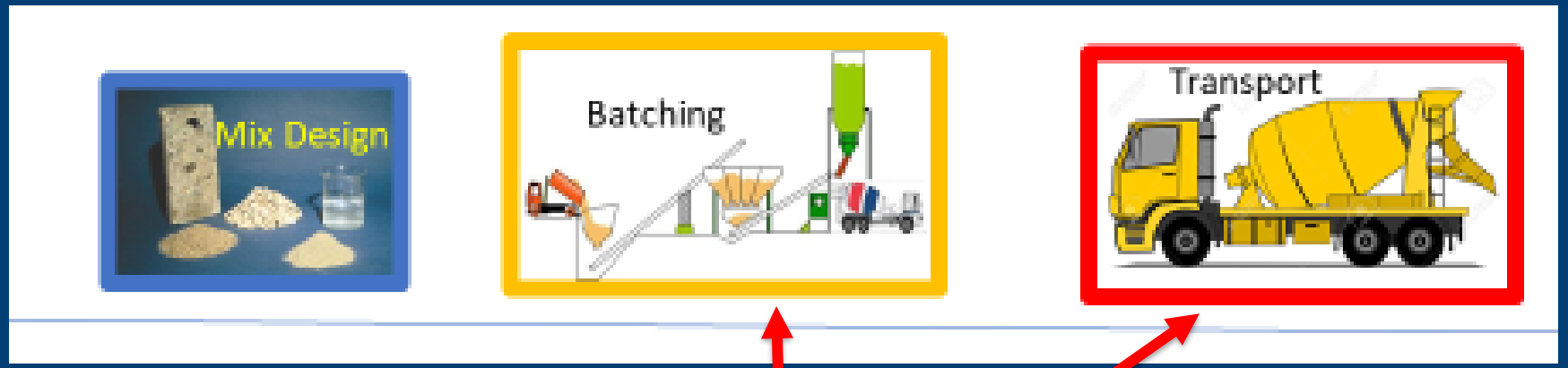
Workability of Pavement Concrete for Successful Construction

Matching Vibration Energy to Concrete Workability

Vibration Energy is Not Static

Vibration can be variable…but

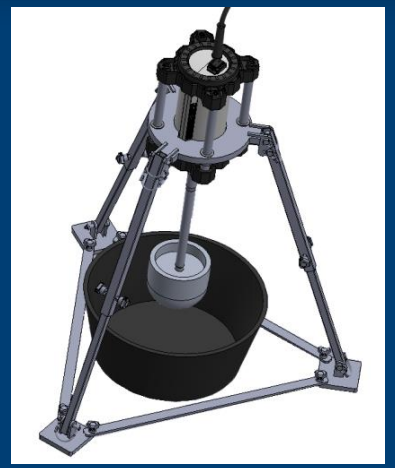
A. Vibration Energy can be Controlled
B. Vibration Energy can be Quantified
C. Vibration Energy can adjust to Workability Variances

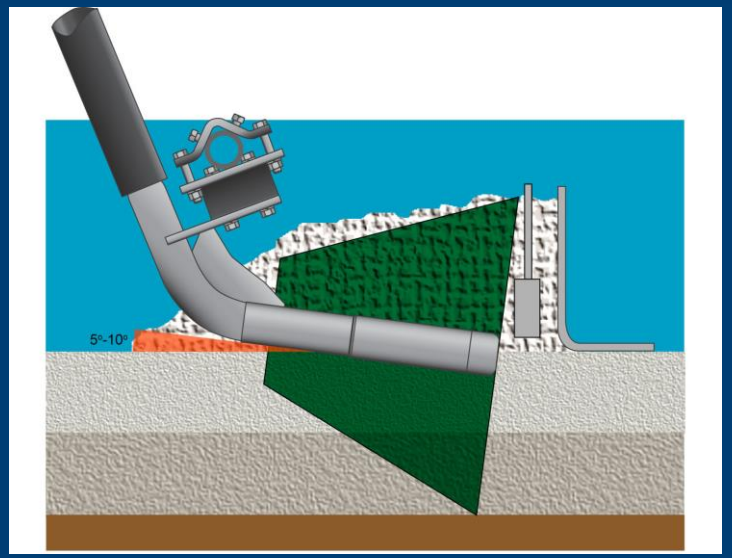


Variability from Batching or Transport

The Range of Workability Must Fit the Range of Vibration Energy

The VKELLY
Test Index is used for measuring Concrete Workability when evaluating mixtures in the Lab





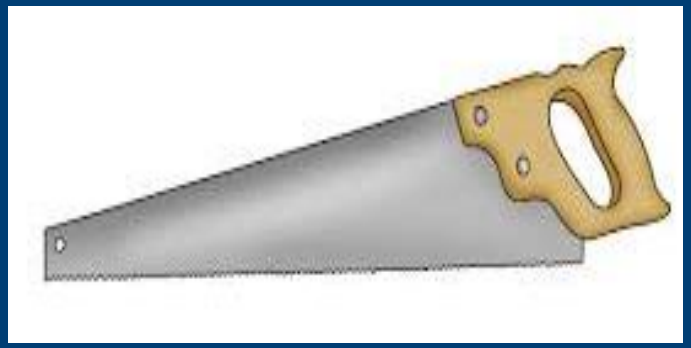
5,000 to 8,000vpm
Is the most accepted Vibrator Frequency Range used by Specifiers to match pavement mixtures

The BOX Test is used for testing the Concrete Mixtures ability to react to vibration

The MORE workable the mixture---The LESS Vibration Energy is Required

Best Analogy: The Piston, The Saw, and Concrete Workability

- The PISTON (P-waves) is applying the pressure to the mixture as the SAW is reducing the particle friction to allow dynamic flow



The SAW is set at a frequency to reduce the particle friction to allow dynamic flow. The best marriage of vibration is to match the best PISTON and SAW with the level of Concrete Workability.

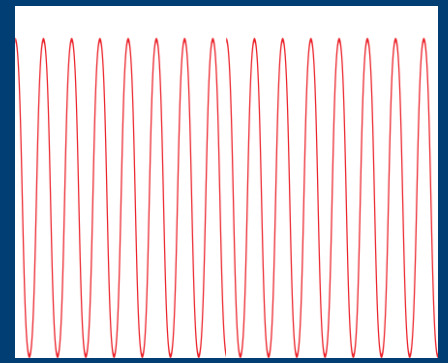
What To Expect From Vibrator Energy

A Vibrator Gives Off Two Different Energy Waves

1. Shear Stress or Pressure on the Paving Mixture (P-waves)

- They’re Harmonics that transfer through all particles equally
- Important in concrete flow or the paving extrusion process

2. Shear Rate or Frequency on the Paving Mixture (S-waves)



- They’re high amplitude waves that reduce interparticle friction
- Important in allowing pressure waves in dynamic concrete flow
- Since S-waves travel through different material densities unequally, higher frequencies will separate materials—especially water

Workability Measurements

We Measure mixtures for particle friction as the mixture is designed in the lab. We can monitor changes in mixtures:

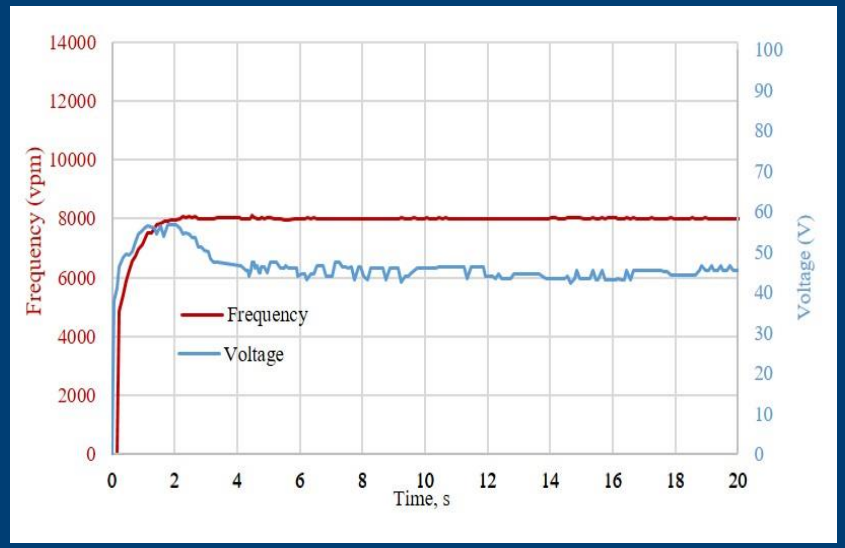
Effecting the Workability/Vibration Balance

Aggregate Gradation	Size of Aggregate	Shape of Aggregate
Aggregate Characteristics	Use of WRAs	Paste Volume
Sand Amount	% Manufactured Sand	Water/Cement Ratio

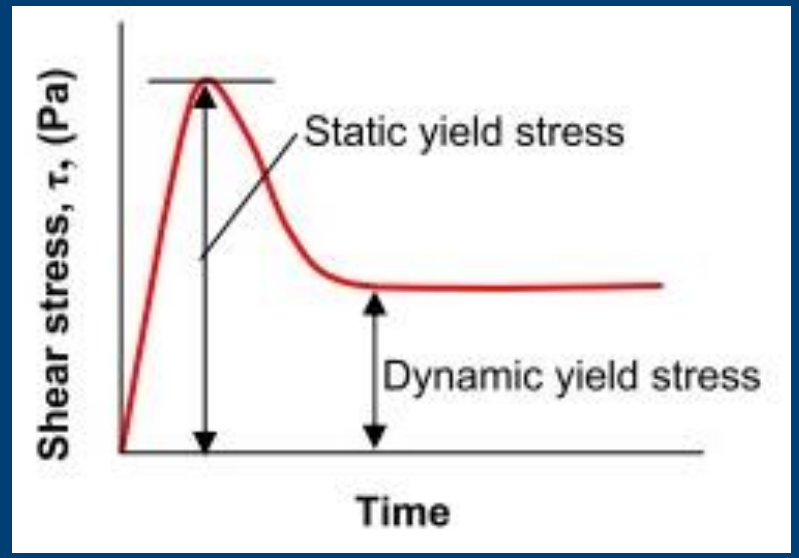
How About Process Variances?

VKelly Accuracy and Logging Workability Data

Not Being Used by DOTs



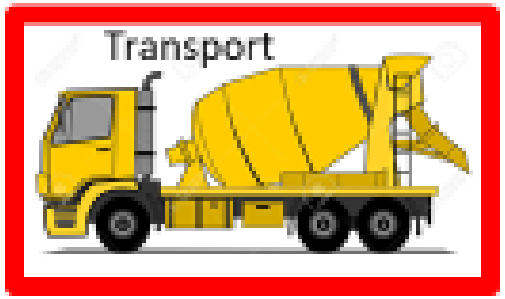
Electrical Impedance Curve

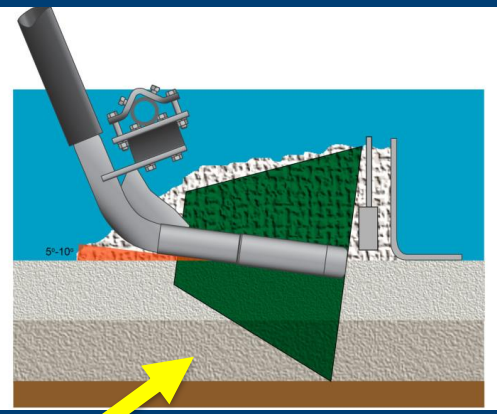


Bingham Model

Seeing Workability Signatures in Curve

Concrete Process Variations and Workability Changes





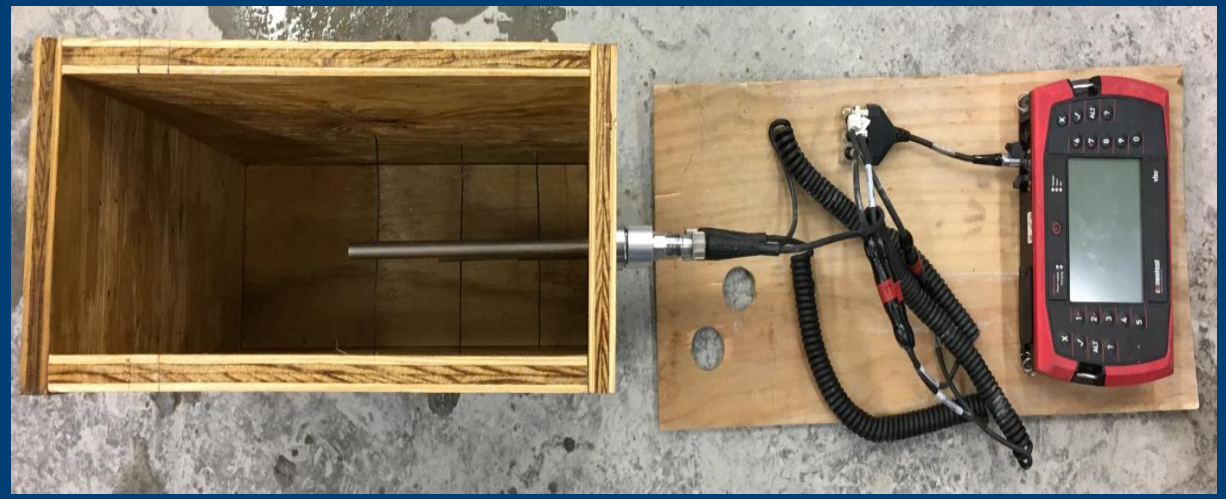
How Does Process Variances Effect Vibration Settings?

Batching

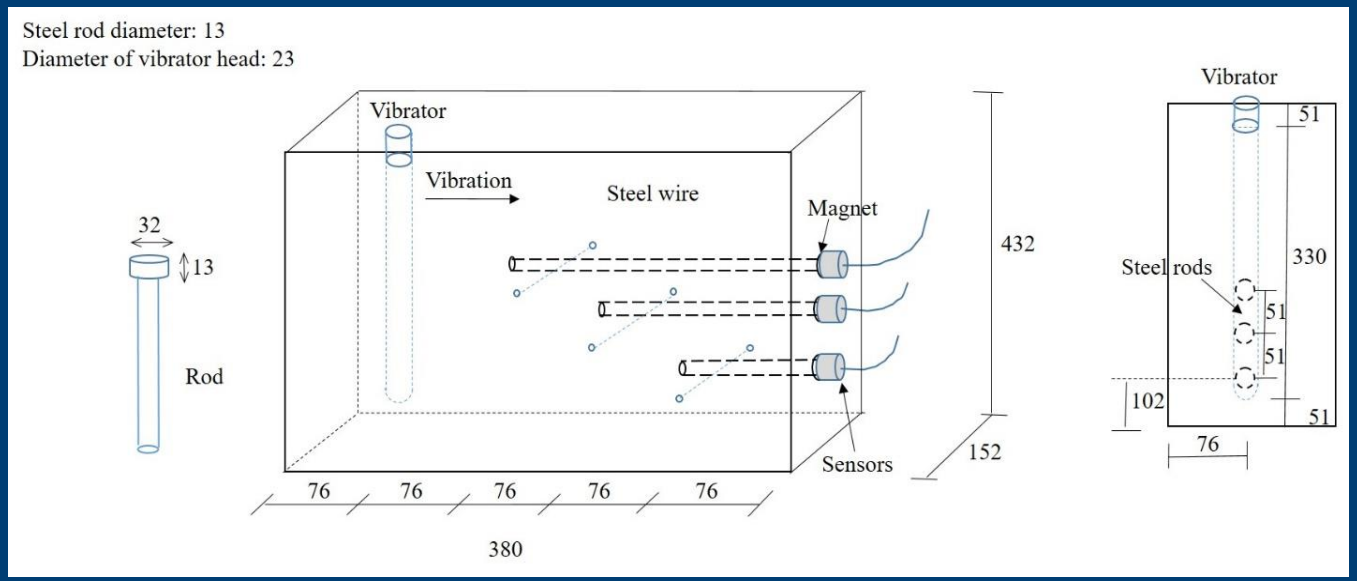
Blending of Cement/SCMs
Material Moisture
Batching Uniformity
Separated Aggregates
Material Temperature

Transport

Water Additions
Slump Loss
Inconsistent Dry Batch

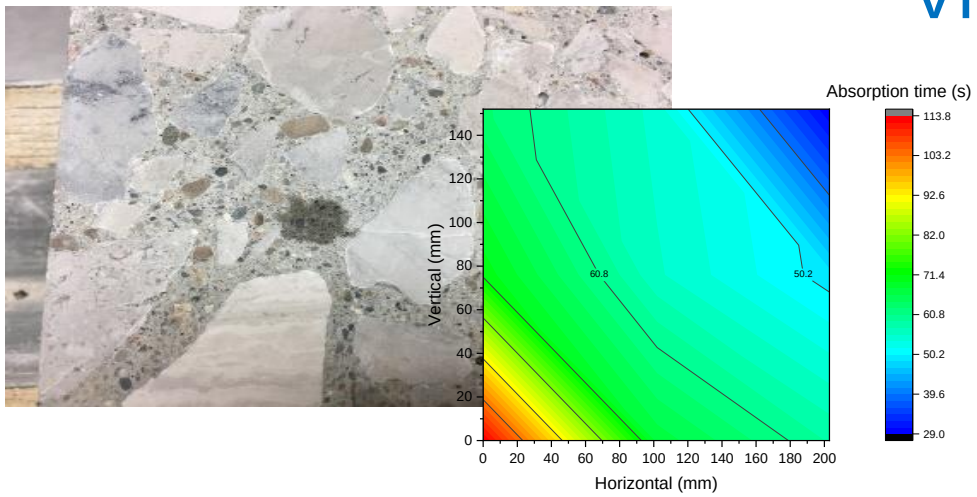


The Effects of Higher Frequencies are Measurable

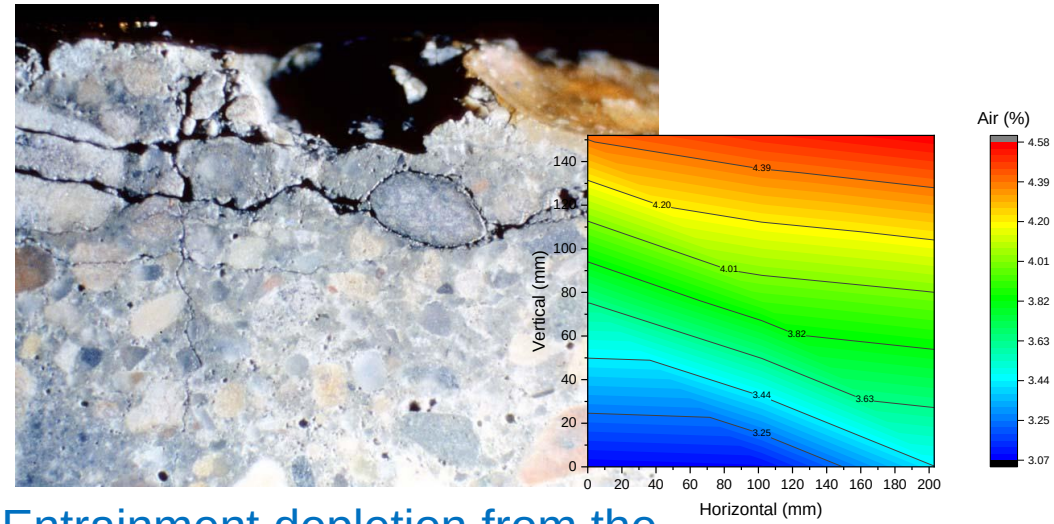


Iowa State Study

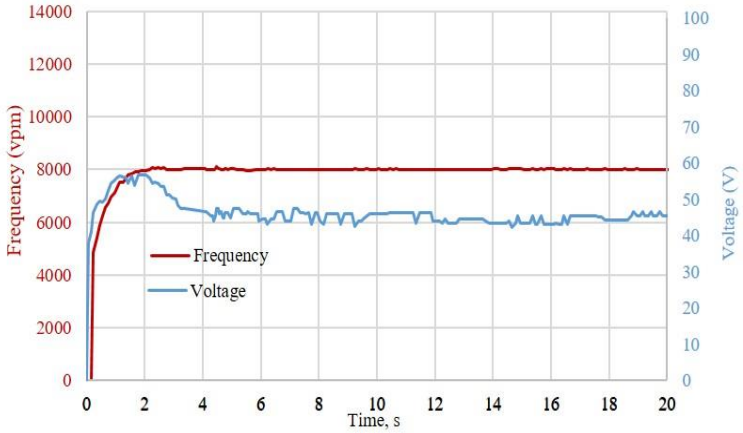
Vibration's Effects on Concrete



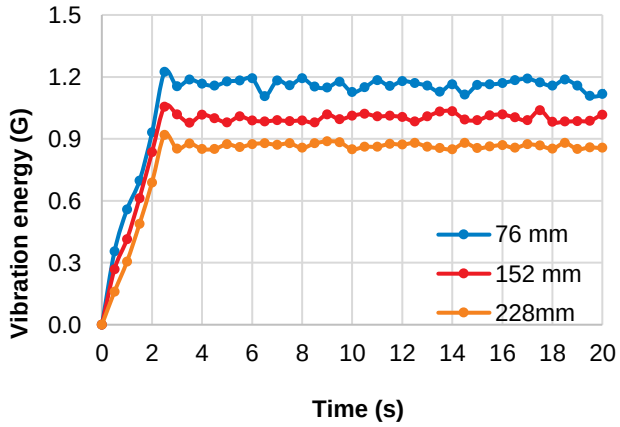
Drop Test to track water separation and its effects on Permeability



Air Entrainment depletion from the area around the vibrator heads effecting Freeze/Thaw Durability



Energy In and Dynamic Flow



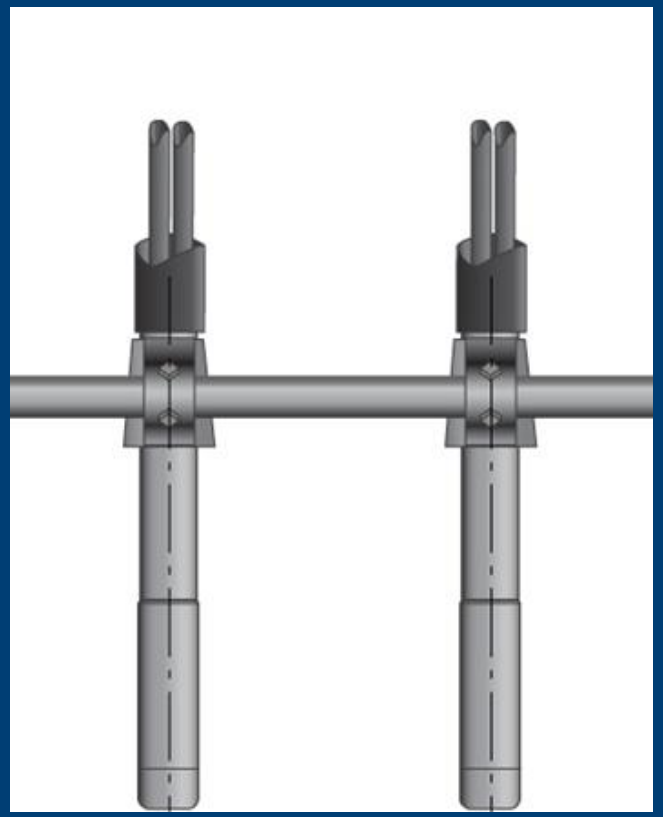
Energy Transfers in Dynamic Flow

How Much Vibration Energy Do You Need

About 2 to 3 Gs to Reverse Gravity

The standard specification for Vibrator Spacing on a paver 16 inches.

The Vibrator Monitoring System will not pick up frequency if it drops below 4.6 g-force

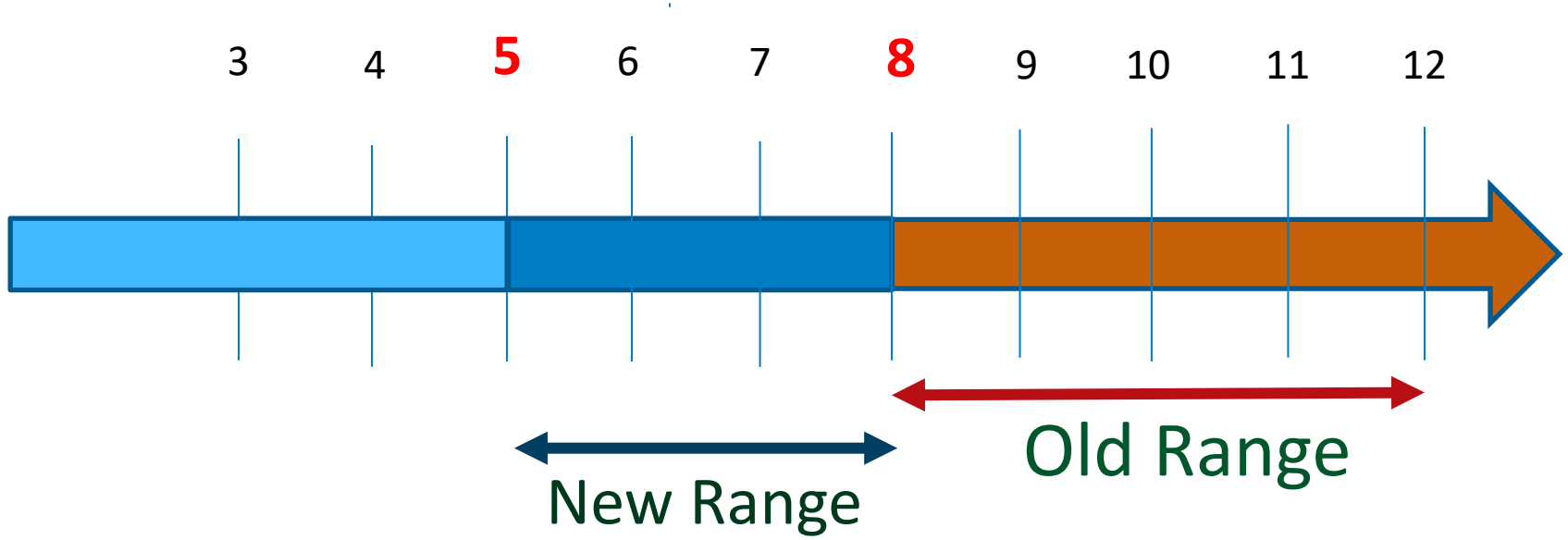


OFF-CENTER Weight Calculation

The Standard Off-Center Weight is over sized and develops a high number of G-forces to the concrete even at the low range of frequency operation

Frequency Range and Forward Travel

FWHA Study
PCA R&D s/n 2398



Suggested Machine Travel 4ft per Minute

15 seconds
Per Cubic ft

Monitoring Frequency is Important to Matching Workability

Is the Vibrator (Frequency) causing Material Separation?

High Frequency may cause areas of poor aggregate arrangement

What Happens with Too Much Vibration Frequency

Streams of water coming from the vibrated concrete

Too Much Grout at Surface from High Frequency –Uneven Tining

The Marriage between Vibration Energy/Concrete Workability has had positive strides in the past decade

The research into Workability vs Vibration Energy has had major progress the past three years

Both Efforts Combined—Opens the Door for Machine Learning

There Cannot Be Paving Machine Automation Without Science

Measure and Limit Variability
Control what you can Control

Learn to Adjust

Thank you

For the most up-to-date information please visit the American Concrete Institute at:
www.concrete.org