AASHTO Design Example

(Rigid Pavements)

Problem Statement

We are going to design a limited-access highway in an exurban area. The predominate terrain is rolling hills. In order to accommodate expected commuter traffic of 20,000 to 30,000 vehicles/day, we require 3 traffic lanes in each direction. The two-way ADTT is expected to be 1000 trucks/day in the first year of operation. Based on statewide averages, the average LEF for rigid pavements is 0.98. It is assumed that truck traffic will grow at a rate of 3% per year over the 25-year design life.

Design ESALs

$$ESAL = 365(ADTT)(T_f)(D)(L)\left[\frac{(1+g)^n - 1}{g}\right]$$

Number of Lanes in **Each** Direction	Percent of Loads in Design Lane
1	100
2	80-100
3	60-80
4	50-75

Problem Statement

Local practice is to use a granular subbase that will drain within a few hours. The subbase has a resilient modulus of 15,000 psi when wet and 25,000 psi when dry. The roadbed soil has a resilient modulus of 3000 psi during the 7 months "wet" months and 7000 psi the rest of the year. Based on rainfall data, we expect that the subbase will approach saturation one week per month during the wet season.

Problem Statement

According to local practice, the pavement will be designed as JPCP with tied concrete shoulders. The slab length will be 30 feet and dowels will provide load transfer at the joints. The concrete slab is designed for a compressive strength of 5500 psi. We will assume that the initial pavement serviceability index will be 4.5. Based on the high traffic volume, we will select a terminal serviceability level of 2.5.

Design Equation

$$\log_{10} W_{18} = Z_R S_0 + 7.35 \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.5-1.5}\right)}{1.0 + \frac{1.62\times 10^{7}}{(D+1)^{8.46}}}$$

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$$+ (4.22 - 0.32 p_t)\log_{10}\left[\left(\frac{S'_c \cdot C_d}{215.63 \cdot J}\right)\frac{\left(D^{0.75} - 1.132\right)}{\left(D^{0.75} - \frac{18.42}{\sqrt[4]{E_c/k}}\right)}\right]$$

Rigid Pavement Properties

Z_r = *standard normal deviate*

S_o = *standard deviation of* W_{18}

E_c = *concrete modulus of elasticity (psi)*

S'_c = *concrete modulus of rupture (psi)*

C_d = *drainage coefficient*

J = *joint load transfer coefficient*

LS = *loss of support factor*

k = *modulus of subgrade reaction (psi/in)*

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Recommended Reliability

Functional Classification	**Urban**	**Rural**
Interstate and Other Freeways	85 – 99.9%	80 – 99.9%
Principal Arterials	80 – 99%	75 – 99%
Collectors	80 – 95%	75 – 95%
Local	50 – 80%	50 – 80%

Reliability, Z_R

Reliability (%)	Z_R
50	-0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405

Reliability (%)	Z_R
93	-1.476
94	-1.555
95	-1.645
96	-1.751
97	-1.881
98	-2.054
99	-2.327
99.9	-3.090
99.99	-3.750

Standard Deviation, S_o

Source	**Flexible**	**Rigid**
AASHO Road Test S_n	0.35	0.25
AASHO Road Test S_o	0.45	0.35
Typical Range for S_o	0.40 – 0.50	0.30 – 0.40

Rigid Pavement Properties

Z_r = standard normal deviate

S_o = standard deviation of W_{18}

E_c = concrete modulus of elasticity (psi)

S'_c = concrete modulus of rupture (psi)

C_d = drainage coefficient

J = joint load transfer coefficient

k = modulus of subgrade reaction (psi/in)

LS = loss of support factor

Typical Concrete Properties

$$S'_c = 8.4\sqrt{f'_c} \quad (psi)$$

$$f_t = 6.7\sqrt{f'_c} \quad (psi)$$

$$E_c = 57,000\sqrt{f'_c} \quad (psi)$$

Rigid Pavement Properties

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Drainage Quality

Quality	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	No drainage

Drainage Coefficient, C_d

Quality	Percentage of Time Material Approaches Saturation			
	< 1%	**1-5%**	**5-25%**	**> 25%**
Excellent	1.25-1.20	1.20-1.15	1.15-1.10	1.10
Good	1.20-1.15	1.15-1.10	1.10-1.00	1.00
Fair	1.15-1.10	1.10-1.00	1.00-0.90	0.90
Poor	1.10-1.00	1.00-0.90	0.90-0.80	0.80
Very Poor	1.00-0.90	0.90-0.80	0.80-0.70	0.70

Load Transfer Coefficient, J

	Asphalt Shoulders		Tied PCC Shoulders	
	Dowels	No Dowels	Dowels	No Dowels
JPCP JRCP	3.2	3.8 - 4.4	2.5 - 3.1	3.6 - 4.2
CRCP	2.9 - 3.2		2.3 - 2.9	

NOTE: Use higher *J* values when you have (a) low *k* values, (b) lots of trucks, (c) high concrete thermal coefficients, or (d) large variations in temperature.

Rigid Pavement Properties

Z_r = *standard normal deviate*

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k = *modulus of subgrade reaction (psi/in)*

LS = *loss of support factor*

TABLE 15.17
Recommended Loss of Subgrade Support Factors

Type of Material	Loss of Support (LS)
Cement-treated granular base (E = 1,000,000–2,000,000 psi)	0.0–1.0
Cement aggregate mixtures (E = 500,000–1,000,000 psi)	0.0–1.0
Asphalt-treated base (E = 350,000–1,000,000 psi)	0.0–1.0
Bituminous stabilized mixtures (E = 40,000–300,000 psi)	0.0–1.0
Lime stabilized (E = 20,000–70,000 psi)	1.0–3.0
Unbound granular materials (E = 15,000–45,000 psi)	1.0–3.0
Fine-grained or natural subgrade materials (E = 3000–40,000 psi)	2.0–3.0

Source: Reprinted from Portland Cement Association (PCA), *Design and Control of Concrete Mixtures*, Engineering Bulletin 001, 14th edn., PCA, Skokie, IL, 2002.

Note: E in this table refers to the general symbol for the elastic or resilient modulus of the material.

Trial Subbase: Type Unbound Granular

Thickness (in) 6.0

Loss of Support 1.0

Depth to Rigid Foundation (feet) ∞

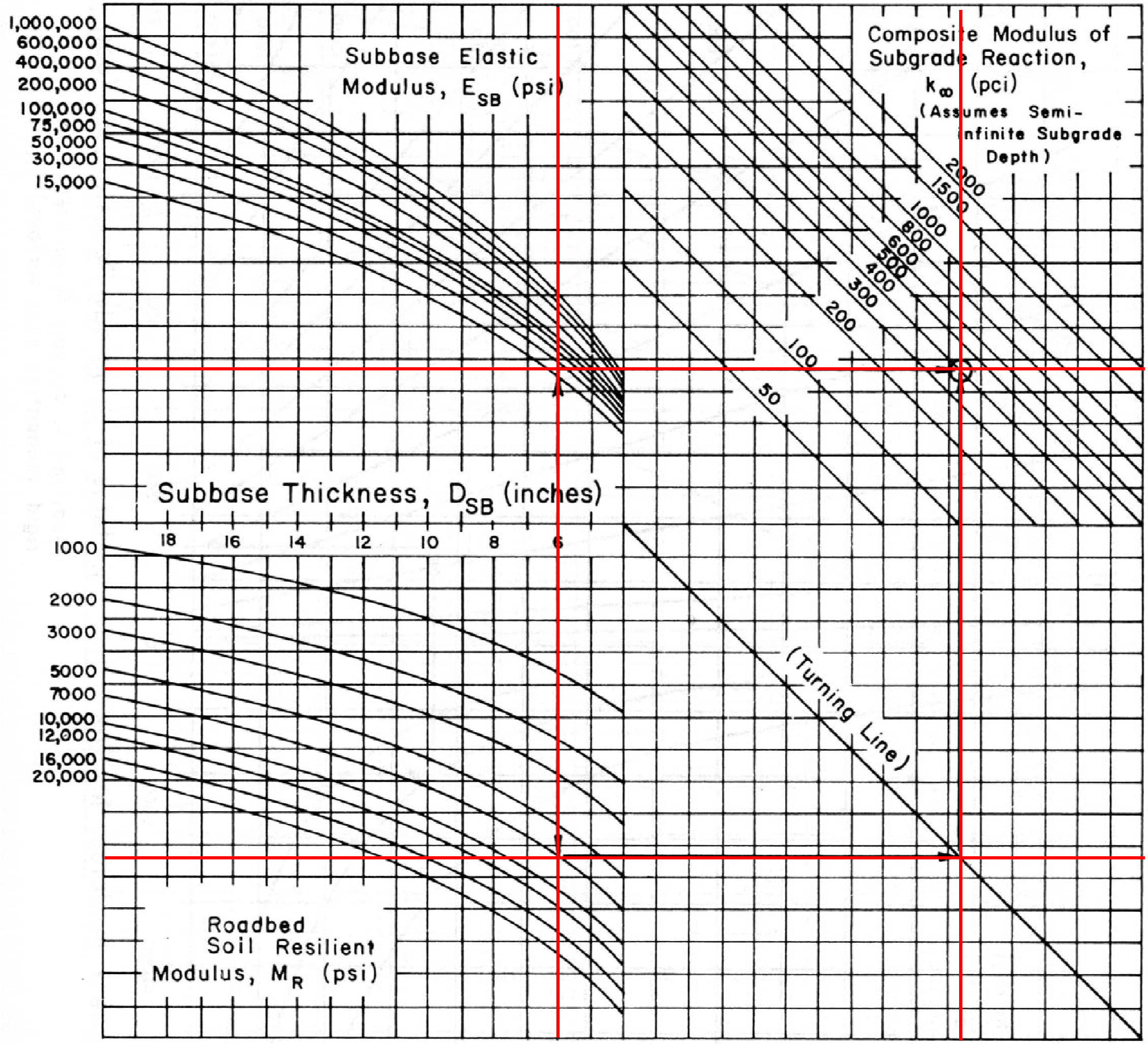
Projected Slab Thickness (in) ______

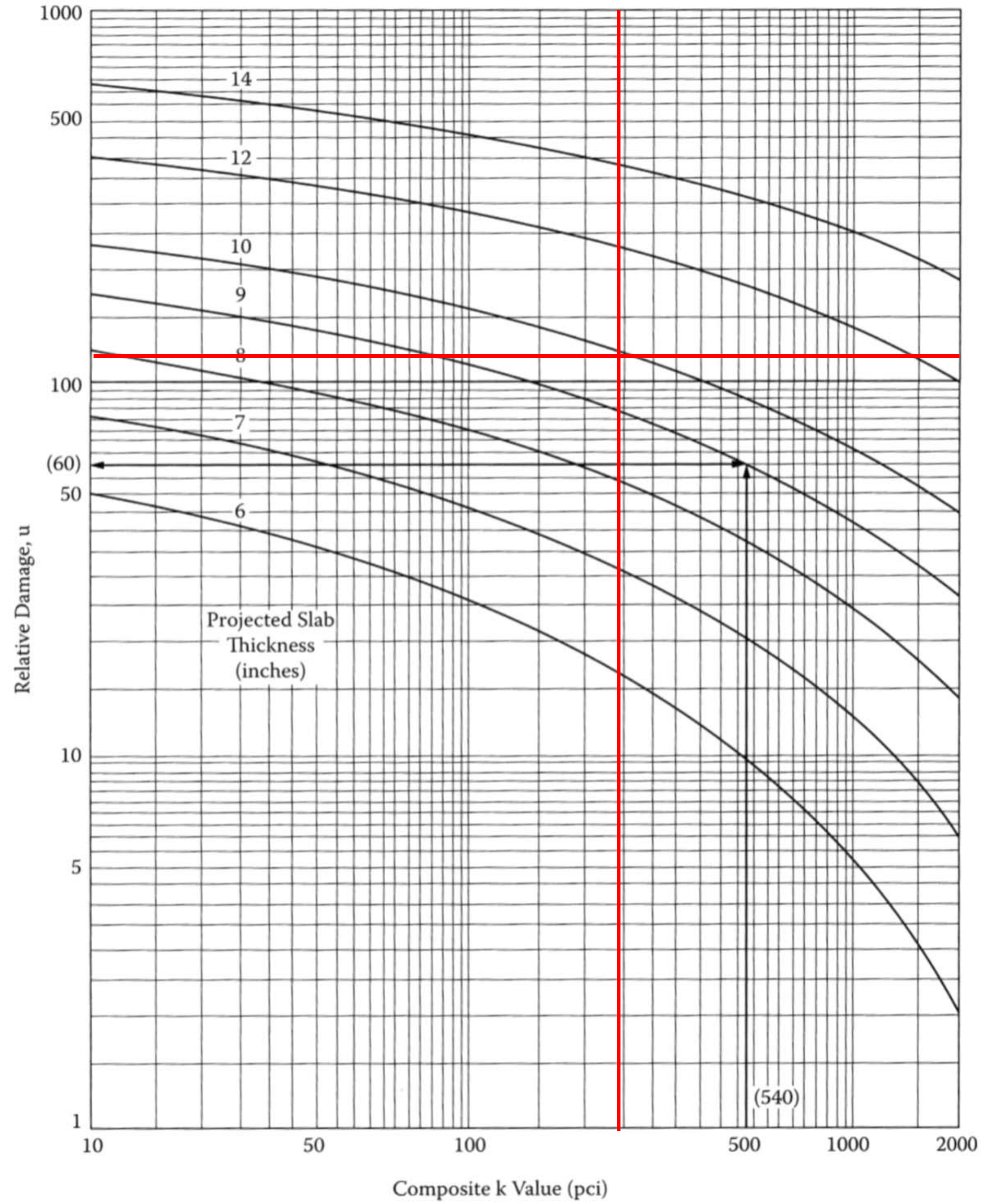
Length of Season (months)	Roadbed Modulus M_R (psi)	Subbase Modulus E_{SB} (psi)	k_∞ (psi/in)	k_{rf} (psi/in)	Damage Factor (u_r)

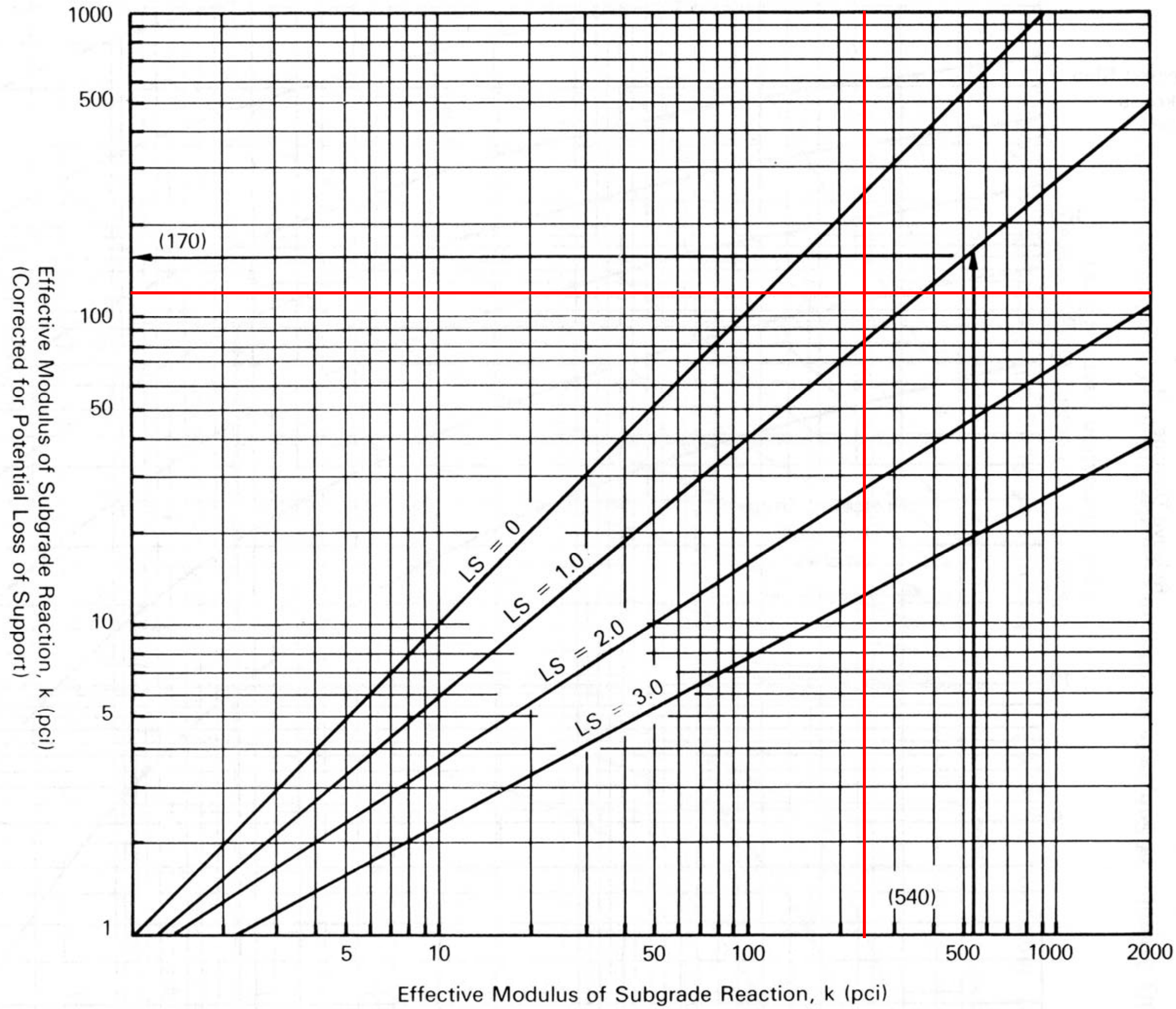
Average damage factor, $\bar{u}_r$ ______

Effective modulus of subgrade reaction (psi/in) ______

Effective modulus corrected for loss of support (psi/in) ______


Subbase Elastic Modulus, E_{SB} (psi)
1,000,000
600,000
400,000
200,000
100,000
75,000
50,000
30,000
15,000
Composite Modulus of Subgrade Reaction, k_{∞} (pci)
(Assumes Semi-infinite Subgrade Depth)
2000
1500
1000
800
600
500
400
300
200
100
50
Subbase Thickness, D_{SB} (inches)
18
16
14
12
10
8
6
1000
2000
3000
5000
7000
10,000
12,000
16,000
20,000
(Turning Line)
Roadbed Soil Resilient Modulus, M_R (psi)


1000
500
100
(60)
50
10
5
1
14
12
10
9
8
7
6
Projected Slab
Thickness
(inches)
(540)
10
50
100
500
1000
2000
Relative Damage, u
Composite k Value (pci)


1000
500
100
50
10
5
1
5
10
50
100
500
1000
2000
(170)
(540)
LS = 0
LS = 1.0
LS = 2.0
LS = 3.0
Effective Modulus of Subgrade Reaction, k (pci)
(Corrected for Potential Loss of Support)
Effective Modulus of Subgrade Reaction, k (pci)