Why the Box Test & Super Air Meter are Important to Your QA Program

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Acknowledgements

• Gary Ficke
• Peter Taylor
• Brent Burwell
• Jerry Voigt
• Leif Wathne
Outline

- What is the key to QA?
- Workability
  - Box Test
  - *Tarantula Curve!*
- Air Voids Systems
  - Super Air Meter
- Summary
What is the key to QA?
What is the key to QA?

Consistency!!!
How do we get consistency?
How do we get consistency?

Hold as many parameters constant as possible.

Pay close attention to your raw materials and product.

Use testing to track important performance.

We should know where we are now and where we want to be.
Workability

www.optimizedgraded.com
What if we had a miniature paver?
What part of a paver is the most critical for concrete consolidation?

- Auger
- Strike off
- Vibrator
- Tamper
- Profile Pan
- Side Form

Paving Direction
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
<table>
<thead>
<tr>
<th>Box Test Ranking Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>4</td>
</tr>
<tr>
<td>Over 50% overall surface voids.</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>10-30% overall surface voids.</td>
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</table>
# Box Test Ranking Scale

<p>| | | |</p>
<table>
<thead>
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<tr>
<td>4</td>
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<tr>
<td>Over 50% overall surface voids.</td>
<td>30-50% overall surface voids.</td>
<td>10-30% overall surface voids.</td>
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<td>[Image]</td>
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<tr>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>Less than 10% overall surface voids.</td>
<td></td>
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</tbody>
</table>
Edge Slumping

Bottom Edge Slumping

Top Edge Slumping
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!!!
Testing Overview

• We evaluated over **350** concrete mixtures
  – 13 coarse aggregate sources
  – 4 fine aggregate sources

• Looked at the following:
  – different aggregate gradations
  – paste contents
  – w/cm
  – water reducer dosages
The TARANTULA curve!

- Fine sand sum of #30 through #200 between 24 to 34% for slip formed.
- Between 25 to 40% for flowable.
- Coarse sand sum of #8 through #30 greater than 20%.
- Decreases workability and promotes segregation.
- Increases cohesion.
- Creates surface finishing problems.

Not in Scope of work.
What about other mixture procedures?

- Power 45
- Coarseness Factor
Power 45-Poor Workability

Percent Passing (%) vs. Sieve Number

- Maximum Density Line
- Maximum Passing Boundary
- Minimum Passing Boundary

Sieve Sizes:
- #200
- #100
- #50
- #30
- #16
- #8
- #4
- 3/8"
- 1/2"
- 3/4"
- 1"
- 1.5"
Power 45-Good Workability

The graph illustrates the percent passing (%) through various sieve numbers from #200 to 1.5" for a material designated as Power 45. The x-axis represents the sieve number, and the y-axis represents the percent passing. The graph includes the following lines:

- **Maximum Density Line**
- **Maximum Passing Boundary**
- **Minimum Passing Boundary**

Each line corresponds to different criteria for passing materials, with the maximum density line indicating the ideal distribution for good workability.
Where is the Detail?

Poor Mix
Summary Of Power 45

• At first glance, the Power 45 has the potential to be helpful.

• Using a best fit line on the Power 45:
  – Just does not show enough detail to the changes in slope of the gradation line.
  – Does not address the volumes ranges of fine and coarse sand.

• We think the Tarantula Curve is better.
Coarseness Factor Chart

Let's look at these!
Summary

• The limits in the Coarseness Factor Chart do not always produce mixtures with satisfactory workability.

• The Coarseness Factor and Workability Factor equations were a good start but they are too basic.
Use in the field
Data from Maria Masten
Minnesota 2009
87% of mixtures met the sand criteria

Data from Maria Masten
Minnesota
2010
98% of mixtures met the sand criteria

Data from Maria Masten
Field Concrete

• The Minnesota contractors are producing gradations that fit within the Tarantula and having good success with them.

• They are doing this with trial and error and no knowledge of the Tarantula Curve.

• Similar data is available for Iowa.
What else...

• The Tarantula Curve was used on 10 lane miles of highway in Texas with 447 lbs of binder/CY.

• The FHWA Mobile Concrete Lab has shown that the Tarantula Curve and Box Test is a useful tool to predict performance of pavements on field projects.

• Oklahoma, Minnesota, and Texas DOT have integrated the Tarantula Curve into their optimized graded specifications for pavements.
What about aggregate shape?
Why is the WR dosage different?

Crushed Limestone B
- Cubic Shaped
- Medium Angular
- Low Texture

Crushed Gravel
- Slightly Flat Shaped
- Low Angular
- Low Texture

Crushed Limestone A
- Flat Shaped
- Medium Angular
- Medium Texture

0.0 oz/cwt

3.0 oz/cwt

6.9 oz/cwt
Summary

• The aggregate flatness and angularity plays a role in workability.

• The more flatness and angularity the lower the workability.
ASTM D4791

• Measures flatness, elongation, and overall shape of a particle.
• This is based off ratios such as 1:1, 1:3, or 1:5.
• We recommend less than 15% on the 1:3.
www.optimizedgraded.com
What Affects Air-Entrainment?
What Affects Air-Entrainment?

Everything!
Batching Process

Cement
- Admixture dosage based on cement content
- Fineness
- Alkalies

Supplementary Materials
- Fly ash, silica fume
- Carbon in fly ash can absorb AEAs

Aggregates
- Sand Gradation
- Fine/Coarse
- Ultra fines (< #200) harmful

Admixtures
- Compatibility should be examined
- Some water reducers modify the air void system
Mixing

- w/cm
- Slump
- Temperature
- Mixing Speed
- Order of Addition
- Mix Size
- Drum Condition
- Type of Mixer
- Moisture Correction
- Hardness of water
- Length of Mixing Time
Placement

Method of Transportation
Haul Time
Retempering
Paver Settings
Consolidation
Finishing
Temperature

PCA photo
The least consistent aspect of concrete is air entrainment.

A major reason for these issues is the size of your air voids.
What Do You Want in an Air-Void System?

- Volume of air provided is the same for both.
- Case B has a better air void distribution.
Why are large bubbles bad?

They create unstable air void systems
They don’t help with freeze-thaw durability
They reduce your strength more than smaller bubbles
Hardened Air Void Analysis

From Hover
Hardened Air Void Analysis

From Hover
• Spacing Factor – $\frac{1}{2}$ of the average distance of an average sized void uniformly distributed in the paste

• **Desired Value < 0.008 in (ACI 201)**

real concrete

idealized concrete

Spacing factor from Hover
digital gauge

different bleeder valve

six clamps!
AASHTO TP 118

www.superairmeter.com
How does it work?

Use ASTM C231 procedures to fill the measurement bowl
Secure the lid
Add water through the petcocks
release pressure in both chambers
**Controlled Air Pressure Extender**

aka **CAPE**

**Step 1** (14.5 psi)

**Step 2** (30 psi)

**Step 3** (45 psi)
Discussion

The Super Air Meter gives you the air content and the SAM number.

The SAM number will correlate to air void size and spacing.
This test takes 7–14 days

This test takes 5–10 minutes

92% Agreement

Yes!
No

ACI 201.2R

Spacing Factor (in)
SAM Number (psi)
Lab Data OSU
Field Data
LAB Data FHWA
This test takes 3.5 months

80% agreement w/ 0.20 limit

89% agreement w/ 0.25 limit

This test takes 5 - 10 minutes
ASTM C 457 Spacing Factor, in
Air %
WROS .45
WROS .45 + PC1
ACI 201.2R

Small bubbles

Large bubbles

ACI 201.2R

Yes!

No!
WROS .45
WROS .45 + PC1
ACI 201.2R
A SAM number of 0.20 corresponds well with a spacing factor of 0.008” and satisfactory performance in the rapid freeze thaw test.

How does that help me?
You can get all this information in 5-10 minutes
Discussion

In 5 minutes the SAM can measure the size and volume of your air void system in fresh concrete.

This will give you great insights into the stability of your air void system as well as the impact on strength.
Why is this useful?

This can give you important QA information that was almost impossible to get in the past.

This is helpful when:

– mixtures are designed in the lab
– trial batching in the field
– troubleshooting field problems
– measuring variation in materials
The following states have a SAM

- Michigan (5)
- Kansas (8)
- Utah
- Colorado (2)
- Iowa (2)
- Illinois (5)
- Indiana (2)
- Wisconsin (4)
- Massachusetts
- Idaho (2)
- Tennessee
- Pennsylvania
- Missouri (2)
- N. Carolina (3)
- N. Dakota
- Oklahoma (9)
- Nebraska (3)
- Ohio (3)
- Minnesota (2)
- Texas (2)
- FHWA (4)
- Georgia
- New Jersey
- New York
- S. Dakota
- Mississippi
- Iowa (2)
- Manitoba (3)
- Ontario (2)
How can this group help?

Tell someone else about the SAM!
Try the SAM for yourself
We need to get the SAM used!
Summary

We have new tools to help us with QA of our concrete that we have never had previously.

Let’s use these tools to help us make more consistent concrete!
Live Demonstration!!!

- Come and see a live demonstration of the Box Test and Super Air Meter!!!!

- Also come and see the FHWA Mobile Concrete Lab and all of their toys!
Questions???
Tyler.ley@okstate.edu
www.optimizedgraded.com
www.superairmeter.com

May the Force be with you!!!!
The Float Test

- Evaluates the surface finishability 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 in the 3 holes
   - create a smooth finish
1. Place and Level Concrete
2. Create Three 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
The Float Test

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<td>30 to 50% of area was textured</td>
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<table>
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<th>1</th>
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<td>10 to 30% of area was textured</td>
<td>Less than 10% of area was textured</td>
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The Float Test

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Why?
- Fine sand sum of #30 through #200
  - Between 24 to 34% for slip formed
  - Between 25 to 40% for flowable

- Coarse sand sum of #8 greater than 20%
  - Increases cohesion

- Decreases workability and promotes segregation

- Creates surface finishing problems

- Not in Scope of work

% Retained

Sieve No.: #200 #100 #50 #30 #16 #8 #4 0.375 0.5 0.75 1 1.5
Limestone A

Overall Workability

- Poor
- Moderate
- Good

% Retained

Sieve No.

#200 #100 #50 #30 #16 #8 #4 3/8" 1/2" 3/4" 1" 1.5"
Slump Test

High Coarse  Moderate Amount  High Intermediate
Visual Observations

- Excessive Coarse
- Sufficient Amount
- Excessive Intermediate
Valleys

% Retained

Sieve No.

#200  #100  #50  #30  #16  #8  #4  3/8"  1/2"  3/4"  1"  1.5"

Good

Good
Valleys

Sieve No. % Retained

#200 17
#100 18
#50 5
#30 17
#16 18
#8 5
#4 Good
3/8" Good
1/2" Good
3/4"
1"
1.5"
• Maximum boundary limit of 20 % on $\frac{3}{4}$” to #4 sieve size

• The **double or single valley** did not drastically change the workability of the concrete as long as no coarse sieve size went above 20%.
Fine sand
sum of #30
through #200
Between 24 to 34%
for slip formed
Between 25 to 40%
for flowable

Increases cohesion

Coarse sand
sum of #8
greater than 20%

Decreases workability and
promotes segregation

Decreases workability

Creates surface
finishing problems

Not in Scope of work

% Retained

#200  #100  #50  #30  #16  #8  #4  0.375  0.5  0.75  1  1.5

Sieve No.
Ideal Bell Shaped Curve

% Retained vs Sieve No.

Sieve No.: #200 #100 #50 #30 #16 #8 #4 3/8" 1/2" 3/4" 1" 1.5"

- Good
- Moderate*

Legend:
- 21
- 5
Visual Observation Of Ideal Bell Shaped Curve

Before Finishing

After 8 Passes
Investigation of Coarse Sand

• To understand and observe the coarse sand behavior #8, #16, and #30 sieve sizes were removed.

• Various amounts of each sieve size was gradually added.
Discussion of Coarse Sand

- For cohesion, a minimum of 20% retained on the #8-#30 sieve sizes was needed.
- Finishability issues created a maximum boundary limit on #8 & #16 of 12% on each sieve size.
Repeat tarantula with sand highlighted and the fine sand range between 24 to 34% for slip formed and between 25 to 40% for flowable.

Coarse sand sum of #8 through #30 greater than 20% increases cohesion.

Decreases workability and promotes segregation.

Decreases workability.

Creates surface finishing problems.

Not in scope of work.
Visual Observations

Excessive Sand

Sufficient Sand

Deficient Sand
From the Slump Test

Excessive Sand  Sufficient Sand  Deficient Sand
What about strength?

<table>
<thead>
<tr>
<th>Source</th>
<th>7 Day Strength</th>
<th>28 Day Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min-Max (psi)</td>
<td>Average (psi)</td>
</tr>
<tr>
<td>Limestone A</td>
<td>4000-6320</td>
<td>5180</td>
</tr>
<tr>
<td>Limestone B</td>
<td>4990-5270</td>
<td>5130</td>
</tr>
<tr>
<td>River Rock</td>
<td>3990-4850</td>
<td>4440</td>
</tr>
</tbody>
</table>

All mixtures had 4.5 sacks of total cementitious with 20% fly ash.