APPENDIX G

Pavement Design Report

US-97 / Murphy Road: Brookswood to Parrell Project—Pavement Design Report

PREPARED FOR: US-97 / Murphy Road: Brookswood to Parrell Design Team

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PROJECT NUMBER: 407067.02.05.05

Introduction

This technical memorandum describes the Asphalt Concrete Pavement (ACP) and Portland Cement Concrete Pavement (PCCP) design completed for the US-97 / Murphy Road: Brookswood to Parrell Project and provides the basis for development of the eleven typical pavement sections proposed for use within the following project segments:

- Two ACP segments of Murphy Road: Brookswood to 3rd Street (Section #1) and 3rd Street to Parrell (Section #2), including tie-in legs to 3rd Street and Parrell roundabouts.
- Two new ACP ramps to US-97 at the proposed partial interchange with 3rd Street: On-Ramp for southbound traffic (Section #3) and Off-ramp for northbound traffic (Section #4).
- The ACP segment of 3rd Street between the proposed interchange with US-97 and the proposed 3rd Street roundabout at Murphy Road (Section #5).
- The ACP segment of Brookswood west of the proposed Brookswood roundabout with Murphy Road (Section #6) and the roundabout leg tie-ins with Larkwood Drive and Pinebrook Blvd.
- Three PCCP roundabouts at: Brookswood (Section #7), 3rd Street (Section #8) and Parrell Rd (Section #9).
- An alternative minimum ACP section (Section #10) for use in rock cut areas.
- A pedestrian and bicycle pathway (Section #11).

This pavement design was completed in accordance with American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures.*

Figure 1 shows the Location and Vicinity Maps for the project Work.

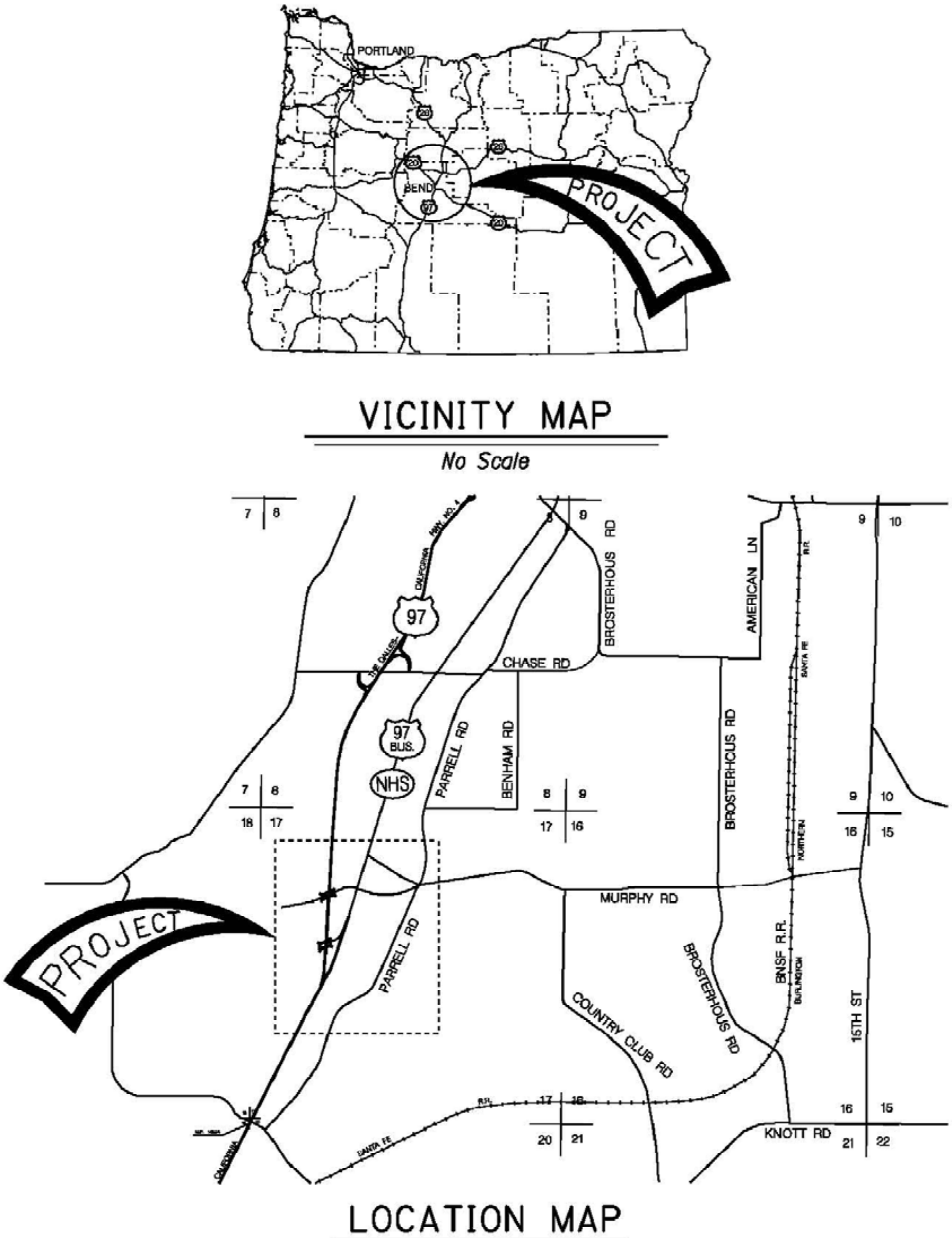


FIGURE 1

LOCATION AND VICINITY MAP

Design Parameters

Soil Conditions

A geotechnical exploration program and laboratory testing program has been performed for the US97/Murphy Road: Brookswood to Parrell Project. The purpose of the exploration program was to evaluate subsurface conditions and to determine the necessary requirements for support of bridge and retaining wall foundations, for approach fill slopes and roadway cut slopes, and for pavement subgrade conditions. The exploration program consisted of drilling 20 soil and rock borings and excavating 9 test pits. These explorations were performed between September and November 2010. Laboratory testing consisted of unconfined compression tests on intact rock samples to determine rock strengths. Detailed geotechnical data, including boring and test pit location plans and logs, and laboratory testing results are included in the Geotechnical Data Report, located in Appendix C-1. Figures 2, 3 and 4 in Appendix C-1 show the location of the borings and test pits in relation to the proposed improvements.

The generalized subsurface conditions at the site consist of 0 to 5 feet of soil, consisting of silty sand with gravel and cobbles underlain by hard basalt bedrock. The subsurface conditions at the site are generally favorable for conventional shallow footings, founded on the bedrock, to support the Murphy Road and 3rd Street bridges overcrossing the Bend Parkway/US97.

A preliminary foundation report has been prepared, which includes preliminary geotechnical and bridge foundation design and construction recommendations, seismic design parameters, and general pavement subgrade design parameters. The preliminary foundation report is included in Appendix C-2.

Groundwater Elevation

Groundwater was not encountered in any of the test pits or borings and is therefore not a consideration in the pavement design.

Resilient Modulus

Material parameters for design were estimated based on soil exploration by CH2M HILL and testing completed by Wallace Group of Bend. A California Bearing Ratio (CBR) was estimated using the soil types and blow count data recorded during explorations. This CBR value of 12 percent was selected for design based on the following assumptions:

- The designed pavement section will not bear directly on competent rock. If competent rock is encountered see alternative minimum section discussion on page 10.
- Base and subgrade compaction will not remain at 95 percent of modified proctor for full pavement life cycle.
- The Silty Sand (SM) and Silty Sand with occassional boulders soil classifications support CBR values between 10 and 40 percent.
- Variance in construction practices suggest designing to a conservative CBR that is based on soil type.

Using a correlation developed by National Cooperative Highway Research Program (NCHRP) Project 128[1], the resilient modulus was estimated to be 10,637 pounds per square inch (psi) and is appropriately conservative for design; therefore, it was used to develop the structural number for all the asphalt concrete pavement (ACP) sections.

For portland cement concrete pavement (PCCP) sections (used only for roundabouts), a subgrade k-value was developed using the seasonal k-value method contained in the AASHTO Rigid Pavement Design program. Subgrade k-values for each season were estimated to reflect the spring breakup and weakening of subgrade. See Table 1 below for the values used within the AASHTO Rigid Pavement Design program.

Table 1

SEASONAL SUBGRADE K-VALUES USED OF PCCP DESIGN

Season	Number of Months	Subgrade k-Value, psi/in	W_{18}, millions	Relative Damage in the Season
Summer	5	250	44.70	0.1119
Fall	2	220	45.35	0.0441
Winter	3	200	45.78	0.0655
Spring	2	150	46.78	0.0428
Total:	12		Mean Damage:	0.0220

CALCULATE

W_{18}: 45.41

Seasonally Adjusted Subgrade k-Value (psi/in): **220**

Clear

k-Value Information

Export to Fill/Rigid Adjustment Sheet

Export to Input Form

Forecasted Traffic & ESALs

Traffic studies were conducted in 2010 by CH2M HILL (see Attachment A). For the purposed of pavement design,the traffic study looked at future potential phases of improvements to affected roadways and used the maximum foreseeable scenarios for traffic as well as truck percentages. Pavement designs were conducted with the following traffic assumptions:

- Maximum foreseeable traffic and truck percentages were used to limit structural upgrades needed when future phases are built.
- Future phase pavement construction will not include replacement or supplementation of current pavements. It will only include the construction of the additional pavement areas needed for the future out functionality.

Average daily traffic (ADT) was forcasted for year 2013, which corresponds to the assumed opening year of the project. A pavement analysis period of 20 years was selected for the new

[1] O.J. Porter, "Foundations for Flexible Pavements," Highway Research Board Proceedings on the Twenty-second Annual Meeting, Vol. 22, Pages 100-136.

Asphalt Concrete Pavement (ACP) and 30 years for the new Portland Cement Concrete Pavement (PCCP) designs.

The percentage of trucks in the projected volumes was estimated at 10.37 percent based on actual truck percentages reported at Oregon Department of Transportation (ODOT) Automatic Traffic Recorder (ATR) station 09-003, which is located at mile point 142.41 of US-97. This ATR is near the project (0.17 miles south of China Hat road) and is representative of the truck traffic that could be expected on the proposed facility. Axle conversions were made based on truck type distribution ratios from the ATRs. The resulting Equivalent Single Axle Loads (ESALs) were scaled by the design lane factor and escalated through the design year to determine the "design" ESALs. The traffic analysis is summarized in Table 2 and described in more detail in Attachment A.

TABLE 2
Forecasted Traffic and ESALs

	Total Design Equivalent Single Axle Loads (ESALs)		
Design Segment	**Base Year (2013)**	**20-Year (2033) for New ACP**	**30-Year (2043) for new PCCP**
Murphy Road (Brookswood to 3rd) (#1)	113,000	2,925,000	N/A
Murphy Road (3rd to Parrell), 3rd Street Tie-ins, and Parrell Road Tie-ins (#2)	187,000	4,683,000	N/A
US 97 Southbound On Ramp (#3)	280,000	6,850,000	N/A
US 97 Northbound Off Ramp (#4)	146,000	3,184,000	N/A
3rd Street (US 97I/C to Murphy) (#5)	305,000	7,452,000	N/A
Brookswood (West of Murphy Road) and Larkwood and Pinebrook Tie-in legs (#6)	252,000	6,275,000	N/A
Brookswood Blvd PCCP Roundabout (#7)	667,000	N/A	24,940,000
3rd Street PCCP Roundabout (#8)	1,128,000	N/A	45,010,000
Parrell Road PCCP Roundabout (#9)	618,000	N/A	26,520,000
Alternative ACP section over Competent Rock (#10)	Use Max. of 305,000	Use Max. of 7,452,000	N/A
Pedestrian & Bicycle Pathway (#11)[2]	N/A	N/A	N/A

Notes:

1. N/A = Not applicable.
2. Traffic volumes and ESALs were not calculated for the Pedestrian & Bicycle Pathway, although a pavement thickness recommendation is included for this segment.

Pavement Parameters

The AASHTO procedure requires parameters for the design of the pavement thickness. These parameters are variable based on the functional classification of the facility, local material sources, agency requirements, and judgment of the pavement designer. For this project, rehabilitation will not be considered, because only new sections are being provided.

The sections below indicate which parameters are necessary for project pavement design and provide a brief explanation of the selected parameter.

Reliability—The reliability for the design was set at 90 percent, in accordance with the ODOT *Pavement Design Guide* reliability value for urban major/rural minor arterials.

Standard Deviation—A standard deviation of 0.49 was chosen for ACP and 0.39 for PCCP, in accordance with the ODOT *Pavement Design Guide*.

Initial Serviceability—An initial serviceability of 4.2 was selected for the asphalt concrete sections, which is typical for flexible pavements.

Terminal Serviceability—The terminal serviceability of 2.5 was selected in accordance with the ODOT *Pavement Design Guide*.

Drainage Coefficient—This parameter modifies the structural layer coefficients for untreated base materials based on the influence of water in the pavement section. The embankment fill is expected to be constructed of well-draining materials, and therefore, a drainage coefficient of 1.00 was selected.

Structural Layer Coefficients—The structural layer coefficients are the backbone of AASHTO's flexible pavement design. The coefficients are assigned based on ODOT recommendations given in the 2007 *Pavement Design Guide,* as well as knowledge of local material sources and specifications. The assigned values for layer coefficients for this project are as follows:

- Asphalt Concrete Pavement—0.40 to 0.42
- Aggregate Base—0.10
- Aggregate Subbase—0.08

ODOT Mix Design Level— Using Table J-3 of the ODOT Pavement Design Guide, the Hot Mix Asphalt Concrete (HMAC) mix design level for the all roadway sections was set at Level 3 because the forecasted ESALs are 1 million or above. The mix design level recommended for all other portions of the project are also recommended as Level 3 HMAC even though the ESALs are below the 1-million ESAL threshold. The use of Level 2 HMAC for the pathway would likely not provide any cost savings, because the relative quantities are low . If the construction phasing is such that pathway paving occurs in a completely different phase from the mainline paving, dropping the mix design to Level 2 would be acceptable and would likely save several dollars per ton.

Asphalt Binder Type—The binder type recommended for this project is PG 70-28 for all roadways. Similarly, it is not recommended to specify a smaller temperature range asphalt binder for the relatively small quantities of pathway paving. However, PG 64-28 could be used if construction phasing supports a binder change.

Pavement Sections

Eleven pavement sections were considered for this project. All roadways and pathways were designed using ACP and all roundabouts were designed using PCCP. See Attachment B for the pavement thickness design calculations and refer the text below for design naratives. Table 2 below summarizes the pavement thickness designs by project segment.

TABLE 2

PRELIMINARY PAVEMENT SECTIONS BY PROJECT SEGMENT

Section No.	Location - Project Segment	Design ESALs (20 years for ACP & 30 years for PCCP)	Pavement Thickness (inches)	Crushed Aggregate Base Thickness (inches)	Total Pvmt. Thickness (inches)
1	Murphy Road (Brookswood to 3rd)	2,925,000	8" ACP	10"	18"
2	Murphy Road (3rd to Parrell), 3rd Street Tie-in, and Parrell Road Tie-ins	4,683,000	8" ACP	10"	18"
3	US 97 Southbound On Ramp	6,850,000	8" ACP	10"	18"
4	US 97 Northbound Off Ramp	3,184,000	8" ACP	10"	18"
5	3rd Street (US 97 to Murphy)	7,452,000	8" ACP	10"	18"
6	Brookswood (West of Murphy Road) and Larkwood and Pinebrook Tie-ins.	6,275,000	8" ACP	10"	18"
7	Brookswood Blvd PCCP Roundabout	24,940,000	11" PCCP	6"	17"
8	3rd Street PCCP Roundabout	45,010,000	12" PCCP	6"	18"
9	Parrell Road PCCP Roundabout	26,520,000	11" PCCP	6"	17"
10	Alternative ACP section over Competent Rock	Up to 7,500,000	Maintain 8" ACP	Minimum of 6"	14"
11	Pedestrian & Bicycle Pathway	N/A	3" ACP	6"	9"

Notes:

1. *All pavement sections include a soil separation geotextile fabric between the native subgrade and crushed aggregate base. A minimum of 6 inches of crushed aggregate should be placed over this fabric.*

The recommendations for the eleven pavement sections are categorized into four groups, as follows: Mainline pavement; Ramps; Roundabouts, Pathways and an Alternative minimum ACP section to be used over competent rock. All recommended pavement sections for roadways and the pathway are ACP and are based on a 20-year service life. All recommended pavement sections for roundabouts are PCCP and are based on a 30 year service life. The individual pavement thickness designs for ACP and PCCP are included in Attachment B.

Mainline Pavement Design

This pavement section is intended for the new roadway construction of 3rd Street, Murphy Road, Brookswood, and tie-in legs between the roundabout limits and the existing ACP pavements on 3rd Street, Brookswood, Parrell and Larkwood. Loading for these segments of the proposed project vary from 2.9 to 7.5 million ESAL's. The lower limit of traffic (Murphy Rd - Brookswood to 3rd) could be accomodated with 7 inches of ACP, however, 8 inches is shown for continuity with the other higher used pavements. A separation geotextile is recommended in this pavement section because fine-grained soils have been reported in most borings and test pit samples. The geotextile will prevent the migration of fines and keep the fines from fouling the aggregate base course over the life of the pavement. Table 2 shows the 20-year design life recommended sections for the mainline paving section.

The asphalt materials specified for this pavement section are from ODOT specification section 00745. The various courses expected for construction of this ACP section will be 3 lifts of ½-inch dense HMAC. The aggregate base specified for this pavement section is ¾-inch - 0, based on ODOT specification section 00641. The first lift over the geotextile fabric should be 6 inches and the remaining lifts should be between a maximum of 6 inches and a minimum of 4 inches.

If competent rock is found during roadway excavation that does not permit the full pavement section to be constructed without rock excavation, an alternative minimum AC pavement section is provided below.

Ramps

The following pavement section is for ramps to and from the proposed interchange with US97. Loading for these segments of the proposed project vary from 3.2 to 6.9 million ESAL's. The traffic on the Northbound off-ramp (3.2 million ESALs) could be accomodated with 7 inches of ACP, however, 8 inches is shown for continuity with the estimated higher use of the southbound ramp. A separation geotextile is recommended in this pavement section because fine-grained soils have been reported in most borings and test pit samples. The geotextile will prevent the migration of fines and keep the fines from fouling the aggregate base course over the life of the pavement. Table 2 shows the 20-year design life recommended sections for ramps.

The asphalt materials specified for this pavement section are from ODOT specification section 00745. The various courses expected for construction of the ACP section will be 3 lifts of ½-inch dense HMAC. The aggregate base specified for this pavement section is ¾-inch - 0, based on ODOT specification section 00641. The first lift over the geotextile fabric should be 6 inches and the remaining lifts should be between a maximum of 6 inches and a minimum of 4 inches.

If competent rock is found during roadway excavation that does not permit the full pavement section to be constructed without rock excavation, an alternative minimum AC pavement section is provided below.

Roundabouts

This pavement section is intended for all three proposed roundabouts in the project. CH2M HILL's scope of work specified that roundabouts be constructed in concrete and based on a design service life of 30 years. The AASHTO Rigid pavement design software was used to develop pavement thicknesses. The design inputs for PCCP thickness design include the following additional parameters and considerations:

Flexural Strength of Concrete: 650 psi was selected to provide resistance to stud wear and to minimize the thickness of the section.

Base Properties: A base thickness of 6 inches crushed aggregate base course (30,000 psi elastic modulus) was selected to provide a good leveling platform and drainage later for the concrete placement.

Climatic Properties: Wind, temperature and precipitation values were estimted and entered as well as seasonal subgrade support figures based on Central Oregon.

Pavement Type & Joint Spacing: Jointed, non-reinforced PCCP was selected along with a 12 foot typical joint spacing with 2 foot widened slab.

Design ESAL's: ESAL's were estimated by the traffic engineers for each roundabout based on a 30 year services life and the traffic approaching each leg of the proposed roundabout. These volumes were adjusted for the number of lanes (lane factor) being provided and were them summed to create the design ESAL used. This method is somewhat conservative since not all traffic will use the entire roundabout circumferance each time through. A sensitivity analysis was completed during the design process in order to make this claim and to check other input parameters listed below:

PCCP Parameters

- Thickness (11 inches minimum to 12 inches maximum)
- Modulus of Rupture (650 psi flexure was selected)
- Elastic Modulus (4,100,000 psi was selected)
- Joint Spacing (12 foot by 14 foot nominal was selected)

Crushed Aggregate Base Parameters

- Thickness (6 inches was selected)
- Elastic Modulus (30,000 psi was selected)

Subgrade Parameters

- K-value of Subgrade (Seasonal value of 220 psi/inch was selected)

General Design Parameters

- Reliability (90% selected – recommended by ODOT)
- Standard Deveiation (0.39 selected – recommended by ODOT)

The pavement designs and sensitivity analyses are included in Attachment B.

For all roundabouts, a separation geotextile is recommended as part of this pavement section because fine-grained soils have been reported in most borings and test pit samples. The geotextile will prevent the migration of fines and keep the fines from fouling the aggregate base course over the life of the pavement. The aggregate base specified for this pavement section is ¾-inch - 0, based on ODOT specification section 00641. The first lift over the geotextile fabric should be the full 6 inches that is recommended.

Table 2 shows the 30-year design life recommended sections for roundabouts.

Pathways

This pavement section is for the Multi-Use Trail/Pathway proposed along the western side of US 97 and other possible locations within the project limits. The pavement section design for this area is based on an assumed low usage by motorized vehicles and no truck traffic. Table 2 shows the 20-year design life recommended section for pathways.

The asphalt materials specified for this pavement section are from ODOT specification section 00745. The 3-inch ACP section will be one lift of 3 inches. The aggregate base specified for this pavement section is ¾-inch - 0, based on ODOT specification section 00641. The base should be placed in one 6-inch lift over the geotextile fabric for protection of the fabric. The subgrade should be cleared of all volcanic rock, roots and vegetative matter to a depth of at least 12 inches.

Alternative minimum ACP Section over competent rock

Volcanic rock of varying degrees of competence was found in nearly all the test pits and borings. It seems prudent to consider it a high likelyhood that competent rock will be found within the proposed excavation limits and to make some provisions for this occurance. Therefore, an alternative pavement section was developed to be an option to blasting competent rock to the full depth of the proposed pavement section. If competent rock is found during roadway excavation that does not permit the full pavement section to be constructed without blasting or extensive rock ripping/excavation the alternative minimum ACP section can be placed. It is important to keep the surfacing depth consistent for the entire segment so the thickness of the aggregate base can be reduced to a minimum of 6 inches to provide a level paving surface and so that drainage can be accomplished between the competent rock and surfacing. If rock can be ripped or blasted cost-effectively, the full section is preferred.

Attachment A
Traffic Calculations

ESAL Summary

No.	Location	2013 ESALs	2033 ESALs	2043 ESALs
1	Murphy Road (Brookswood to 3rd)	113,000	2,925,000	4,990,000
2	Murphy Road (3rd to Parrell)	187,000	4,683,000	7,860,000
3	US 97 Southbound On Ramp	280,000	6,850,000	11,370,000
4	US 97 Northbound Off Ramp	146,000	3,184,000	4,980,000
5	3rd Street (US 97 to Murphy)	305,000	7,452,000	12,350,000
6	Brookswood (West of Murphy Road)	252,000	6,275,000	10,490,000
7	Brookswood Roundabout	667,000	15,460,000	24,940,000
8	3rd Street Roundabout	1,128,000	27,294,000	45,010,000
9	Parrell Road Roundabout	618,000	15,689,000	26,520,000

Location 1 - Murphy Road (Brookswood to 3rd)

Part 1: Traffic Data

Pavement Type: Asphalt Concrete	
Year of Opening:	2013
Structural Design Life:	20 years
2013 Two-Way ADT	5360
2033 Two-Way ADT	8550
20-year expansion factor	1.60

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)	
E = Expansion Factor	1.60
n = Number of Years	20

R = 2.36

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (Two Way)	Year 2013 ESAL's
2	3.39%	182	50	9,100
3	0.52%	28	110	3,080
4	1.24%	66	160	10,560
5	4.58%	245	325	79,625
6+	0.64%	34	325	11,050
	Truck Count:	555	Total ESAL:	113,415

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	113,415	113,415		
2014	116,094	229,509		
2015	118,837	348,346		
2016	121,644	469,990		
2017	124,518	594,508		
2018	127,459	721,967		
2019	130,470	852,437		
2020	133,552	985,989		
2021	136,707	1,122,696		
2022	139,937	1,262,632		
2023	143,242	1,405,875		
2024	146,626	1,552,501		
2025	150,090	1,702,591		
2026	153,635	1,856,226		
2027	157,265	2,013,491		
2028	160,980	2,174,471		
2029	164,783	2,339,253		
2030	168,675	2,507,929		
2031	172,660	2,680,589		
2032	176,739	2,857,327		
2033	180,914	3,038,241	20 Year Design ESAL's	2,924,826
2034	185,188	3,223,429		
2035	189,562	3,412,991		
2036	194,040	3,607,032		
2037	198,624	3,805,656		
2038	203,316	4,008,972		
2039	208,119	4,217,091		
2040	213,036	4,430,127		
2041	218,068	4,648,195		
2042	223,220	4,871,415		
2043	228,493	5,099,907	30 Year Design ESAL's	4,986,492

Location 2 - Murphy Road (3rd to Parrell)

Part 1: Traffic Data

Pavement Type: Asphalt Concrete	
Year of Opening:	2013
Structural Design Life:	20 years
2013 Two-Way ADT	8820
2033 Two-Way ADT	13360
20-year expansion factor	1.51

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)	
E = Expansion Factor	1.51
n = Number of Years	20

R = 2.10

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (Two Way)	Year 2013 ESAL's
2	3.39%	299	50	14,950
3	0.52%	46	110	5,060
4	1.24%	109	160	17,440
5	4.58%	404	325	131,300
6+	0.64%	56	325	18,200
	Truck Count:	914	Total ESAL:	186,950

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	186,950	186,950		
2014	190,872	377,822		
2015	194,876	572,698		
2016	198,965	771,663		
2017	203,139	974,802		
2018	207,401	1,182,203		
2019	211,752	1,393,954		
2020	216,194	1,610,148		
2021	220,730	1,830,878		
2022	225,360	2,056,238		
2023	230,088	2,286,327		
2024	234,915	2,521,242		
2025	239,844	2,761,086		
2026	244,875	3,005,961		
2027	250,013	3,255,974		
2028	255,258	3,511,231		
2029	260,613	3,771,844		
2030	266,080	4,037,924		
2031	271,662	4,309,587		
2032	277,362	4,586,948		
2033	283,180	4,870,129	20 Year Design ESAL's	4,683,179
2034	289,121	5,159,250		
2035	295,187	5,454,437		
2036	301,380	5,755,817		
2037	307,702	6,063,519		
2038	314,158	6,377,677		
2039	320,749	6,698,426		
2040	327,478	7,025,903		
2041	334,348	7,360,251		
2042	341,362	7,701,613		
2043	348,524	8,050,137	30 Year Design ESAL's	7,863,187

Location 3 - US 97 Southbound On Ramp

Part 1: Traffic Data

Pavement Type: Asphalt Concrete
Year of Opening: 2013
Structural Design Life: 20 years

2013 One-Way ADT 6590
2033 One-Way ADT 9590

20-year expansion factor 1.46

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)
E = Expansion Factor 1.46
n = Number of Years 20

R = 1.89

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (One Way)	Year 2013 ESAL's
2	3.39%	223	100	22,300
3	0.52%	34	220	7,480
4	1.24%	82	320	26,240
5	4.58%	302	650	196,300
6+	0.64%	42	650	27,300
	Truck Count:	683	Total ESAL:	279,620

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	279,620	279,620		
2014	284,915	564,535		
2015	290,310	854,844		
2016	295,807	1,150,651		
2017	301,408	1,452,059		
2018	307,115	1,759,175		
2019	312,931	2,072,105		
2020	318,856	2,390,962		
2021	324,894	2,715,855		
2022	331,046	3,046,901		
2023	337,314	3,384,216		
2024	343,702	3,727,917		
2025	350,210	4,078,127		
2026	356,841	4,434,968		
2027	363,598	4,798,566		
2028	370,483	5,169,049		
2029	377,498	5,546,547		
2030	384,646	5,931,193		
2031	391,930	6,323,123		
2032	399,351	6,722,474		
2033	406,913	7,129,387	20 Year Design ESAL's	6,849,767
2034	414,618	7,544,005		
2035	422,469	7,966,473		
2036	430,469	8,396,942		
2037	438,620	8,835,562		
2038	446,925	9,282,487		
2039	455,388	9,737,874		
2040	464,011	10,201,885		
2041	472,797	10,674,682		
2042	481,750	11,156,432		
2043	490,872	11,647,304	30 Year Design ESAL's	11,367,684

Location 4 - US 97 Northbound Off Ramp

Part 1: Traffic Data

Pavement Type: Asphalt Concrete	
Year of Opening:	2013
Structural Design Life:	20 years
2013 One-Way ADT	3455
2033 One-Way ADT	4045
20-year expansion factor	1.17

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)	
E = Expansion Factor	1.17
n = Number of Years	20

R = 0.79

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (One Way)	Year 2013 ESAL's
2	3.39%	117	100	11,700
3	0.52%	18	220	3,960
4	1.24%	43	320	13,760
5	4.58%	158	650	102,700
6+	0.64%	22	650	14,300
	Truck Count:	358	Total ESAL:	146,420

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	146,420	146,420		
2014	147,579	293,999		
2015	148,747	442,746		
2016	149,924	592,669		
2017	151,110	743,780		
2018	152,306	896,086		
2019	153,512	1,049,598		
2020	154,727	1,204,325		
2021	155,951	1,360,276		
2022	157,185	1,517,461		
2023	158,429	1,675,890		
2024	159,683	1,835,574		
2025	160,947	1,996,521		
2026	162,221	2,158,741		
2027	163,505	2,322,246		
2028	164,799	2,487,044		
2029	166,103	2,653,147		
2030	167,417	2,820,564		
2031	168,742	2,989,307		
2032	170,078	3,159,384		
2033	171,424	3,330,808	20 Year Design ESAL's	3,184,388
2034	172,780	3,503,588		
2035	174,148	3,677,736		
2036	175,526	3,853,262		
2037	176,915	4,030,177		
2038	178,315	4,208,492		
2039	179,726	4,388,219		
2040	181,149	4,569,368		
2041	182,582	4,751,950		
2042	184,027	4,935,978		
2043	185,484	5,121,462	30 Year Design ESAL's	4,975,042

Location 5 - 3rd Street (US 97 to Murphy)

Part 1: Traffic Data

Pavement Type: Asphalt Concrete	
Year of Opening:	2013
Structural Design Life:	20 years
2013 Two-Way ADT	14360
2033 Two-Way ADT	20820
20-year expansion factor	1.45

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)	
E = Expansion Factor	1.45
n = Number of Years	20

R = 1.87

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (Two Way)	Year 2013 ESAL's
2	3.39%	487	50	24,350
3	0.52%	75	110	8,250
4	1.24%	178	160	28,480
5	4.58%	658	325	213,850
6+	0.64%	92	325	29,900
	Truck Count:	1,490	Total ESAL:	304,830

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	304,830	304,830		
2014	310,545	615,375		
2015	316,366	931,741		
2016	322,297	1,254,038		
2017	328,339	1,582,378		
2018	334,495	1,916,872		
2019	340,765	2,257,638		
2020	347,154	2,604,792		
2021	353,662	2,958,454		
2022	360,292	3,318,745		
2023	367,046	3,685,792		
2024	373,927	4,059,719		
2025	380,937	4,440,656		
2026	388,079	4,828,735		
2027	395,354	5,224,089		
2028	402,766	5,626,855		
2029	410,316	6,037,171		
2030	418,008	6,455,179		
2031	425,845	6,881,024		
2032	433,828	7,314,852		
2033	441,961	7,756,813	20 Year Design ESAL's	7,451,983
2034	450,246	8,207,060		
2035	458,687	8,665,747		
2036	467,286	9,133,033		
2037	476,046	9,609,079		
2038	484,971	10,094,050		
2039	494,062	10,588,113		
2040	503,325	11,091,437		
2041	512,760	11,604,198		
2042	522,373	12,126,571		
2043	532,166	12,658,737	30 Year Design ESAL's	12,353,907

Location 6 - Brookswood (West of Murphy Road extension)

Part 1: Traffic Data

Pavement Type: Asphalt Concrete

Year of Opening:	2013
Structural Design Life:	20 years
2013 Two-Way ADT	14000
2033 Two-Way ADT	20910
20-year expansion factor	1.49

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)	
E = Expansion Factor	1.49
n = Number of Years	20

R = 2.03

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (Two Way)	Year 2013 ESAL's
2	2.88%	403	50	20,150
3	0.44%	62	110	6,820
4	1.05%	148	160	23,680
5	3.89%	545	325	177,125
6+	0.54%	76	325	24,700
	Truck Count:	1,234	Total ESAL:	252,475

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	252,475	252,475		
2014	257,590	510,065		
2015	262,809	772,875		
2016	268,134	1,041,009		
2017	273,567	1,314,576		
2018	279,110	1,593,686		
2019	284,765	1,878,450		
2020	290,534	2,168,985		
2021	296,421	2,465,406		
2022	302,427	2,767,832		
2023	308,554	3,076,386		
2024	314,806	3,391,192		
2025	321,184	3,712,376		
2026	327,692	4,040,068		
2027	334,331	4,374,399		
2028	341,105	4,715,504		
2029	348,016	5,063,520		
2030	355,067	5,418,587		
2031	362,261	5,780,848		
2032	369,601	6,150,449		
2033	377,089	6,527,538	20 Year Design ESAL's	6,275,063
2034	384,730	6,912,268		
2035	392,525	7,304,793		
2036	400,478	7,705,270		
2037	408,592	8,113,862		
2038	416,870	8,530,732		
2039	425,316	8,956,049		
2040	433,934	9,389,982		
2041	442,726	9,832,708		
2042	451,696	10,284,404		
2043	460,848	10,745,252	30 Year Design ESAL's	10,492,777

Location 7 - Brookswood Roundabout

Part 1: Traffic Data

Pavement Type: Asphalt Concrete
Year of Opening: 2013
Structural Design Life: 30 years

2013 One-Way ADT 13225
2033 One-Way ADT 17410

20-year expansion factor 1.32

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)
E = Expansion Factor 1.32
n = Number of Years 20

R = 1.38

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (One Way)	Year 2013 ESAL's
2	2.88%	381	100	38,100
3	0.44%	58	270	15,660
4	1.05%	139	400	55,600
5	3.89%	515	950	489,250
6+	0.54%	72	950	68,400
	Truck Count:	1,165	Total ESAL:	667,010

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	667,010	667,010		
2014	676,243	1,343,253		
2015	685,603	2,028,855		
2016	695,093	2,723,948		
2017	704,714	3,428,662		
2018	714,469	4,143,131		
2019	724,358	4,867,489		
2020	734,384	5,601,873		
2021	744,550	6,346,423		
2022	754,855	7,101,278		
2023	765,304	7,866,582		
2024	775,897	8,642,479		
2025	786,637	9,429,116		
2026	797,525	10,226,641		
2027	808,564	11,035,205		
2028	819,756	11,854,961		
2029	831,103	12,686,064		
2030	842,607	13,528,671		
2031	854,270	14,382,941		
2032	866,095	15,249,035		
2033	878,083	16,127,118	20 Year Design ESAL's	15,460,108
2034	890,237	17,017,355		
2035	902,559	17,919,914		
2036	915,052	18,834,966		
2037	927,718	19,762,685		
2038	940,559	20,703,244		
2039	953,578	21,656,822		
2040	966,777	22,623,600		
2041	980,159	23,603,759		
2042	993,726	24,597,485		
2043	1,007,481	25,604,967	30 Year Design ESAL's	24,937,957

Location 8 - Third Street Roundabout

Part 1: Traffic Data

Pavement Type: Asphalt Concrete
Year of Opening: 2013
Structural Design Life: 30 years

2013 One-Way ADT 19000
2033 One-Way ADT 27045

20-year expansion factor 1.42

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)
E = Expansion Factor 1.42
n = Number of Years 20

R = 1.78

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (One Way)	Year 2013 ESAL's
2	3.39%	644	100	64,400
3	0.52%	99	270	26,730
4	1.24%	236	400	94,400
5	4.58%	870	950	826,500
6+	0.64%	122	950	115,900
	Truck Count:	1,971	Total ESAL:	1,127,930

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	1,127,930	1,127,930		
2014	1,148,018	2,275,948		
2015	1,168,464	3,444,413		
2016	1,189,275	4,633,687		
2017	1,210,455	5,844,143		
2018	1,232,014	7,076,156		
2019	1,253,956	8,330,112		
2020	1,276,288	9,606,400		
2021	1,299,019	10,905,419		
2022	1,322,154	12,227,574		
2023	1,345,702	13,573,276		
2024	1,369,669	14,942,944		
2025	1,394,062	16,337,007		
2026	1,418,890	17,755,897		
2027	1,444,161	19,200,058		
2028	1,469,881	20,669,939		
2029	1,496,059	22,165,998		
2030	1,522,704	23,688,702		
2031	1,549,823	25,238,526		
2032	1,577,426	26,815,951		
2033	1,605,519	28,421,470	20 Year Design ESAL's	27,293,540
2034	1,634,113	30,055,584		
2035	1,663,217	31,718,801		
2036	1,692,839	33,411,639		
2037	1,722,988	35,134,627		
2038	1,753,674	36,888,301		
2039	1,784,907	38,673,208		
2040	1,816,696	40,489,904		
2041	1,849,051	42,338,955		
2042	1,881,982	44,220,937		
2043	1,915,500	46,136,437	30 Year Design ESAL's	45,008,507

Location 9 - Parrell Road Roundabout

Part 1: Traffic Data

Pavement Type: Asphalt Concrete
Year of Opening: 2013
Structural Design Life: 30 years

2013 One-Way ADT 10410
2033 One-Way ADT 16135

20-year expansion factor 1.55

Part 2: Annual Growth Rate

R=[E(power(1/n)) - 1] * 100

R = Annual Growth (%)
E = Expansion Factor 1.55
n = Number of Years 20

R = 2.22

Part 3: ESAL for year 2013

Number of Axles	Percent Trucks	Number of Trucks	Conversion Factor (One Way)	Year 2013 ESAL's
2	3.39%	353	100	35,300
3	0.52%	54	270	14,580
4	1.24%	129	400	51,600
5	4.58%	477	950	453,150
6+	0.64%	67	950	63,650
	Truck Count:	1,080	Total ESAL:	618,280

Part 4: ESAL for Design Life

Ex: 2014 ESAL's = 2013 ESAL's [1+(R/100)]

Year	ESAL's	Summation		
2013	618,280	618,280		
2014	631,977	1,250,257		
2015	645,977	1,896,234		
2016	660,287	2,556,521		
2017	674,915	3,231,436		
2018	689,866	3,921,302		
2019	705,149	4,626,450		
2020	720,770	5,347,220		
2021	736,737	6,083,957		
2022	753,058	6,837,015		
2023	769,740	7,606,756		
2024	786,793	8,393,548		
2025	804,222	9,197,770		
2026	822,038	10,019,809		
2027	840,249	10,860,058		
2028	858,863	11,718,921		
2029	877,889	12,596,810		
2030	897,337	13,494,147		
2031	917,216	14,411,363		
2032	937,535	15,348,898		
2033	958,304	16,307,203	20 Year Design ESAL's	15,688,923
2034	979,534	17,286,736		
2035	1,001,233	18,287,970		
2036	1,023,414	19,311,383		
2037	1,046,085	20,357,468		
2038	1,069,259	21,426,728		
2039	1,092,947	22,519,674		
2040	1,117,159	23,636,833		
2041	1,141,907	24,778,740		
2042	1,167,204	25,945,943		
2043	1,193,061	27,139,004	30 Year Design ESAL's	26,520,724

Attachment B
Pavement Design Calculations

NAME : Kevin Cooley, P.E.
PROJECT : US 97/Murphy Road: Brookswood - Parrell, Project Development
SUBJECT : Pavement Design
PROJ. # : 407067.02.05.05
DATE : 1/24/2011

1) Traffic

See Attachment B for Traffic Calculations

No.	Location	2013 ESAL	20 Yr Life 2033 ESAL
1	Murphy Rd (Brookswood to 3rd)	110,000	2,925,000

2) Estimate Other Pavement Design Parameters

Misc. Parameters

Reliability = 90% for urban principal arterial
Standard Deviation = .49 — Per ODOT for Flexible Pavements
Initial Serviceability = 4.2
Terminal Serviceability = 2.5
Drainage Coefficient Assume m = 1.00

Layer Parameters

ACP	range between 0.40 and 0.42
Aggregate Base	0.10
New Aggregate Subbase (if needed)	0.08

Unit Price Assumptions

ACP Level 3 HMAC	$	53.65	/TN
Aggregate Base	$	17.25	/TN
Soil Separation Fabric	$	1.00	/SY

3) Estimate Soil Conditions

Using Soils data from CH2M HILL, soil exploration shows a CBR value between 12 and 16 which yields a resilient modulus between 10,637 and 12.951 psi. We recommend using an Mr=10,637 psi (CBR 12%) which cooresponds with sandy silt (SM) soil with occassional boulders and no volcanic rock layer present within section. Rock is found at the following depths in nearby locations: 3' @ B-3-10 & B-4-10; 3.5' @ TP-3-10 & TP-4-10 and a minimum depth of 1.2' at B-2-10. See Table 1 in Geotech Data Report for additional depths to rock for this site. If pavement excavation encounters competent rock, use alternative minimum pavement section discussed in report.

Recommended Mr. - For Flexible Design = 10,637 as shown below.

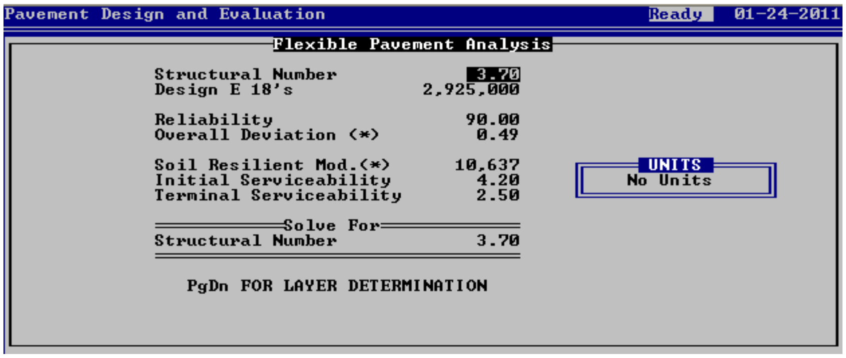
Empirical relationships have been developed between the CBR (California Bearing Ratio) value (using dynamic compaction),the R-value, and the in-situ resilient modulus of the soil.

CBR Value: 12.0 — or — R-Value:
Resilient Modulus, psi: 10,637 — Resilient Modulus, psi:

Subgrade Resilient Modulus: 10,637 psi

The correlations used in this program were developed under NCHRP Project 128, "Evaluation of AASHO Interim Guide for the Design of Pavement Structures." This study found a non-linear relationship between resilient modulus and CBR or R-Value. Although equation 1.5.1 of the AASHTO Guide suggests a relationship of 1500 * CBR for the resilient modulus of the subgrade, this correlation is only valid for fine-grained soils with low CBR values. Other studies (Indiana, Ohio) have shown a correlations as low as 800 * CBR, and ranging from 750 to 3,000 times the CBR value. This range agrees with the correlation established in NCHRP Project 128.

4a) Calculation of Structural Number



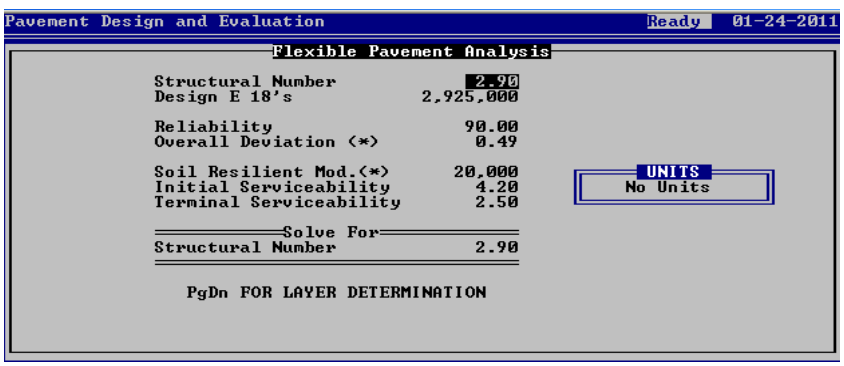
Required SN	3.70*

4b) Layer Thickness Determination

Determine Minimum ACP Thickness

Typical values for resilient modulus of unbound aggregate bases range from 15,000 to 45,000 psi. This design will assume a value of 20,000 psi for the determination of the total thickness of the ACP layer above a compacted unbound aggregate base.

Reqd. SN	ACP Coef.	Min ACP Thickness
2.9	0.42	6.9



ACP over Aggregate Base

Coef.	Material		Drain Coef.	Layer Thickness	SNi	$ / SF		
0.40	Level 3, ½" Dense, HMAC	3 lifts	1.00	8	3.20	$	2.72	
0.10	¾" - 0 Aggregate Base *	3 lifts	1.00	10	1.00	$	0.98	
0.00	Soil Separation Fabric	on subgrade	0.00	0	-	$	0.11	
SN					4.20	$	3.81	per SF
Design OK?					☑			

* First lift over fabric must be 6" depth. Remaining layers shall be 4" min and 6 in max.

5) Portland Cement Concrete Pavement Alternative Design - Not Designed.

NAME : Kevin Cooley, P.E.
PROJECT : US 97/Murphy Road: Brookswood - Parrell, Project Development
SUBJECT : Pavement Design
PROJ. # : 407067.02.05.05
DATE : 1/24/2011

1) Traffic

See Attachment B for Traffic Calculations

			20 Yr Life
No.	**Location**	**2013 ESAL**	**2033 ESAL**
2	Murphy Rd (3rd to Parrell)	187,000	4,683,000

2) Estimate Other Pavement Design Parameters

Misc. Parameters

Reliability = 90% for urban principal arterial
Standard Deviation = .49 — Per ODOT for Flexible Pavements
Initial Serviceability = 4.2
Terminal Serviceability = 2.5
Drainage Coefficient Assume m = 1.00

Layer Parameters

ACP	range between 0.40 and 0.42
Aggregate Base	0.10
New Aggregate Subbase (if needed)	0.08

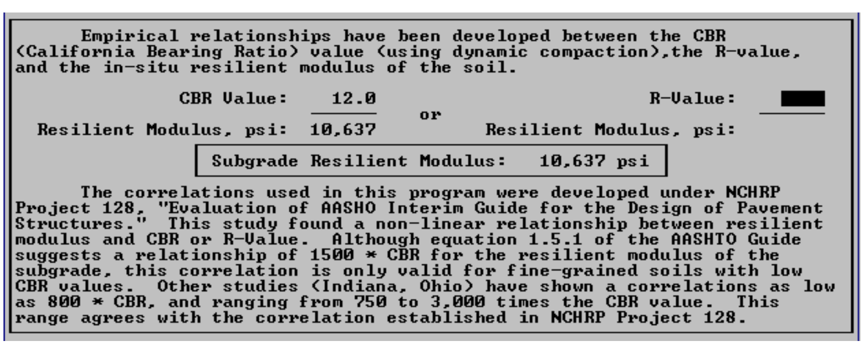
Unit Price Assumptions

ACP Level 3 HMAC	$	53.65	/TN
Aggregate Base	$	17.25	/TN
Soil Separation Fabric	$	1.00	/SY

3) Estimate Soil Conditions

Using Soils data from CH2M HILL, soil exploration shows a CBR value between 12 and 16 which yields a resilient modulus between 10,637 and 12.951 psi. We recommend using an Mr=10,637 psi (CBR 12%) which cooresponds with sandy silt (SM) soil with occassional boulders and no volcanic rock layer present within section. Rock is found at the following depths in nearby locations: 7' @ TP-5-10 and 3.7' at B-8-10 and a minimum depth of 3.5' at TP-4-10. See Table 1 in Geotech Data Report for additional depths to rock for this site. If pavement excavation encounters competent rock, use alternative minimum pavement section discussed in report.

Recommended Mr. - For Flexible Design = 10,637 as shown below.



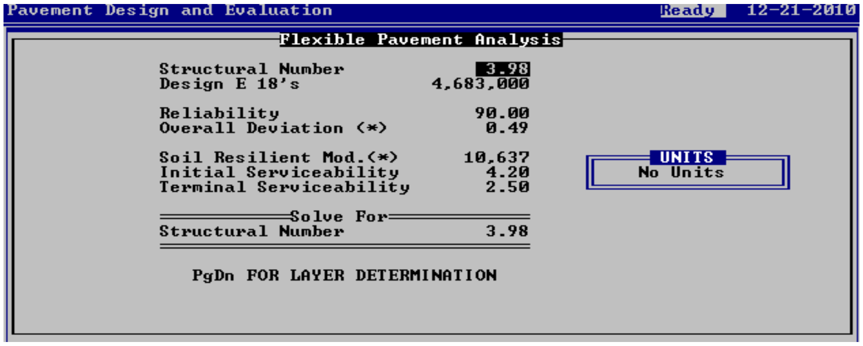
Empirical relationships have been developed between the CBR (California Bearing Ratio) value (using dynamic compaction), the R-value, and the in-situ resilient modulus of the soil.

CBR Value: 12.0 — or — R-Value:
Resilient Modulus, psi: 10,637 — Resilient Modulus, psi:

Subgrade Resilient Modulus: 10,637 psi

The correlations used in this program were developed under NCHRP Project 128, "Evaluation of AASHO Interim Guide for the Design of Pavement Structures." This study found a non-linear relationship between resilient modulus and CBR or R-Value. Although equation 1.5.1 of the AASHTO Guide suggests a relationship of 1500 * CBR for the resilient modulus of the subgrade, this correlation is only valid for fine-grained soils with low CBR values. Other studies (Indiana, Ohio) have shown a correlations as low as 800 * CBR, and ranging from 750 to 3,000 times the CBR value. This range agrees with the correlation established in NCHRP Project 128.

4a) Calculation of Structural Number



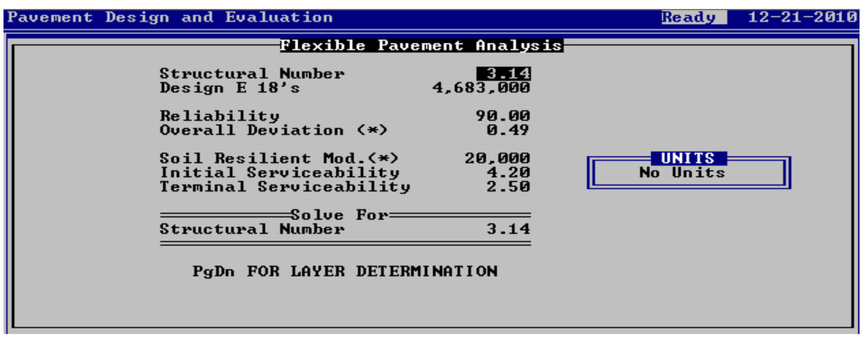
Required SN	3.98*

4b) Layer Thickness Determination

Determine Minimum ACP Thickness

Typical values for resilient modulus of unbound aggregate bases range from 15,000 to 45,000 psi. This design will assume a value of 20,000 psi for the determination of the total thickness of the ACP layer above a compacted unbound aggregate base.

Reqd. SN	ACP Coef.	Min ACP Thickness
3.14	0.42	7.5



ACP over Aggregate Base

Coef.	Material		Drain Coef.	Layer Thickness	SNi	$ / SF		
0.40	Level 3, ½" Dense, HMAC	3 lifts	1.00	8	3.20	$	2.72	
0.10	¾" - 0 Aggregate Base *	3 lifts	1.00	10	1.00	$	0.98	
0.00	Soil Separation Fabric	on subgrade	0.00	0	-	$	0.11	
SN					4.20	$	3.81	per SF
Design OK?					☑			

* First lift over fabric must be 6" depth. Remaining layers shall be 4" min and 6 in max.

5) Portland Cement Concrete Pavement Alternative Design - Not Designed.

NAME : Kevin Cooley, P.E.
PROJECT : US 97/Murphy Road: Brookswood - Parrell, Project Development
SUBJECT : Pavement Design
PROJ. # : 407067.02.05.05
DATE : 1/24/2011

1) Traffic

See Attachment B for Traffic Calculations

No.	Location	2013 ESAL	20 Yr Life 2033 ESAL
3	US 97 Southbound On ramp	259,000	6,850,000

2) Estimate Other Pavement Design Parameters

Misc. Parameters

Reliability = 90% for urban principal arterial
Standard Deviation = .49 — Per ODOT for Flexible Pavements
Initial Serviceability = 4.2
Terminal Serviceability = 2.5
Drainage Coefficient Assume m = 1.00

Layer Parameters

ACP	range between 0.40 and 0.42
Aggregate Base	0.10
New Aggregate Subbase (if needed)	0.08

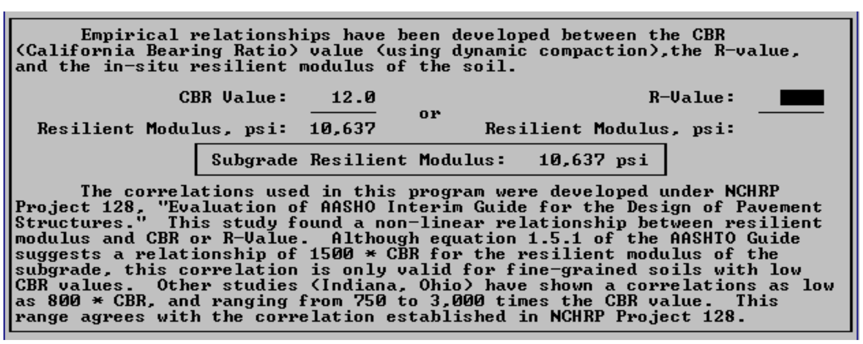
Unit Price Assumptions

ACP Level 3 HMAC	$	53.65	/TN
Aggregate Base	$	17.25	/TN
Soil Separation Fabric	$	1.00	/SY

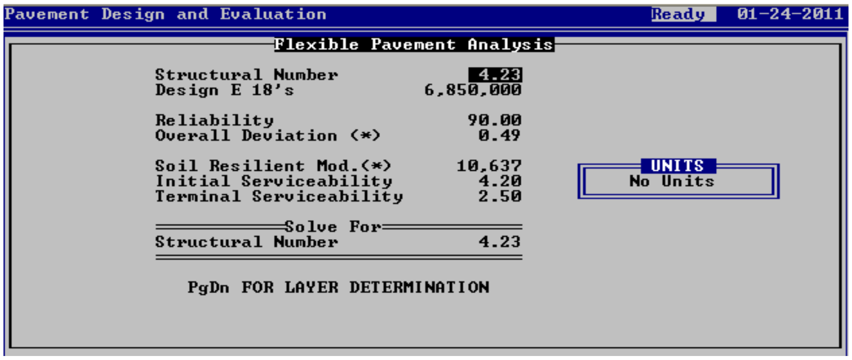
3) Estimate Soil Conditions

Using Soils data from CH2M HILL, soil exploration shows a CBR value between 12 and 16 which yields a resilient modulus between 10,637 and 12.951 psi. We recommend using an Mr=10,637 psi (CBR 12%) which cooresponds with sandy silt (SM) soil with occassional boulders and no volcanic rock layer present within section. Rock is found at the following depths in nearby locations: 1.8' @ B-15-10; 7.5' @ B-17-10; 2.5' at B-9-10 and a minimum depth of 1.0' at TP-7-10. See Table 1 in Geotech Data Report for additional depths to rock for this site.
If pavement excavation encounters competent rock, use alternative minimum pavement section discussed in report.

Recommended Mr. - For Flexible Design = 10,637 as shown below.



4a) Calculation of Structural Number



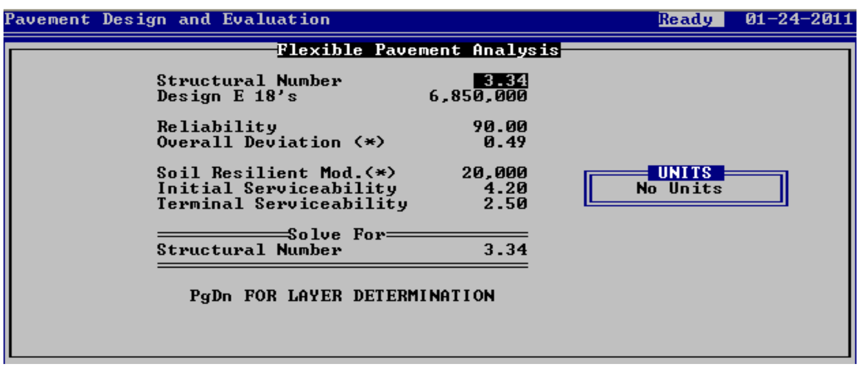
Required SN	4.23*

4b) Layer Thickness Determination

Determine Minimum ACP Thickness

Typical values for resilient modulus of unbound aggregate bases range from 15,000 to 45,000 psi. This design will assume a value of 20,000 psi for the determination of the total thickness of the ACP layer above a compacted unbound aggregate base.

Reqd. SN	ACP Coef.	Min ACP Thickness
3.34	0.42	8.0



ACP over Aggregate Base

Coef.	Material		Drain Coef.	Layer Thickness	SNi	$ / SF	
0.40	Level 3, ½" Dense, HMAC	3 lifts	1.00	8	3.23	$	2.72
0.10	¾" - 0 Aggregate Base *	3 lifts	1.00	10	1.00	$	0.98
0.00	Soil Separation Fabric	on subgrade	0.00	0	-	$	0.11
SN					4.23	$	3.81 per SF
Design OK?					☑		

* First lift over fabric must be 6" depth. Remaining layers shall be 4" min and 6 in max.

5) Portland Cement Concrete Pavement Alternative Design - Not Designed.

NAME : Kevin Cooley, P.E.
PROJECT : US 97/Murphy Road: Brookswood - Parrell, Project Development
SUBJECT : Pavement Design
PROJ. # : 407067.02.05.05
DATE : 1/24/2011

1) Traffic

See Attachment B for Traffic Calculations

No.	Location	2013 ESAL	20 Yr Life 2033 ESAL
4	US 97 Northbound Off Ramp	73,000	3,184,000

2) Estimate Other Pavement Design Parameters

Misc. Parameters

Reliability = 90% for urban principal arterial
Standard Deviation = .49 — Per ODOT for Flexible Pavements
Initial Serviceability = 4.2
Terminal Serviceability = 2.5
Drainage Coefficient Assume m = 1.00

Layer Parameters

ACP	range between 0.40 and 0.42
Aggregate Base	0.10
New Aggregate Subbase (if needed)	0.08

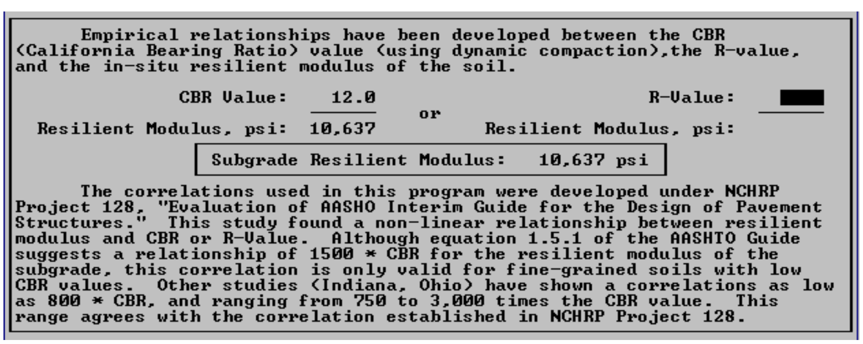
Unit Price Assumptions

ACP Level 3 HMAC	$	53.65	/TN
Aggregate Base	$	17.25	/TN
Soil Separation Fabric	$	1.00	/SY

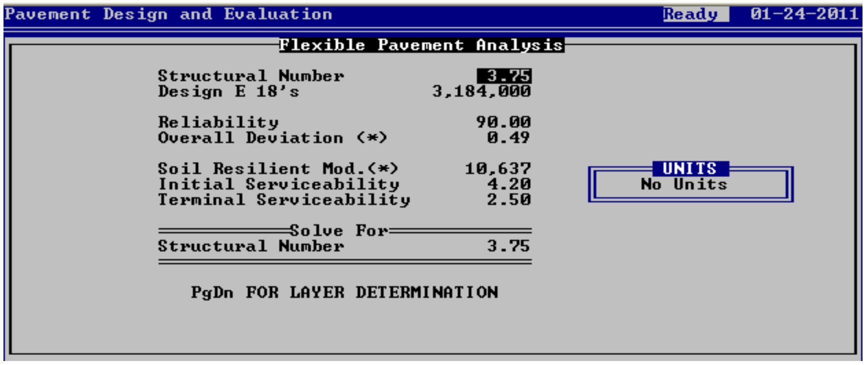
3) Estimate Soil Conditions

Using Soils data from CH2M HILL, soil exploration shows a CBR value between 12 and 16 which yields a resilient modulus between 10,637 and 12.951 psi. We recommend using an Mr=10,637 psi (CBR 12%) which cooresponds with sandy silt (SM) soil with occassional gravel and no volcanic rock layer present within section. Rock is found at the following depths in nearby locations: 5' @ B-18-10; 3' @ TP-8-10; 1.5' @ B-19-10 and a minimum depth of 0.5' at TP-8-10. See Table 1 in Geotech Data Report for additional depths to rock for this site.
If pavement excavation encounters competent rock, use alternative minimum pavement section discussed in report.

Recommended Mr. - For Flexible Design = 10,637 as shown below.



4a) Calculation of Structural Number



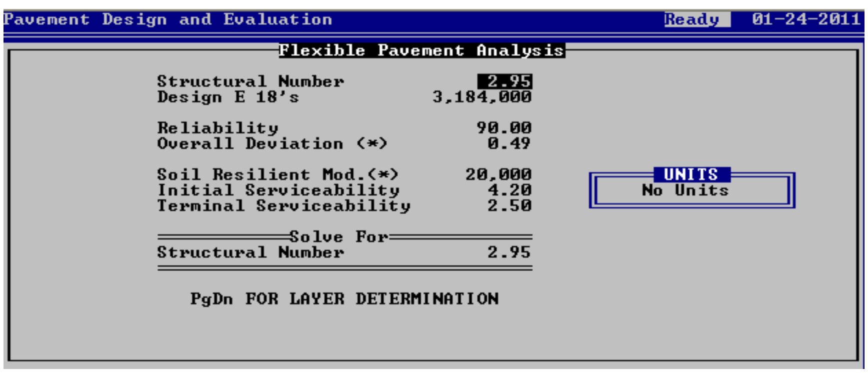
Required SN	3.75*

4b) Layer Thickness Determination

Determine Minimum ACP Thickness

Typical values for resilient modulus of unbound aggregate bases range from 15,000 to 45,000 psi. This design will assume a value of 20,000 psi for the determination of the total thickness of the ACP layer above a compacted unbound aggregate base.

Reqd. SN	**ACP Coef.**	**Min ACP Thickness**
2.95	0.42	7.0



ACP over Aggregate Base

Coef.	**Material**		**Drain Coef.**	**Layer Thickness**	**SNi**	**$ / SF**		
0.40	Level 3, ½" Dense, HMAC	3 lifts	1.00	8	3.20	$	2.72	
0.10	¾" - 0 Aggregate Base *	3 lifts	1.00	10	1.00	$	0.98	
0.00	Soil Separation Fabric	on subgrade	0.00	0	-	$	0.11	
SN					4.20	$	3.81	per SF
Design OK?					☑			

* First lift over fabric must be 6" depth. Remaining layers shall be 4" min and 6 in max.

5) Portland Cement Concrete Pavement Alternative Design - Not Designed.

NAME : **Kevin Cooley, P.E.**
PROJECT : **US 97/Murphy Road: Brookswood - Parrell, Project Development**
SUBJECT : **Pavement Design**
PROJ. # : **407067.02.05.05**
DATE : **1/24/2011**

1) Traffic

See Attachment B for Traffic Calculations

			20 Yr Life
No.	**Location**	**2013 ESAL**	**2033 ESAL**
5	3rd Street (US 97 to Murphy Rd.)	305,000	7,452,000

2) Estimate Other Pavement Design Parameters

Misc. Parameters

Reliability = 90% for urban principal arterial
Standard Deviation = .49 — Per ODOT for Flexible Pavements
Initial Serviceability = 4.2
Terminal Serviceability = 2.5
Drainage Coefficient Assume m = 1.00

Layer Parameters

ACP	range between 0.40 and 0.42
Aggregate Base	0.10
New Aggregate Subbase (if needed)	0.08

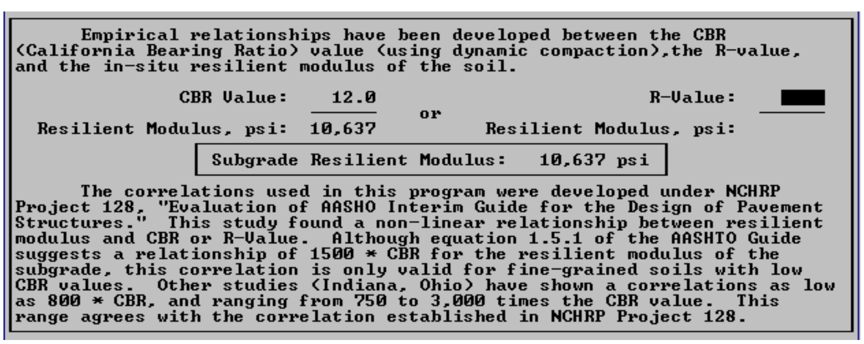
Unit Price Assumptions

ACP Level 3 HMAC	$	53.65	/TN
Aggregate Base	$	17.25	/TN
Soil Separation Fabric	$	1.00	/SY

3) Estimate Soil Conditions

Using Soils data from CH2M HILL, soil exploration shows a CBR value between 12 and 16 which yields a resilient modulus between 10,637 and 12.951 psi. We recommend using an Mr=10,637 psi (CBR 12%) which cooresponds with sandy silt (SM) soil with occassional gravel and no volcanic rock layer present within section. Rock is found at the following depths in nearby locations: 7' @ TP-5-10 and 4' at B-14-10 and a minimum depth of 1.5' at TP-9-10. See Table 1 in Geotech Data Report for additional depths to rock for this site.
If pavement excavation encounters competent rock, use alternative minimum pavement section discussed in report.

Recommended Mr. - For Flexible Design = 10,637 as shown below.

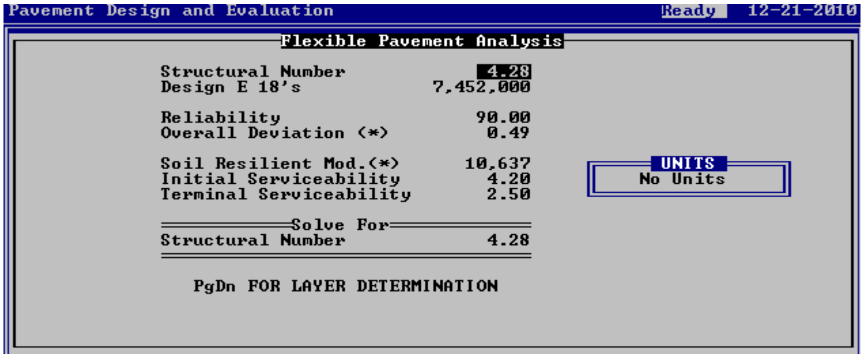

Empirical relationships have been developed between the CBR (California Bearing Ratio) value (using dynamic compaction),the R-value, and the in-situ resilient modulus of the soil.

CBR Value: 12.0 — or — R-Value:
Resilient Modulus, psi: 10,637 — Resilient Modulus, psi:

Subgrade Resilient Modulus: 10,637 psi

The correlations used in this program were developed under NCHRP Project 128, "Evaluation of AASHO Interim Guide for the Design of Pavement Structures." This study found a non-linear relationship between resilient modulus and CBR or R-Value. Although equation 1.5.1 of the AASHTO Guide suggests a relationship of 1500 * CBR for the resilient modulus of the subgrade, this correlation is only valid for fine-grained soils with low CBR values. Other studies (Indiana, Ohio) have shown a correlations as low as 800 * CBR, and ranging from 750 to 3,000 times the CBR value. This range agrees with the correlation established in NCHRP Project 128.

4a) Calculation of Structural Number



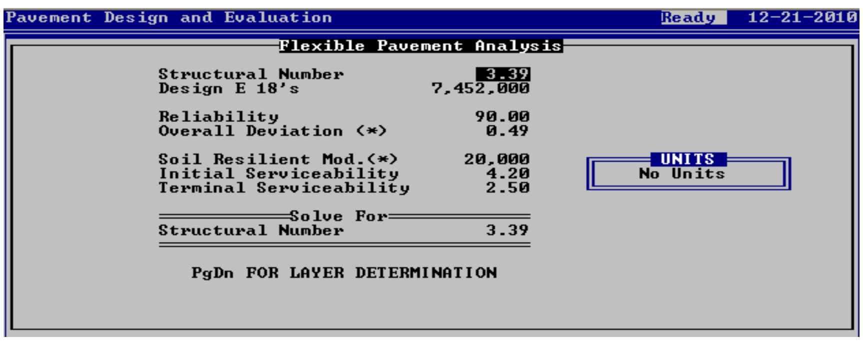
Required SN	4.28*

4b) Layer Thickness Determination

Determine Minimum ACP Thickness

Typical values for resilient modulus of unbound aggregate bases range from 15,000 to 45,000 psi. This design will assume a value of 20,000 psi for the determination of the total thickness of the ACP layer above a compacted unbound aggregate base.

Reqd. SN	ACP Coef.	Min ACP Thickness
3.39	0.42	8.1



ACP over Aggregate Base

Coef.	Material		Drain Coef.	Layer Thickness	SNi	$ / SF
0.41	Level 3, ½" Dense, HMAC	3 lifts	1.00	8	3.28	$ 2.72
0.10	¾" - 0 Aggregate Base *	3 lifts	1.00	10	1.00	$ 0.98
0.00	Soil Separation Fabric	on subgrade	0.00	0	-	$ 0.11
SN					4.28	$ 3.81 per SF
Design OK?					☑	

* First lift over fabric must be 6" depth. Remaining layers shall be 4" min and 6 in max.

5) Portland Cement Concrete Pavement Alternative Design - Not Designed.

NAME : Kevin Cooley, P.E.
PROJECT : US 97/Murphy Road: Brookswood - Parrell, Project Development
SUBJECT : Pavement Design
PROJ. # : 407067.02.05.05
DATE : 1/24/2011

1) Traffic

See Attachment B for Traffic Calculations

No.	Location	2013 ESAL	20 Yr Life 2033 ESAL
6	Brookswood (West of Murphy)	293,000	6,275,000

2) Estimate Other Pavement Design Parameters

Misc. Parameters

Reliability = 90% for urban principal arterial
Standard Deviation = .49 — Per ODOT for Flexible Pavements
Initial Serviceability = 4.2
Terminal Serviceability = 2.5
Drainage Coefficient Assume m = 1.00

Layer Parameters

ACP	range between 0.40 and 0.42
Aggregate Base	0.10
New Aggregate Subbase (if needed)	0.08

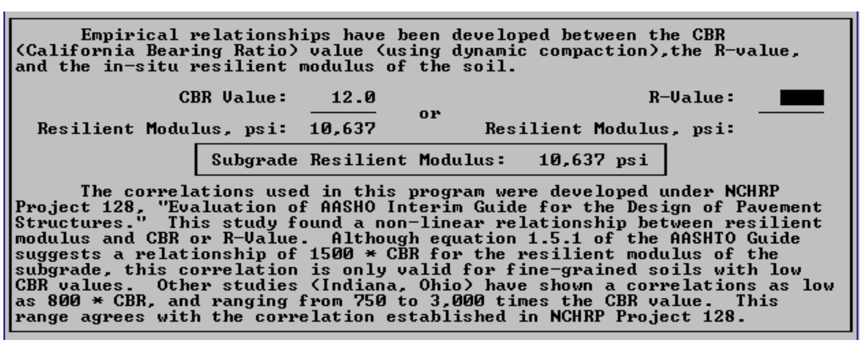
Unit Price Assumptions

ACP Level 3 HMAC	$	53.65	/TN
Aggregate Base	$	17.25	/TN
Soil Separation Fabric	$	1.00	/SY

3) Estimate Soil Conditions

Using Soils data from CH2M HILL, soil exploration shows a CBR value between 12 and 16
which yields a resilient modulus between 10,637 and 12.951 psi. We recommend using an Mr=10,637 psi (CBR 12%)
which cooresponds with sandy silt (SM) soil with occassional gravel and no volcanic rock layer present within section.
Rock is found at the following depths in nearby locations: 2' @ B-1-10 and a minimum depth of 1.2 feet @ B-2-10.
See Table 1 in Geotech Data Report for additional depths to rock for this site.
If pavement excavation encounters competent rock, use alternative minimum pavement section discussed in report.

Recommended Mr. - For Flexible Design = 10,637 as shown below.



Empirical relationships have been developed between the CBR (California Bearing Ratio) value (using dynamic compaction), the R-value, and the in-situ resilient modulus of the soil.

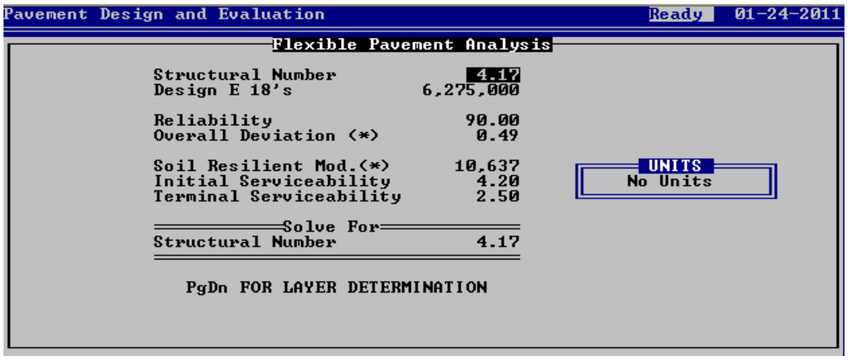
CBR Value: 12.0 — or — R-Value:

Resilient Modulus, psi: 10,637 — Resilient Modulus, psi:

Subgrade Resilient Modulus: 10,637 psi

The correlations used in this program were developed under NCHRP Project 128, "Evaluation of AASHO Interim Guide for the Design of Pavement Structures." This study found a non-linear relationship between resilient modulus and CBR or R-Value. Although equation 1.5.1 of the AASHTO Guide suggests a relationship of 1500 * CBR for the resilient modulus of the subgrade, this correlation is only valid for fine-grained soils with low CBR values. Other studies (Indiana, Ohio) have shown a correlations as low as 800 * CBR, and ranging from 750 to 3,000 times the CBR value. This range agrees with the correlation established in NCHRP Project 128.

4a) Calculation of Structural Number



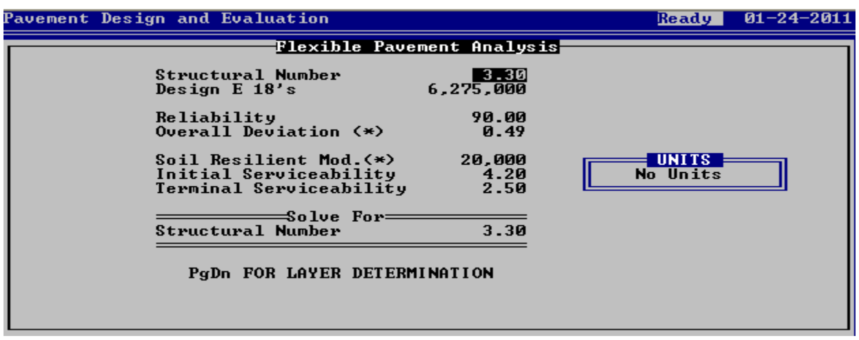
Required SN	4.17*

4b) Layer Thickness Determination

Determine Minimum ACP Thickness

Typical values for resilient modulus of unbound aggregate bases range from 15,000 to 45,000 psi. This design will assume a value of 20,000 psi for the determination of the total thickness of the ACP layer above a compacted unbound aggregate base.

Reqd. SN	ACP Coef.	Min ACP Thickness
3.30	0.42	7.9



ACP over Aggregate Base

Coef.	Material		Drain Coef.	Layer Thickness	SNi	$ / SF	
0.40	Level 3, ½" Dense, HMAC	3 lifts	1.00	8	3.20	$ 2.72	
0.10	¾" - 0 Aggregate Base *	3 lifts	1.00	10	1.00	$ 0.98	
0.00	Soil Separation Fabric	on subgrade	0.00	0	-	$ 0.11	
SN					4.20	$ 3.81	per SF
Design OK?					☑		

* First lift over fabric must be 6" depth. Remaining layers shall be 4" min and 6 in max.

5) Portland Cement Concrete Pavement Alternative Design - Not Designed.

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

I. General

Agency: City of Bend
Street Address: Murphy Rd. Project
City: Bend
State: OR

Project Number: 407067.02.05.05 | ID: US 97

Description: High Cement Content, low water/cement ratio for rut resistance

Location: Brookswood Roundabout

II. Design

Serviceability

Initial Serviceability, P1: 4.5
Terminal Serviceability, P2: 2.5

PCC Properties

28-day Mean Modulus of Rupture, (S'_c)': 650 psi
Elastic Modulus of Slab, E_c: 4,100,000 psi
Poisson's Ratio for Concrete, m: 0.15

Base Properties

Elastic Modulus of Base, E_b: 30,000 psi
Design Thickness of Base, H_b: 6.0 in
Slab-Base Friction Factor, f: 1.4

Reliability and Standard Deviation

Reliability Level (R): 90.0 %
Overall Standard Deviation, S_0: 0.39

Climatic Properties

Mean Annual Wind Speed, WIND: 9.0 mph
Mean Annual Air Temperature, TEMP: 45.0 ^oF
Mean Annual Precipitation, PRECIP: 17.0 in

Subgrade k-Value

220 psi/in

Design ESALs

24.9 million

Pavement Type, Joint Spacing (L)

(●) JPCP
( ) JRCP
( ) CRCP

Joint Spacing: 12.0 ft

JPCP

Effective Joint Spacing: 144 in

Edge Support

( ) Conventional 12-ft wide traffic lane
( ) Conventional 12-ft wide traffic lane + tied PCC
(●) 2-ft widened slab w/conventional 12-ft traffic lane

Edge Support Factor: 0.92

Sensitivity Analysis

Slab Thickness used for Sensitivity Analysis: 10.81 in

(●) Modulus of Rupture
( ) Elastic Modulus (Slab)
( ) Elastic Modulus (Base)
( ) Base Thickness
( ) k-Value
( ) Joint Spacing
( ) Reliability
( ) Standard Deviation

Calculated Slab Thickness for Above Inputs: 10.81 in

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

I. General

Agency: City of Bend
Street Address: Murphy Rd. Project
City: Bend
State: OR

Project Number: 407067.02.05.05

ID: US 97

Description: High Cement Content, low water/cement ratio for rut resistance

Location: 3rd Street Roundabout

II. Design

Serviceability

Initial Serviceability, P1: 4.5
Terminal Serviceability, P2: 2.5

PCC Properties

28-day Mean Modulus of Rupture, $(S'_c)'$: 650 psi
Elastic Modulus of Slab, E_c: 4,100,000 psi
Poisson's Ratio for Concrete, m: 0.15

Base Properties

Elastic Modulus of Base, E_b: 30,000 psi
Design Thickness of Base, H_b: 6.0 in
Slab-Base Friction Factor, f: 1.4

Reliability and Standard Deviation

Reliability Level (R): 90.0 %
Overall Standard Deviation, S_0: 0.39

Climatic Properties

Mean Annual Wind Speed, WIND: 9.0 mph
Mean Annual Air Temperature, TEMP: 45.0 ^{o}F
Mean Annual Precipitation, PRECIP: 17.0 in

Subgrade k-Value

220 psi/in

Design ESALs

45.0 million

Pavement Type, Joint Spacing (L)

(●) JPCP
( ) JRCP
( ) CRCP

Joint Spacing: 12.0 ft

JPCP

Effective Joint Spacing: 144 in

Edge Support

( ) Conventional 12-ft wide traffic lane
( ) Conventional 12-ft wide traffic lane + tied PCC
(●) 2-ft widened slab w/conventional 12-ft traffic lane

Edge Support Factor: 0.92

Sensitivity Analysis

Slab Thickness used for Sensitivity Analysis: 11.95 in

( ) Modulus of Rupture
( ) Elastic Modulus (Slab)
( ) Elastic Modulus (Base)
( ) Base Thickness
( ) k-Value
( ) Joint Spacing
( ) Reliability
(●) Standard Deviation

Calculated Slab Thickness for Above Inputs: 11.95 in

Rigid Pavement Design - Based on AASHTO Supplemental Guide

Reference: *LTPP DATA ANALYSIS - Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction*

I. General

Agency:	City of Bend
Street Address:	Murphy Rd. Project
City:	Bend
State:	OR
Project Number:	407067.02.05.05
ID:	US 97
Description:	High Cement Content, low water/cement ratio for rut resistance
Location:	Parrell Road Roundabout

II. Design

Serviceability

Initial Serviceability, P1:	4.5	
Terminal Serviceability, P2:	2.5	

PCC Properties

28-day Mean Modulus of Rupture, $(S'_c)'$:	650	psi
Elastic Modulus of Slab, E_c:	4,100,000	psi
Poisson's Ratio for Concrete, m:	0.15	

Base Properties

Elastic Modulus of Base, E_b:	30,000	psi
Design Thickness of Base, H_b:	6.0	in
Slab-Base Friction Factor, f:	1.4	

Reliability and Standard Deviation

Reliability Level (R):	90.0	%
Overall Standard Deviation, S_0:	0.39	

Climatic Properties

Mean Annual Wind Speed, WIND:	9.0	mph
Mean Annual Air Temperature, TEMP:	45.0	^oF
Mean Annual Precipitation, PRECIP:	17.0	in

Subgrade k-Value

220 psi/in

Design ESALs

26.5 million

Pavement Type, Joint Spacing (L)

- (●) JPCP
- ( ) JRCP
- ( ) CRCP

Joint Spacing: 12.0 ft

JPCP

Effective Joint Spacing: 144 in

Edge Support

- ( ) Conventional 12-ft wide traffic lane
- ( ) Conventional 12-ft wide traffic lane + tied PCC
- (●) 2-ft widened slab w/conventional 12-ft traffic lane

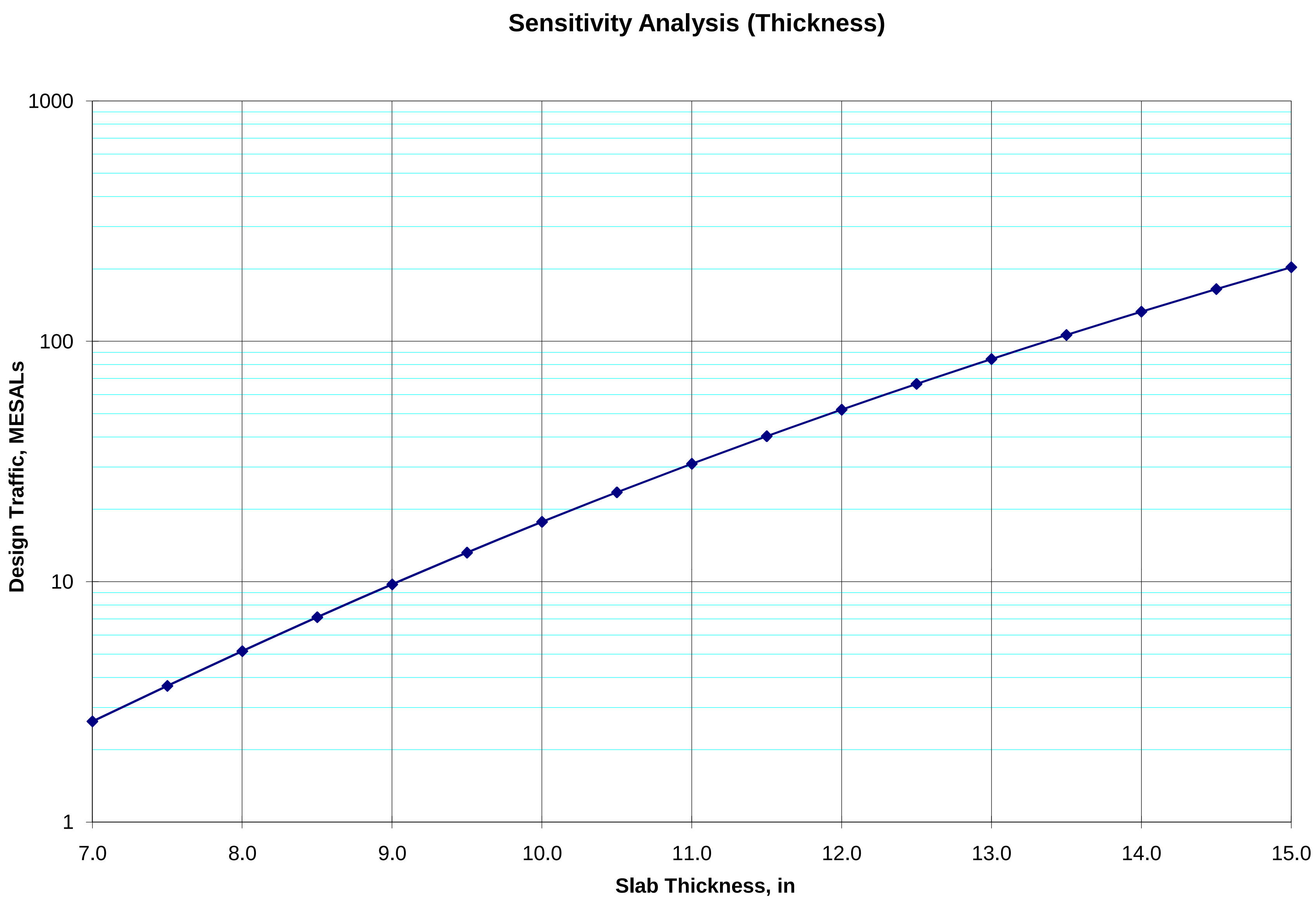
Edge Support Factor: 0.92

Sensitivity Analysis

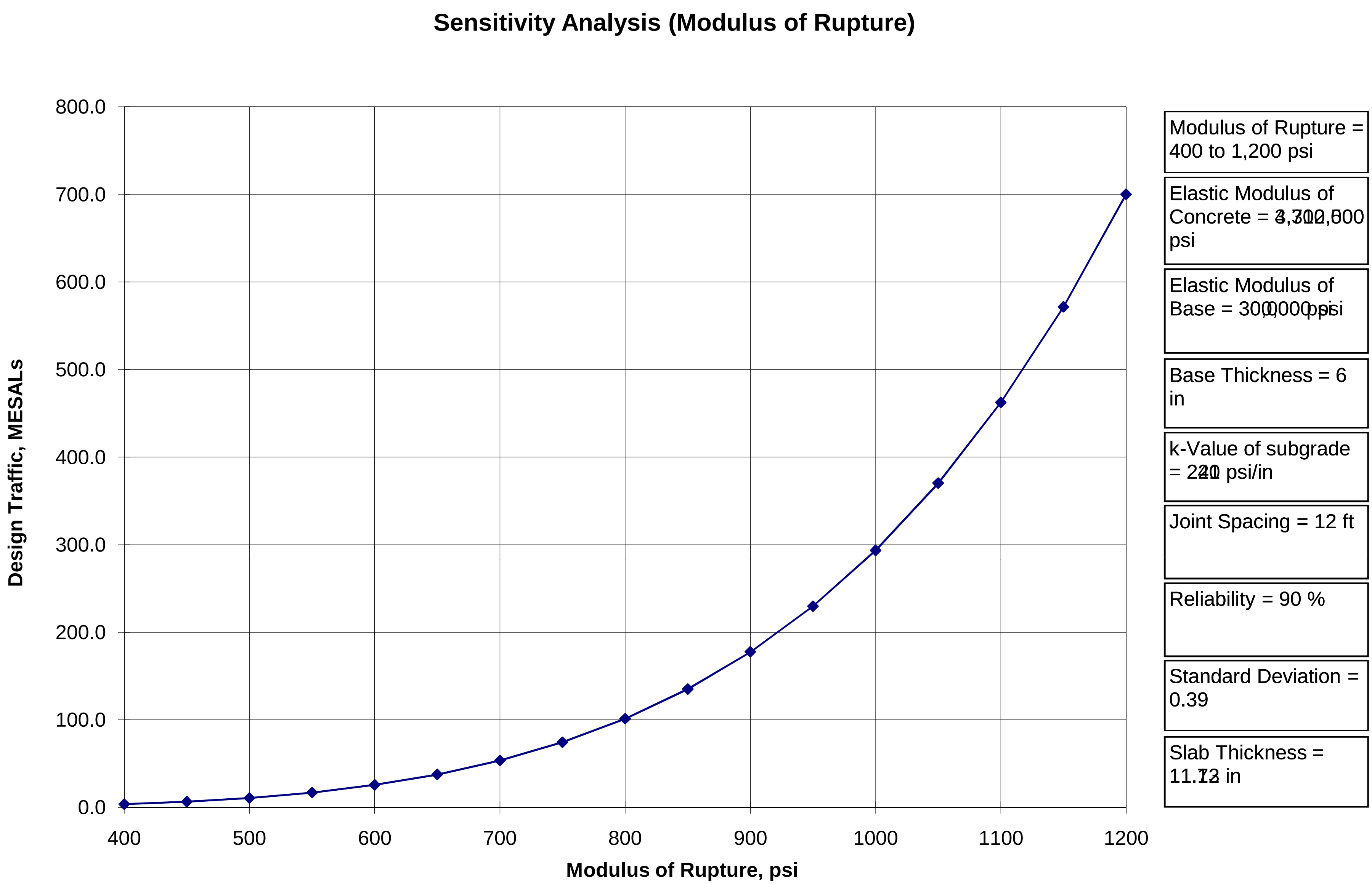
Slab Thickness used for Sensitivity Analysis: 10.93 in

- (●) Modulus of Rupture
- ( ) Elastic Modulus (Slab)
- ( ) Elastic Modulus (Base)
- ( ) Base Thickness
- ( ) k-Value
- ( ) Joint Spacing
- ( ) Reliability
- ( ) Standard Deviation

Calculated Slab Thickness for Above Inputs: 10.93 in

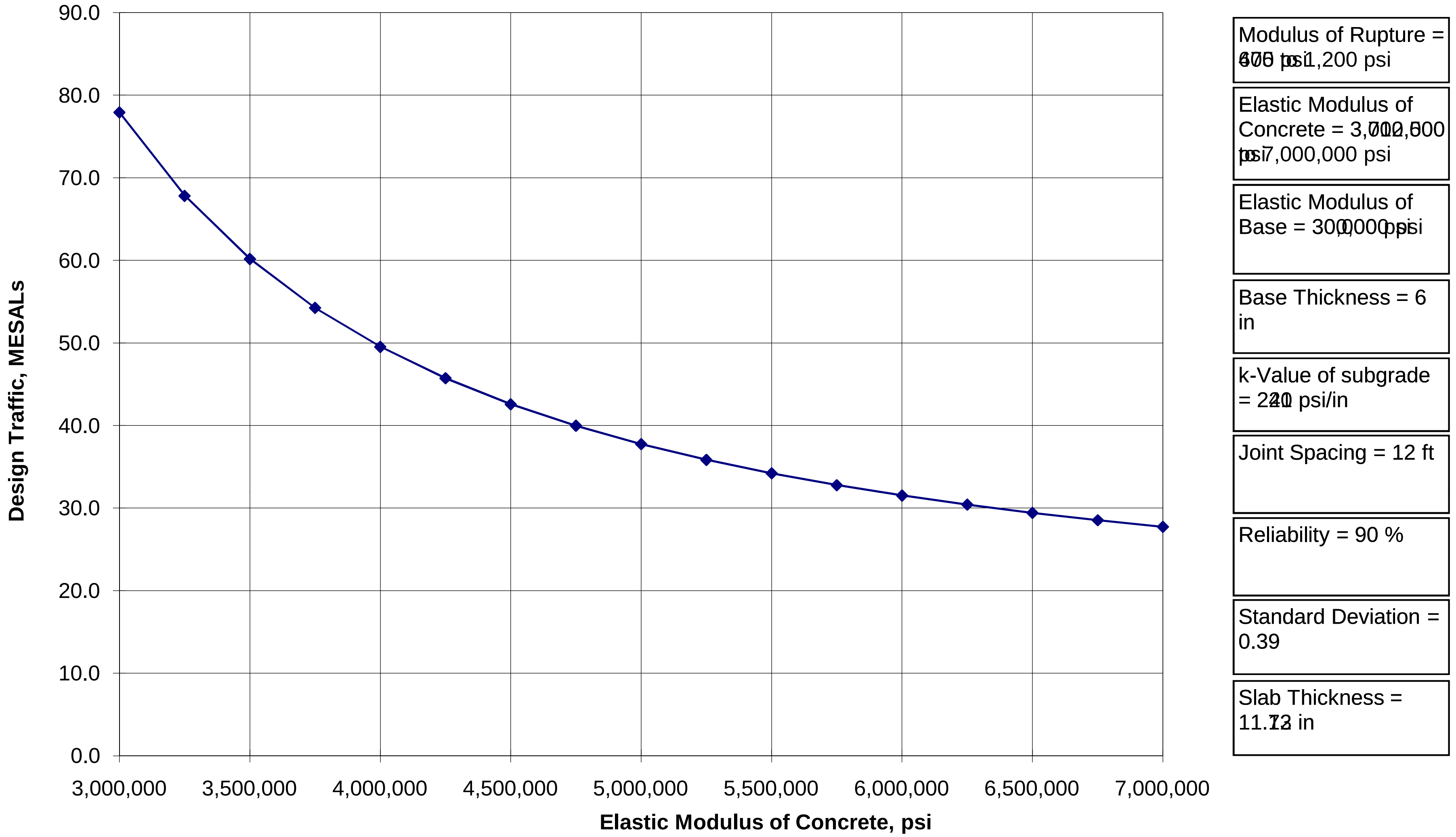


Sensitivity Analysis (Thickness)
1000
100
10
1
Design Traffic, MESALs
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
Slab Thickness, in

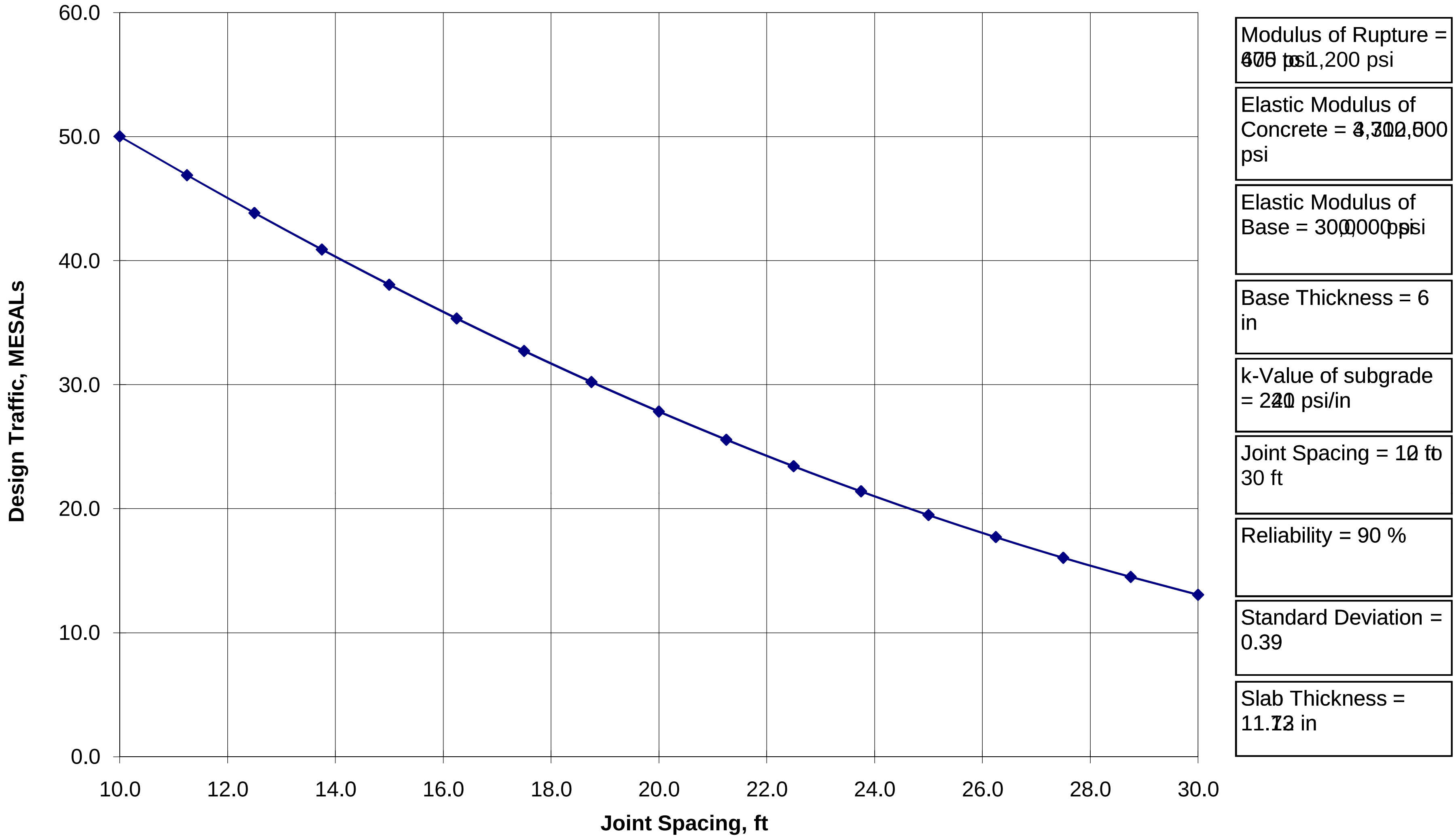


Sensitivity Analysis (Modulus of Rupture)
Design Traffic, MESALs
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
400
500
600
700
800
900
1000
1100
1200
Modulus of Rupture, psi
Modulus of Rupture = 400 to 1,200 psi
Elastic Modulus of Concrete = psi
Elastic Modulus of Base = psi
Base Thickness = 6 in
k-Value of subgrade = psi/in
Joint Spacing = 12 ft
Reliability = 90 %
Standard Deviation = 0.39
Slab Thickness = in

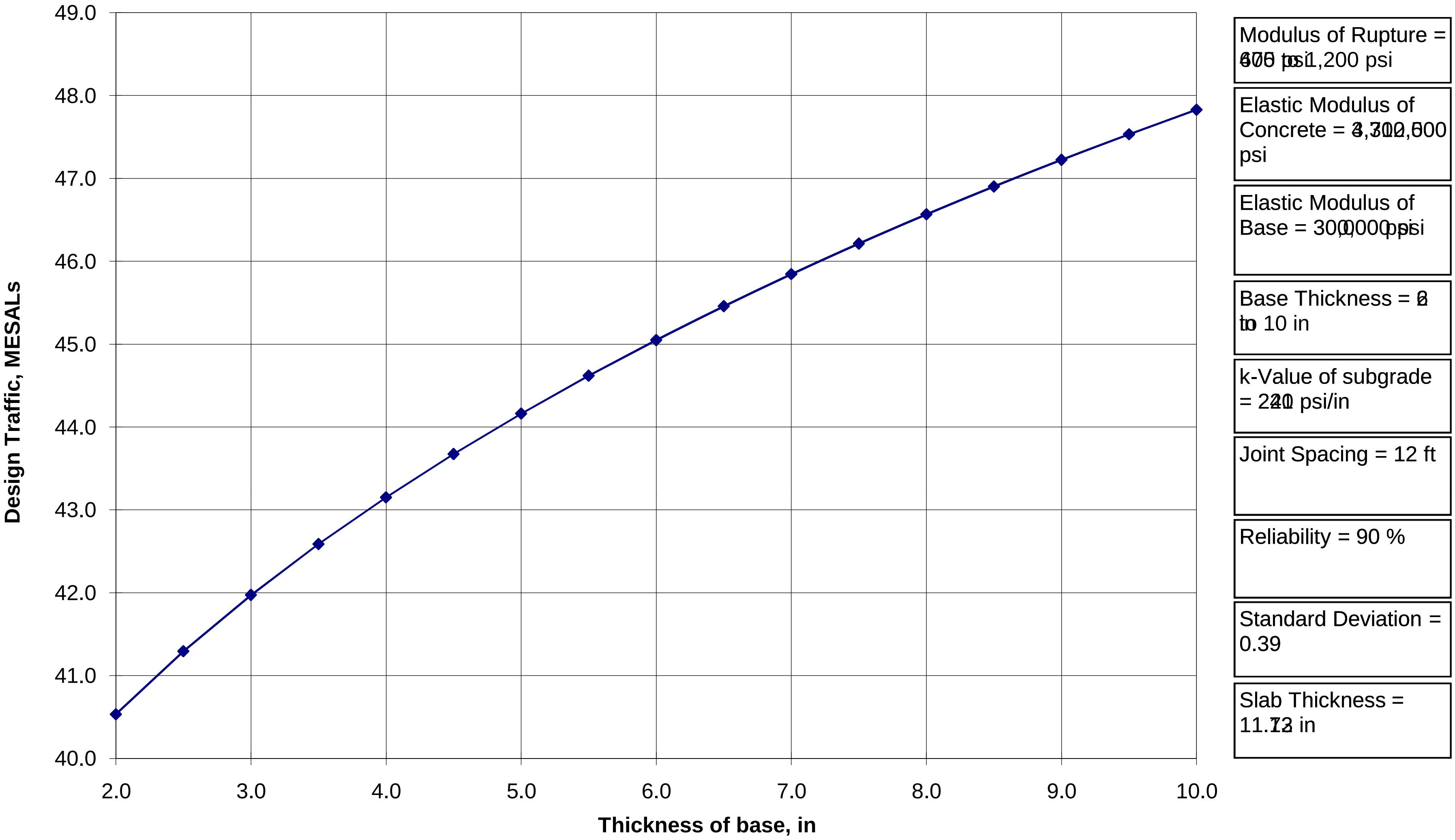
Sensitivity Analysis (Elastic Modulus of Concrete)



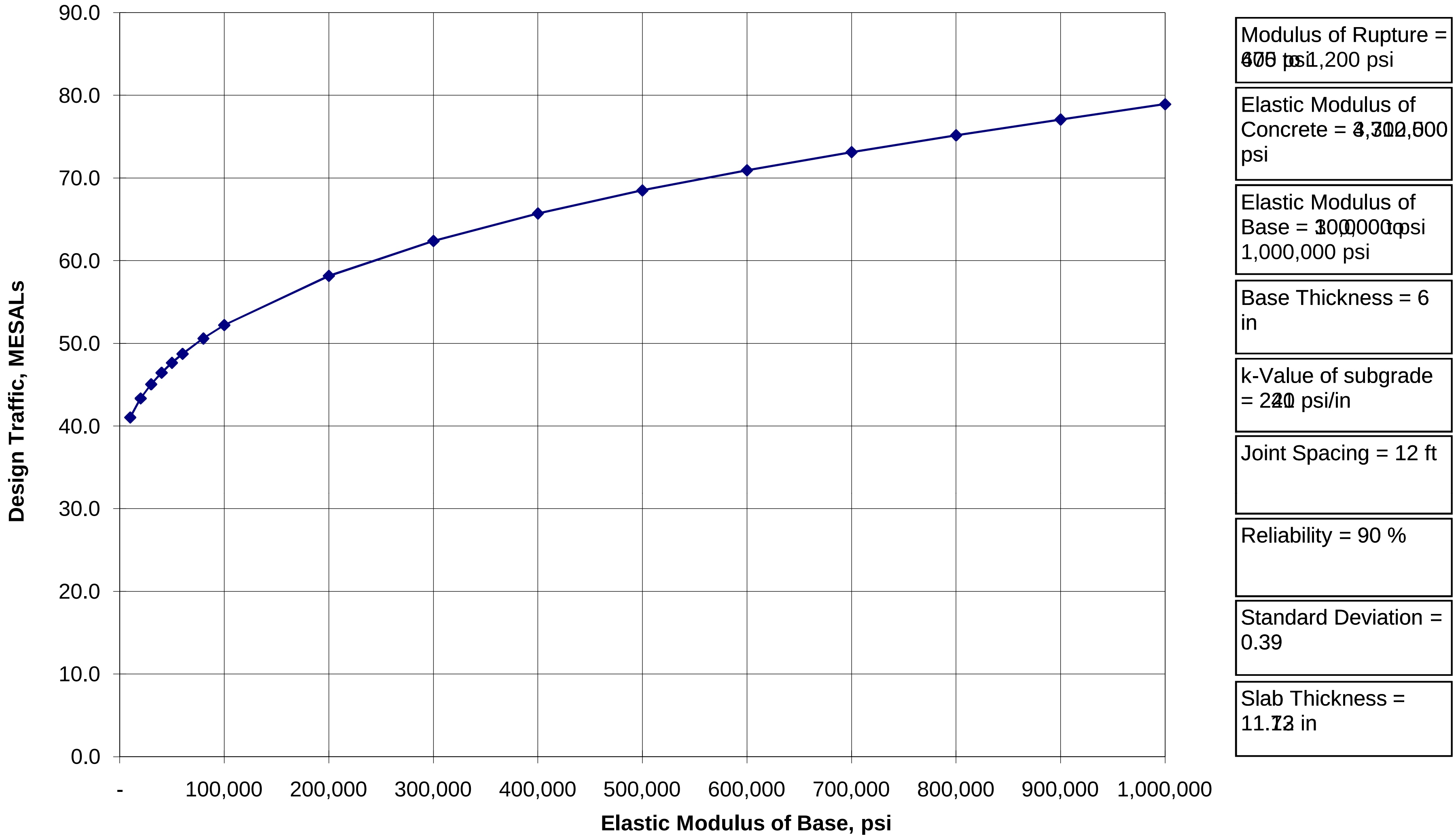
Sensitivity Analysis (Joint Spacing)



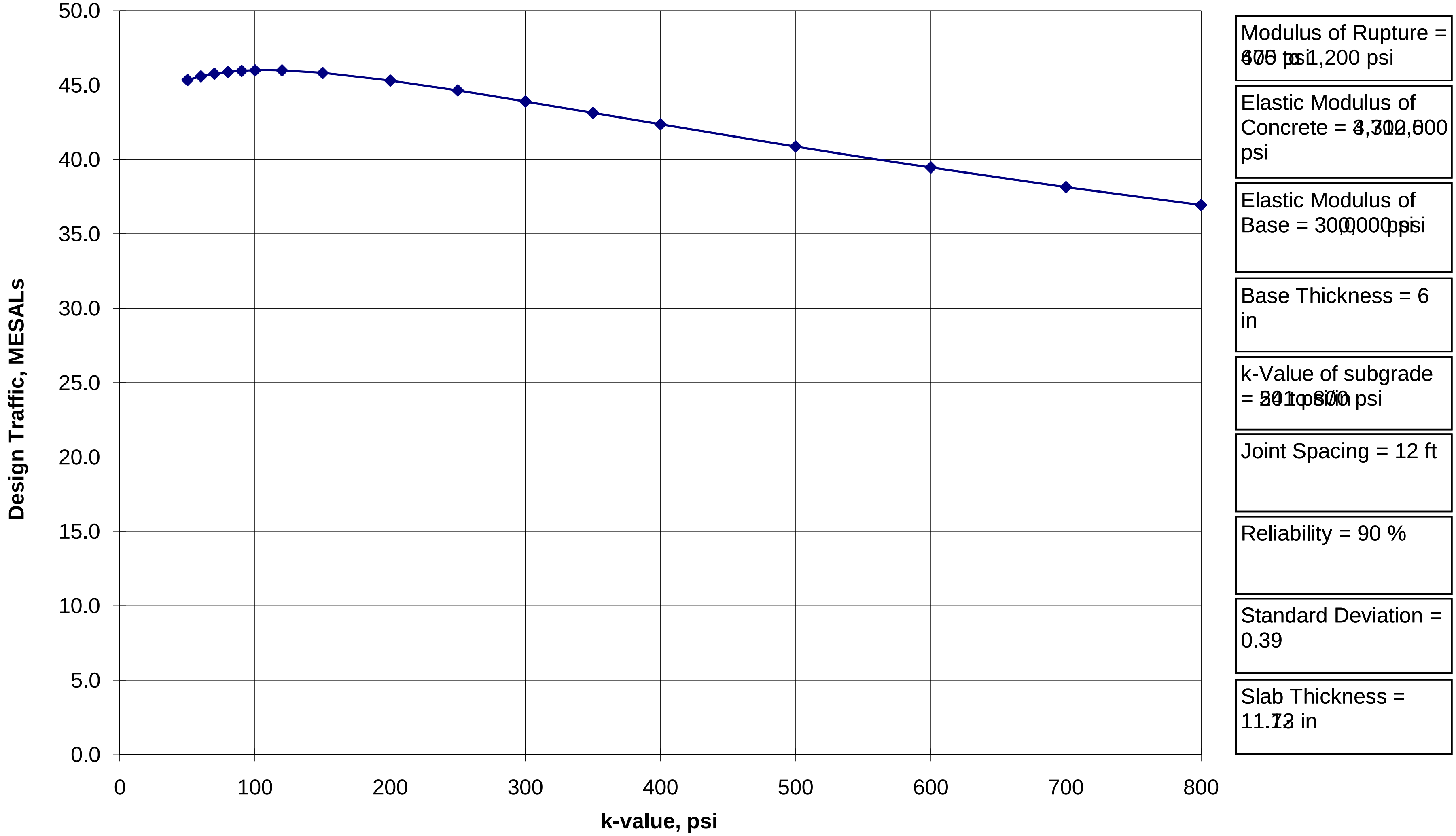
Sensitivity Analysis (Base Thickness)



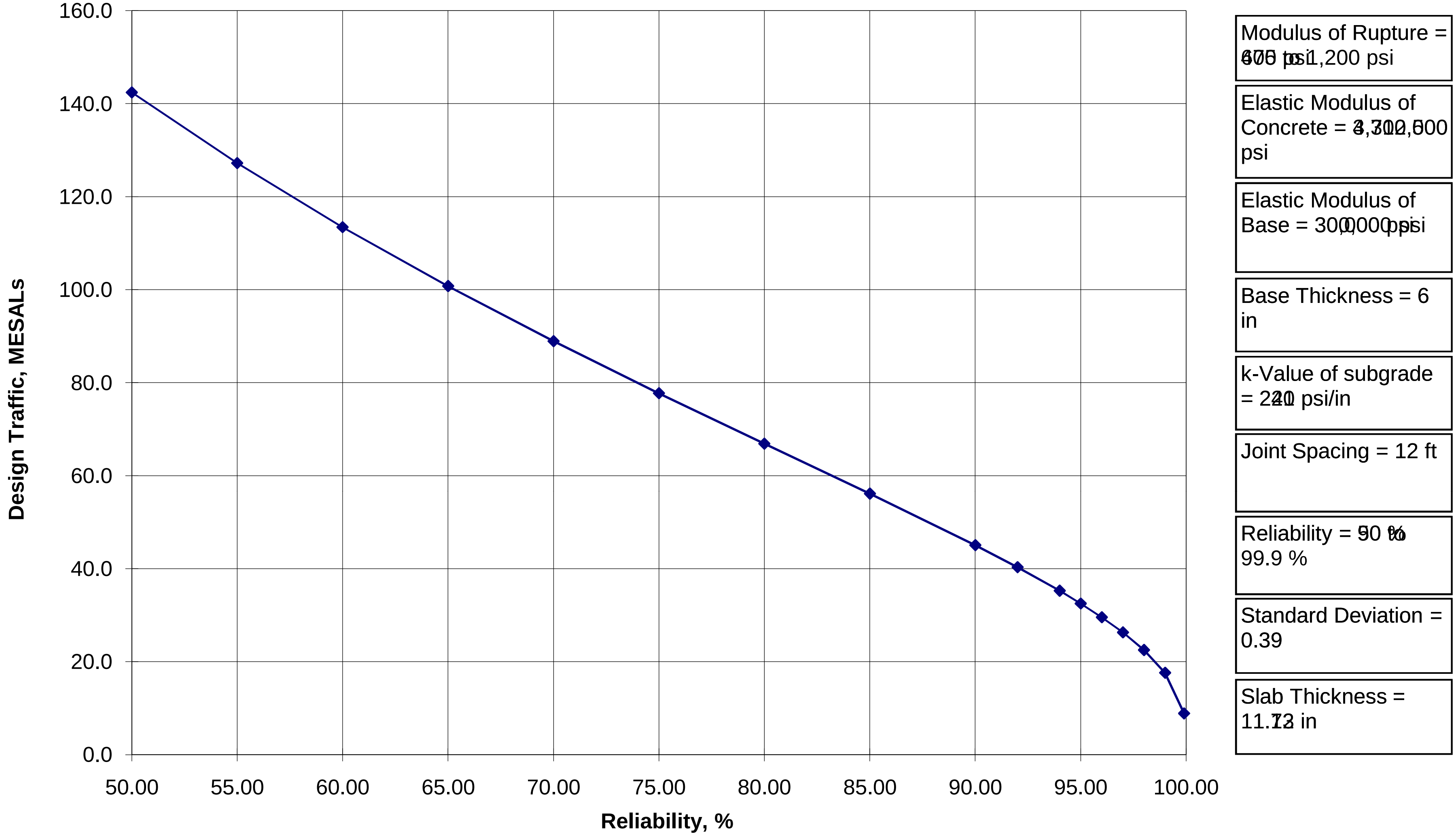
Sensitivity Analysis (Elastic Modulus of Base)

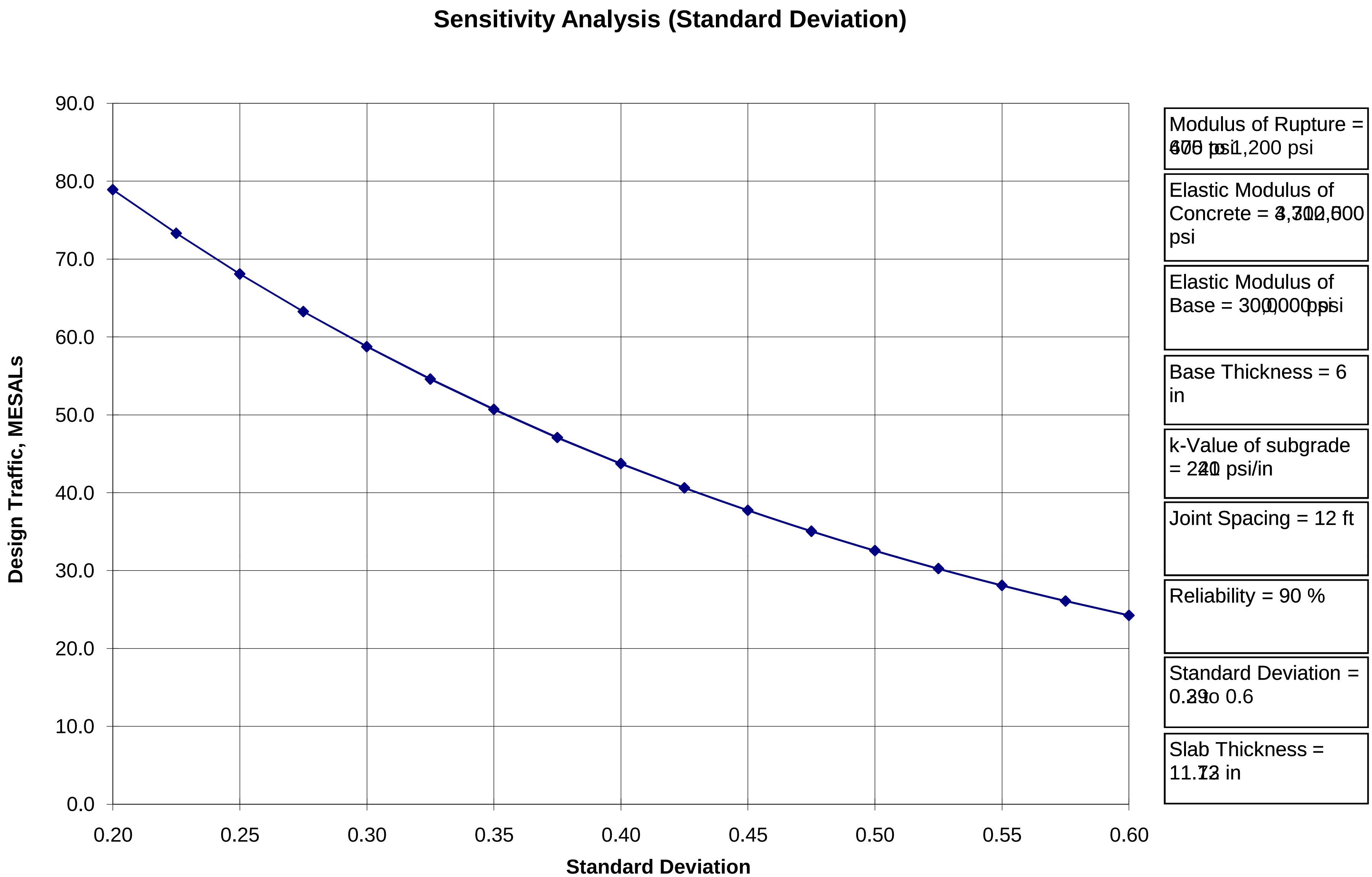


Sensitivity Analysis (Effective Subgrade Support)



Sensitivity Analysis (Desired Reliability)




Sensitivity Analysis (Standard Deviation)
Design Traffic, MESALs
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
Standard Deviation
Modulus of Rupture =
Elastic Modulus of Concrete =
psi
Elastic Modulus of Base =
Base Thickness = 6 in
k-Value of subgrade =
psi/in
Joint Spacing = 12 ft
Reliability = 90 %
Standard Deviation =
Slab Thickness =
in