minnesota concrete council
Dedicated to Cast-in-Place Concrete

Extended Joint Floors:
Concepts, Systems & Material Choices

Tuesday September 13, 2022

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WHO IS CRT CONCRETE CONSULTING, LLC?

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BACKGROUND OF TULL

- BS in Civil Engineering from Cornell University
- Industry Experience:
  - *Concrete Contractor (3 years)*
  - *Construction Manager (3 years)*
  - *Ready Mix Concrete (17 years)*
- ACI Member
  - 330 Parking Lots (Past Chair)
  - 302 Slab Construction
  - 332 Residential Concrete
  - 327 Roller Compacted Concrete
  - 522 Pervious Concrete
- Registered Professional Engineer in Indiana
- LEED AP

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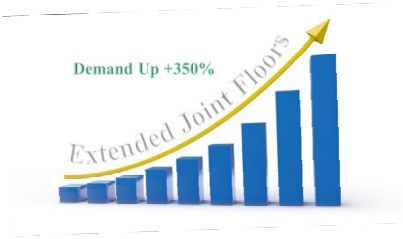
Market Trend



Why?

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Performance Requirements

What Do You Want from Your Floors?

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Q: Where are Your Slab Problems?

- Joints.
- Properly eliminate the joints, eliminate problems.
- Yes… I said properly. More to come on this.

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Common Sense

- Our problems are at the joints.
- Minimize the joints, minimize the problem.
- The trick:
  - Extending the joints without increasing the curling.

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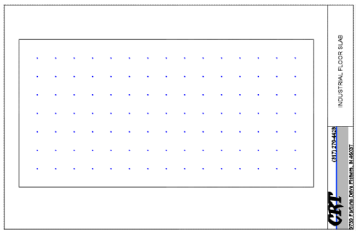
Typical 50’ Columns



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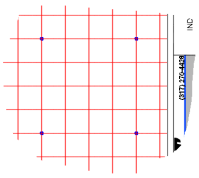
Sawcut 12’-6” on Center



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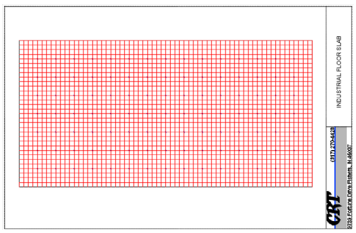
50,000 lf of joints!



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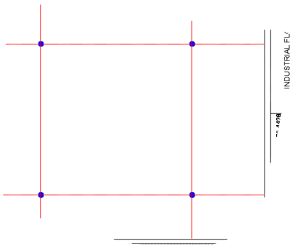
Redesign to sawcuts at 50’ o.c.



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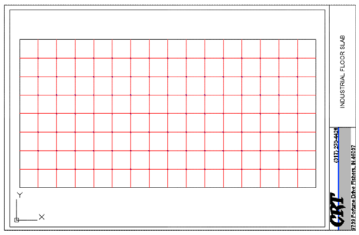
11,600’ of Joints



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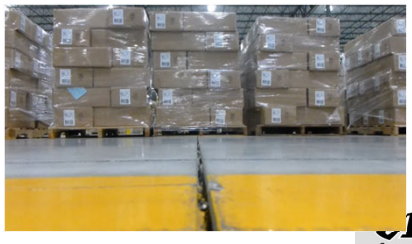
Hard Wheels Hitting Curled Joint



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Joint Damage

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Shrinkage Goes to Curling

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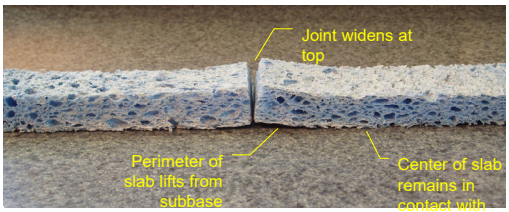
Howard Kanare



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Curling

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What Shrinks?

- Coarse aggregate?
- Fine aggregate?
- Paste!
  - Minimize paste volume
- This is not water cement ratio

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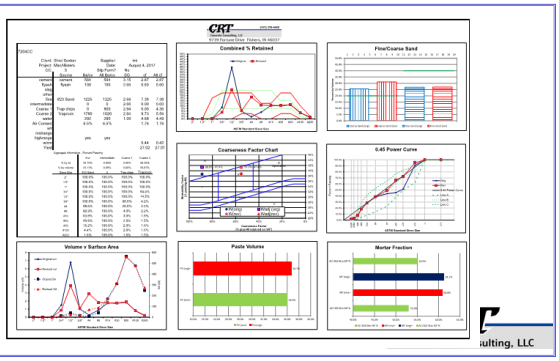

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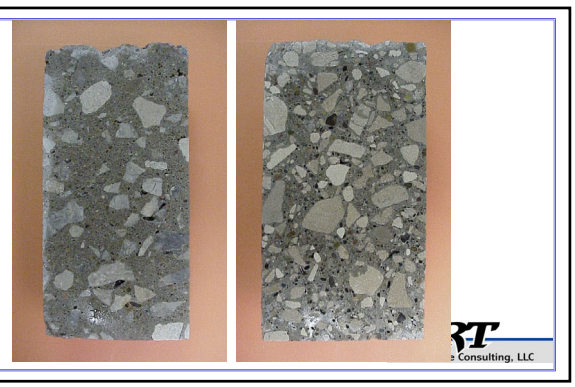

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These Design Analysis Tools are by Volume, not by Weight.

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What About Thermal Stresses

- Not well understood.

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ACI 360 and Thermal Stresses

14.2—Drying and thermal shrinkage

Typical portland-cement concrete, along with shrinkage-compensating concrete, shrinks approximately 0.04 to 0.08% due to drying (PCA 2002). For slabs-on-ground, the shrinkage restraint from the subgrade varies with the coefficient of friction and planarity of the surface of the subbase. Thermal movement is caused by a change in slab temperature from the time of initial placement. Consider this for any floor when casting concrete at a significantly different temperature than the normal operating temperature. Thermal contraction can be calculated by using the concrete's coefficient of thermal expansion of 5.5×10^{-6} per °F (9.9×10^{-6} per °C). For example, lowering the temperature of a floor slab from 70 to 0°F (21 to –18°C) can shorten a 100 ft (30 m) slab by 0.46 in. (12 mm), assuming no subgrade restraint.

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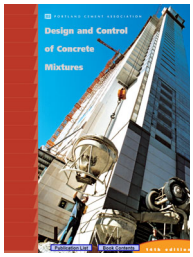
PCA Design and Control



Chapter 15
Volume Changes
of Concrete

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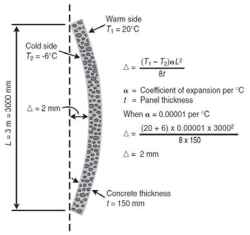
Precast Wall Example



$$\Delta = \frac{(T_1 - T_2)\alpha L^2}{8t}$$

α = Coefficient of expansion per °C
t = Panel thickness
When $\alpha = 0.00001$ per °C

$$\Delta = \frac{(20 + 6) \times 0.00001 \times 3000^2}{8 \times 150}$$

$\Delta = 2$ mm

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Coefficient of Thermal Expansion

Table 15-1. Effect of Aggregate Type on Thermal Coefficient of Expansion of Concrete

Aggregate type (from one source)	Coefficient of expansion, millionths per °C	Coefficient of expansion, millionths per °F
Quartz	11.9	6.6
Sandstone	11.7	6.5
Gravel	10.8	6.0
Granite	9.5	5.3
Basalt	8.6	4.8
Limestone	6.8	3.8

Coefficients of concretes made with aggregates from different sources may vary widely from these values, especially those for gravels, granites, and limestones (Davis 1930).

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Actual vs Published Values

- Limestone
- Published: 3.8 x 10^{-6} in/in/°F
- Actual: 4.8 x 10^{-6} in/in/°F
- Stress are:
  - (4.8-3.8)÷3.8 = 26% higher than you think they are!

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Getting Our Hand Around Shrinkage

- When joints are close… thermal likely may not be an issue.
- Joints are 50' apart… Thermal likely will be an issue.
- When thermal is an issue, CRT recommends that extended joints be completed under roof.

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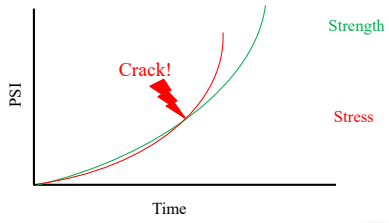
When Does Cracking Occur?



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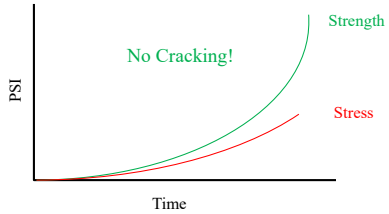
When Does Cracking Occur?



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Goal

- Make sure strength exceeds stress
- How do we do this?
- Option 1:
  - Increase rate or amount of strength gain
  - Difficult to do
- Option 2:
  - Lower rate or amount of stress
  - More practical option

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Increase Rate of Strength Gain

- Temperature
- Type III cement
- Lower w/c ratio
- More cement
- This can be difficult and lead to more shrinkage that leads to more stress.

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Reduce Rate or Overall Stresses

- Many options….
- Use one or
- A combination of many
- Systems

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Place Slab Under Roof

Reduce or eliminate thermal concerns

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Issues

- Tilt up??
- We can't eliminate early thermal stresses.

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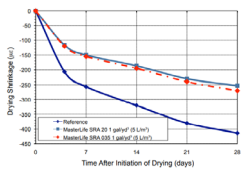
Reduce shrinkage

- Shrinkage reducing admixture
  - Can be costly



Master Builders Data

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Delay Shrinkage

- Curing
  - Prevent moisture loss
  - Delay… may not reduce. Can be ok.

Sika

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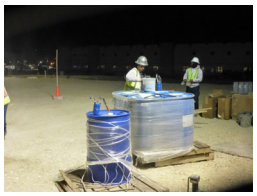
Delay Shrinkage

- Admixtures
  - Proprietary
  - Latex?
  - Colloidal silicates?
  - Many options



Ductilecrete

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Reduce Stresses

- Smooth subbase reduces restraint between the concrete and subbase

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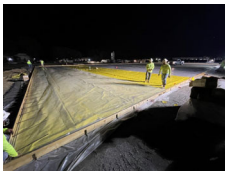
Reduce Stresses

- Slip sheets lower the coefficient of friction between the concrete and the subbase



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Keep Slab in Compression

- Post tensioned slab

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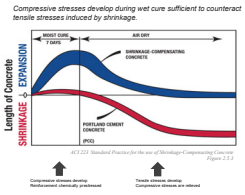
Keep Slab in Compression

- Expansive cement
  - Original expansion
  - Once shrinkage occurs it's net zero.
  - "chemically induced prestressing".



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Advantage?

- Extending joints reduces joint exposure.
- But….
- If we can reduce shrinkage and curling we have more capacity in the slab.

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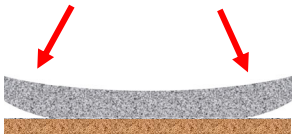
Curling Stress



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Reduce Curl

- More capacity available for the loads
- FS goes down
- Slab can be thinner

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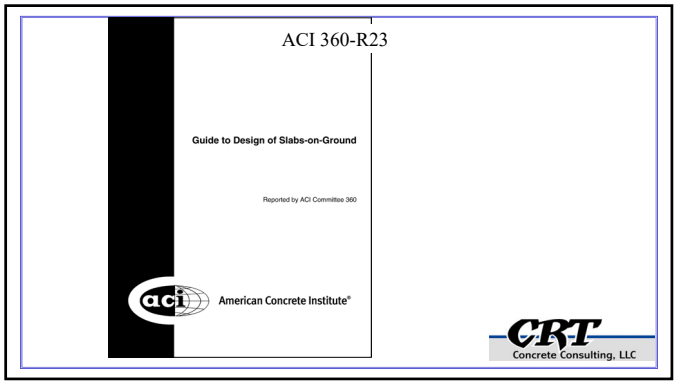

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New Chapter on Extended Joints

- Extended Joint Slab Types
  - A. Continuously reinforced
  - B. High volume fiber reinforced
  - C. Enhanced aggregate interlock bar reinforced with lower shrinkage concrete.
  - D. Fiber-reinforced low shrinkage slabs.
  - E. Shrinkage compensated slabs.
  - F. Post tensioned slabs.

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New Chapter on Extended Joints

- Classification of Slab with Extended Joints

Classification	Joint Spacing Ranges	Comments
Moderate	Joint spacing exceeding Figure 6.6 up to 25'	Type A, B, C, D slabs are more common for this class of extended joint slabs. Provide proper base, penetrations and joint details, maximum concrete shrinkage if needed for design, minimum fiber dosage or minimum or maximum bar reinforcement ratio depending on slab type.

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New Chapter on Extended Joints

- Classification of Slab with Extended Joints

Classification	Joint Spacing Ranges	Comments
Intermediate	Joint spacing between 30 and 60'	Type A, B, C, D slabs are more common for this class of extended joint slabs. Provide proper base, penetrations and joint details, maximum concrete shrinkage if needed for design, minimum fiber dosage or minimum or maximum bar reinforcement ratio depending on slab type.

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Joint Opening

- Gave a talk at WOC 2020
- Comment from the developer in the audience:
  - "I prefer more joints that are ¼" wide than fewer joint that are ½" (or more) wide.
- From a colleague in the joint filler industry:
  - "I sell just as much joint filler in a $^%$^ extended joint system as I do a conventionally jointed floor".
- We're quickly learning: Wide joints can be an issue.

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Wide Joints

Metzger McGuire

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Wide Joints

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Wide Joints

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Wide Joints

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Case Studies

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Case Study 1: No Joints

- Proprietary system
- Expansive cement
- High volume of steel fibers

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Steel Fiber

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Blower to Place Steel Fiber

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Water Cure

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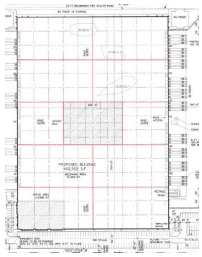
Project Layout



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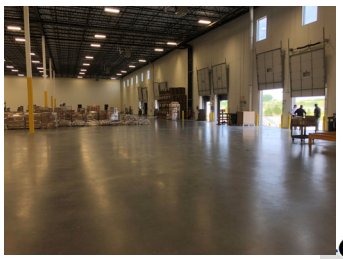
No Joints



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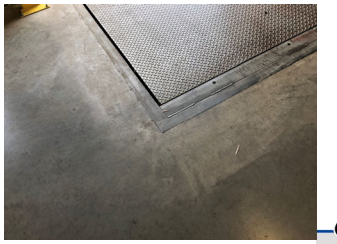
No Cracking at Dock Angles



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Only 1 Crack

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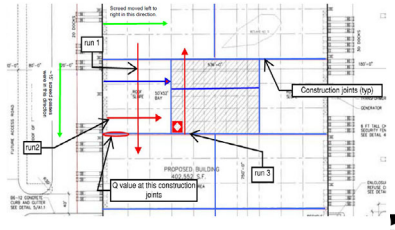
Inclinometer Work



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Tabular Results

FLOOR FLATNESS INSPECTION REPORT
Appendix B - Table of Results

Surface	Section	Area (ft^2) :	Run	Readings (ft)	F_F	F_F<90% CI>	F_L	F_L<90% CI>
SURFACE_1	SECTION_1		RUN_1	171	49.6	<45.1 - 54>	40.88	<37.1 - 44.7>
			RUN_2	125	114.0	<101.6 - 126.4>	59.03	<52.4 - 65.7>
		Area (ft^2) :	RUN_3	161	25.8	<23.4 - 28.2>	20.03	<18.1 - 22>
	Totals for SECTION_1:			457	37.7	<35.8 - 39.6>	29.06	<27.6 - 30.5>
Totals for SURFACE_1:	0				#DIV/0!		#DIV/0!	

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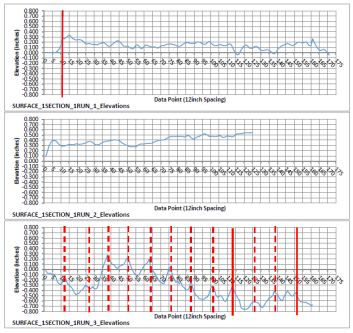
Graphical Results



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Case Study 2:
High Volume Macro Fiber

- Extended joints
- Joints only at column lines

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The Client is Secret

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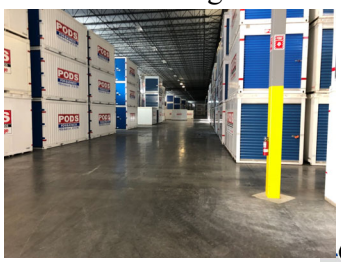
Good Looking Floor



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Sawcuts Were Opening

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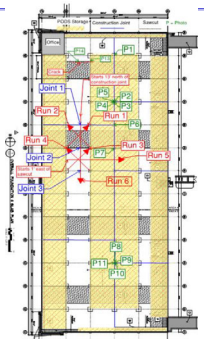
Inclinometer Work



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Tabular Results

Appendix B - Table of Results

Surface	Section	Area (ft²):	Run	Readings (ft)	F_F	F_F<90% CI>	F_L	F_L<90% CI>
SURFACE_1	SECTION_1		RUN_1	68	102.9	<87.2 - 118.7>	43.26	<36.2 - 50.4>
			RUN_2	68	74.6	<63.1 - 86>	51.66	<43.2 - 60.1>
			RUN_3	68	53.0	<44.8 - 61.1>	51.85	<43.3 - 60.3>
			RUN_4	68	48.2	<40.9 - 55.6>	21.62	<18.1 - 25.2>
			RUN_5	121	59.1	<52.6 - 65.7>	41.19	<36.4 - 45.9>
		Area (ft²):	RUN_6	128	52.5	<46.9 - 58.2>	36.60	<32.5 - 40.7>
		Totals for SECTION_1:		521	58.3	<55.7 - 61>	36.18	<34.5 - 37.8>
Totals for SURFACE_1:		0			#DIV/0!		#DIV/0!	

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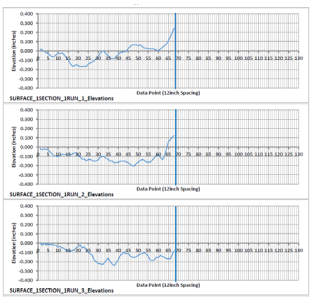

Graphical Results

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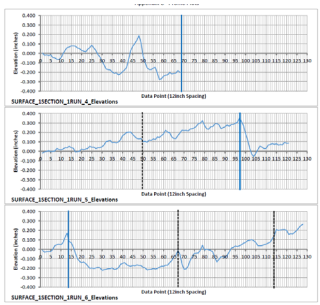

Graphical Results

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Any Questions?

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