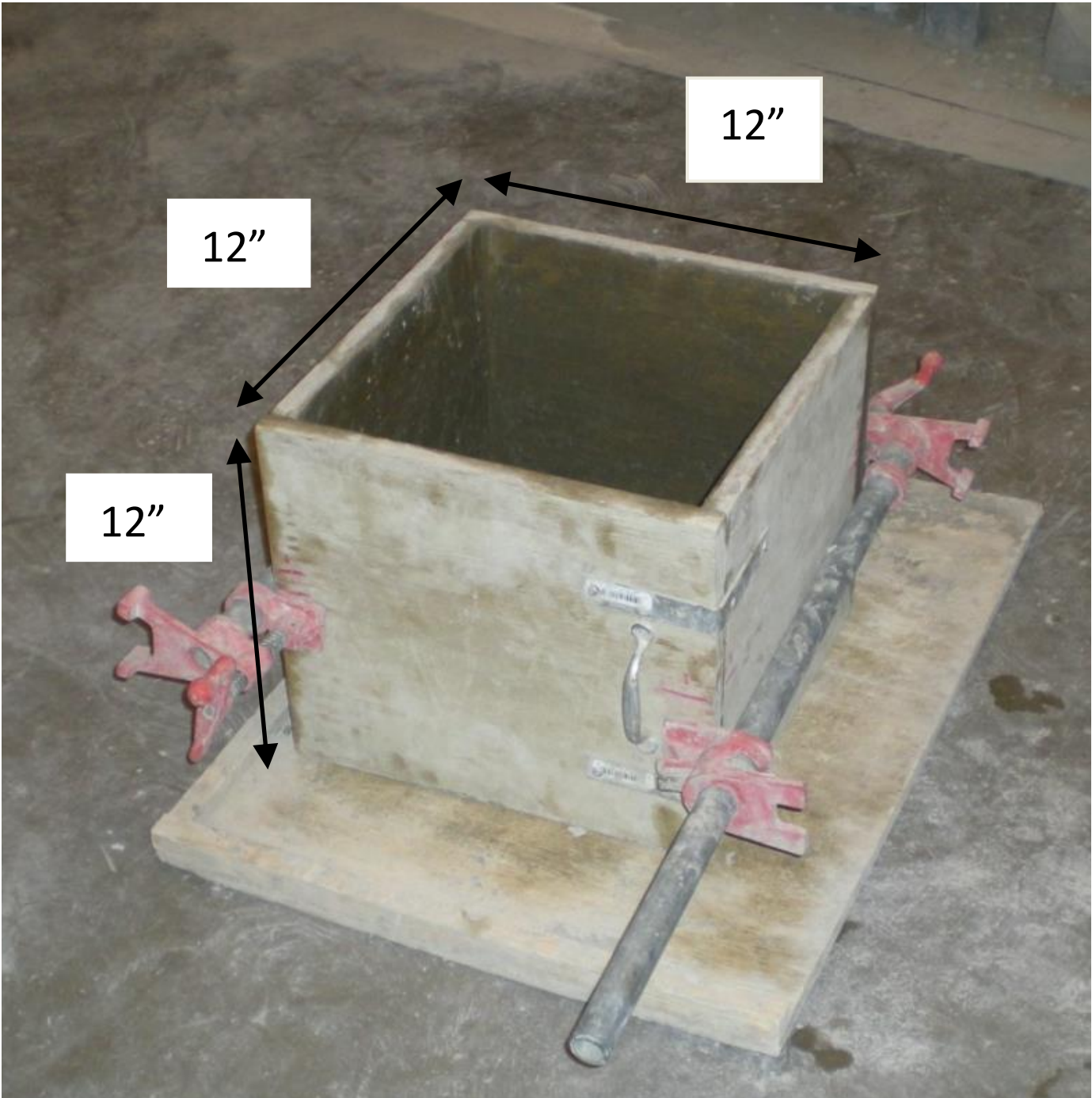
What part of a paver is the most critical for concrete consolidation?



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)

The slump test can not tell us this!



Box Test – AASHTO TP 137

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

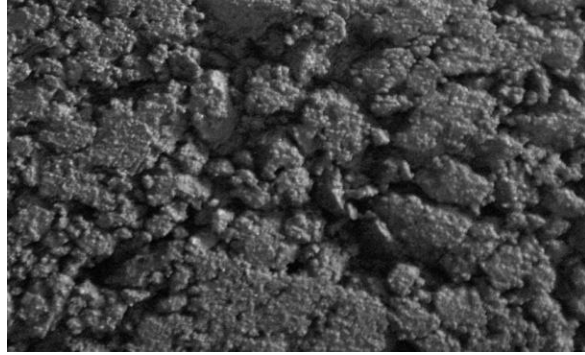
The edges of the box are then removed and inspected for honey combing or edge slumping





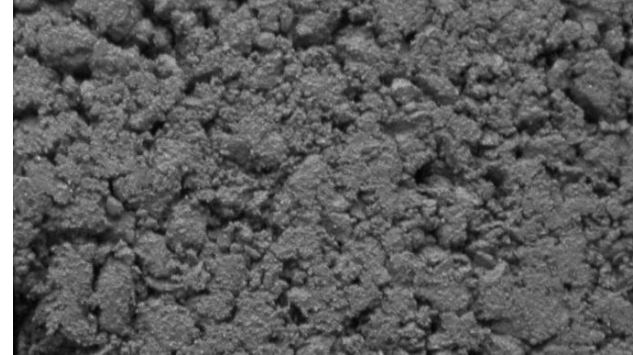


Box Test Ranking Scale



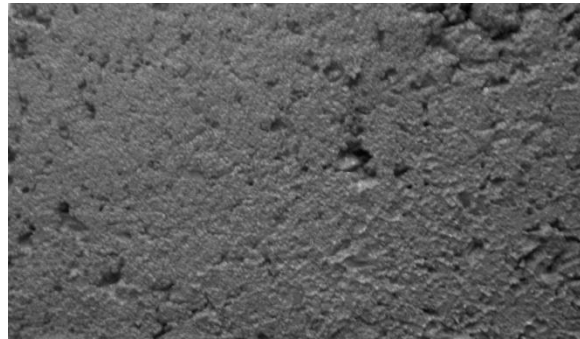
4

Over 50% overall surface voids.



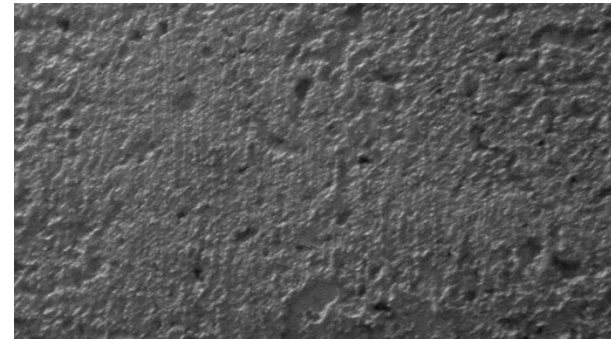
3

30-50% overall surface voids.



2

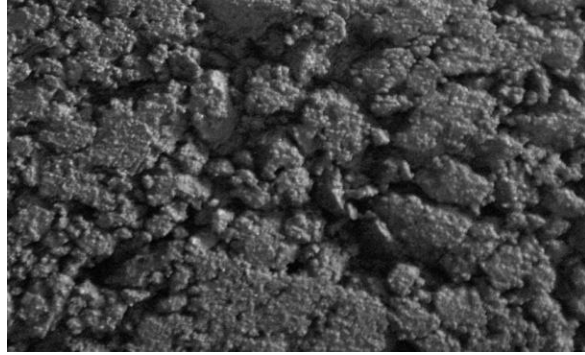
10-30% overall surface voids.



1

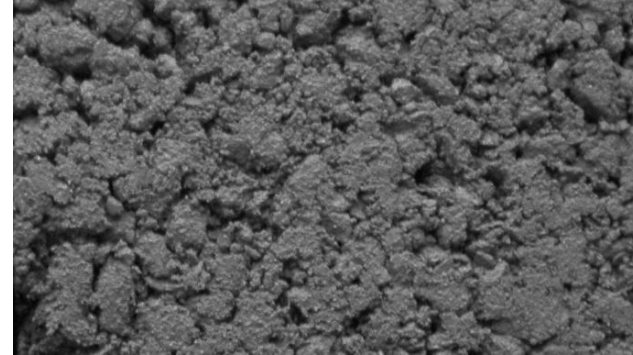
Less than 10% overall surface voids.

Box Test Ranking Scale



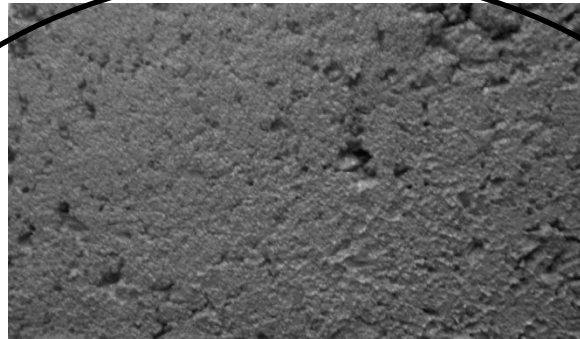
4

Over 50% overall surface voids.



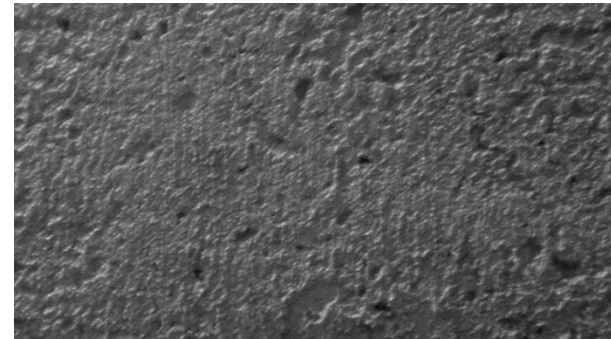
3

30-50% overall surface voids.



2

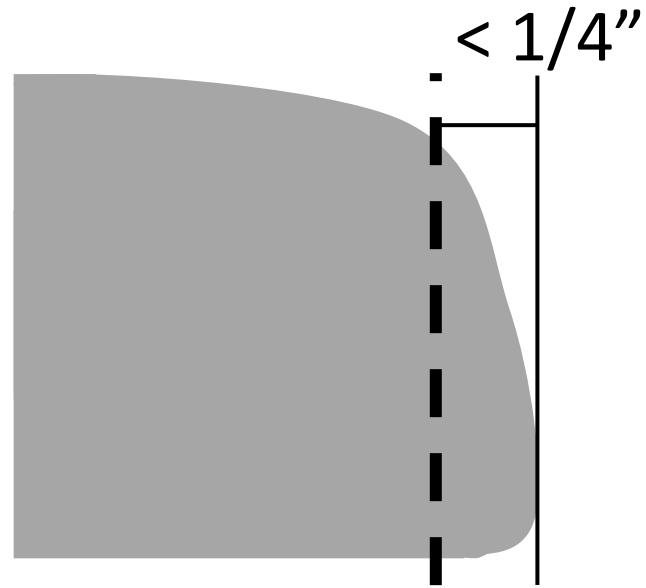
10-30% overall surface voids.



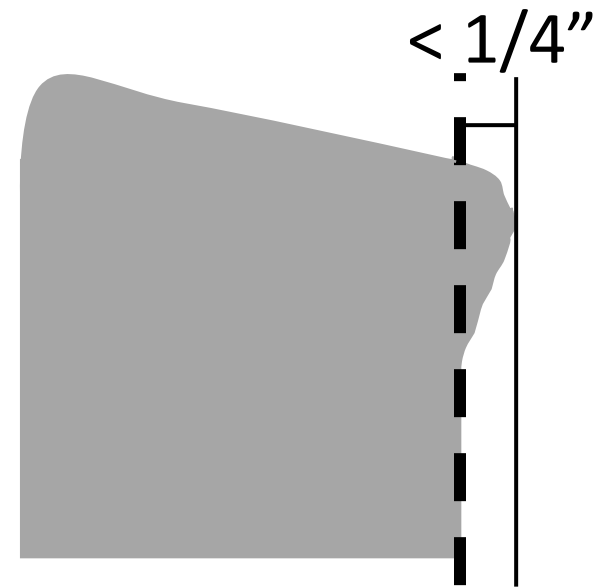
1

Less than 10% overall surface voids.

Edge Slumping



Bottom Edge Slumping



Top Edge Slumping

No Edge Slump



Edge Slump



Summary

The Box Test examines the window of workability for concrete pavement mixtures

This is helpful when:

- mixtures are designed in the lab
- trial batching in the field
- troubleshooting field problems
- measuring variation in production

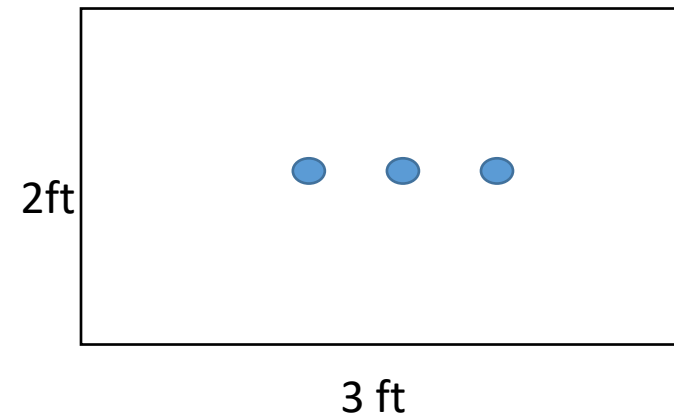
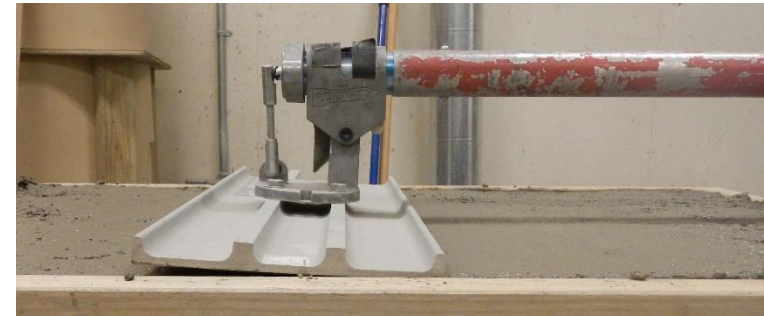
It is like having a miniature paver!!!

The Float Test

Evaluates the surface finish of a mixture.

Steps:

1. Place concrete in 3' x 2' x 3" forms and strike concrete
2. Create 3 known 1" diameter and 1" deep holes
3. Move bull-float at a fixed angle over surface at a constant speed
4. Measure number of passes to:
 - close the 3 holes
 - create a smooth finish



1. Place and Level Concrete



2. Create Three Holes

Place Template



Create Holes



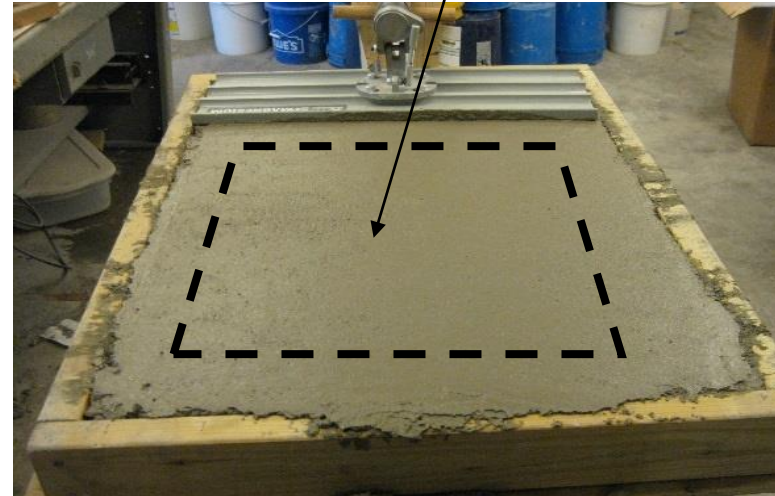
3. Float Surface

- The sides of the form are marked and a metronome is used to help the operator move at a constant rate.

The float is trimmed to only ride on the concrete

The yolk keeps the angle constant

Evaluate only this area

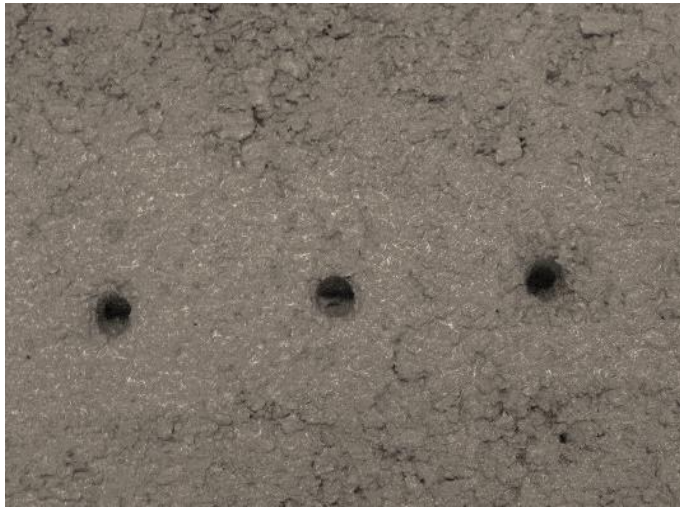


First Pass with Bull Float

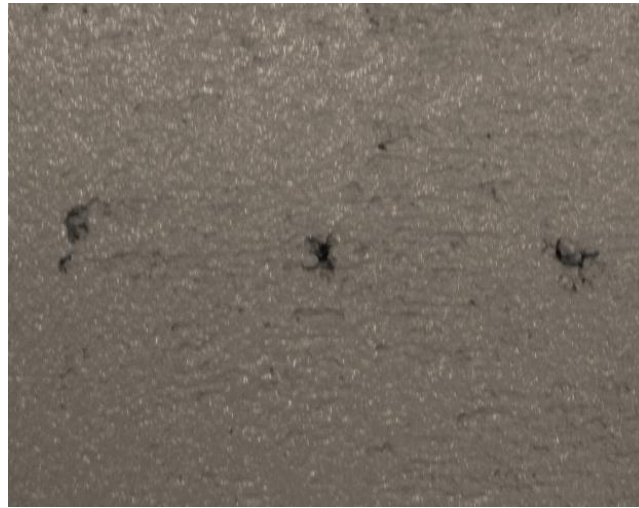
Last Pass with Bull Float

Example of Holes Closing

0 Passes



2 Passes



4 Passes





4

Over 50% of area was textured



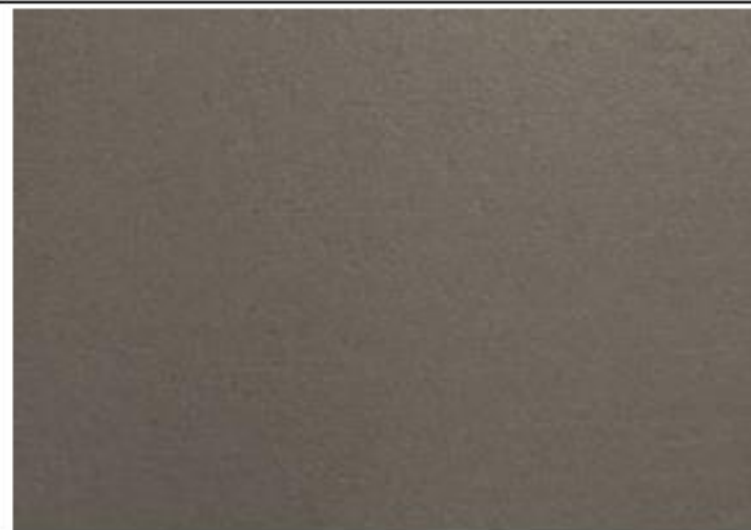
3

30 to 50% of area was textured



2

10 to 30% of area was textured



1

Less than 10% of area was textured



4

Over 50% of area was textured



3

30 to 50% of area was textured



2

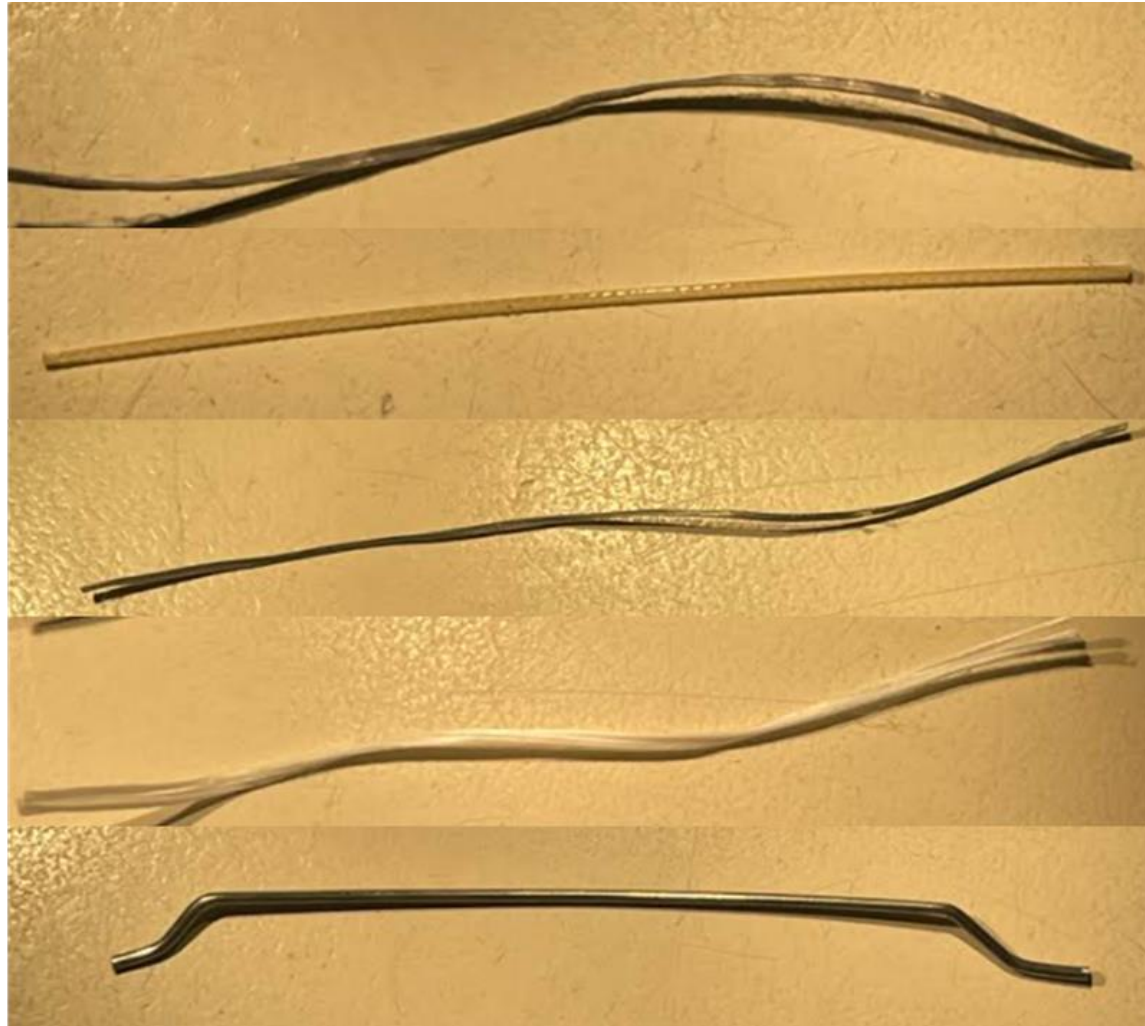
10 to 30% of area was textured



1

Less than 10% of area was textured

How do different fiber types and dosage impact finishing?



Copolymer

Polyolefin

Polypropylene

Polypropylene

Steel

Overview

All concrete mixtures are the same but they use different types and dosage of fibers

We will use the float test to compare the performance

Float Test – 4 lb/cy fibers macrosynthetic



0 Passes



4 Passes



Final (7) Passes

Float Test – 8 lb/cy fibers



0 Passes

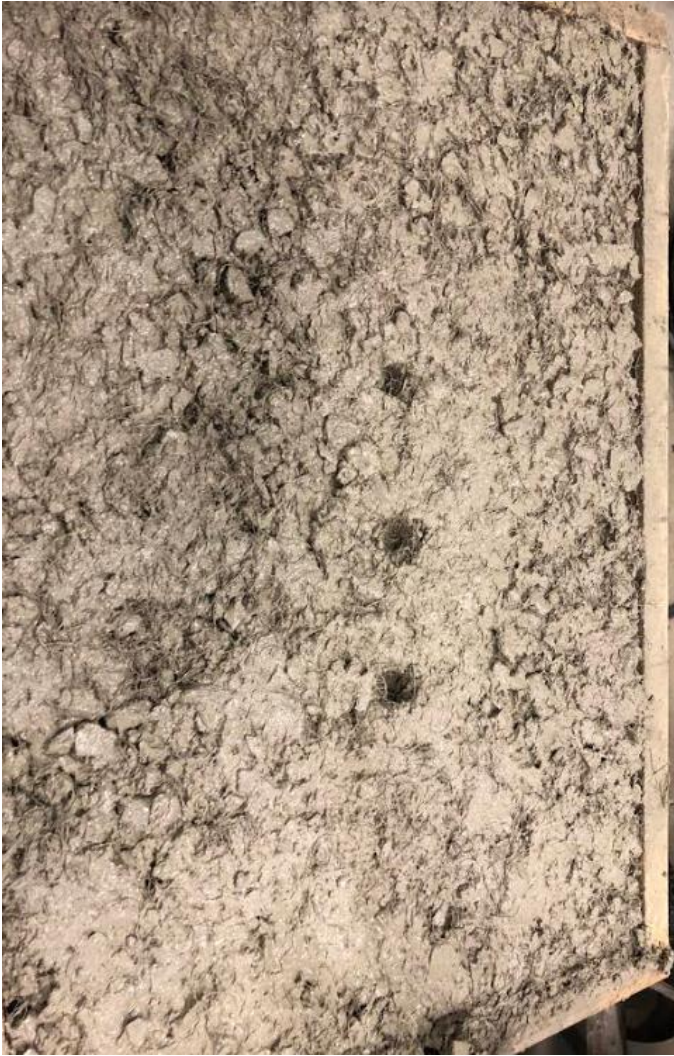


4 Passes

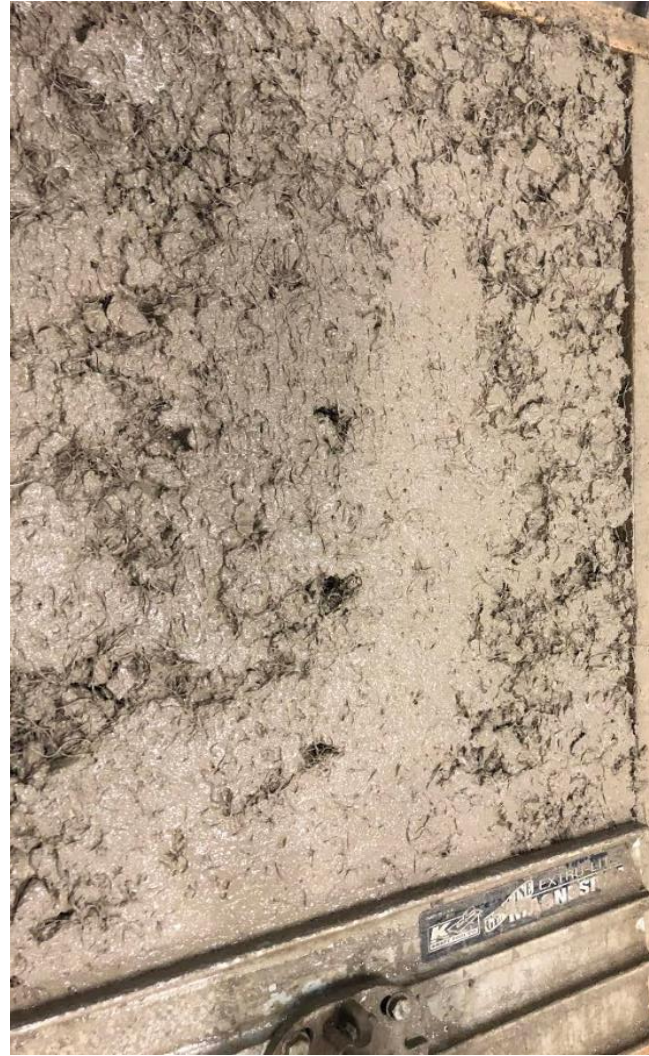


Final (10) Passes

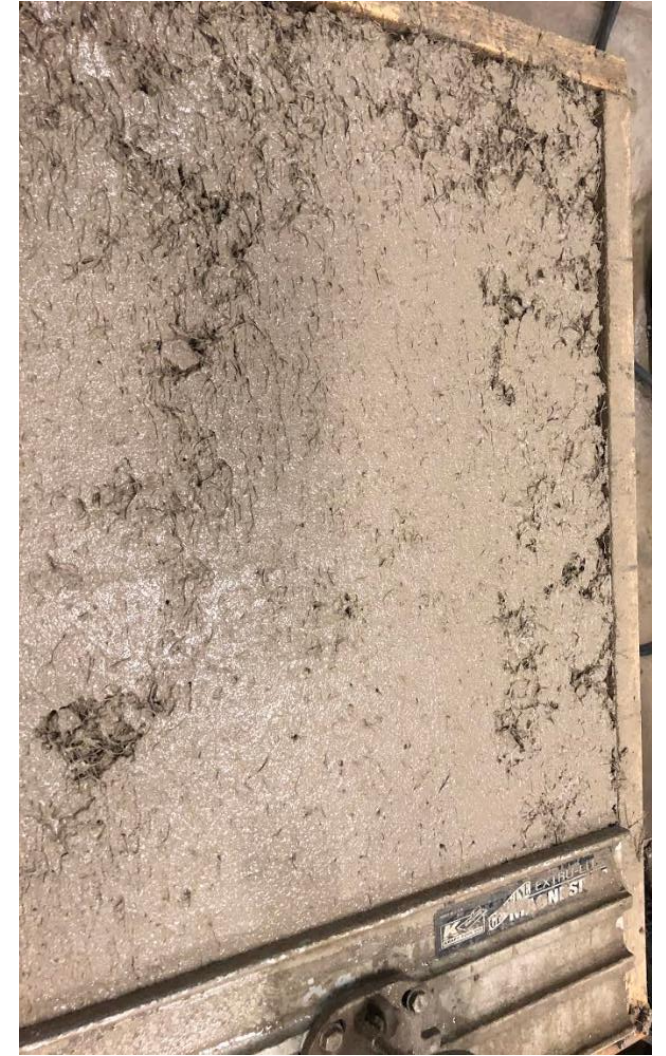
Float Test – 12 lb/cy fibers



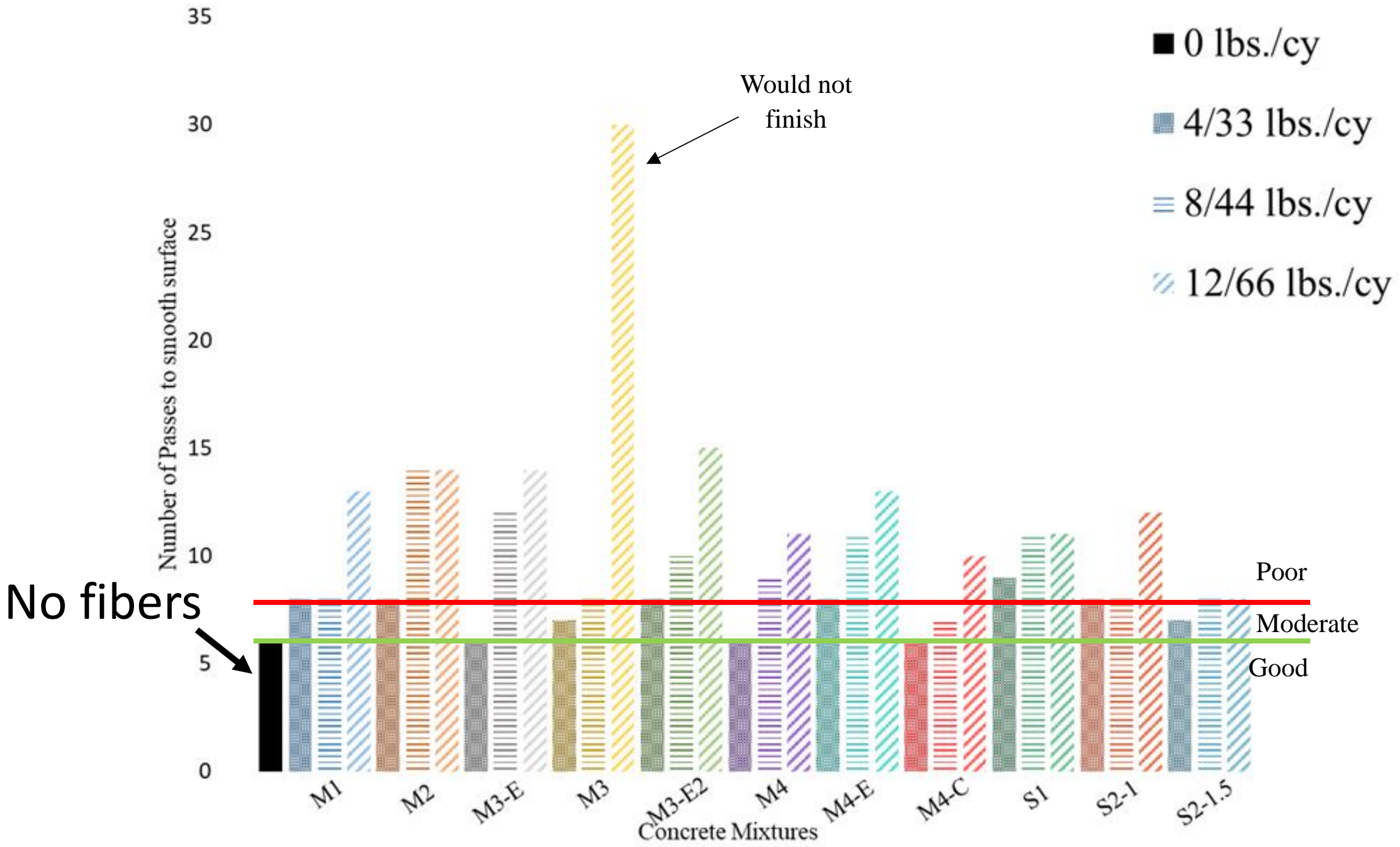
0 Passes

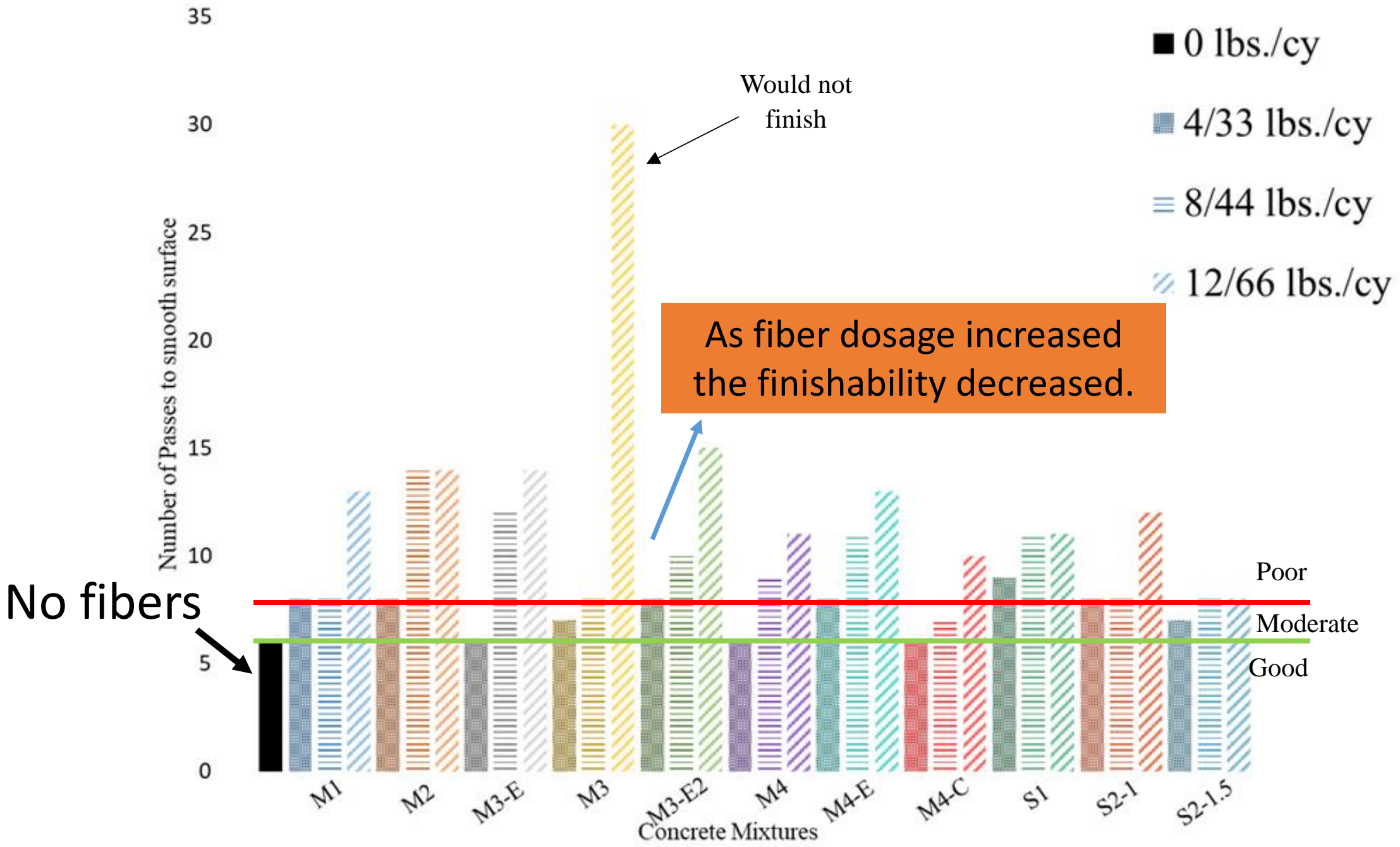


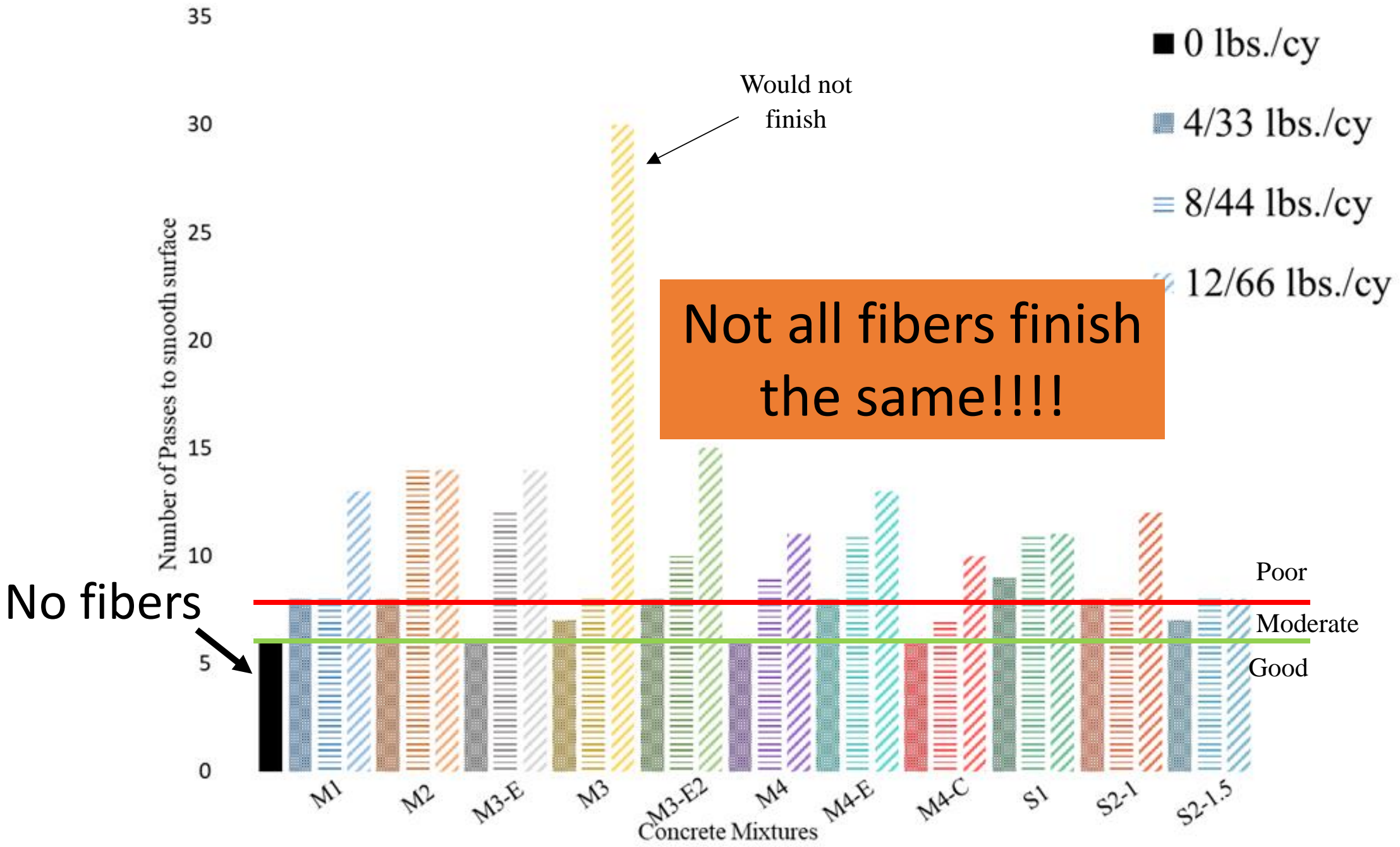
4 Passes

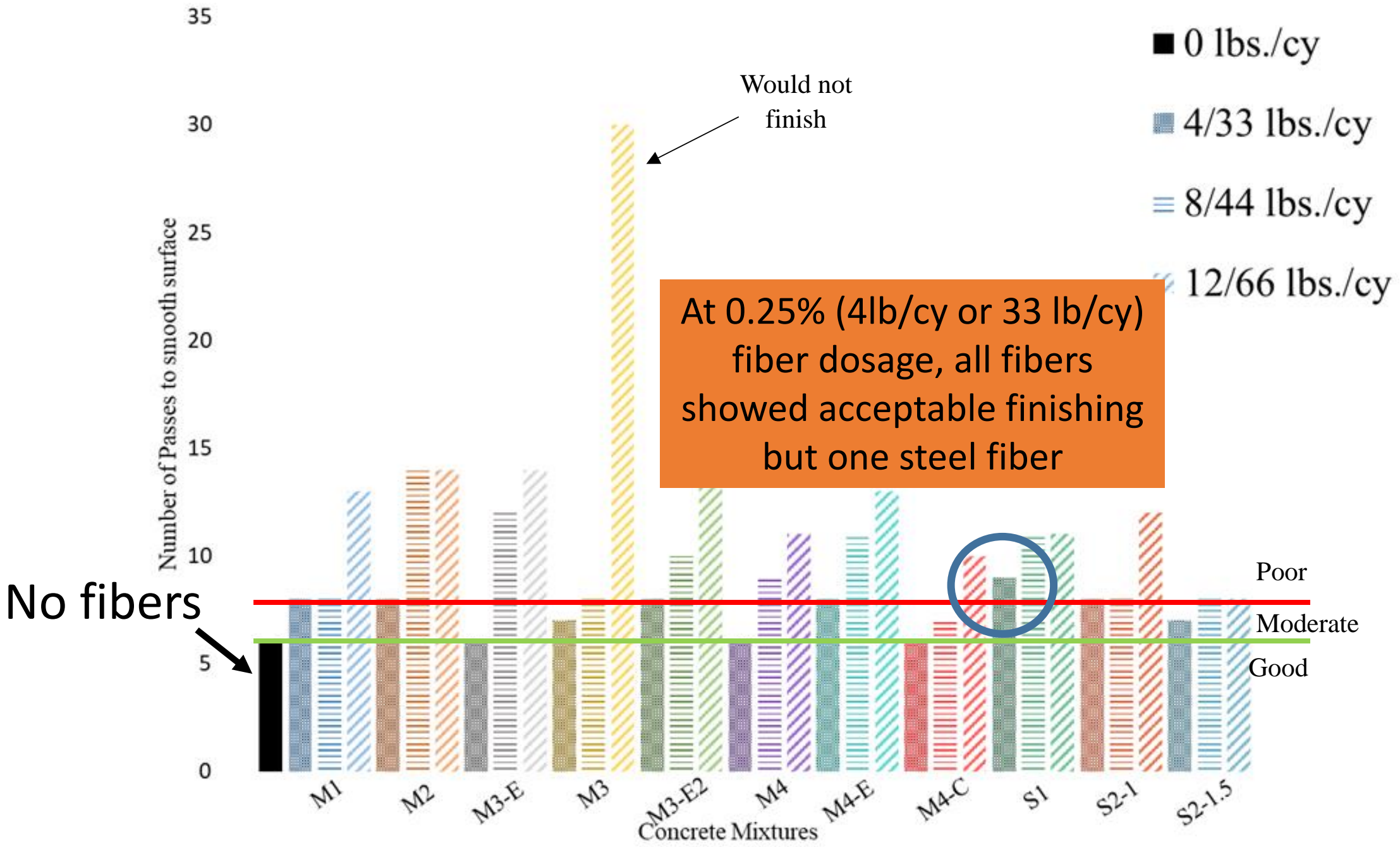


Final (12) Passes









Discussion

- The float test is a useful tool to use in the trial batch to ensure that mixtures are workable.
- 4lb/cy and 33lb/cy of fiber is typically a safe volume to allow the fibers to be finished
- High fiber dosages are challenging to finish.

Testing Overview

We evaluated over **650** concrete mixtures

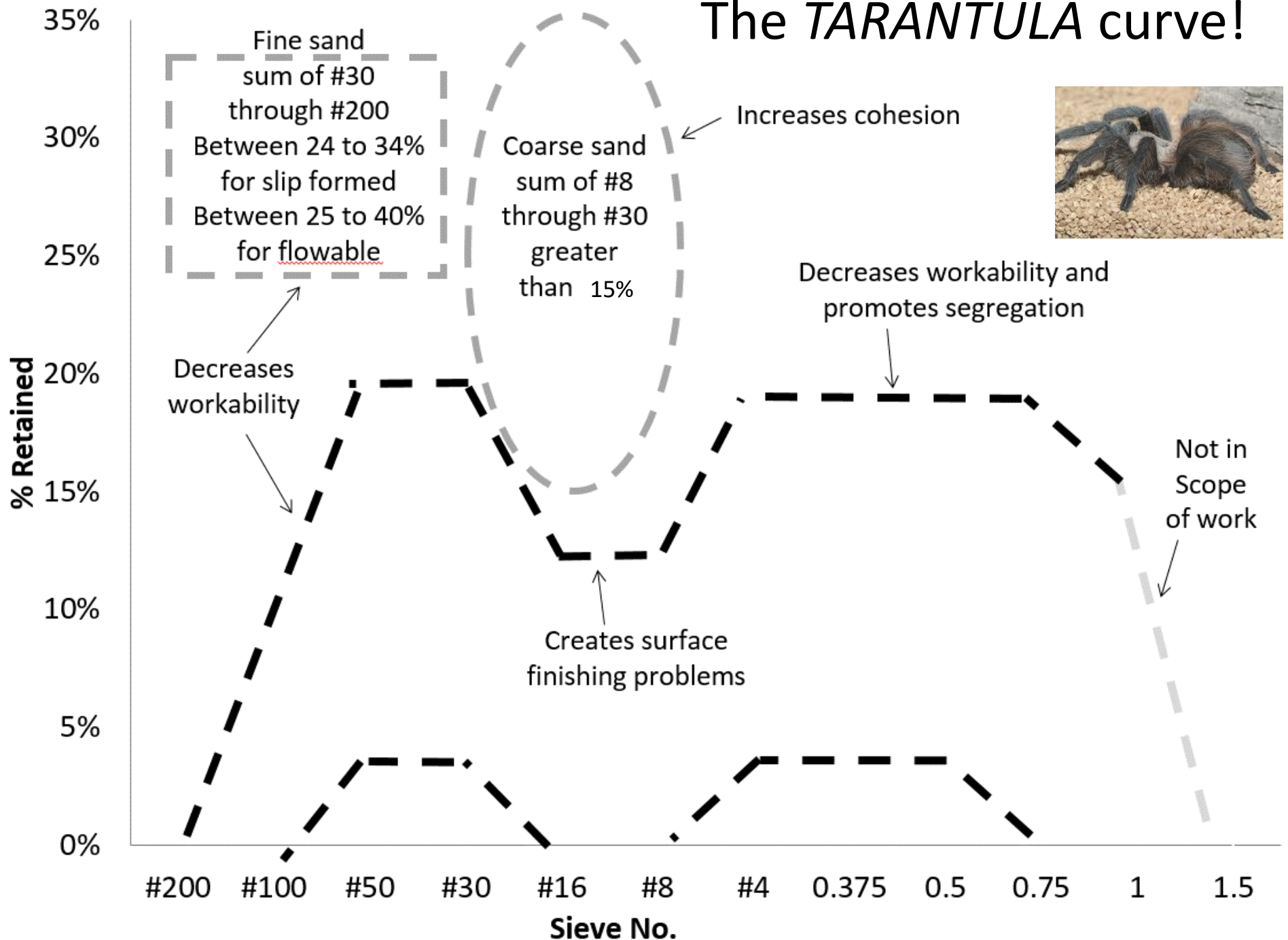
- 13 coarse aggregate sources
- 4 fine aggregate sources

Looked at slip formed to highly workable concrete

Looked at the following:

- different aggregate gradations
- paste contents
- w/cm
- water reducer dosages

The *TARANTULA* curve!



How else are we using these tools?

Manufactured Sands

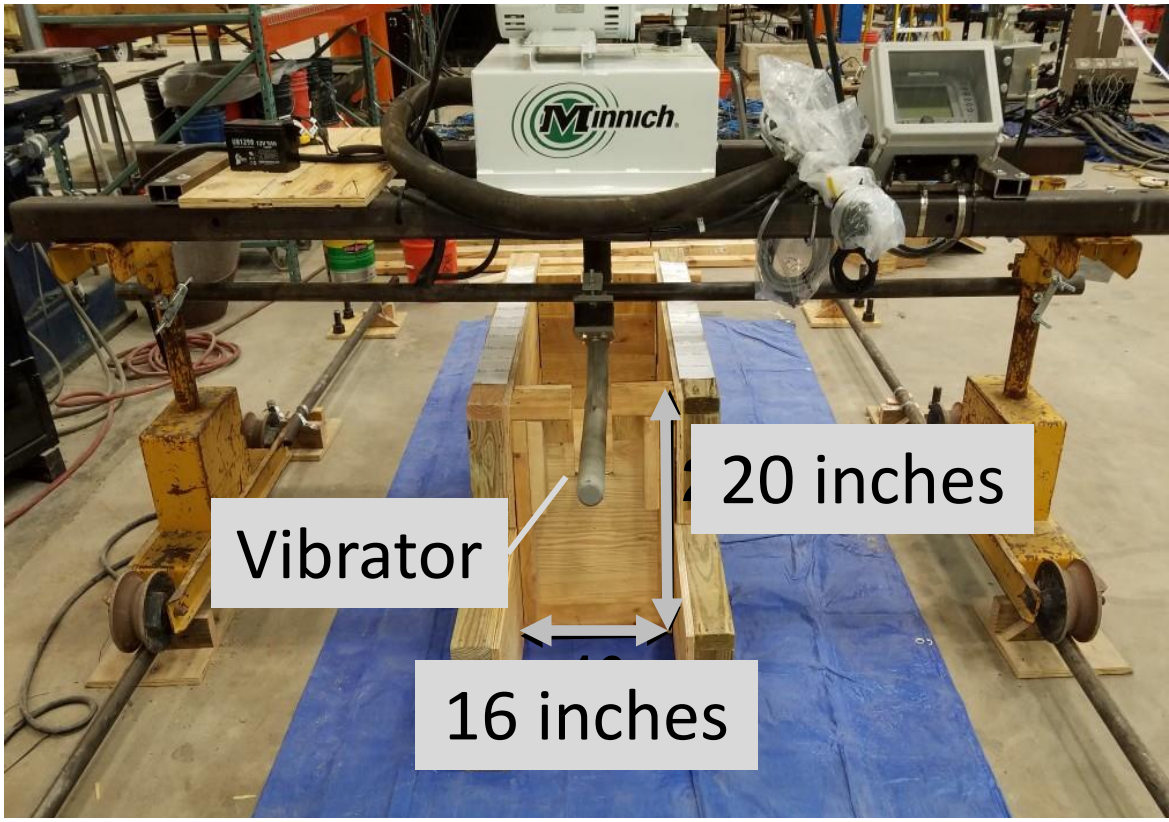
Benefits of larger aggregates

Mixture design for airfield pavements

Low slump overlays

Total mixture design tool – Determine the paste and w/cm based on aggregates.

Vibrating Sled





Concrete paver
owned by Oklahoma
State University

www.tarantulacurve.com

www.tylerley.com/tarantulavideos

Conclusion

The Box Test and Float Test are useful tools to evaluate the workability of concrete for pavement applications.

These tests give you important insights into the design of concrete mixtures.

They can be used in the lab to design mixtures or to troubleshoot issues in the field.

www.tylerley.com

www.youtube.com/tylerley

tyler.ley@okstate.edu

WHAT IS FIBER

REINFORCED

CONCRETE?

TYLER LEY, PE, PHD



Does the aggregate shape matter?

Water reducer dosage to get a 4" slump.

0.0 oz/cwt



Crushed Limestone
Cubic Shaped
Medium Angular
Low Texture

3.0 oz/cwt



Crushed Gravel
Slightly Flat Shaped
Low Angular
Low Texture

6.9 oz/cwt

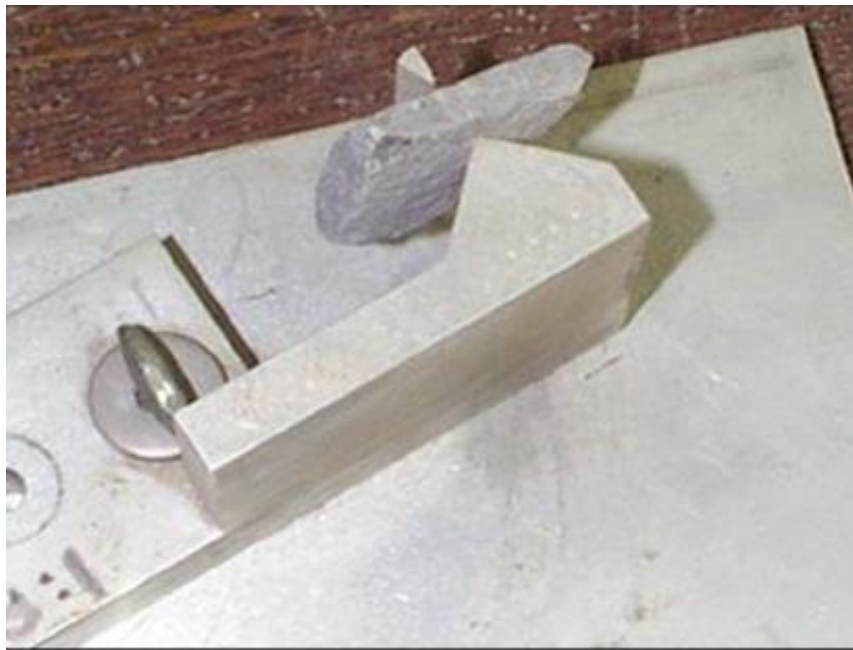


Crushed Limestone
Flat Shaped
Medium Angular
Medium Texture

ASTM D4791

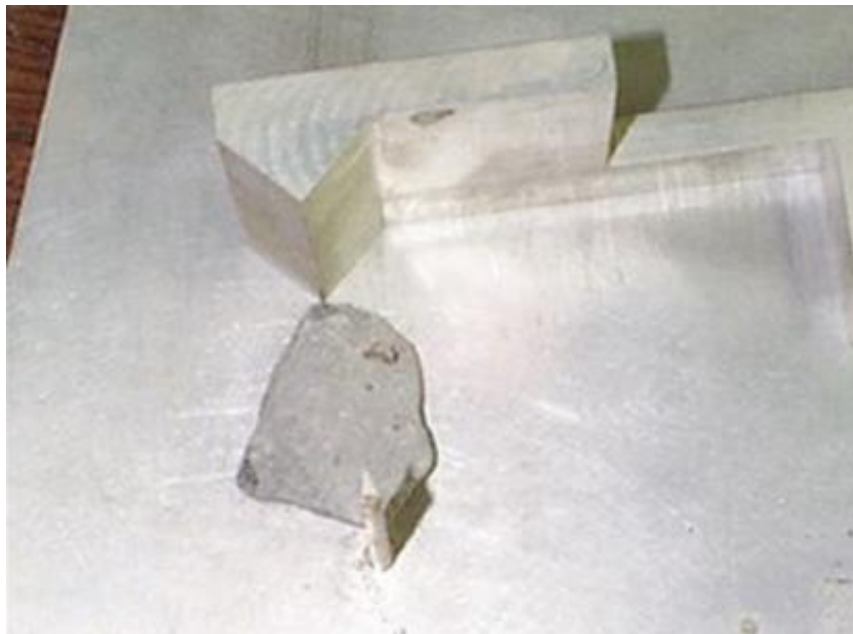
Measures flatness, elongation, and overall shape of a particle.





Min
dimension

Min/Max = flatness ratio



Max
dimension

If less than **15%** of your particles have a flatness ratio of **1:3** then this will improve your workability.

Do aggregates really matter?

The following mixtures look the same on paper:

1850 lbs coarse

1250 lbs sand

445 lbs cement

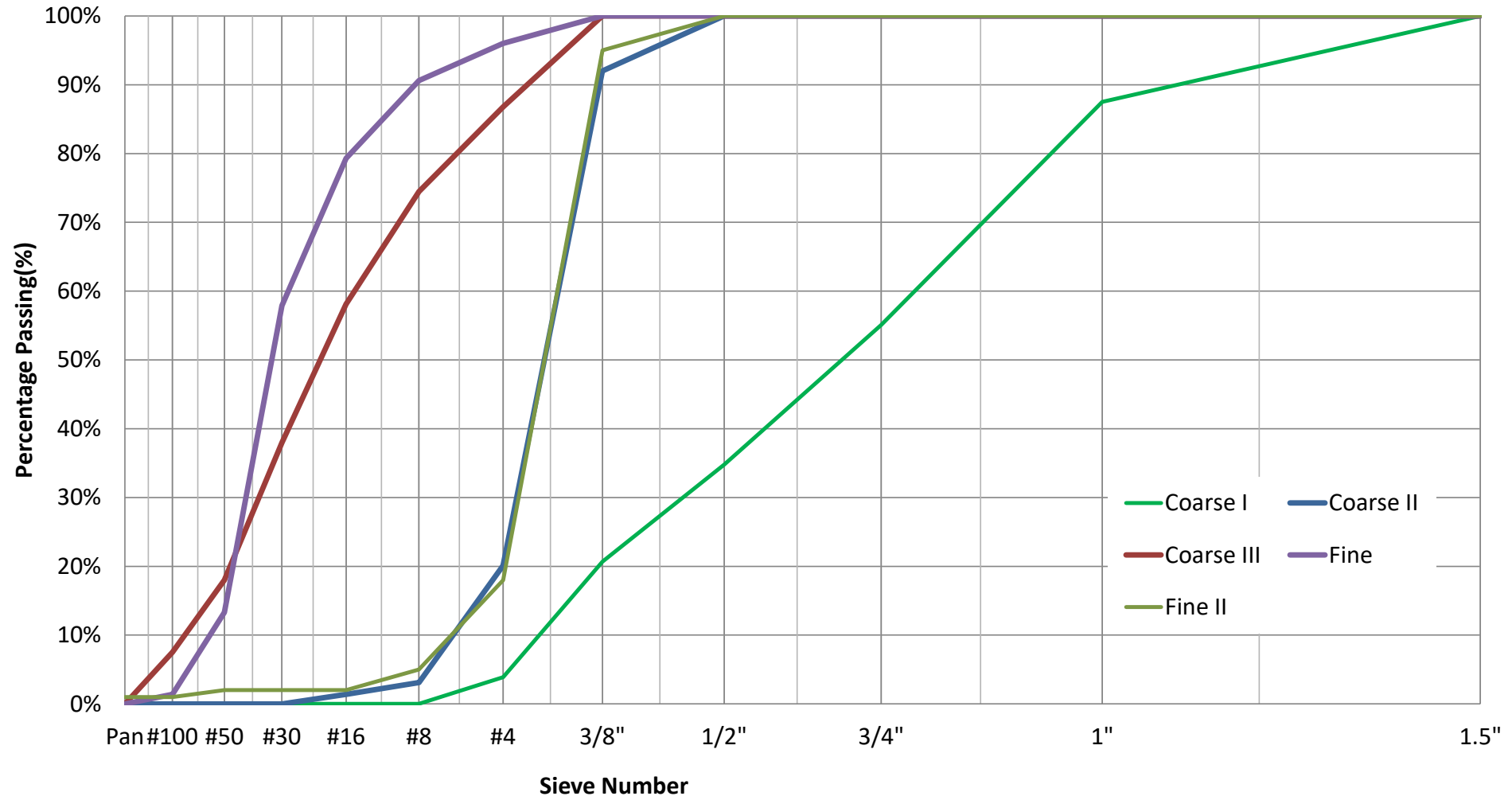
180 lbs fly ash

250 lbs water

} 625 lbs total

Each mix has a different aggregate gradation

The gradation is the particle size distribution.



Deficient Fine Sand



Excessive fine sand



Just right...



High Intermediate



High Coarse



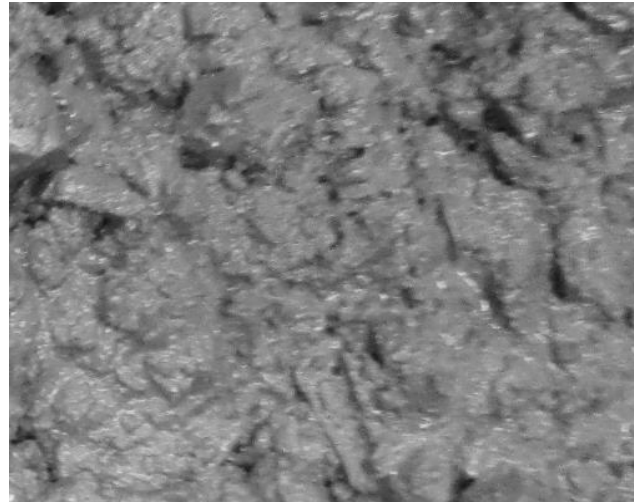
Deficient Fine Sand



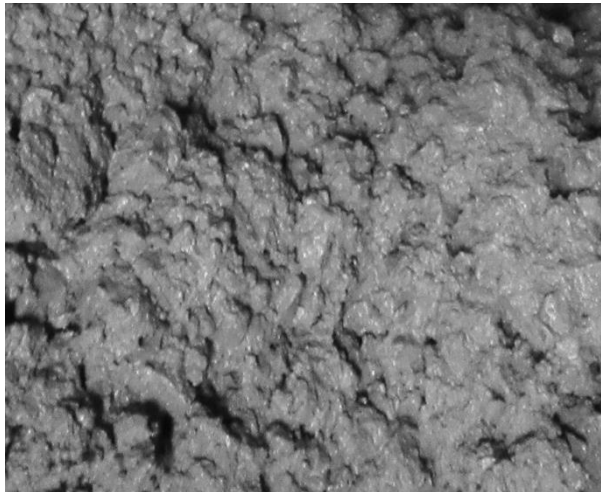
Excessive Fine Sand



Just right...

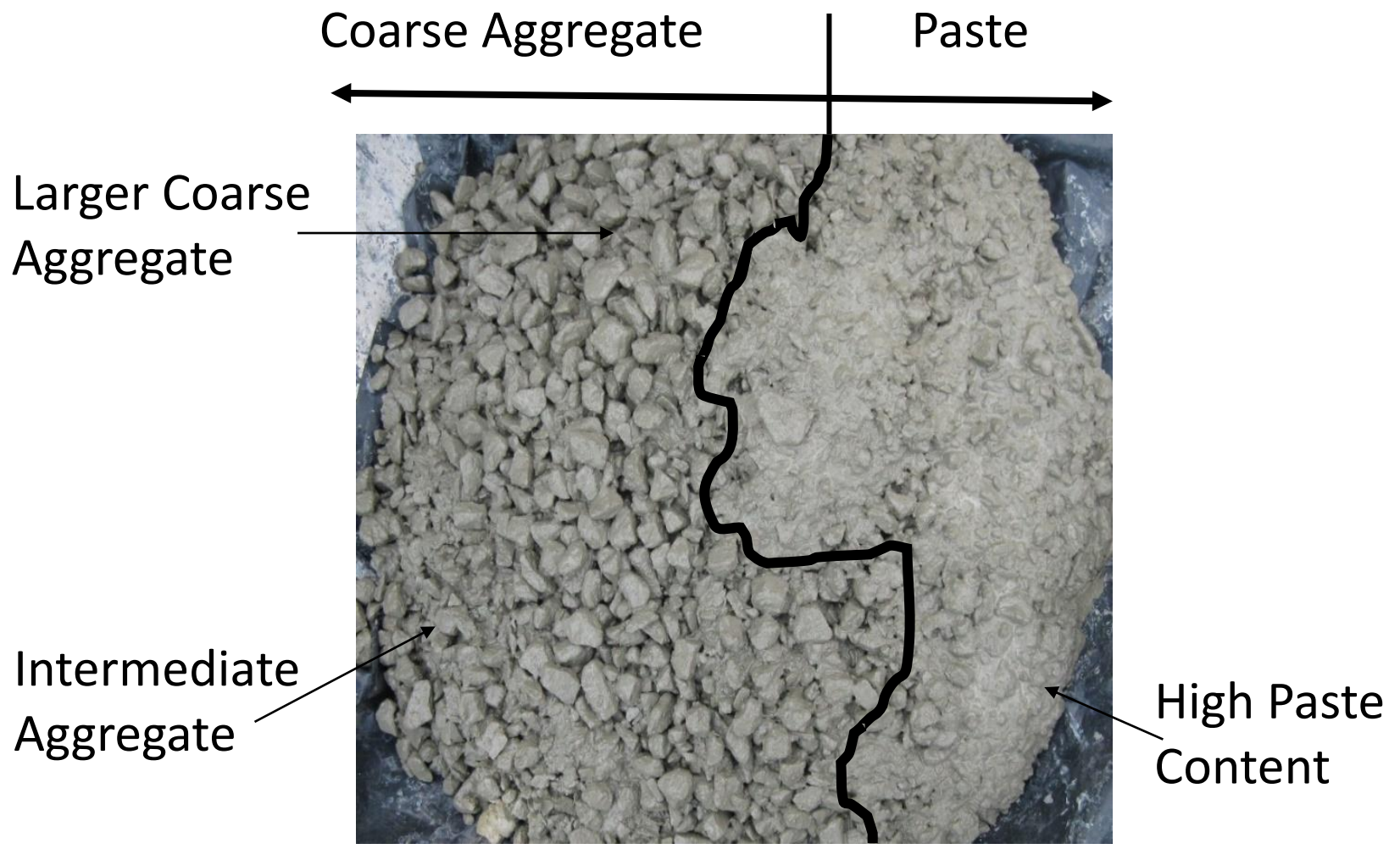


Excessive Intermediate



Excessive Coarse





Overview of the Research at Oklahoma State University

- Use a suite of tests to evaluate how aggregate gradation impacts the practical workability properties of concrete.
- We will present data for mixtures from a wide range of concretes
 - Slip formed to flowable concrete
 - Slump from 0" to 8"

Research by Dan Cook, PhD

Workability Tests

Slump

The Box Test

ICAR Rheometer

Visual Observation

The Float Test

Use in a Pump

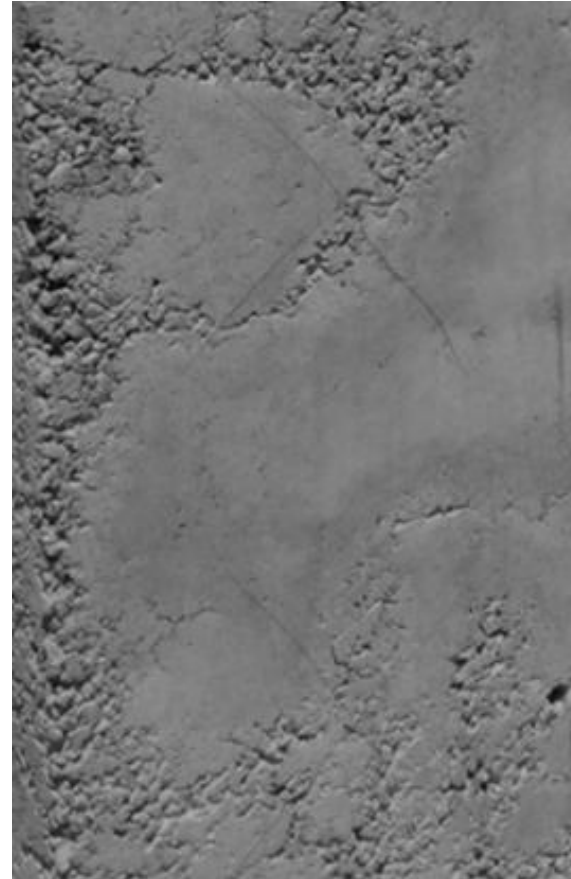


Vibration is also important for walls and columns

Good Vibration



Bad Vibration



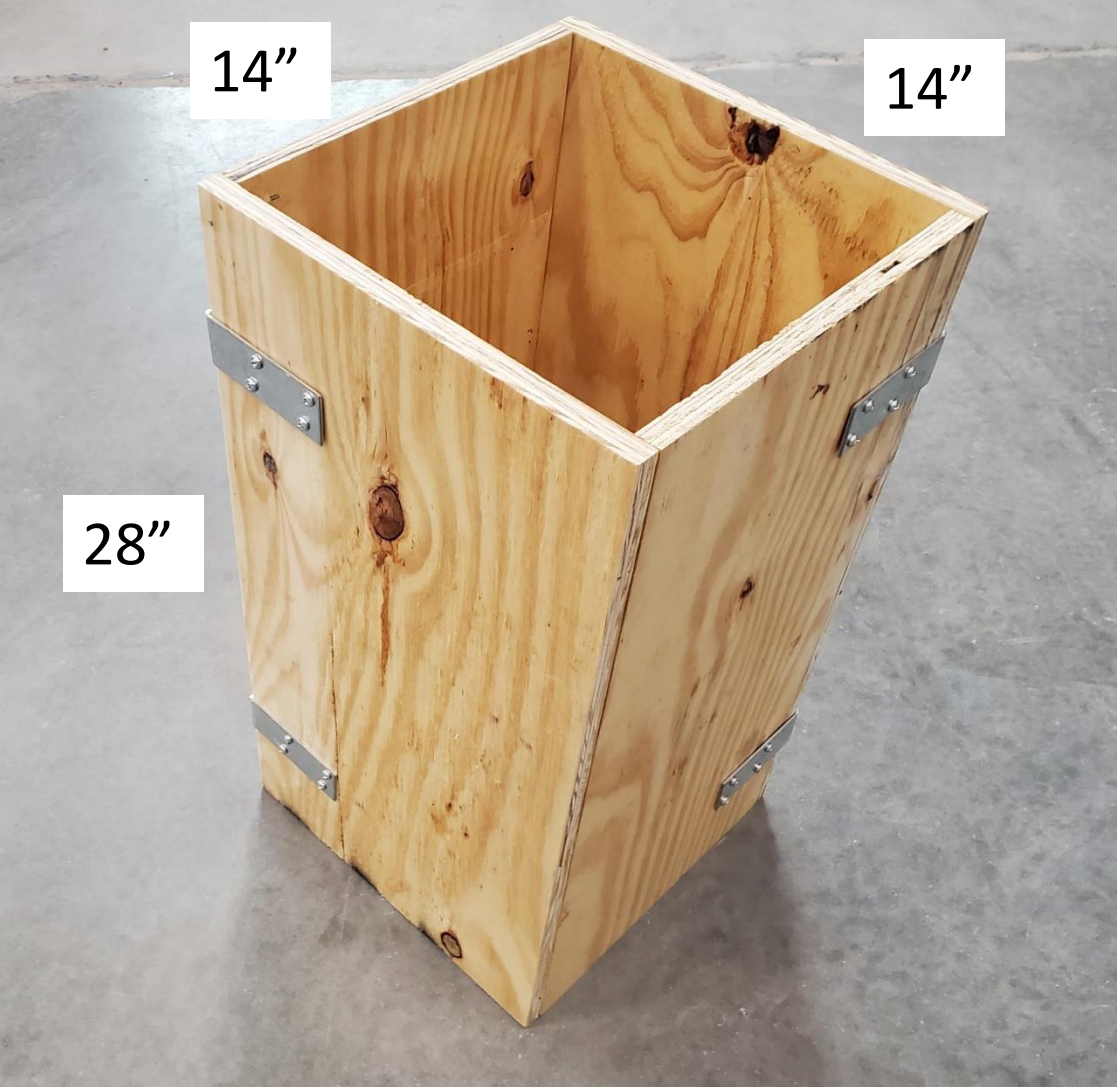
Consolidation Issues

The water can sometimes separate out of mixtures



**Water trapped
in the corner**

Prototype FAA Box Test



Controlled speed vibrator



Prototype FAA Box Test



Controlled speed vibrator

