FDOT TRANSPORTATION SYMPOSIUM 2019

Thermal Gradient in a Steel Box - Phase 1

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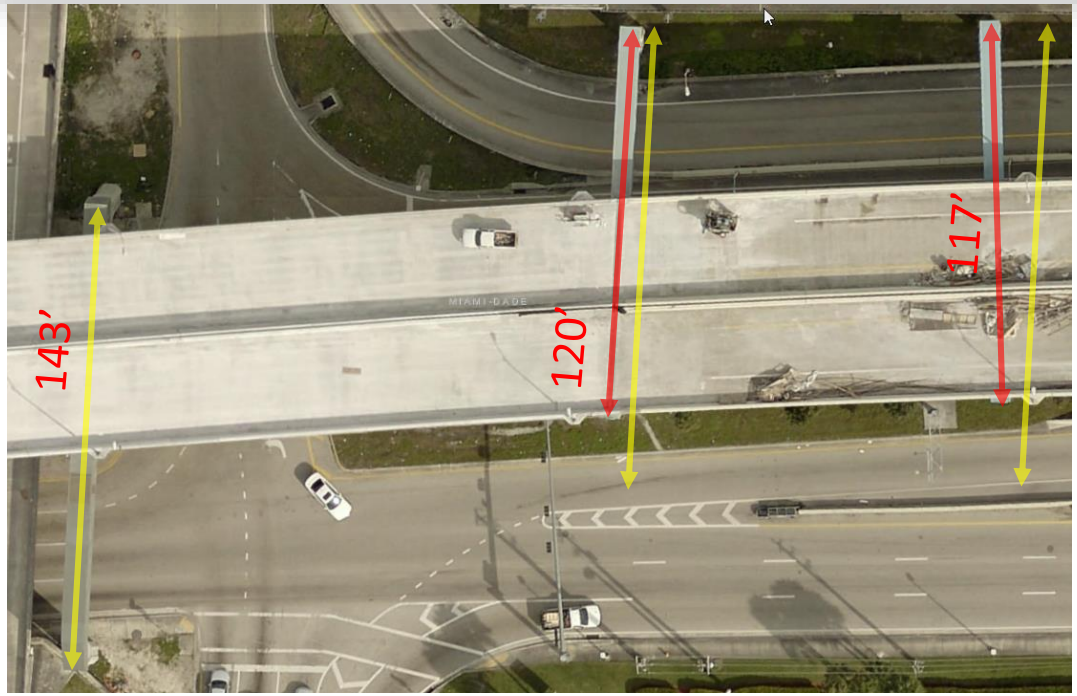
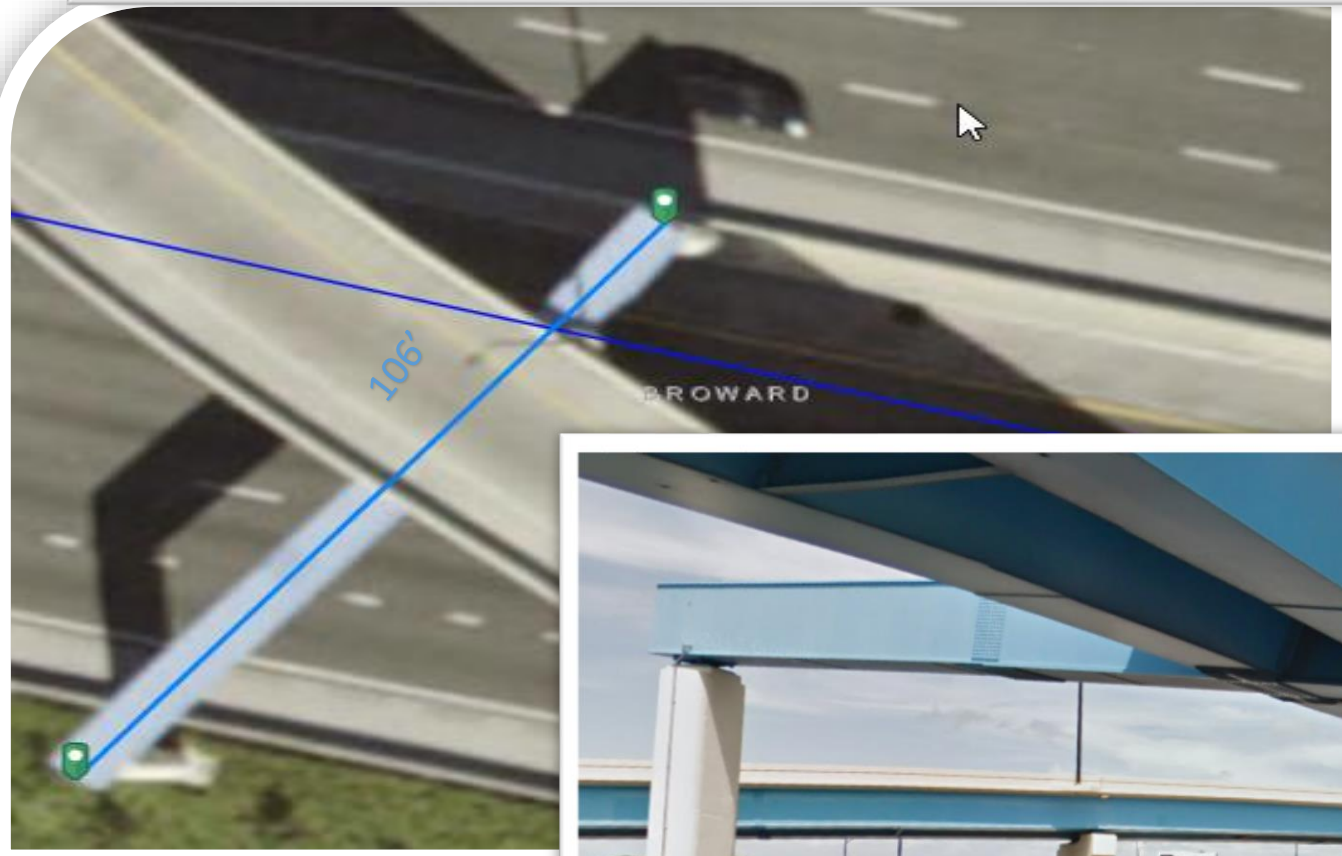
WSP

The FDOT Structures Design Office is encountering more and more steel straddle bents that solve bridging over complicated roadway alignments resulting in bent lengths exceeding 100 feet (maximum is up to 145'*).

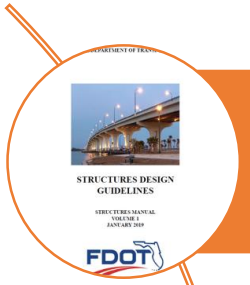


Multiple steel straddle caps
NW 25th Street

Should engineers be designing for a temperature gradient for this type of structure?

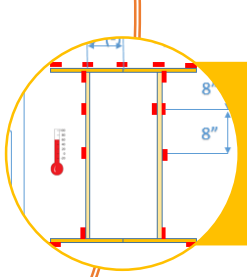


Agenda

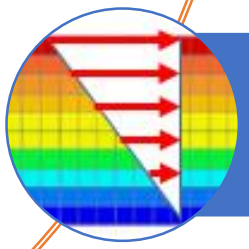


Specifications

Project Overview



Phase 1



Summary

Specifications

2.7.2 Temperature Gradient [3.12.3]

Delete the second paragraph of ***LRFD*** [3.12.3] and substitute the following:

"Include the effects of Temperature Gradient in the design of continuous concrete superstructures only. The vertical Temperature Gradient shall be taken as shown in ***LRFD*** [Figure 3.12.3-2]."

3.12—FORCE EFFECTS DUE TO SUPERIMPOSED DEFORMATIONS: *TU, TG, SH, CR, SE, PS*

3.12.3—Temperature Gradient

For the purpose of this Article, the country shall be subdivided into zones as indicated in Figure 3.12.3-1. Positive temperature values for the zones shall be taken as specified for various deck surface conditions in Table 3.12.3-1. Negative temperature values shall be obtained by multiplying the values specified in Table 3.12.3-1 by −0.30 for plain concrete decks and −0.20 for decks with an asphalt overlay.

The vertical temperature gradient in concrete and steel superstructures with concrete decks may be taken as shown in Figure 3.12.3-2.

The load factor for temperature gradient, γ_{TG}, should be considered on a project-specific basis. In lieu of project-specific information to the contrary, γ_{TG} may be taken as:

- 0.0 at the strength and extreme event limit states,
- 1.0 at the service limit state when live load is not considered, and
- 0.50 at the service limit state when live load is considered.

The load factor for temperature gradient should be determined on the basis of the:

- Type of structure, and
- Limit state being investigated.

Open girder construction and multiple steel box girders have traditionally, but perhaps not necessarily correctly, been designed without consideration of temperature gradient, i.e., γ_{TG} = 0.0.

Table 3.4.1-1—Load Combinations and Load Factors

Load Combination Limit State	*DC DD DW EH EV ES EL PS CR SH*	*LL IM CE BR PL LS*	*WA*	*WS*	*WL*	*FR*	*TU*	*TG*	*SE*
Strength I (unless noted)	γ_p	1.75	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}
Strength II	γ_p	1.35	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}
Strength III	γ_p	—	1.00	1.00	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}
Strength IV	γ_p	—	1.00	—	—	1.00	0.50/1.20	—	—
Strength V	γ_p	1.35	1.00	1.00	1.00	1.00	0.50/1.20	γ_{TG}	γ_{SE}
Extreme Event I	1.00	γ_{EQ}	1.00	—	—	1.00	—	—	—
Extreme Event II	1.00	0.50	1.00	—	—	1.00	—	—	—
Service I	1.00	1.00	1.00	1.00	1.00	1.00	1.00/1.20	γ_{TG}	γ_{SE}
Service II	1.00	1.30	1.00	—	—	1.00	1.00/1.20	—	—
Service III	1.00	γ_{LL}	1.00	—	—	1.00	1.00/1.20	γ_{TG}	γ_{SE}
Service IV	1.00	—	1.00	1.00	—	1.00	1.00/1.20	—	1.00

Steel & Concrete

γ_{TG}=0.5 or 1.0 (w/o LL)

Steel & Concrete

Steel

Concrete

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Steel Girder with Concrete Deck

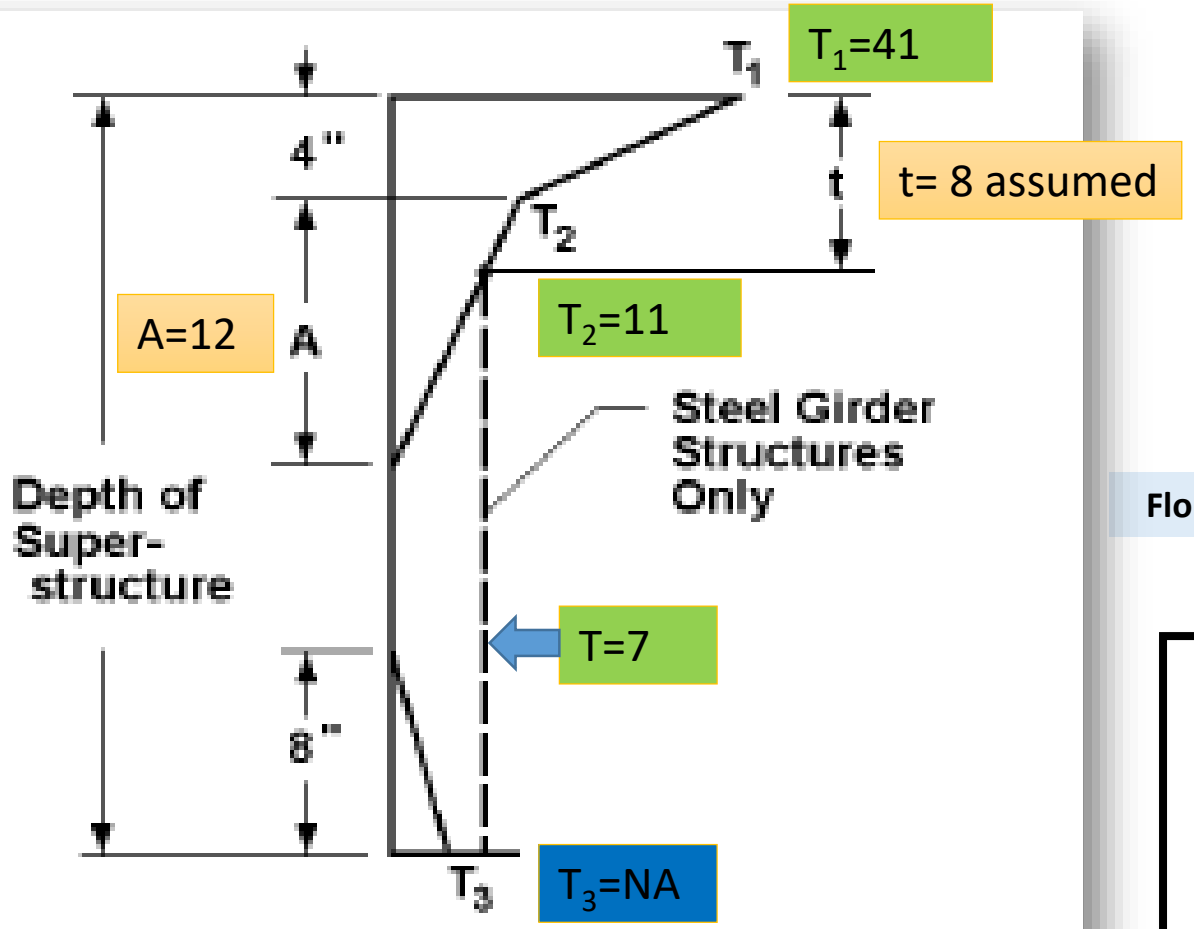


Figure 3.12.3-2—Positive Vertical Temperature Gradient in Concrete and Steel Superstructures

Dimension *A* in Figure 3.12.3-2 shall be taken as:

- For concrete superstructures that are 16.0 in. or more in depth—12.0 in.
- For concrete sections shallower than 16.0 in.—4.0 in. less than the actual depth
- For steel superstructures—12.0 in. and the distance *t* shall be taken as the depth of the concrete deck

Table 3.12.3-1—Basis for Temperature Gradients

Zone	T_1 (°F)	T_2 (°F)
1	54	14
2	46	12
Florida 3	41	11
4	38	9

C3.12.3

Temperature gradient is included in various load combinations in Table 3.4.1-1. This does not mean that it need be investigated for all types of structures. If experience has shown that neglecting temperature gradient in the design of a given type of structure has not lead to structural distress, the Owner may choose to exclude temperature gradient. Multibeam bridges are an example of a type of structure for which judgment and past experience should be considered.

SO.....

Steel Girder with Concrete Deck

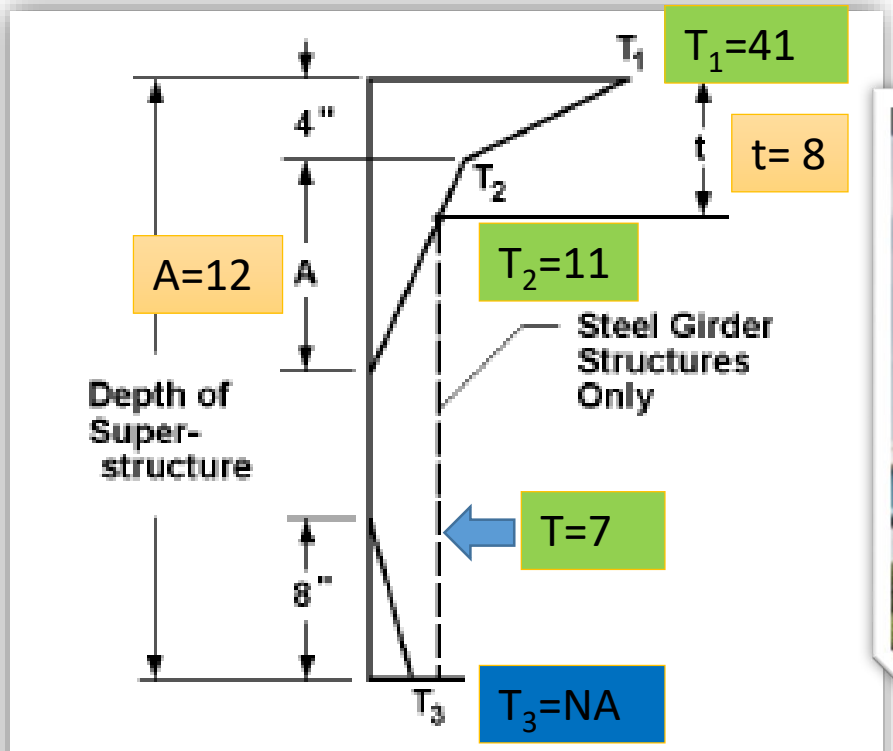
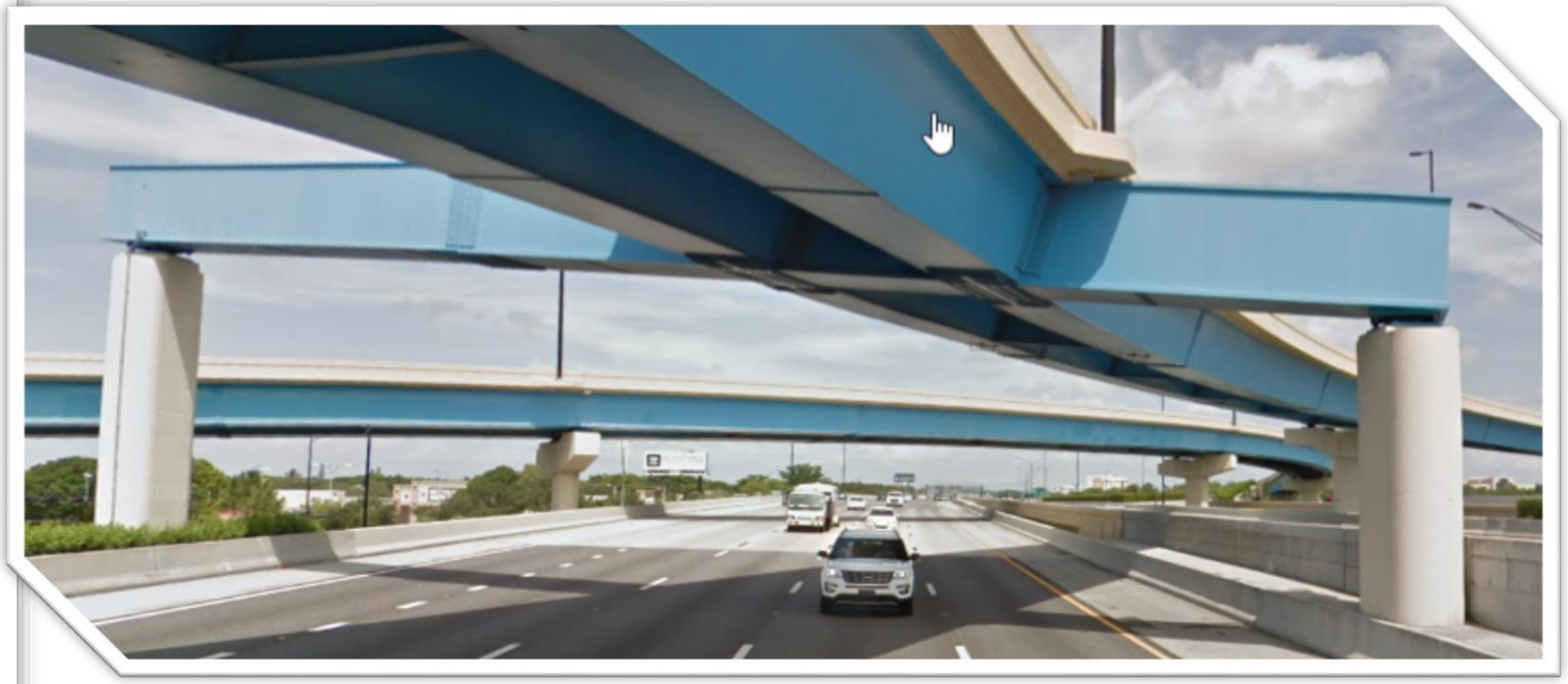


Figure 3.12.3-2—Positive Vertical Temperature Gradient in Concrete and Steel Superstructures



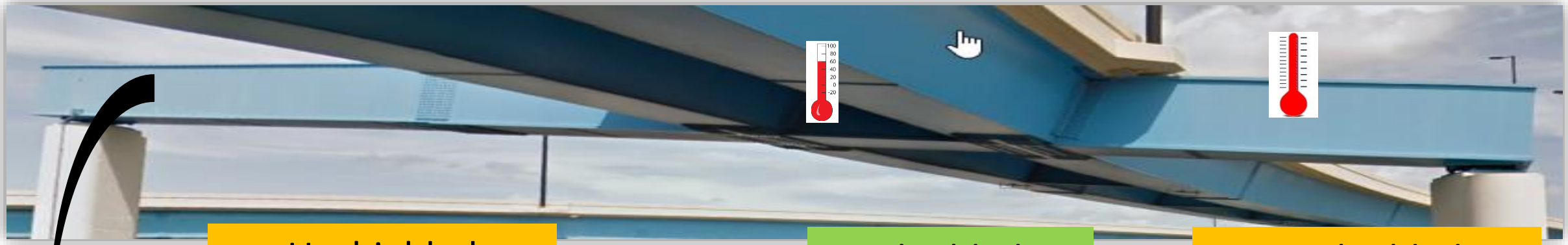
AASHTO Guide Specifications Thermal Effects in Concrete Bridge Superstructures

Technical Papers

Eurocodes EN 1991-1-5: 2003

<u>Approach 1:</u>
Linear vertical difference
<u>Approach 2:</u>
Non-linear vertical difference (Normal and Simplified Procedure for composite)

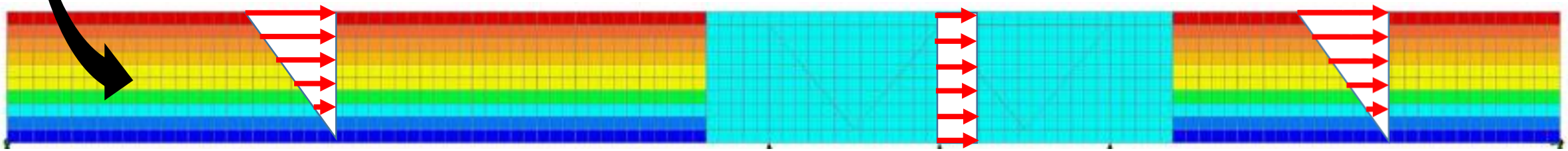
Phase 1 – Preliminary Conclusions



Unshielded
Straight line Profile

Shielded
Uniform Profile

Unshielded
Straight line Profile



Project Overview

Goals	*Develop a temperature gradient*	Curved
		Straight
	Develop numerical analysis techniques (FEM)	Elements
		Loading
	Evaluate temperature gradient effects on the structure using FEM	Deck stresses at Service II
		Steel stresses at Service II
		Deflection at Service II
Experimental Testing	*Structures Research Center (SRC) Test Specimen*	Temperature gradient
		Develop finite element model (FEM) techniques
	Monitor an existing bridge that has a straddle bent to measure in-situ temperature gradients and associated deflections	Develop a finite element model (FEM) to replicate measured values.
		Evaluate "design" temperature gradient effect on the structure.

Phase 1 – Structures Research Center (SRC) Testing and FEM Techniques (in-progress)

Phase 2 – FEM (LUSAS) large scale model – 200’-200’ spans with and w/o integral straddle cap (in-progress)

Phase 3 – Field Instrumentation of Existing Bridges and FEM Evaluation (TBD)

Phase 4 – Revisions to SDG/SDM/460 Specifications (TBD)

Phase 1

Instrumentation Plan

- Equipment
- ★ Sensor Layout
- Data Collection

★ Test Set-up

- 4 configurations in a N-S orientation
- 4 configurations in a E-W orientation

Develop Temperature Profile

- Curved and straight profiles
- Steel box & steel box partially shielded with concrete slab

★ Develop Numerical Analysis (FEM- LUSAS) Techniques

- Element Type
- Loading

Steel Plates Painted with Two Colors

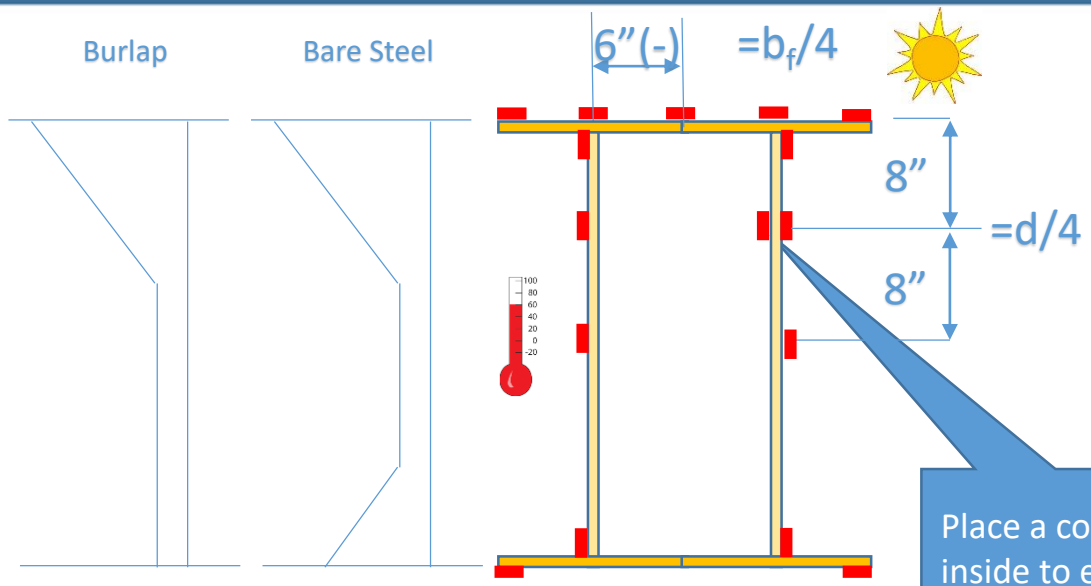
- Surface temperature
- Through thickness temperature

FDOT Structures Research Center (SRC)

Google Earth Pro

Sensor Layout

Double W33x118 – each W is:
A=34.7
d=32 7/8”
t_w = 9/16”
b_f = 11 ½”
t_f = ¾”
36’-4” total length, with stiffeners 17’-8” from each end



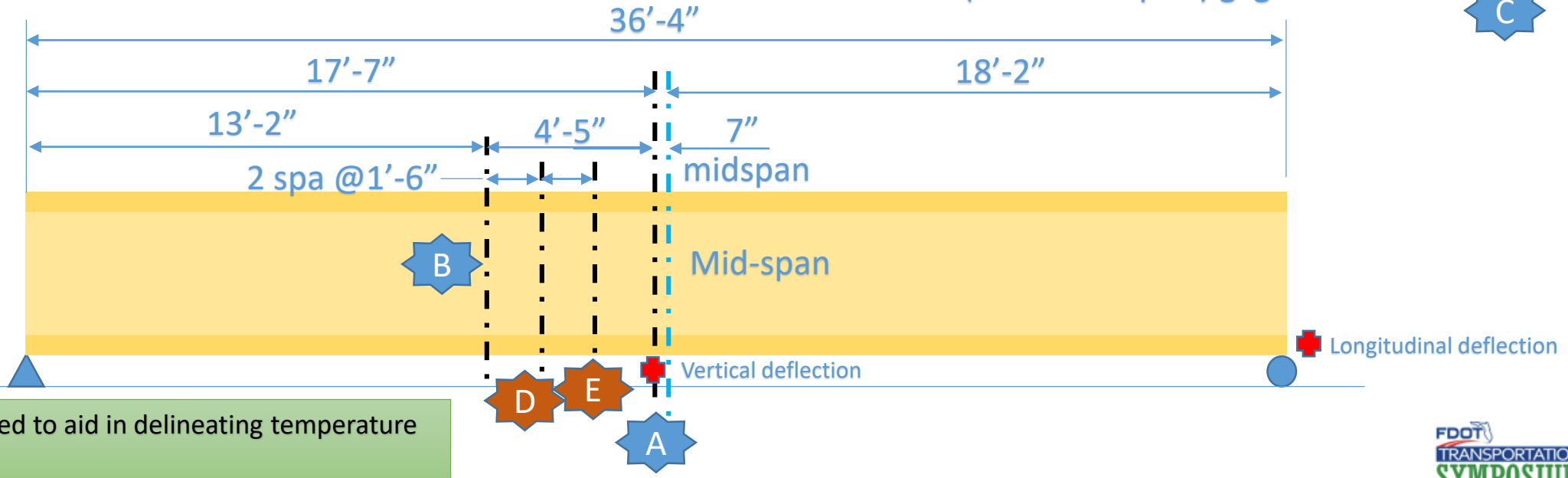
Place a couple inside to evaluate through thickness temperature gradient

Vertical Temperature Gradient?

15 per section – 30 total

32 max (thermocouples) gages

C



9/11/18 Section D and E added to aid in delineating temperature zones for Test C and D (E-W)

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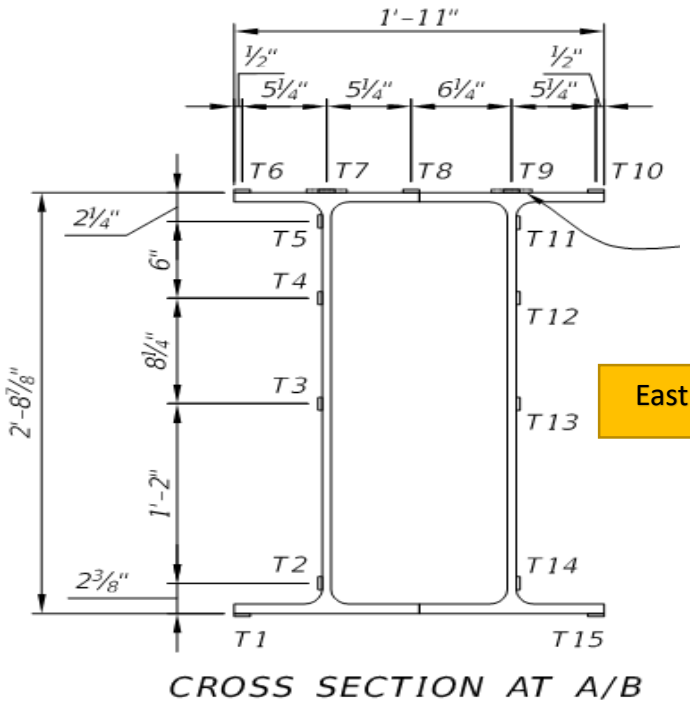
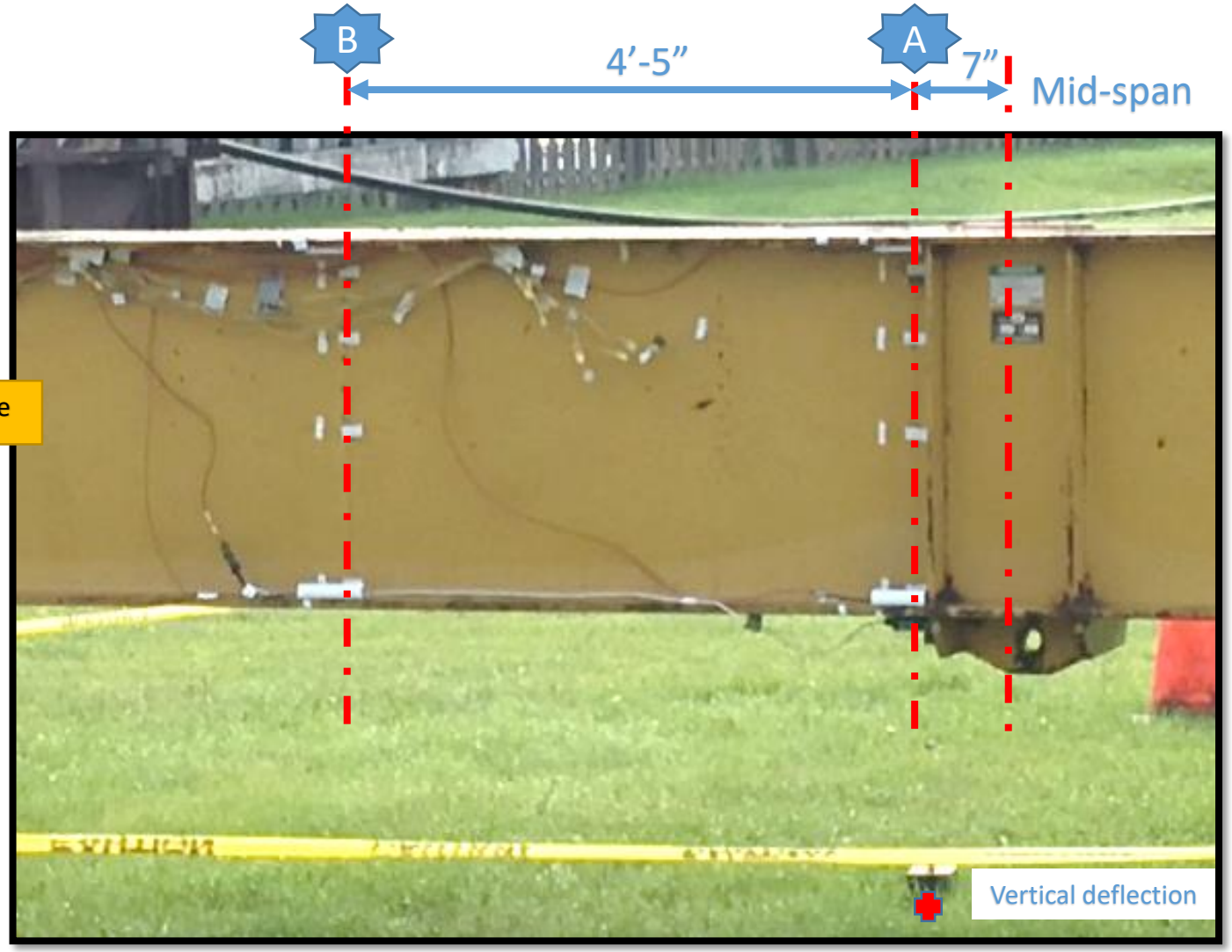
Sensor Layout



West Side

East Side



N-S orientation

Four Testing Configurations: A, B, C & D

A- Bare steel

B- Shaded sides with burlap Entire Length of girder

Shown in N-S Orientation

Four Testing Configurations: A, B, C & D

C- Shaded top with concrete slab wrapped in Burlap

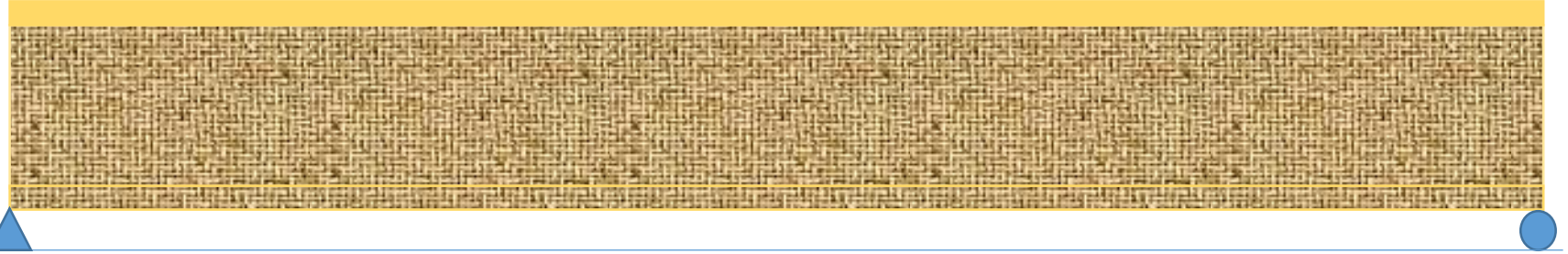
D- Shaded top with concrete slab

Shown in N-S Orientation

N-S B

N-S B	6/12/18 8:00 AM	6/19/18 8:00 AM

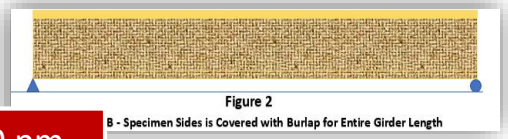
B - Shaded sides with burlap Entire Length of girder



TRANSPORTATION SYMPOSIUM

N-S B

Chart shows 7 day testing period for top flange and ambient temperatures, and Solar Radiation



6/18/18 2:20 pm

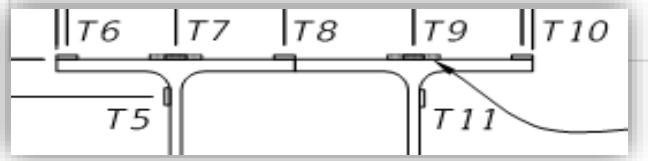
Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 | Day 7

130 °F

(°F) | (W/m²)

6/18/18 2:40 PM, 92.9

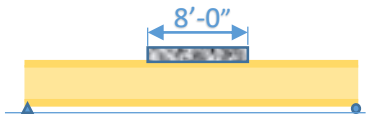
Ambient Temperature | AVG T6A-T10A | AVG T6B-T10B | Solar Radiation

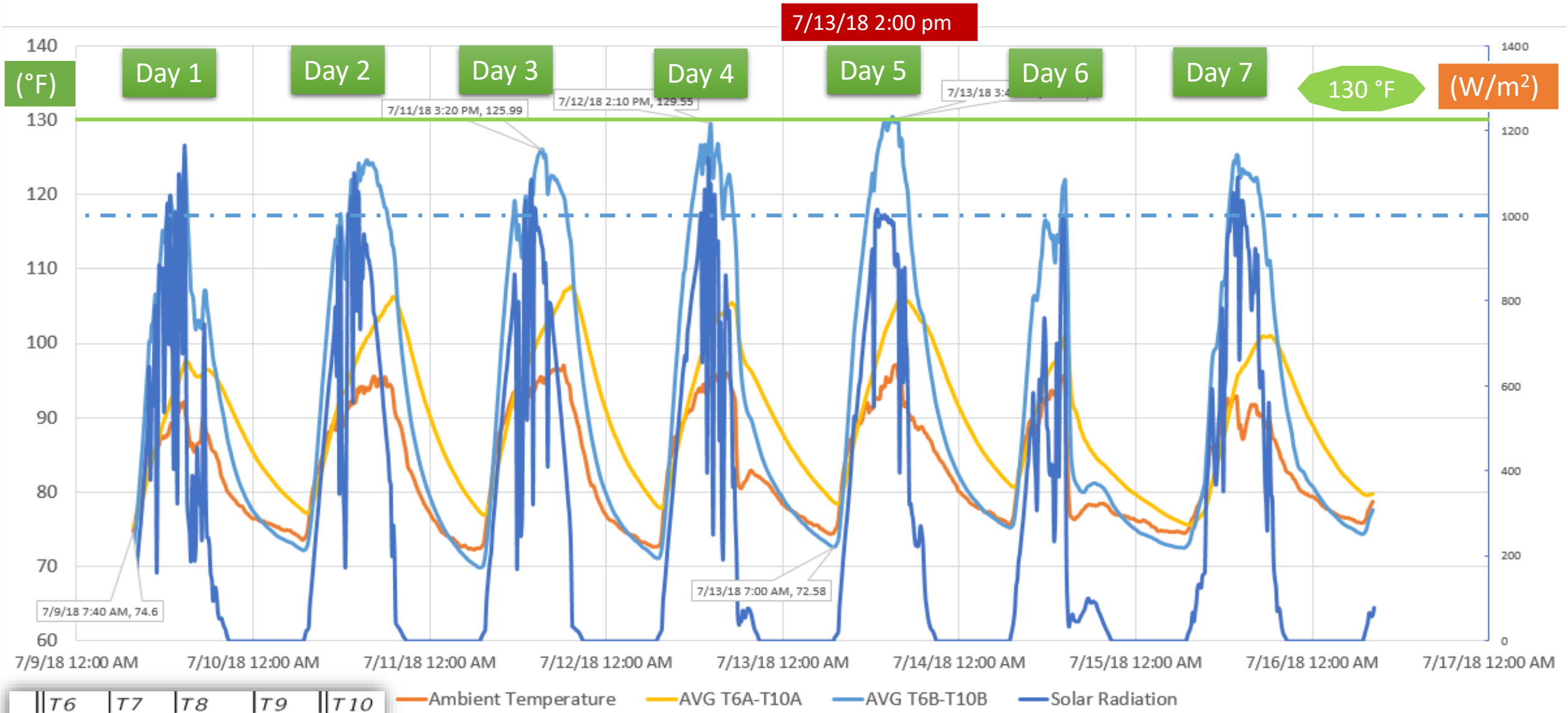


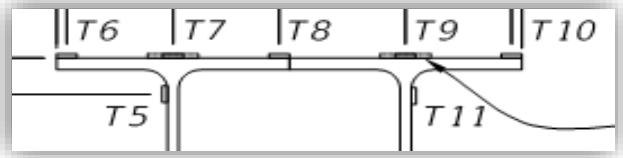
FDOT TRANSPORTATION SYMPOSIUM

N-S D

Chart shows 7 day testing period for top flange and ambient temperatures, and Solar Radiation







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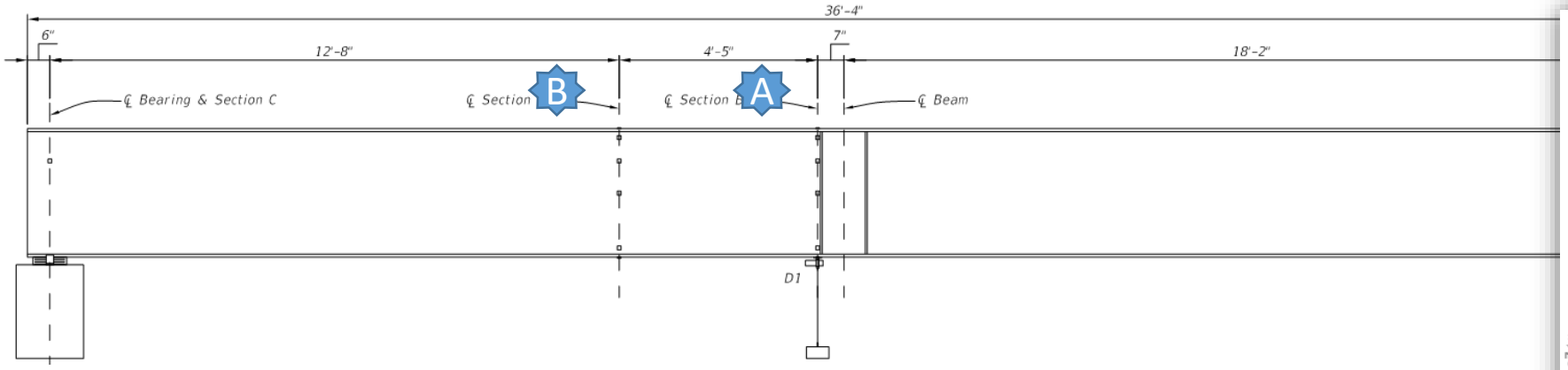
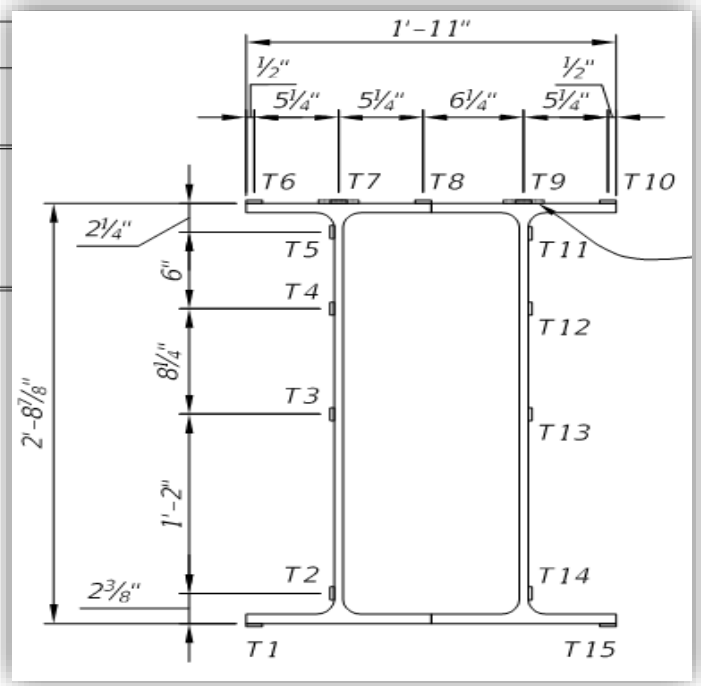
Gradient Equations





CROSS SECTION AT A/B

LOCAL GRADIENTS

Section A (Shifting Reference)

Yleft

YgradT5A-SR=(T6A-T5A)/Y1

YgradT4A-SR=(T5A-T4A)/Y2

YgradT3A-SR=(T4A-T3A)/Y3

YgradT2A-SR=(T3A-T2A)/Y4

YgradT1A-SR=(T2A-T1A)/Y5

Xtop

XgradT7A-SR=(T6A-T7A)/X1T

XgradT8A-SR=(T7A-T8A)/X2T

XgradT9A-SR=(T8A-T9A)/X3T

XgradT10A-SR=(T9A-T10A)/X4T

Section A (Fixed Reference)

Yleft

YgradT5A-FR=(T6A-T5A)/Y1

YgradT4A-FR=(T6A-T4A)/SUM(Y1...Y2)

T12A)/SUM(Y1...Y2)

YgradT3A-FR=(T6A-T3A)/SUM(Y1...Y3)

T13A)/SUM(Y1...Y3)

YgradT2A-FR=(T6A-T2A)/SUM(Y1...Y4)

T14A)/SUM(Y1...Y4)

YgradT1A-FR=(T6A-T1A)/SUM(Y1...Y5)

T15A)/SUM(Y1...Y5)

GLOBAL GRADIENTS

Section A

YgradGlobalA=[AVG(T6A...T10A)-AVG(T1A,T15A)]/SUM(Y1...Y5)

XgradGlobalA=[AVG(T2A...T5A)-AVG(T11A...T14A)]/SUM(X2T...X3T)

MaxgradA=MAX(T1A...T15A)-MIN(T1A...T15A)

Section B

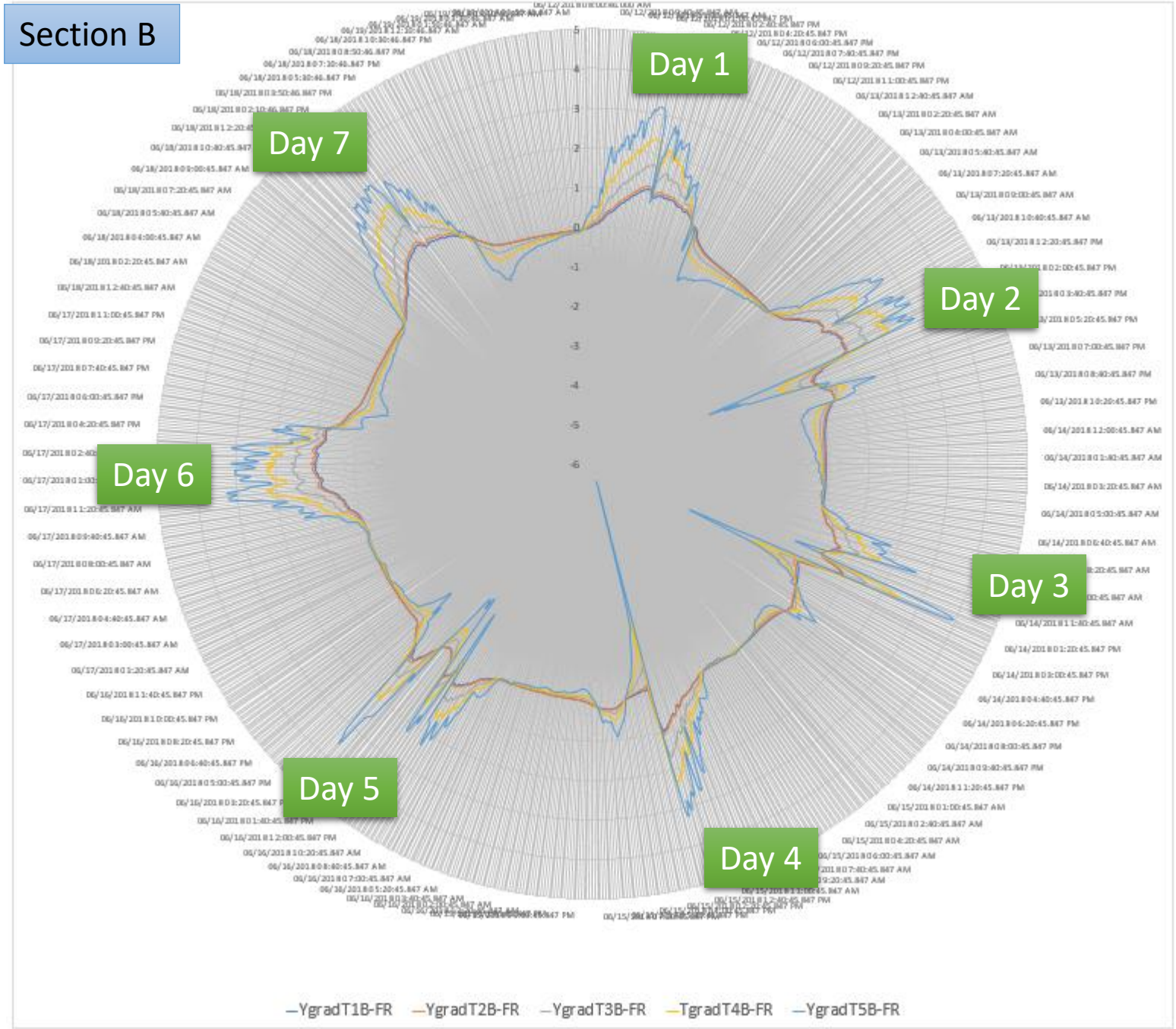
YgradGlobalB=[AVG(T6B...T10B)-AVG(T1B,T15B)]/SUM(Y1...Y5)

XgradGlobalB=[AVG(T2B...T5B)-AVG(T11B...T14B)]/SUM(X2T...X3T)

MaxgradB=MAX(T1B...T15B)-MIN(T1B...T15B)

N-S B

Charts show 7 day testing period with temperature gradient for Fixed Reference for all gradients (°F/in)



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1st chart shows 7 day testing period for midspan displacement, D1

N-S B

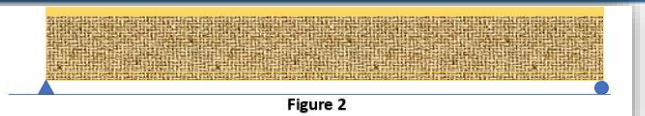
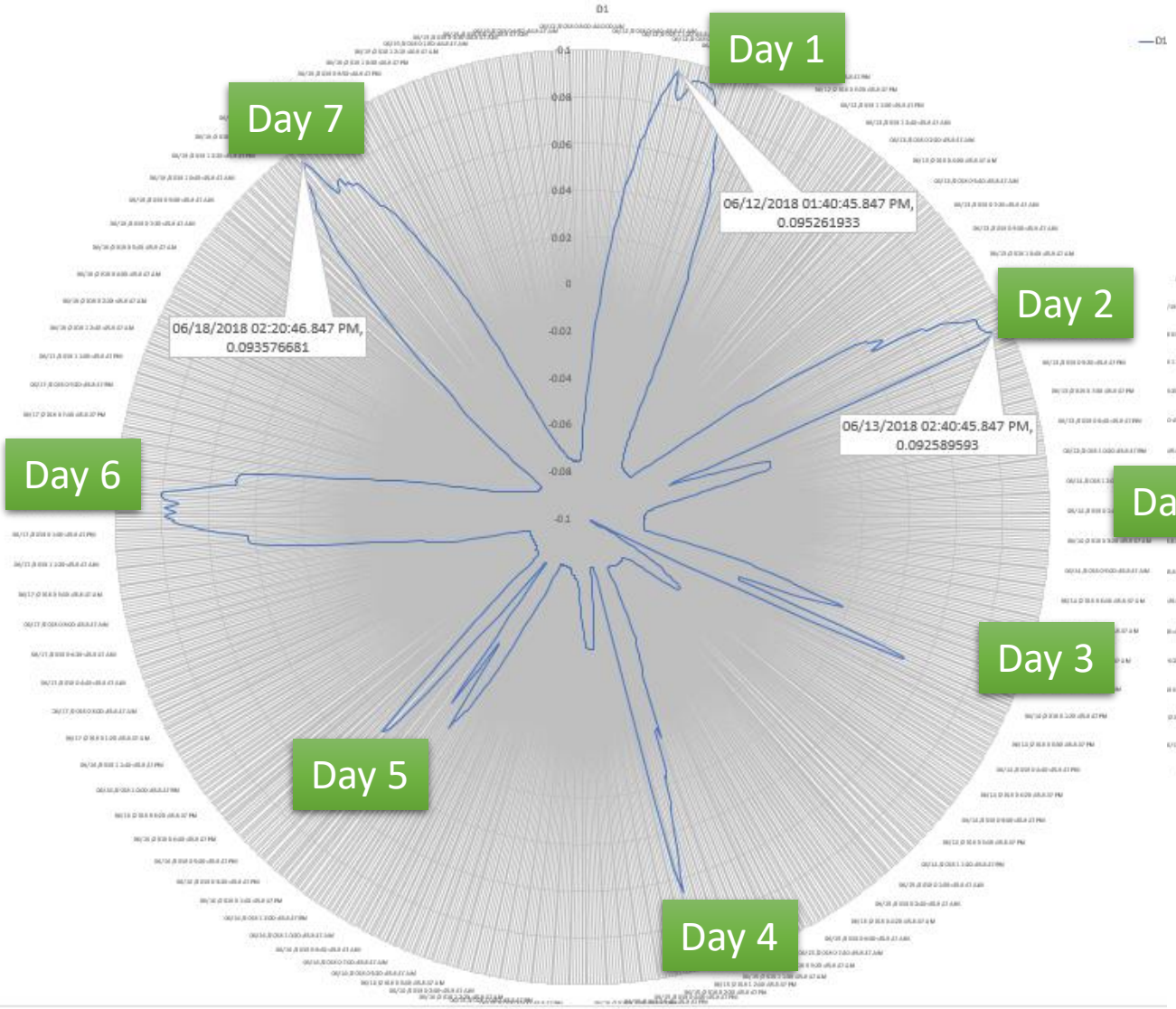
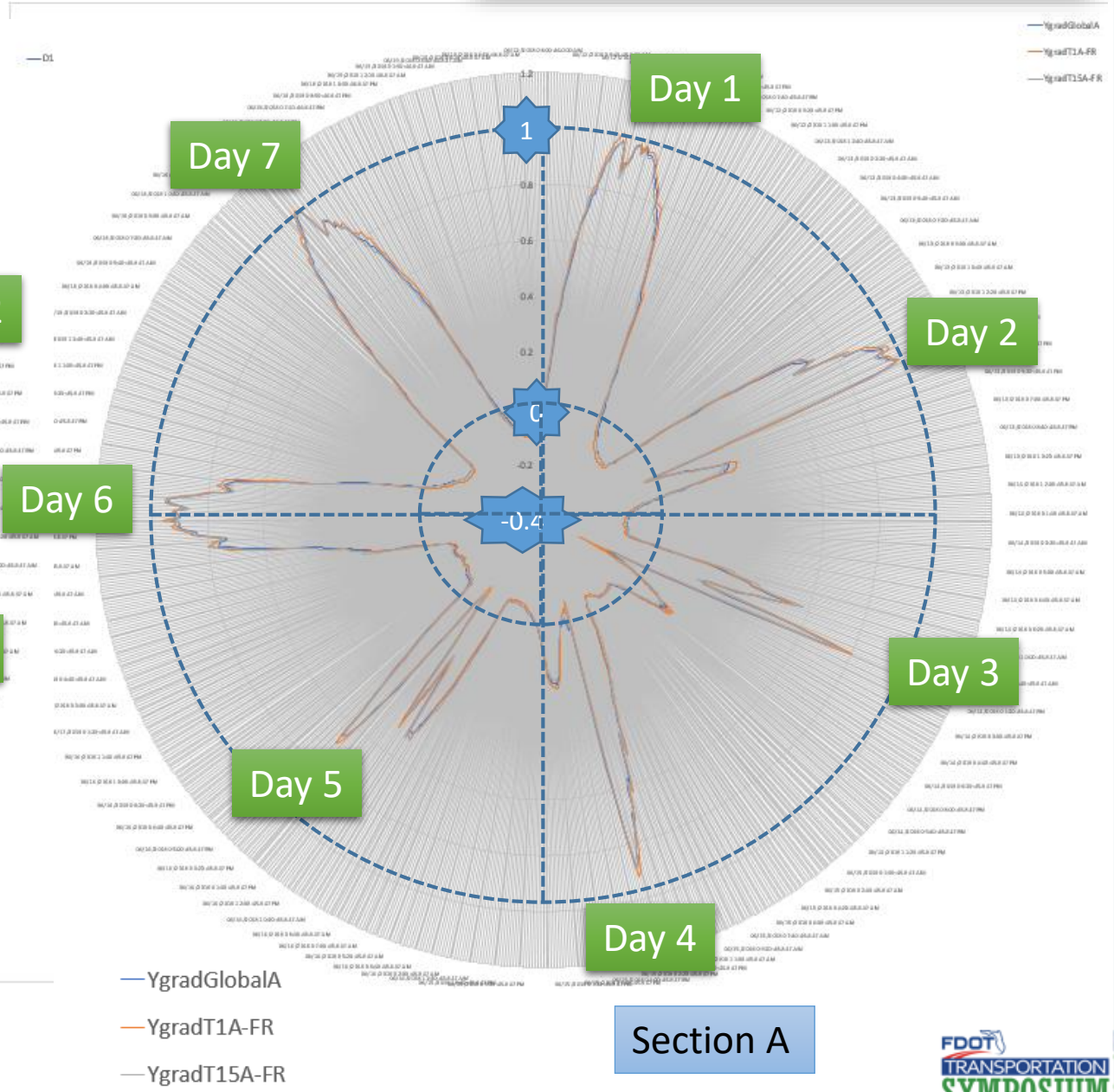


Figure 2
Condition B - Specimen Sides is Covered with Burlap for Entire Girder Length



Midspan Deflection, D1



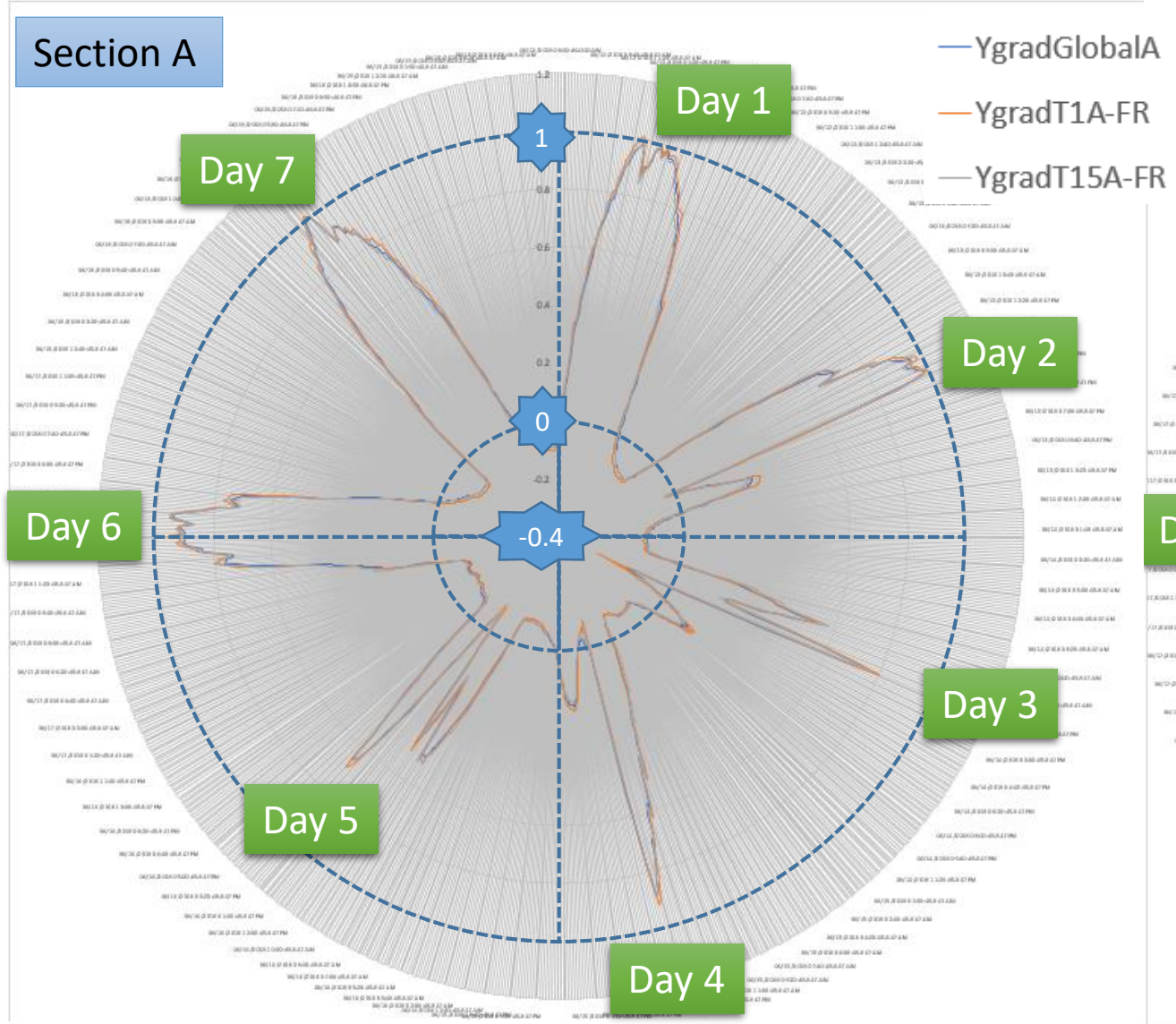
Section A

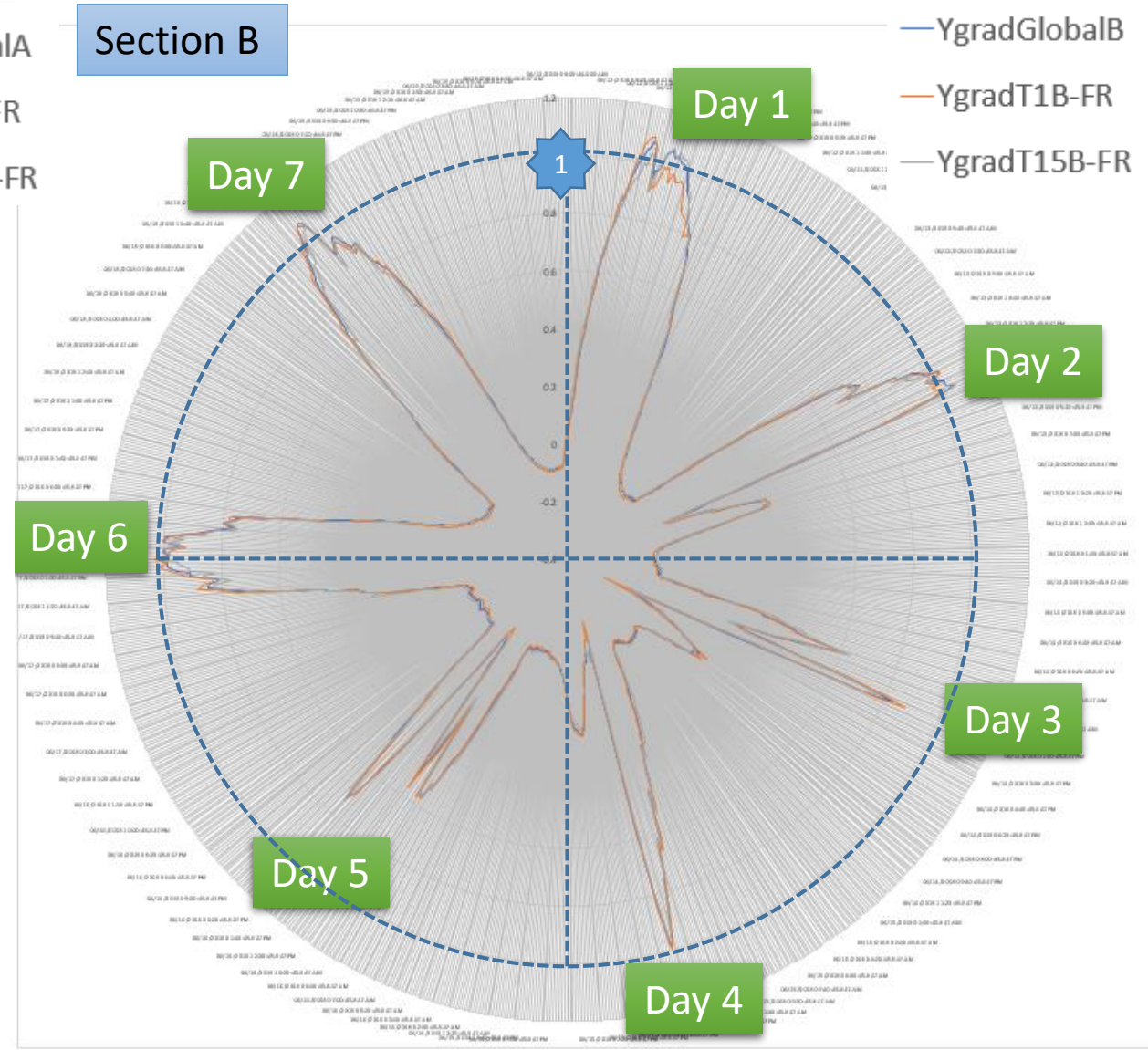
FDOT TRANSPORTATION SYMPOSIUM

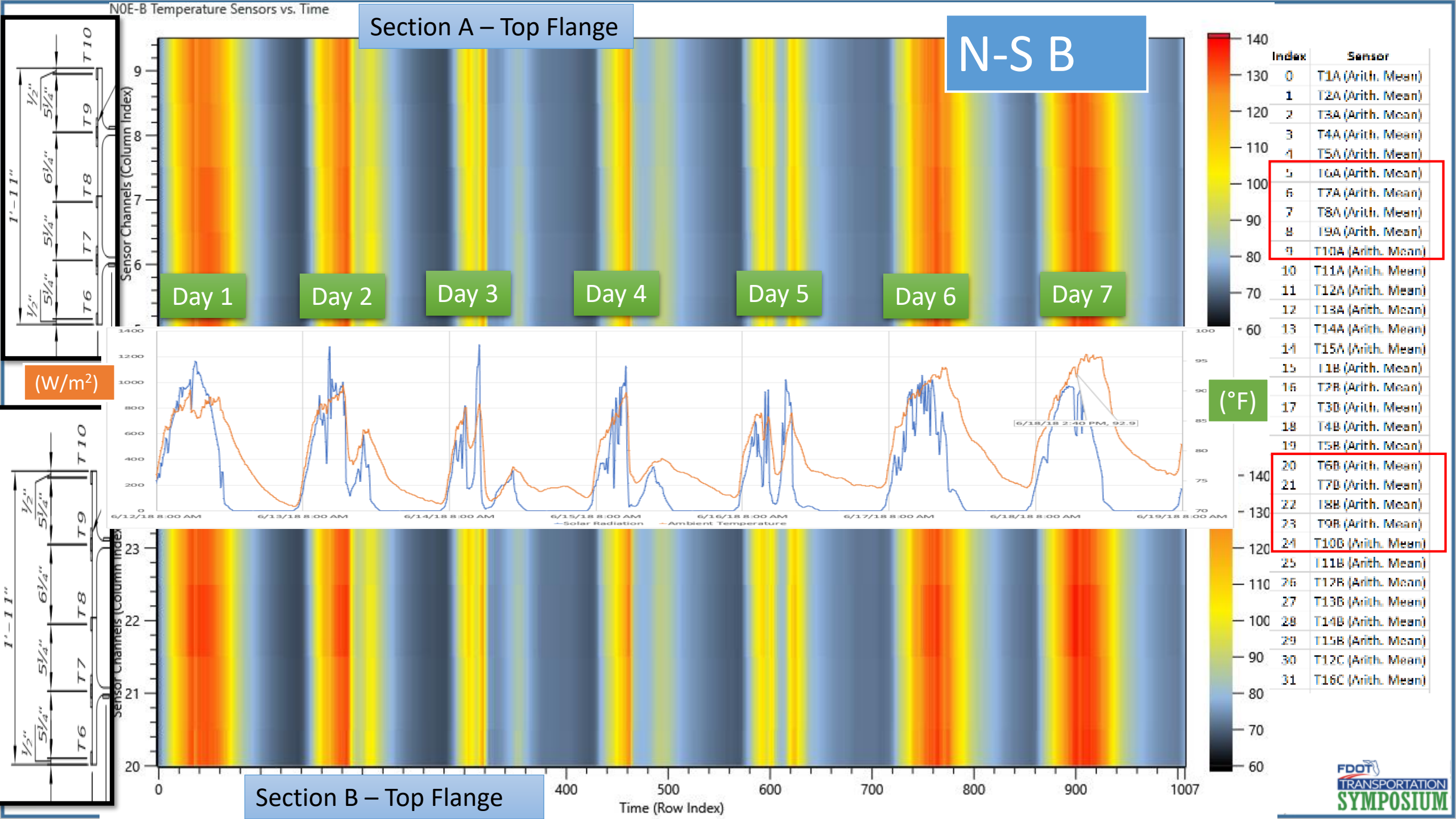
Charts show 7 day testing period with temperature gradient (°F/in) for Global and Fixed Reference measure from top flange to bottom flange

N-S B

Figure 2
Condition B - Specimen Sides is Covered with Burlap for Entire Girder Length

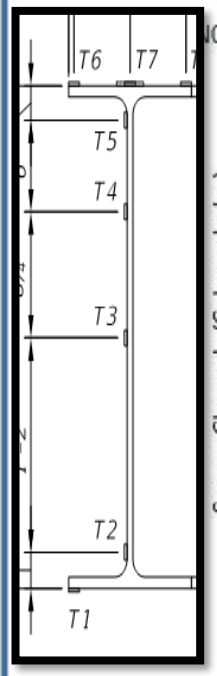


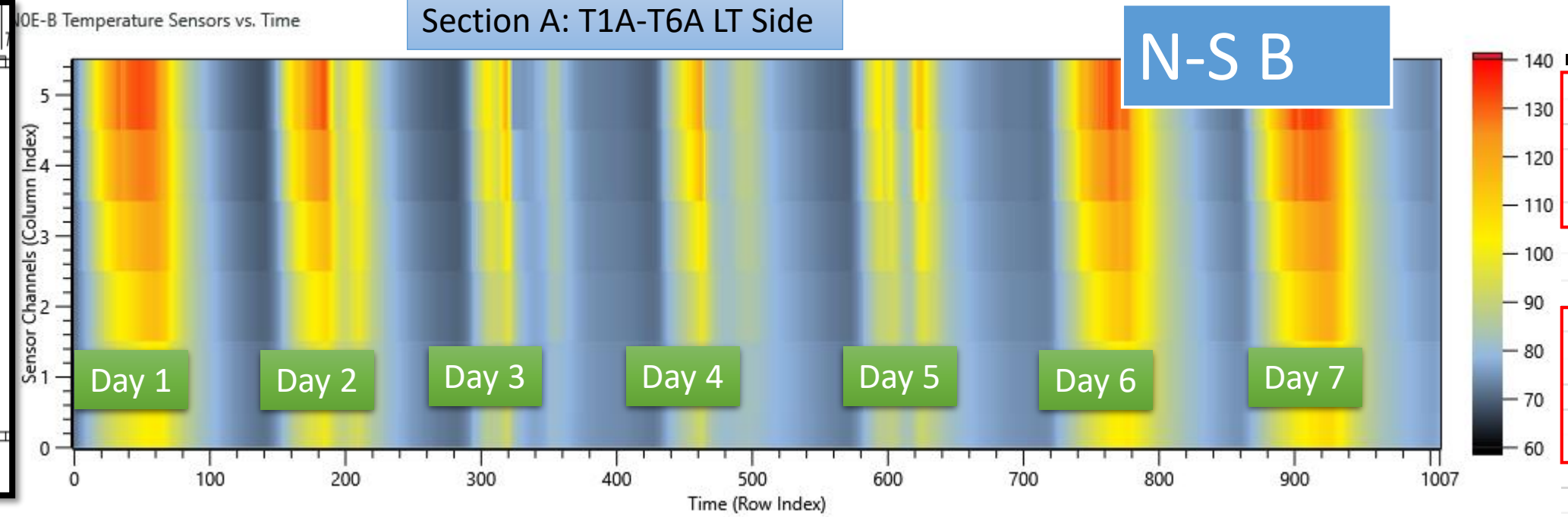



N0E-B Temperature Sensors vs. Time
Section A – Top Flange
N-S B
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Sensor Channels (Column Index)
(W/m²)
(°F)
6/18/18 2:40 PM, 92.9
Solar Radiation
Ambient Temperature
Section B – Top Flange
Time (Row Index)
Index
Sensor
0 T1A (Arith. Mean)
1 T2A (Arith. Mean)
2 T3A (Arith. Mean)
3 T4A (Arith. Mean)
4 T5A (Arith. Mean)
5 T6A (Arith. Mean)
6 T7A (Arith. Mean)
7 T8A (Arith. Mean)
8 T9A (Arith. Mean)
9 T10A (Arith. Mean)
10 T11A (Arith. Mean)
11 T12A (Arith. Mean)
12 T13A (Arith. Mean)
13 T14A (Arith. Mean)
14 T15A (Arith. Mean)
15 T1B (Arith. Mean)
16 T2B (Arith. Mean)
17 T3B (Arith. Mean)
18 T4B (Arith. Mean)
19 T5B (Arith. Mean)
20 T6B (Arith. Mean)
21 T7B (Arith. Mean)
22 T8B (Arith. Mean)
23 T9B (Arith. Mean)
24 T10B (Arith. Mean)
25 T11B (Arith. Mean)
26 T12B (Arith. Mean)
27 T13B (Arith. Mean)
28 T14B (Arith. Mean)
29 T15B (Arith. Mean)
30 T12C (Arith. Mean)
31 T16C (Arith. Mean)
FDOT TRANSPORTATION SYMPOSIUM

N-S B

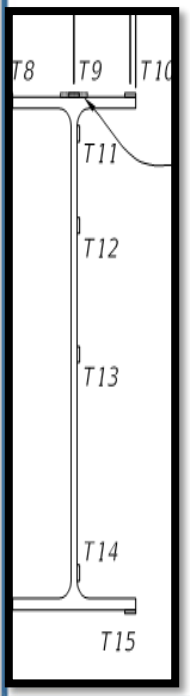
Section A: T1A-T6A LT Side

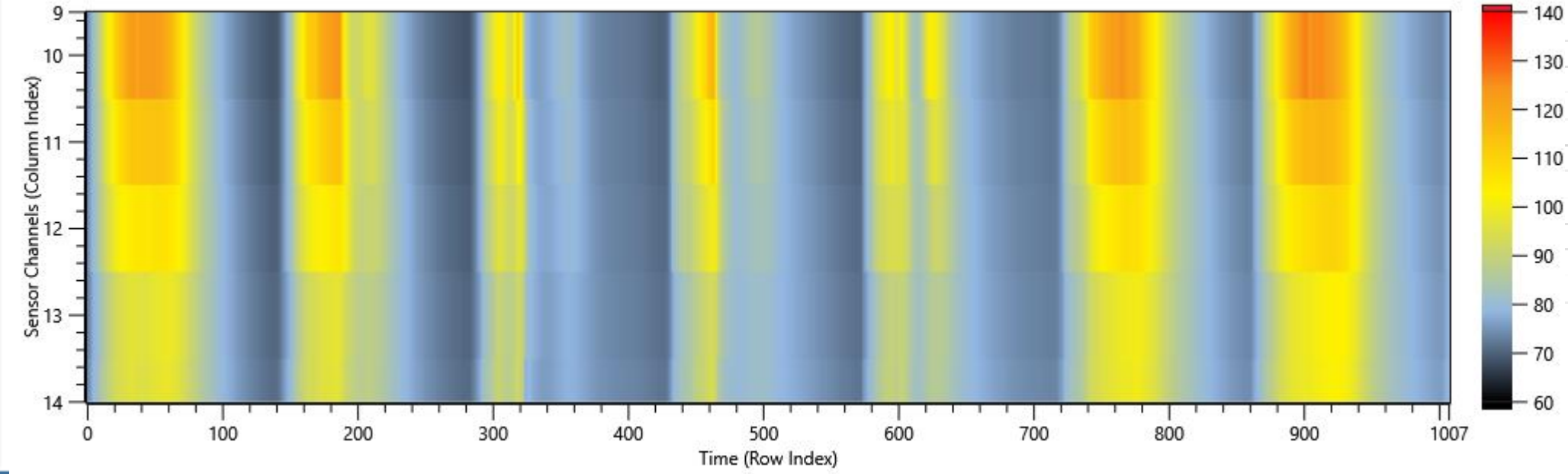




Index	Sensor
0	T1A (Arith. Mean)
1	T2A (Arith. Mean)
2	T3A (Arith. Mean)
3	T4A (Arith. Mean)
4	T5A (Arith. Mean)
5	T6A (Arith. Mean)
6	T7A (Arith. Mean)
7	T8A (Arith. Mean)
8	T9A (Arith. Mean)
9	T10A (Arith. Mean)
10	T11A (Arith. Mean)
11	T12A (Arith. Mean)
12	T13A (Arith. Mean)
13	T14A (Arith. Mean)
14	T15A (Arith. Mean)
15	T1B (Arith. Mean)
16	T2B (Arith. Mean)
17	T3B (Arith. Mean)
18	T4B (Arith. Mean)
19	T5B (Arith. Mean)
20	T6B (Arith. Mean)
21	T7B (Arith. Mean)
22	T8B (Arith. Mean)
23	T9B (Arith. Mean)
24	T10B (Arith. Mean)
25	T11B (Arith. Mean)
26	T12B (Arith. Mean)
27	T13B (Arith. Mean)
28	T14B (Arith. Mean)
29	T15B (Arith. Mean)
30	T12C (Arith. Mean)
31	T16C (Arith. Mean)

Section A: T10A – T15A RT Side

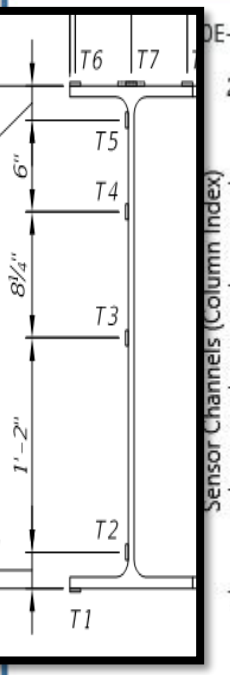


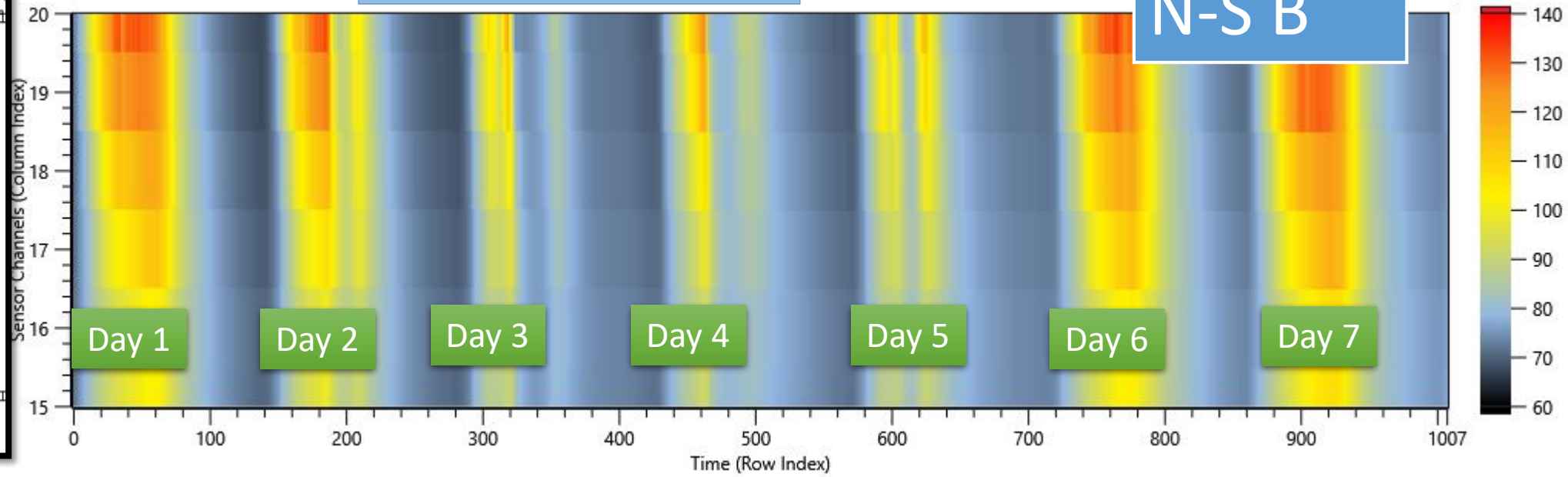


FDOT TRANSPORTATION SYMPOSIUM

N-S B

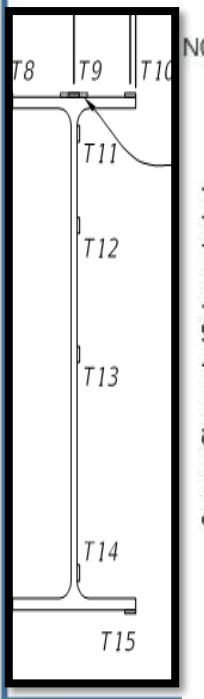
Section B: T1B-T6B LT Side

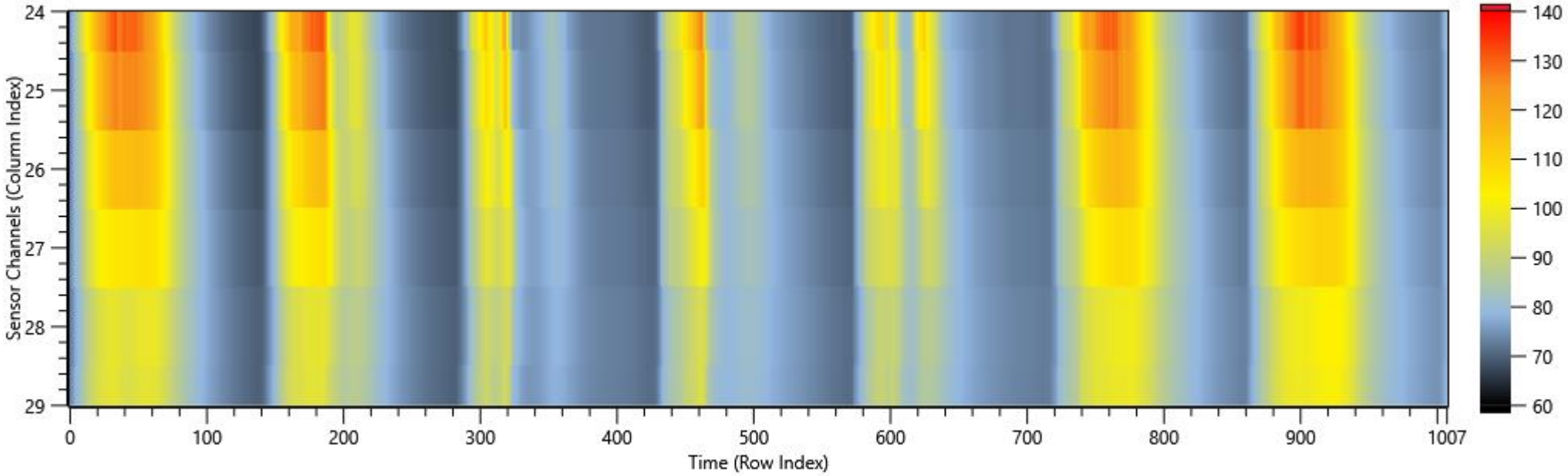




Index	Sensor
0	T1A (Arith. Mean)
1	T2A (Arith. Mean)
2	T3A (Arith. Mean)
3	T4A (Arith. Mean)
4	T5A (Arith. Mean)
5	T6A (Arith. Mean)
6	T7A (Arith. Mean)
7	T8A (Arith. Mean)
8	T9A (Arith. Mean)
9	T10A (Arith. Mean)
10	T11A (Arith. Mean)
11	T12A (Arith. Mean)
12	T13A (Arith. Mean)
13	T14A (Arith. Mean)
14	T15A (Arith. Mean)
15	T1B (Arith. Mean)
16	T2B (Arith. Mean)
17	T3B (Arith. Mean)
18	T4B (Arith. Mean)
19	T5B (Arith. Mean)
20	T6B (Arith. Mean)
21	T7B (Arith. Mean)
22	T8B (Arith. Mean)
23	T9B (Arith. Mean)
24	T10B (Arith. Mean)
25	T11B (Arith. Mean)
26	T12B (Arith. Mean)
27	T13B (Arith. Mean)
28	T14B (Arith. Mean)
29	T15B (Arith. Mean)
30	T12C (Arith. Mean)
31	T16C (Arith. Mean)

Section B: T10B – T15B RT Side



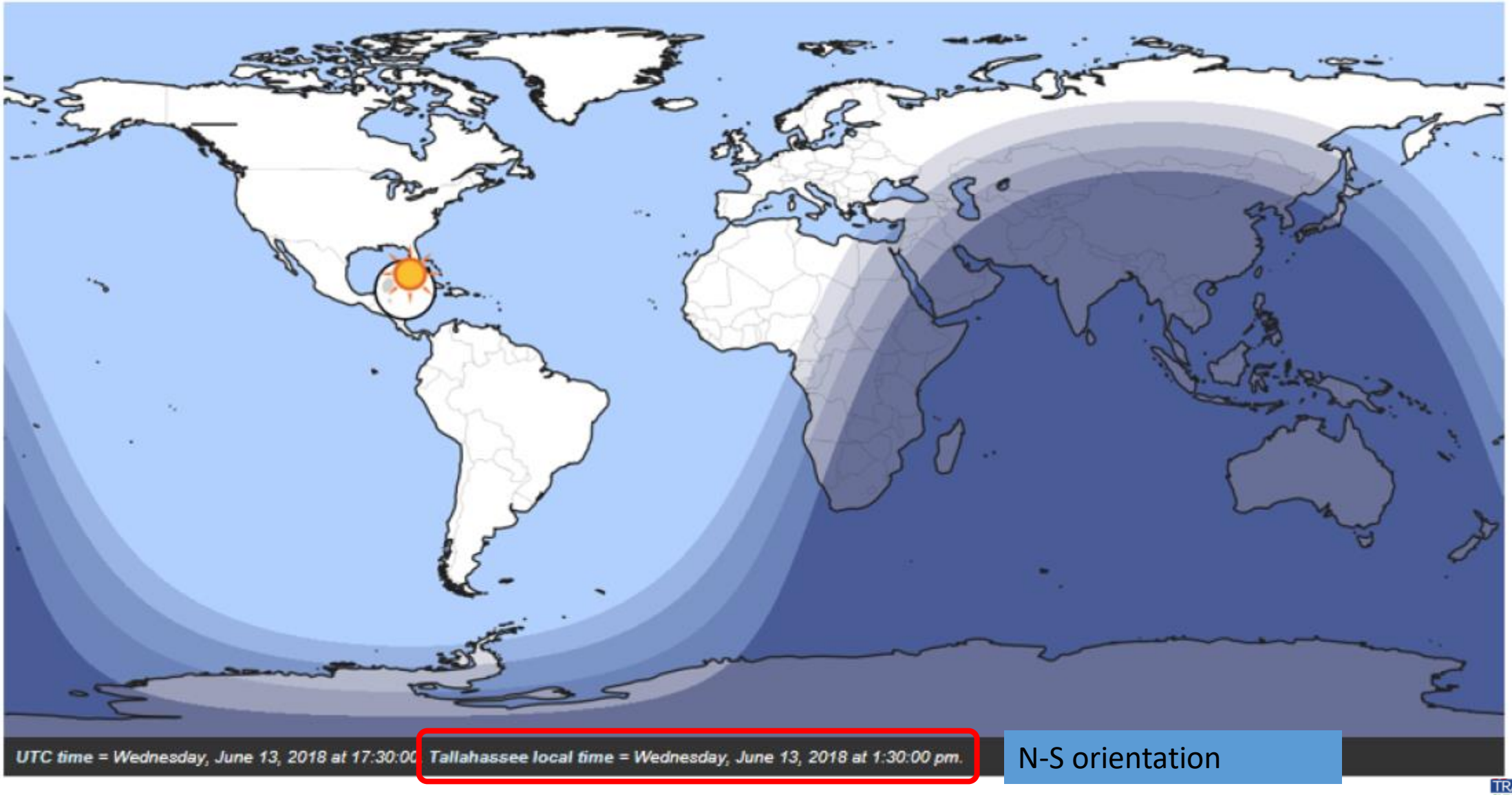


FDOT TRANSPORTATION SYMPOSIUM

Day and Night World Map

Map Satellite

The map below shows the current position of the Sun and the Moon. It shows which areas of the Earth are in daylight and which are in night.



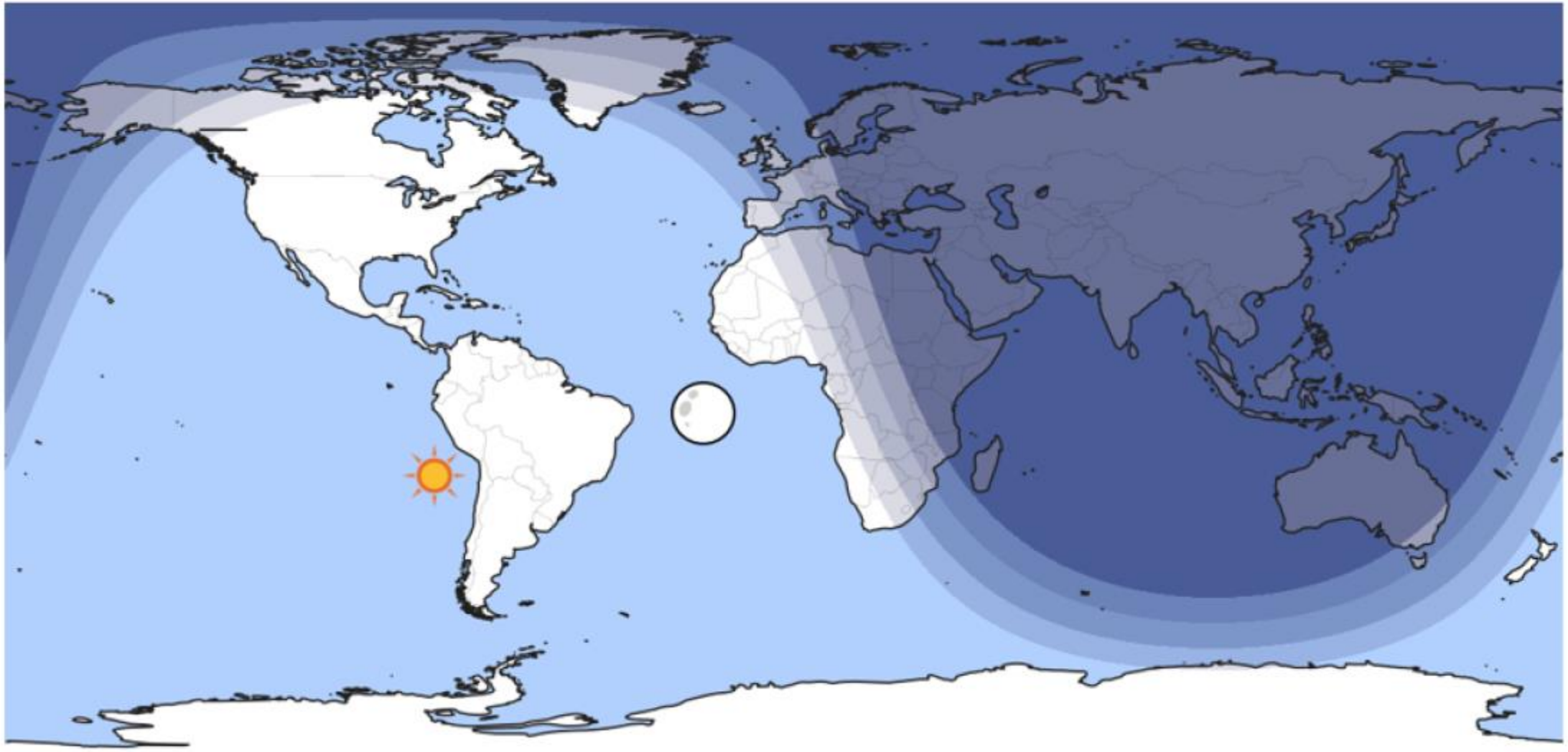
N-S orientation

TRANSPORTATION SYMPOSIUM

Day and Night World Map

Map Satellite

The map below shows the current position of the Sun and the Moon. It shows which areas of the Earth are in daylight and which are in night.



UTC time = Friday, January 11, 2019 at 17:30:00 *Tallahassee local time = Friday, January 11, 2019 at 12:30:00 pm.*

E-W orientation

TRANSPORTATION SYMPOSIUM

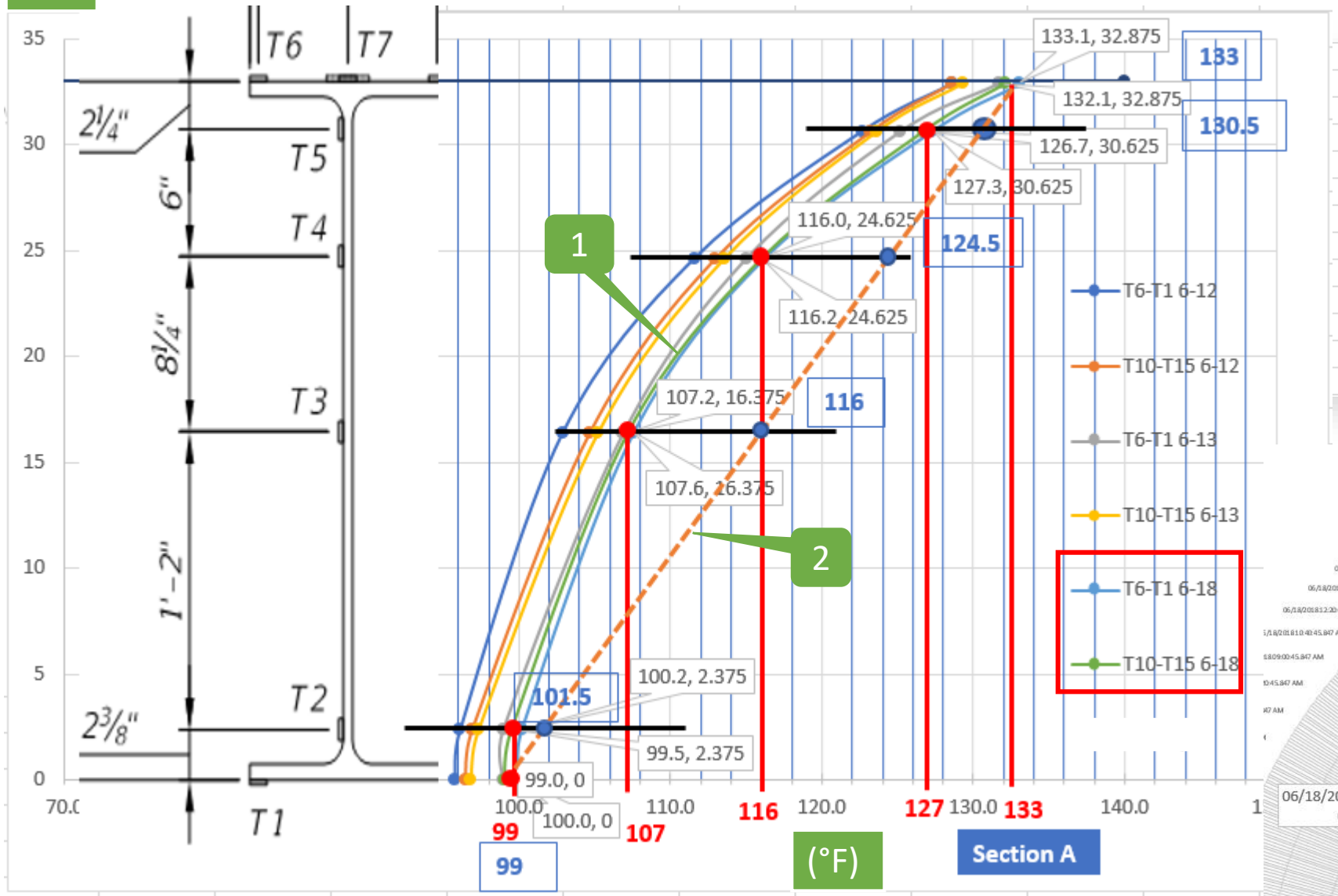
Chart shows Temperature Sensor readings for 6/18 2:20 pm occurring at Midspan Deflection

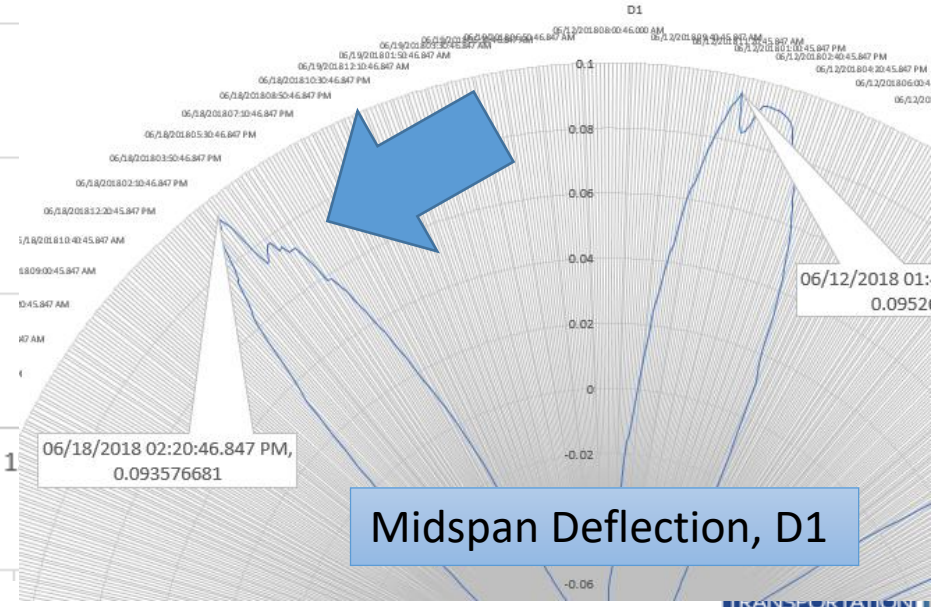
N-S B

Figure 2
Condition B - Specimen Sides is Covered with Burlap for Entire Girder Length

6/18/18 2:20 pm

Distance	Secton A at 6/12 1:40		Secton A at 6/13 2:40		Secton A at 6/18 2:20	
32.875	T6	128.6	T6	131.7	T6	133.1
30.625	T5	122.7	T5	125.2	T5	127.3
24.625	T4	111.6	T4	115.0	T4	116.2
16.375	T3	102.9	T3	106.9	T3	107.6
2.375	T2	96.1	T2	98.9	T2	100.2
0	T1	95.8	T1	98.9	T1	100.0
	T10	128.6	T10	129.3	T10	132.1
	T11	123.3	T11	123.7	T11	126.7
	T12	113.0	T12	113.6	T12	116.0
	T13	104.7	T13	105.2	T13	107.2
	T14	96.9	T14	97.3	T14	99.5
	T15	96.5	T15	96.8	T15	99.0





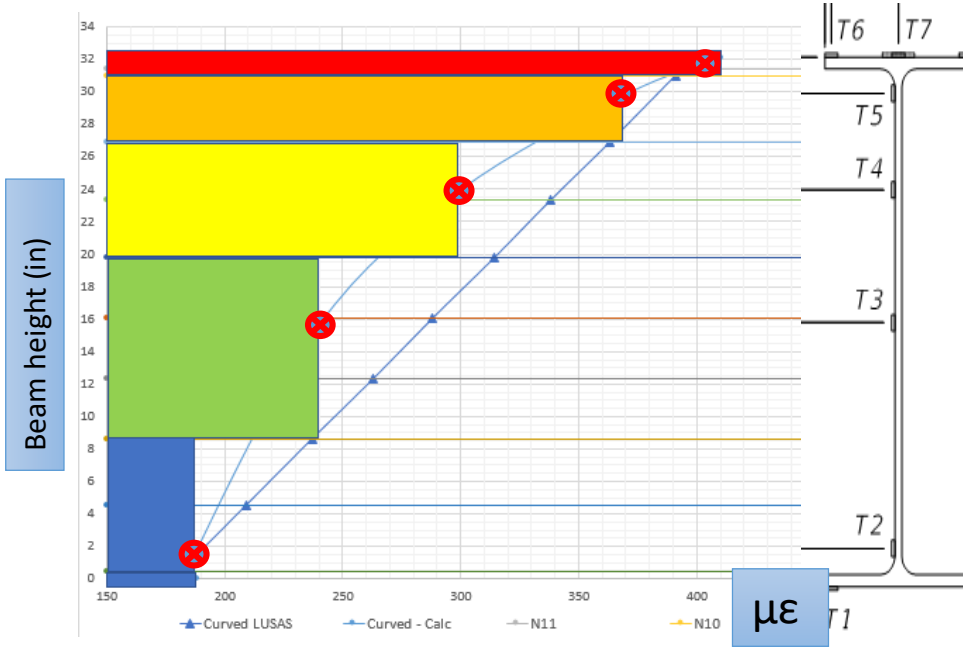
Midspan Deflection, D1

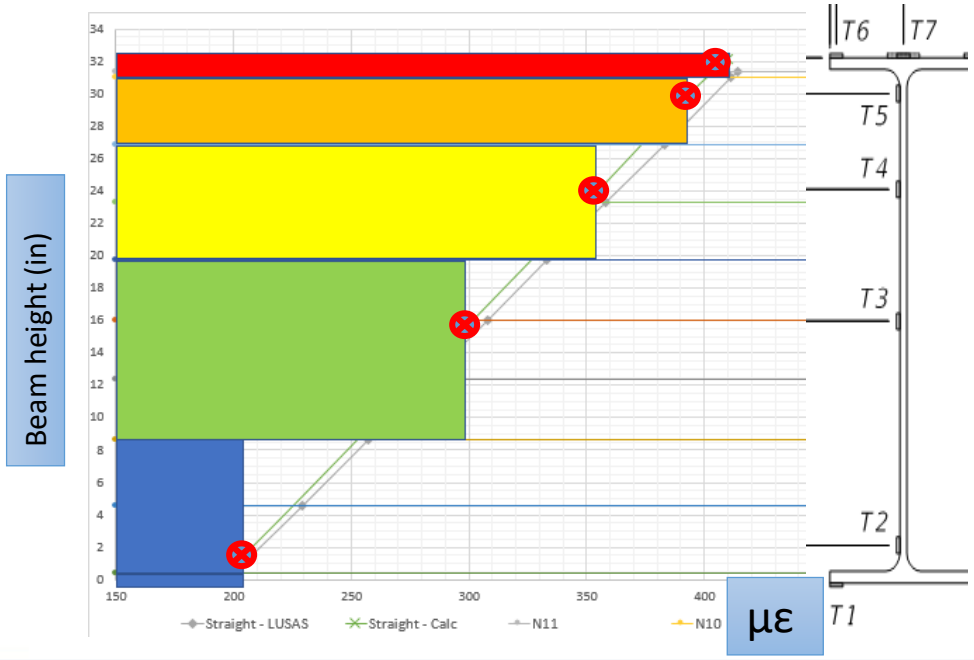
2 TG profiles were developed: 1) Curved (Red), and 2) Straight (Orange)

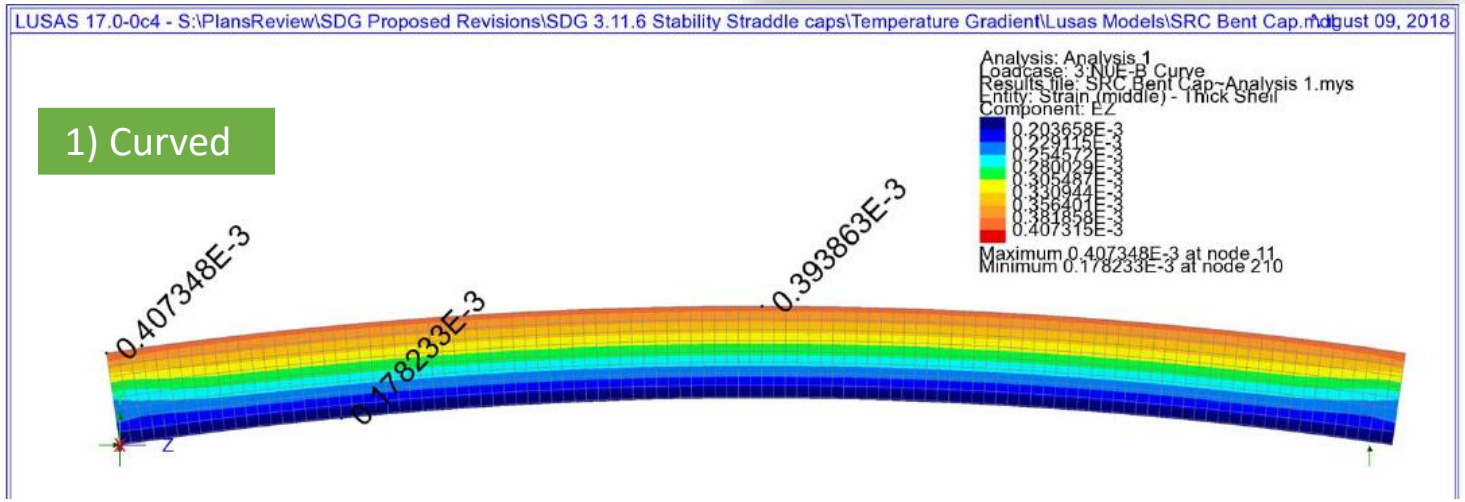
Structural Analysis Model using LUSAS (Longitudinal Strains)

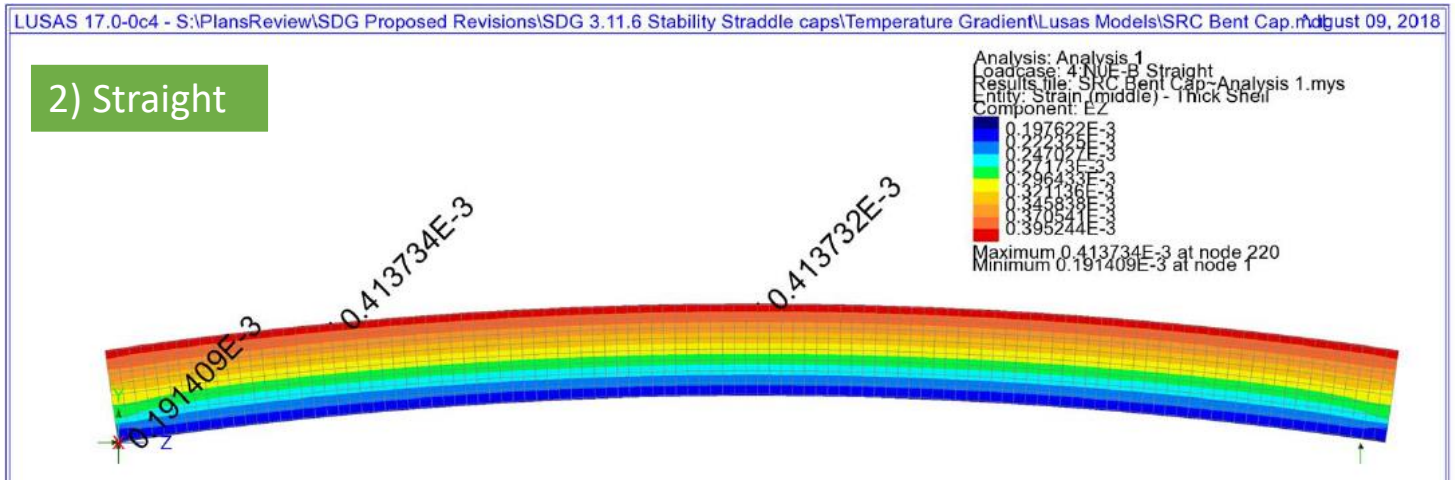
N-S B

Figure 2
Condition B - Specimen Sides is Covered with Burlap for Entire Girder Length









FDOT TRANSPORTATION SYMPOSIUM

Structural Analysis Model using LUSAS (Vertical Deflection)

N-S B

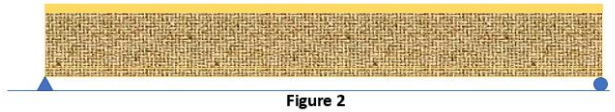
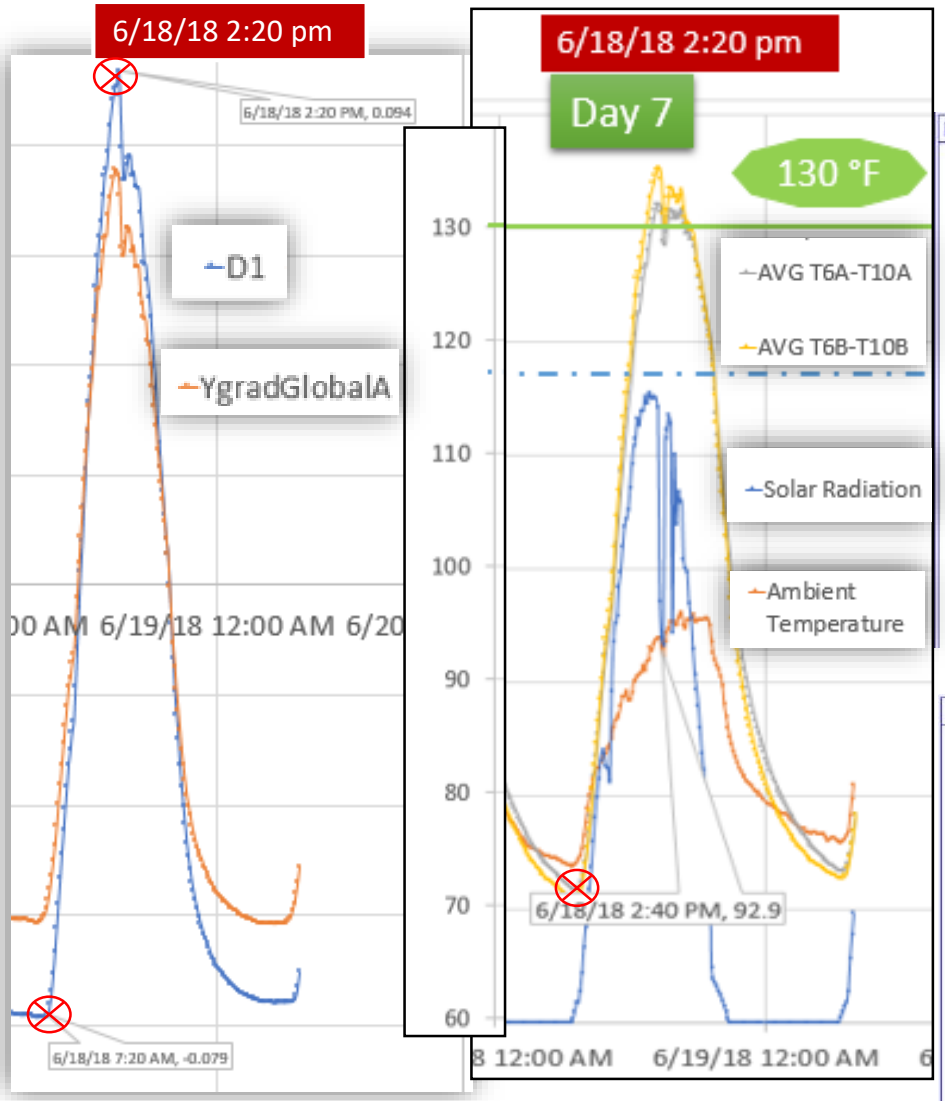
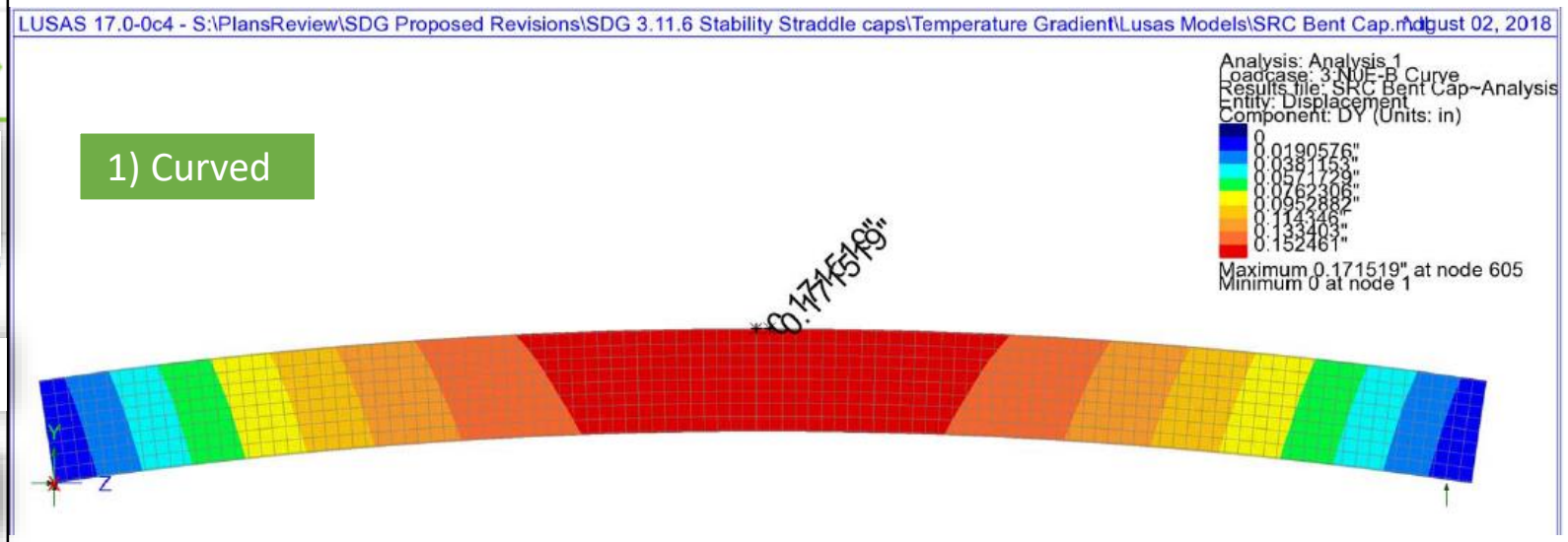
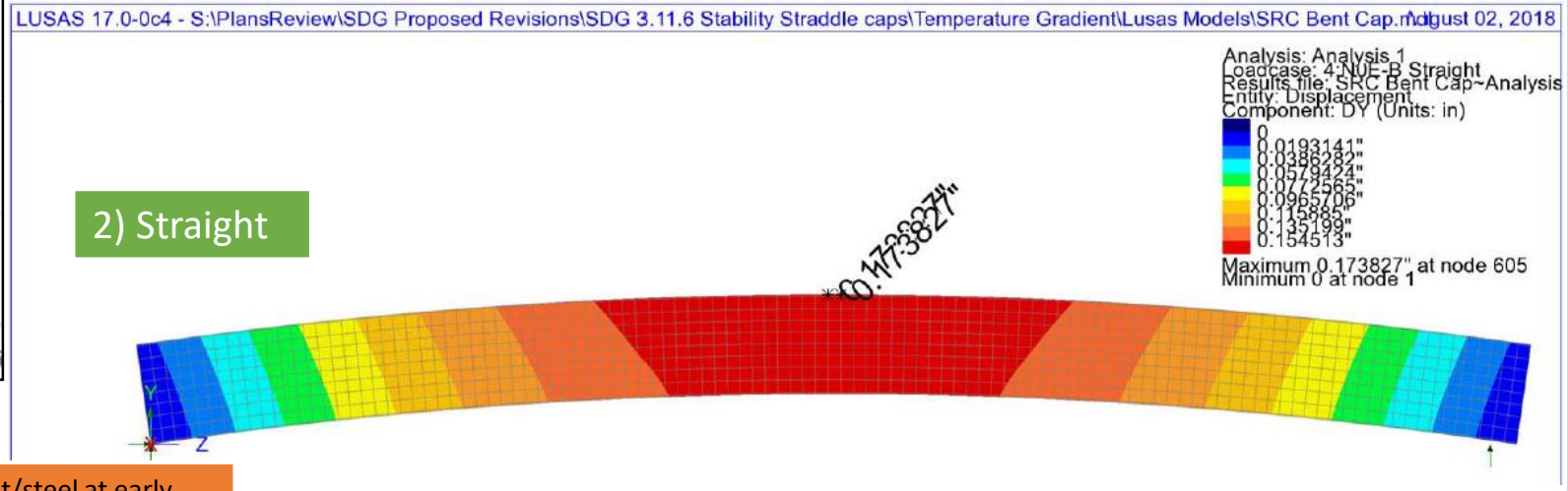


Figure 2
Condition B - Specimen Sides is Covered with Burlap for Entire Girder Length







Testing on 6/18 2:20 pm.
midspan displacement is:
0.094 – (-)0.079 = 0.173 (~3/16”)

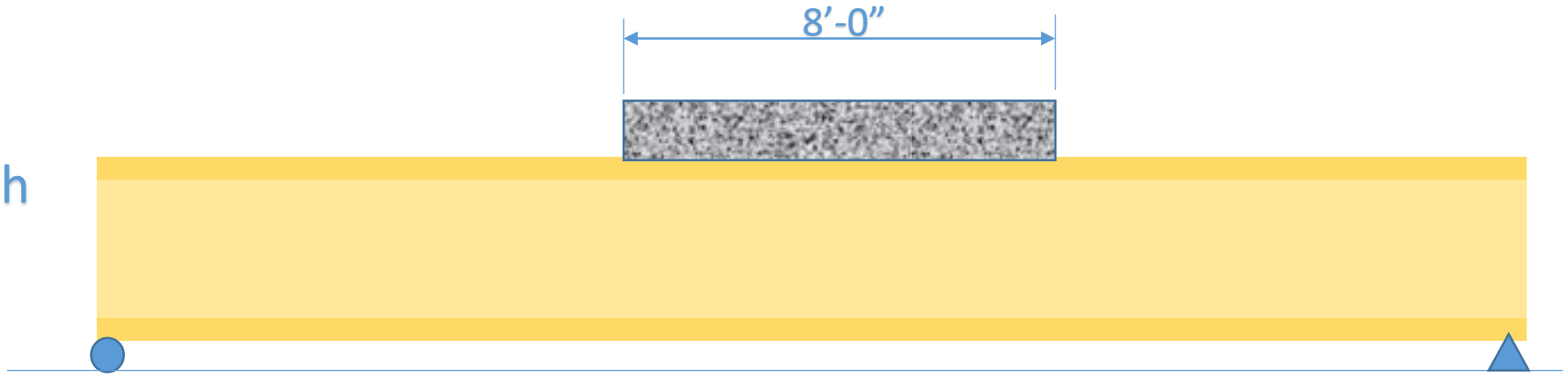
70°F was ambient/steel at early morning, not to be confused with 92°F ambient temperature at 2pm.

FDOT TRANSPORTATION SYMPOSIUM

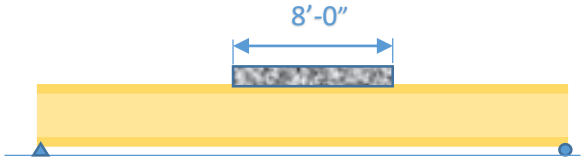
N-S D

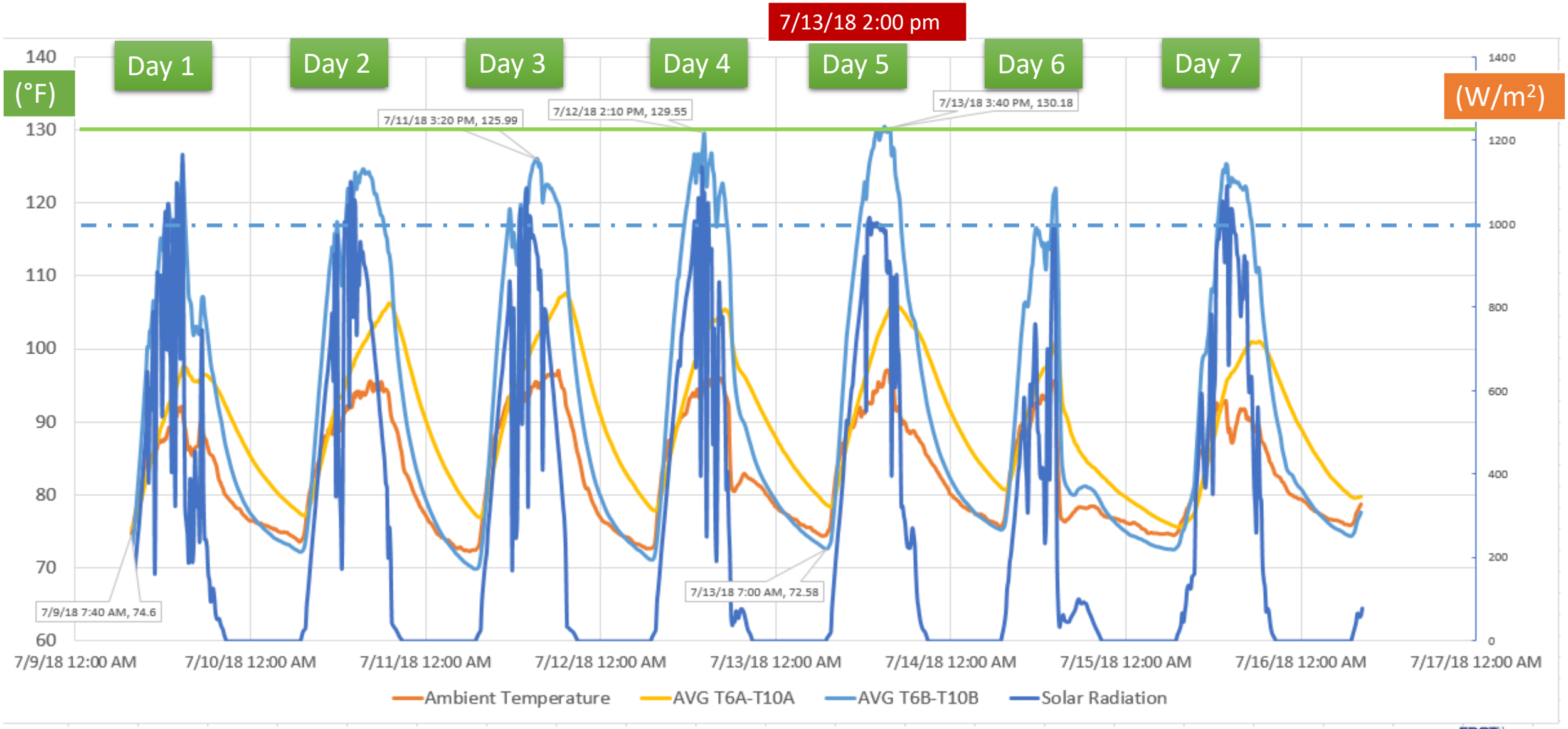
N-S D	7/9/18 7:40 AM	7/16/18 8:10 AM

D - Shaded top with concrete slab



N-S D

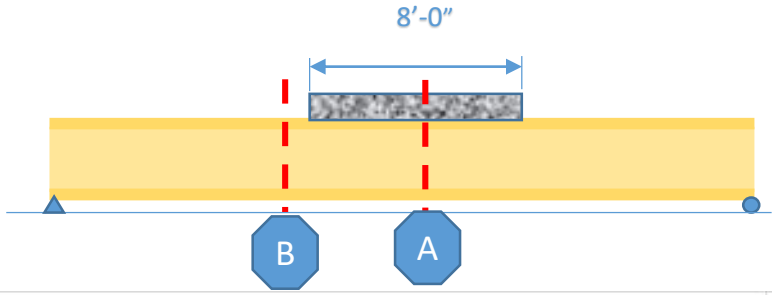




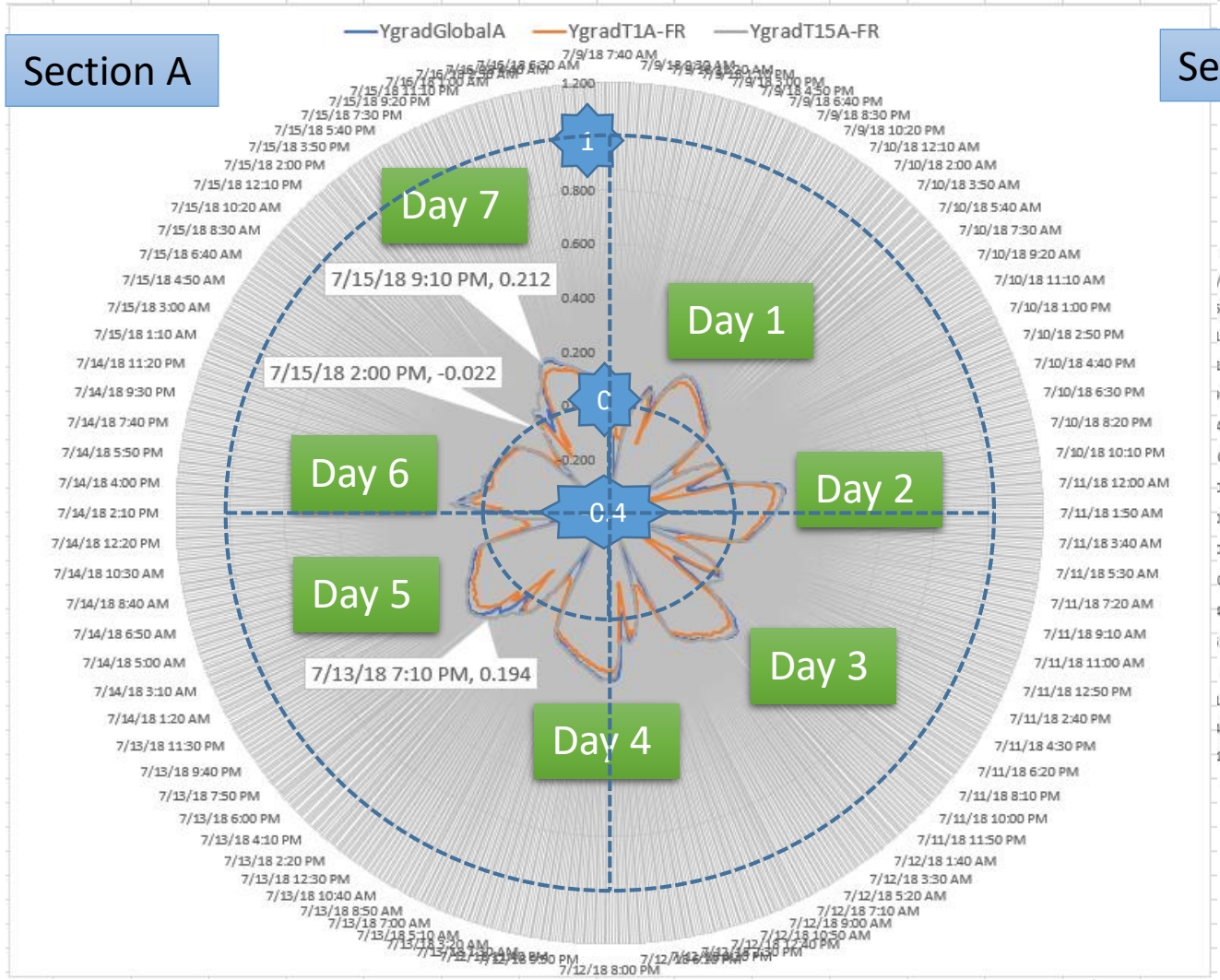
FDOT TRANSPORTATION SYMPOSIUM

N-S D

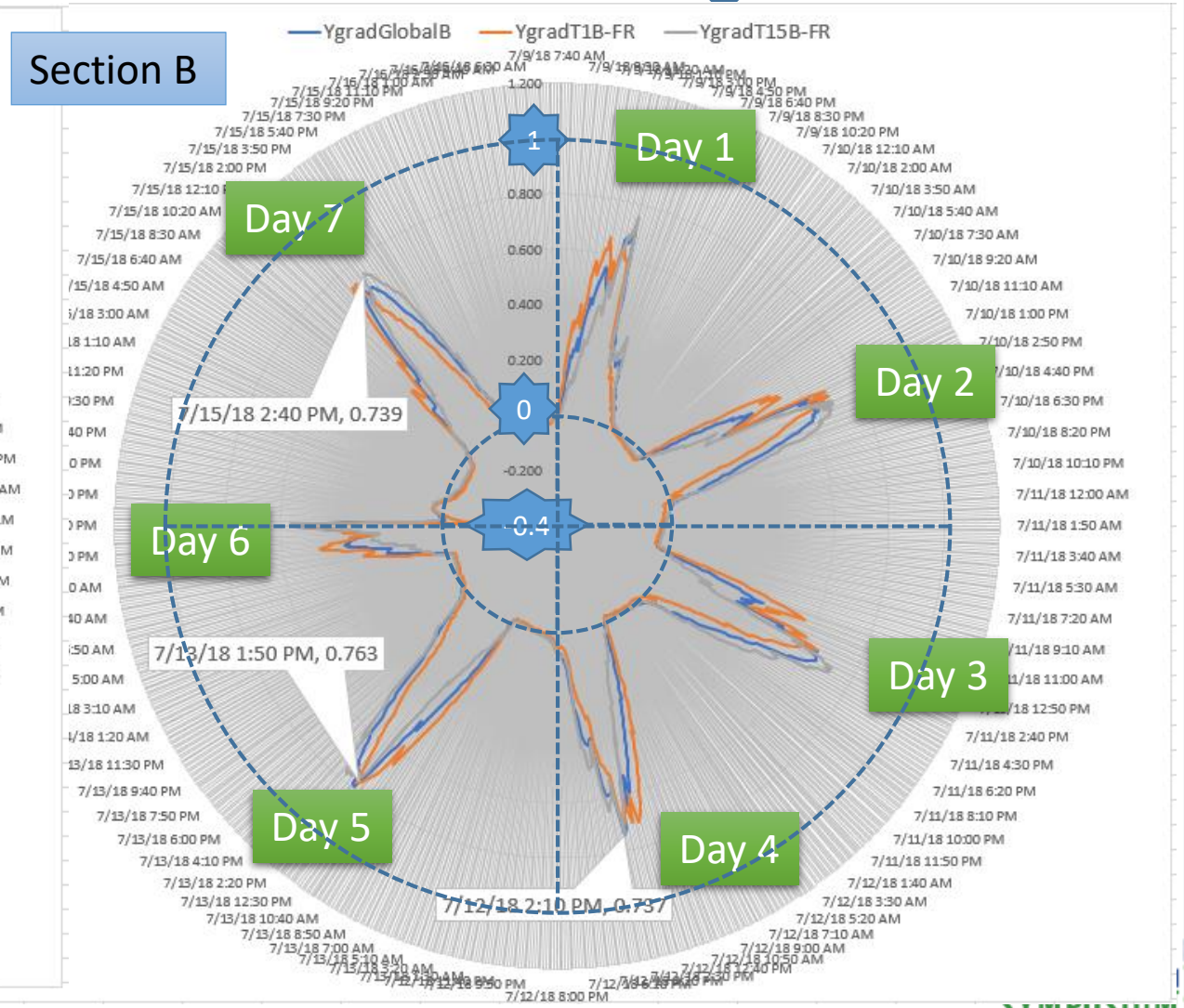
Charts show 7 day testing period with temperature gradient for Global and Fixed Reference measure from top flange to bottom flange



Section A

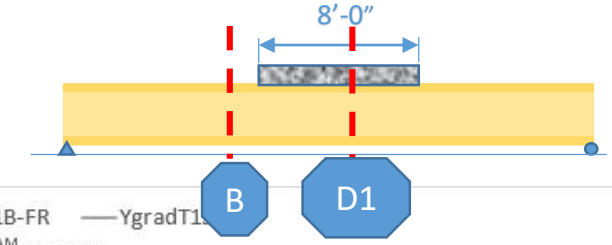


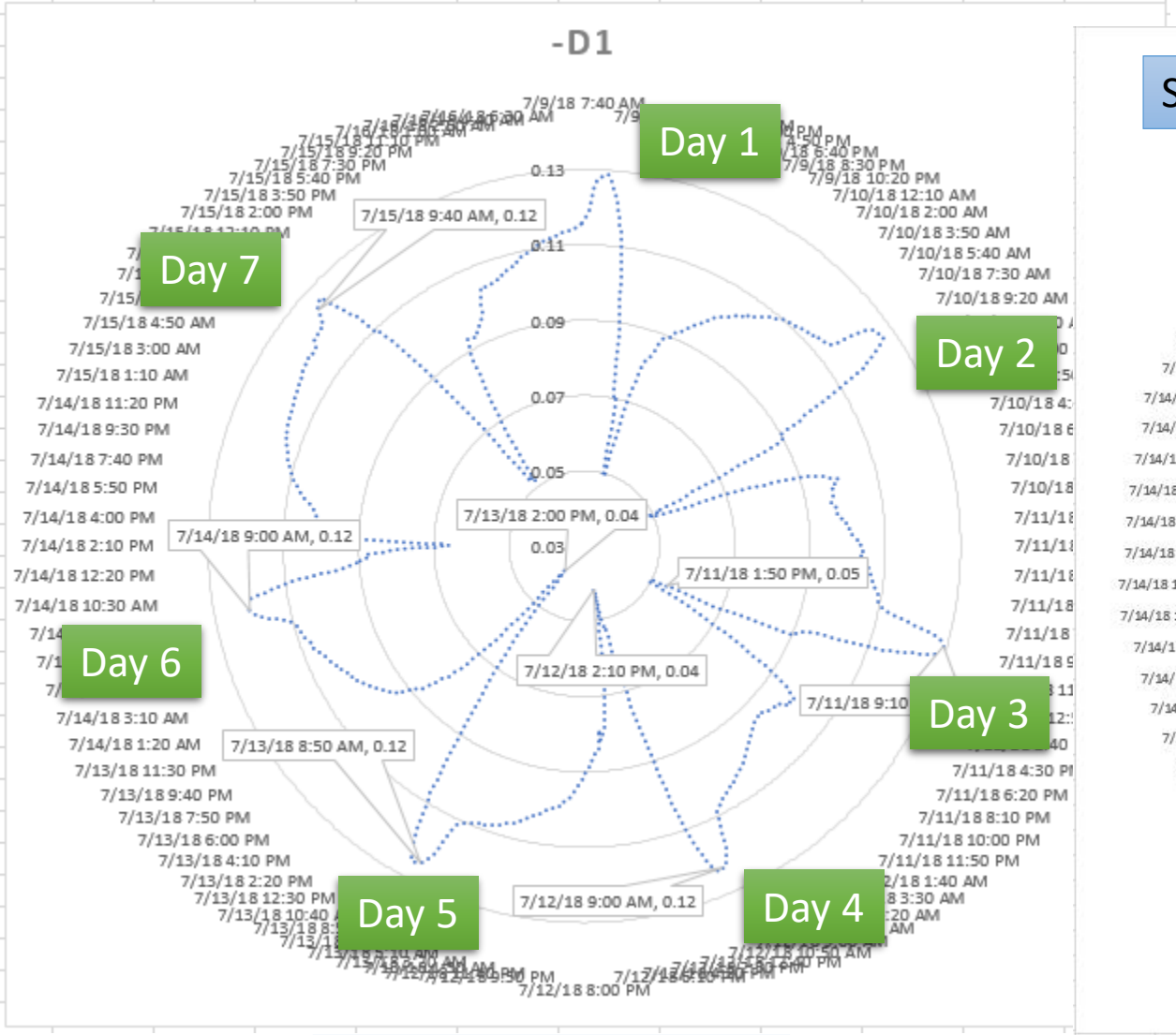
Section B



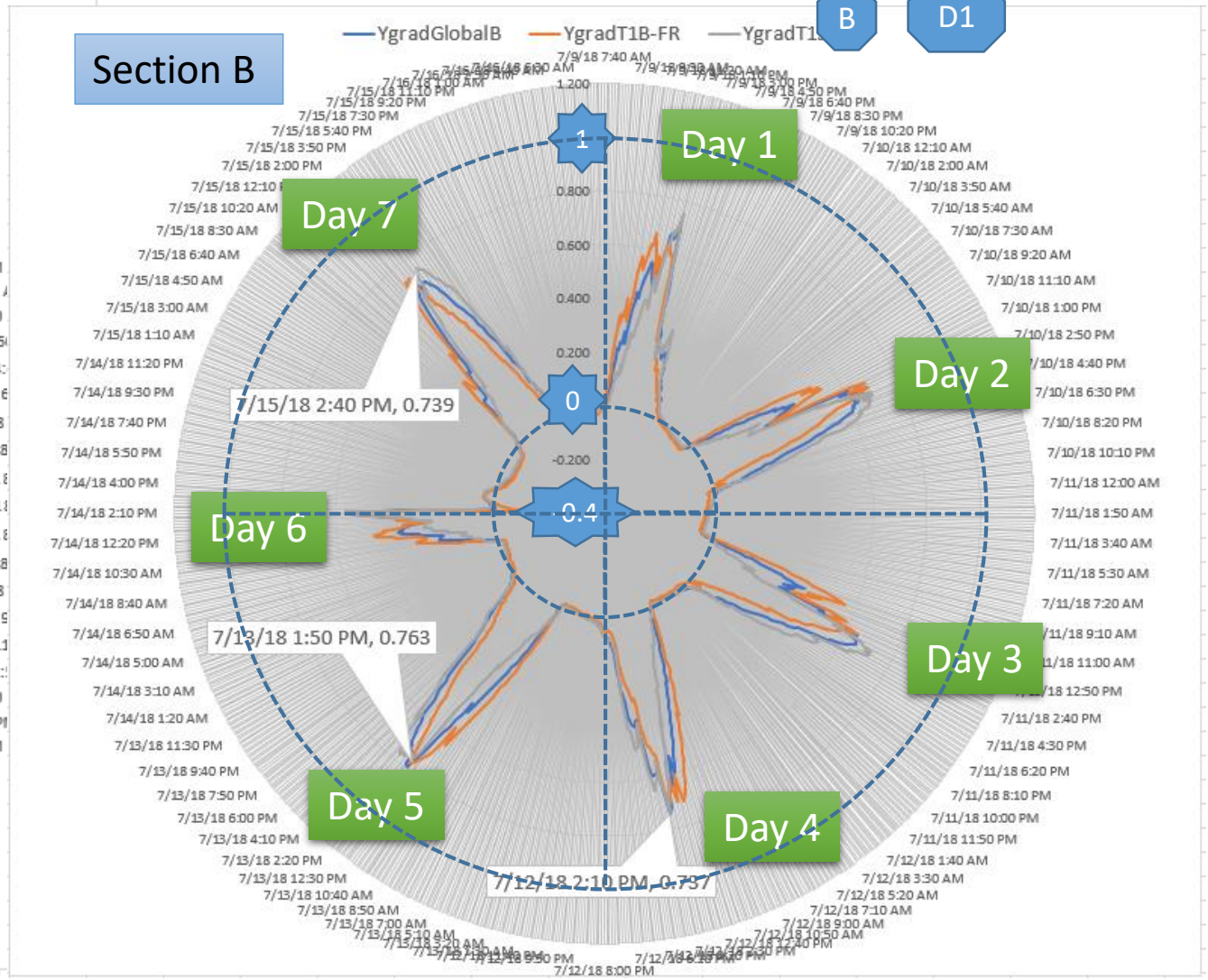
N-S D

1st chart shows 7 day testing period for midspan displacement, D1





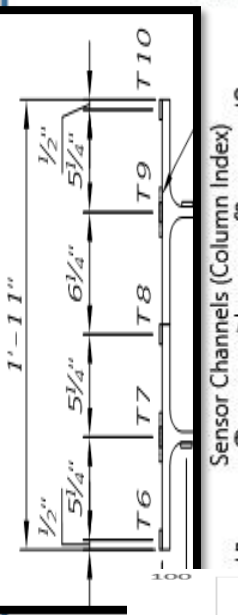
Midspan Deflection, D1

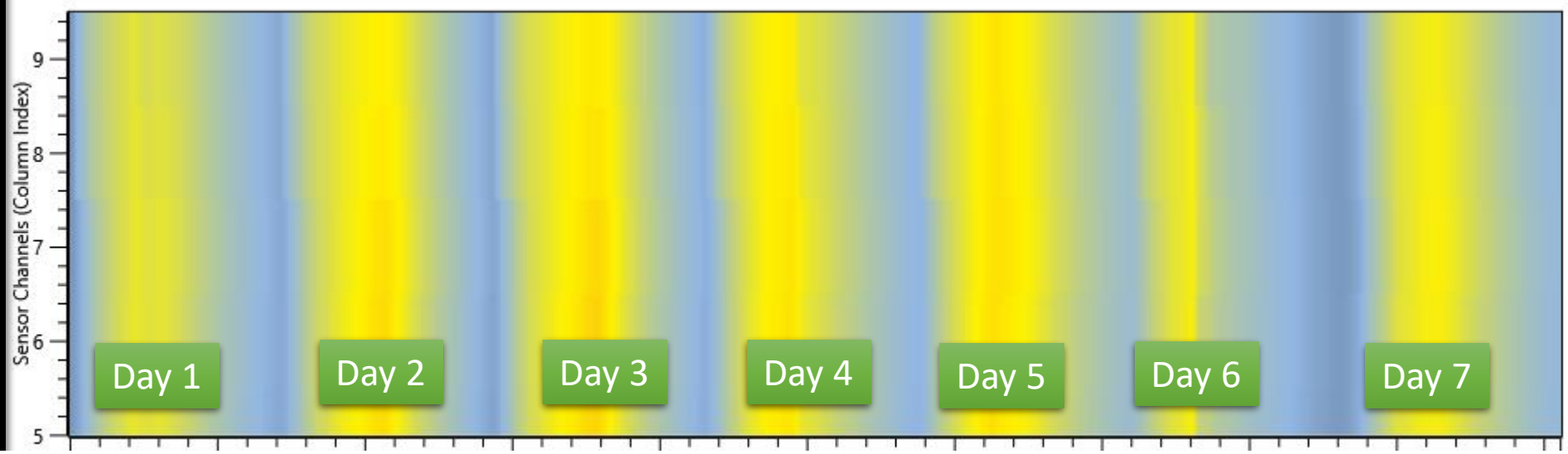


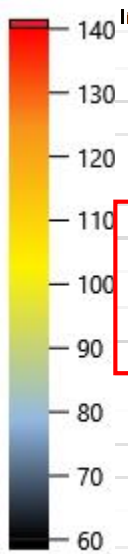
FDOT TRANSPORTATION SYMPOSIUM

N0E-D-Temperature Sensors vs. Time

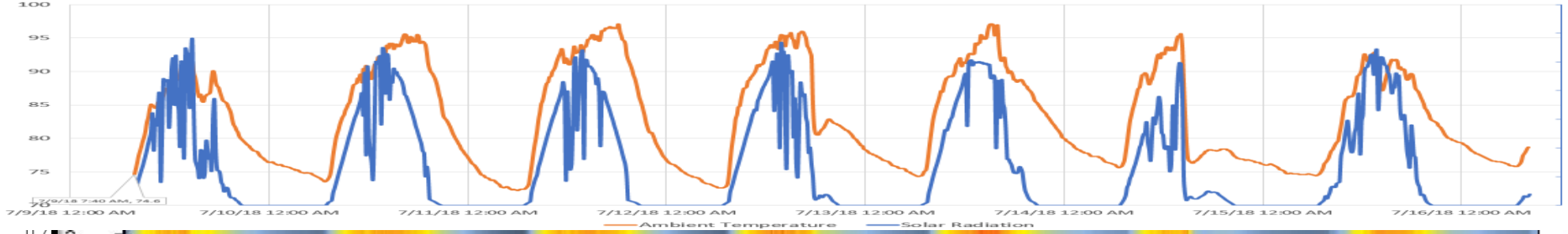
Section A – Top Flange

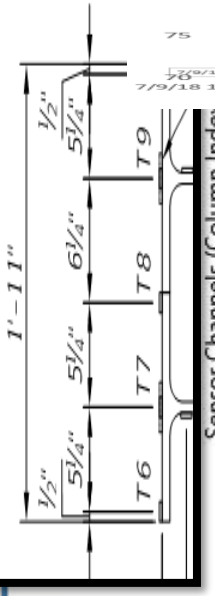


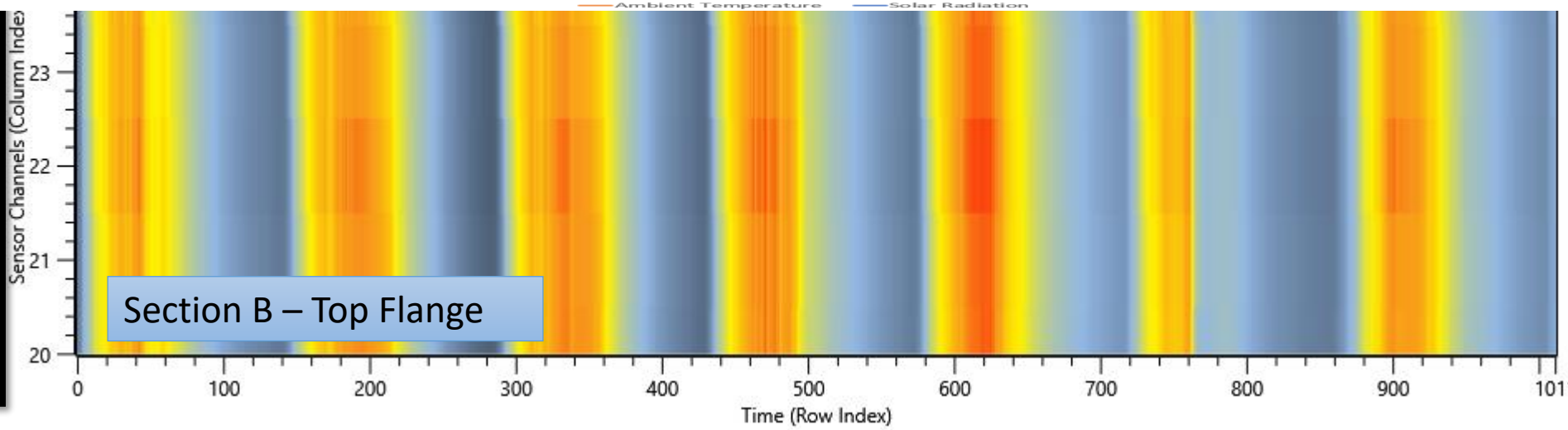


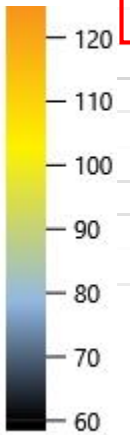


Index	Sensor
0	T1A (Arith. Mean)
1	T2A (Arith. Mean)
2	T3A (Arith. Mean)
3	T4A (Arith. Mean)
4	T5A (Arith. Mean)
5	T6A (Arith. Mean)
6	T7A (Arith. Mean)
7	T8A (Arith. Mean)
8	T9A (Arith. Mean)
9	T10A (Arith. Mean)
10	T11A (Arith. Mean)
11	T12A (Arith. Mean)
12	T13A (Arith. Mean)
13	T14A (Arith. Mean)
14	T15A (Arith. Mean)
15	T1B (Arith. Mean)
16	T2B (Arith. Mean)
17	T3B (Arith. Mean)
18	T4B (Arith. Mean)
19	T5B (Arith. Mean)
20	T6B (Arith. Mean)
21	T7B (Arith. Mean)
22	T8B (Arith. Mean)
23	T9B (Arith. Mean)
24	T10B (Arith. Mean)
25	T11B (Arith. Mean)
26	T12B (Arith. Mean)
27	T13B (Arith. Mean)
28	T14B (Arith. Mean)
29	T15B (Arith. Mean)
30	T12C (Arith. Mean)
31	T16C (Arith. Mean)

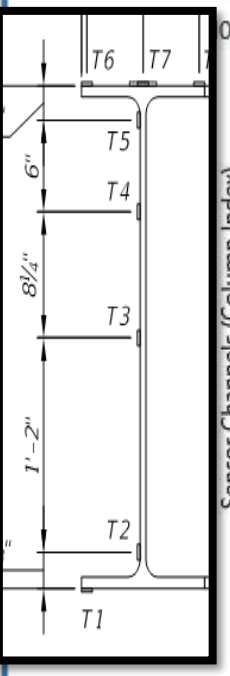


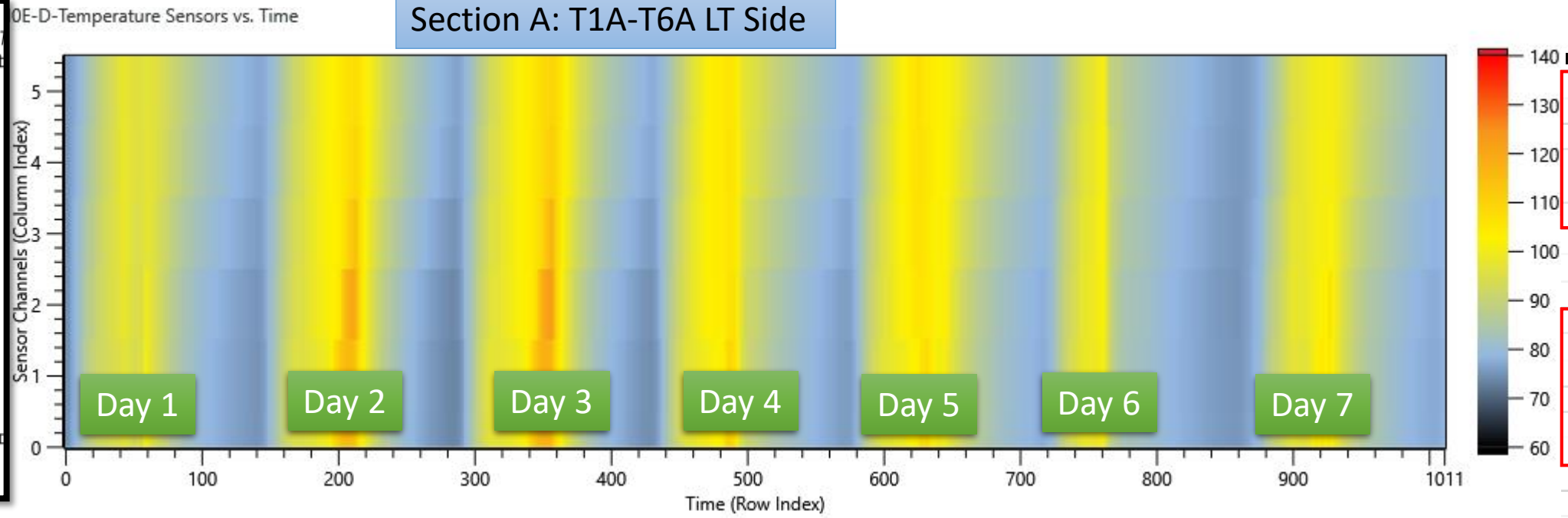




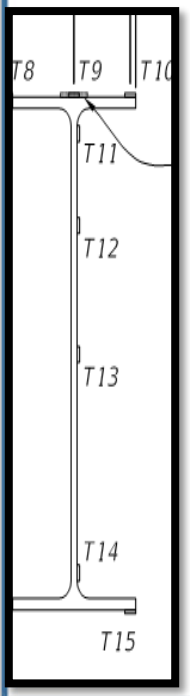


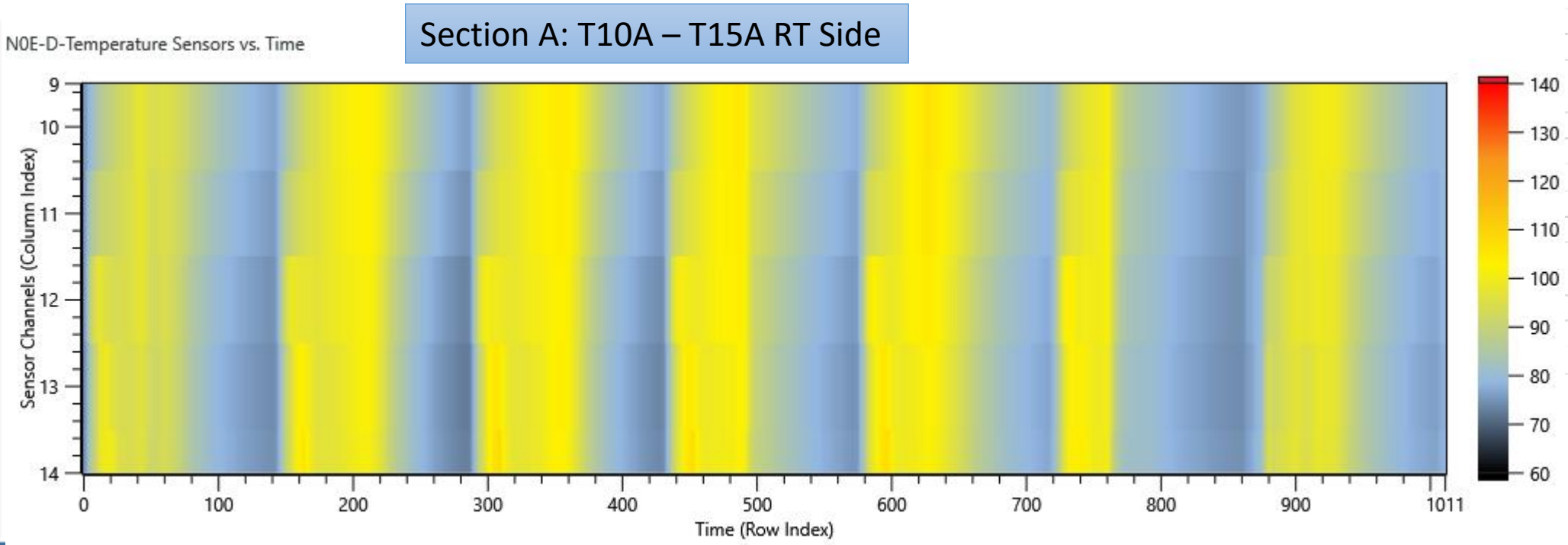
FDOT TRANSPORTATION SYMPOSIUM



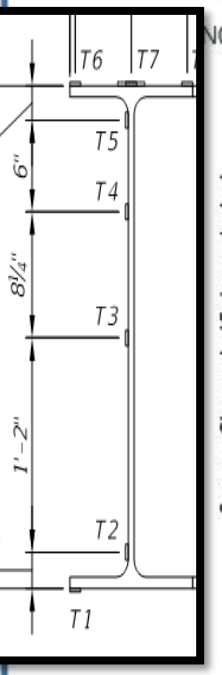


Index	Sensor
0	T1A (Arith. Mean)
1	T2A (Arith. Mean)
2	T3A (Arith. Mean)
3	T4A (Arith. Mean)
4	T5A (Arith. Mean)
5	T6A (Arith. Mean)
6	T7A (Arith. Mean)
7	T8A (Arith. Mean)
8	T9A (Arith. Mean)
9	T10A (Arith. Mean)
10	T11A (Arith. Mean)
11	T12A (Arith. Mean)
12	T13A (Arith. Mean)
13	T14A (Arith. Mean)
14	T15A (Arith. Mean)
15	T1B (Arith. Mean)
16	T2B (Arith. Mean)
17	T3B (Arith. Mean)
18	T4B (Arith. Mean)
19	T5B (Arith. Mean)
20	T6B (Arith. Mean)
21	T7B (Arith. Mean)
22	T8B (Arith. Mean)
23	T9B (Arith. Mean)
24	T10B (Arith. Mean)
25	T11B (Arith. Mean)
26	T12B (Arith. Mean)
27	T13B (Arith. Mean)
28	T14B (Arith. Mean)
29	T15B (Arith. Mean)
30	T12C (Arith. Mean)
31	T16C (Arith. Mean)

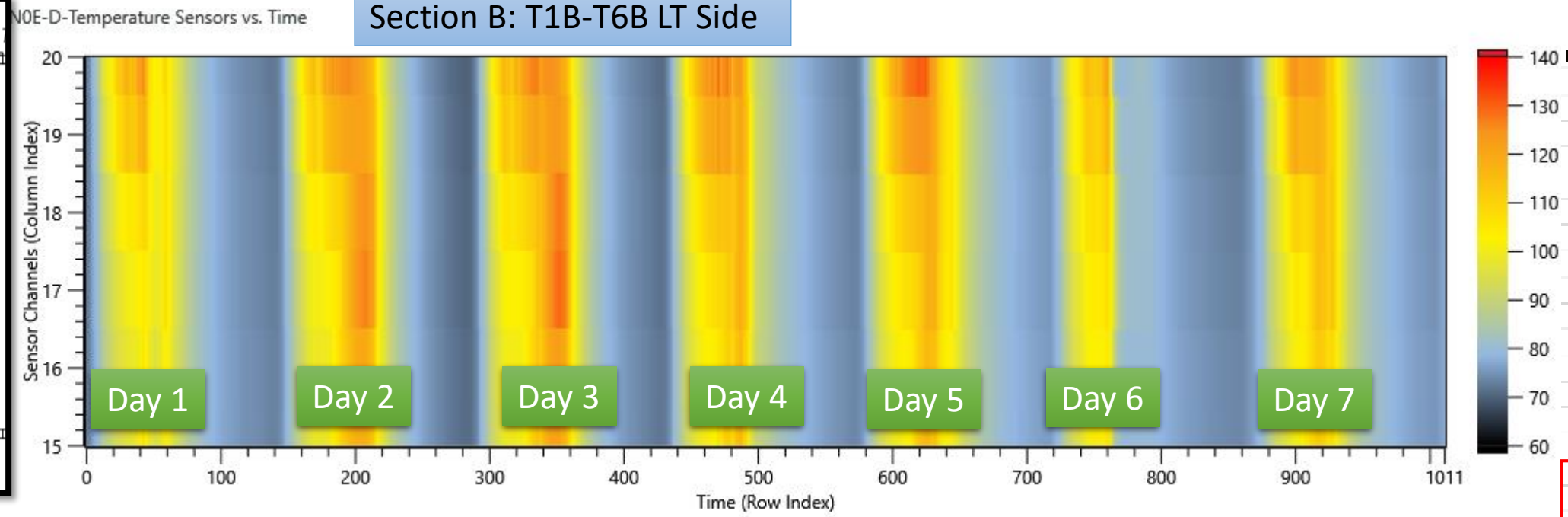




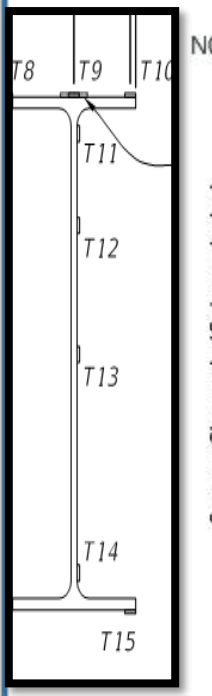
FDOT TRANSPORTATION SYMPOSIUM



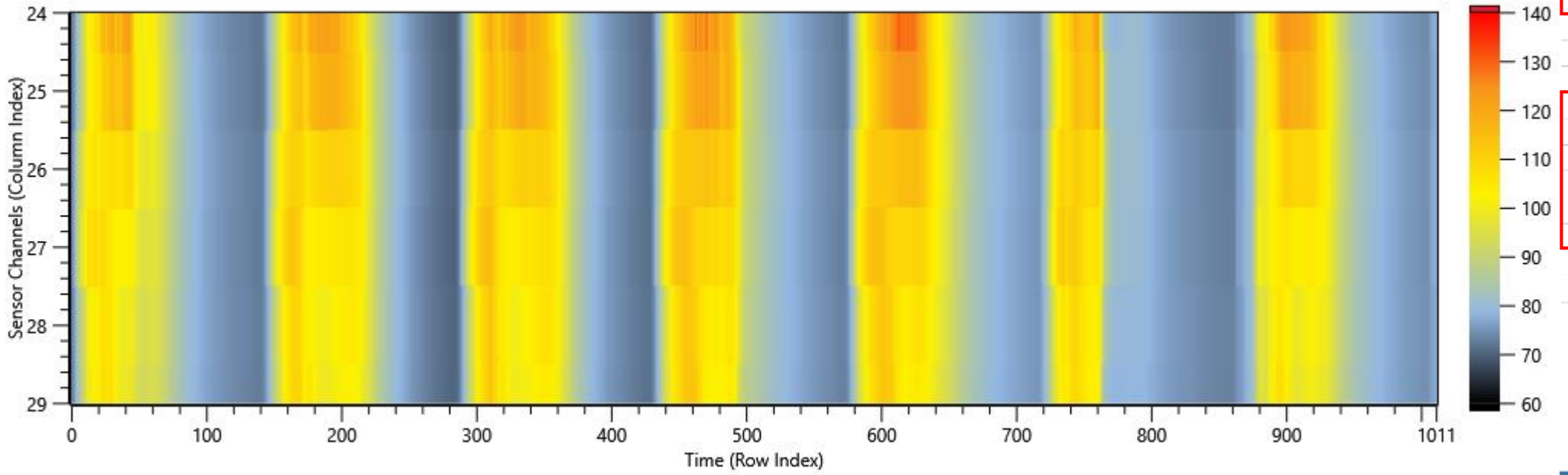
Section B: T1B-T6B LT Side



Index	Sensor
0	T1A (Arith. Mean)
1	T2A (Arith. Mean)
2	T3A (Arith. Mean)
3	T4A (Arith. Mean)
4	T5A (Arith. Mean)
5	T6A (Arith. Mean)
6	T7A (Arith. Mean)
7	T8A (Arith. Mean)
8	T9A (Arith. Mean)
9	T10A (Arith. Mean)
10	T11A (Arith. Mean)
11	T12A (Arith. Mean)
12	T13A (Arith. Mean)
13	T14A (Arith. Mean)
14	T15A (Arith. Mean)
15	T1B (Arith. Mean)
16	T2B (Arith. Mean)
17	T3B (Arith. Mean)
18	T4B (Arith. Mean)
19	T5B (Arith. Mean)
20	T6B (Arith. Mean)
21	T7B (Arith. Mean)
22	T8B (Arith. Mean)
23	T9B (Arith. Mean)
24	T10B (Arith. Mean)
25	T11B (Arith. Mean)
26	T12B (Arith. Mean)
27	T13B (Arith. Mean)
28	T14B (Arith. Mean)
29	T15B (Arith. Mean)
30	T12C (Arith. Mean)
31	T16C (Arith. Mean)



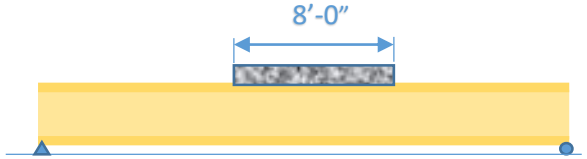
Section B: T10B – T15B RT Side

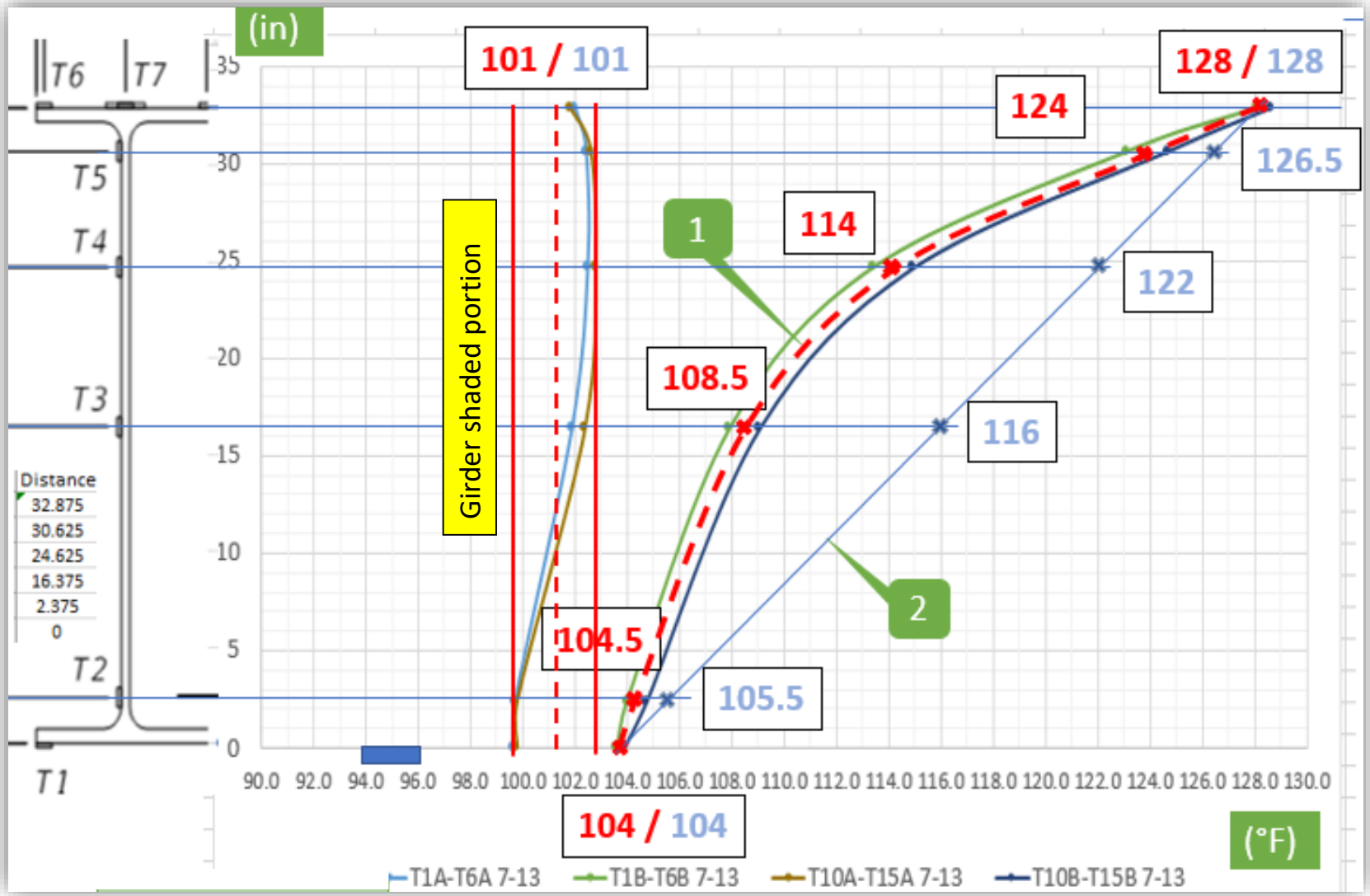


FDOT TRANSPORTATION SYMPOSIUM

N-S D

Chart shows Temperature Sensor readings for 7/13 2:00 pm occurring at Midspan Deflection





Secton A at 7/13 2:00	
T6	102.0
T5	102.4
T4	102.5
T3	101.9
T2	99.7
T1	99.6
T10	101.8
T11	102.6
T12	102.8
T13	102.4
T14	99.8
T15	99.8

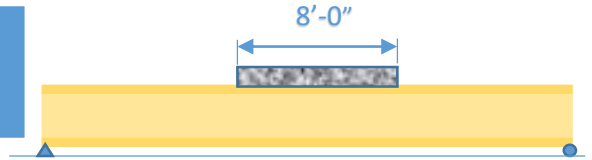
Secton B at 7/13 2:00	
T6	128.1
T5	123.1
T4	113.4
T3	107.9
T2	104.0
T1	103.6
T10	128.6
T11	124.7
T12	115.0
T13	109.1
T14	104.7
T15	103.9

2 TG profiles were developed: 1) Curved (red), and 2) Straight (blue)

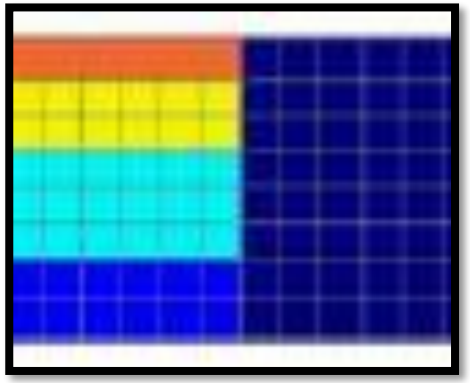
FDOT TRANSPORTATION SYMPOSIUM

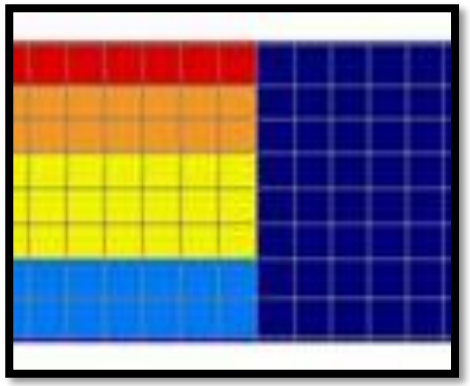
Structural Analysis Model using LUSAS (Longitudinal Strains)

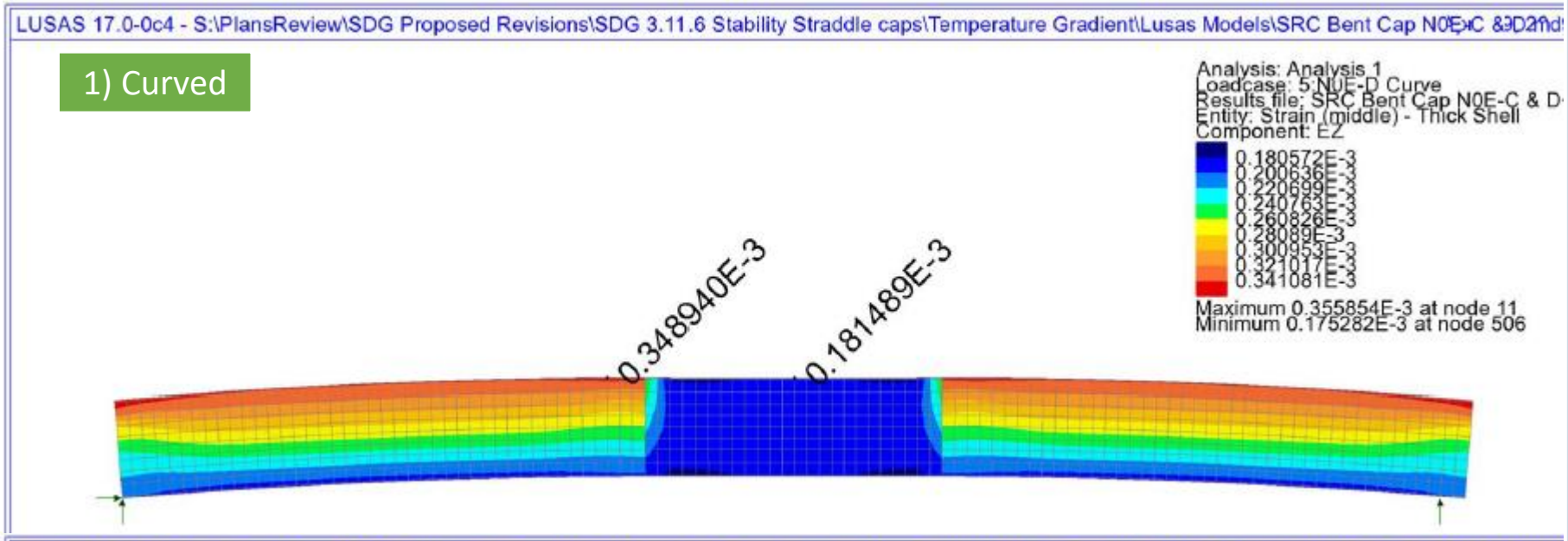
N-S D

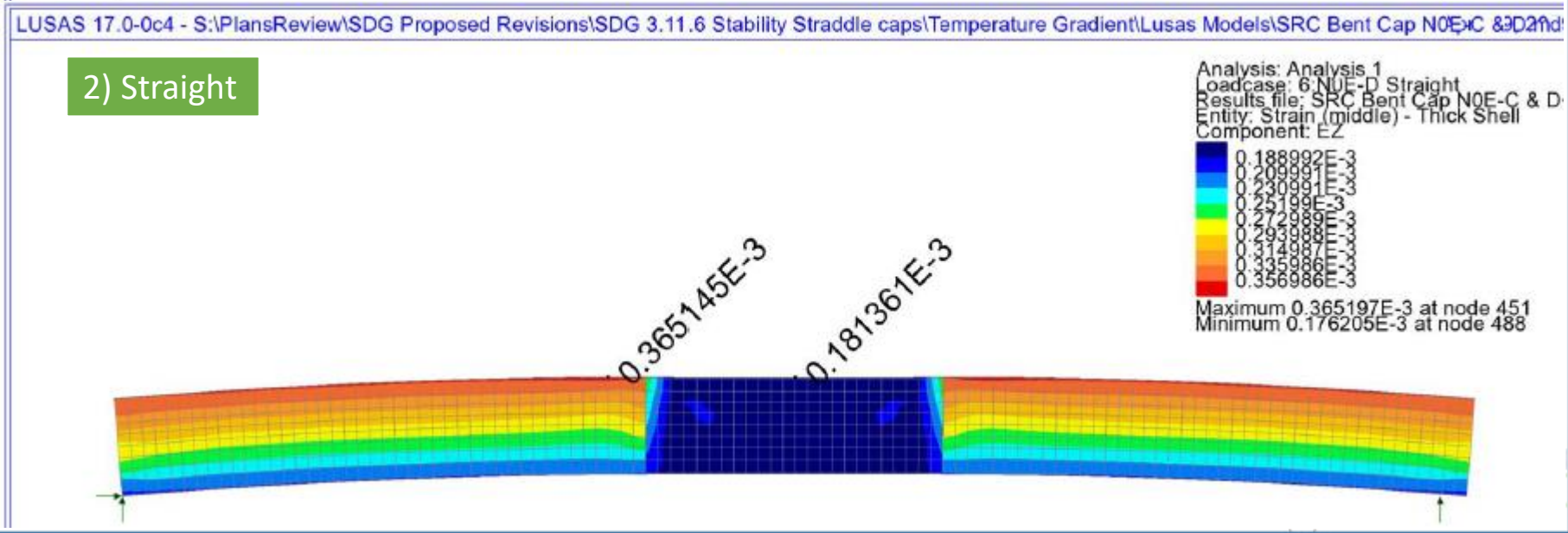


LUSAS – Temperature Loading



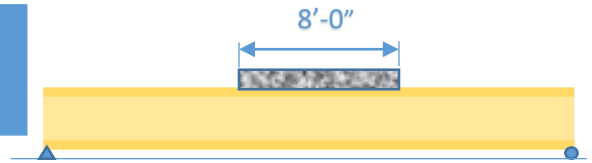




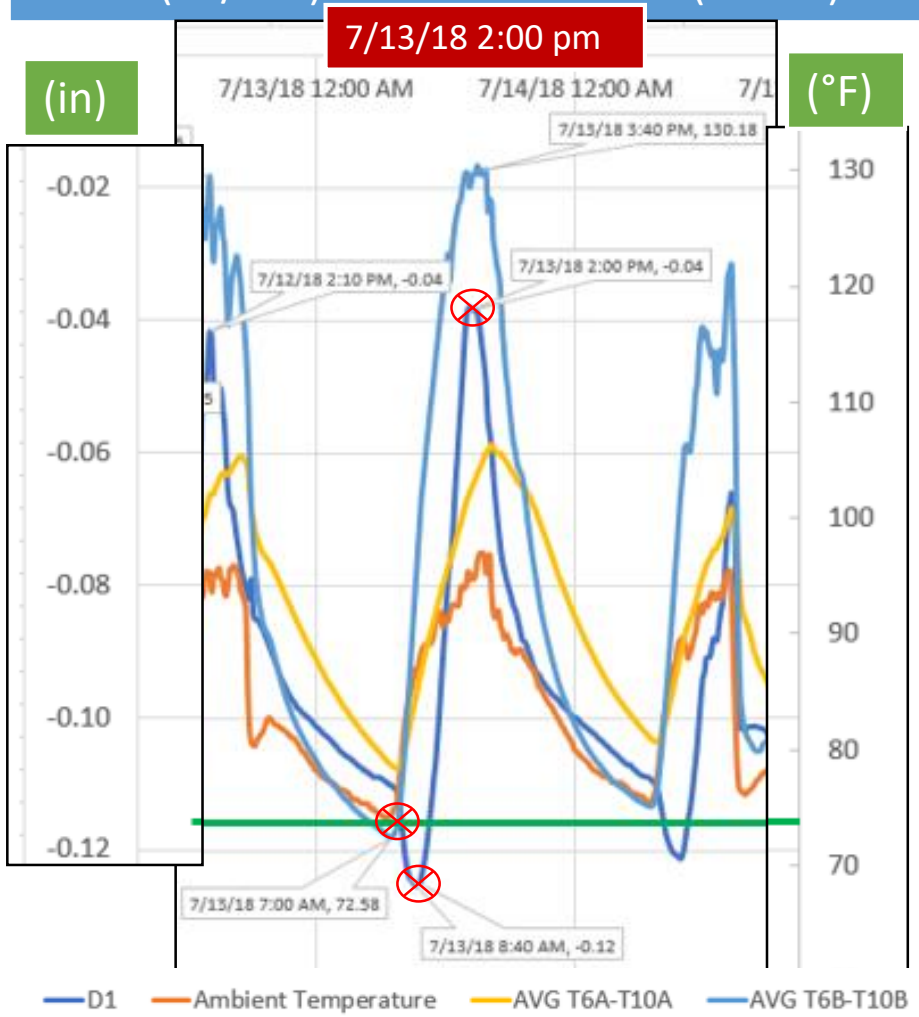


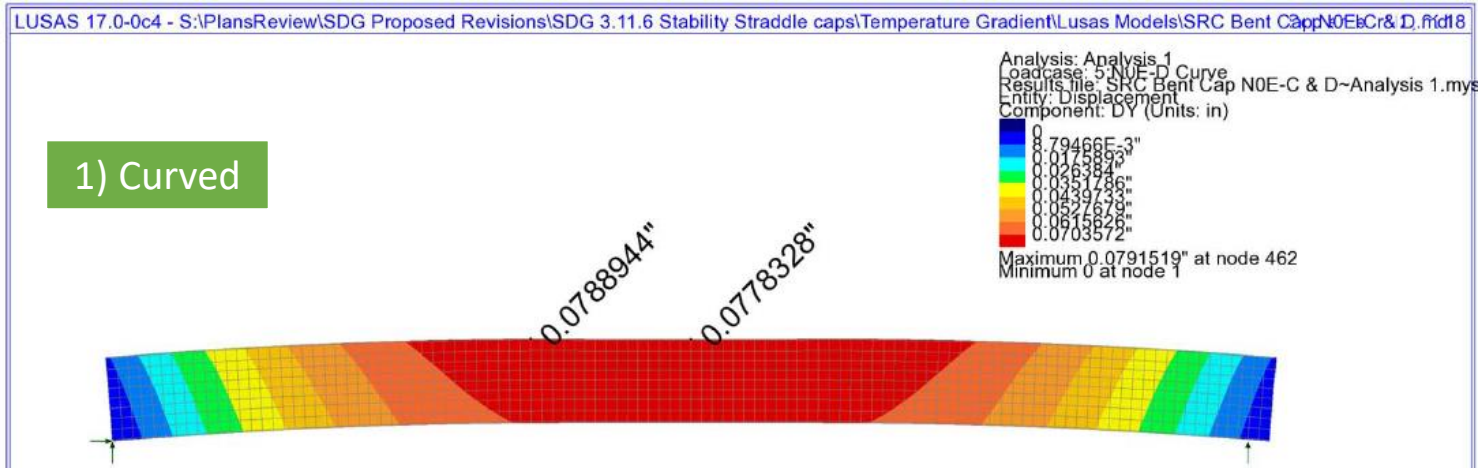
Structural Analysis Model using LUSAS (Vertical Deflection)

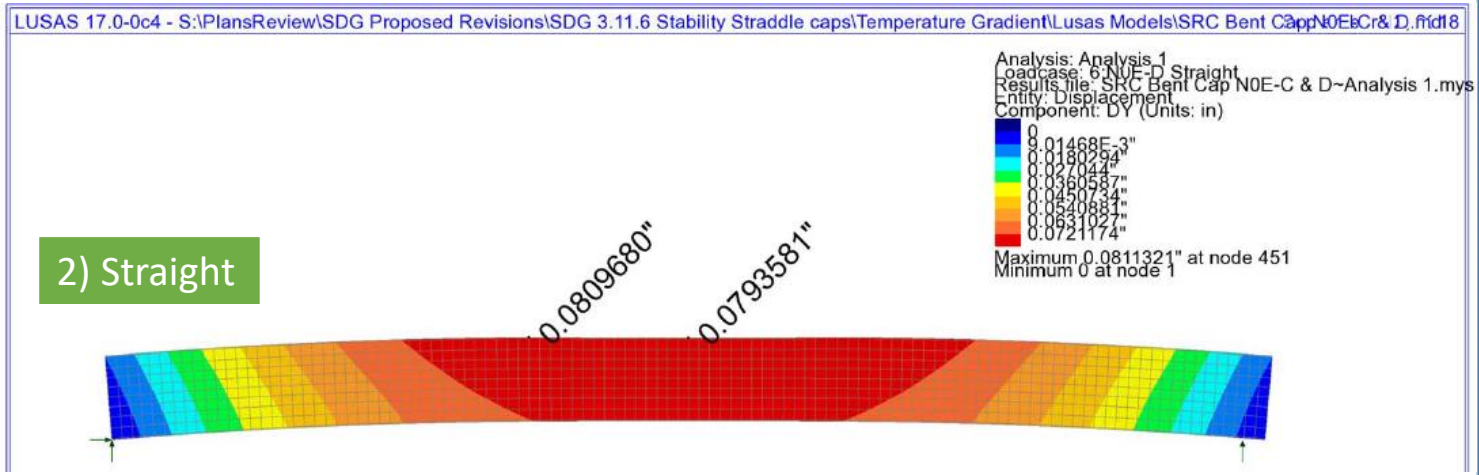
N-S D



On 7/13/18 2:00 pm:
midspan displacement would be
= -0.04 – (-)0.12
= 0.08 (~1/16") vs. 0.078 or 0.079 (LUSAS)





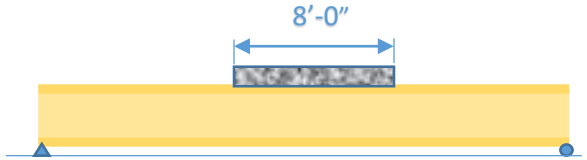


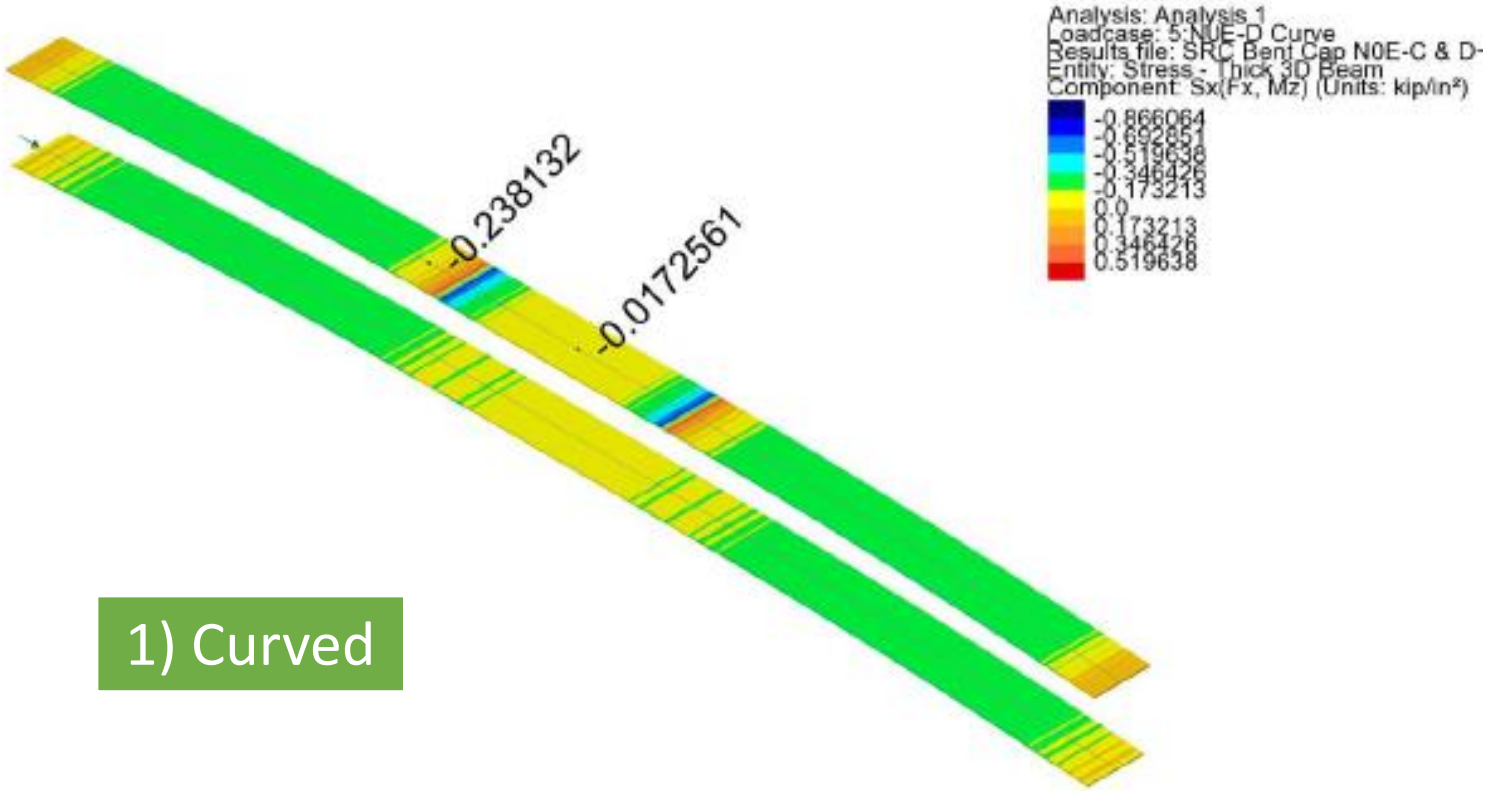
73°F was ambient/steel at early morning, not to be confused with 94°F ambient temperature at 2pm.

FDOT TRANSPORTATION SYMPOSIUM

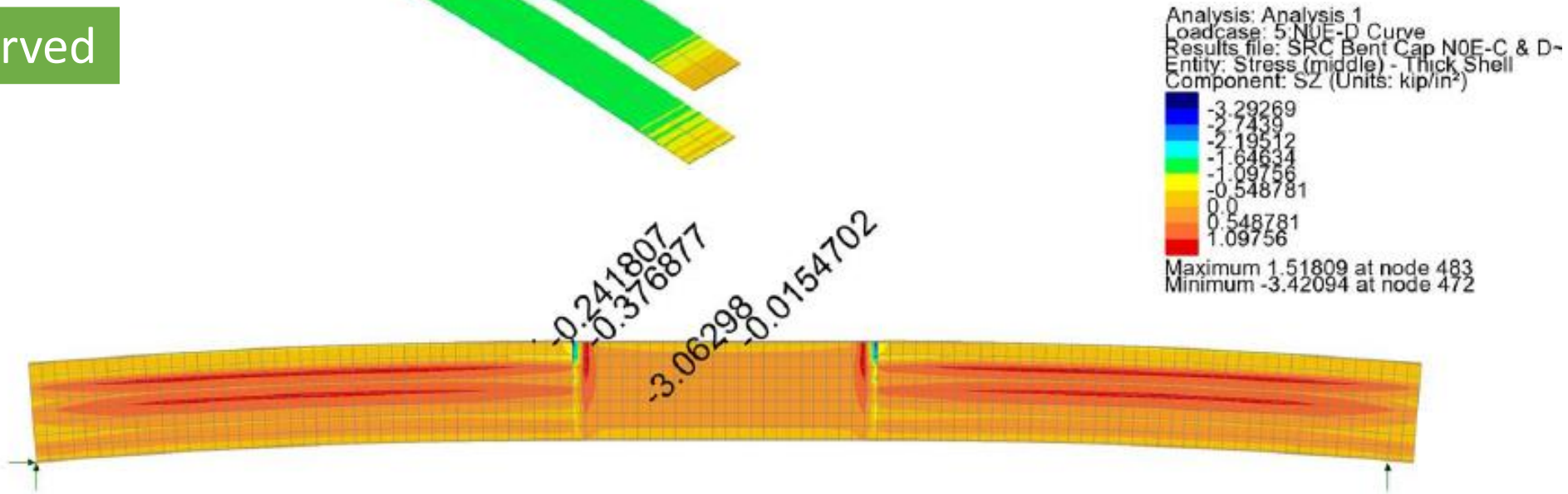
N-S D

Structural Analysis Model using LUSAS (stresses)





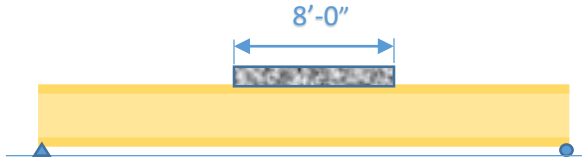
1) Curved

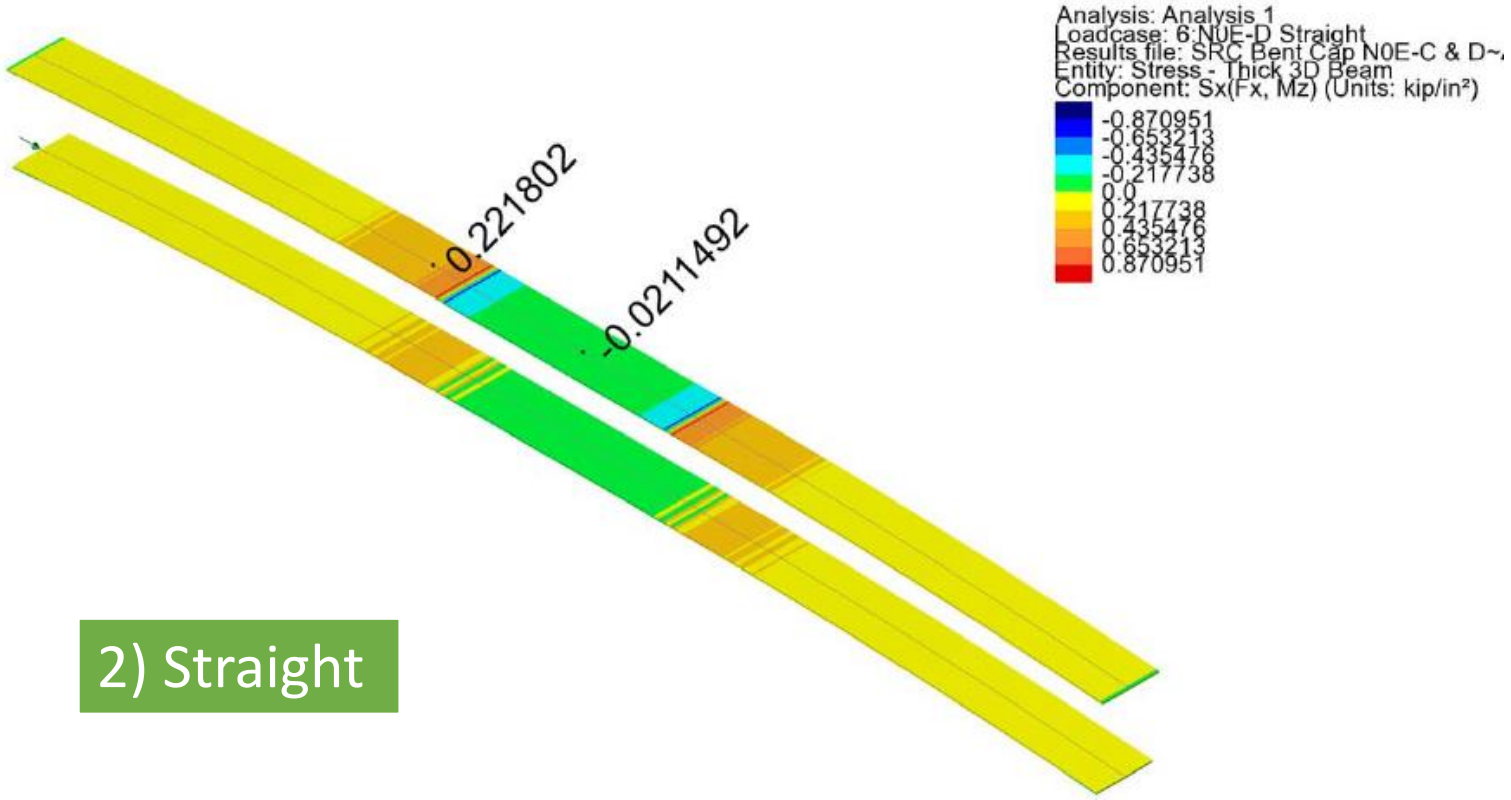


FDOT TRANSPORTATION SYMPOSIUM

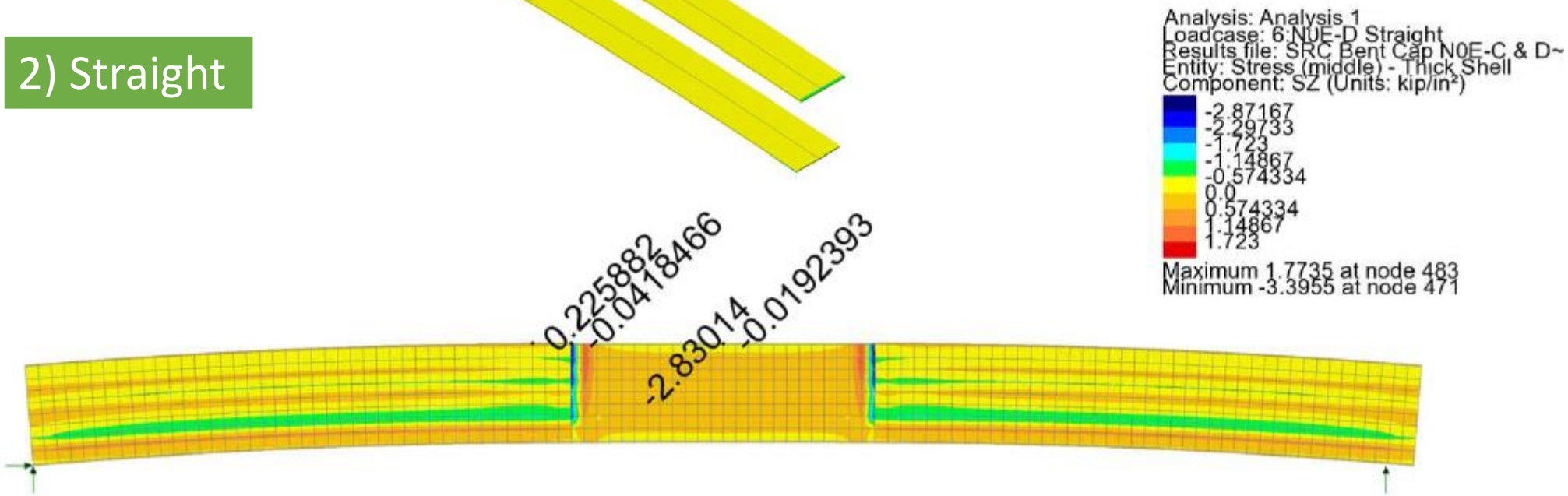
N-S D

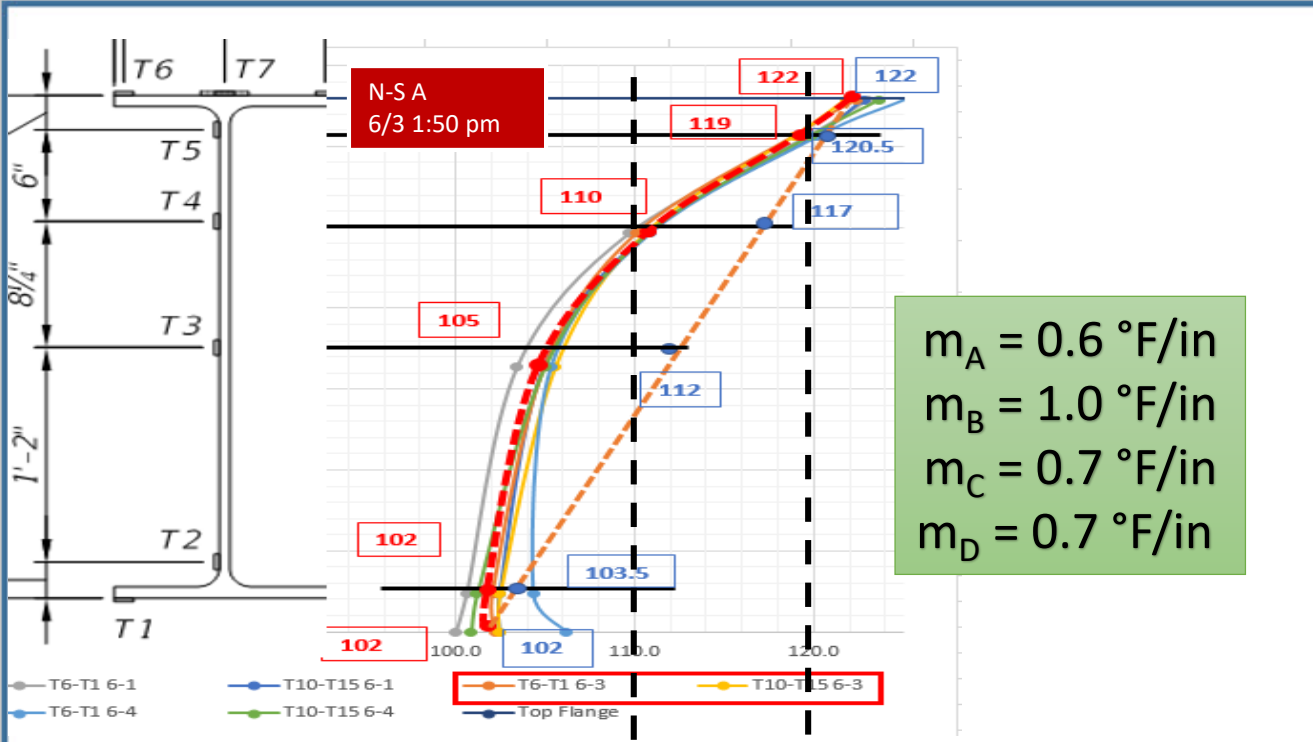
Structural Analysis Model using LUSAS (stresses)



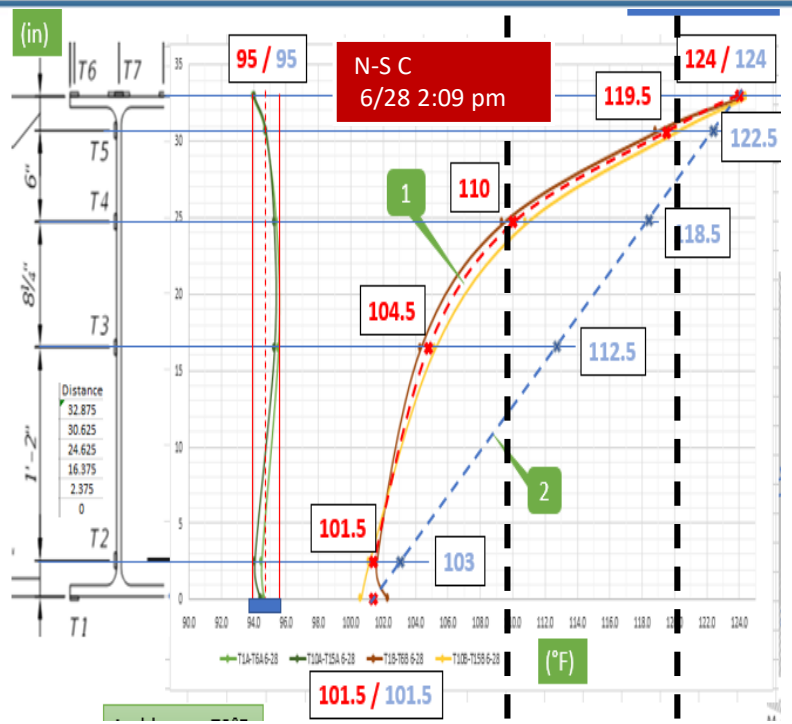


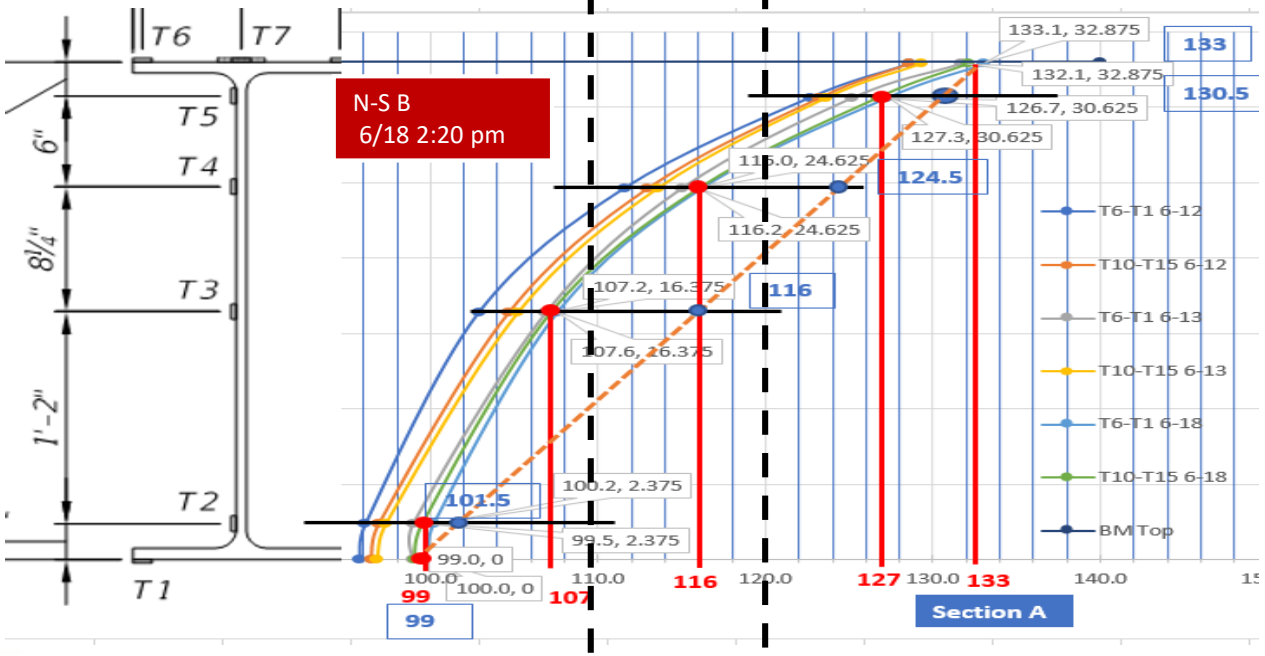
2) Straight

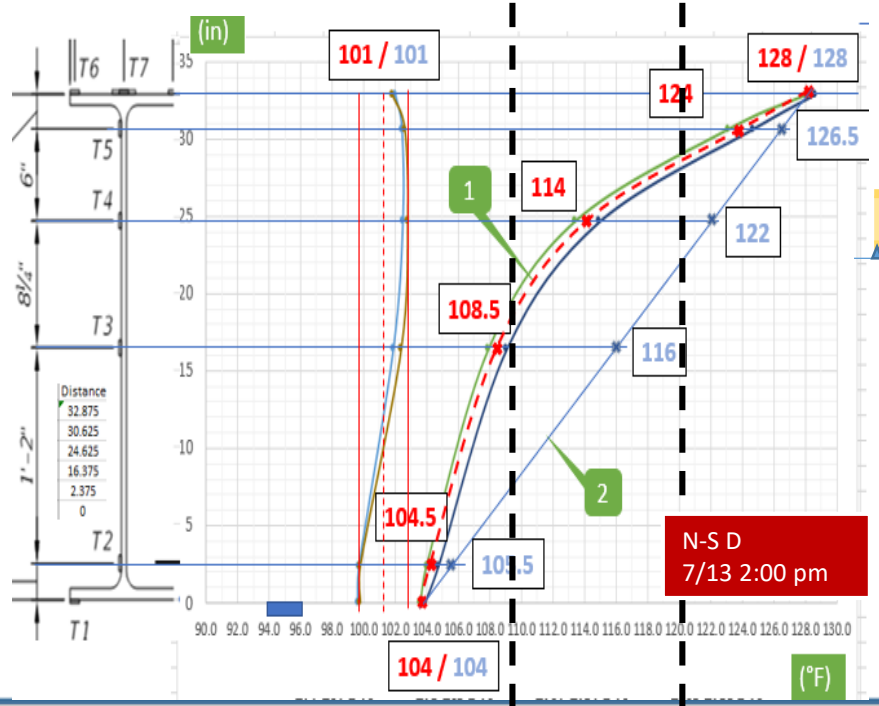




$m_A = 0.6$ °F/in
$m_B = 1.0$ °F/in
$m_C = 0.7$ °F/in
$m_D = 0.7$ °F/in

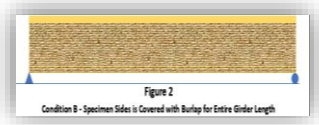




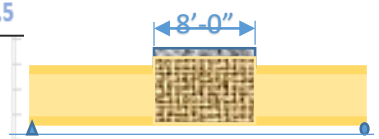


N-S A-rev1

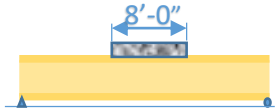
N-S B



N-S C



N-S D

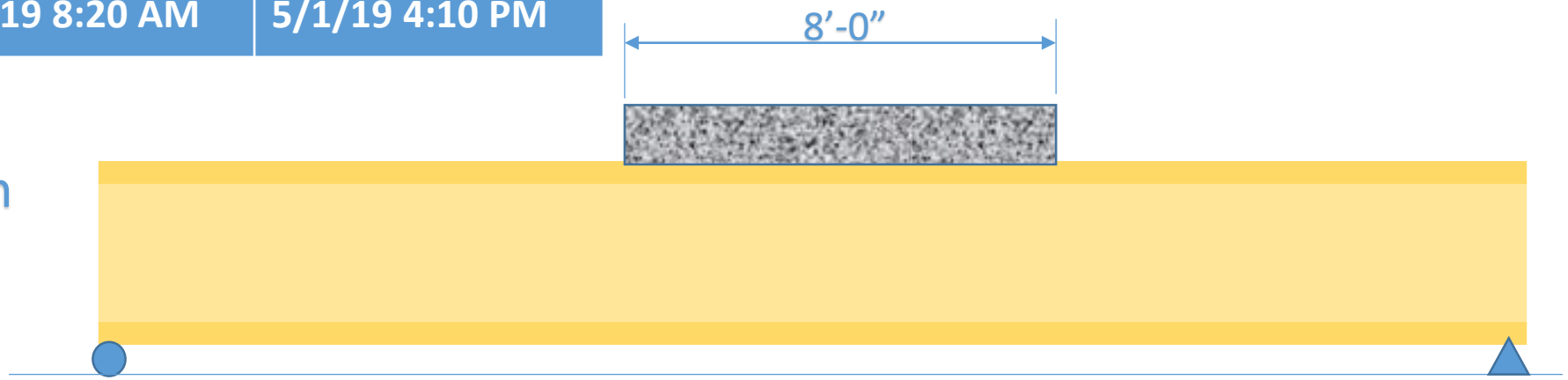


FDOT TRANSPORTATION SYMPOSIUM

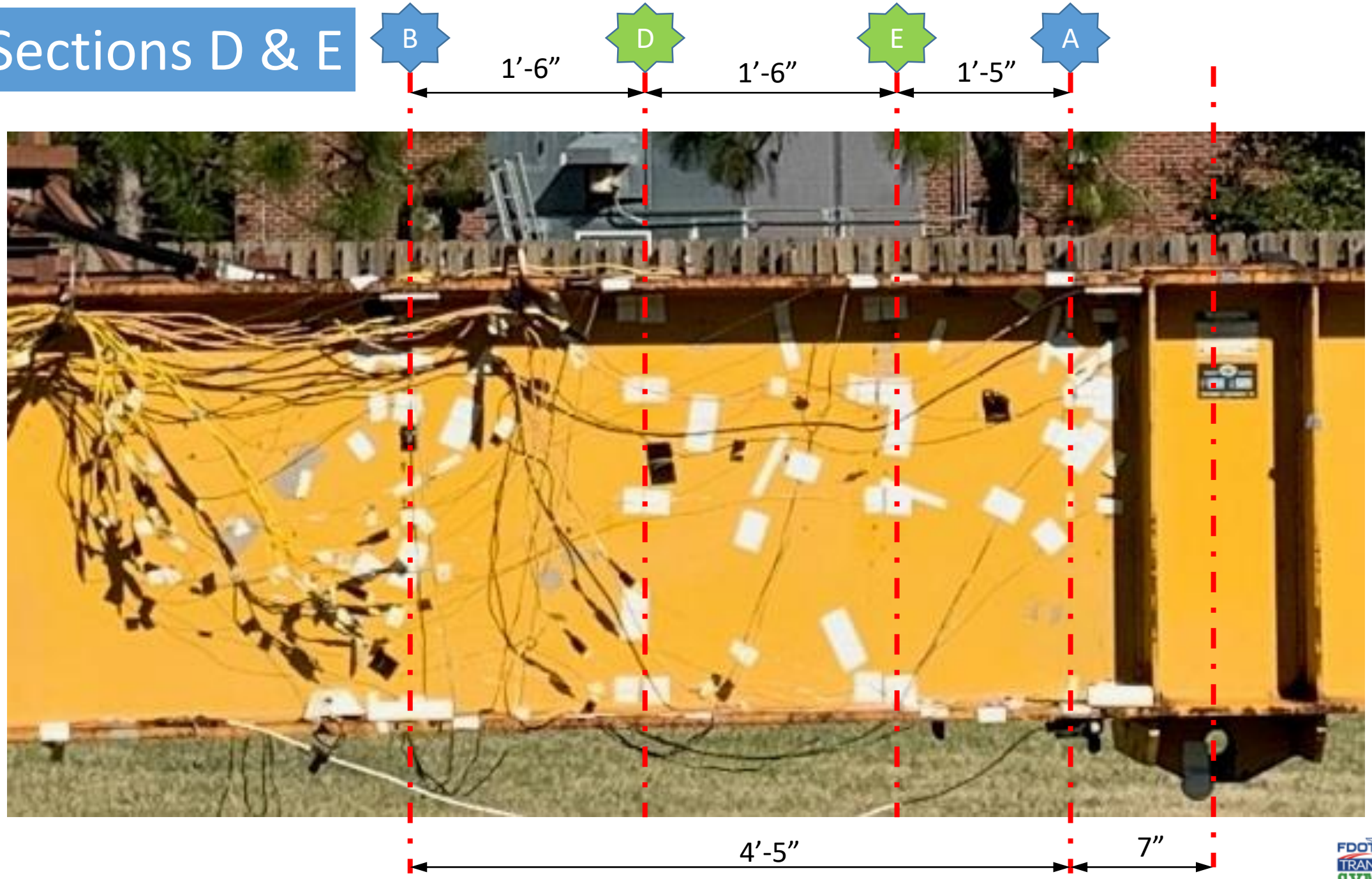
E-W D

E-W D	4/25/19 8:20 AM	5/1/19 4:10 PM

4- Shaded top with concrete slab

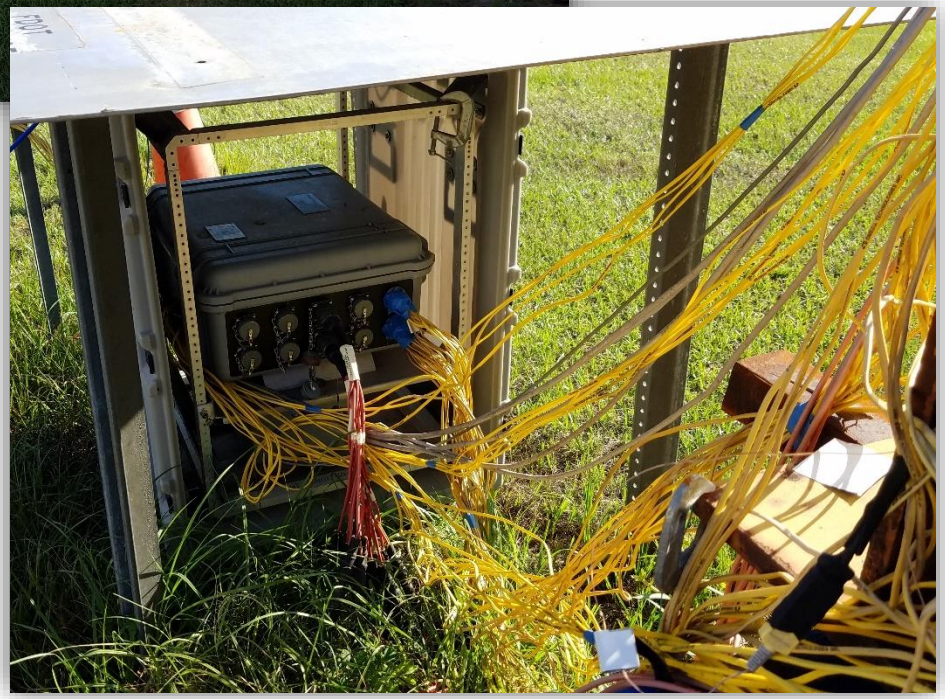


New Sections D & E

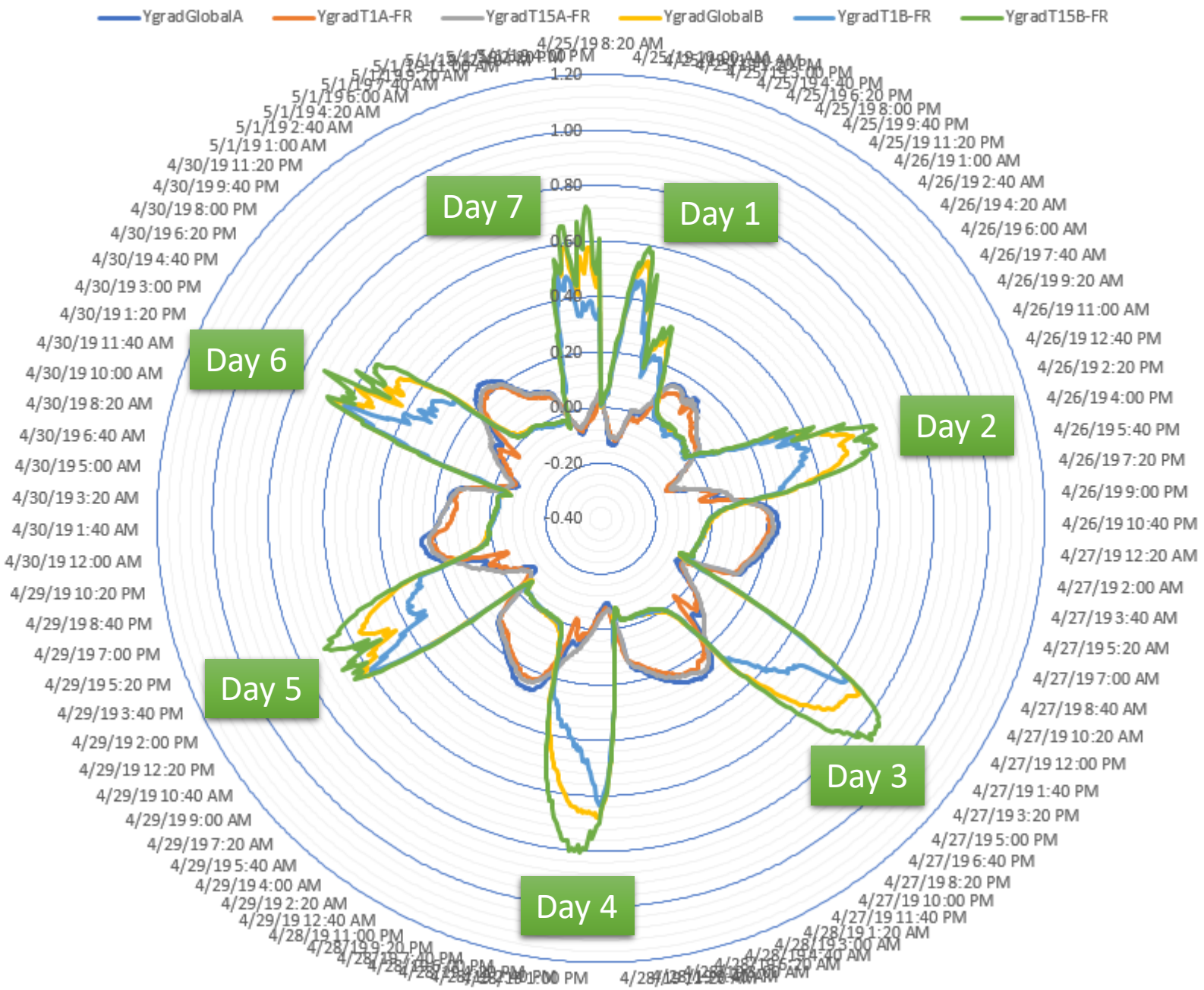


FDOT TRANSPORTATION SYMPOSIUM

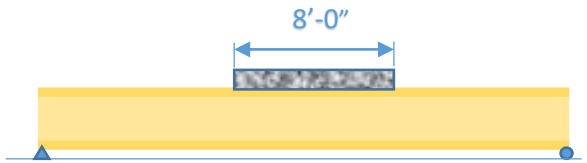
5 TON CA



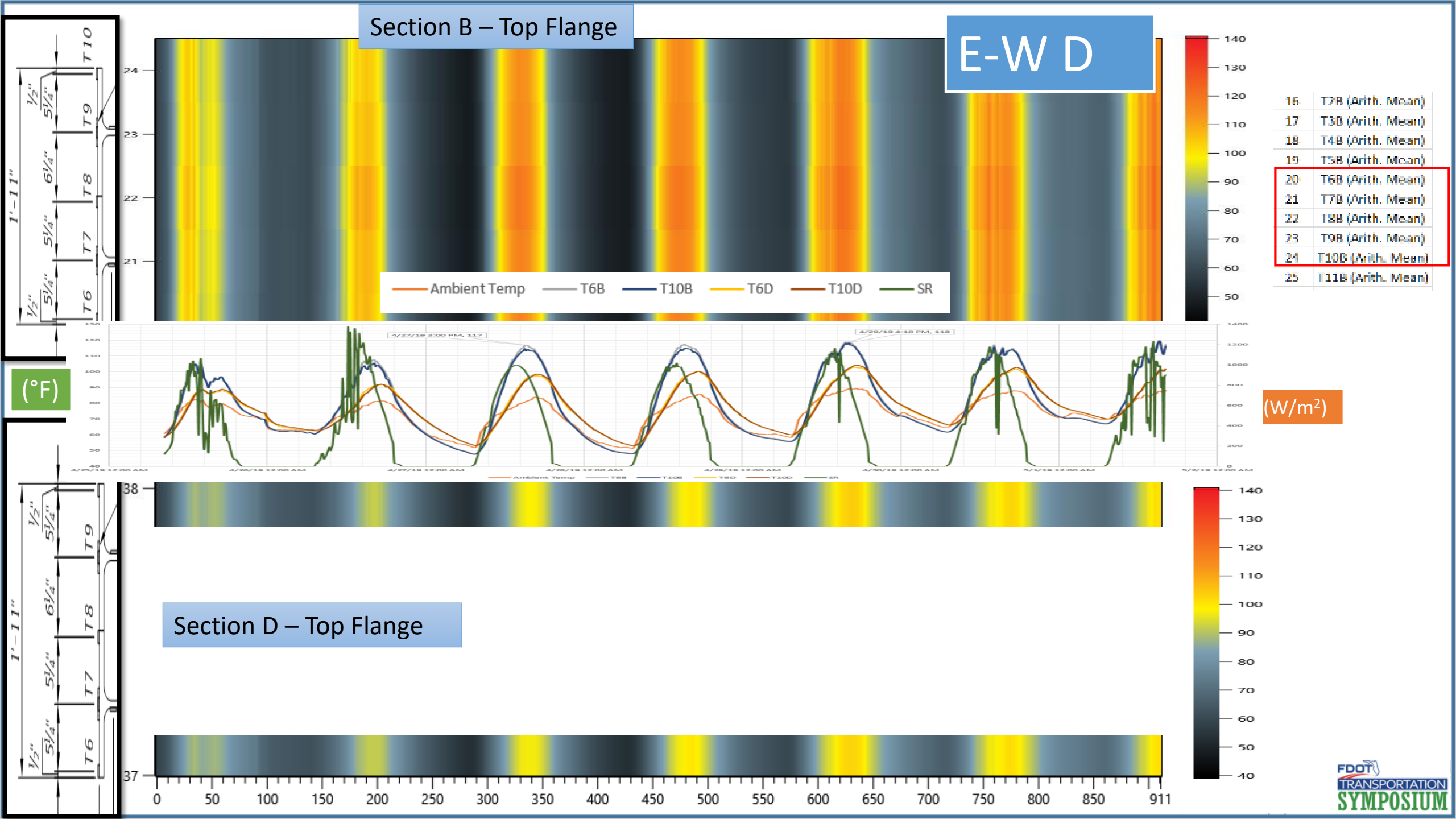
S.R.C.-C O



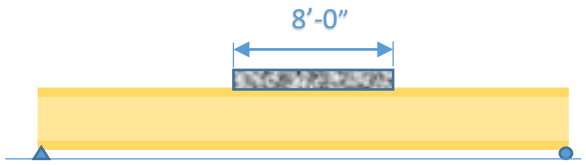
E-W D

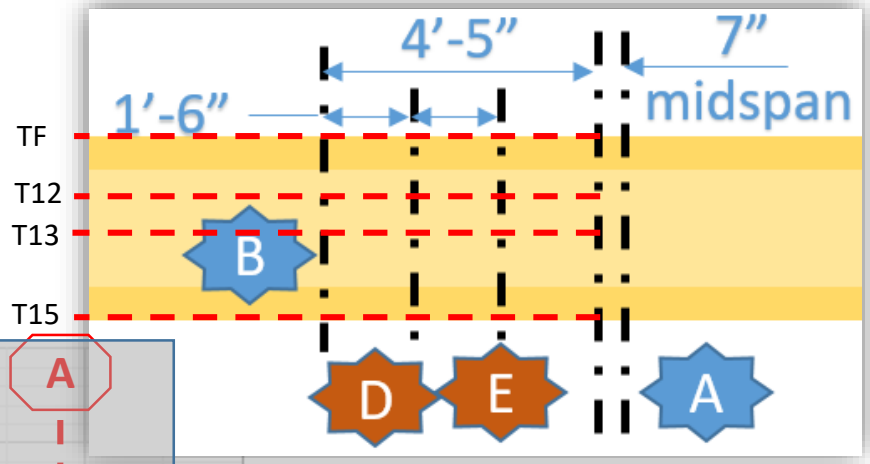


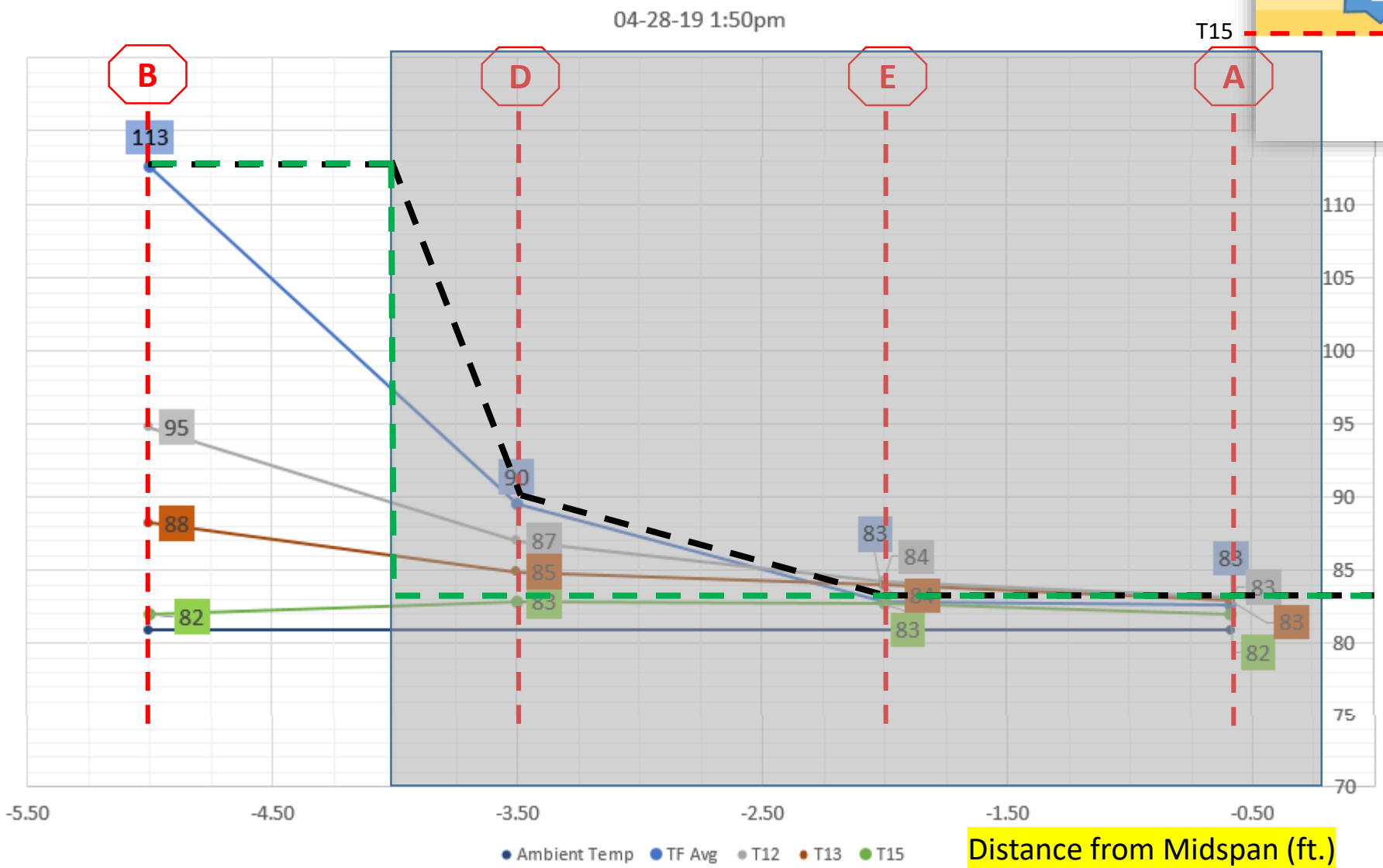
FDOT TRANSPORTATION SYMPOSIUM

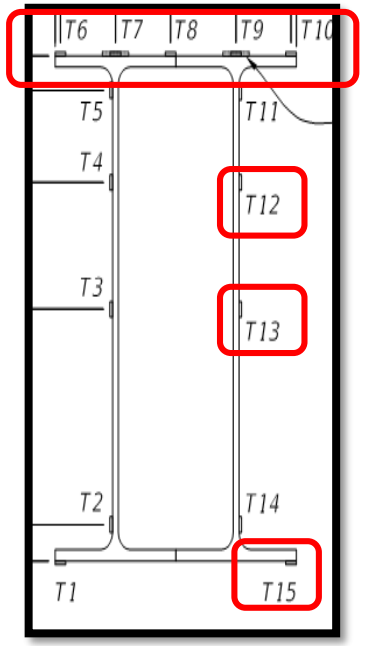

Section B – Top Flange
E-W D
Section D – Top Flange
(°F)
(W/m²)
Ambient Temp
T6B
T10B
T6D
T10D
SR
16 T2B (Arith. Mean)
17 T3B (Arith. Mean)
18 T4B (Arith. Mean)
19 T5B (Arith. Mean)
20 T6B (Arith. Mean)
21 T7B (Arith. Mean)
22 T8B (Arith. Mean)
23 T9B (Arith. Mean)
24 T10B (Arith. Mean)
25 T11B (Arith. Mean)
FDOT TRANSPORTATION SYMPOSIUM

E-W D









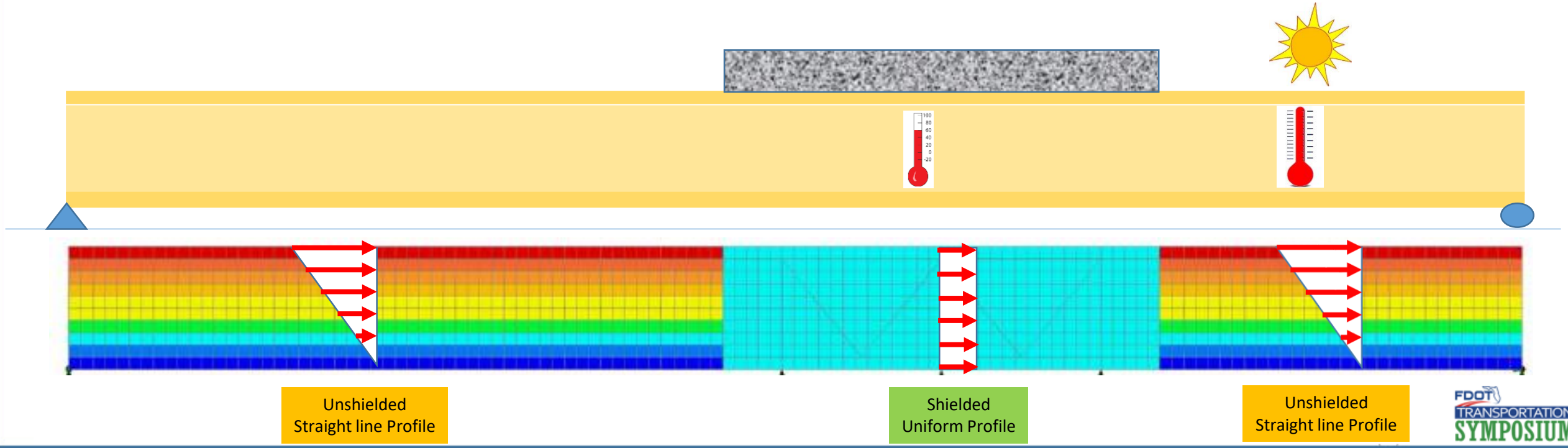
FDOT TRANSPORTATION SYMPOSIUM

Preliminary Conclusions

The steel box can be divided into two sections:
unshielded and shielded from solar radiation with each section having a separate temperature gradient

The temperature gradient can be modeled with a straight line profile
Even though the actual temperature profile is curved, FEM analysis showed the difference in strains between the two profiles is insignificant

FEM Techniques
LUSAS software
Flanges were modeled with thick beam elements (BMI21) and the web with thick shell elements (QTS4)
The web was divided into 8 horizontal layers to allow different temperature loads
The temperature load requires an initial and a final temperature

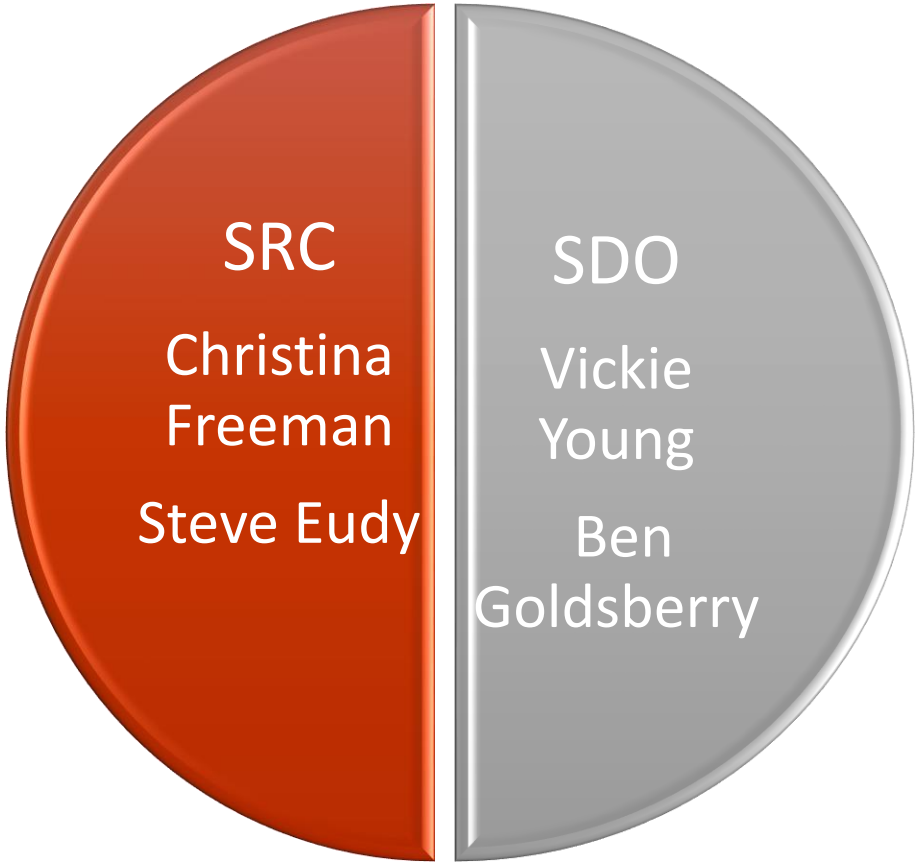


Phase 1 – SRC

Phase 2 – FEM (LUSAS) large scale model (in-progress)

Phase 3 – Field Instrumentation of Existing Bridges and FEM Evaluation (TBD)

Phase 4
Revisions
to SDG
SDM
460



Thank You

Dennis Golabek, P.E.

WSP

FTS 2019

FDOT TRANSPORTATION SYMPOSIUM