Workability of Mixtures for Slipform Concrete Pavements

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Steps to Long Life

Target performance

Workability – response to handling / vibration as needed
Durability – survive the environment
Strength – enough

Design Levers

Gradation – Tarantula Curve
Paste Volume – Fill void space + a bit
Cementitious – w/cm, SCMs
Admixtures – AVS, flow, bleed rate

Batching

Uniformity – Water control
– Cementitious blending
– Adjustments for incoming variability
Mixing – Time and energy

Transport

Mixing – equipment used
Workability
– Time and weather
– Added water / admixtures
Segregation – mixture

Placement

Workability – Time and equipment
Air-void-system – pumping, vibration, finishing
Uniformity – Handling and vibration

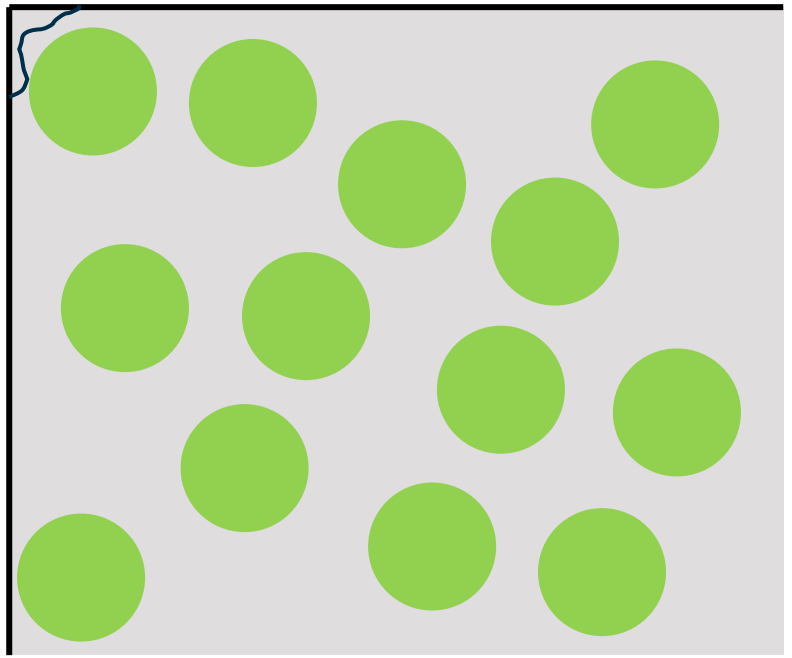
Finishing

Surface – air, bleeding, weather, setting time, smoothness
Curing – methods, duration
Sawing – Timing, equipment

Workability

- Not too wet / Not too dry
- Right for the equipment you are using

- Yield stress/viscosity
- Response to vibration



Rheology for Engineers

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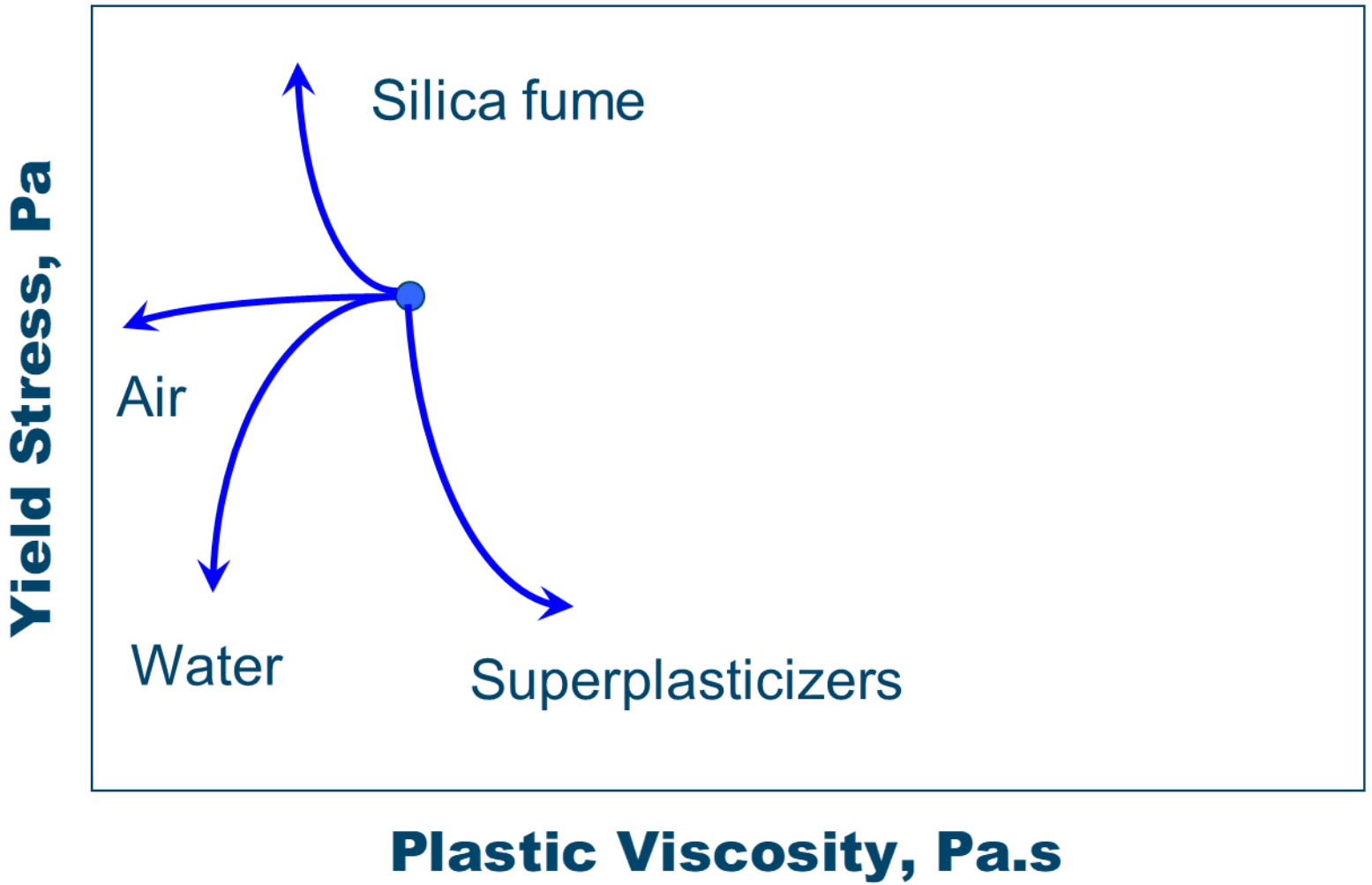


Rheology for Engineers

Vibration –
The Good the Bad and the Ugly

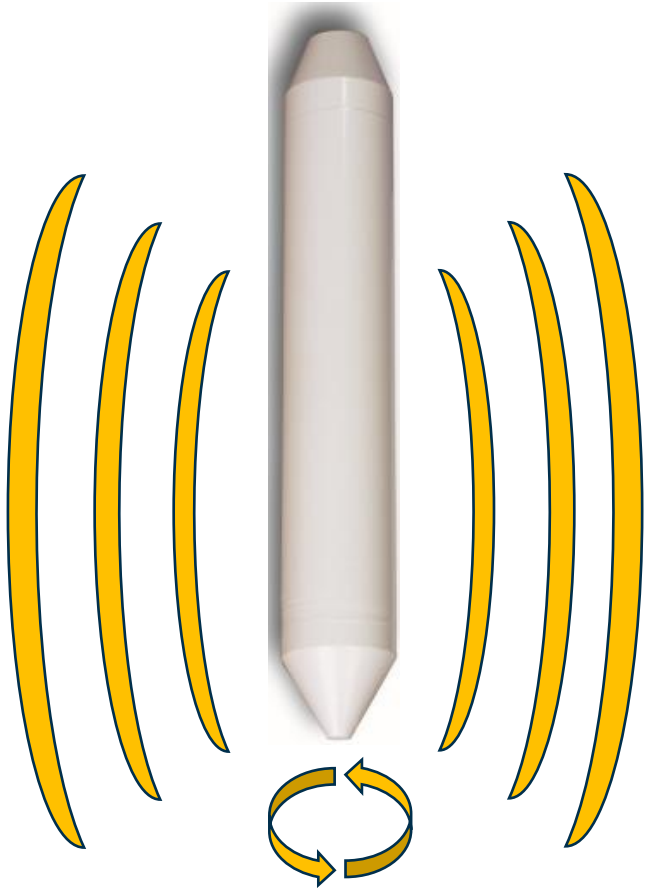
Purpose

- To remove unwanted air
- Assist with levelling
- To get some paste to the surface

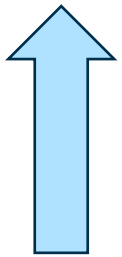
The Theory

- Reduce yield stress and viscosity
  - Allow big bubbles to float out
  - Allow mixture to move

What Is Happening under Vibration?

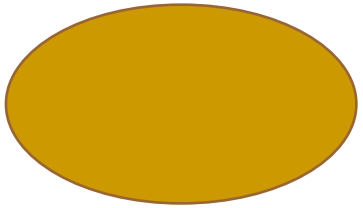


Shaft oscillates in a circle sending out P and S waves



Acceleration allows air to float up and out
(Uplift > yield stress)

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

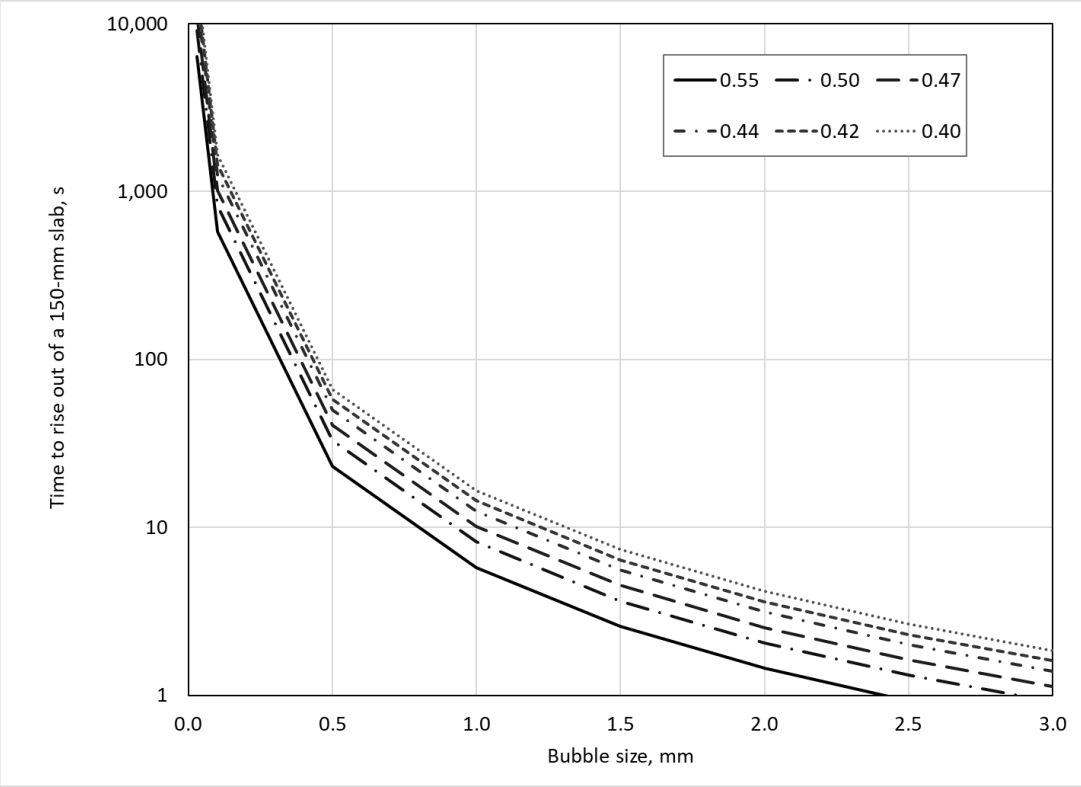
But how?

What is a good vibration?

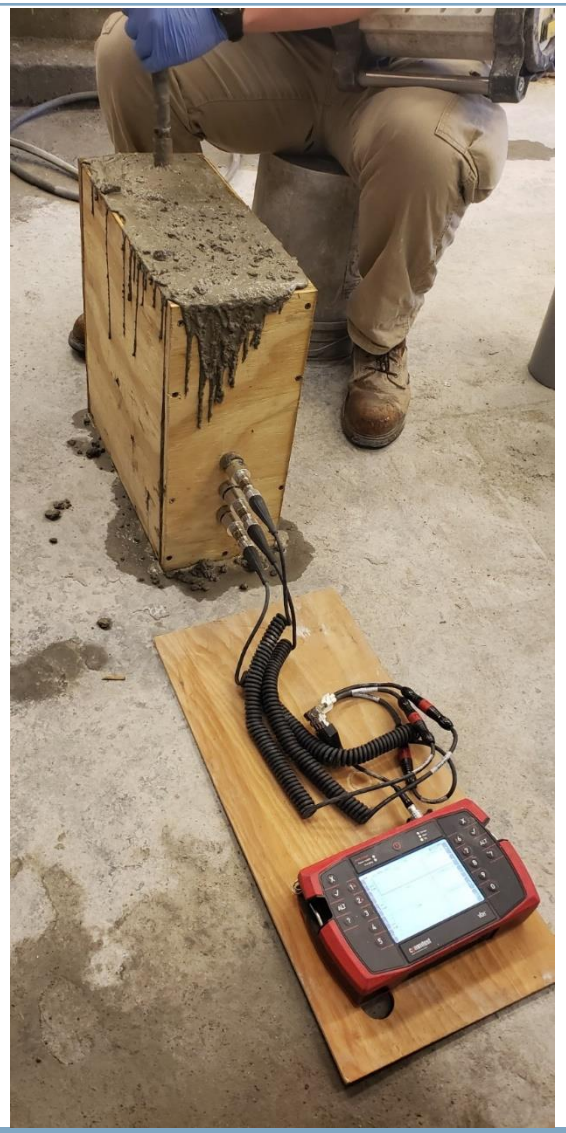
- Missing is fundamental understanding of the “how to” details
  - Energy
  - Frequency
  - Amplitude
  - Duration
  - Spacing
- For a given
  - Workability
  - Air void system
  - Bleed / segregation
  - …

Hypothesis

- Increased frequency
  - Moves water sideways
- Excess vibration
  - Moves air up
- Mixture segregation and bleeding increase effects



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

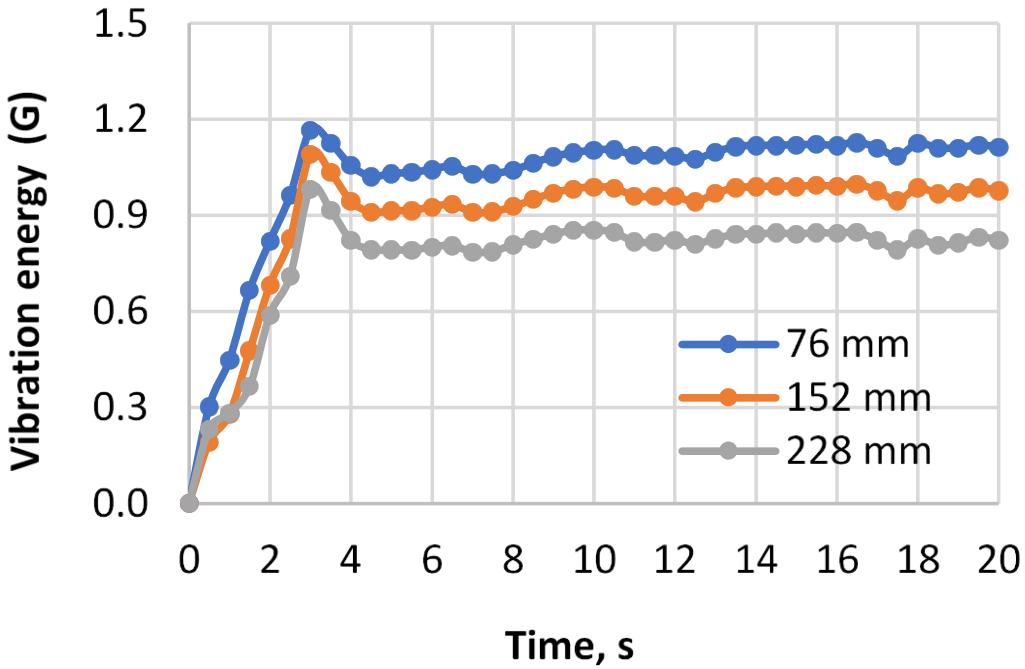
Matrix

- Mixture 1 – low air (3.7%), high slump (10 cm), moderate w/c (0.4)
- Mixture 2 – high air (7.2%), high slump (10 cm), moderate w/c (0.4)
- Mixture 3 – low air (3.0%), low slump (2.5 cm), low w/c (0.25)
- Mixture 4 – low air (3.1%), high slump (10 cm), low w/c with WR (0.29)

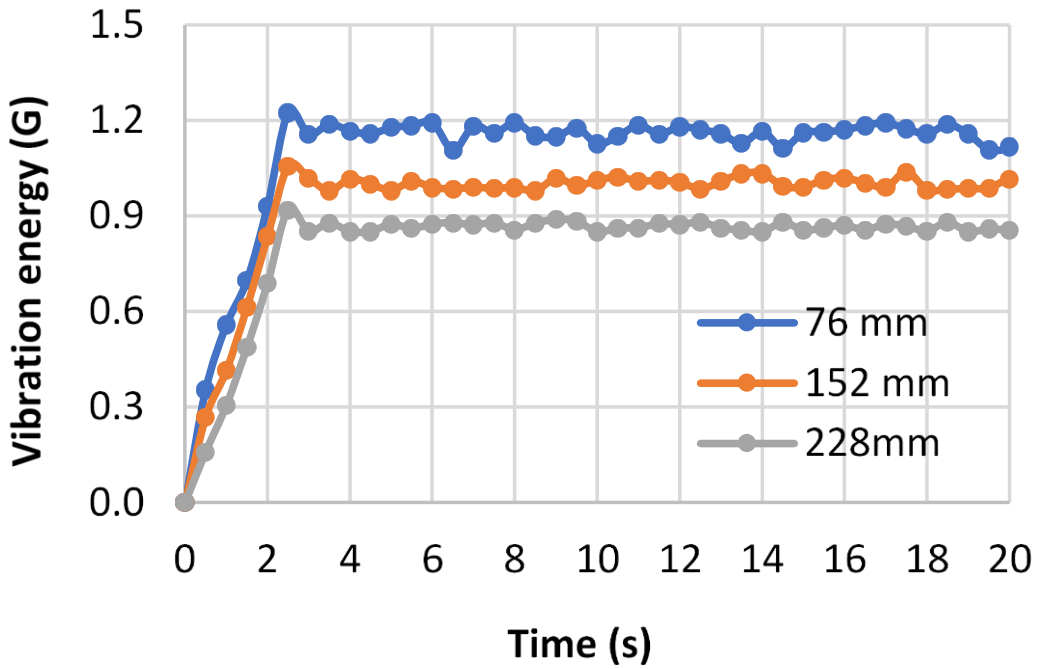
- Frequency
  - Mixtures 1 - 4 at 8,000 vpm
  - Mixture 1 at 12,500 vpm

Effect of Air Content

- Little difference in energy transfer



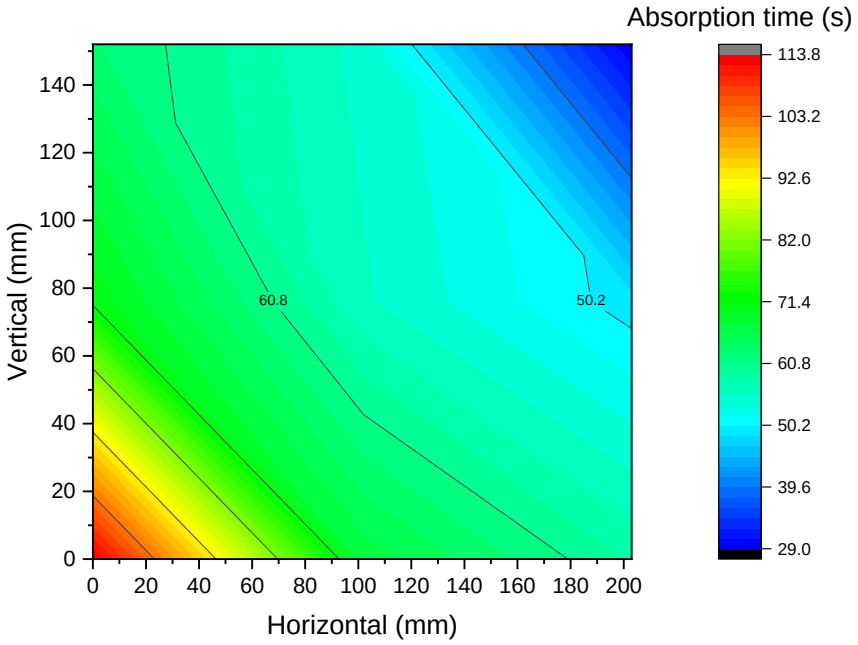
(a) Mixture 1 - air 3.7%



(b) Mixture 2 - air 7.2%

Effect of Air Content

- Water is shown to move away from vibrator tip



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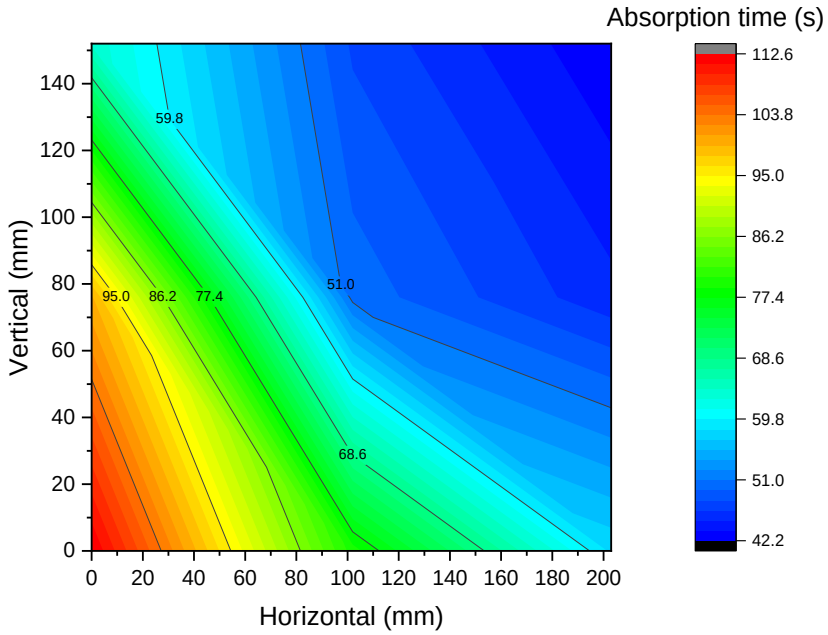
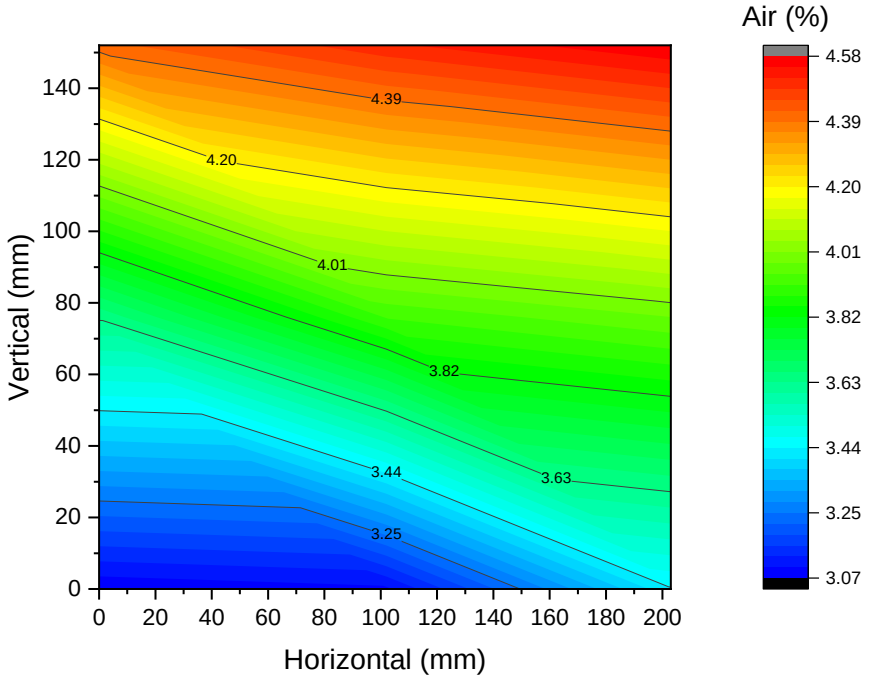


(b) Mixture 2 - air 7.2%

Effect of Air Content

- Air is shown to move up from vibrator tip



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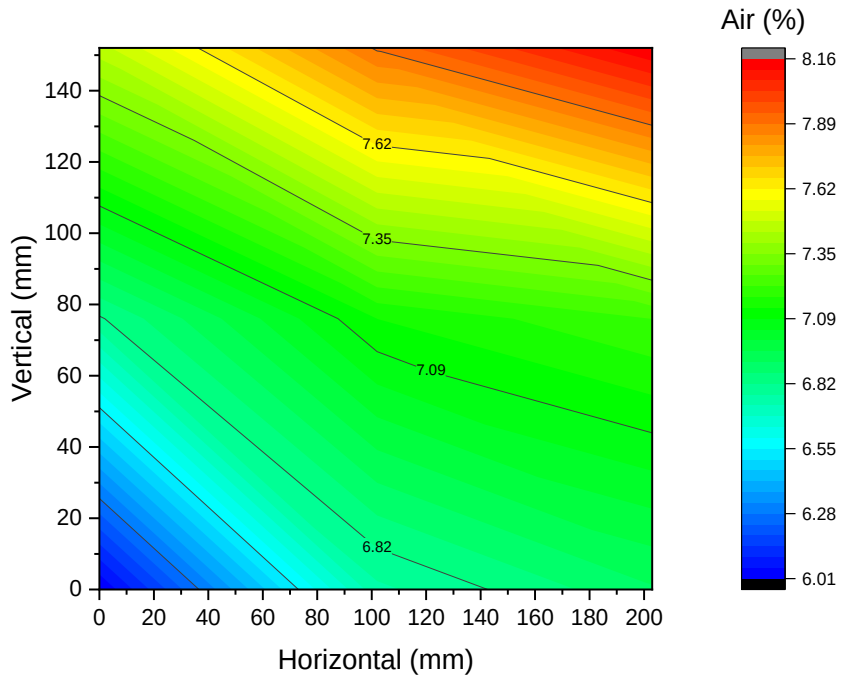
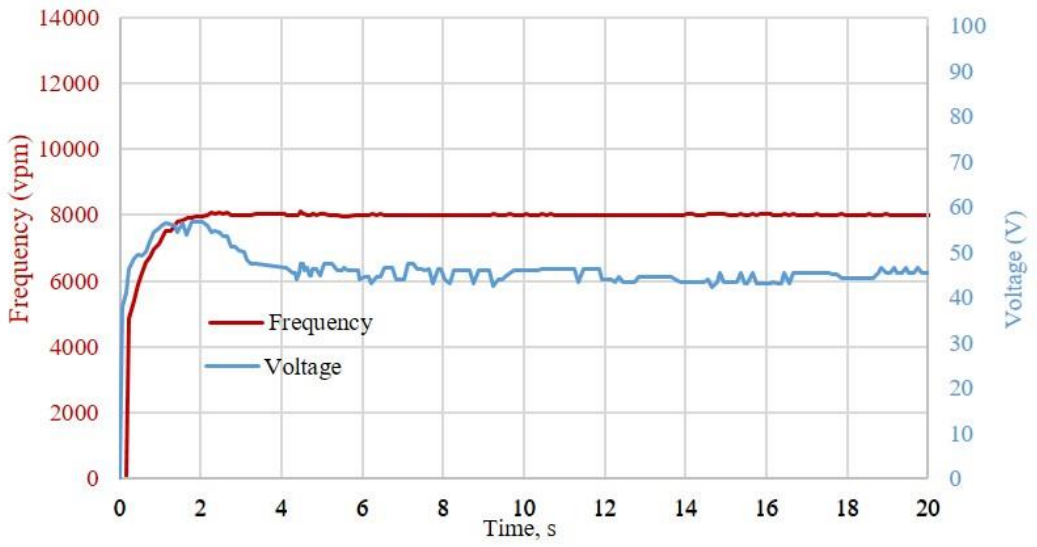


(b) Mixture 2 - air 7.2%

Effect of Air Content

- Little difference in energy demand



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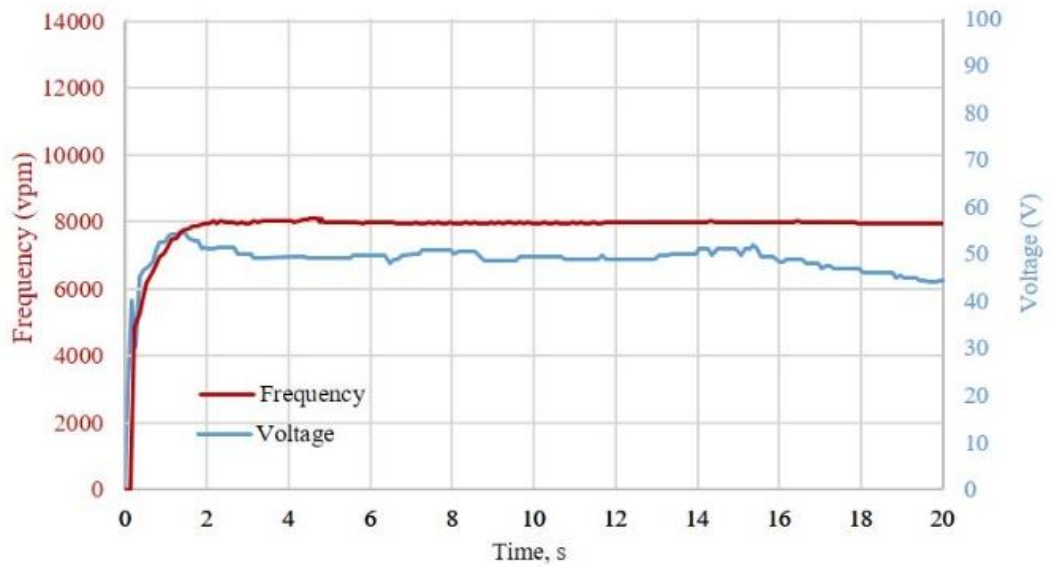
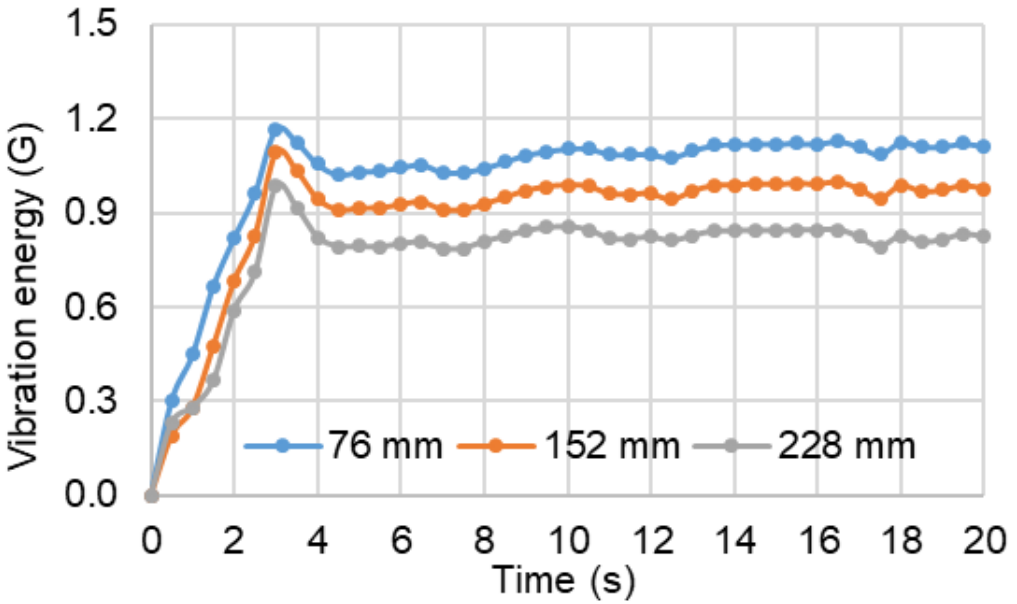


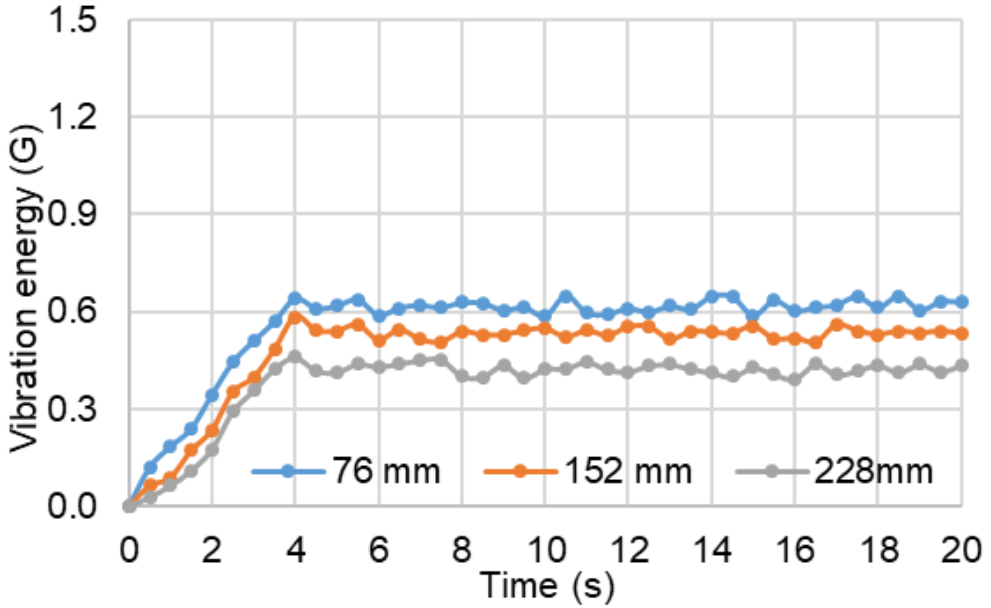
(b) Mixture 2 - air 7.2%

Effect of Water Content

- Less energy transfer in dryer mixture



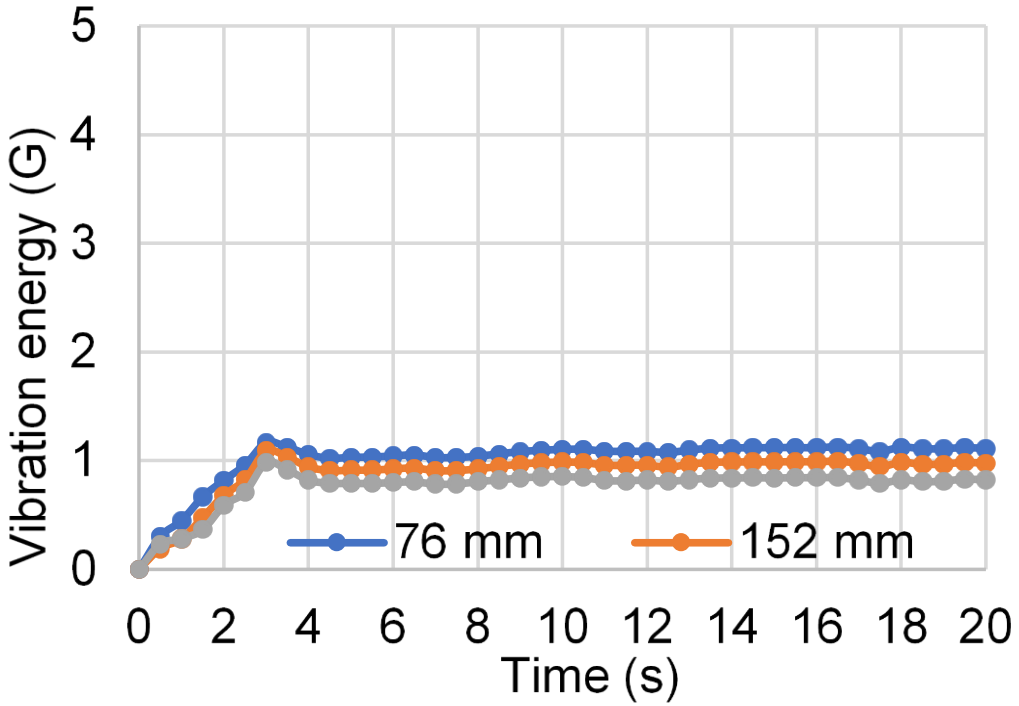
(a) Mixture 1 - slump 10cm



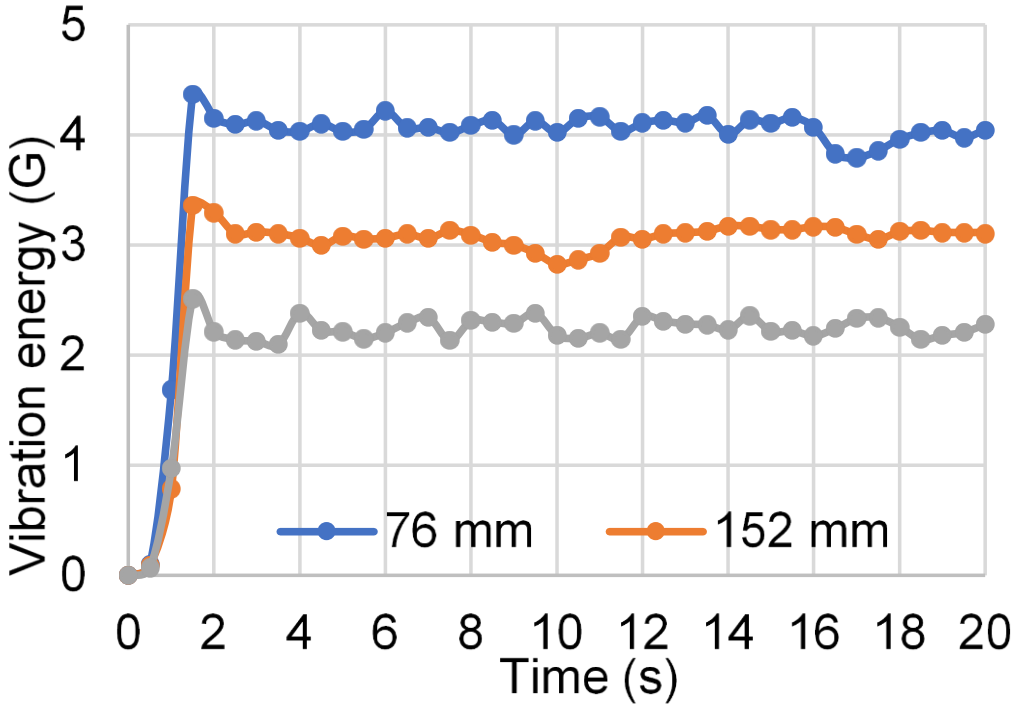
(b) Mixture 3 - slump 2.5cm

Effect of Frequency

- More energy transfer in high frequency mixture
- More loss over distance



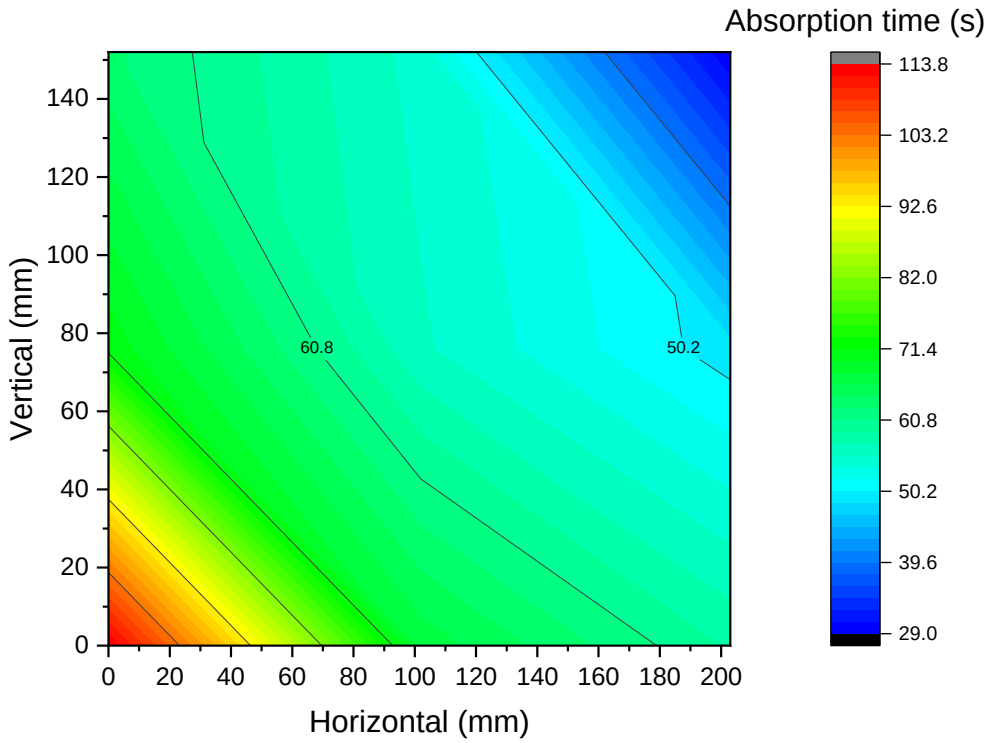
(a) 8,000 vpm



(b) 12,500 vpm

Effect of Frequency

- Water moves in both cases



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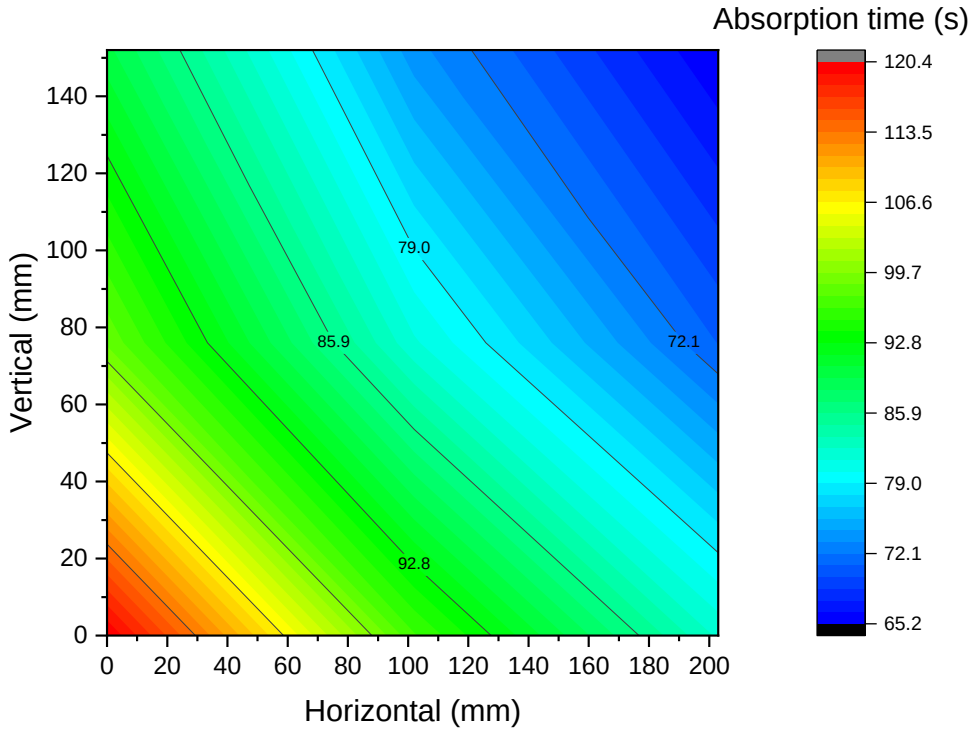

(b) 12,500 vpm

Therefore

- Need tools that measure all the workability parameters
- Potential to design “vibrator proof” or machine specific mixtures is real
- As is real-time feedback to pavers and batch plants