Appendix E

Validation of the Product $\alpha(\Delta T/D)$

Table E- 1: Experimental matrix

	Validation#1	Validation#2	Validation#3	Validation#4	Validation#5	Validation#6	Validation#7	Validation#8	Validation#9
Shoulder Type	PCC	AC	Widened Lane	PCC	AC	Widened Lane	PCC	AC	Widened Lane
PCC thickness, in.	10"	10"	10"	12"	12"	12"	8"	8"	8"
Base/subbase thickness, in.	16"	26"	4"	26"	4"	16"	4"	16"	26"
k-value, psi/in.	100	30	200	200	100	30	30	200	100
Loading type	Single Axle	Tandem Axle	Multi-Axle (8)	Tandem Axle	Multi-Axle (8)	Single Axle	Multi-Axle (8)	Single Axle	Tandem Axle
Joint spacing, in.	177	315	315	177	177	315	315	177	177

Table E- 2: Validation#1

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	118.2	76.0	75.6	0	5.00	116.1	74.8	74.0
2.5	+2 or -2	1.25	141.9	89.4	94.5	+0.5 or -0.5	5.00	141.9	89.4	94.5
5.0	+2 or -2	2.50	167.7	104.0	115.1	+1 or -1	5.00	167.7	104.0	115.1
7.5	+2 or -2	3.75	193.4	118.6	135.6	+1.5 or -1.5	5.00	193.4	118.6	135.6
10.0	+2 or -2	5.00	219.2	133.2	156.2	+2 or -2	5.00	219.2	133.2	156.2
12.5	+2 or -2	6.25	245.2	149.7	177.3	+2.5 or -2.5	5.00	245.2	149.7	177.3
15.0	+2 or -2	7.50	271.2	166.3	198.3	+3 or -3	5.00	271.2	166.3	198.3
17.5	+2 or -2	8.75	297.2	182.8	219.4	+3.5 or -3.5	5.00	297.2	182.8	219.4
20.0	+2 or -2	10.00	323.2	199.3	240.4	+4 or -4	5.00	323.2	199.3	240.4

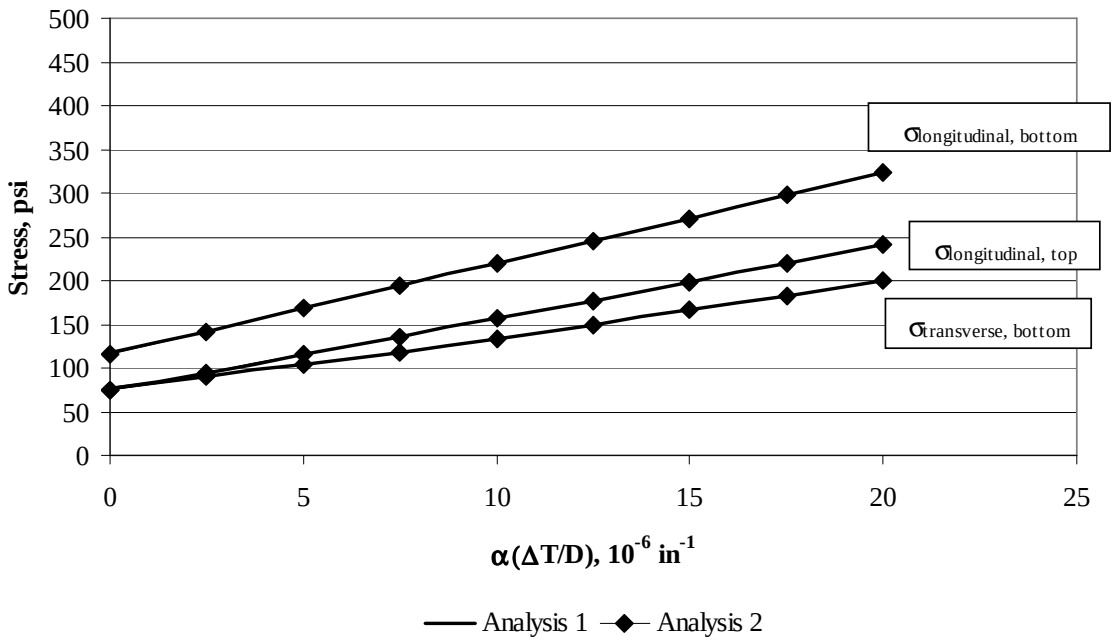

Figure E- 1: Plot of validation#1

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: PCC
- PCC thickness: 10”
- Base/subbase thickness: 16”
- k-value: 100 psi/in.
- Loading type: single axle
- Joint spacing: 177”

Table E- 3: Validation#2

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	201.6	78.0	125.3	0	5.00	198.1	77.0	122.7
2.5	+2 or -2	1.25	241.8	89.6	155.4	+0.5 or -0.5	5.00	241.8	89.6	155.4
5.0	+2 or -2	2.50	285.6	102.2	188.1	+1 or -1	5.00	285.6	102.2	188.1
7.5	+2 or -2	3.75	329.3	114.7	220.7	+1.5 or -1.5	5.00	329.3	114.7	220.7
10.0	+2 or -2	5.00	373.0	127.3	253.4	+2 or -2	5.00	373.0	127.3	253.4
12.5	+2 or -2	6.25	416.8	139.9	296.6	+2.5 or -2.5	5.00	416.8	139.9	296.6
15.0	+2 or -2	7.50	460.5	152.4	339.7	+3 or -3	5.00	460.5	152.4	339.7
17.5	+2 or -2	8.75	504.3	165.0	382.9	+3.5 or -3.5	5.00	504.3	165.0	382.9
20.0	+2 or -2	10.00	548.0	177.5	426.0	+4 or -4	5.00	548.0	177.5	426.0

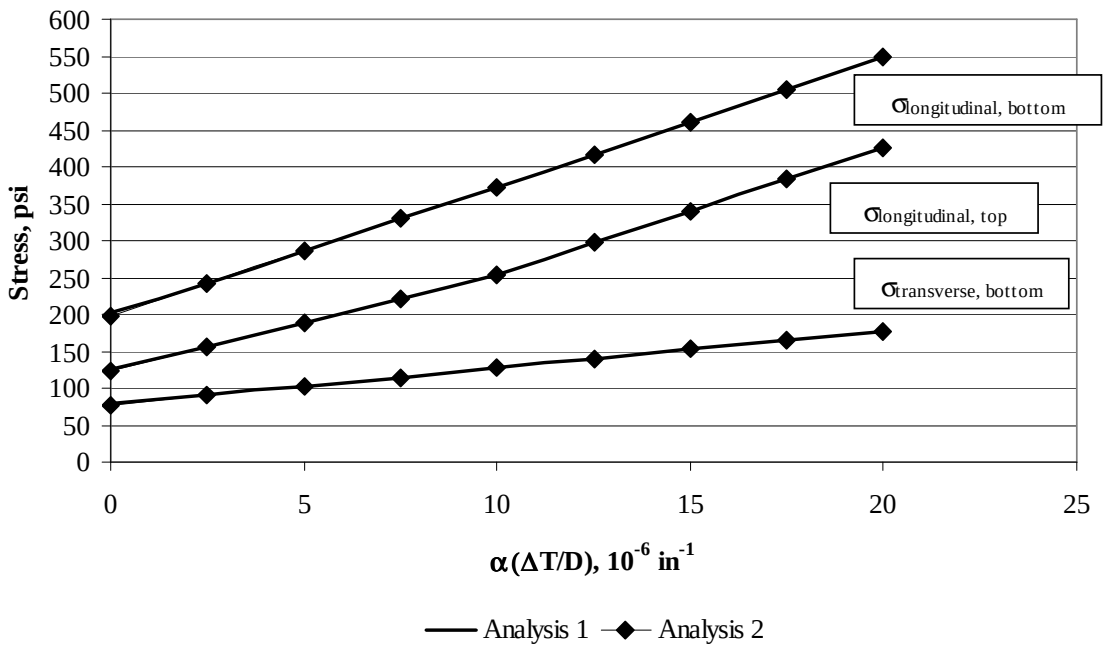

Figure E- 2: Plot of validation#2

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: AC
- PCC thickness: 10”
- Base/subbase thickness: 26”
- k-value: 30 psi/in.
- Loading type: tandem axle
- Joint spacing 315”

Table E- 4: Validation#3

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	57.2	88.8	29.5	0	5.00	52.8	86.4	24.8
2.5	+2 or -2	1.25	107.8	116.7	84.1	+0.5 or -0.5	5.00	107.8	116.7	84.1
5.0	+2 or -2	2.50	162.9	147.0	143.4	+1 or -1	5.00	162.9	147.0	143.4
7.5	+2 or -2	3.75	217.9	177.3	202.7	+1.5 or -1.5	5.00	217.9	177.3	202.7
10.0	+2 or -2	5.00	272.9	207.6	262.0	+2 or -2	5.00	272.9	207.6	262.0
12.5	+2 or -2	6.25	331.3	240.2	316.3	+2.5 or -2.5	5.00	331.3	240.2	316.3
15.0	+2 or -2	7.50	389.7	272.9	370.7	+3 or -3	5.00	389.7	272.9	370.7
17.5	+2 or -2	8.75	448.0	305.5	425.0	+3.5 or -3.5	5.00	448.0	305.5	425.0
20.0	+2 or -2	10.00	506.4	338.1	479.3	+4 or -4	5.00	506.4	338.1	479.3

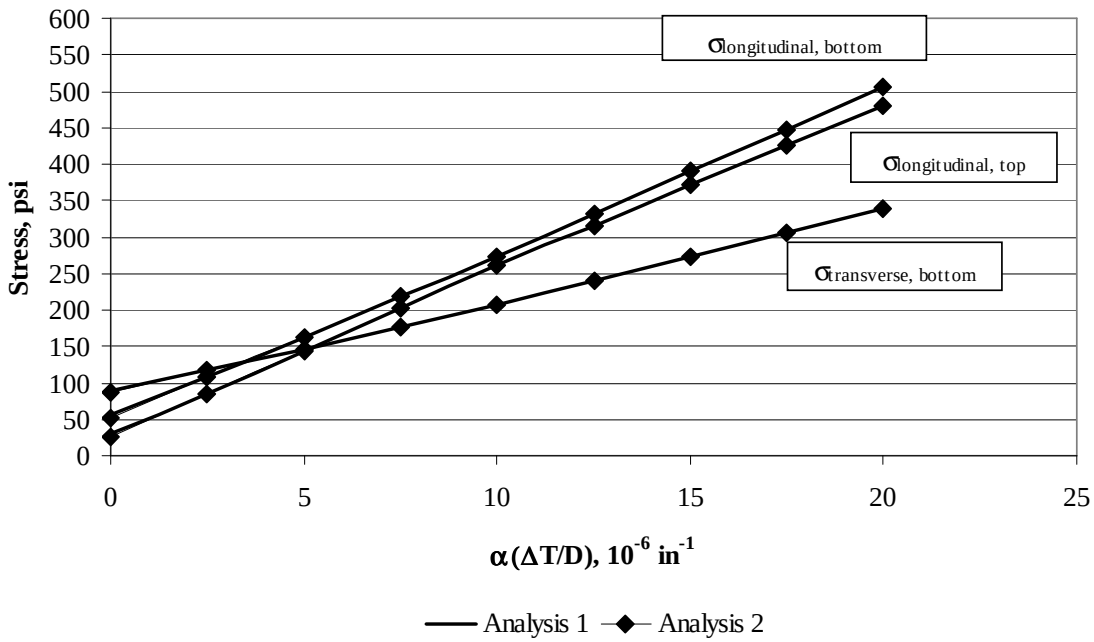

Figure E- 3: Plot of validation#3

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: Widened lane
- PCC thickness: 10”
- Base/subbase thickness: 4”
- k-value: 200 psi/in.
- Loading type: Multi-axle (8)
- Joint spacing 315”

Table E- 5: Validation#4

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	88.1	60.4	64.9	0	5.00	85.5	58.6	62.5
2.5	+2 or -2	1.25	118.4	81.1	91.9	+0.5 or -0.5	5.00	118.4	81.1	91.9
5.0	+2 or -2	2.50	151.4	103.5	121.2	+1 or -1	5.00	151.4	103.5	121.2
7.5	+2 or -2	3.75	184.3	126.0	150.6	+1.5 or -1.5	5.00	184.3	126.0	150.6
10.0	+2 or -2	5.00	217.2	148.4	179.9	+2 or -2	5.00	217.2	148.4	179.9
12.5	+2 or -2	6.25	248.6	169.6	206.8	+2.5 or -2.5	5.00	248.6	169.6	206.8
15.0	+2 or -2	7.50	280.1	190.8	233.7	+3 or -3	5.00	280.1	190.8	233.7
17.5	+2 or -2	8.75	311.5	211.9	260.6	+3.5 or -3.5	5.00	311.5	211.9	260.6
20.0	+2 or -2	10.00	342.9	233.1	287.5	+4 or -4	5.00	342.9	233.1	287.5

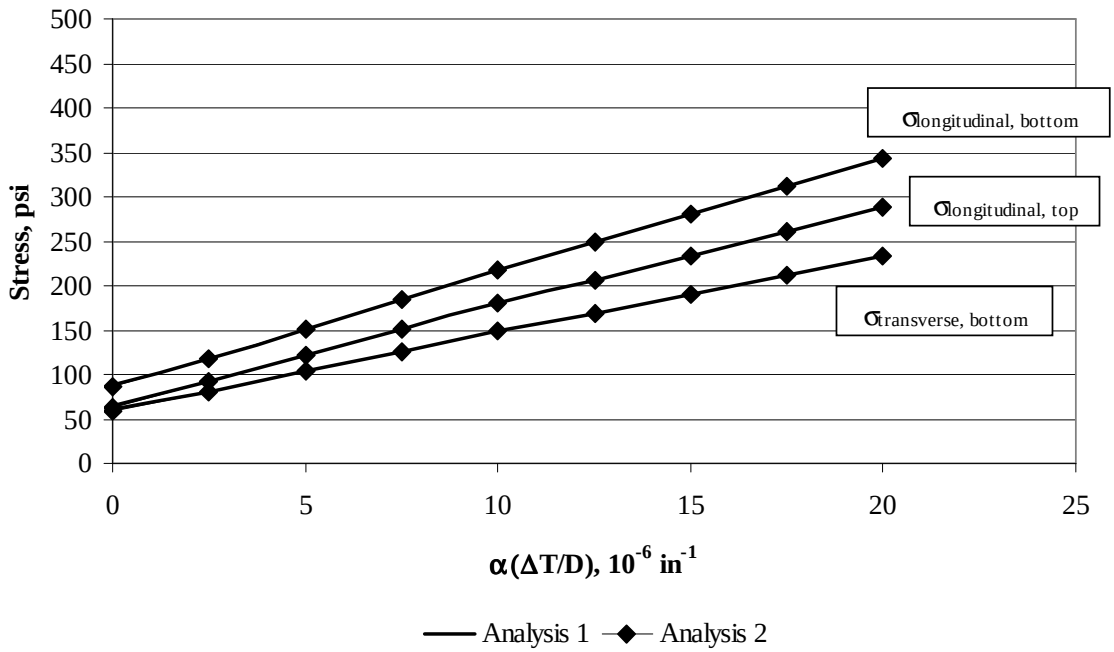

Figure E- 4: Plot of validation#4

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: PCC
- PCC thickness: 12”
- Base/subbase thickness: 26”
- k-value: 200 psi/in.
- Loading type: tandem axle
- Joint spacing 177”

Table E- 6: Validation#5

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	52.9	56.6	66.4	0	5.00	51.6	55.8	65.0
2.5	+2 or -2	1.25	68.4	65.7	82.5	+0.5 or -0.5	5.00	68.4	65.7	82.5
5.0	+2 or -2	2.50	85.1	75.6	100.1	+1 or -1	5.00	85.1	75.6	100.1
7.5	+2 or -2	3.75	101.9	85.4	117.6	+1.5 or -1.5	5.00	101.9	85.4	117.6
10.0	+2 or -2	5.00	118.6	95.3	135.2	+2 or -2	5.00	118.6	95.3	135.2
12.5	+2 or -2	6.25	133.3	106.6	147.8	+2.5 or -2.5	5.00	133.3	106.6	147.8
15.0	+2 or -2	7.50	148.0	118.0	160.3	+3 or -3	5.00	148.0	118.0	160.3
17.5	+2 or -2	8.75	162.6	129.3	172.9	+3.5 or -3.5	5.00	162.6	129.3	172.9
20.0	+2 or -2	10.00	177.3	140.6	185.4	+4 or -4	5.00	177.3	140.6	185.4

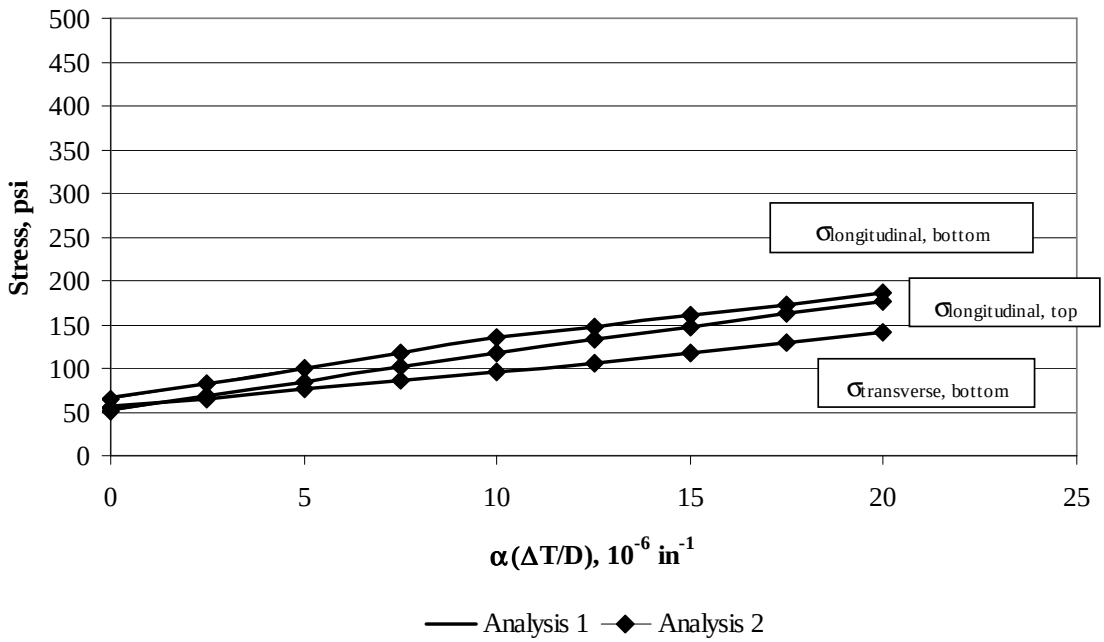

Figure E- 5: Plot of validation#5

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: AC
- PCC thickness: 12”
- Base/subbase thickness: 4”
- k-value: 100 psi/in.
- Loading type: Multi-axle (8)
- Joint spacing 177”

Table E- 7: Validation#6

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	124.1	63.0	64.3	0	5.00	120.7	62.3	61.3
2.5	+2 or -2	1.25	162.9	70.5	98.5	+0.5 or -0.5	5.00	162.9	70.5	98.5
5.0	+2 or -2	2.50	205.1	78.7	135.8	+1 or -1	5.00	205.1	78.7	135.8
7.5	+2 or -2	3.75	247.2	86.8	173.0	+1.5 or -1.5	5.00	247.2	86.8	173.0
10.0	+2 or -2	5.00	289.4	95.0	210.2	+2 or -2	5.00	289.4	95.0	210.2
12.5	+2 or -2	6.25	331.6	103.2	252.6	+2.5 or -2.5	5.00	331.6	103.2	252.6
15.0	+2 or -2	7.50	373.8	111.3	295.0	+3 or -3	5.00	373.8	111.3	295.0
17.5	+2 or -2	8.75	416.0	119.5	337.3	+3.5 or -3.5	5.00	416.0	119.5	337.3
20.0	+2 or -2	10.00	458.2	127.6	379.7	+4 or -4	5.00	458.2	127.6	379.7

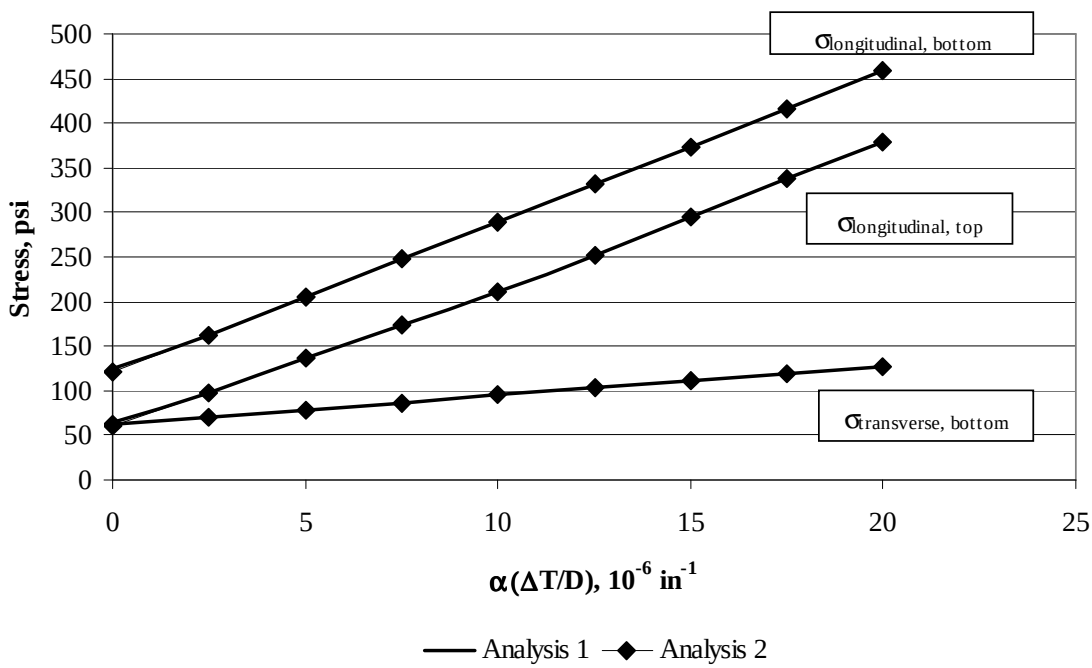

Figure E- 6: Plot of validation#6

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: Widened lane
- PCC thickness: 12”
- Base/subbase thickness: 16”
- k-value: 30 psi/in.
- Loading type: single axle
- Joint spacing 315”

Table E- 8: Validation#7

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	113.9	158.4	68.9	0	5.00	111.2	157.8	65.7
2.5	+2 or -2	1.25	144.7	165.2	105.8	+0.5 or -0.5	5.00	144.7	165.2	105.8
5.0	+2 or -2	2.50	178.2	172.6	145.9	+1 or -1	5.00	178.2	172.6	145.9
7.5	+2 or -2	3.75	211.7	179.9	185.9	+1.5 or -1.5	5.00	211.7	179.9	185.9
10.0	+2 or -2	5.00	245.2	187.3	226.0	+2 or -2	5.00	245.2	187.3	226.0
12.5	+2 or -2	6.25	284.4	196.0	264.8	+2.5 or -2.5	5.00	284.4	196.0	264.8
15.0	+2 or -2	7.50	323.6	204.7	303.6	+3 or -3	5.00	323.6	204.7	303.6
17.5	+2 or -2	8.75	362.7	213.4	342.3	+3.5 or -3.5	5.00	362.7	213.4	342.3
20.0	+2 or -2	10.00	401.9	222.1	381.1	+4 or -4	5.00	401.9	222.1	381.1

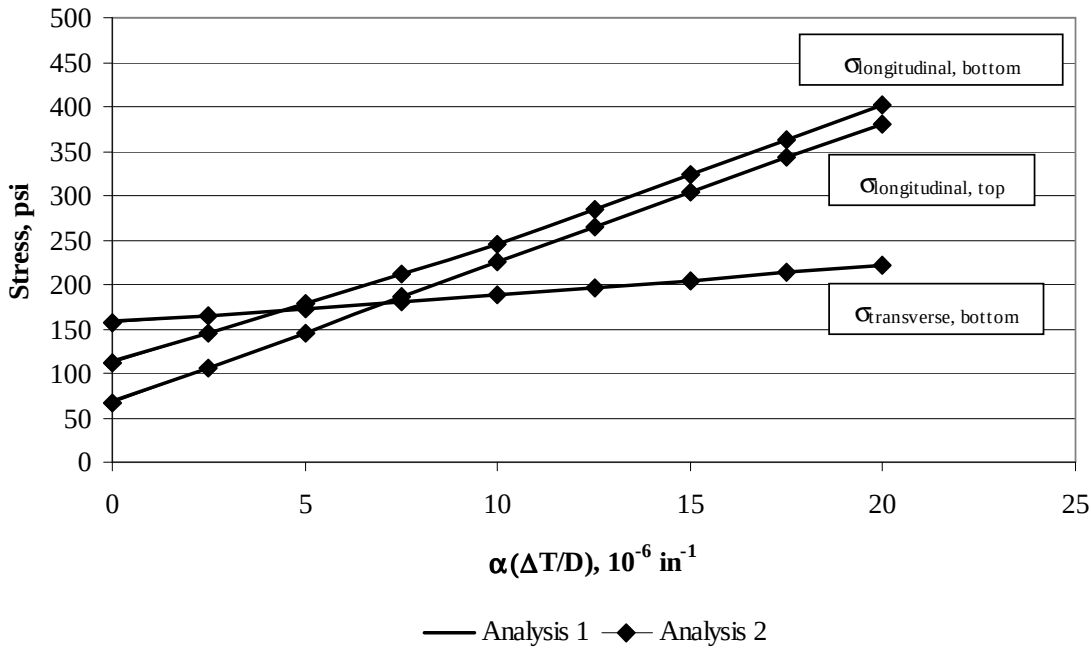

Figure E- 7: Plot of validation#7

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: PCC
- PCC thickness: 8”
- Base/subbase thickness: 4”
- k-value: 30 psi/in.
- Loading type: Multi-axle (8)
- Joint spacing 315”

Table E- 9: Validation#8

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	154.8	96.5	87.1	0	5.00	151.9	94.4	84.9
2.5	+2 or -2	1.25	188.7	120.4	112.1	+0.5 or -0.5	5.00	188.7	120.4	112.1
5.0	+2 or -2	2.50	225.4	146.4	139.4	+1 or -1	5.00	225.4	146.4	139.4
7.5	+2 or -2	3.75	262.2	172.4	166.6	+1.5 or -1.5	5.00	262.2	172.4	166.6
10.0	+2 or -2	5.00	298.9	198.4	193.8	+2 or -2	5.00	298.9	198.4	193.8
12.5	+2 or -2	6.25	335.5	227.6	228.0	+2.5 or -2.5	5.00	335.5	227.6	228.0
15.0	+2 or -2	7.50	372.1	256.8	262.3	+3 or -3	5.00	372.1	256.8	262.3
17.5	+2 or -2	8.75	408.7	286.0	296.5	+3.5 or -3.5	5.00	408.7	286.0	296.5
20.0	+2 or -2	10.00	445.3	315.2	330.7	+4 or -4	5.00	445.3	315.2	330.7

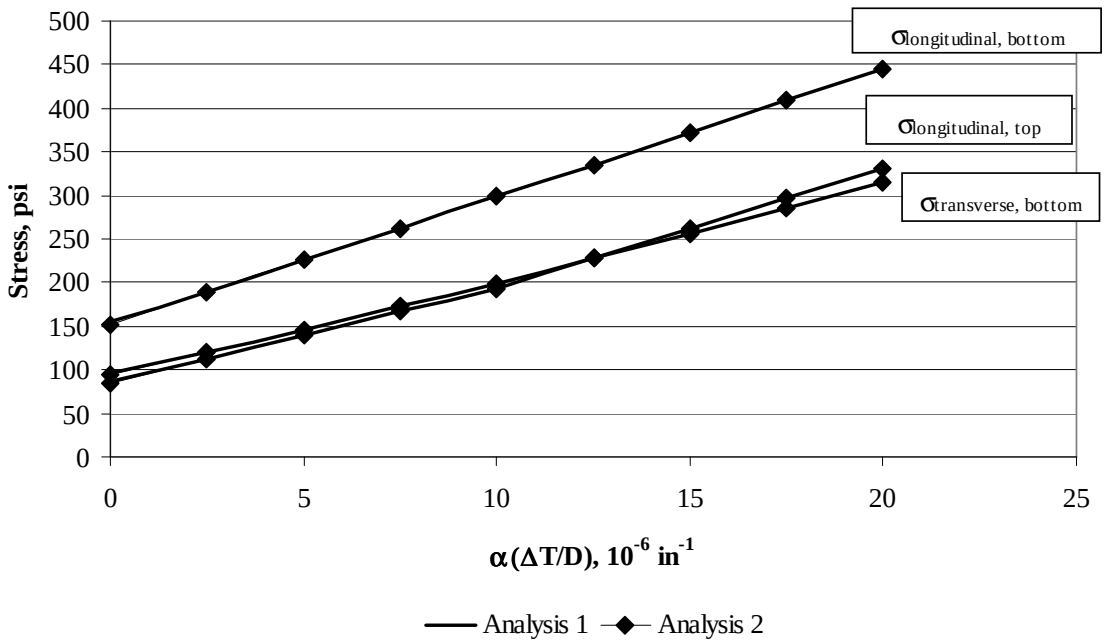

Figure E- 8: Plot of validation#8

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: AC
- PCC thickness: 8”
- Base/subbase thickness: 16”
- k-value: 200 psi/in.
- Loading type: single axle
- Joint spacing 177”

Table E- 10: Validation#9

$\alpha(\Delta T/D)$ (10^{-6} in.$^{-1}$)	Analysis 1					Analysis 2				
	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)	Gradient (^{o}F/in.)	CTE (10^{-6} in./in./^{o}F)	$\sigma_{long,bottom}$ (psi)	$\sigma_{trans,bottom}$ (psi)	$\sigma_{long,top}$ (psi)
0.0	+2 or -2	0.10	153.8	108.4	79.3	0	5.00	151.4	106.3	77.1
2.5	+2 or -2	1.25	181.9	132.2	105.1	+0.5 or -0.5	5.00	181.9	132.2	105.1
5.0	+2 or -2	2.50	212.4	158.2	133.1	+1 or -1	5.00	212.4	158.2	133.1
7.5	+2 or -2	3.75	242.8	184.1	161.2	+1.5 or -1.5	5.00	242.8	184.1	161.2
10.0	+2 or -2	5.00	273.3	210.0	189.2	+2 or -2	5.00	273.3	210.0	189.2
12.5	+2 or -2	6.25	303.8	237.2	220.0	+2.5 or -2.5	5.00	303.8	237.2	220.0
15.0	+2 or -2	7.50	334.3	264.4	250.8	+3 or -3	5.00	334.3	264.4	250.8
17.5	+2 or -2	8.75	364.8	291.6	281.5	+3.5 or -3.5	5.00	364.8	291.6	281.5
20.0	+2 or -2	10.00	395.3	318.8	312.3	+4 or -4	5.00	395.3	318.8	312.3

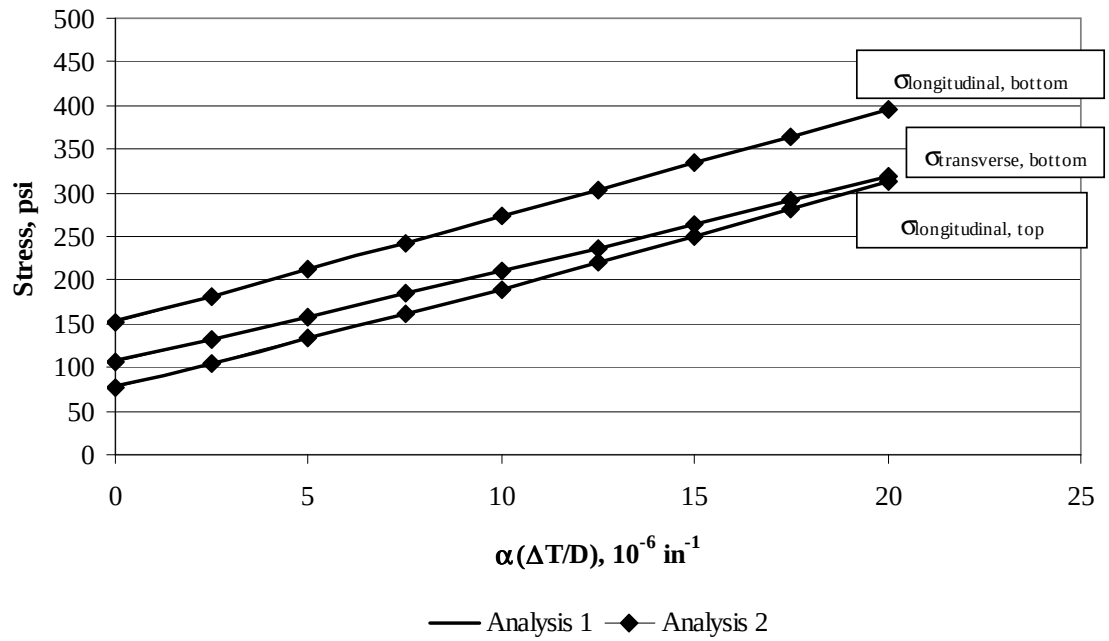

Figure E- 9: Plot of validation#9

Analysis 1: Constant temperature gradient (+2 ^{o}F/in.) with variation of CTE (0.1×10^{-6} to 10×10^{-6} in./in./^{o}F)

Analysis 2: Constant CTE (5×10^{-6} in./in./^{o}F) with variation of temperature gradient (0 to +4 ^{o}F/in.)

- Shoulder type: Widened lane
- PCC thickness: 8”
- Base/subbase thickness: 26”
- k-value: 100 psi/in.
- Loading type: tandem axle
- Joint spacing 177”