Machine vs Concrete Building long lasting concrete pavements (PEM2)

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PEM Philosophy

• What do we want?
• How do we know its good?
• How do we deliver it?
PEM 1 – The mixture

• Transport
• Cold weather
• Strength
• Aggregates
• Shrinkage

• Workability
PEM 2 – The mixture after it is dumped

- Consolidation
- Smoothness
- Thickness
- Finishing
- Curing
- Sawing
But how do we get there?

- What levers can we pull?
- What tests inform our decisions?
PEM properties
Uniform Workable
Segregation
Smooth Finished
In the Lab

- Aggregate stability – AASHTO / ASTM protocols
- Shrinkage – paste content

- Transport properties (permeability) - resistivity
- Cold weather resistance – air void system
- Strength – compression / flexural
In the Lab

• Workability
  • Segregation
  • Response to vibration
  • Edge slump
  • Finishability

• Other tests?
In the Lab

Proportioning to achieve performance goals

<table>
<thead>
<tr>
<th>Aggregate System</th>
<th>Workability</th>
<th>Transport</th>
<th>Strength</th>
<th>Cold weather</th>
<th>Shrinkage</th>
<th>Aggregate stability</th>
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<td>Paste quality</td>
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At the Batch Plant

• Workability
  - Power meter
  - Call from the paving supervisor
  - Data from the paver?
  - Augur power demand?
  - Torque to move paver
  - Drag on burlap

• Uniformity
  • Stockpile control
  • Water control
  • Loading sequence
  • Mixing time
  - No standard test
  - Moisture probes
  - -
In front of the paver

- Segregation
  - Aggregate gradation
  - Uniform delivery
  - Placing method

No standard test
Behind the Paver

• Finish and Smoothness
  • Vibration
  • Pan setup
  • Grout box
  • Paver speed
  • Finishing

• Real time smoothness
  • Internal sensors
Tining Bridge

- Texture
- Tine setup
- Bridge speed

- Curing
  - Curing Compound type
  - Spray rate

Sand Patch
Noise

Zollinger method?
Sawing

- Crack free / Saw type
- Blade
- Depth
- Timing

UPV

![Graph showing the relationship between UPV Initial Set and Sawing time, with the equation y = 1.2376x + 272.64 and R² = 0.8525]
Where Next?

- What have we missed above?
- Small bites – started with PEM
- Next bites
  - Vibration
  - Batch (water) control
# Steps to Long Life

## Target performance
- Workability
- Durability
- Strength

## Design Levers
- Gradation
- Paste Volume
- Cementitious
- Admixtures

## Batching
- Uniformity – Water
  - Cementitious system
  - Aggregates
- Mixing
  - Time
  - Energy

## Transportation
- Mixing
- Workability
  - Time and weather
  - Added water / admixtures
- Uniformity

## Placement
- Handling / Vibration
  - Bleeding
  - Segregation
  - Air void system
  - Water movement

## Finishing
- Surface finish
- Curing
- Sawing

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Measure!
Vibration

Purpose
• To remove unwanted air
• Assist with levelling

The Theory
• Reduce yield stress and viscosity
  • Allow bubbles to float out
  • Allow mixture to move

The means
• Vibration
What Is Happening under Vibration?

- Shaft oscillates in a circle sending out P and S waves
- Acceleration drops viscosity and allows air to float up and out
- Water moves horizontally
- Solids wobble and maybe rotate
What is a good vibration?

Ensures
• No segregation
• No entrapped air
• Retain entrained air
• No water movement

But how?
What is a good vibration?

• Missing is fundamental understanding of the “how to” details
  • Energy
  • Frequency
  • Amplitude
  • Duration
  • Spacing
• For a given
  • Workability
  • Air void system
  • Bleed / segregation
  • …
Rheology 101

Yield Stress, Pa

Force needed to start flow (Edge slump)

Plastic Viscosity, Pa.s

Resistance to change in rate (Consolidation)
Rheology 101

Yield Stress, Pa

- Slipform Concrete
- Regular concrete
- Water
- SCC
- Honey

Plastic Viscosity, Pa.s
Rheology 101

Yield Stress, Pa

Silica fume

Air

Water

Superplasticizers

Plastic Viscosity, Pa.s
Rheology 101

Yield Stress, Pa

Plastic Viscosity, Pa.s
Preliminary Lab Work

- Vibration energy (RMS velocity, in/s) at a specific time period across the a range of frequencies – converted to acceleration
- Vibrator reported voltage required to maintain fixed frequency
Water is shown to move away from vibrator tip

(a) Mixture 1 - air 3.7%
(b) Mixture 2 - air 7.2%
Air is shown to move up from vibrator tip

(a) Mixture 1 - air 3.7%

(b) Mixture 2 - air 7.2%