Effects of Vibration on Concrete Mixtures

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With thanks to Dr Peter Taylor and Paul Jaworski
Thixotropy

A property of concrete to:
• Flow under vibration
• Stand up when stationary
Why does concrete need vibration?

- Remove entrapped air
- Assist with levelling
What Is Happening under Vibration?

Acceleration >2g allows air to float up and out (Uplift > viscosity)

Shaft oscillates in a circle sending out compression waves

Water moves horizontally

Solids wobble and maybe rotate
What Is Happening under Vibration?

Assumed that bubble size affected is influenced by:
- G-force (energy)
- Time

(Upward force > viscosity)

Uplift > viscosity

Acceleration > 2g allows air to float up and out
What Is Happening under Vibration?

Energy affected by:
- Amplitude (same in most devices ~0.075”)
- Frequency
- Mass of vibrator weight

Relationships are not understood

Acceleration >2g allows air to float up and out
What Is Happening under Vibration?

More frequency = more water

Not quantified

Water moves horizontally
What Is Happening under Vibration?

Solids wobble
And maybe rotate

Not quantified
May not move back after vibrator removed
What Is Happening under Vibration?

Radius of influence:
- Amplitude
- Frequency
- Mixture:
  - Water content
  - Workability
- Linear / logarithmic / other?
- Assumed to be about 8”
What is a good vibration?

• No segregation
• No entrapped air
• Retain entrained air
• No water movement
How much is enough?

- Rules of thumb (3 s/cu ft)
- Watch for bubbles…
- Listen to the sound…
Controlling Frequency

- Traditional vibrators change frequency under load
- CFV Systems now available

<table>
<thead>
<tr>
<th>Brand</th>
<th>No Load</th>
<th>High Slump</th>
<th>Low Slump</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>17,200</td>
<td>16,000</td>
<td>13,400</td>
</tr>
<tr>
<td>B</td>
<td>14,500</td>
<td>14,500</td>
<td>13,500</td>
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<tr>
<td>C</td>
<td>14,000</td>
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<tr>
<td>D</td>
<td>12,200</td>
<td>11,700</td>
<td>11,200</td>
</tr>
<tr>
<td>E</td>
<td>11,600</td>
<td>11,100</td>
<td>10,500</td>
</tr>
</tbody>
</table>
Frequency Matters

- Vibrators in the right spot move cream to the surface
- Loss of air
- Water movement
Effects of Frequency on Air

Effects of Vibration on the Air-Void System and F-T Durability of Concrete

By David Stark

PCA

![Graph showing the effect of frequency on air with various markers and lines representing different conditions.](image-url)
Air loss and segregation

- Aggregate segregation
- Poor air in vibrator track

High frequency leaves track
Air loss and segregation

- Unworkable concrete
- Beaten into place
- Distress observed after 5 years
- Strength was fine!
Effect of Frequency on Water Movement

12,000 vpm

8,000 and 10,000 vpm
Water Movement
Air loss and segregation

• Paver speed matters
  - some
How to evaluate vibration?

- Vibration energy (RMS velocity amplitude, in/s) at a specific time period across the relevant frequencies
Therefore

We need to understand

- The relationship between vibration energy and
  - Air movement
  - Water movement
  - Aggregate movement
- As a function of mixture
  - Water content
  - PSD
  - Workability
  - Thixotropy
Evaluating energy transfer

Steel rod diameter: 0.5”
Diameter of vibrator head: 0.9”
Vibration energy for different mixtures

- Lower slump: less energy, more time to reach stability
- Longer distance: less energy
Hypothesis

Unconsolidated Vibrator Vibrator

Loose Vibrating Consolidated

Absorbing Energy Densifying Dense

More energy absorbed
Hypothesis

Energy

Absorbed energy

Measured energy

Total energy

Time
Next Steps

Vary:
• AEA dose
• WRA dose
• Aggregate type, shape and content

Measure
• Air void systems at different distances
• Evidence of water movement
• Energy transferred
Make concrete great again!

www.cptechcenter.org