Climatic Considerations

Bonded Concrete Overlay of Asphalt Pavements
Mechanistic-Empirical Design Guide (BCOA – ME)

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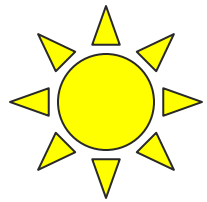
FHWA Pooled Fund Study TPF 5-165

- Effective temperature gradient
- Temperature dependence of E_{HMA}

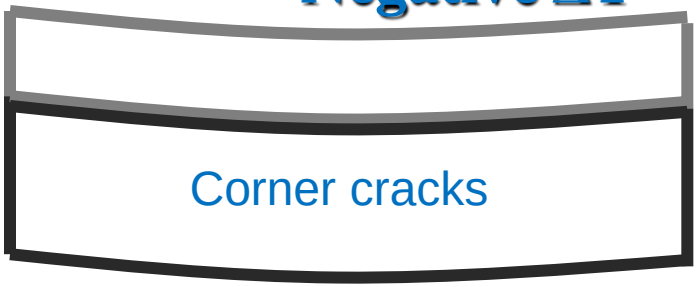
EFFECTIVE TEMPERATURE GRADIENTS

Effective temp. gradient

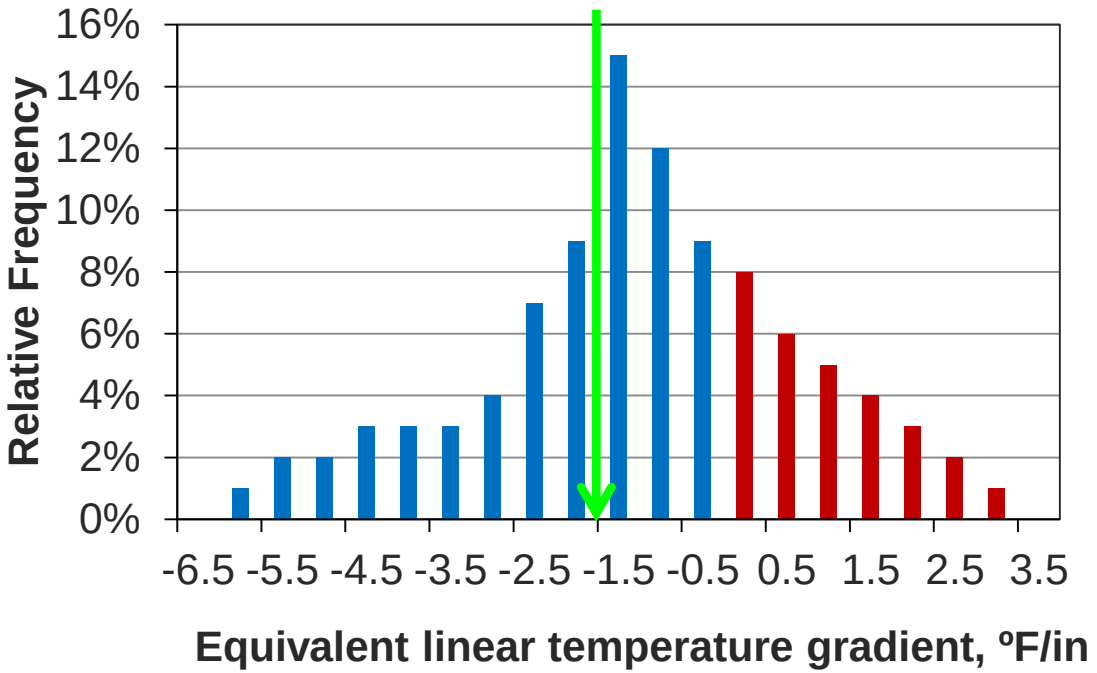


Positive ΔT

Negative ΔT



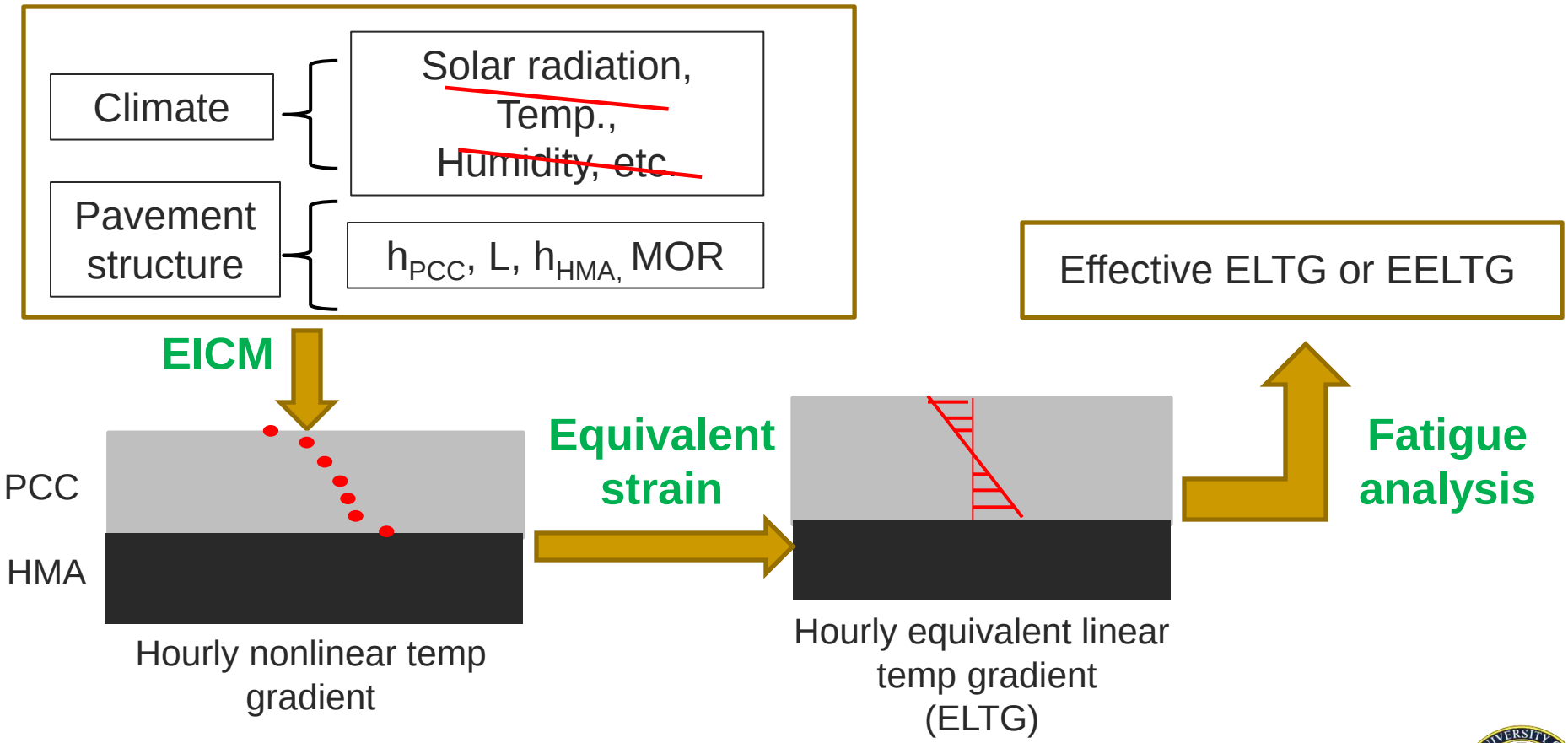
Design input:
Effective temp. gradient (ETG)



Previous design methods

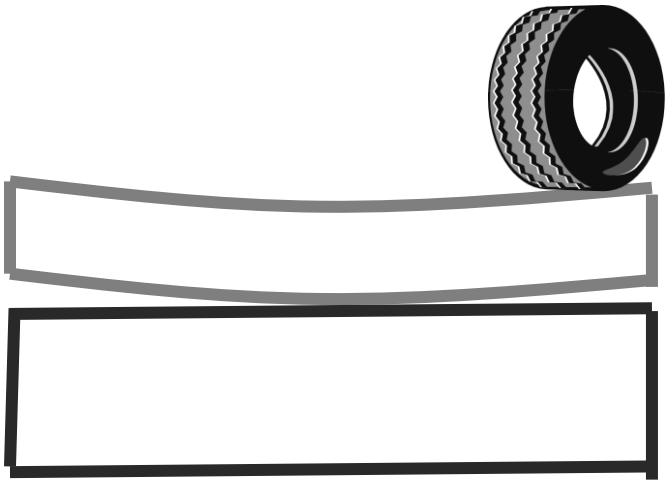
Design Method	Suggested ETG
Colorado DOT	+0 to +5° F/in (based on 2 CO projects)
New Jersey DOT	Use a positive gradient
Portland Cement Association	Use a negative gradient
Illinois Center for Transportation	-1.4° F/in (EICM and equiv. damage in IL)

Effective equivalent linear temp gradient (EELTG)

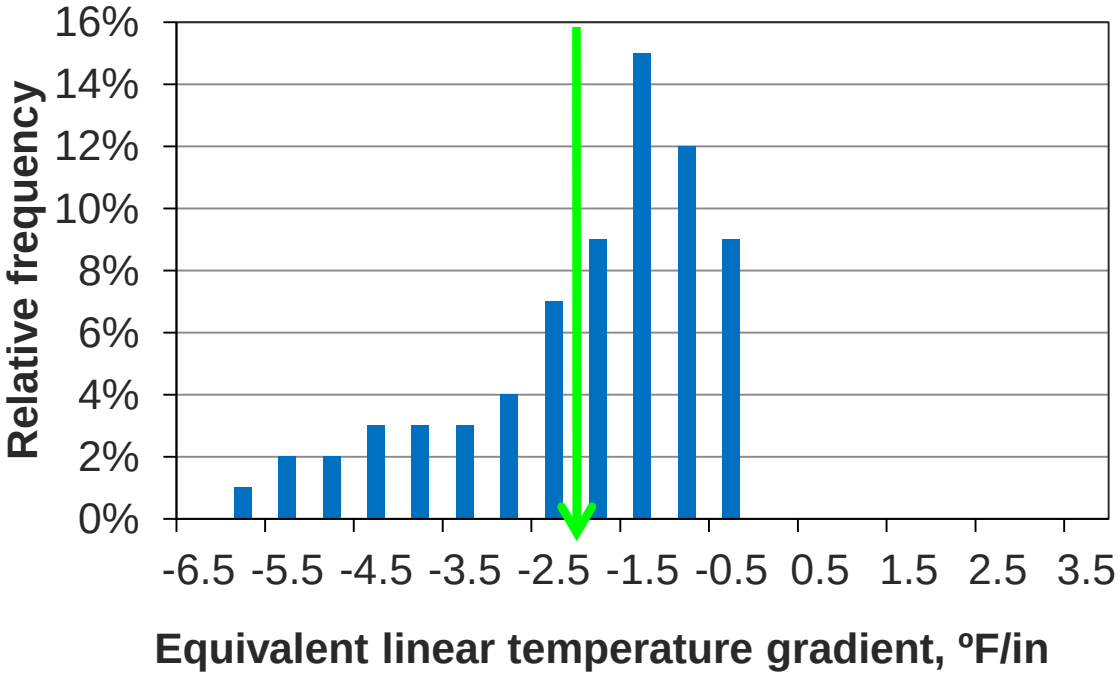


EELTG– corner breaks

Joint spacing ≤ 4.5 ft

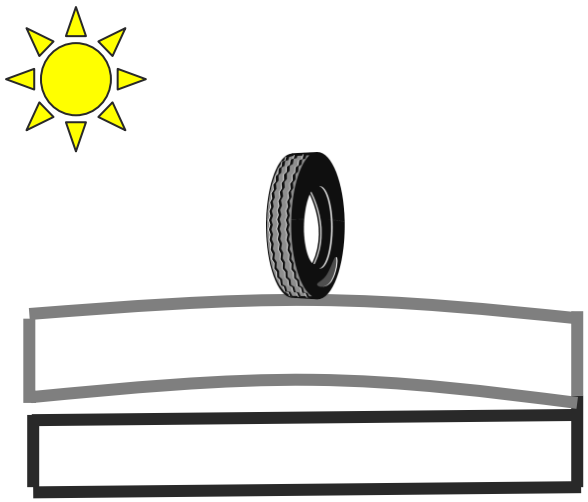


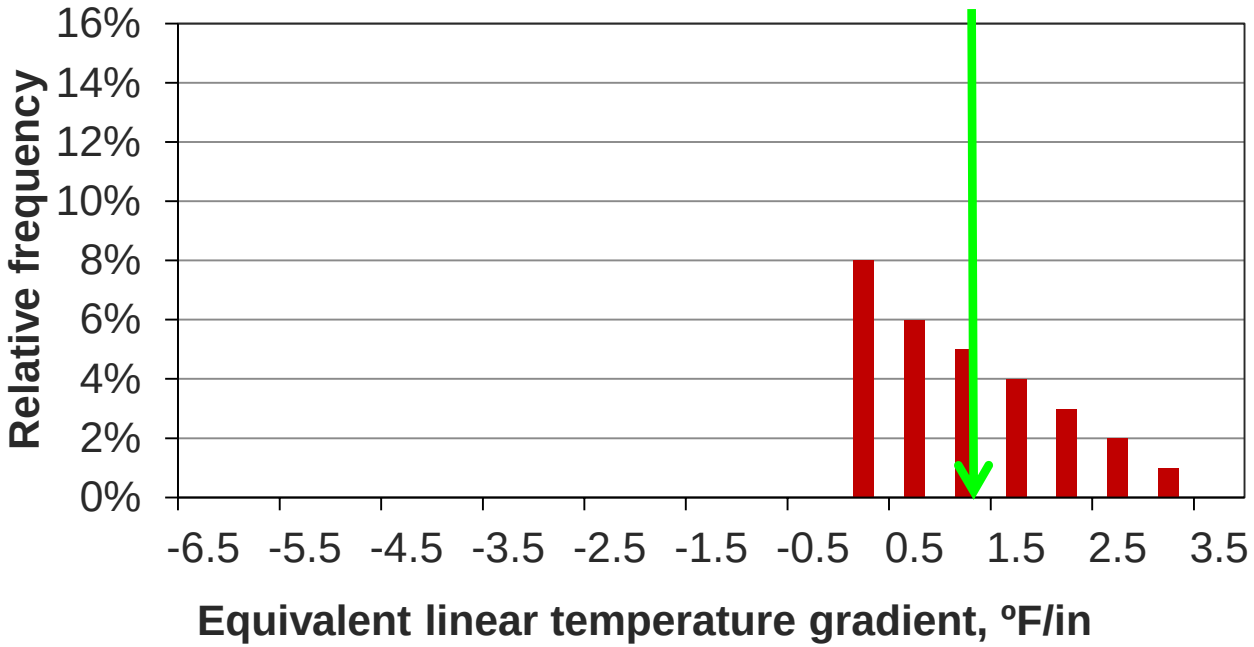
(+ΔT = zero)



EELTG–longitudinal/transverse cracks

4.5 ft < Joint spacing ≤ 6.5 ft





Populating database: Climate

(Google map of continental US as in June, 2010)

Projects at each station

Parameters	Joint spacing ≤ 4.5 ft	4.5 ft<Joint spacing ≤ 7 ft	Joint spacing > 7 ft
L, ft	3 4	6	10
h_{PCC}, in	3 4	3 4 6	5 6
		550 650 750	
h_{HMA}, in	4 8	4 8	4 6 8
		18	18

EELTG Prediction equation

$$EELTG = C_0 + C_1 Latitude + C_2 Longitude + C_3 Elevation + C_4 S_{ave} + C_5 L + C_6 h_{hma} + C_7 M_R + C_8 h_{pcc}$$

Coefficients based on three different slab size categories

Regression coefficients

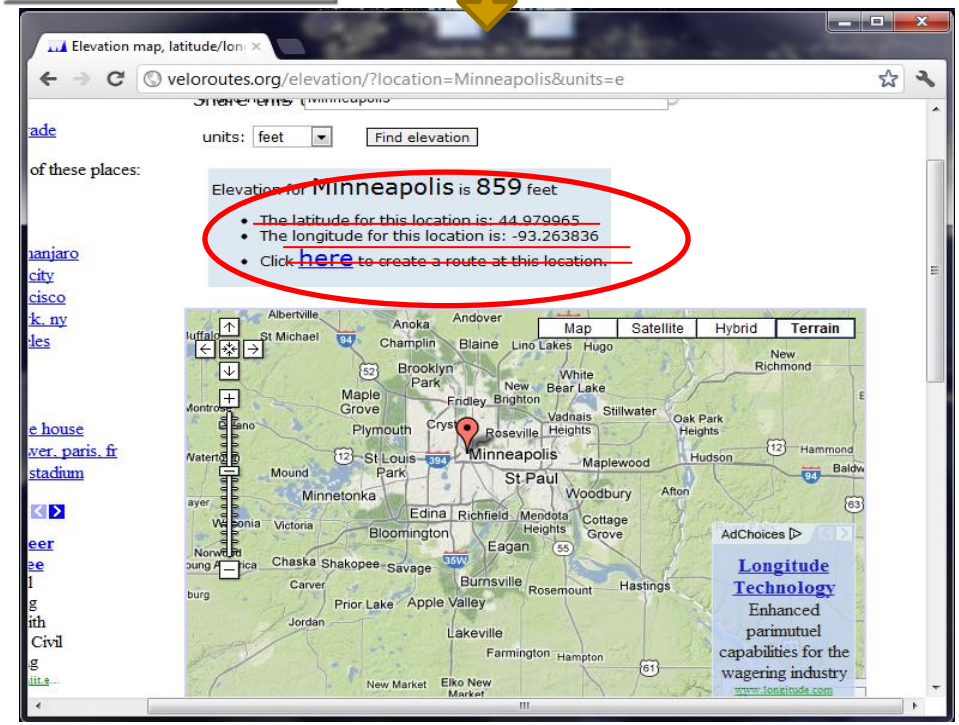
	Variable	Joint spacing ≤ 4.5 ft	4.5 ft < Joint spacing ≤ 7 ft	Joint spacing > 7 ft
C0		0.534	0.85895	2.791
C1	Latitude	-0.0015677	0.0046918	0.011843
C2	Longitude	-0.0009853	0.0018581	0.0013466
C3	Elevation	-0.00002145	0.00000362	0.0000058
C4	S_{ave}	-0.0067836	0.0082567	0.009179
C5	L	0.15843	0	0
C6	h_{hma}	-0.202627	-0.127695	-0.070225
C7	M_R	-0.00175066	0.00077175	0.0013025
C8	h_{pcc}	0	0	-0.45202
R2		0.83	0.59	0.48

Inputs: Geographical information

Climatic Consideration

Latitude (degree):	44.6
Longitude (degree):	-93.77
Elevation (ft):	856
AMDAT Region ID	1
Map of Sunshine Zone	5

Geographic Information



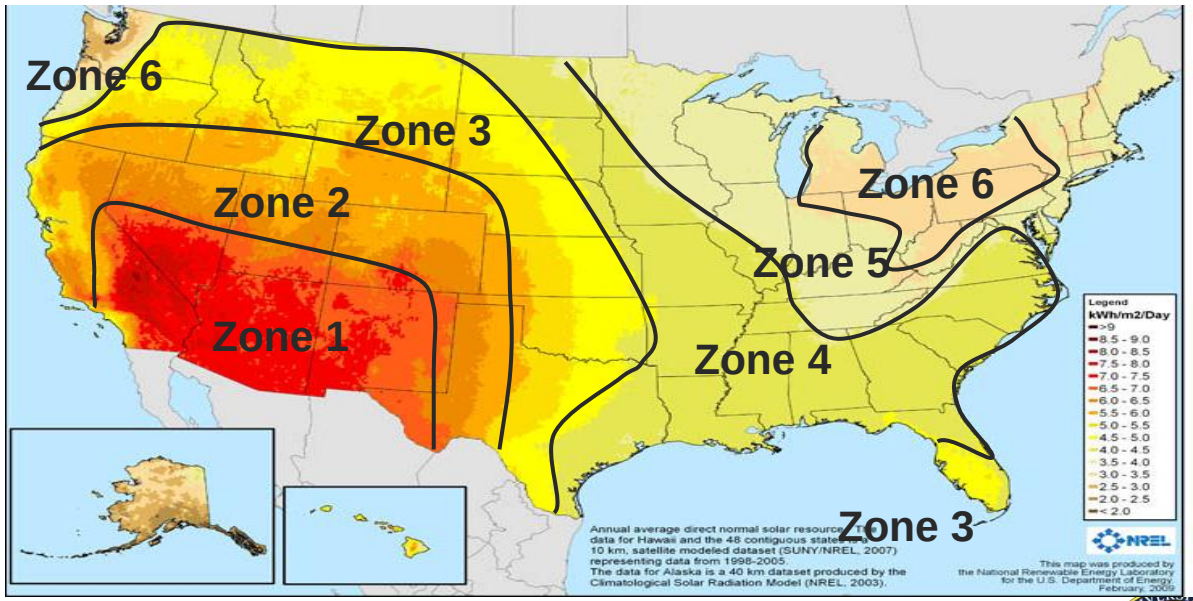
Inputs: sunshine

Climatic Consideration

Latitude (degree):	44.6
Longitude (degree):	-93.77
Elevation (ft):	856
AMDAT Region ID	1
Map of Sunshine Zone	5

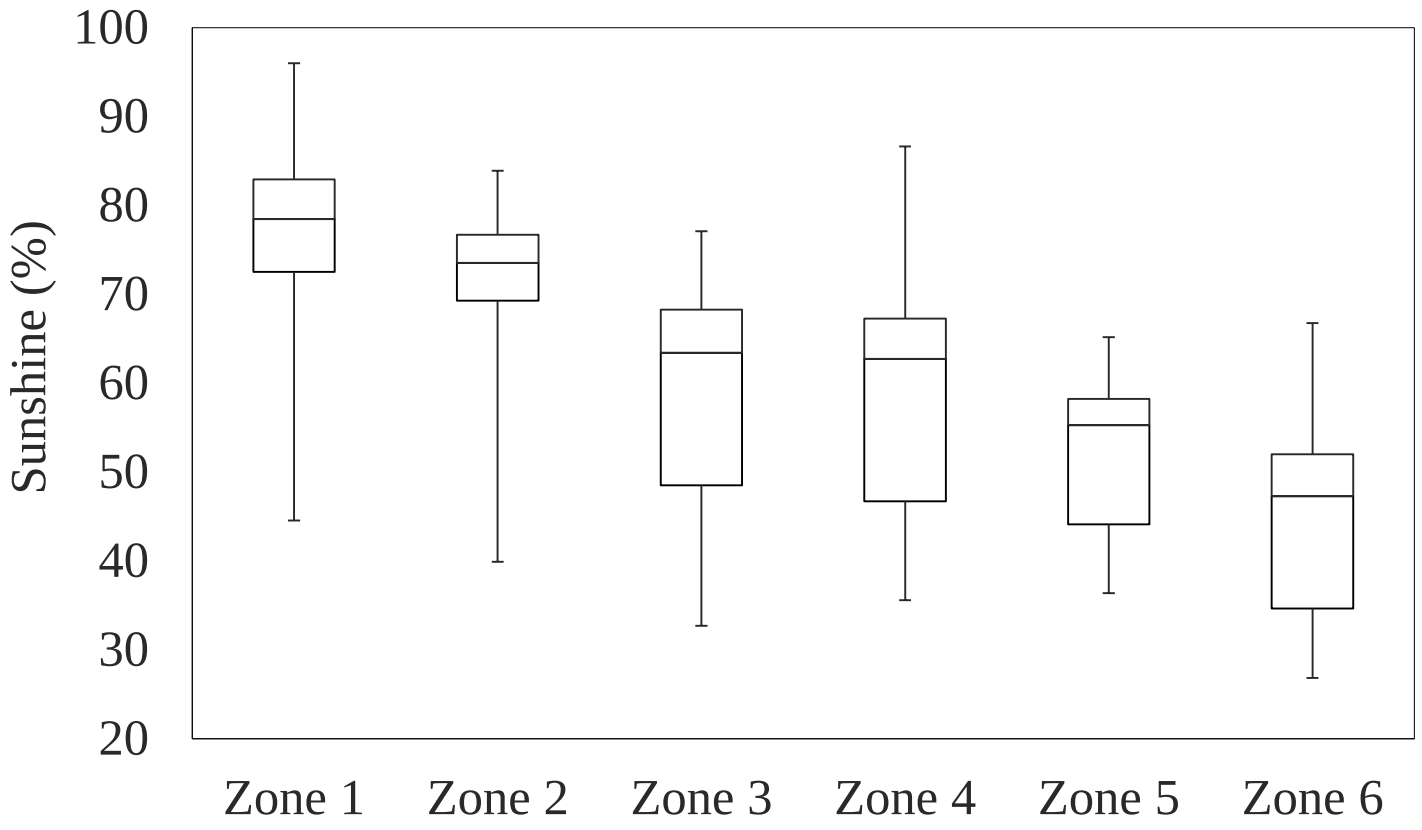
Geographic Information

Annual concentrating solar resource map



(http://www.nrel.gov/gis/solar.html, as in May 2010)

Typical zonal sunshine



TEMPERATURE DEPENDENCE OF E_{HMA}

Seasonal variation

Soft HMA

Stiff HMA

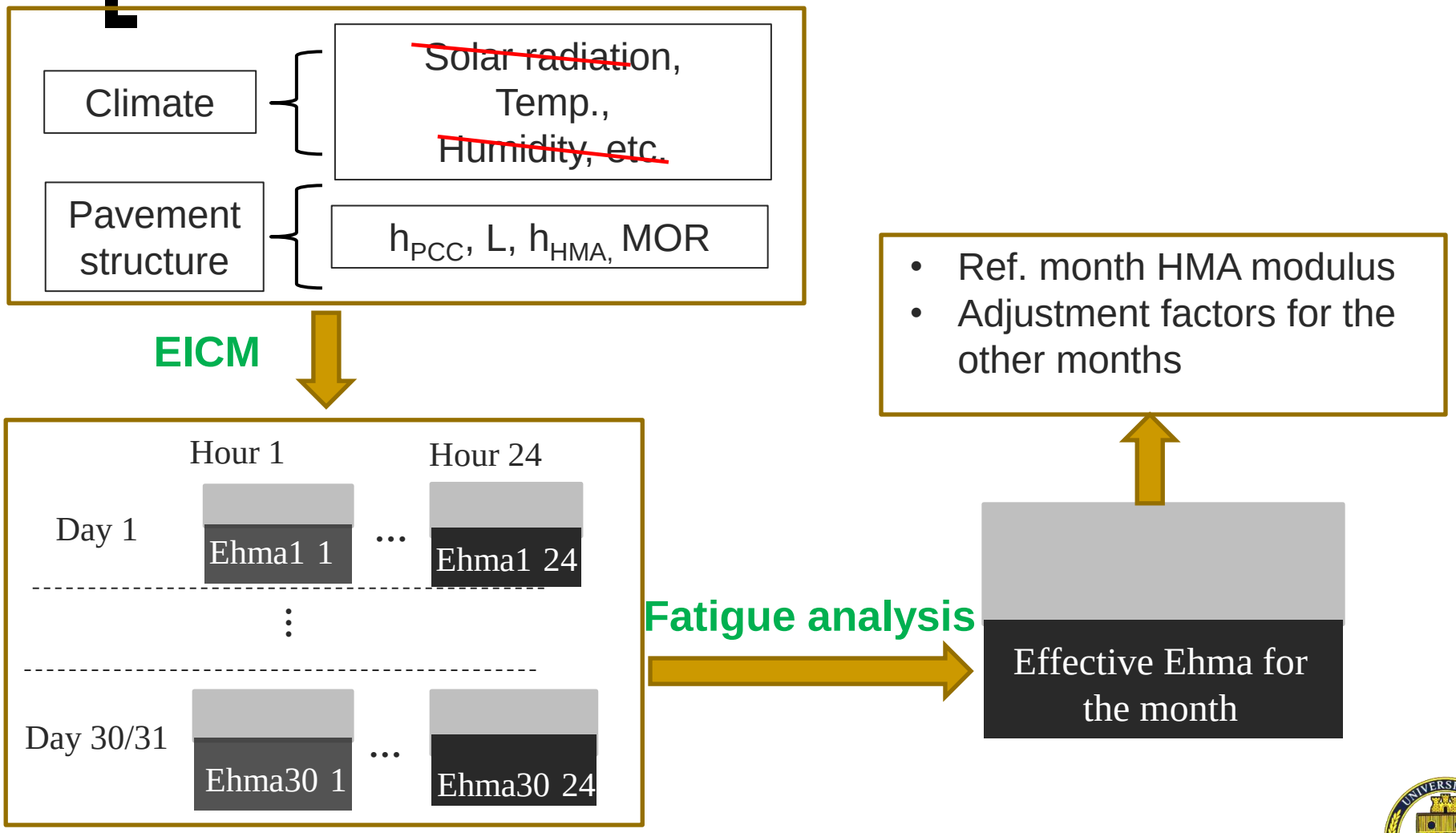
Effective temperature gradient

Daily variation

Soft HMA

Stiff HMA

HMA modulus adjustment factors



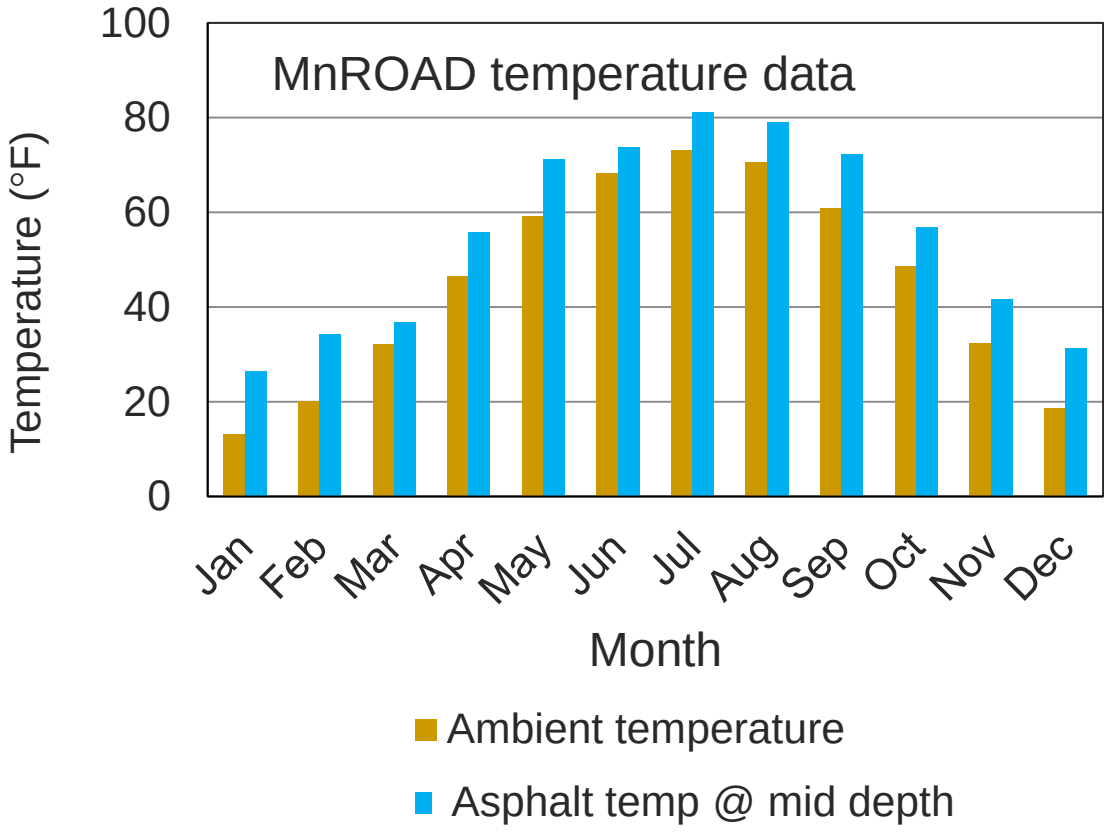
Populating database: Climate

(Google map of continental US as in June, 2010)

Parameters	Joint spacing ≤ 4.5 ft	4.5 ft<Joint spacing ≤ 7 ft	Joint spacing > 7 ft
L, ft	3 4	6	10
h_{PCC}, in	3 4	3 4 6	5 6
MOR_{PCC}, psi	550 650 750	550 650 750	550 650 750
h_{HMA}, in	4 8	4 8	4 6 8
Number of cases	24	18	18

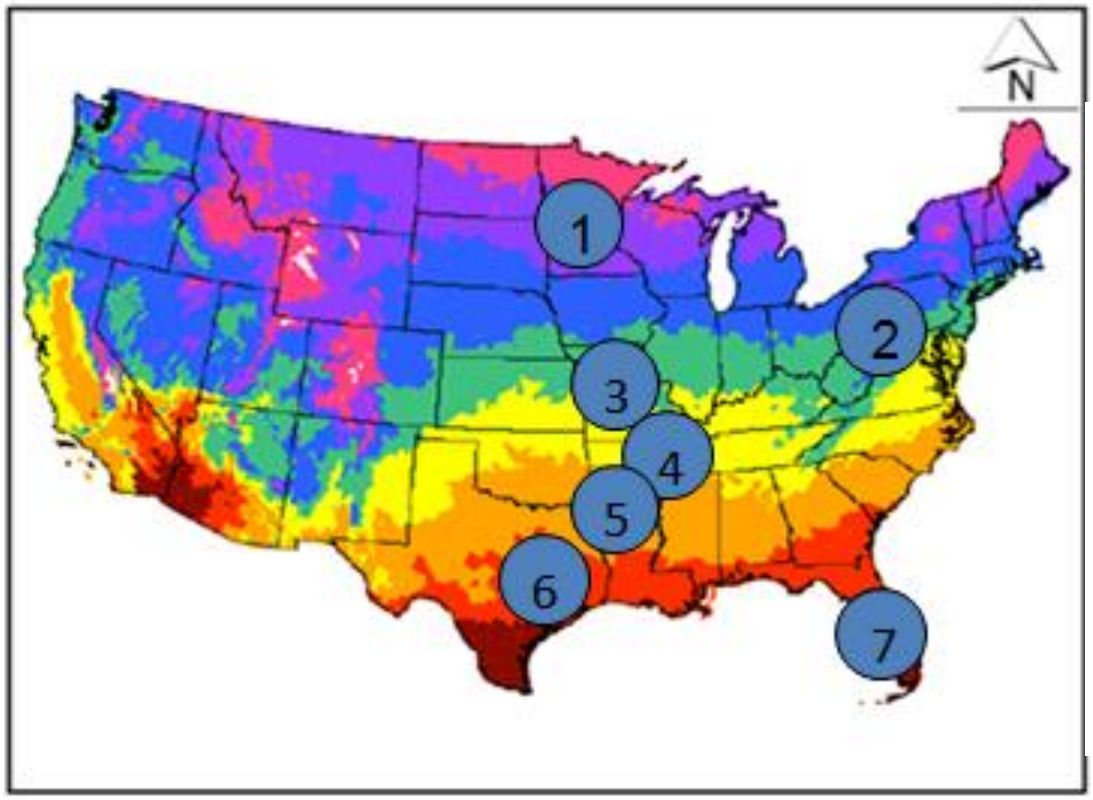
HMA temp. is a function of

1. ~~Pavement structure~~
2. ~~Sunshine~~
3. ~~Humidity~~
4. ~~Wind speed~~
5. Ambient temperature



Seven zones based on AMDAT

AMDAT = Annual mean daily average temp.



Region ID	Color code	AMDAT (°F)
1		32.0-45.0
2		45.1-50.0
3		50.1-55.0
4		55.1-60.0
5		60.1-65.0
6		65.1-70.0
7		>70.0

(http://cdo.ncdc.noaa.gov/climaps/temp0313.pdf, accessed on January, 2010).

Ehma Prediction equations

Adjustment factor for HMA modulus $= C_0 + \frac{C_1}{T_{Norm}} + C_2 h_{HMA}$

$$where\ T_{Norm} = \frac{T_{Mid@a\ month}}{T_{Mid@reference\ month}}$$

HMA modulus @ reference month

(Jan)$= B_0 + B_1 T_{Mid} + B_2 h_{HMA} + B_3 Latitude + B_4 Longitude + B_5 Elevation$

Regression coefficients-adj. factors (1)

Joint spacing ≤ 4.5 ft

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
C1	-0.139	-0.246	-0.300	-0.310	-0.525	-0.654	-0.428
C2	1.07	1.25	1.32	1.31	1.51	1.66	1.41
C3	-0.00576	-0.00657	-0.00804	-0.00764	-0.00335	-0.00540	-0.00705
C4	0	0	0	0	0	0	0
R^2	0.871	0.913	0.892	0.897	0.925	0.944	0.868

Regression coefficients-adj. factors (2)

4.5 ft<Joint spacing≤ 7 ft

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
C1	-0.21688	-0.3455	-0.4058	-0.3747	-0.4566	-0.4726	-0.4968
C2	1.052956	1.18355	1.27727	1.25747	1.46042	1.57509	1.43846
C3	0.005813	0.00801	0.00434	-0.000016	-0.007	-0.0129	-0.0025
C4	0.008295	0.0145	0.01658	0.01371	0.00202	-0.0107	0.00429
R^2	0.857	0.798	0.881	0.870	0.912	0.940	0.862

Regression coefficients-adj. factors (3)

Joint spacing > 7 ft

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
C1	0.09321	0.02420	0.11734	-0.0689	-0.2431	-0.0635	-0.0950
C2	0.76515	0.85253	0.71162	0.92720	1.0960	0.8516	0.9290
C3	0.01936	0.025210	0.02728	0.02867	0.02822	0.02641	0.02136
C4	0	0	0	0	0	0	0
R^2	0.659	0.641	0.563	0.615	0.613	0.652	0.683

Regression coef.-Modulus@Jan.(1)

Joint spacing≤ 4.5 ft

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
C1	6902212	5746174	3919812	3951615	6172028	5657489	4050512
C2	-58060.5	-48590	-20078.4	-52629	-62418	-48939	-39010
C3	-36684	-45205	-45233	-46317	-69110	-52613	-56927
C4	-48511	-32771	17658	25747	-31747	-11091	35689
C5	-3980.3	505.3	-12374.7	-2356	1793.9	-7769	-10707
C6	-9.91	-31.81	52.25	17.61	4.801	-4.95	88.486
R^2	0.901	0.687	0.654	0.859	0.908	0.911	0.856

Regression coef.-Modulus@Jan.(2)

4.5 ft<Joint spacing≤ 7 ft

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
C1	516844	5396644	333077	3458108	3849527	3912042	3901375
C2	-35706	-40139	-26639	-35086	-45022	-40680	-44662
C3	-65351	-89164	-73246	-31812	-3932	-8978	-10529
C4	-22220	-32803	30958	20508	2710	-12689	36735
C5	-6306	4454	-7350	-1956	1245	3328	-7709
C6	30.121	-45.742	64.1	47.1	48.4	25.1	15.89
R^2	0.623	0.558	0.546	0.590	0.723	0.798	0.824

Regression coef.-Modulus@Jan.(3)

Joint spacing > 7 ft

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
C1	2491478	2076287	2173722	2058023	2174744	1718085	1734430
C2	-10560	-6963	-586.2	-1519	-6379	-2601	-7589
C3	-142588	-146622	-145128	-137632	-123582	-107895	-112461
C4	-11145	-198	-4937	99	-3127	-3189	7729
C5	1813.8	596.9	-381.7	-1295.7	69.6	1959	1172
C6	-0.423	4.914	3.028	5.391	-0.576	-9.12	-2.32
R^2	0.681	0.711	0.706	0.685	0.627	0.594	0.687

Inputs for mid-depth HMA temp

Zone	Avg. Reference Month (Jan) Mid Depth HMA Temp (°F)	Std. Dev. Reference Month (Jan) Mid Depth HMA Temp (°F)
1	27.37	7.75
2	29.58	5.61
3	33.67	6.31
4	37.64	6.83
5	46.53	6.64
6	46.63	9.13
7	51.49	11.30

Inputs for equation: T_{norm}

$$T_{Norm} = \frac{T_{Mid@a\ month}}{T_{Mid@reference\ month}}$$

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Zone 1	1.00	1.00	1.41	1.88	2.46	2.75	3.00	2.97	2.36	2.03	1.40	0.94
Zone 2	1.00	1.05	1.36	1.82	2.27	2.53	2.72	2.71	2.21	1.92	1.37	0.97
Zone 3	1.00	1.18	1.39	1.82	2.14	2.37	2.52	2.50	2.10	1.86	1.40	1.04
Zone 4	1.00	1.21	1.37	1.78	2.04	2.22	2.35	2.33	1.98	1.78	1.39	1.01
Zone 5	1.00	1.17	1.28	1.51	1.71	1.84	1.92	1.89	1.67	1.51	1.24	1.04
Zone 6	1.00	1.17	1.27	1.51	1.72	1.85	1.92	1.91	1.70	1.54	1.27	1.04
Zone 7	1.00	1.08	1.27	1.39	1.67	1.76	1.86	1.88	1.60	1.46	1.14	1.05