What's New with Concrete Pavements?

MCEA 13th Annual Summer Conference

Arrowwood Resort

Alexandria, MN

June 16 - 18, 2021

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Concrete Paving Association of MN

Outline/topics

- Opening Strength
- Joint activation
- Concrete Maturity
- Incentives
- Costs
- PavementDesigner.org

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Opening Strength

- Why 3000 psi?
  - Where did that come from?
- Vehicle Tire Pressure
  - Car 35 psi +/-
  - Pickup truck 35 psi – 80 psi
  - Semi truck/trailer 75 psi – 135 psi+
- Quote from MnDOT rep regarding MnROAD
  - "… where Matt gets to try out his crazy ideas"

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Opening Strength

- We can't build concrete because it takes too long to get traffic on the pavement
  - Roadways
  - Intersections
  - Driveways
  - Sidewalks

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Opening Strength Background and Motivation

- Concerns
  - Durability
    - How is the durability of an early loaded pavement affected?
    - How damaging is a rut from an errant vehicle?
    - How damaging is an early load without visible ruts?
  - Related
    - Damage vs strength gain
    - Load repetitions vs damage

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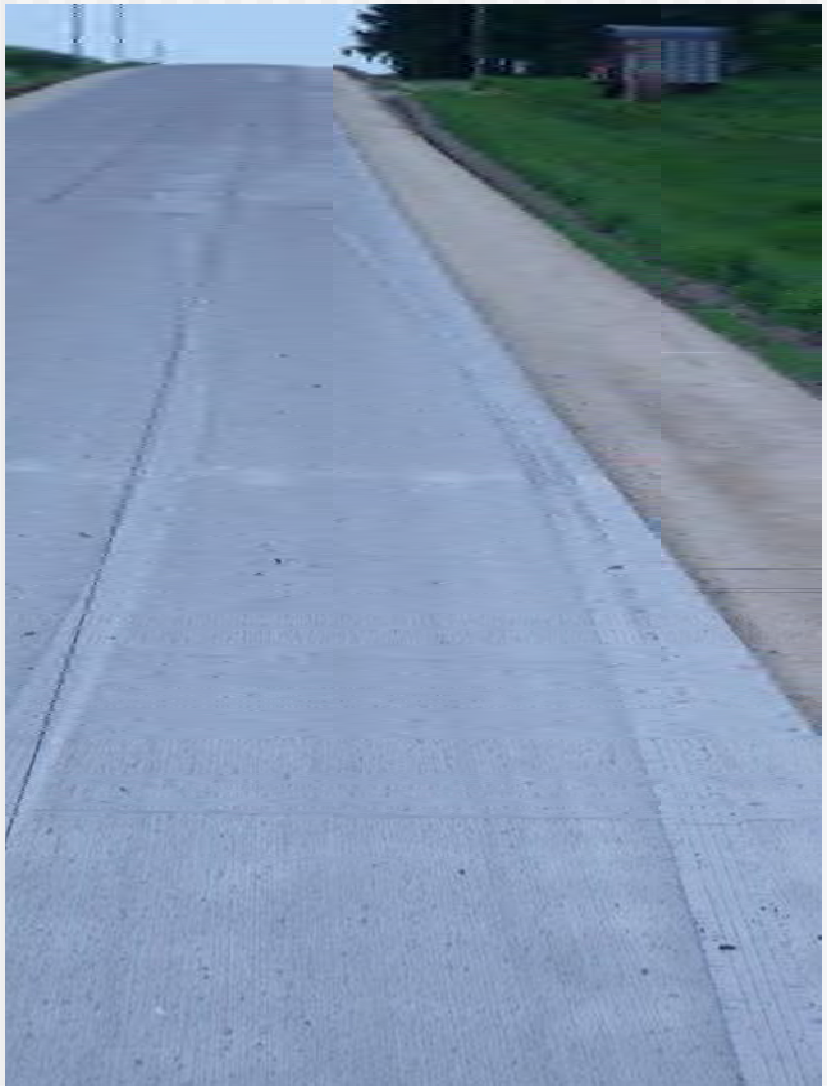
Goodhue Co Hwy 6 (2016)



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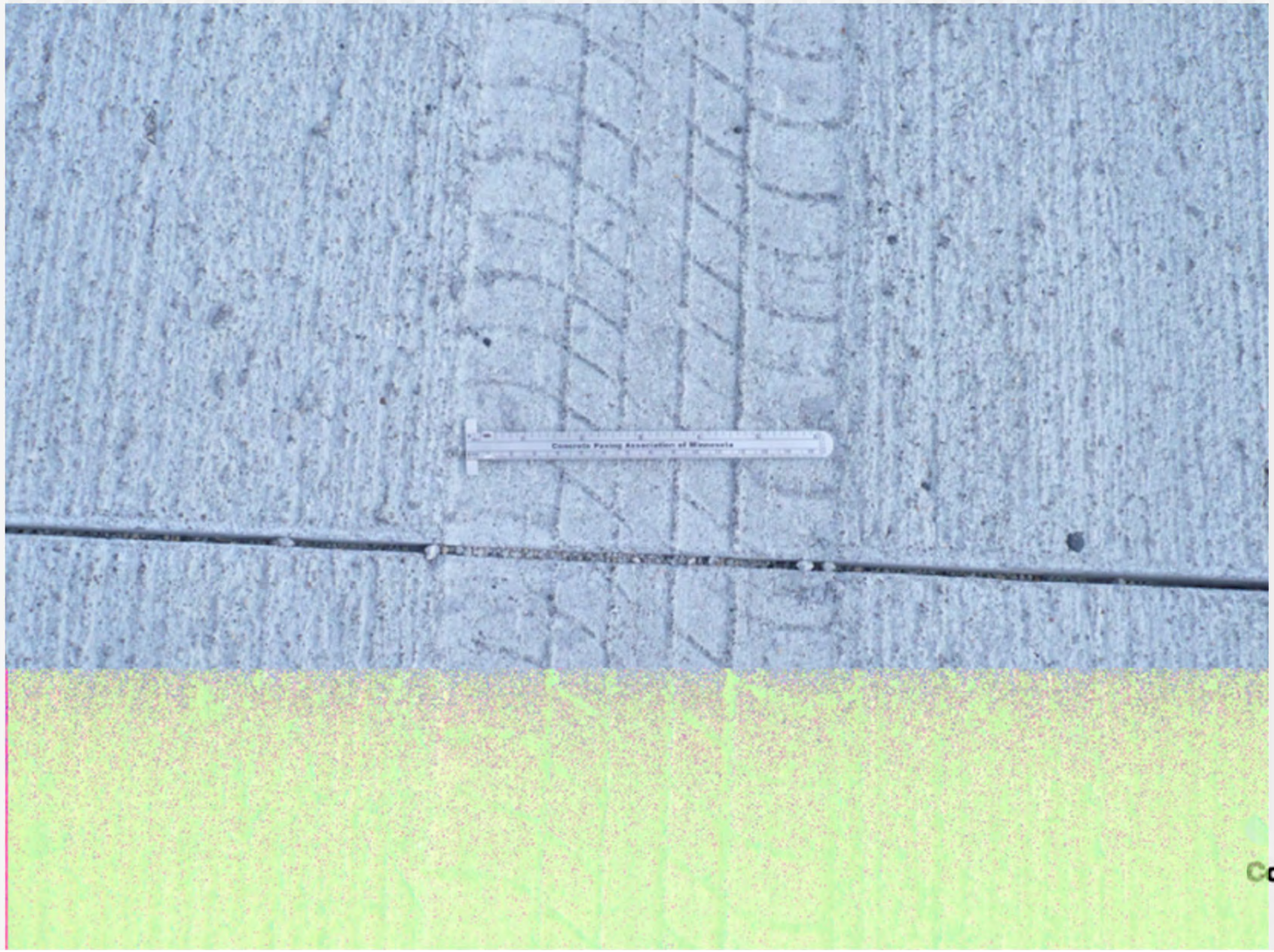

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Goodhue Co Hwy 6 (2016)

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- MnDOT Initial recommendation R&R
- County agreed to core and review
  - Core and run petrographic analysis. If no excessive cracking allow to remain in place
  - Diamond grind to remove excessive ruts and patches
  - Warranty for 2 years

MnDOT TH 12 (Paved 1994, photos taken 2016)

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- 20+ years after the fact, no ill effects

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So, When Can We Allow traffic on New Concrete?

- 1/3/7 Days?
- 2000/3000/4000 psi Compressive?
- 150/300/500 psi Flex?

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Opening Strength Test

Early loading of Cells 124-424

4,000 lb axle vs 14,000 lb axle loads (1st Cell @ 3hrs)

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The Experiment

Concrete Age:

3 hrs.	5-3/4 hrs.	8-1/3 hrs.	10-1/2 hrs.	No Load
124	**224**	**324**	**424**	**524**

Cell x24 Early Loading Sequence		
Maturity (Deg-Hr)	**Flexural (psi)**	**Loads applied to lanes**
100	**73**	**1st Load on Cell 124 (forward and back)**
200	**196**	**1st Load on Cell 224, 2nd load on Cell 124**
300	**267**	**1st Load on Cell 324, 2nd load on Cell 224, 3rd load on Cell 124**
400	**318**	**1st Load on Cell 424, 2nd load on Cell 324, 3rd load on Cell 224, 4th load on Cell 124**

Starting Day 2, 5 passes per day for first week

Burnham - NCC 2017

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3 hours

- https://www.youtube.com/watch?v=A7n-CaONIwU&ab_channel=NRRA

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- https://www.youtube.com/watch?v=ZyNy2UA9mSs&ab_channel=NationalRoadResearchAllianceNationalRoadResearchAlliance

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MnROAD – Early Opening (rut)

Conclusions

- Strain gauges picked up first pass only of the snowplow
- No visible damage
- No damage seen in cores
- 80,000 lb. truck, 80 times per day since day 6
- Ruts not fixed; no additional damage visible

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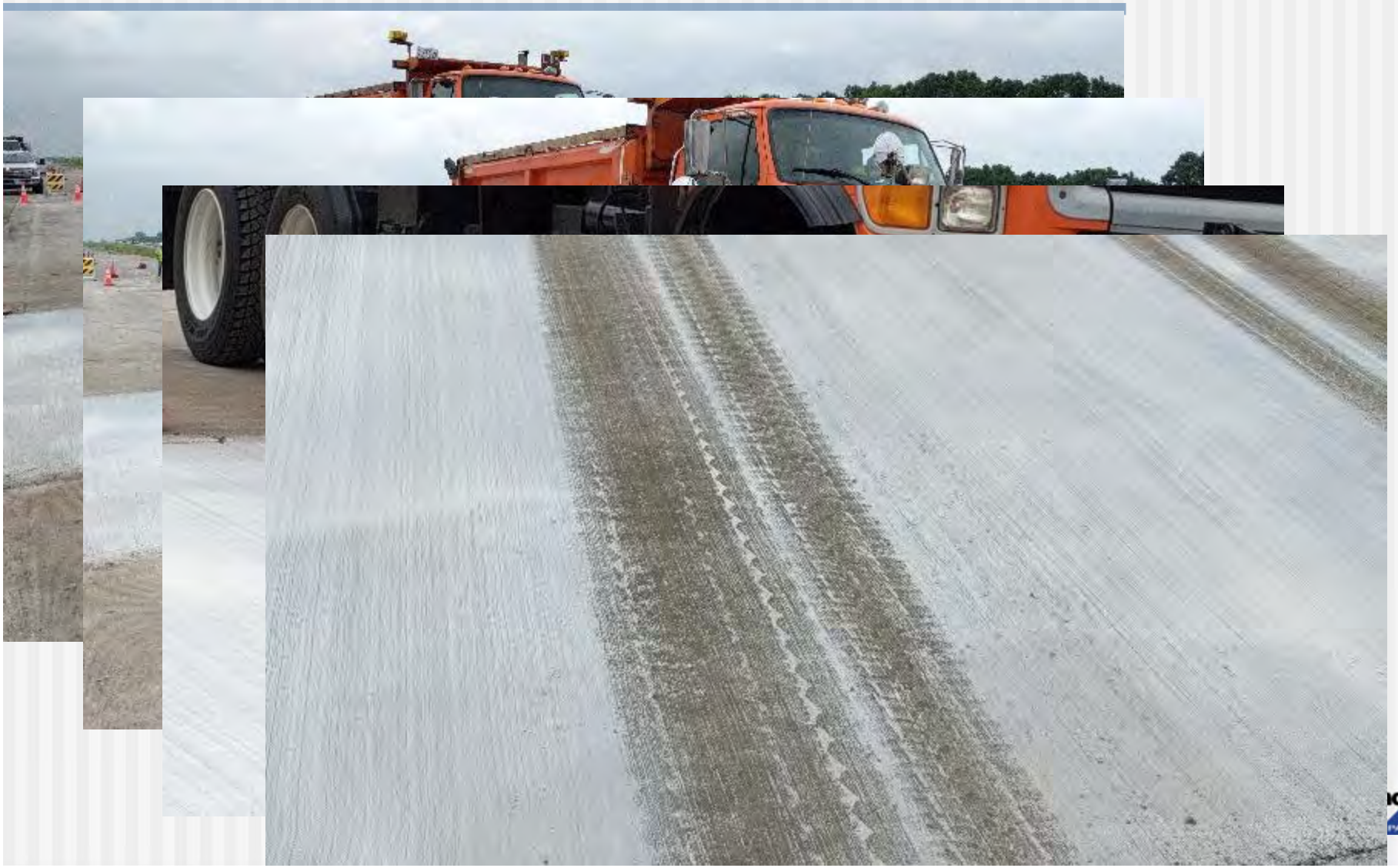
MnROAD – Early Opening (Repair)



MnDOT Preliminary Spec Language

- Opening of Pavement to Local Passenger Traffic: The Contractor may at their own risk allow local passenger traffic (total gross vehicle weight not to exceed 10,000 lbs. or equivalent to a ¾ ton 6.0 L diesel pickup truck) to drive on the new pavement slab to access their residence or business after satisfactory completion of all initial joint sawing, excluding early entry sawing. in accordance with 2301.3N.2, "Joint Establishment" If any damage occurs. the Engineer will evaluate the concrete pavement in accordance with 2301.3.Q, "Workmanship and Quality." Prior to placement of any concrete pavement. provide a Quality Control Plan to the Engineer for acceptance which provides the Contractor's plan for management of local traffic during concrete pavement placement.

A Little More Backup Info

Joint Activation

- 15’ panel length vs 6’ panel length
  - 2.5 times the length
  - 2.5 times the movement (temperature)

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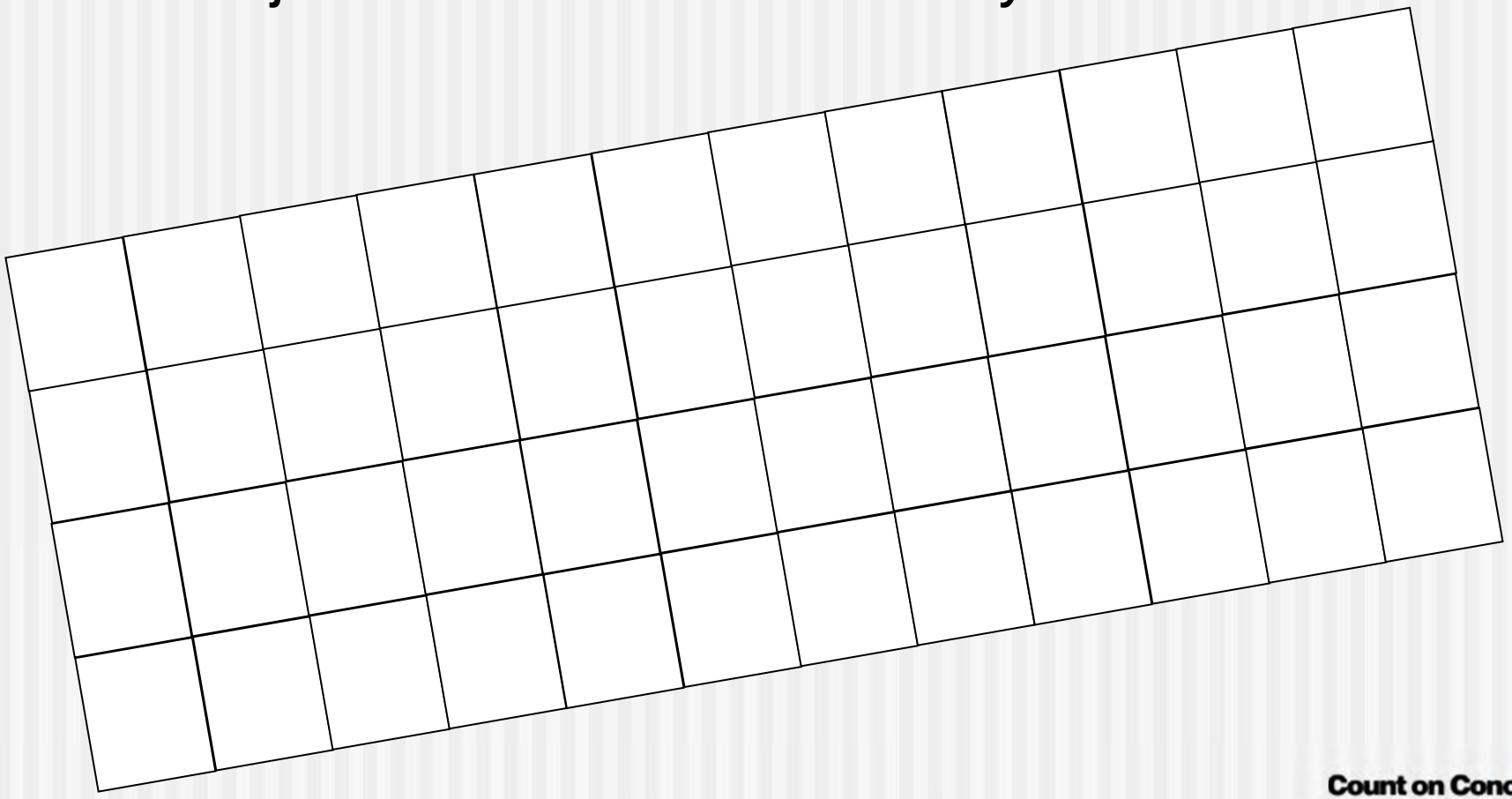
6’ x 6’ Joints

- If all joints activate should barely move



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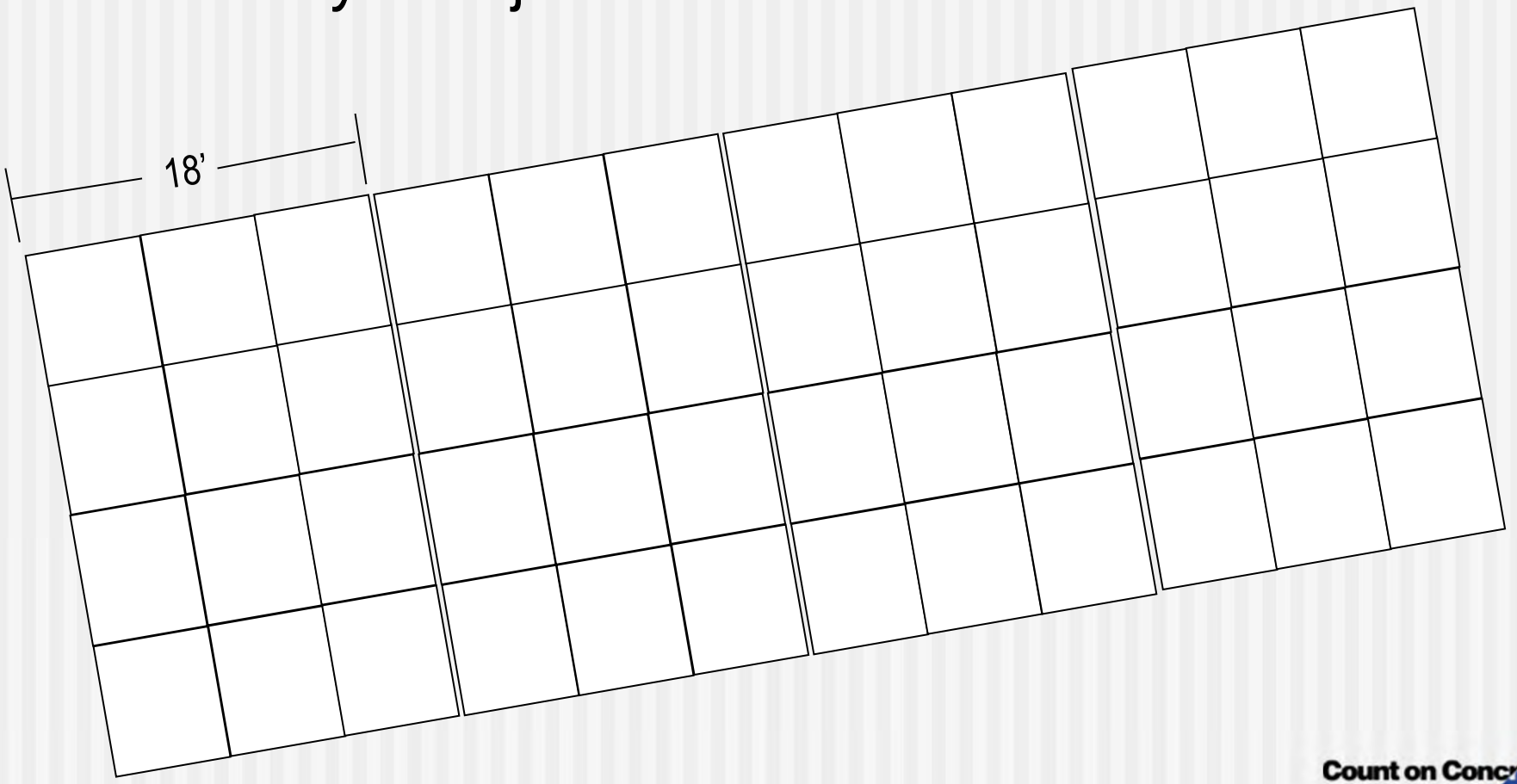
6’ x 6’ Joints

- If every third joint activates…



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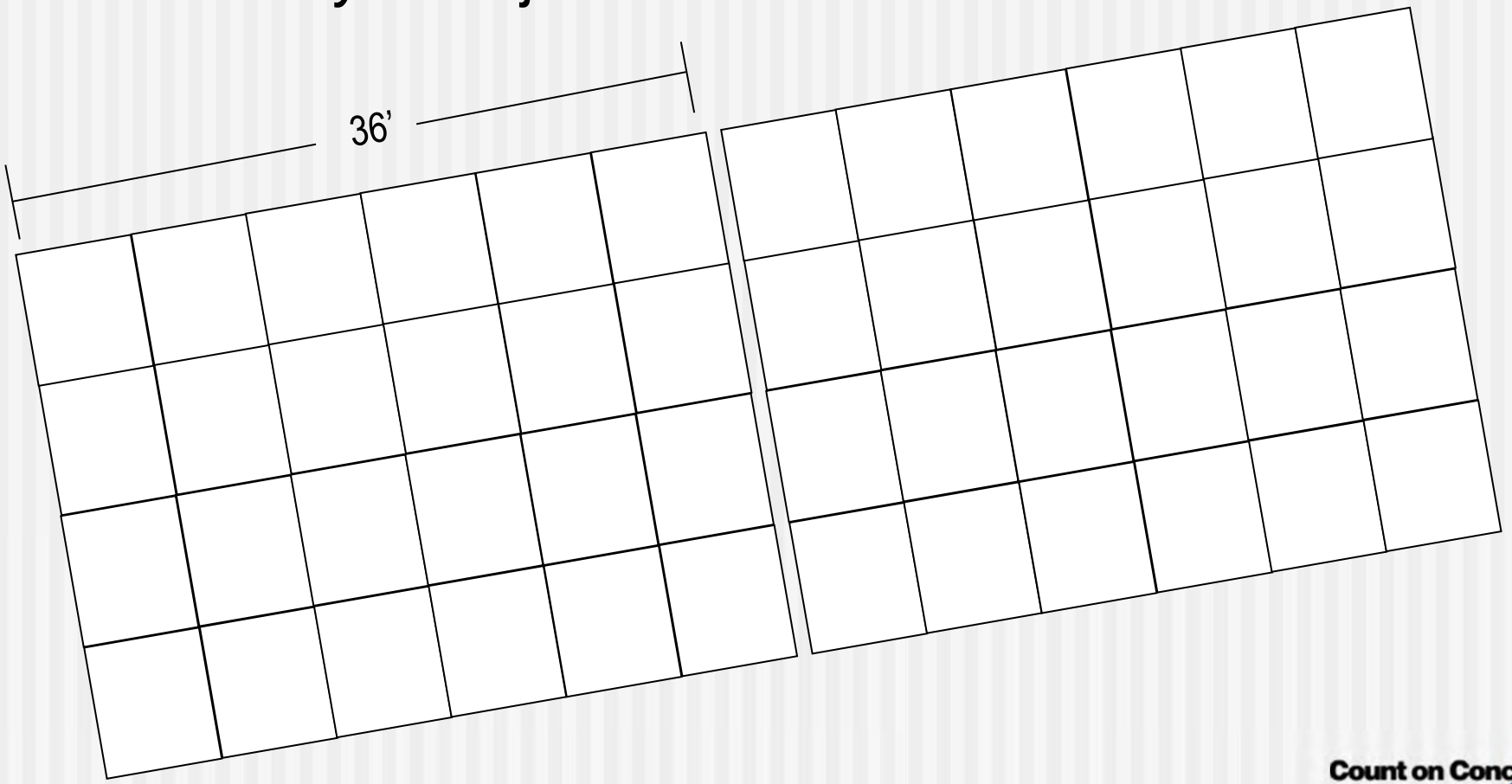
6’ x 6’ Joints

- If every sixth joint activates…



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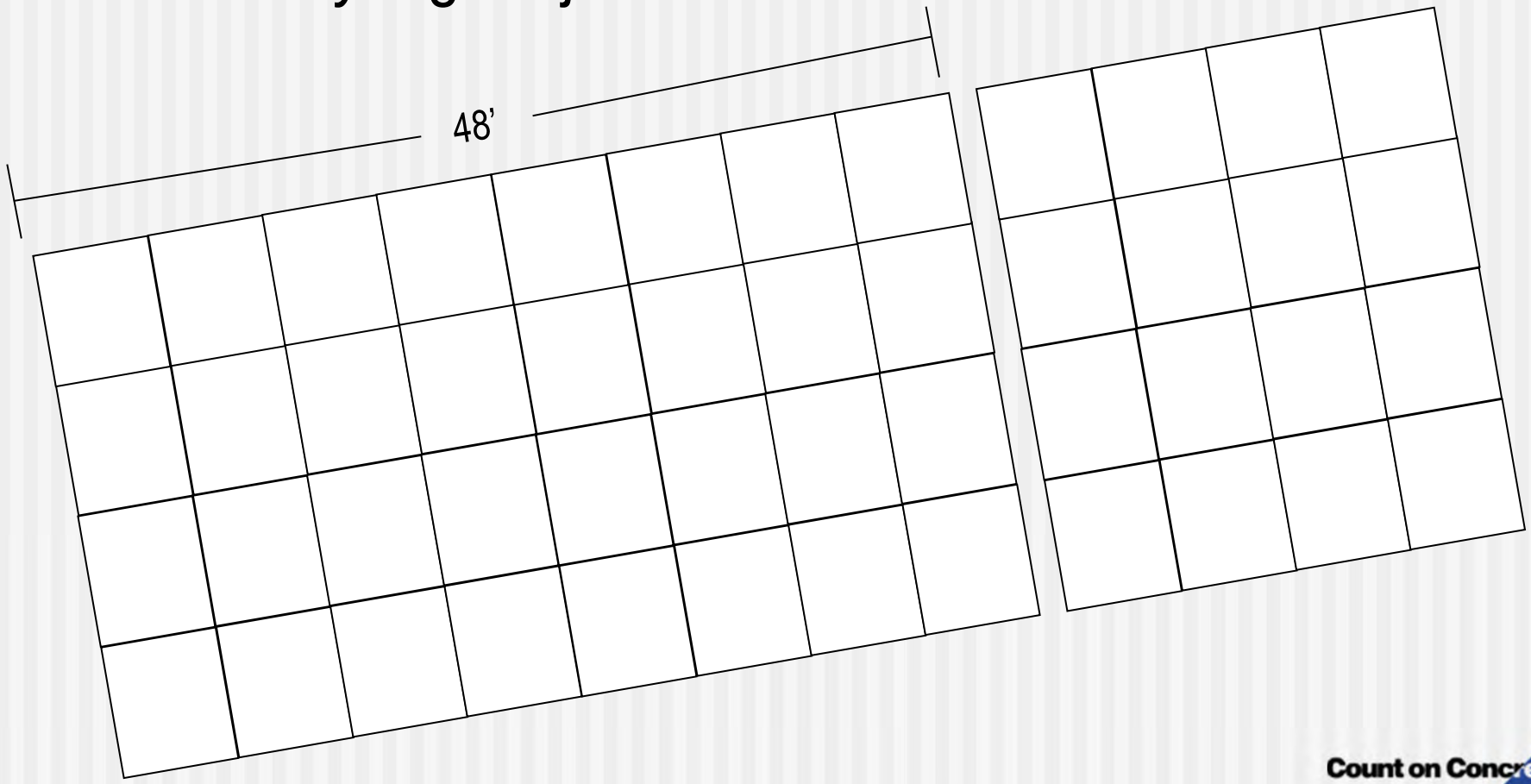
6’ x 6’ Joints

- If every eighth joint activates…



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Joint Activation

- GOAL: Minimize dominant joints; Influence the number of working joints! Narrow joint widths – fibers more beneficial
- HOW: Drive on pavement to activate joints

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Indiana SR 3 - 4.5” FRC (2018)

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TH 63 Joint Activation - Conclusions

- I think we can & should load BCOA early to activate joints
- Maturity test of TTF = 350 seems to be a good target to load (more to come on maturity)
- Probably need to continue to load for several days. Open to construction traffic or batch trucks?
- May have to ensure sawing gets through edge of pavement
- Indiana joint activation was encouraging

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Concrete Maturity Method

- Non-destructive test
- Measures strength of in-place concrete
- Early age test
- Not a 28-day strength test
- Works well with opening strength & joint activation efforts

Slides - courtesy of Todd Hanson, Concrete Materials Engineer, Iowa DOT

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Beams/Cylinders vs. Maturity

Beams/Cylinders

- Specimen – not actual structure
- Different curing than pavement

Maturity

- Direct measurement of pavement concrete
- Actual temperature in pavement

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Maturity Concept

- Time Temperature Factor: TTF
  - Relationship between thermal history and strength of a concrete
- ASTM C 1074
  - Nurse•Saul Equation
  - $M\ (°C \bullet hrs) = \Sigma[(T - T_0)\Delta t]$
    - $where\ T_0 = (-10\ °C)$
  - Time × Temperature = Maturity (TTF)

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Advantages - Contractor

- Use as haul road
- Expedite drain & shoulder work
- Accelerate staged construction
- Reduced construction time & Costs

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Advantages – Public

- Provide local access early
  - Homeowners
  - Businesses
- Reduced Construction Time & Costs

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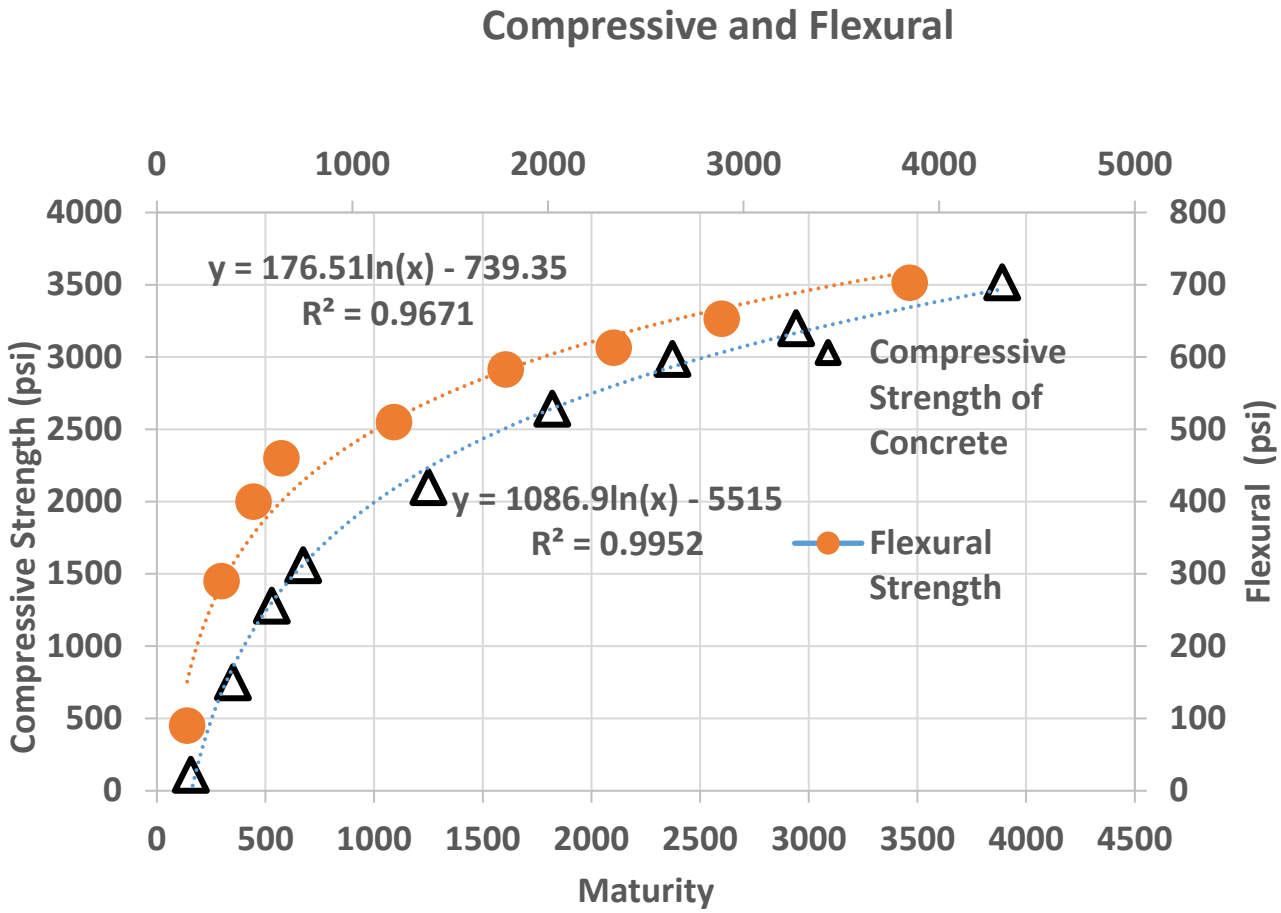
Maturity Meters

MnROAD Maturity Curve

Hours	TTF
3.0	= 100
5.75	= 200
8.33	= 300
10.5	= 400



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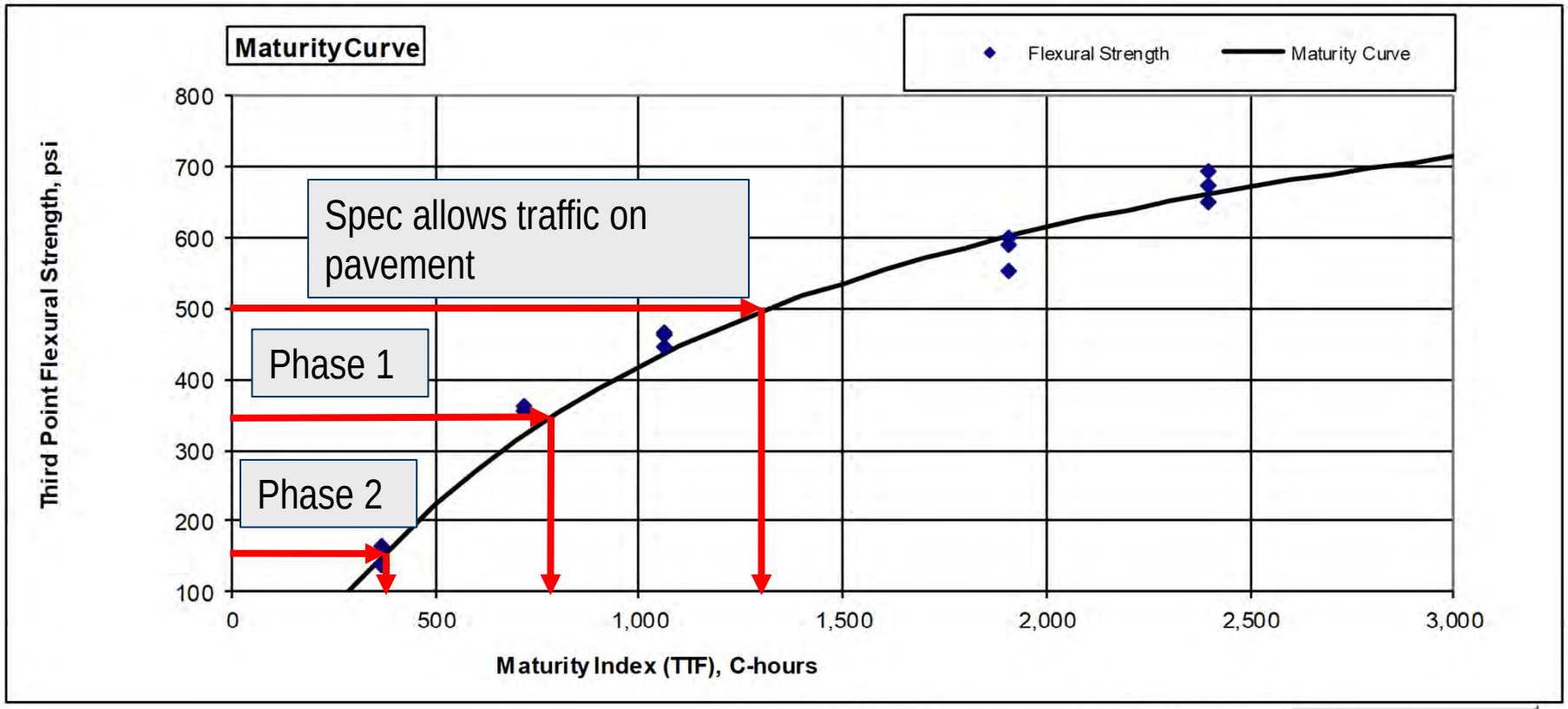
Concrete Maturity



Curve Coefficients:

Su=	1108.79
t=	965.85
a=	0.7210586

Solve Maturity Curve

Required Strength for Opening	500	psi
Required TTF for Opening	**1320**	C-hours

Comments:

Concrete Pavement Incentives

- w/c – Durability
- Smoothness – user satisfaction
- Aggregate gradation – tighter mix, relates to w/c
- Aggregate quality – durability; specs already require durable aggregates

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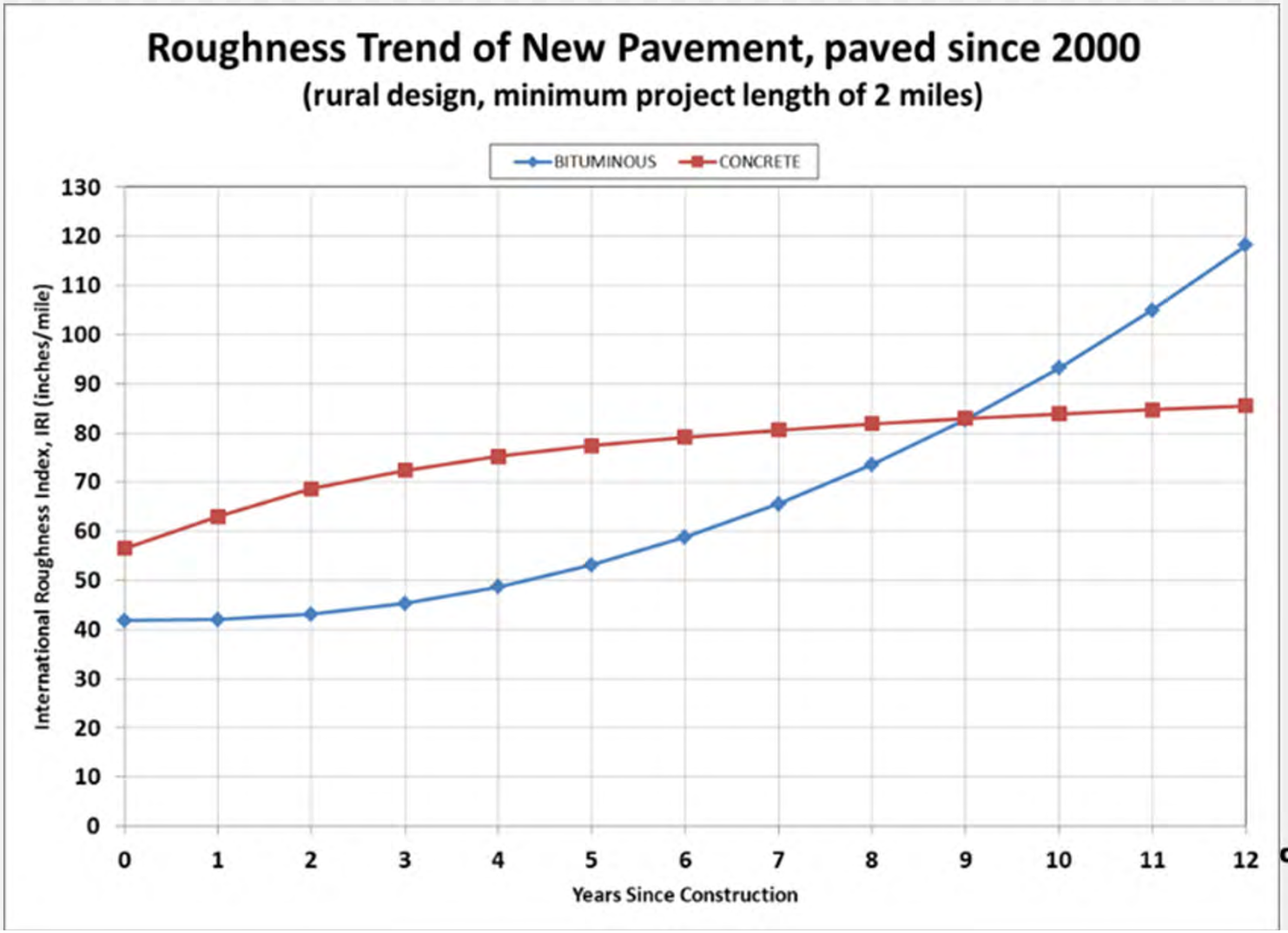
Comparing Smoothness Trends



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W/C Ratio Incentive

	1995 – 2010	2011 – Present	1995 Adj for Inflation*
<=0.35	$4.00	$3.00	$7.12
0.36	$3.00	$3.00	$5.34
0.37	$2.00	$3.00	$3.56
0.38	$1.25	$1.75	$2.23
0.39	$0.50	$0.50	$0.89
0.40	$0.00	$0.00	$0.00

* $1.00 in 1995 is worth $0.56 in 2021; or it takes $1.78 today to buy what $1.00 bought in 1995 per US Bureau of Labor Statistics

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Smoothness Incentive per lane

(per 0.1 mile segment)

	1995-2004	2005-2013	2014-current	1995 Adj for Inflation*
Max	$854	$788	$890	$1,520

* $1.00 in 1995 is worth $0.56 in 2021; or it takes $1.78 today to buy what $1.00 bought in 1995 per US Bureau of Labor Statistics

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Concrete Pavement Incentives

- Do we need them
  - Short answer – No
    - Meeting the minimum specifications is pretty easy. But in a low bid system is that what you are looking for?
  - Long Answer – You should want them
    - Getting more than minimum does not cost a lot. Quality contractors know how to achieve with minimal effort and cost. They can take some of their expected incentive out of their bid.

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Concrete Pavement Incentives

- Why not just spec higher quality concrete?
  - You could. Then when the lower quality contractor gets the bid (biggest flaw of low bid system is no qualification) you get to fight with them and go to court.

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Concrete Pavement Incentives

- Incentives are a way around the low bid system
- Incentives give an advantage to the contractors who do quality work
- Incentives have to be high enough to make a difference
- Incentives can be "bid in" to eliminate the need to go back to your board to request more funds

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Concrete Pavement Incentives

- If you are looking to change the incentives
  - Consider eliminating the ones that do not really give a benefit – aggregate gradation and aggregate quality (aggregate quality intended for areas with marginal aggregates)
  - w/c is the single most important design element to assure durability
  - Smoothness is what the public wants

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Concrete Pavement Incentives

- My recommendation
  - Double the w/c and smoothness incentive, don't cut them in half
  - Eliminate the aggregate incentives

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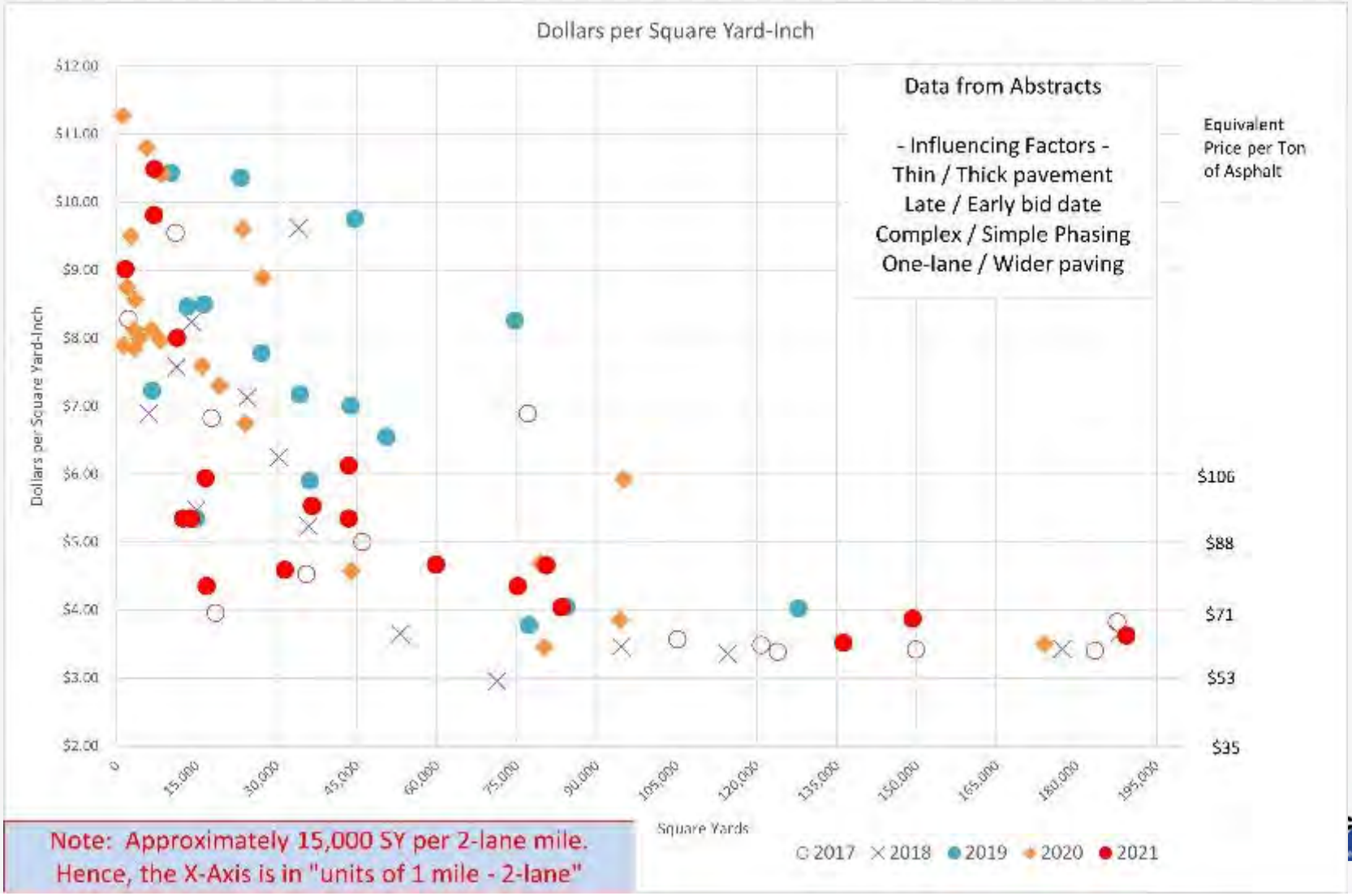
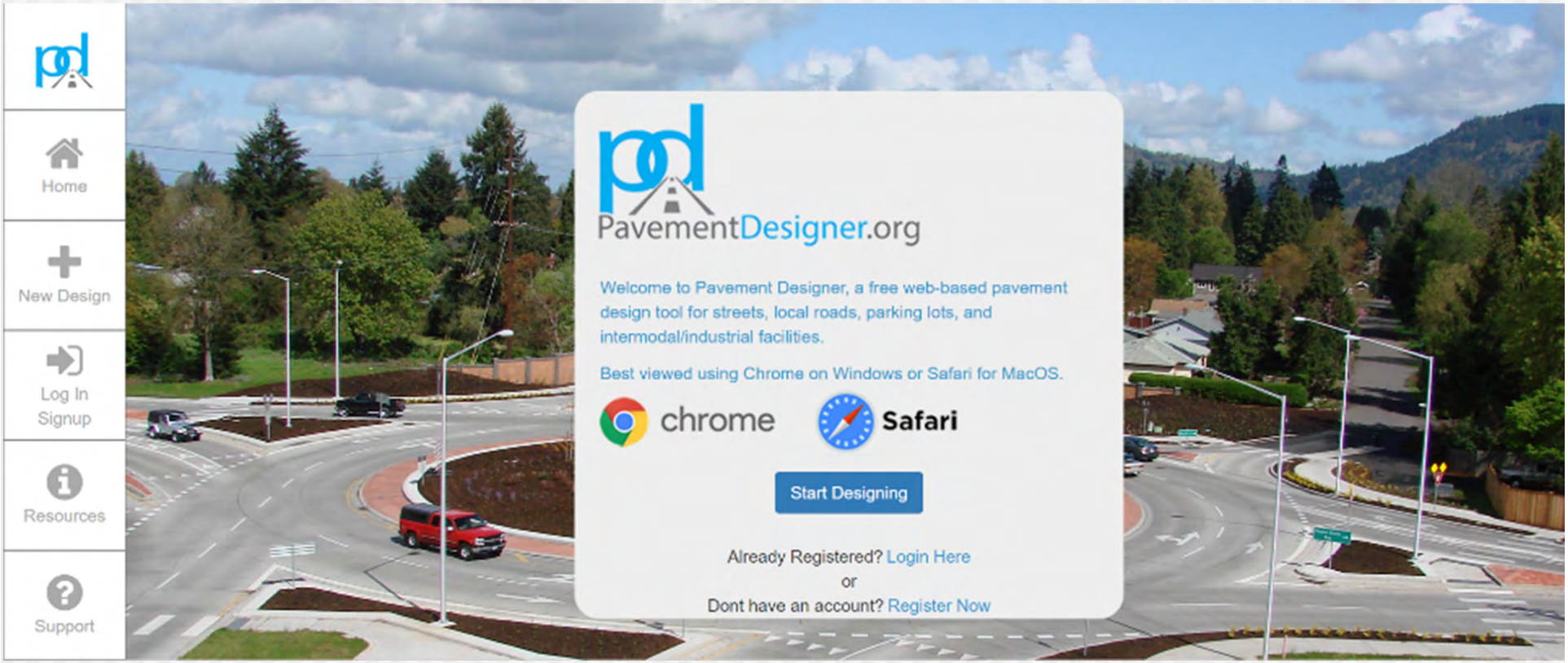
Concrete Prices



PavementDesigner.org



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PavementDesigner.org

- Online design program
- Free
- Incorporates StreetPave
- Approved by MnDOT State Aid

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PavementDesigner.org

- Introduction presentation
  - https://vimeo.com/479110538

Thank You - Questions?

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