Machine vs Concrete
Building long lasting concrete pavements

Peter Taylor, PhD, PE (IL), FACI

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center
Tech Center

But how do we get there?

- What levers can we pull?
- What tests inform our decisions?

PEM properties

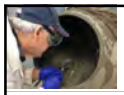
Uniform
Workable

Not segregated

Smooth Finished

Textured Cured

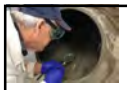
Crack free



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 — No test
  - Response to vibration — VKelly / Box
  - Edge slump — VKelly / Box
  - Finishability — Ruler
  - Other tests?

In the Lab

Proportioning to achieve performance goals

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

11

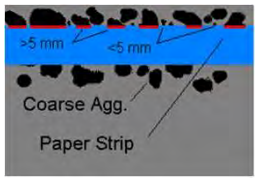
At the Batch Plant

- Workability — Power meter; Call from the paving supervisor; Data from the paver?

- Uniformity — No standard test
  - Stockpile control — -
  - Water control — Moisture probes
  - Loading sequence — -
  - Mixing time — -

In front of the paver

- Segregation — No standard test (Tayabji)
  - Aggregate gradation
  - Uniform delivery
  - Placing method

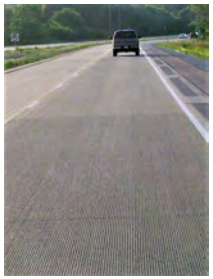


Behind the Paver

- Finish and Smoothness — Real time smoothness
  - Vibration — Internal sensors
  - Pan setup
  - Grout box
  - Paver speed
  - Finishing

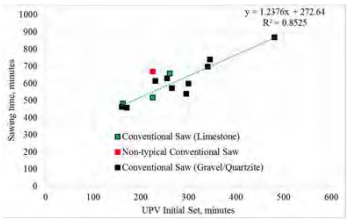
Tining Bridge

- Texture — Sand Patch; Noise
  - Tine setup
  - Bridge speed
- Curing — Zollinger method?
  - Curing Compound type
  - Spray rate
  - Timing



Sawing

- Crack free
  - Saw type
  - Blade
  - Depth
  - Timing — UPV



Where Next?

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

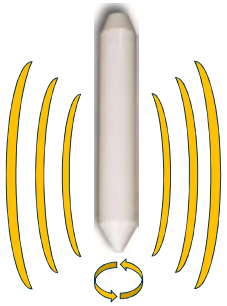
Vibration

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

19

What is a good vibration?

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

But how?

20

What is a good vibration?

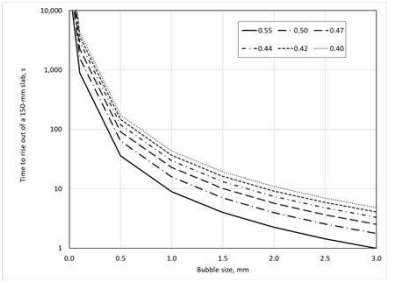
- Missing is fundamental understanding of the “how to” details
  - Energy
  - Frequency
  - Amplitude
  - Duration
  - Spacing
- For a given
  - Workability
  - Air void system
  - Bleed / segregation
  - …

21

Hypothesis

- Increased frequency
  - Moves water sideways
- Excess vibration
  - Impacts air void system
- Mixture segregation and bleeding increase effects

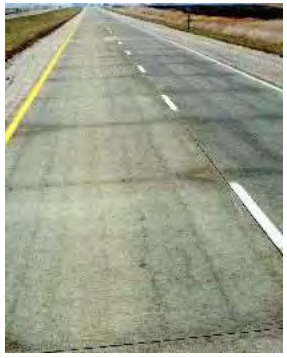
For example:



22

Air loss and segregation

- Unworkable concrete
- Beaten into place



23

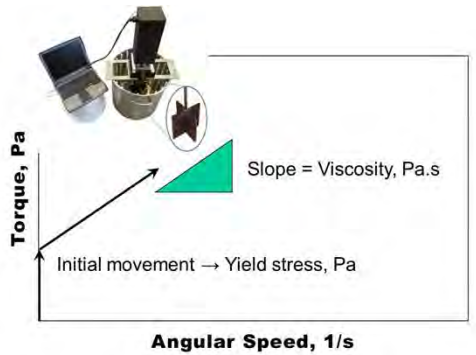
Water Movement

8,000 and 10,000 vpm

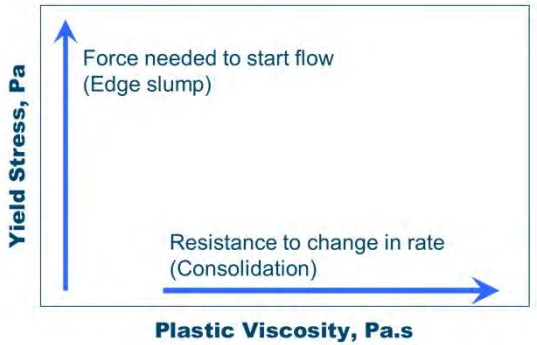
12,000 vpm

24

Rheology 101



Rheology 101



Rheology 101

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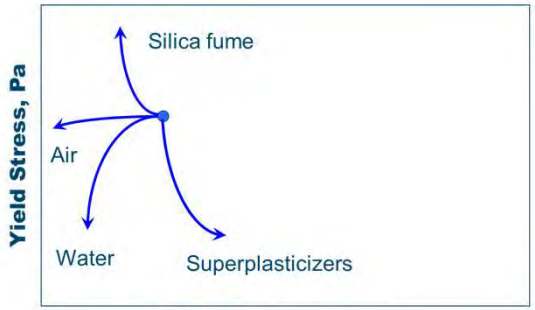
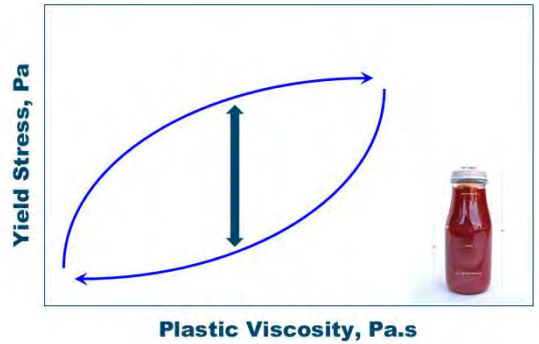


Rheology 101



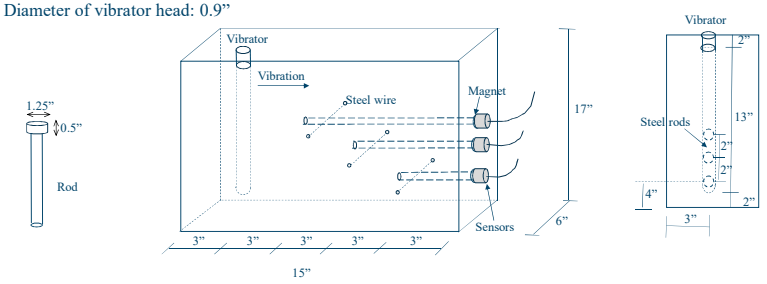
Preliminary Lab Work

- 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

30

Evaluating energy transfer

Steel rod diameter: 0.5”
Diameter of vibrator head: 0.9”



31

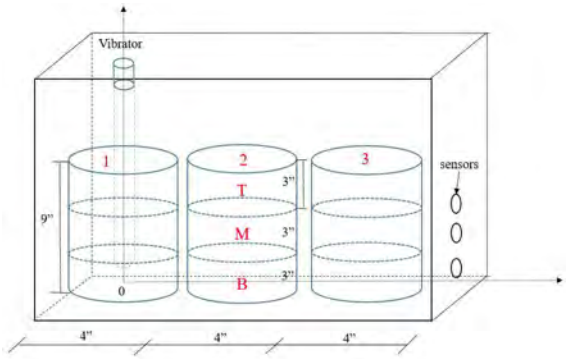
Matrix

- 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

32

Core samples



33

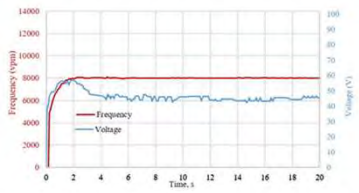
Drop Test

- Drop 5 µL water on a dry surface
- Record time for sheen to disappear
- Longer is better
- Great for localized comparisons

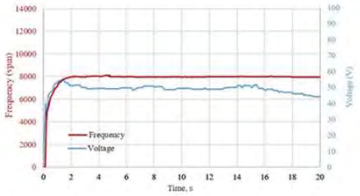
34

Effect of Air Content

- Little difference in energy demand
- Less thixotropy with air



(a) Mixture 1 - air 3.7%

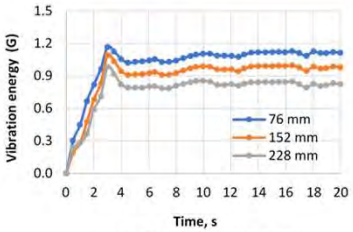


(b) Mixture 2 - air 7.2%

35

Effect of Air Content

- Little difference in energy transfer



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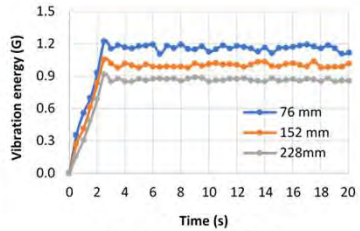
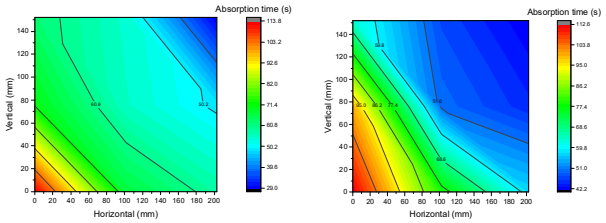


(b) Mixture 2 - air 7.2%

36

Effect of Air Content

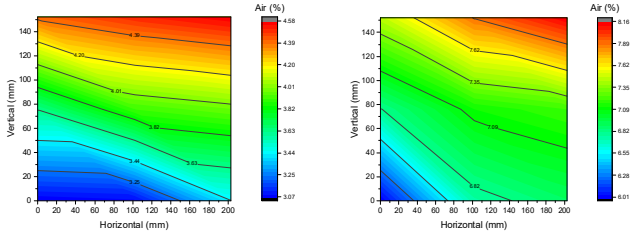
- Water is shown to move away from vibrator tip



(a) Mixture 1 - air 3.7% (b) Mixture 2 - air 7.2%

Effect of Air Content

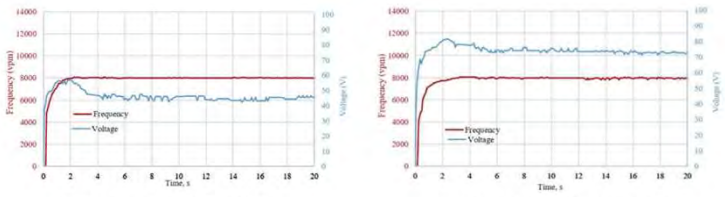
- Air is shown to move up from vibrator tip



(a) Mixture 1 - air 3.7% (b) Mixture 2 - air 7.2%

Effect of Water Content

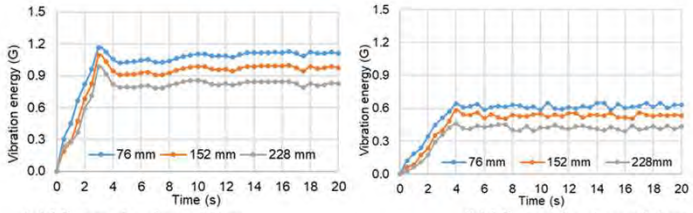
- Higher energy demand in dry mixture



(a) Mixture 1 - slump 10cm (b) Mixture 3 - slump 2.5cm

Effect of Water Content

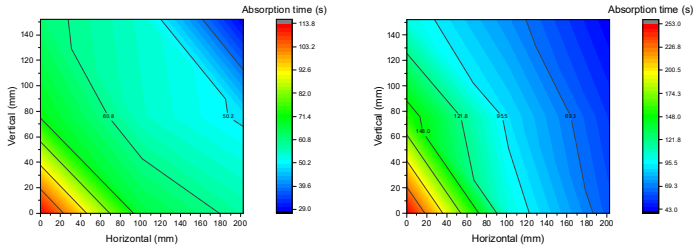
- Less energy transfer in dryer mixture



(a) Mixture 1 - slump 10cm (b) Mixture 3 - slump 2.5cm

Effect of Water Content

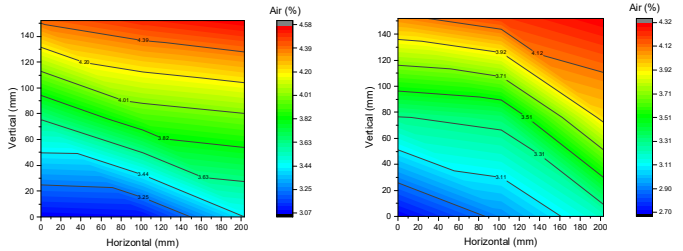
- Water moves in both cases



(a) Mixture 1 - slump 10cm (b) Mixture 3 - slump 2.5cm

Effect of Water Content

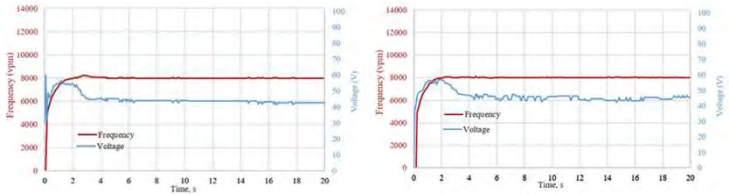
- Little difference in air movement



(a) Mixture 1 - slump 10cm (b) Mixture 3 - slump 2.5cm

Effect of WRA

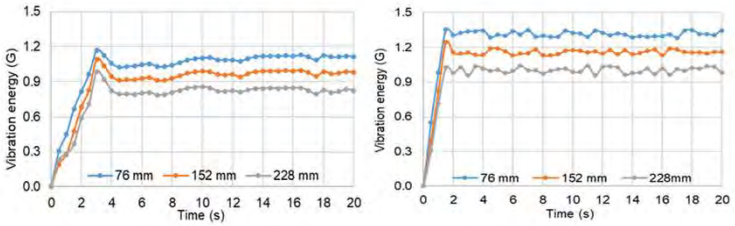
- Little difference in energy demand



(a) Mixture 1 - without WR (b) Mixture 4 - with WR

Effect of WRA

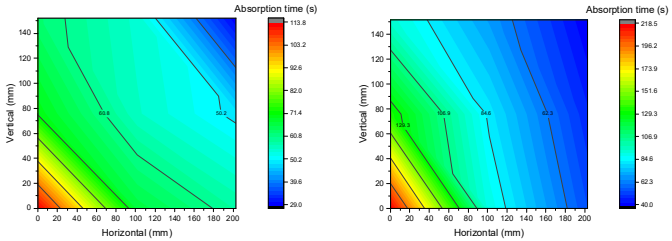
- More energy transfer in WRA mixture



(a) Mixture 1 - without WR (b) Mixture 4 - with WR

Effect of WRA

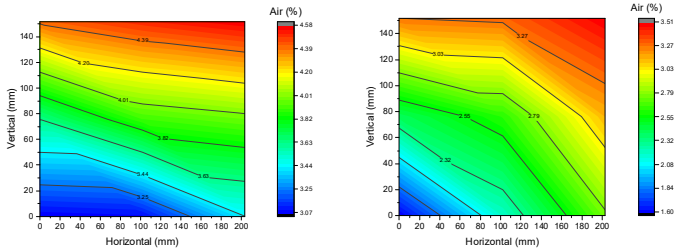
- Water moves in both cases



(a) Mixture 1 - without WR (b) Mixture 4 - with WR

Effect of WRA

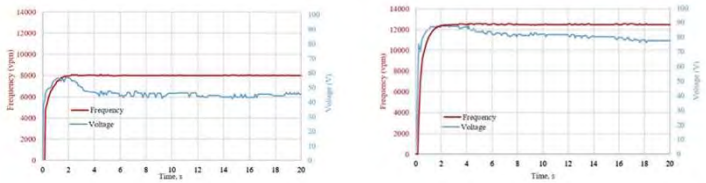
- Little difference in air movement



(a) Mixture 1 - without WR (b) Mixture 4 - with WR

Effect of Frequency

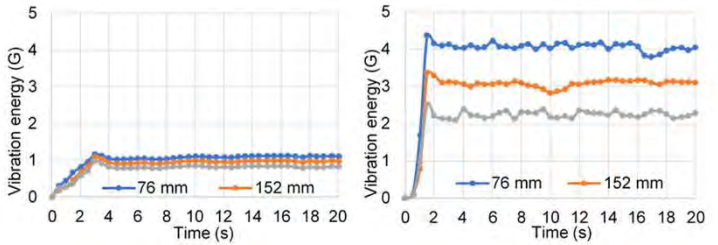
- More energy demand at high frequency



(a) 8,000 vpm (b) 12,500 vpm

Effect of Frequency

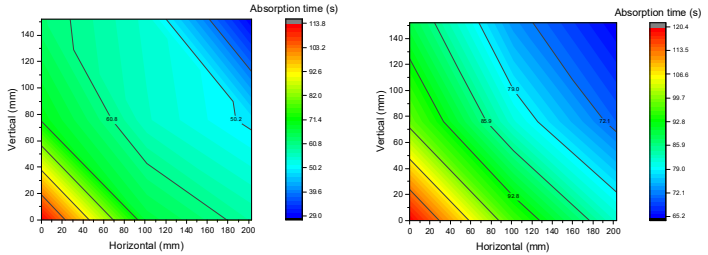
- More energy transfer in high frequency mixture
- More loss over distance



(a) 8,000 vpm (b) 12,500 vpm

Effect of Frequency

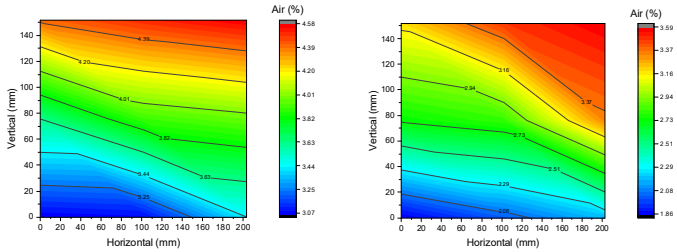
- Water moves in both cases



(a) 8,000 vpm (b) 12,500 vpm

Effect of Frequency

- Appears that more air is lost to the high frequency system



(a) 8,000 vpm (b) 12,500 vpm

Therefore

- Hypothesis seems right
- More research needed to pin down details
- Potential to design “vibrator proof” or machine specific mixtures is real
- As is real-time feedback to pavers and batch plants
- Pooled fund is being launched

But wait, there’s more

ACI MATERIALS JOURNAL TECHNICAL PAPER

Effect of Controlled Vibration Dynamics on Concrete Mixtures

by Viking Ling and Peter Taylor


National Concrete Pavement
Technology Center
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www.cptechcenter.org
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ACPA Research, Technology, and Innovation Functional Committee (RT&I)

Larry Scofield

Purpose:

- To Develop and Guide the Association's Research Needs and Priorities
- To Communicate These Needs/Priorities to the Research and Industry Communities
- Be a Lightning Rod for New Ideas

RT&I Members

Chairman: Matt Fonte- Castle Rock
Vice Chairman: Jim Mack- Cemex

Staff: Dr. Mark Snyder- Consultant
Larry Scofield-IGGA/ACPA

Task Forces

- **Concrete Batching** — Paul Jaworski, Minnich
- **In-Service in Hrs** — Gordon Smith, CP Tech Center
- **Paver Changes** — Dave Scuillo, Golden Triangle
- **Real Time Sensing** — Dr. Tyler Ley, OSU
- **2040 Vision** — Gary Fick, Transtec

Members

Name		Organization	Category
Jeff	Borden	COLD SPRING CONSTRUCTION CO.	Contractor
Gary	Fick	THE TRANSTEC GROUP, INC.	Consultant
Ron	Guntert	GUNTERT & ZIMMERMAN CONST. DIV., INC.	Equipment Mfg
Paul	Jaworski	MINNICH MANUFACTURING	Equipment Mfg
Tyler	Jensen	ASH GROVE CEMENT COMPANY	Cement
Kevin	Klein	GOMACO CORPORATION	Equipment Mfg
Tim	Lewellen	BOH BROTHERS CONST. CO., LLC	Contractor
Charles	Nmai	BASF CORPORATION (ADMIXTURE SYSTEMS)	Material Supplier
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Adam	Komornicki	ASTEC INDUSTRIES	Equipment Mfg
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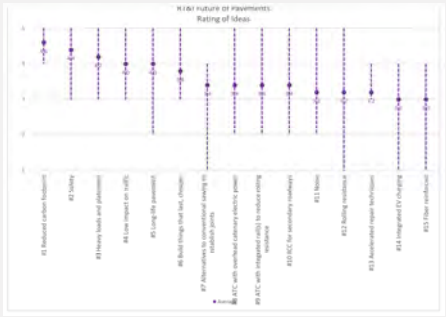
Kevin	McMullen	WISCONSIN CONCRETE PAVEMENT ASSN.	Chapter/State
Angela	Folkestad	COLORADO/WYOIMING ACPA CHAPTER	Chapter/State

Process:

- Brainstormed What the Industry Needed to Have
- RT&I Group Then Prioritized Needs Statements
- Created Five Task Forces to Develop the Highest Ranked Areas
- Submit Ideas/Needs to ACPA Market Forum
- Developing Problem Statements for Research Needs

2040 Task Force



- Reduced Carbon Footprint
- Heavy Loads and Platooned Trucks
- Construction and Maintenance Techniques that Have Low Impact on Traffic
- Long Life Pavement
- Build Things that Last- Cheaper- Optimizing

Batching TF

- Material Moisture Sensing and Automated Compensation
- Use of Dual Cement Weigh Scales for Improved Cementitious Material Blending and Distribution
- Development of Internal Batch Drum Sensors and Tools for Monitoring and Controlling/adjusting Critical Factors that Impact Batch-to-Batch Uniformity

Put In-Service in Hrs TF

- Performance Parameters Have Been Identified for Each Application (new construction/overlays vs. repairs)
- RCC
- Lessons Learned in Fast Track

Real Time Sensing TF

- Focused on Paving Process Impacting Smoothness
- Determined Factors Required to Routinely and Consistently Make Smooth Concrete Pavements
- Attempting to Construct Some Test Sections For Evaluation

Paver Changes TF

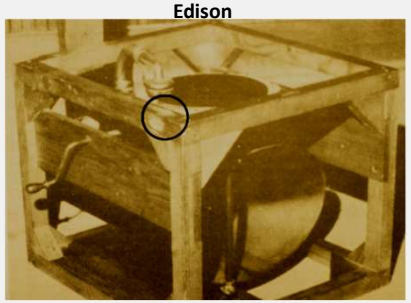
- Drop-off (safety) issues in paving.
- Tie bars – usually needed to prevent joint opening, but a problem in staged construction.
- Early opening mixes needed possibly with different opening times for cars vs heavy trucks

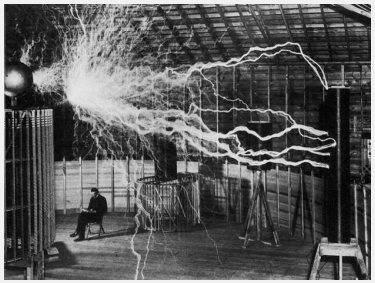
Summary

- Task Forces are a Living Process
- Conducting Webinars to Show Case Emerging Technologies
- Going Out for a Synthesis Project to Summarize and Assess Technologies to Determine their Potential to Control Aggregate Moisture Levels During Batching
- Attempting to Construct Test Sections to Evaluate Machine Parameter Impacts on Initial Smoothness
- Potential For Agencies to Use Pooled Funds to Push Technology Forward

Questions

Edison





Tesla