Consolidation and Compaction of Concrete

American Concrete Pipe Association

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What is consolidation
as compared to compaction
as compared to vibrated?

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Consolidation
Compaction
Vibration

Are these words interchangeable?

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How about this phrase…..

Hand me a Kleenex…..

EVERYONE knows what you want even though that may not be what you get


Kleenex®
BRAND TISSUE
soothing lotion™
4
CUBE
BOXES
260
TOTAL
TISSUES

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We say……. we want to vibrate this form, or this product

We really mean…… we want to consolidate and compact it

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What we're going to learn is what the role of each of these terms are and when applied properly, we get a great product!

Consolidation

"Is the process of inducing a closer arrangement of the solid particles in freshly mixed concrete during placement by the reduction of voids, usually by vibration, rodding or tamping"

Consolidation

- Needed because a mass of freshly placed concrete is usually honeycombed with entrapped air voids that are larger than the intentionally entrained air voids

- If allowed to harden in this condition, the concrete will be weak, porous and poorly bonded to the reinforcement

Consolidation

Demonstration of consolidation

- coarsely arranged shapes
- simulated process of vibration and liquefaction

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CONSOLIDATED

Compaction

Is the process which expels entrapped air from freshly placed concrete and packs the aggregate particles together so as to increase the density of the concrete

COMPACTION

Compaction

There aren’t two tools that create consolidation and compaction

There are TWO stages when compacting concrete

Compaction

Two Stages

- The aggregate particles are set in motion and “slump” to fill in the form giving a level top surface
- Entrapped air is expelled

With vibration, initial consolidation of the concrete can often be achieved relatively quickly. Compaction must be prolonged until no more large air bubbles appear on the surface

How Does Vibration Assist in Consolidation?

- Pressure waves separate the aggregate particles thereby reducing friction which allows the aggregate particles to consolidate

- Liquefaction helps with the consolidation by suspending the aggregate in the paste as it vibrates

Why Vibrate?

- Freshly placed concrete can contain as much as **20%** entrapped air
- Proper vibration increases density by driving out entrapped air (vs.. entrained)
- Results in:
  - Optimum strength
  - Durability
  - Quality appearance
  - Water tightness

Proper Vibration Should

- Eliminate voids and honeycombs by forcing the concrete to consolidate
- Release entrapped air as the compaction stage starts
- Fully encase reinforcement, embedded items, and blockouts with fresh concrete

However…

NONE of this will be possible without a

QUALITY MIX DESIGN

That's

WORKABLE

Vibration

- Except for SCC, making concrete products without vibration is like mix designs without water
- Concrete is a static medium that will support its own weight because the large aggregate will bridge and become immobile unless It is vibrated

Drycast Vibration Demonstration

ZERO SLUMP

Vibration

We need vibration (again, with the exception of SCC) in order to make most precast products

Power Sources for Vibrators

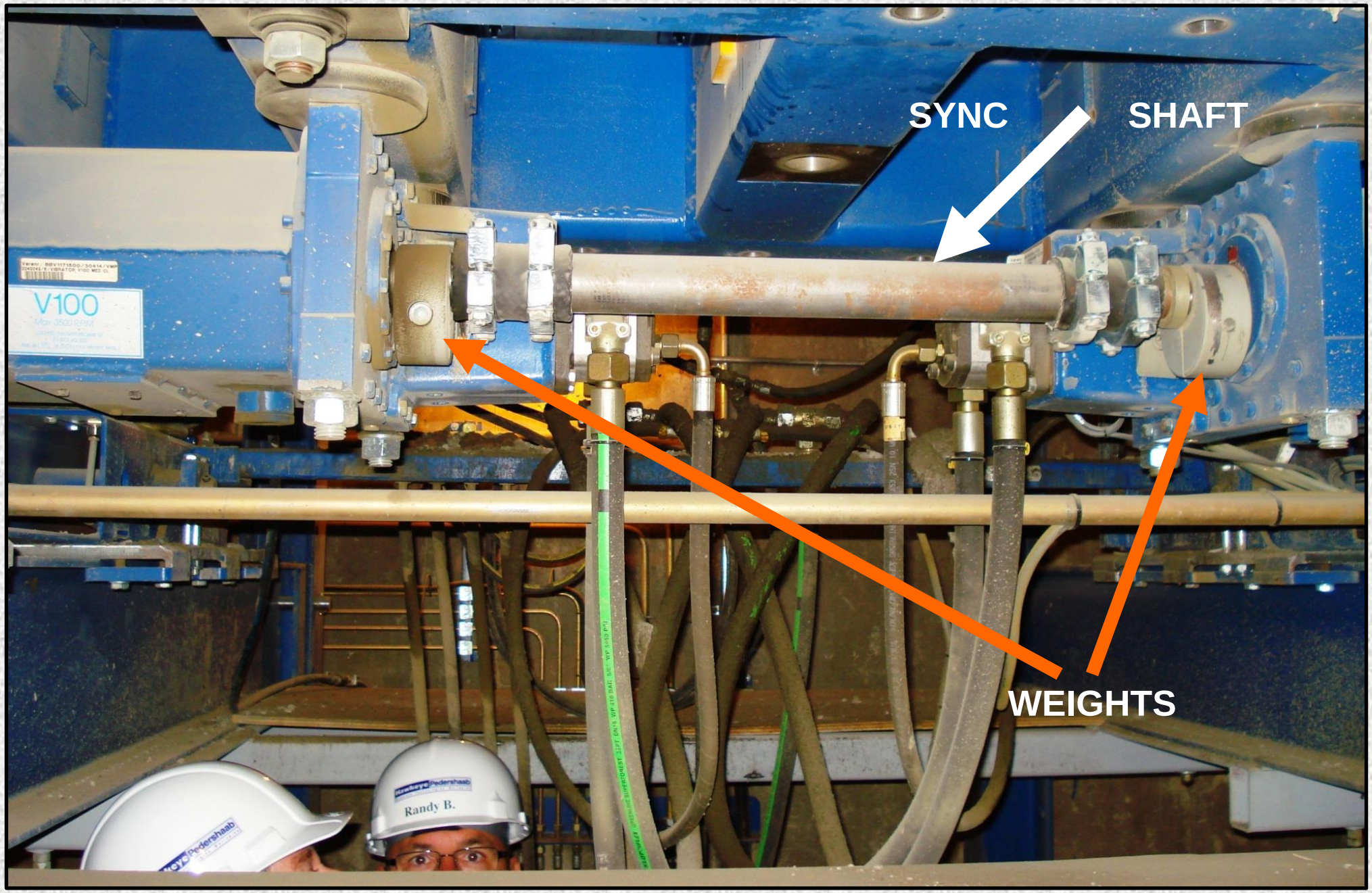
PNEUMATIC

HYDRAULIC

ELECTRIC

Pneumatic

Hydraulic


SYNC
SHAFT
WEIGHTS
V100
Randy B.

Electric

Vibration

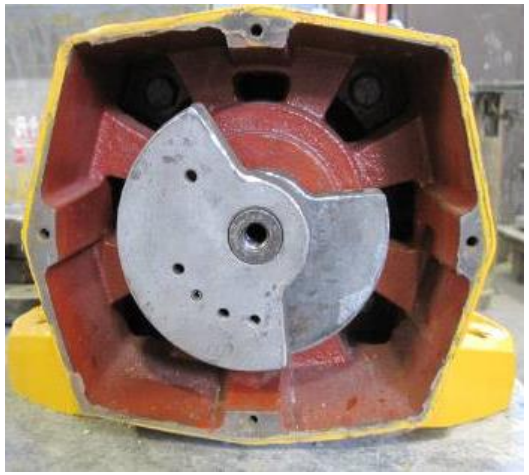
Regardless of the power source, some principles of vibration are common to all types

Vibration – The Theory

- MASS
- FREQUENCY
- AMPLITUDE
- ACCELERATION
- FORCE
- RESONANCE

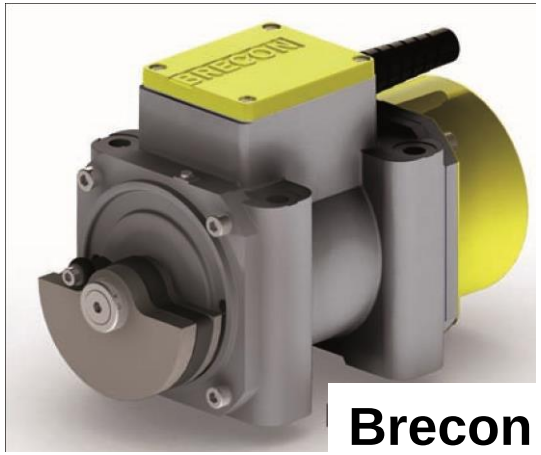
Mass = Weights

COUGAR D-SERIES



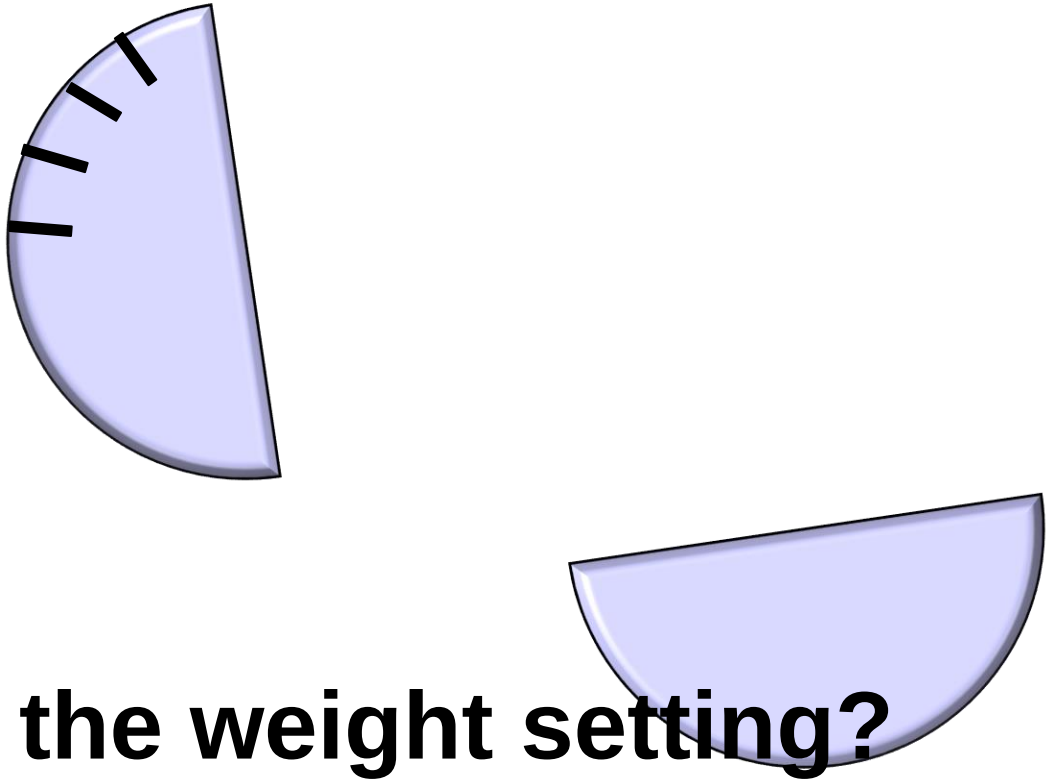
ISKCO HKM75LFS

OLI 5100



Brecon

MASS



What is the weight setting?

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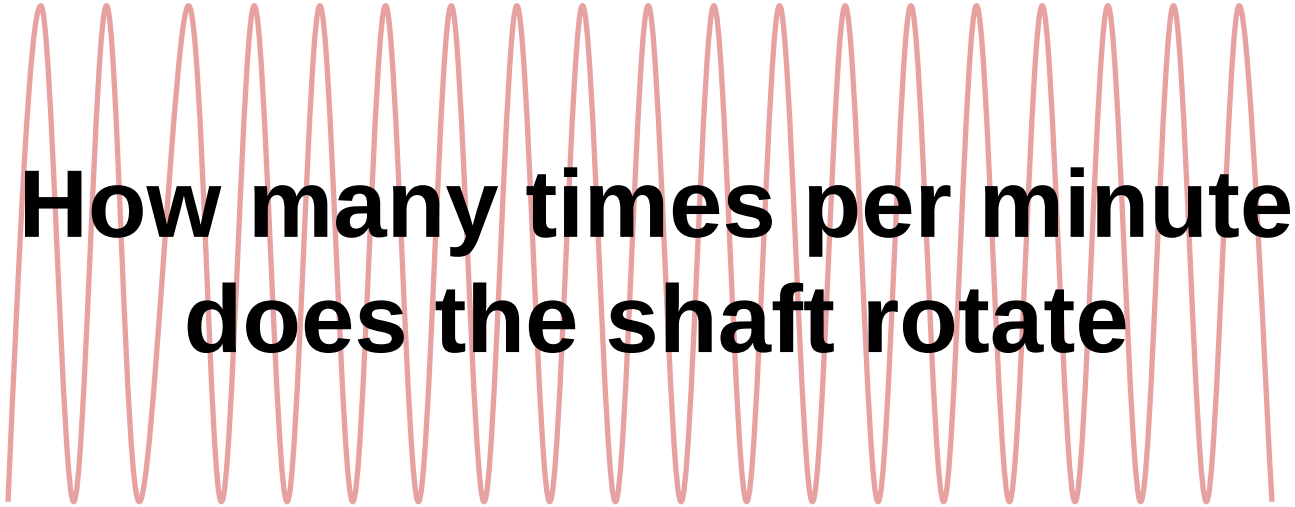
FREQUENCY



How many times per minute does the shaft rotate

3600

3450 **6000**

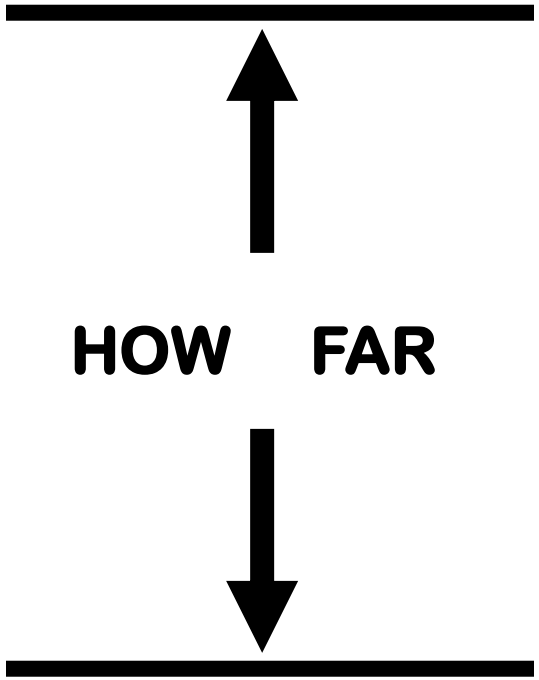
10-15,000

Amplitude

It is affected by frequency….

- The higher the frequency the lower the amplitude
- The lower the frequency the higher the amplitude

AMPLITUDE

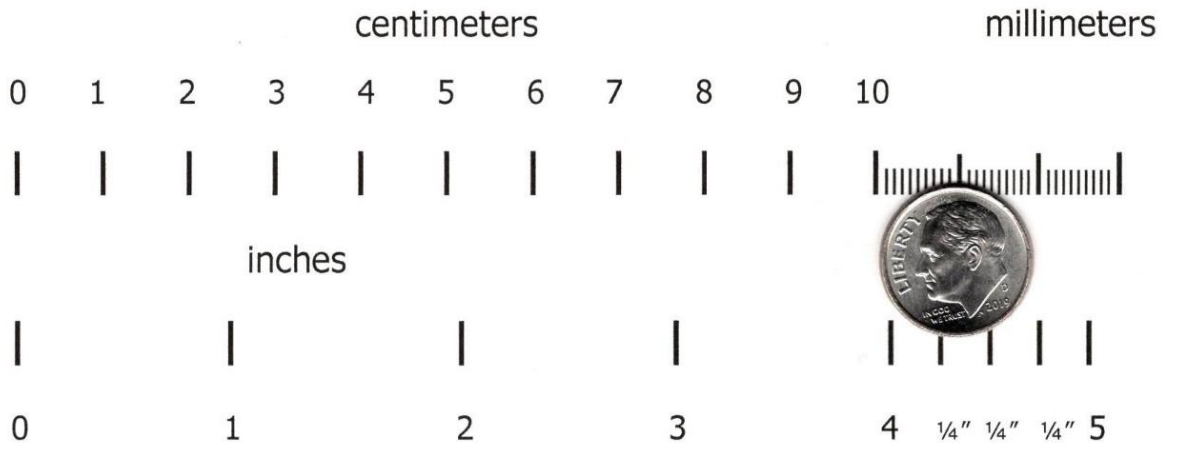


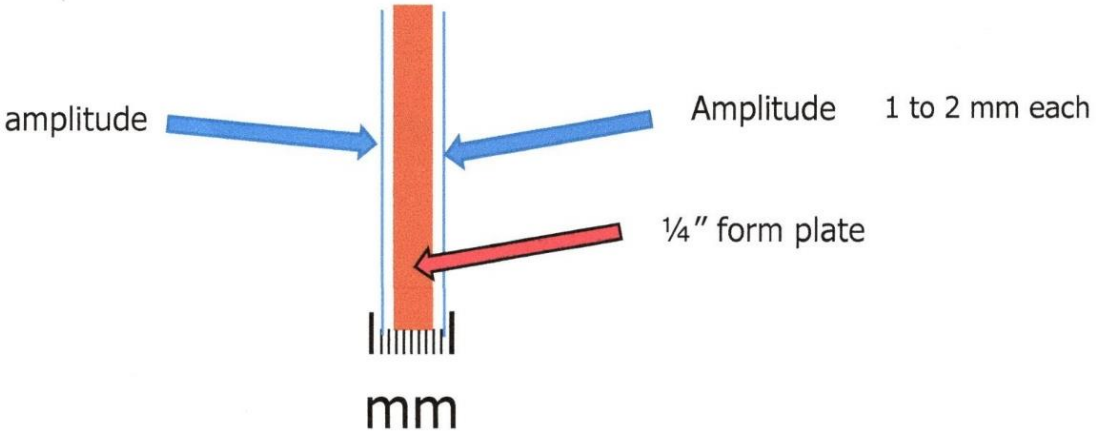
Amplitude

What kind of dimensions are we talking about?

centimeter = 10 millimeters
approximately 25 millimeters in an inch

A dime is approximately
18 millimeters





Amplitude

- Low amplitude

Amplitude

- Low amplitude – Left hand
- High amplitude – Right hand

Vibration Force

Take the MASS
Determine the FREQUENCY
Which affects the AMPLITUDE
Which is also affected by the ACCELERATION (CENTRIPETAL)
And you come up with the FORCE

FORCE IS WHAT IS ACTUALLY DOING THE WORK OF CONSOLIDATION

Amplitude & Frequency of Vibration

Amplitude	Frequency
Effects heavier mass	Effects lighter mass
Moves the aggregate	Moves the paste
Determines the radius of action	Governs liquefaction

Amplitude & Frequency of Vibration

In order to match the vibrator you would have to hit the board

60 TIMES PER SECOND!!

Vibration

What changed in the way the hammer was used?

AMPLITUDE

FREQUENCY

AND FORCE

Methods of Vibration

INTERNAL – Stingers (flexible shaft or immersion)

EXTERNAL – Mounted on forms both jacket and core
– Vibrating tables

Internal Vibration

- Stingers - commonly used for smaller wet cast items and flat work

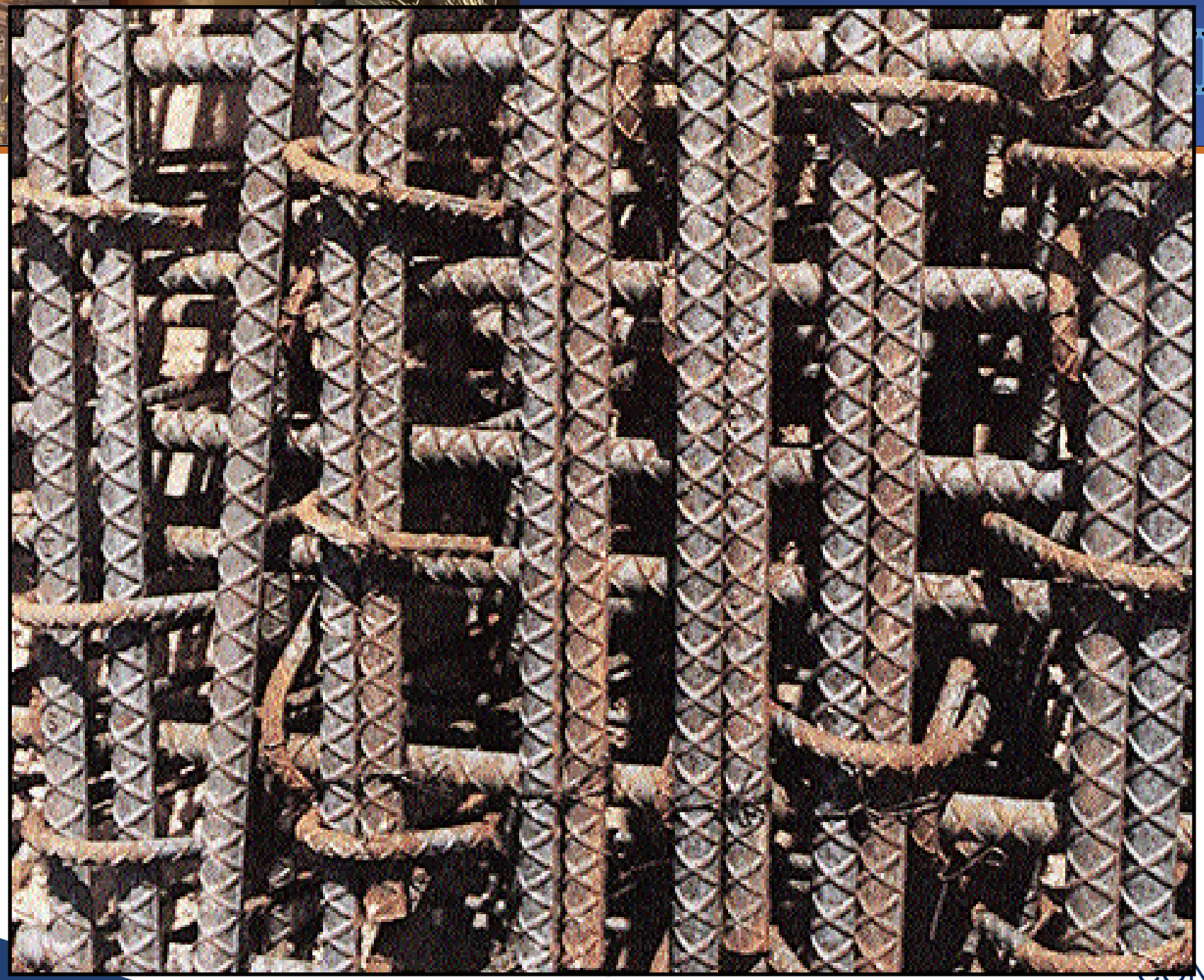
Stinger Vibrators

Rule of Thumb

- The Head Diameter should be approximately

$$\frac{\text{Wall Thickness}}{4}$$

It’s important to assess your common cage configurations



Vibration Frequency

Stinger vibrators are usually VERY HIGH Vibrations per minute

10,000-17,000 VPM

(however they typically loose 20% when inserted in concrete unless the motor is in the head of the stinger)

Be careful when using an air entrainment additive as it may significantly reduce the air if over vibrated

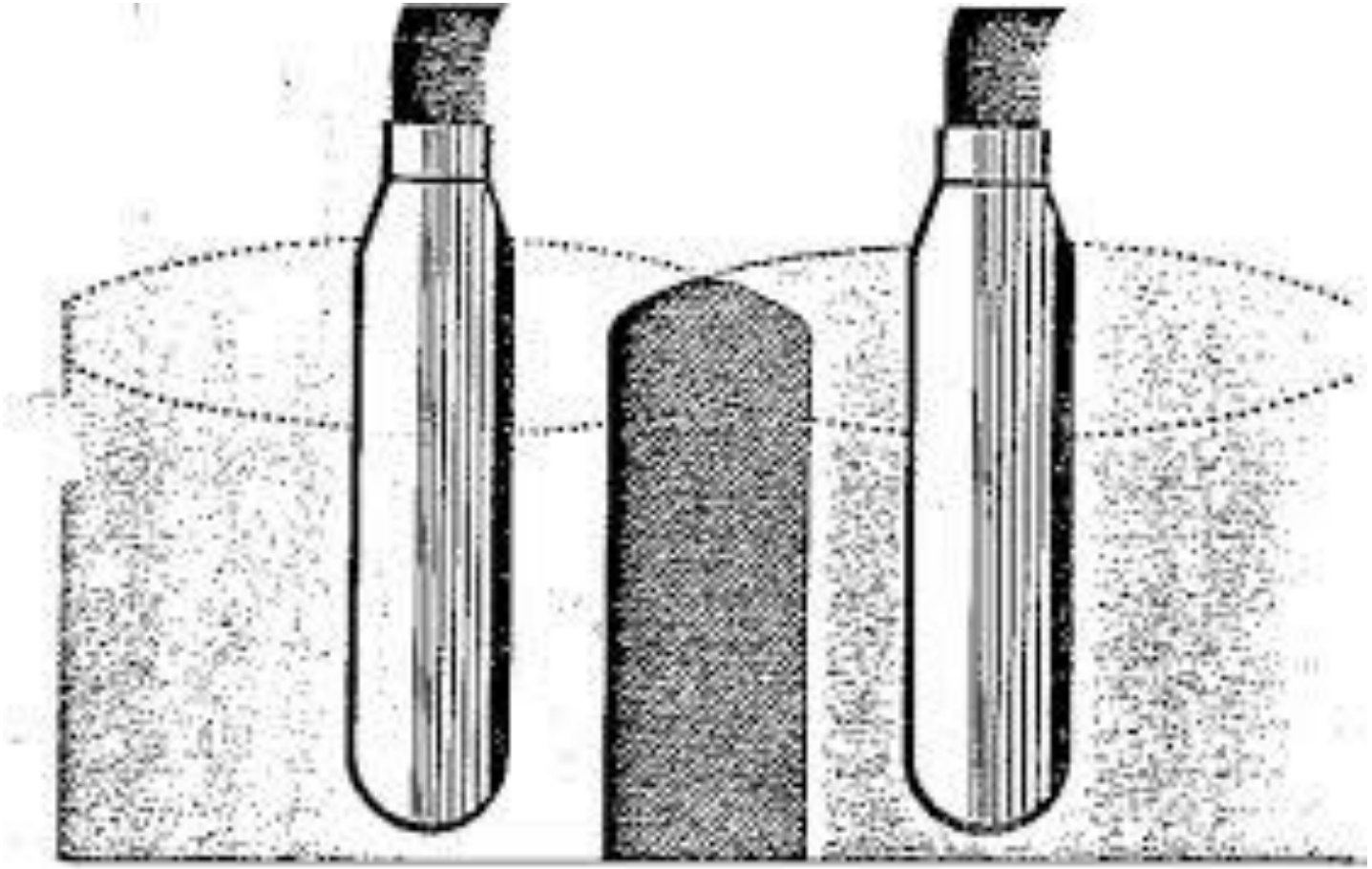
Stinger Vibration Procedure

- Drop vertically under own weight (~1sec/ft)
  - Let gravity do its job

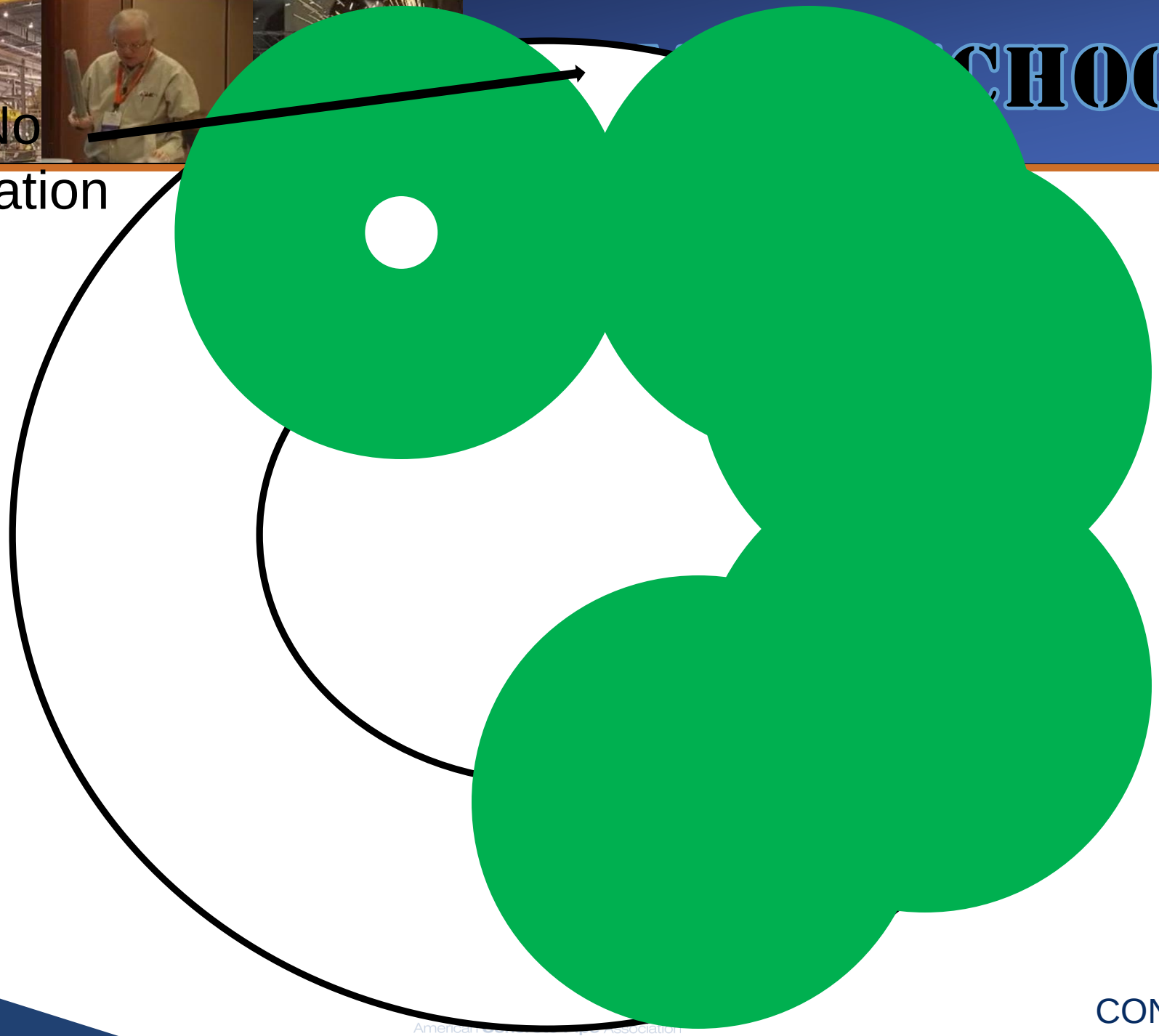
- Withdraw slightly slower than inserted (~3sec/ft)
  - Flowability is the key

- Place stick into each area only once, overlapping the vibrating radius

Overlapping Field of Action



No vibration



Stinger Vibration Procedure

- When layering concrete, place stick ~4” into previous layer

- Vibrate until surface is shiny and level, and no more large breaking bubbles

- Avoid touching formwork

Effects of not Overlapping Fields of Action

Reduced strength and durability because of:

- Voids
- Honeycombing
- Entrapped air
- Reinforcement not covered

As we have seen before….NO consolidation!

External Vibration

Hangs on forms

Vibrating table

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External Vibration

Electric
7200 RPM

Electric 3600
RPM

Pneumatic
6600 RPM

Form Vibration

- Electric
- Pneumatic
- Hydraulic

- Faster filling than stinger vibration but forms must be stronger

What Size Goes on Which Form?

THE CONCEPT IS QUITE SIMPLE….

ENOUGH VIBRATION TO CONSOLIDATE THE CONCRETE WITHOUT DESTROYING THE FORM!!!!

Rule of thumb: Use vibrators with a collective impact force that is 1.5 to 2 times larger than the weight of the concrete plus the weight of the form

Form Vibration

The formula for typical vibration pounds of force requirements

$$\frac{\left(\text{Weight of the form} + \text{Weight of the concrete}\right) \times \text{1.5 - 2.0 safety}}{\text{Number of vibrators}}$$

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PNEUMATIC HIGH FREQUENCY ROLLER

CONVEYOR PRODUCTS / WAM CORPORATION

CR-5500

20 PSI		
VPM	LBS	CFM
5,800	1350	34

MARTIN ENGINEERING COMPAN

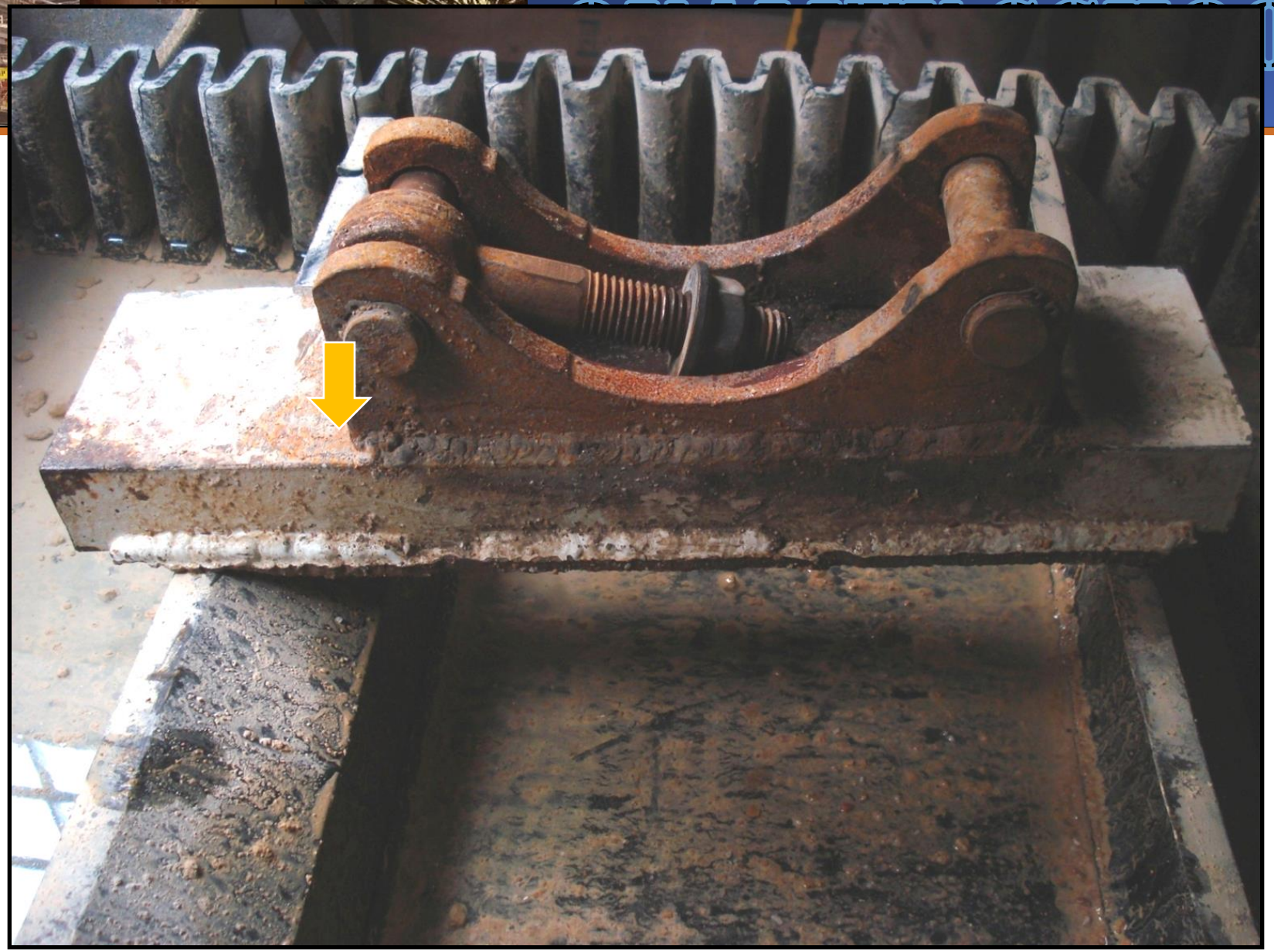
CCR-5500

20 PSI		
VPM	LBS	CFM
6,600	1560	32

Form Vibration

- Mounting brackets should be welded onto the stiffener

- Don’t fasten vibrator directly onto the skin



Torque

- Vibrator bolts must be properly torqued to manufacturers recommendations!!!

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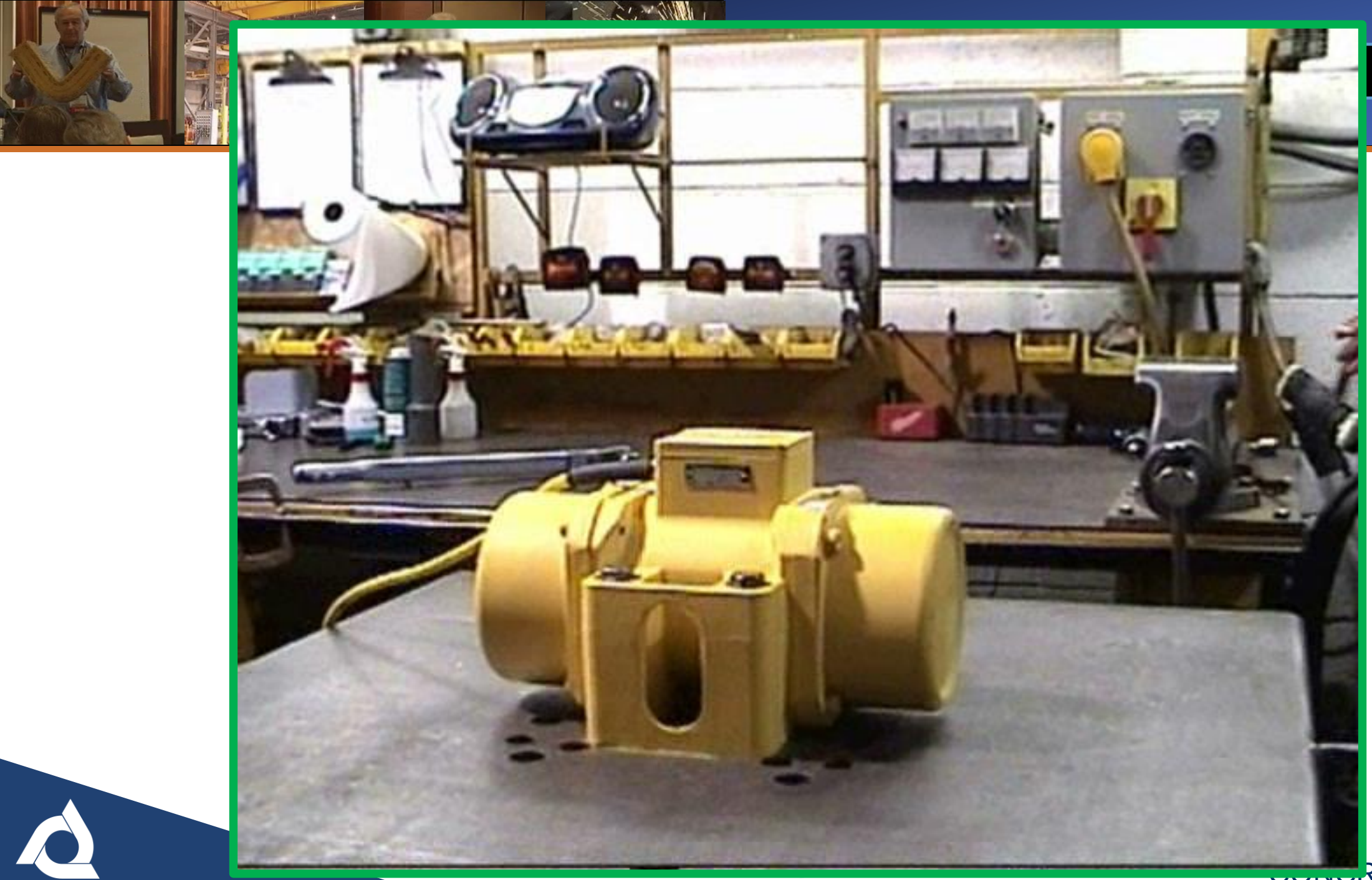
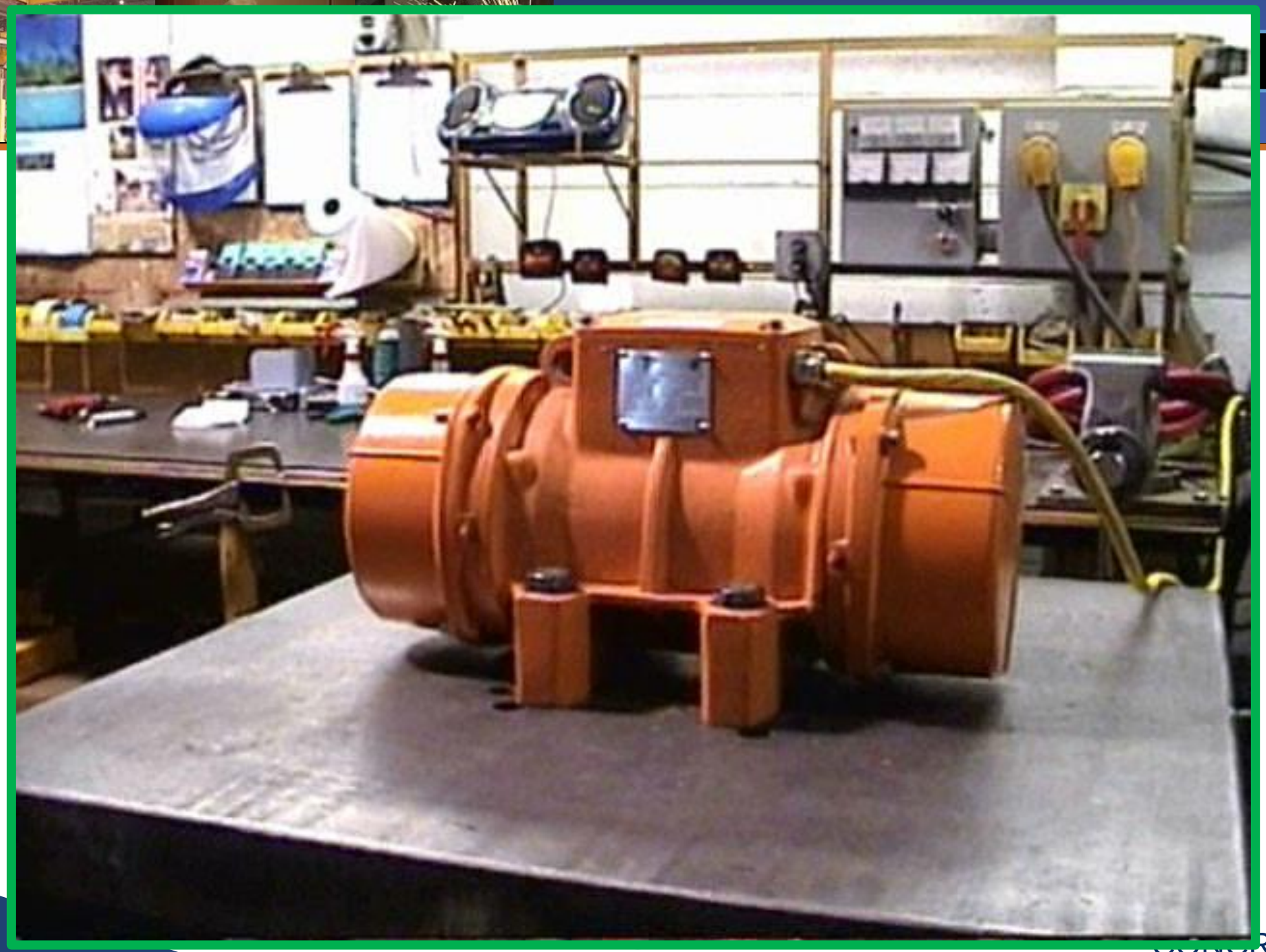
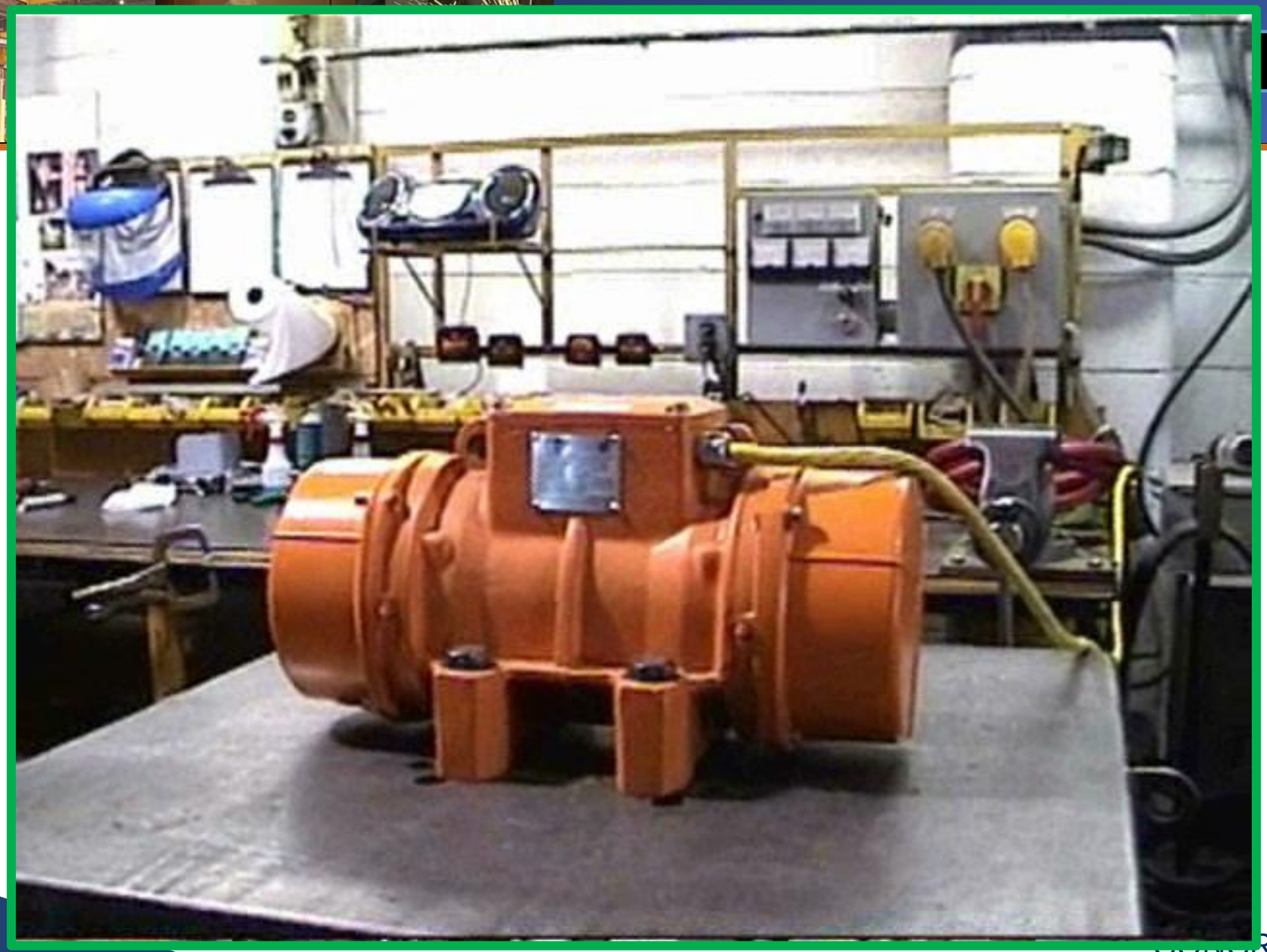
DO YOU TORQUE THE MOUNTING BOLTS?





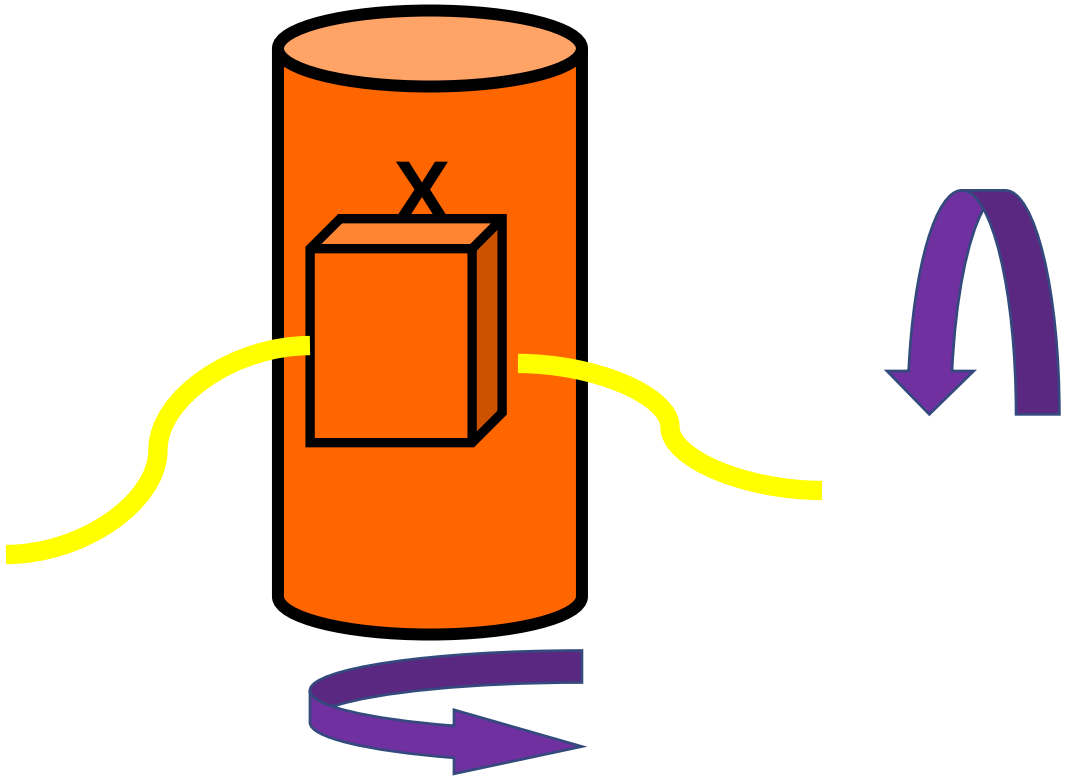


Form Vibration

Check with supplier for orientation and location of vibrators on forms

They can also recommend the number of vibrators to use

Which Way Do the Vibrators Rotate?



Form Vibration Sizing

- The harsher the mix = more power
- The stiffer the form = more power
- More flowability = less power

*Take away: it all varies by plant, forms size and raw materials. Work with your suppliers on sizing

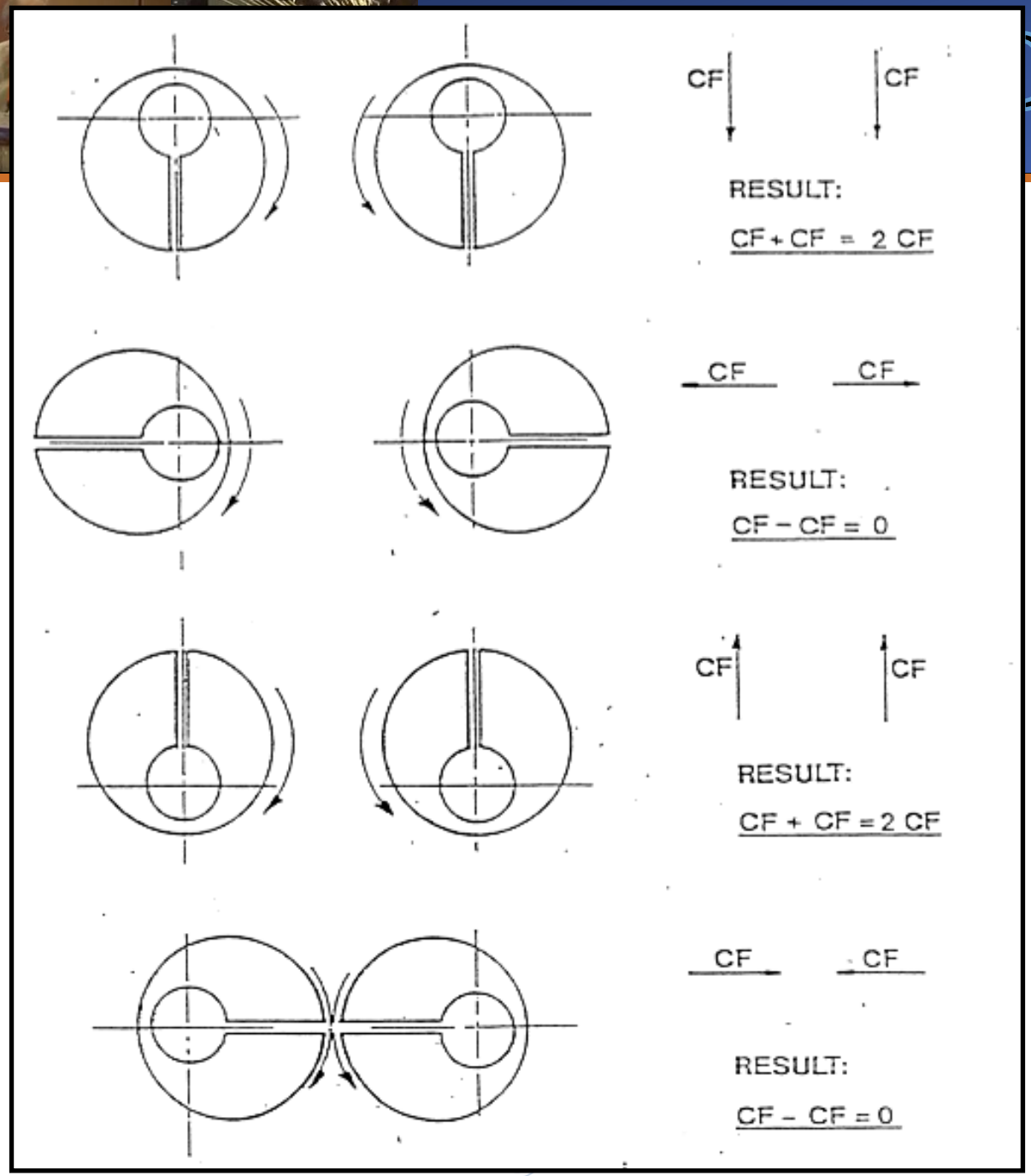
Form Vibration Procedure

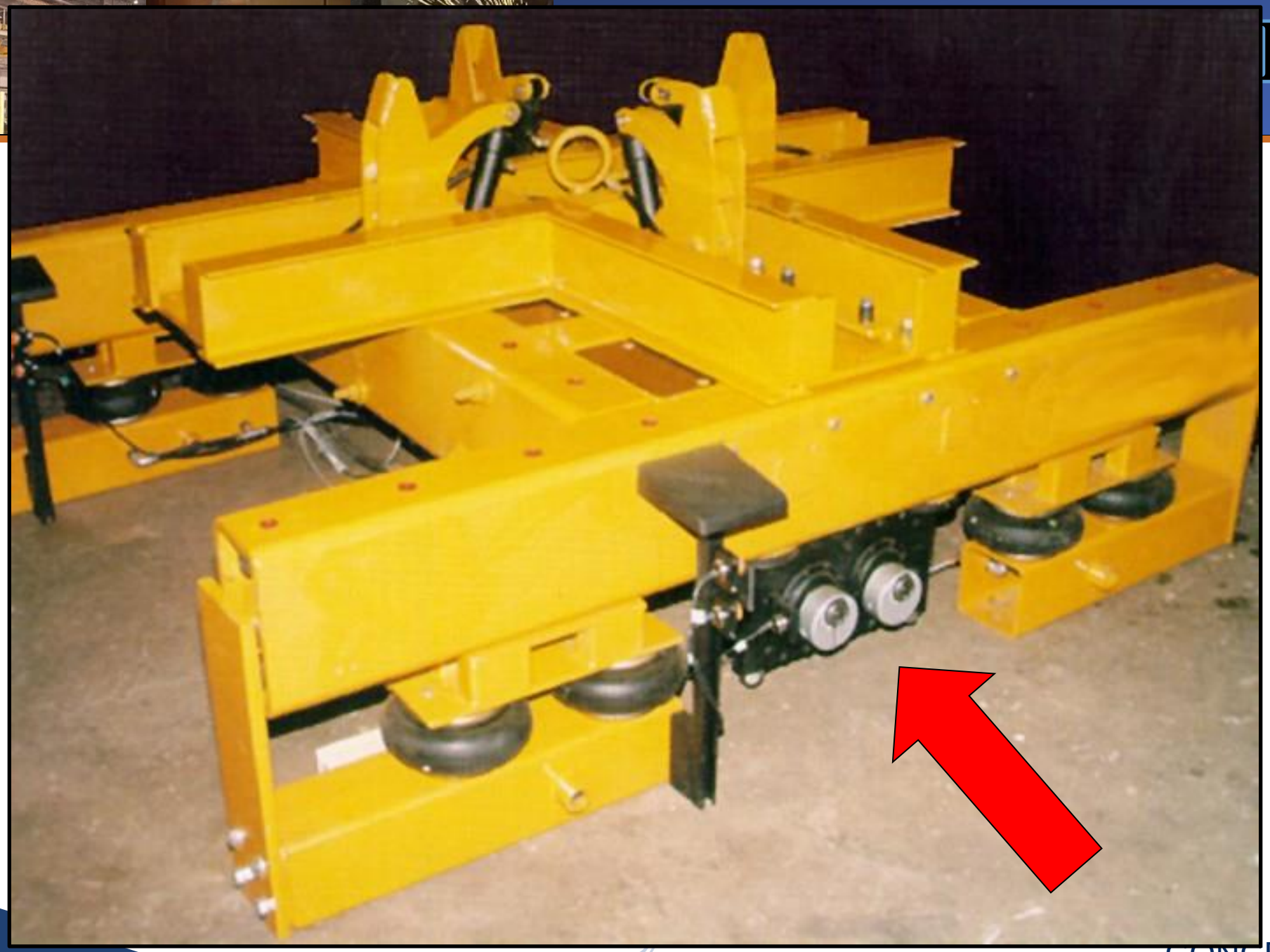
- Ideally start when concrete is 6” above vibrator (Not always the case)
- Stop when concrete is level, glossy surface, and no more large breaking bubbles
- Air bubbles go to vibrating surface

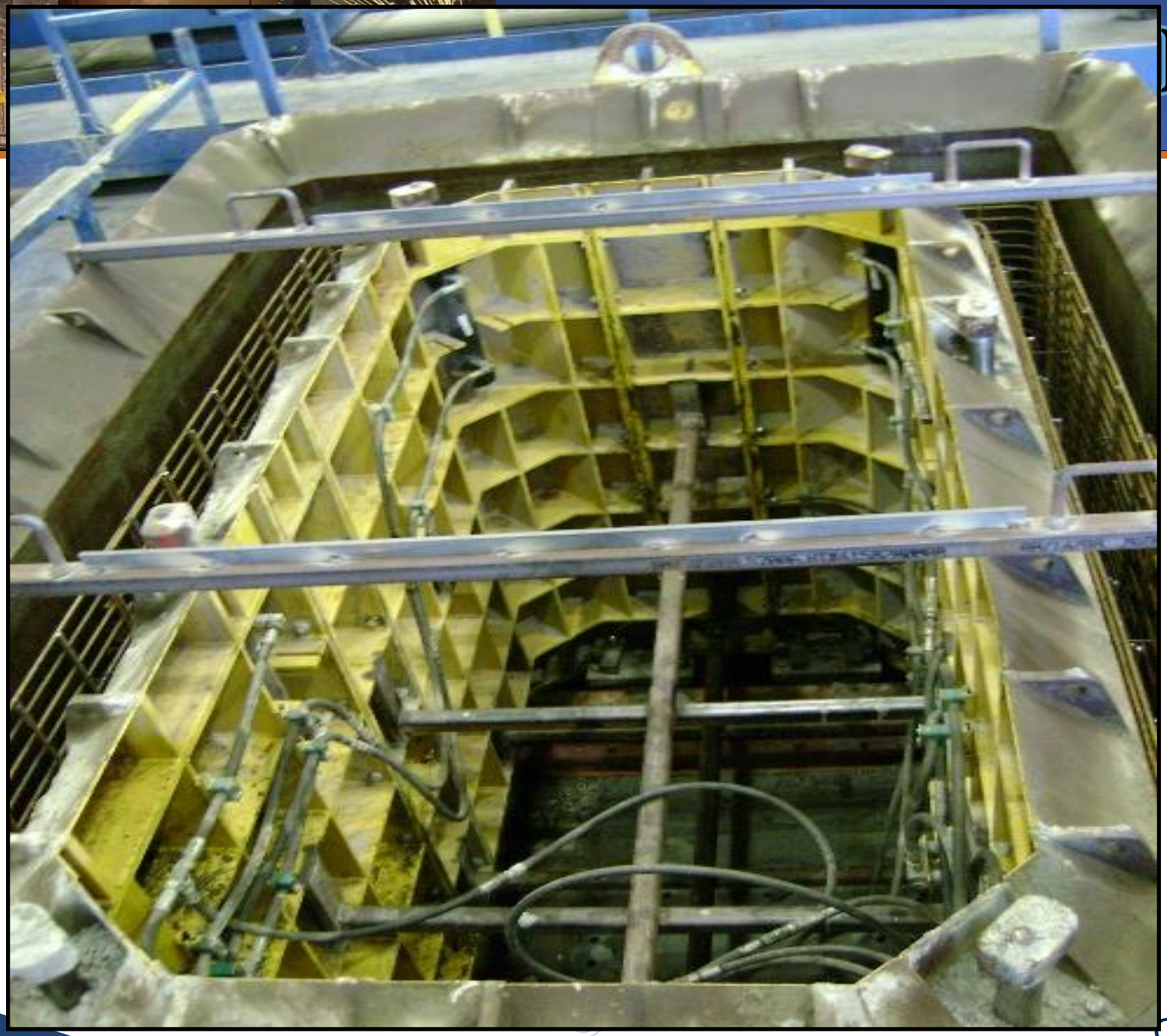
Table Vibration

- Rotary or linear vibrators
- Shaker tables - eccentric shaft
- With rotary vibrators, vibration must be unidirectional to avoid “walking” the concrete
- Sizing
  - Use vibrator with an impact force that is 1.5 to 2 times larger than the weight of the concrete plus the weight of the form

CHOOL


CF
CF
RESULT:
CF + CF = 2 CF
CF
CF
RESULT:
CF – CF = 0
CF
CF
RESULT:
CF + CF = 2 CF
CF
CF
RESULT:
CF – CF = 0





Effects of Under Vibration

Can have serious detrimental effects

- Inadequate Concrete Strength & Durability
  - Excessive entrapped air
  - Unbonded Reinforcement
  - Honeycombing
- Poor Appearance
  - Honeycombing
  - Sand streaks
  - Bug holes

Effects of Dry Concrete

This can have serious detrimental effects

- You can vibrate all you want but if the concrete can't flow it will be very difficult to make it compact or consolidate

- This adds critical minutes to vibrating time that adversely affects production time and often results in a rejected piece of product

Test Your Concrete !!!

The Dry Cast Slump Test will give you a benchmark that can be used to determine the correct range of moisture that will make the fill time much more consistent

Understand what fill rate means to the product !!

The amount of concrete put in per pass is critical to consolidation and that rate MUST be controlled if you are to achieve good, watertight concrete

Effects of Over Vibration

- Segregation
- Form deflection and Damage
- Sand streaks
- Water bleed areas (usually near a vibrator)

Important Note

- Dry-cast vibration is very different from wet-cast vibration
- Dry-cast forms are designed for specific vibration system
- Don’t mix & match dry and wet-cast systems!

Keep this in mind ……..

It’s the form vibrating that consolidates the concrete

If the form remains rigid, the concrete has a very difficult time moving and it will require a larger vibrator to get the required results

Consolidation

Compact the concrete by removing trapped air and forcing the aggregate, sand, and cement to spread uniformly throughout the form while forming a water and air tight matrix that will meet the designed compressive strength requirements


Questions?