Fundamentals of StreetPave Software

A presentation for promotion professionals by the

American Concrete Pavement Association
Skokie, Ill.
and
National Ready Mixed Concrete Association
Silver Spring, Md.

Introduction

Objective

Provide promotion professionals with a resource to guide and assist engineers in using StreetPave™ for streets and roads design.

Presentation Overview

- Basic pavement design principles.
- StreetPave fundamentals.
- Factors affecting pavement design.
- Framework for pavement design optimization.

Presentation Goals

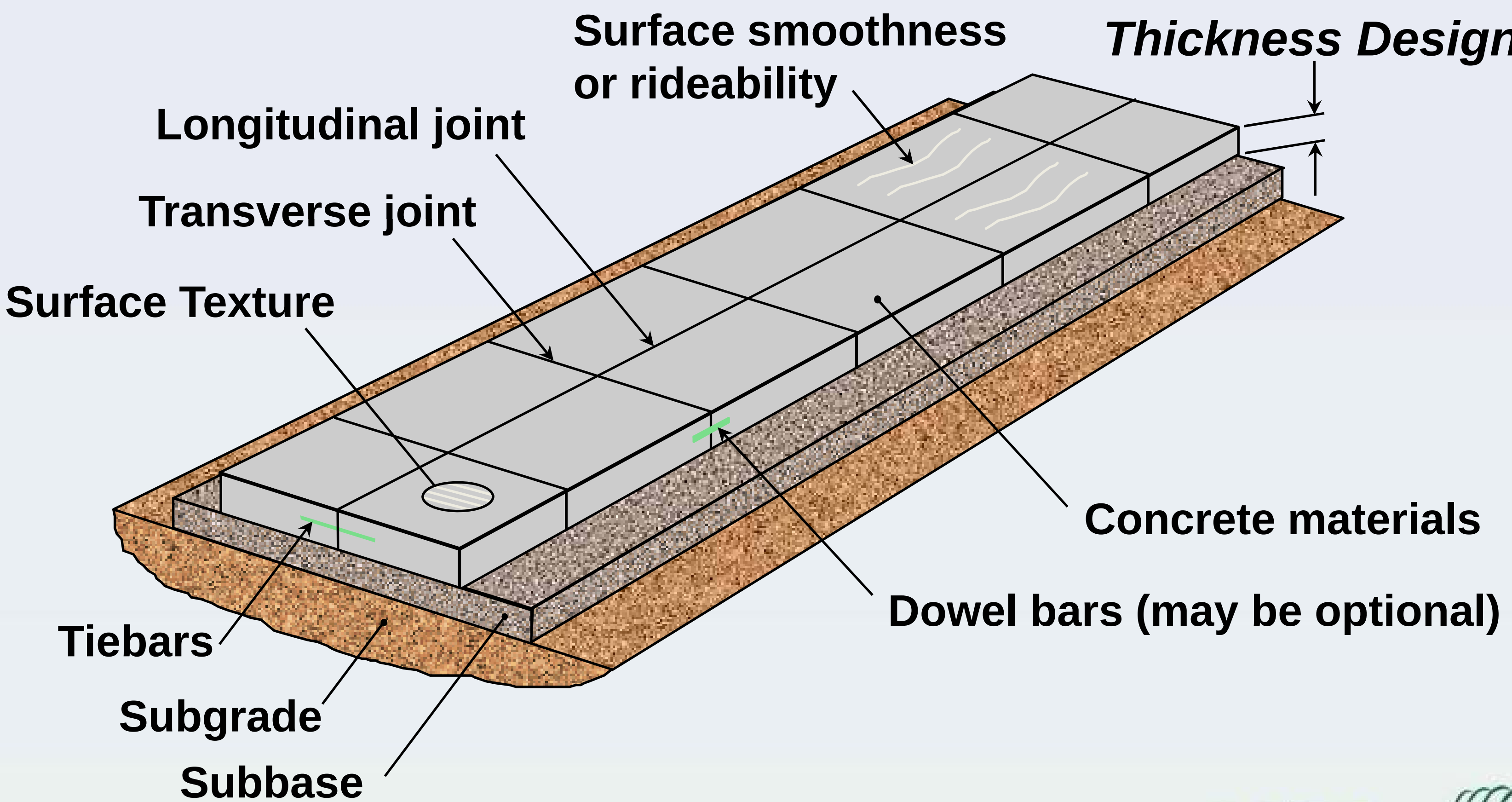
- Understand relationship between design features, costs, and performance.
- Establish framework for assisting customers in pavement type selection.
- Establish framework for assisting customers in optimized designs.

Basic Pavement Design Principles

Some Basic Principles

- Concrete pavements are engineered structures and so, must be designed, not simply placed.
- Pavement design is about more than just meeting specs; designers have the latitude to change a wide range of features.
- Traffic, type of facility, climate, etc. are among variables influencing design and costs.

Streets and Roads Thickness Design



Understanding Design Optimization

- Design optimization is the balance of performance features and costs.
- StreetPave allows designer to vary project-specific "inputs" to achieve optimized design.

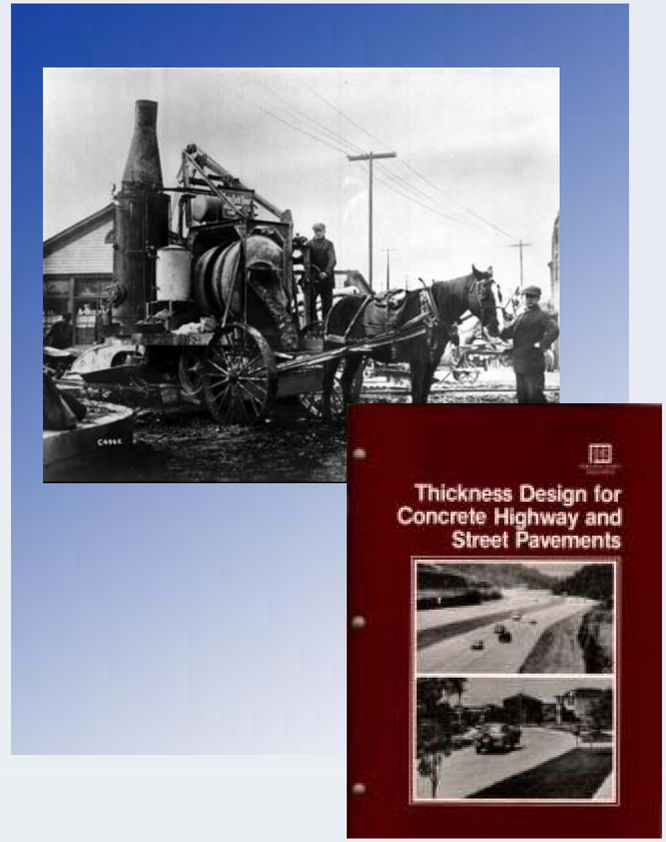
Understanding Design Optimization

- Design optimization involves adjusting variables to:
  - Achieve long life (durability),
  - Reduce initial costs,
  - Minimize maintenance and rehabilitation costs, and/or
  - Enhance sustainability.

StreetPave Fundamentals

Historical Basis for StreetPave

- PCA’s thickness design methodology originally published in 1933
- Updated in 1951, 1966, and again in 1984
- PCA developed *PCAPAV* program for iterative thickness design (latest version 1990)



StreetPave Design Software

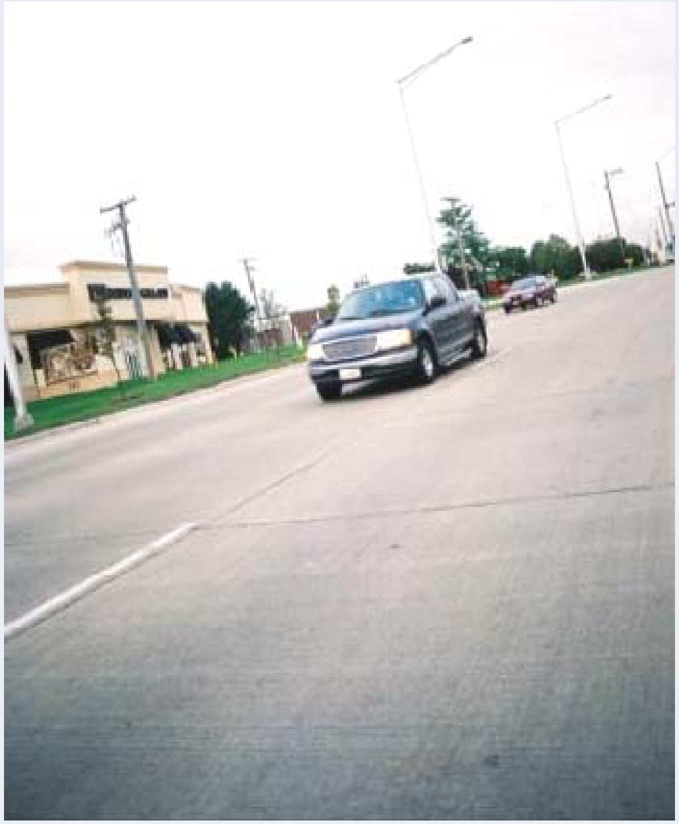
- Pavement design tool geared primarily to streets and roads.
- Based on the PCA's pavement thickness design methodology.
- Used for both new and existing and new pavement design
- StreetPave will analyze design constraints & requirements, pavement properties, and traffic characteristics.

StreetPave Capabilities

- Provides a real-world analysis of individual or combined design features.
- Allows Life cycle cost analysis (LCCA) to compare "hard costs" (if cost & performance data available).
- Considers non-monetary factors.
- Can be used for overlays.

StreetPave Capabilities

For a new concrete pavement analysis, StreetPave will output a design recommendation for concrete thickness, dowel bar use, and maximum transverse joint spacing.



StreetPave Capabilities

For existing concrete pavements, StreetPave will output the theoretical year in which the pavement will fail, along with total erosion and fatigue projections.

Factors Affecting Pavement Design

Understanding Design Variables

- Pavement design inputs can be broadly classified as one of the following:
  - Site condition inputs (fixed, cannot optimize)
    - Traffic
    - Environmental conditions
    - Subgrade support?
  - Project specific variables (variable, can be optimized)
    - Concrete strength
    - Load transfer
    - Others depending on design method used

Design Life

- Commonly 20 to 35 years.
- Shorter or longer period may be economically justified.
- High-performance concrete pavements:
  - Long-life pavements
  - Special haul road (to be used for only a few years)
  - Crossovers
  - Temporary lanes

Levels of Reliability

Functional Classification of Roadway	Recommended Reliability	
	Urban	Rural
Interstates, Freeways, and Tollways	85 - 99	80 – 99
Principal Arterials	80 - 99	75 – 95
Collectors	80 - 95	75 – 95
Residential & Local Roads	50 - 80	50 – 80

Failure Criteria (Slab Cracking)

Roadway Type	**Recommended Percent of Slabs Cracked at End of Design Life**
(Default)	15%
Interstate Highways, Expressways, Tollways, Turnpikes	5%
State Roads, Arterials	10%
Collectors, County Roads	15%
Residential Streets	25%

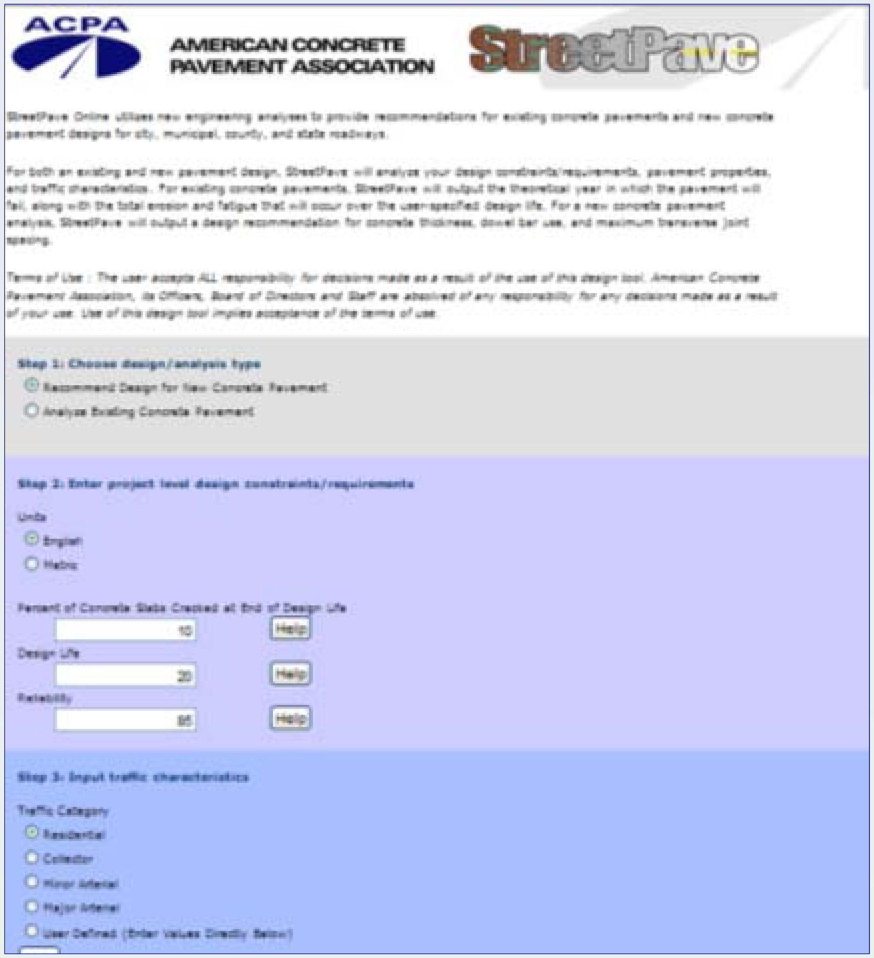
Framework for Pavement Design Optimization

Global Inputs in StreetPave

- Project information
- Design life
- Reliability*
- Failure criteria*
  - Terminal serviceability
  - Percent cracked slabs

**Should be selected based on policy and experience*.

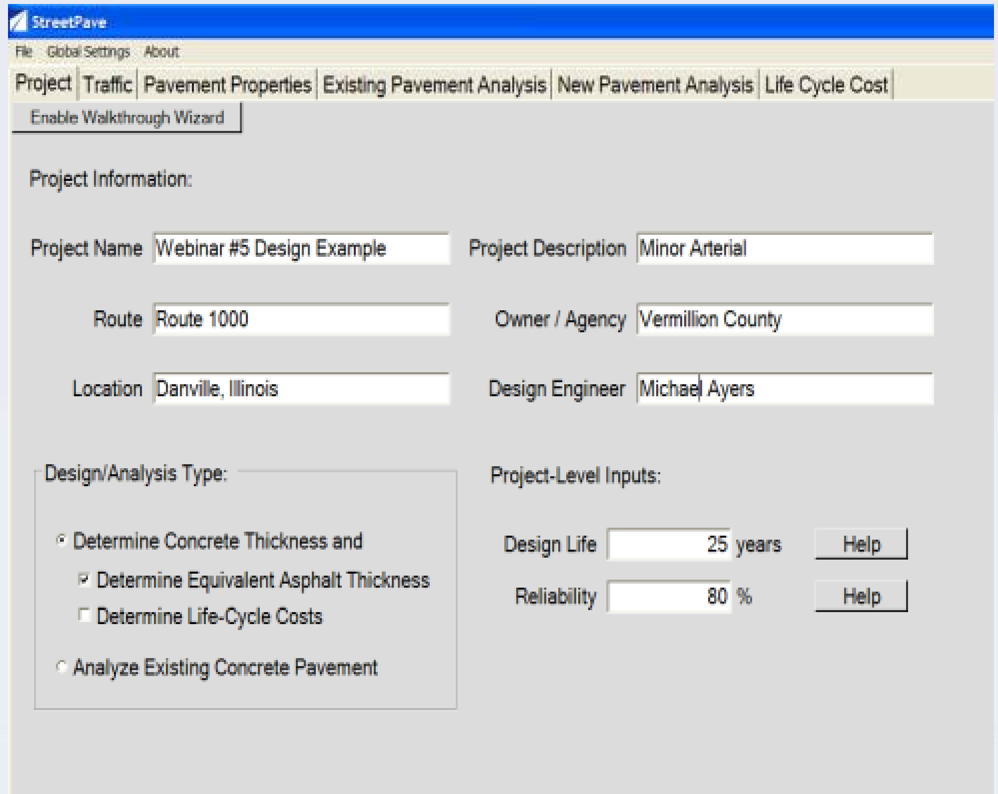
StreetPave Input Examples



StreetPave web version

StreetPave Input Examples

First screen of walkthrough wizard



Global Settings

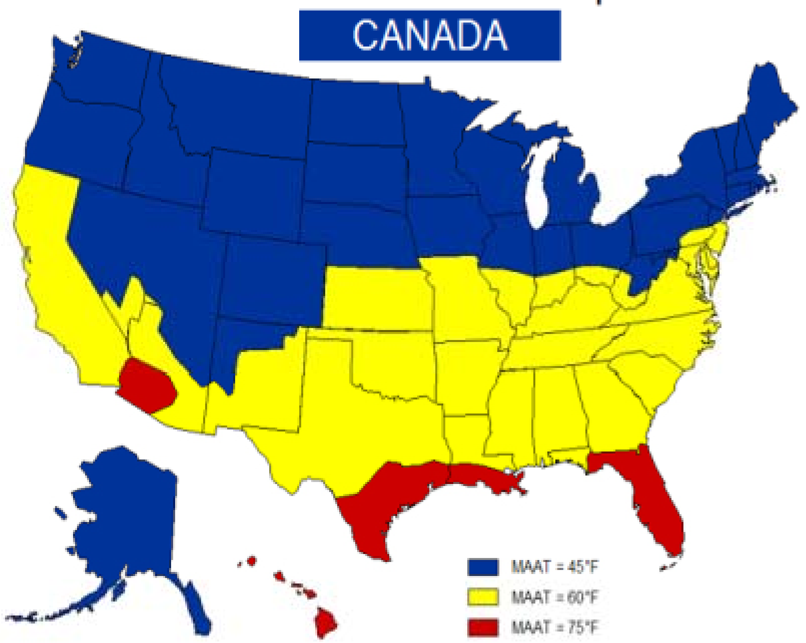
StreetPave Global Settings

Edit your global settings below.

1. Region (refer to map)
   - ○ MAAT = 45°F
   - ◉ MAAT = 60°F
   - ○ MAAT = 75°F
2. Units
   - ◉ English
   - ○ Metric
3. Terminal Serviceability
   2.25 [Help]
4. Percent of Concrete Slabs Cracked at End of Design Life
   15 % [Help]

[Save and Close]

MAAT – Mean Annual Air Temperature



Combined Effects: Reliability & Failure

Table 5. Typical Values of Reliability and Percent Cracking

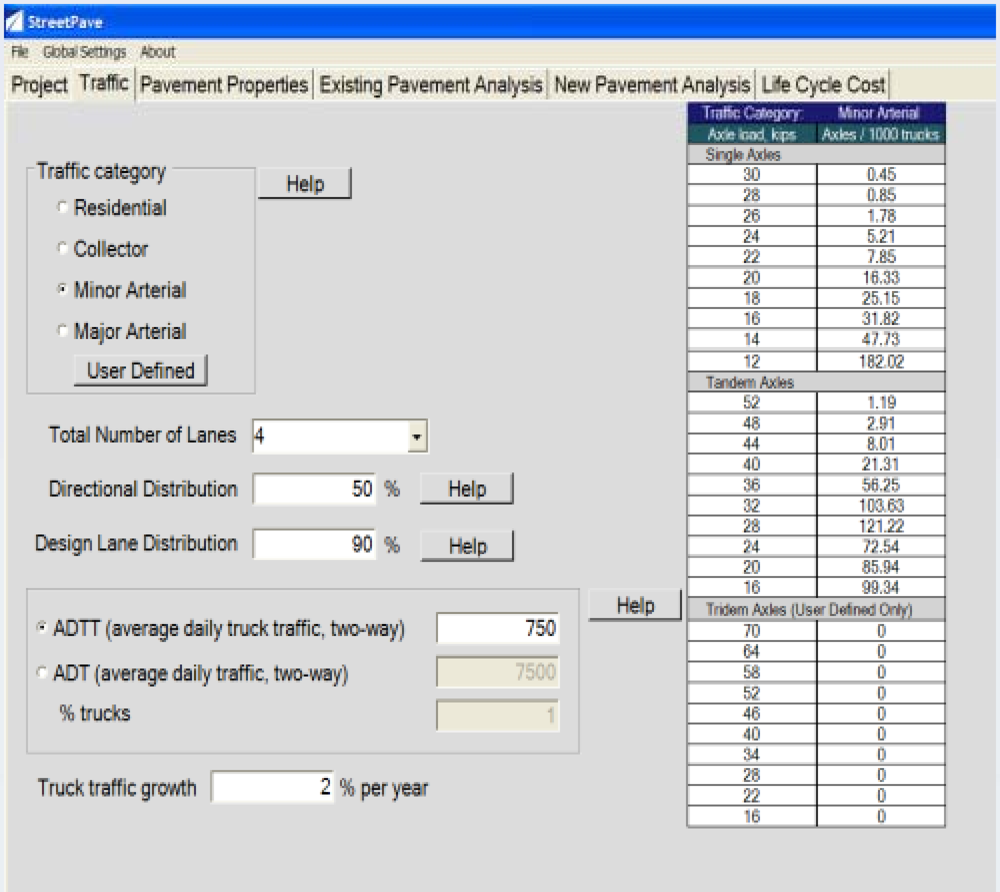
Street classification	Specified reliability	Percent cracking	Average percent cracking
Light residential	75%	15%	7.5%
Residential	80%	15%	6%
Collector	85%	10%	3%
Minor arterial	90%	10%	2%
Major arterial	95%	5%	0.5%

*Average percent cracking = (100 – User-specified reliability) * Percent cracking / 50.*

Site Condition Inputs in StreetPave

- Fixed variables for specific projects and locations
  - Traffic category
  - Total number of lanes
  - Directional distribution
  - Design lane distribution
  - ADTT or ADT plus percentage of trucks
  - Truck traffic growth
  - Subgrade support value (*k*-value)

Traffic Inputs



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Street Classification and Traffic

- Comprehensive traffic studies have shown:

  "Streets of similar character have essentially the same traffic densities and axle load intensities."
- StreetPave has divided SLR pavements into six different classifications.
- Each classification includes:
  - Traffic volumes.
  - Types of vehicles.
  - Maximum axle loadings.

Street Classifications

Street Class	Description	Two-way Average Daily Traffic (ADT)	Two-way Average Daily Truck Traffic (ADTT)	Typical Range of Slab Thickness
Light Residential	Short streets in subdivisions and similar residential areas – often not through-streets.	Less than 200	2-4	4.0 - 5.0 in. (100-125 mm)
Residential	Through-streets in subdivisions and similar residential areas that occasionally carry a heavy vehicle (truck or bus).	200-1,000	10-50	5.0 - 7.0 in. (125-175 mm)
Collector	Streets that collect traffic from several residential subdivisions, and that may serve buses and trucks.	1,000-8,000	50-500	5.5 - 9.0 in. (135-225 mm)

Continued …

Street Classifications

… Continued

Street Class	**Description**	**Two-way Average Daily Traffic (ADT)**	**Two-way Average Daily Truck Traffic (ADTT)**	**Typical Range of Slab Thickness**
Business	Streets that provide access to shopping and urban central business districts.	11,000-17,000	400-700	6.0 - 9.0 in. (150-225 mm)
Industrial	Streets that provide access to industrial areas or parks, and typically carry heavier trucks than the business class.	2,000-4,000	300-800	7.0 - 10.5 in. (175-260 mm)
Arterial	Streets that serve traffic from major expressways and carry traffic through metropolitan areas. Truck and bus routes are primarily on these roads.	4,000-15,000 (minor) 4,000-30,000 (major)	300-600 700-1,500	6.0 - 9.0 in. (150-225 mm) 7.0 - 11.0 in. (175-275 mm)

Traffic Categories

Axle Load Category	Description	Traffic			Maximum Axle Loads (kips)	
		ADT	ADTT**		Single Axles	Tandem Axles
			%	Per Day		
1	Residential streets Rural and secondary roads (L to M)	200-800	1-3	Up to 25	22	36
2	Collector Streets Rural and secondary roads (H) Arterial streets and primary roads (L)	700-5000	5-18	40-1000	26	44
3	Arterial streets and primary roads (M) Expressways; urban and rural interstates (L to M)	3000-12,000 2 lane 3000-50,000+ 4 lane or more	8-30	500-5000+	30	52
4	Arterial streets, primary roads, expressways (H) Urban and rural interstates (M to H)	3000-20,000 2 lane 3000-150,000+ 4 lane or more	8-30	1000-8000+	34	60

Continued …

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Continued …

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Continued …

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Axle Load Distributions

Axle load		Axles per 1,000 trucks**				
kips*	kN	Light residential	Residential	Collector	Minor arterial	Major arterial
SINGLE AXLES						
2	9	5000				
4	18	846.15	1693.31			
6	27	369.97	732.28			
8	36	283.13	483.10	233.60		
10	44	257.60	204.96	142.70		
12	53	103.40	124.00	116.76	182.02	
14	62	39.07	56.11	47.76	47.73	
16	71	20.87	38.02	23.88	31.82	57.07
18	80	11.57	15.81	16.61	25.15	68.27
20	89		4.23	6.63	16.33	41.82
22	98		0.96	2.60	7.85	9.69
24	107			1.60	5.21	4.16
26	116			0.07	1.78	3.52
28	125				0.85	1.78
30	133				0.45	0.63
32	142					0.54
TANDEM AXLES						
4	18	15.12	31.90			
8	36	39.21	85.89	47.01		
12	53	48.34	139.30	91.15		
16	71	72.69	75.02	59.25	99.34	
20	89	64.33	57.10	45.00	85.94	
24	107	42.24	39.18	30.74	72.54	71.16
28	125	38.55	68.48	44.43	121.22	95.79
32	142	27.82	69.59	54.76	103.63	109.54
36	160	14.22	4.19	38.79	56.25	78.19
40	178			7.76	21.31	20.31
44	196			1.16	8.01	3.52
48	214				2.91	3.03
52	231				1.19	1.79
56	249					1.07
60	267					0.57

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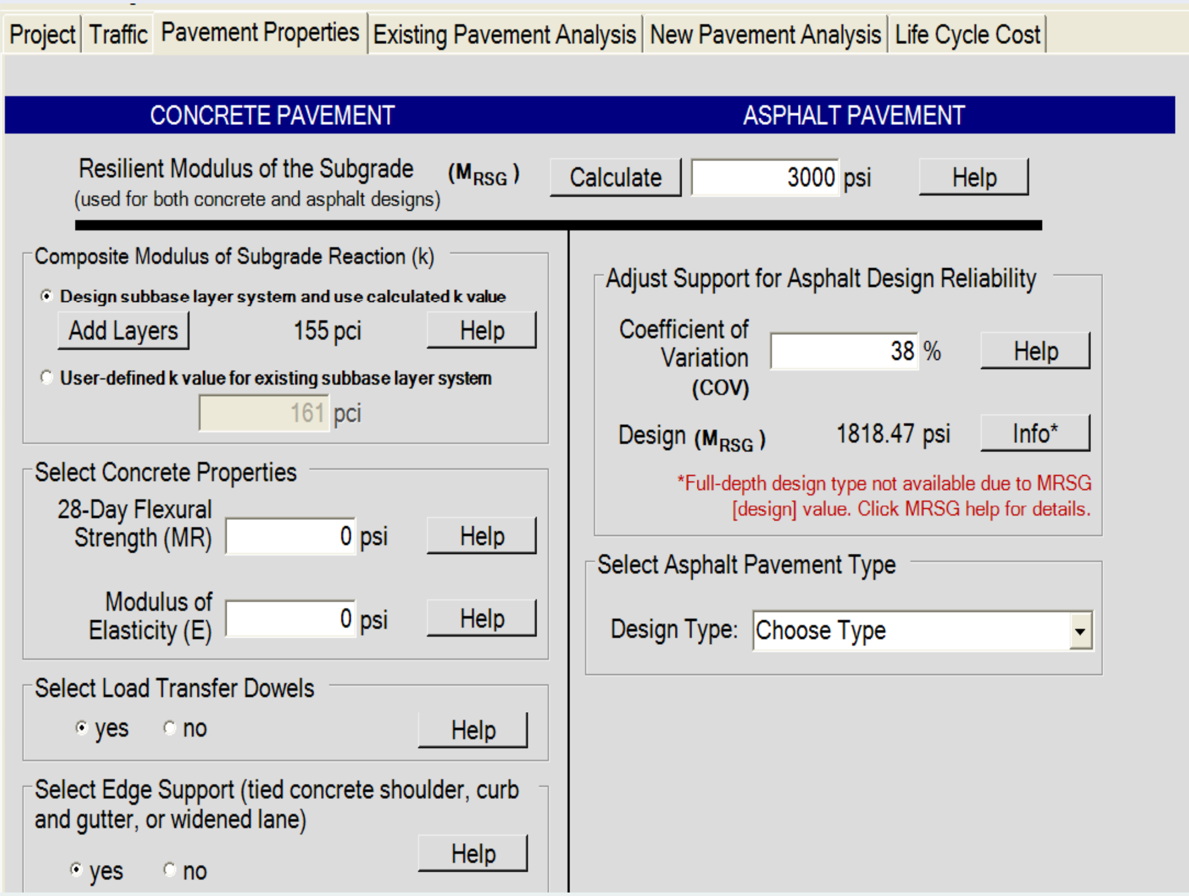
Pavement Property Analysis



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Subgrade Properties

Resilient Modulus of the Subgrade

Soil Type	**Support**	**Resilient Modulus** (MR), psi
Fine-grained with high amounts of silt/clay	Low	1455-2325
Sand and sand-gravel with moderate silt/clay	Medium	2500-3300
Sand and sand-gravel with little or no silt/clay	High	3500-4275

Subgrade Properties

Subgrade Soil Types and Approximate *k*-Values

Type of Soil	**Support**	***k*-value range**
Fine-grained soils in which silt and clay-size particles predominate	Low	75 - 120 pci (20 - 34 MPa/m)
Sands and sand-gravel mixtures with moderate amounts of silt and clay	Medium	130 - 170 pci (35 - 49 MPa/m)
Sands and sand-gravel mixtures relatively free of plastic fines	High	180 - 220 pci (50 - 60 MPa/m)

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Project Specific Variables in StreetPave

- Variables which can be optimized for specific projects
  - Subbase type, thickness and strength (composite *k*)
  - Concrete properties
    - Modulus of rupture (MR)
    - Elastic modulus (related to MR)
  - Load transfer type
  - Edge support conditions

Design Example For Sensitivity Analysis

- The following input values were used to establish a baseline pavement design.

Your current Resilient Modulus of Subgrade value (M_{RSG}) is: 3000 psi

The corresponding k-value before adding subbase layer(s) is: 155 pci

To determine the k-value for a subbase layer system, use the calculator tool below. First input the subbase(s) resilient modulus and thickness. Next, click the calculate k-value button.

Step 1 - From the Top Down, Input Subbase(s) Resilient Modulus and Thickness

Number of subbase layers between subgrade and concrete pavement: 1 Layer

Top Layer: Unbound Compacted Granular Materials (sand/gravel, crushed stone)

Resilient Modulus of Subbase **M** $_{RSB}$ 25000 psi
Alllowable Range: 15,000 - 45,000

Thickness of Subbase 6 in.

Layer 2: Choose Layer

Resilient Modulus of Subbase **M** $_{RSB}$ 0 psi
Alllowable Range: Choose Layer Type

Thickness of Subbase 0 in.

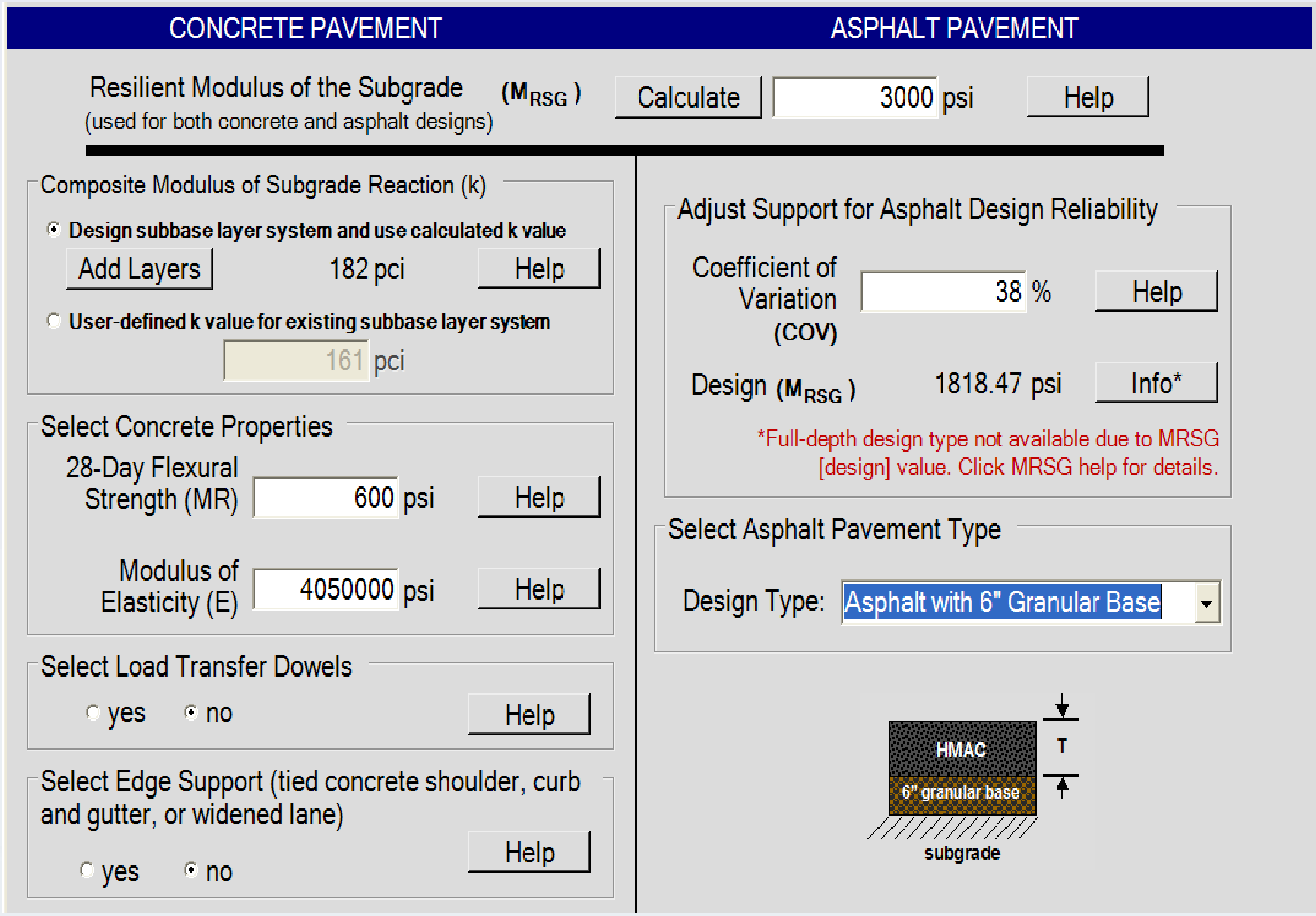
Layer 3: Choose Layer

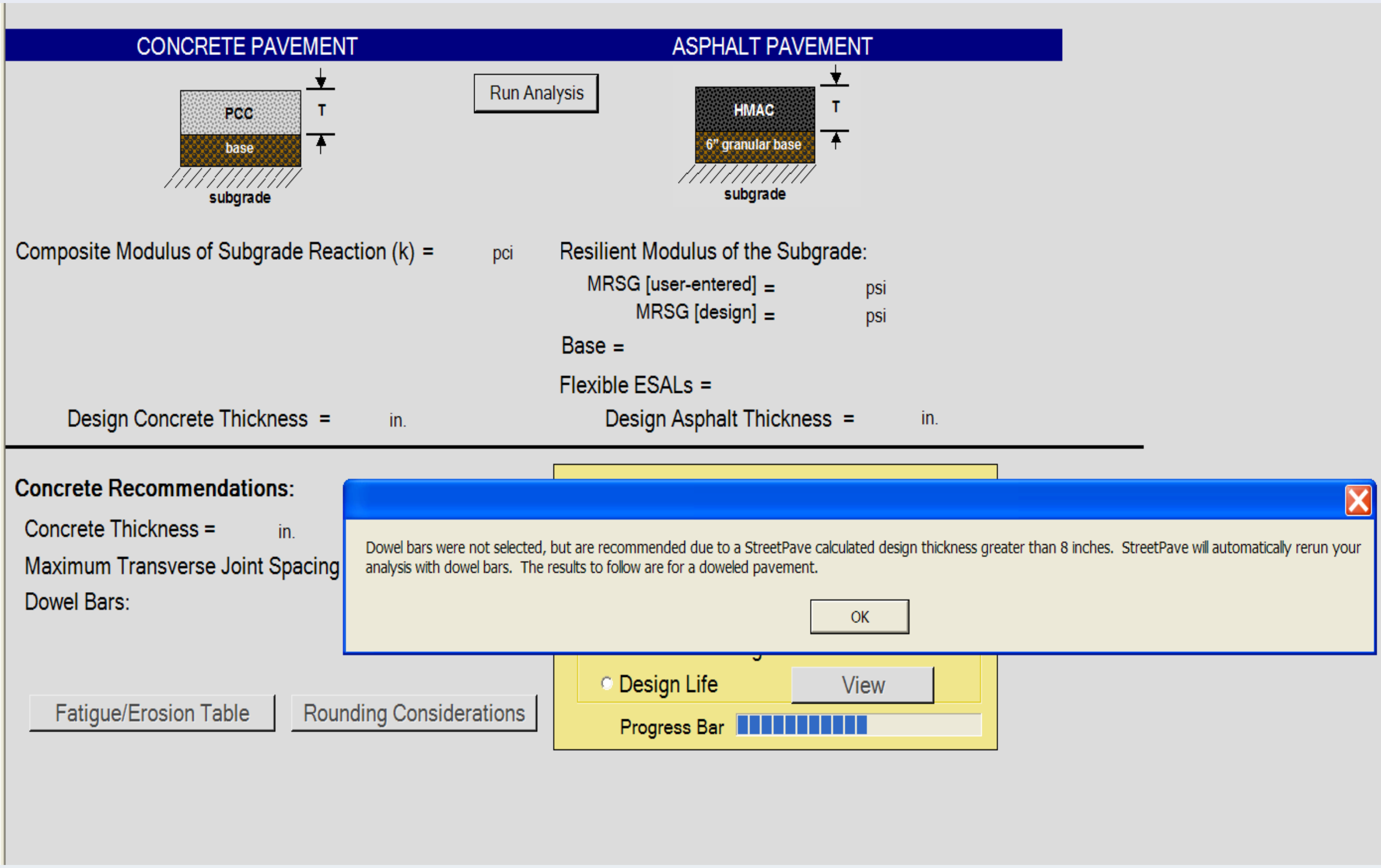
Resilient Modulus of Subbase **M** $_{RSB}$ 0 psi
Alllowable Range: Choose Layer Type

Thickness of Subbase 0 in.

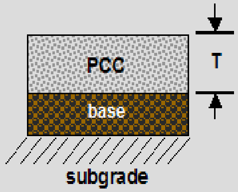
Step 2 - Calculate K | **K Value** 182 pci

Close Window and Save K

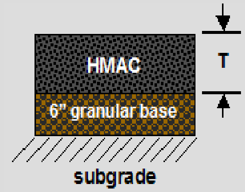

CONCRETE PAVEMENT
ASPHALT PAVEMENT
Resilient Modulus of the Subgrade (MRSG)
(used for both concrete and asphalt designs)
Calculate
3000 psi
Help
Composite Modulus of Subgrade Reaction (k)
Design subbase layer system and use calculated k value
Add Layers
182 pci
Help
User-defined k value for existing subbase layer system
161 pci
Select Concrete Properties
28-Day Flexural Strength (MR)
600 psi
Help
Modulus of Elasticity (E)
4050000 psi
Help
Select Load Transfer Dowels
yes
no
Help
Select Edge Support (tied concrete shoulder, curb and gutter, or widened lane)
Help
yes
no
Adjust Support for Asphalt Design Reliability
Coefficient of Variation (COV)
38 %
Help
Design (MRSG)
1818.47 psi
Info*
*Full-depth design type not available due to MRSG [design] value. Click MRSG help for details.
Select Asphalt Pavement Type
Design Type:
Asphalt with 6" Granular Base
HMAC
T
6" granular base
subgrade


CONCRETE PAVEMENT
ASPHALT PAVEMENT
PCC
base
T
subgrade
Run Analysis
HMAC
6" granular base
T
subgrade
Composite Modulus of Subgrade Reaction (k) = pci
Resilient Modulus of the Subgrade:
MRSG [user-entered] = psi
MRSG [design] = psi
Base =
Flexible ESALs =
Design Concrete Thickness = in.
Design Asphalt Thickness = in.
Concrete Recommendations:
Concrete Thickness = in.
Maximum Transverse Joint Spacing
Dowel Bars:
Dowel bars were not selected, but are recommended due to a StreetPave calculated design thickness greater than 8 inches. StreetPave will automatically rerun your analysis with dowel bars. The results to follow are for a doweled pavement.
OK
Design Life
View
Progress Bar
Fatigue/Erosion Table
Rounding Considerations

CONCRETE PAVEMENT	ASPHALT PAVEMENT



Run Analysis



Composite Modulus of Subgrade Reaction (k) = 182 pci

Top Layer = Unbound Compacted Granular Materials 6 in.

Design Concrete Thickness = 7.95 in.

Resilient Modulus of the Subgrade:

MRSG [user-entered] = 3000 psi

MRSG [design] = 2040.6 psi

Base = 6 inch Granular Base

Flexible ESALs = 4,144,884

Design Asphalt Thickness = 13.88 in.

Concrete Recommendations:

Concrete Thickness = 8.00 in.

Maximum Transverse Joint Spacing = 15 ft.

Dowel Bars: Use dowel bars with 1.25 in. diameter

Fatigue/Erosion Table

Rounding Considerations

View and Print Reports

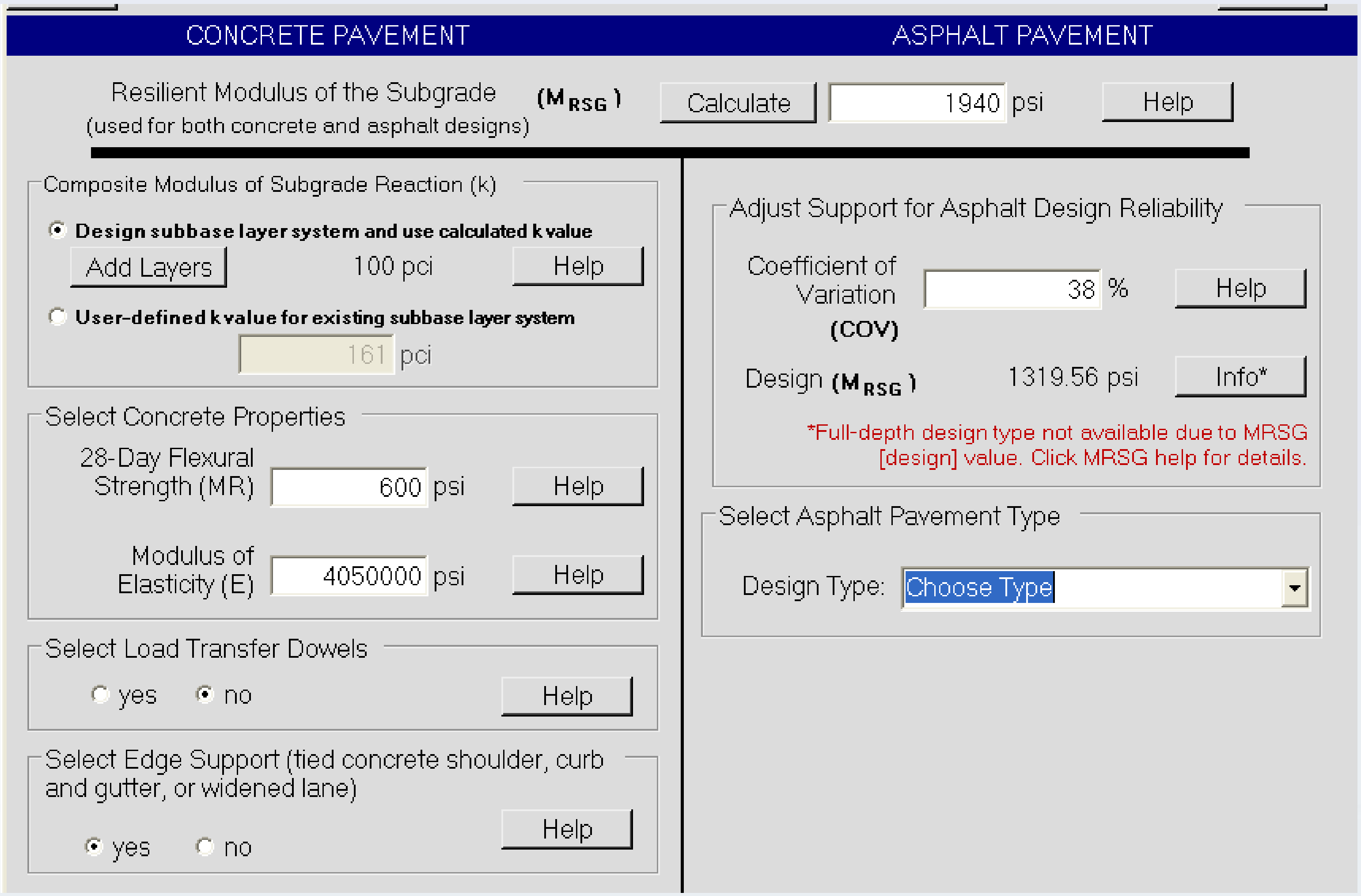
Design and Analysis Summary

Sensitivity Analysis of:

- (•) k-value
- ( ) Reliability
- ( ) Concrete Strength
- ( ) % Slabs Cracked
- ( ) Design Life

View

Progress Bar



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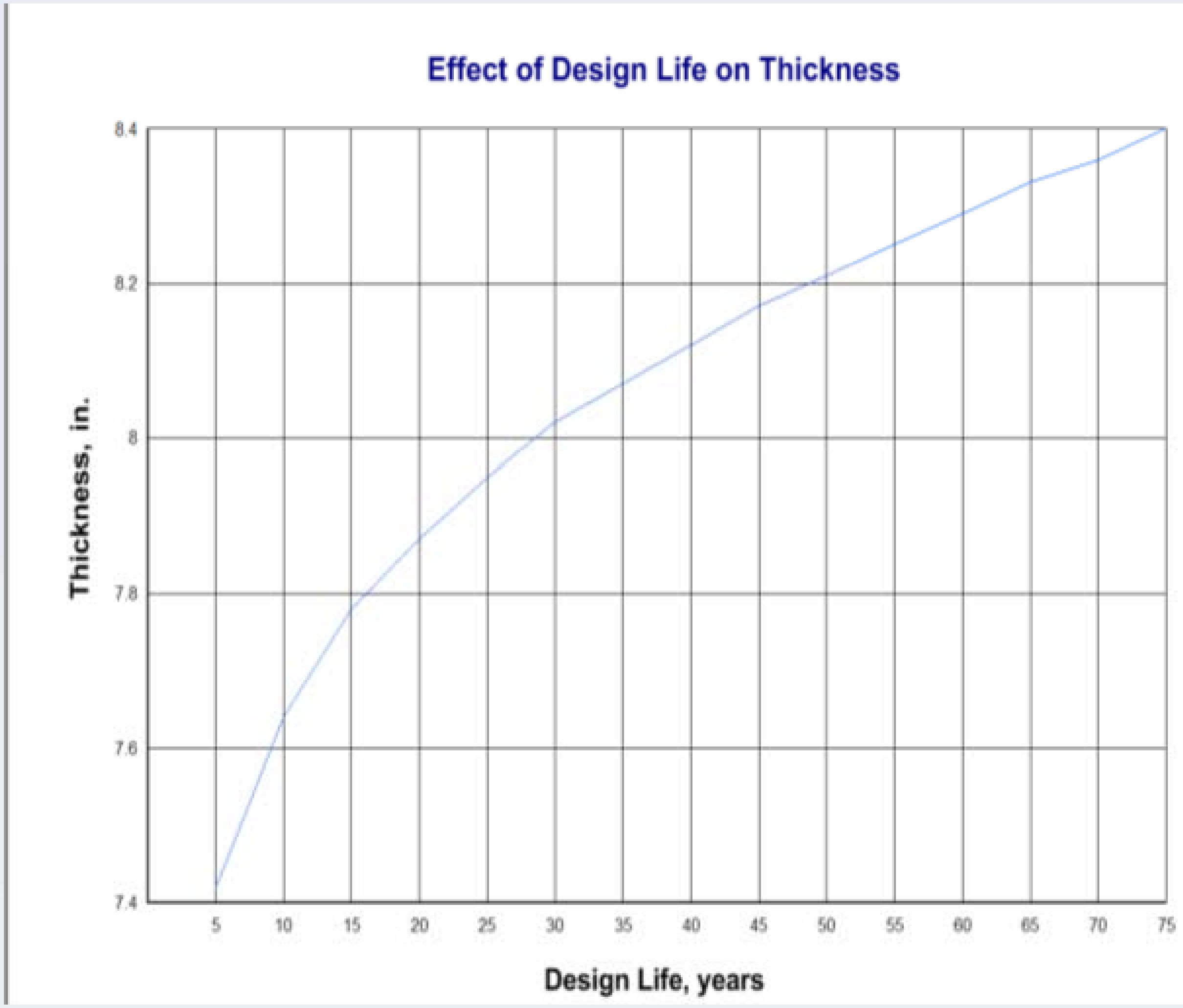
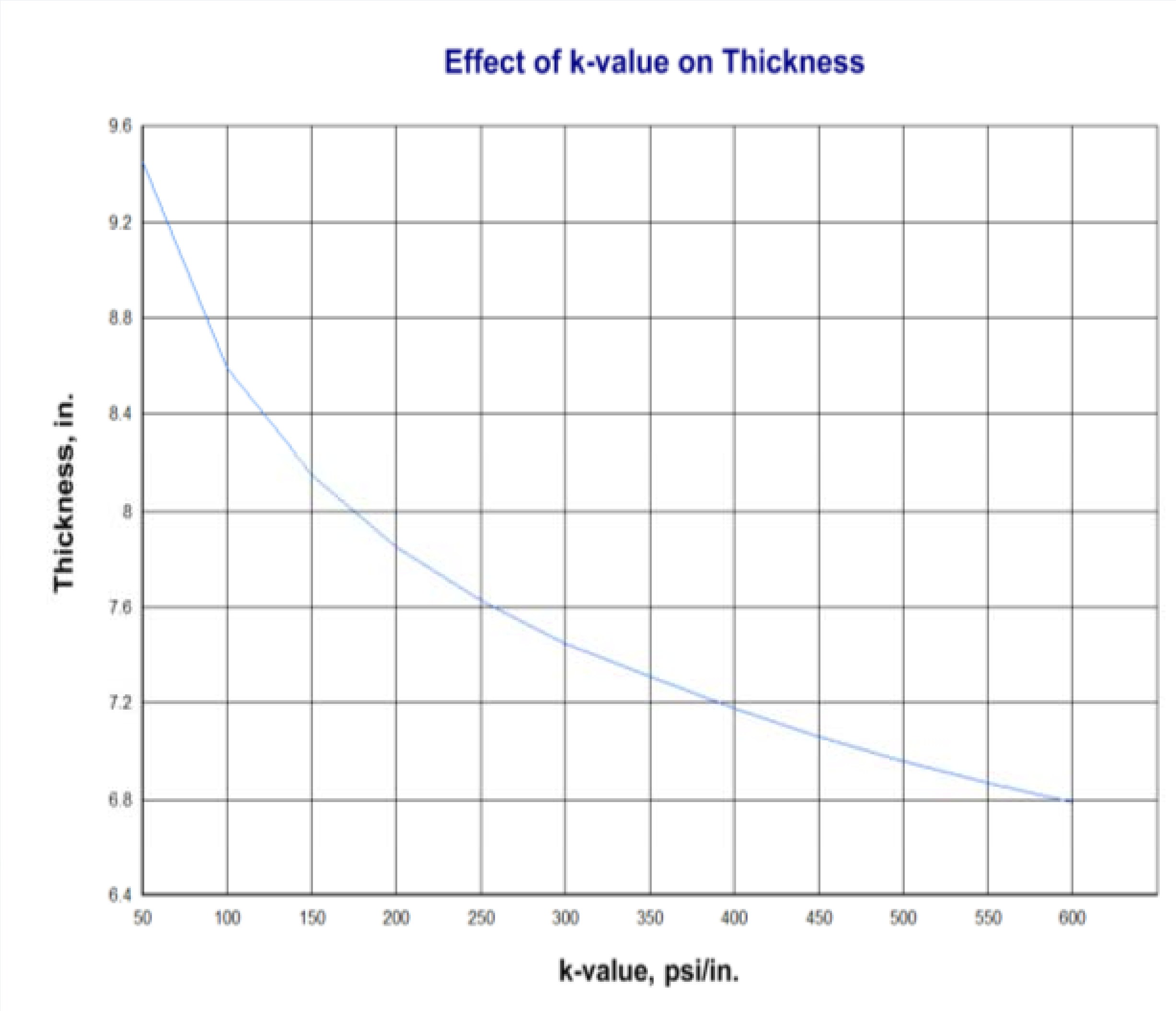
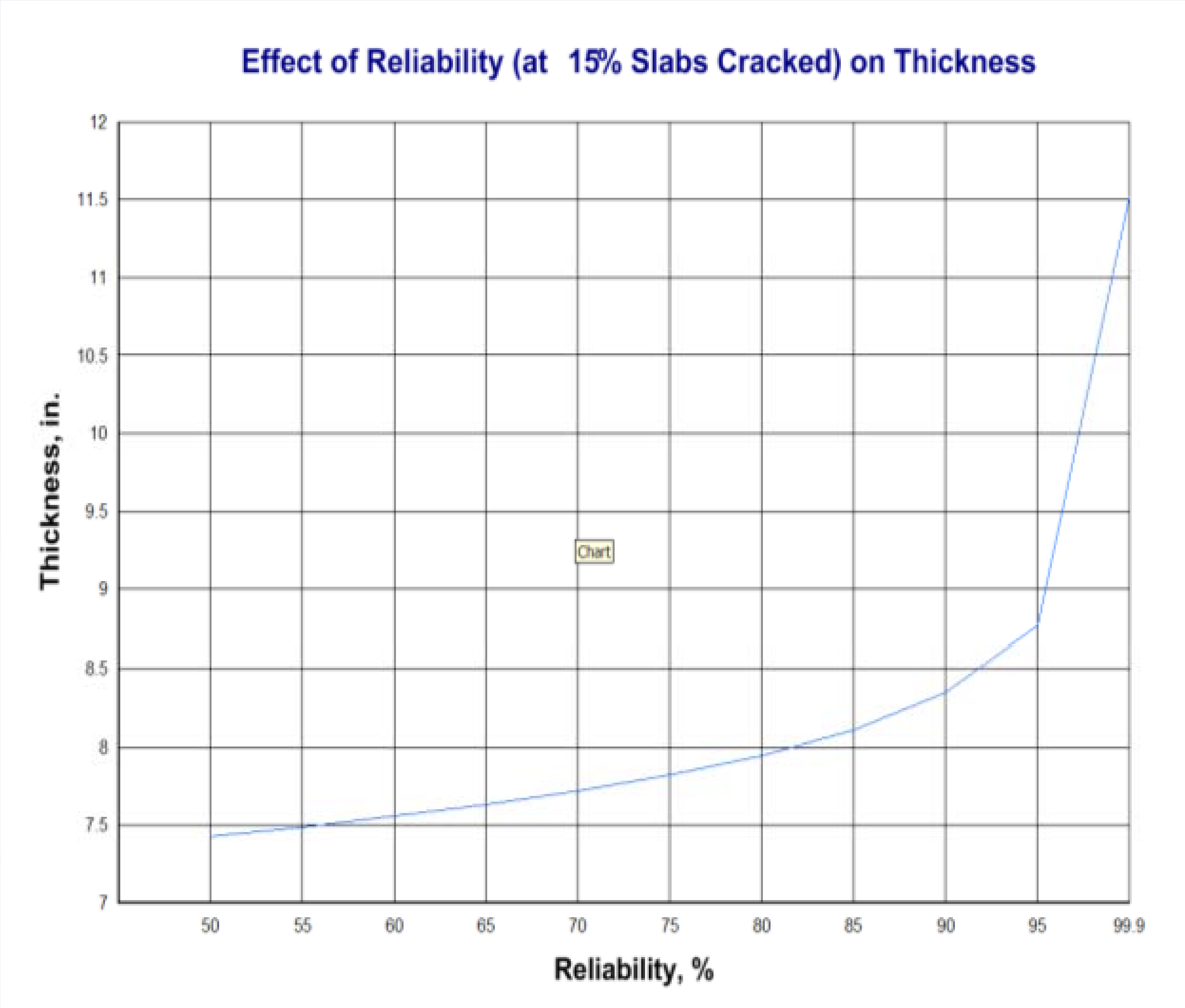
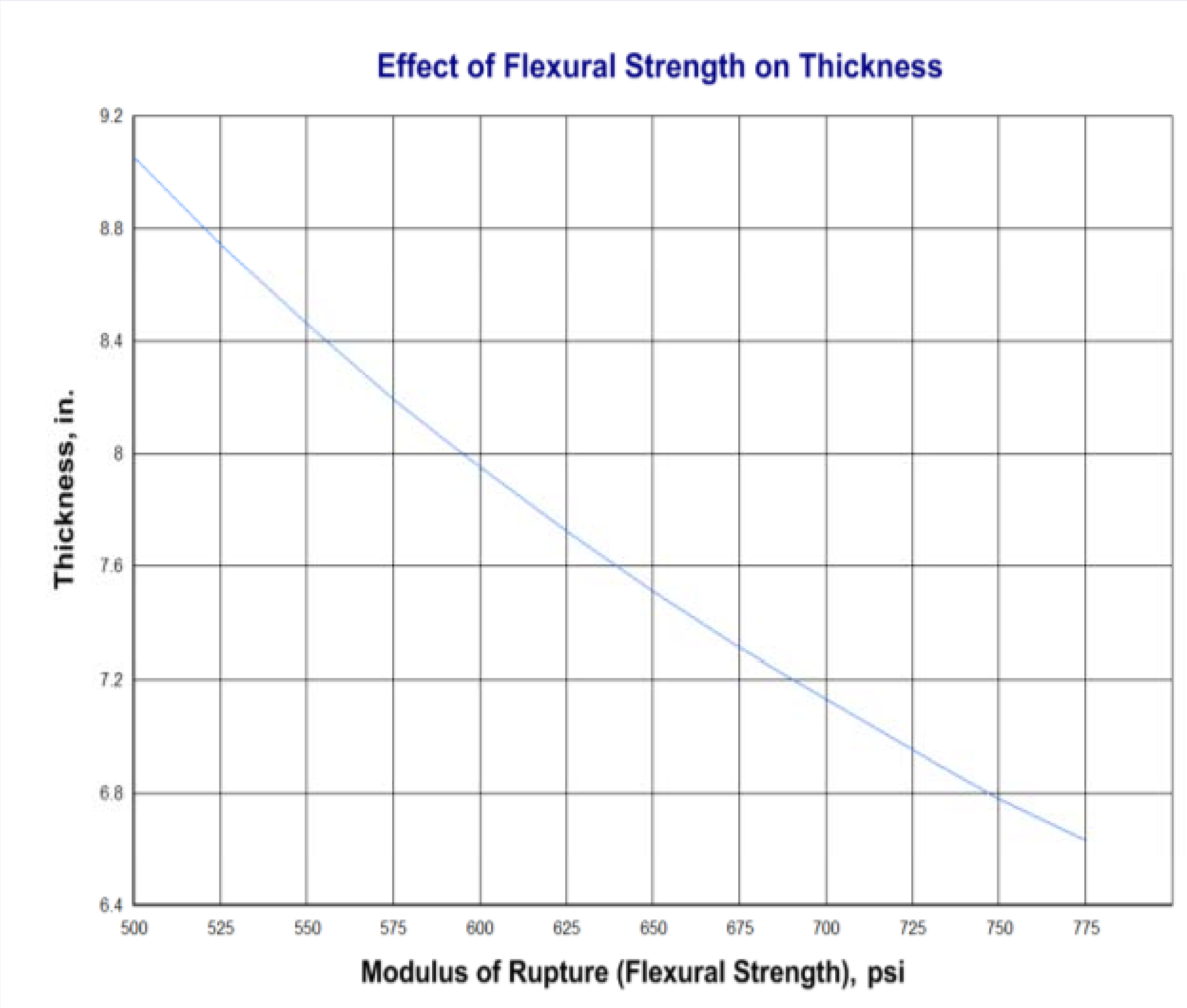


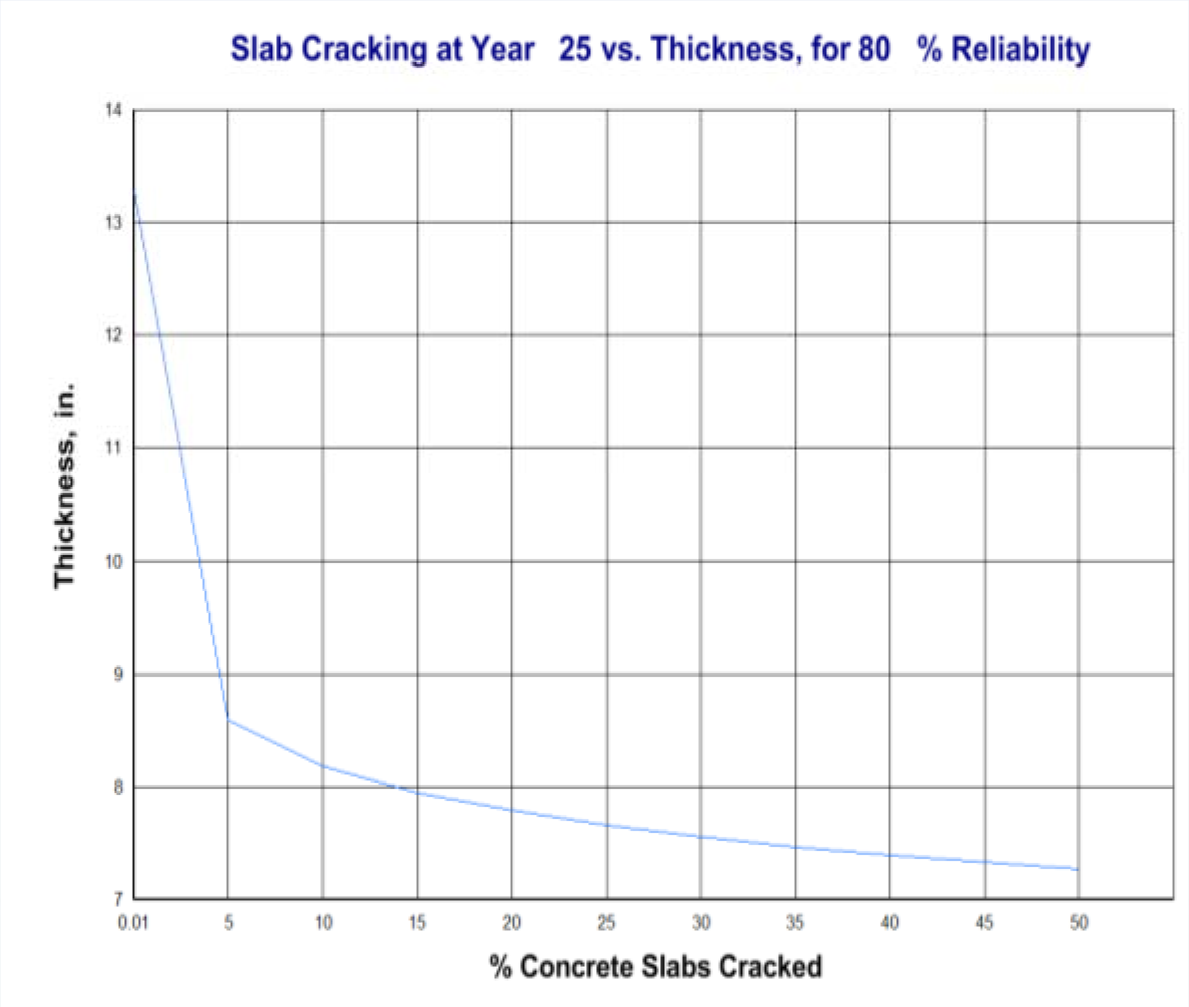
Effect of Design Life on Thickness
Thickness, in.
8.4
8.2
8
7.8
7.6
7.4
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Design Life, years



Effect of k-value on Thickness
Thickness, in.
9.6
9.2
8.8
8.4
8
7.6
7.2
6.8
6.4
50
100
150
200
250
300
350
400
450
500
550
600
k-value, psi/in.


Effect of Reliability (at 15% Slabs Cracked) on Thickness
Thickness, in.
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
Chart
50
55
60
65
70
75
80
85
90
95
99.9
Reliability, %


Effect of Flexural Strength on Thickness
9.2
8.8
8.4
8
7.6
7.2
6.8
6.4
Thickness, in.
500
525
550
575
600
625
650
675
700
725
750
775
Modulus of Rupture (Flexural Strength), psi



Slab Cracking at Year 25 vs. Thickness, for 80 % Reliability
Thickness, in.
14
13
12
11
10
9
8
7
0.01
5
10
15
20
25
30
35
40
45
50
% Concrete Slabs Cracked

CONCRETE PAVEMENT | **ASPHALT PAVEMENT**

Resilient Modulus of the Subgrade (M_{RSG}) [Calculate] 3000 psi [Help]
(used for both concrete and asphalt designs)

Composite Modulus of Subgrade Reaction (k)

(•) Design subbase layer system and use calculated k value

[Add Layers] 182 pci [Help]

( ) User-defined k value for existing subbase layer system

161 pci

Select Concrete Properties

28-Day Flexural Strength (MR) 600 psi [Help]

Modulus of Elasticity (E) 4050000 psi [Help]

Select Load Transfer Dowels

(•) yes ( ) no [Help]

Select Edge Support (tied concrete shoulder, curb and gutter, or widened lane)

(•) yes ( ) no [Help]

Adjust Support for Asphalt Design Reliability

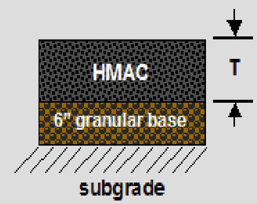
Coefficient of Variation (COV) 38 % [Help]

Design (M_{RSG}) 2040.55 psi [Info*]

*Full-depth design type not available due to MRSG [design] value. Click MRSG help for details.

Select Asphalt Pavement Type

Design Type: Asphalt with 6" Granular Base



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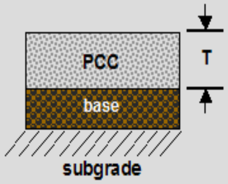
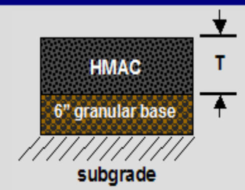
CONCRETE PAVEMENT	ASPHALT PAVEMENT



Run Analysis



Composite Modulus of Subgrade Reaction (k) = 182 pci

Top Layer = Unbound Compacted Granular Materials 6 in.

Design Concrete Thickness = 6.83 in.

Resilient Modulus of the Subgrade:

MRSG [user-entered] = 3000 psi

MRSG [design] = 2040.6 psi

Base = 6 inch Granular Base

Flexible ESALs = 4,203,798

Design Asphalt Thickness = 13.90 in.

Concrete Recommendations:

Concrete Thickness = 7.00 in.

Maximum Transverse Joint Spacing = 14 ft.

Dowel Bars: Dowels are not recommended.

Fatigue/Erosion Table | Rounding Considerations

View and Print Reports

Design and Analysis Summary

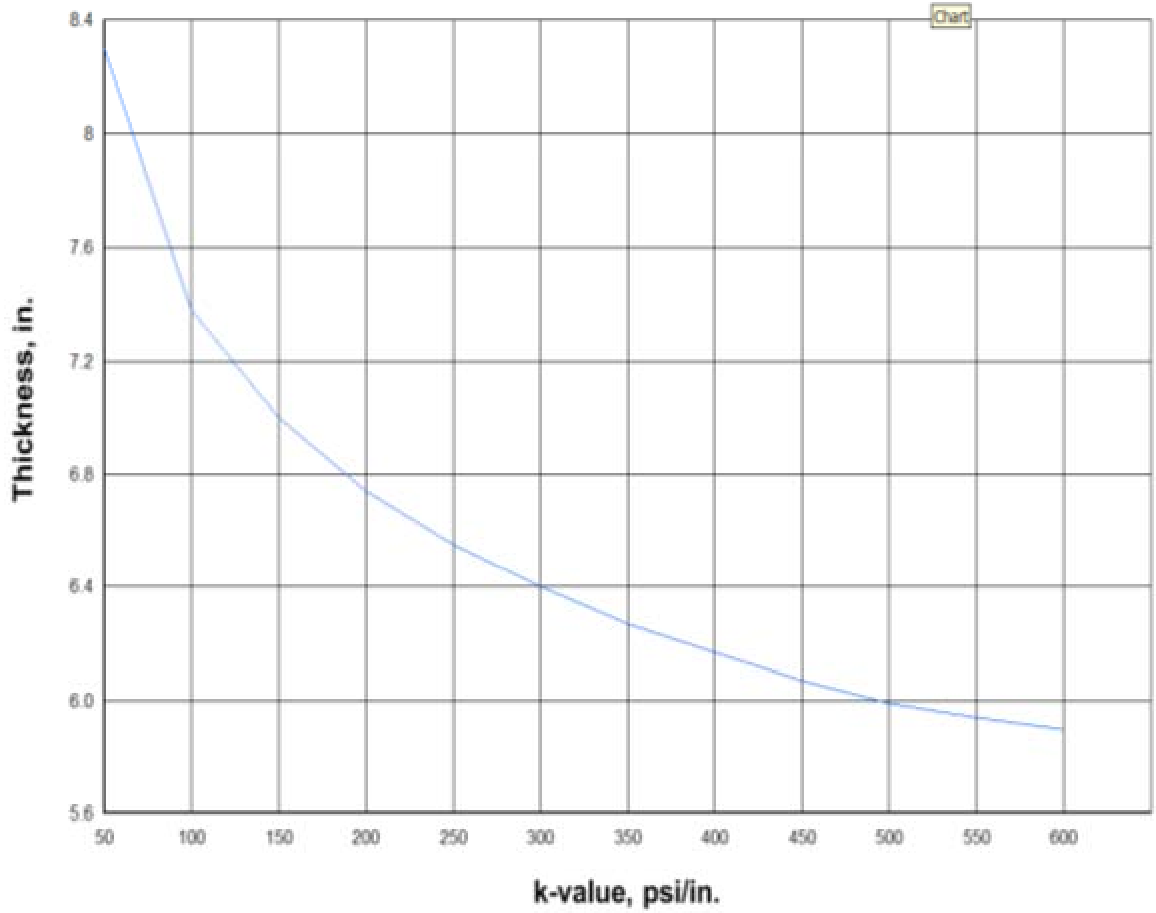
Sensitivity Analysis of:

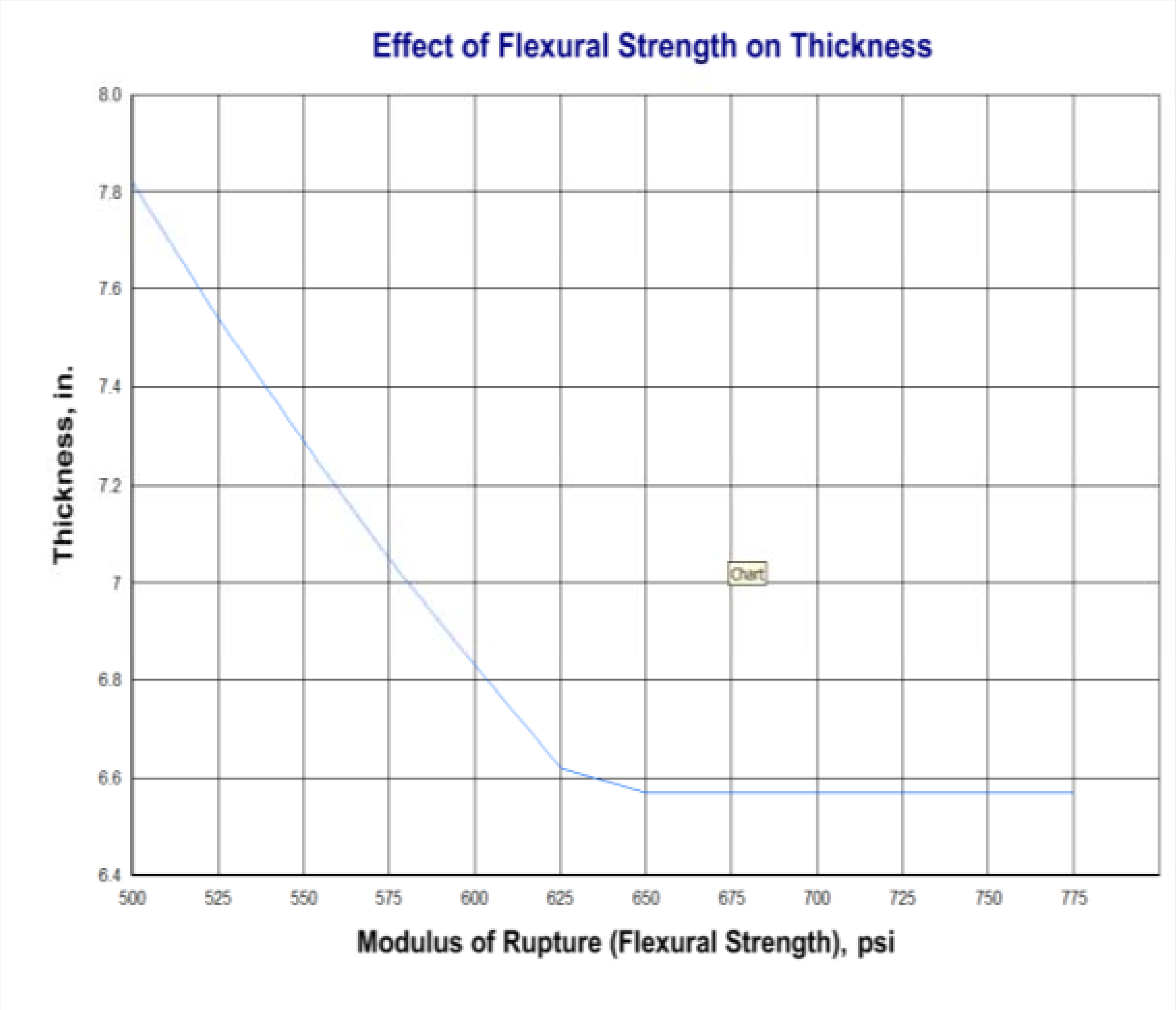
- k-value
- Reliability
- Concrete Strength
- % Slabs Cracked
- Design Life

View

Progress Bar

Effect of k-value on Thickness





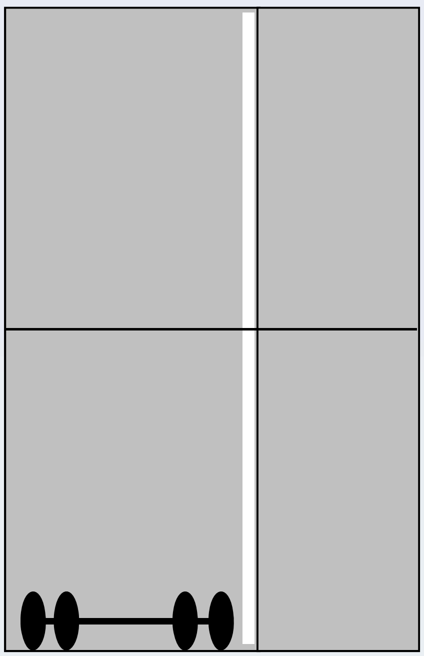
Effect of Flexural Strength on Thickness
8.0
7.8
7.6
7.4
7.2
7
6.8
6.6
6.4
Thickness, in.
500
525
550
575
600
625
650
675
700
725
750
775
Chart
Modulus of Rupture (Flexural Strength), psi

Subbase & Subbase Considerations

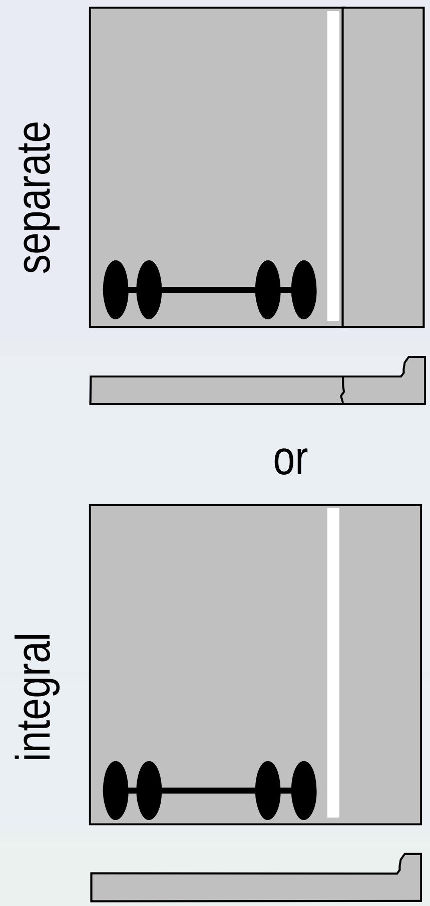
- Subgrade strength is not critical to thickness design.
- Subbase materials can be used to significantly change the composite support value (*k*).
  - Subgrade: *k* 100 psi/in.
  - Granular subbase: *k* 150 psi/in.
  - Asphalt treated subbase: *k* 300 psi/in.
  - Cement treated/lean concrete subbase: *k* 500 psi/in.

Methods for Providing Edge Support

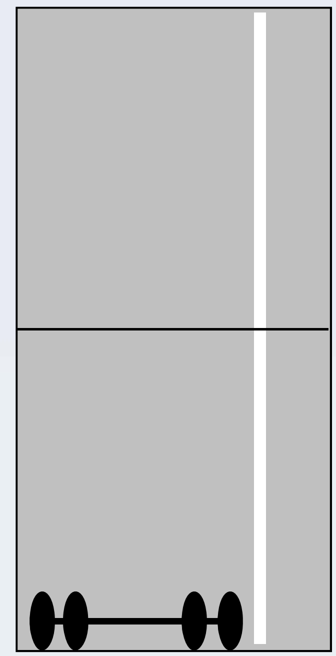
Concrete Shoulder



Curb & Gutter



Widened Lane



Dowel Recommendations

- Dowel recommendations:
  - Not recommended if pavement thickness is 7 in. or less.
  - Use 1 in. dowels, stabilized subgrade, or 4 to 6 in subbase if pavement thickness is 7.0 in. & 7.5 in.
  - Use 1-1/4 in. dowels if pavement thickness is 8 in. or greater.

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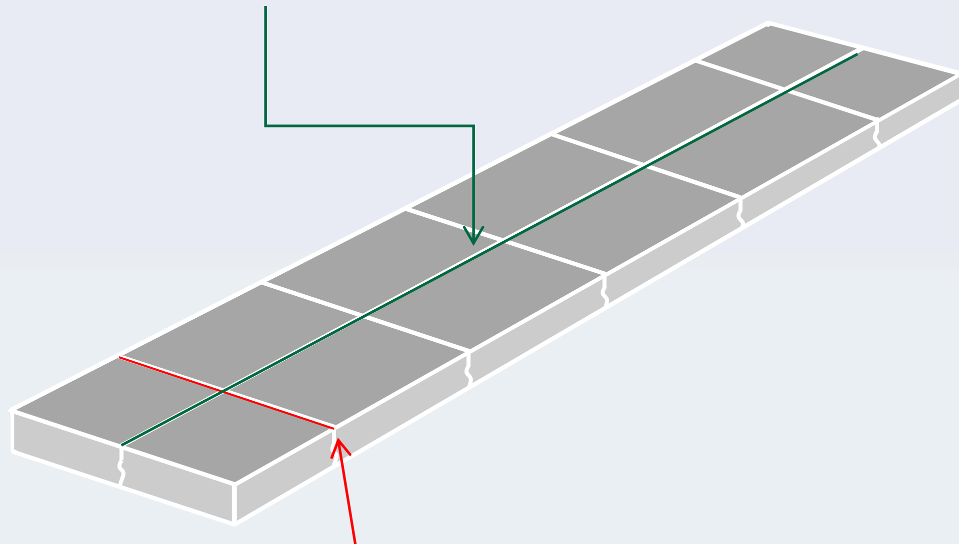
Jointing Considerations

- Control transverse and longitudinal crack from internal slab stresses.
- Divide pavement into construction lanes or increments.
- Accommodate slab movements.
- Provide load transfer.

Longitudinal Joints

Divides pavement lanes (8-14 ft.)

Depth 1/4 to 1/3 pavement thickness



Transverse Joints

Transverse Contraction Joints (8-20 ft.)

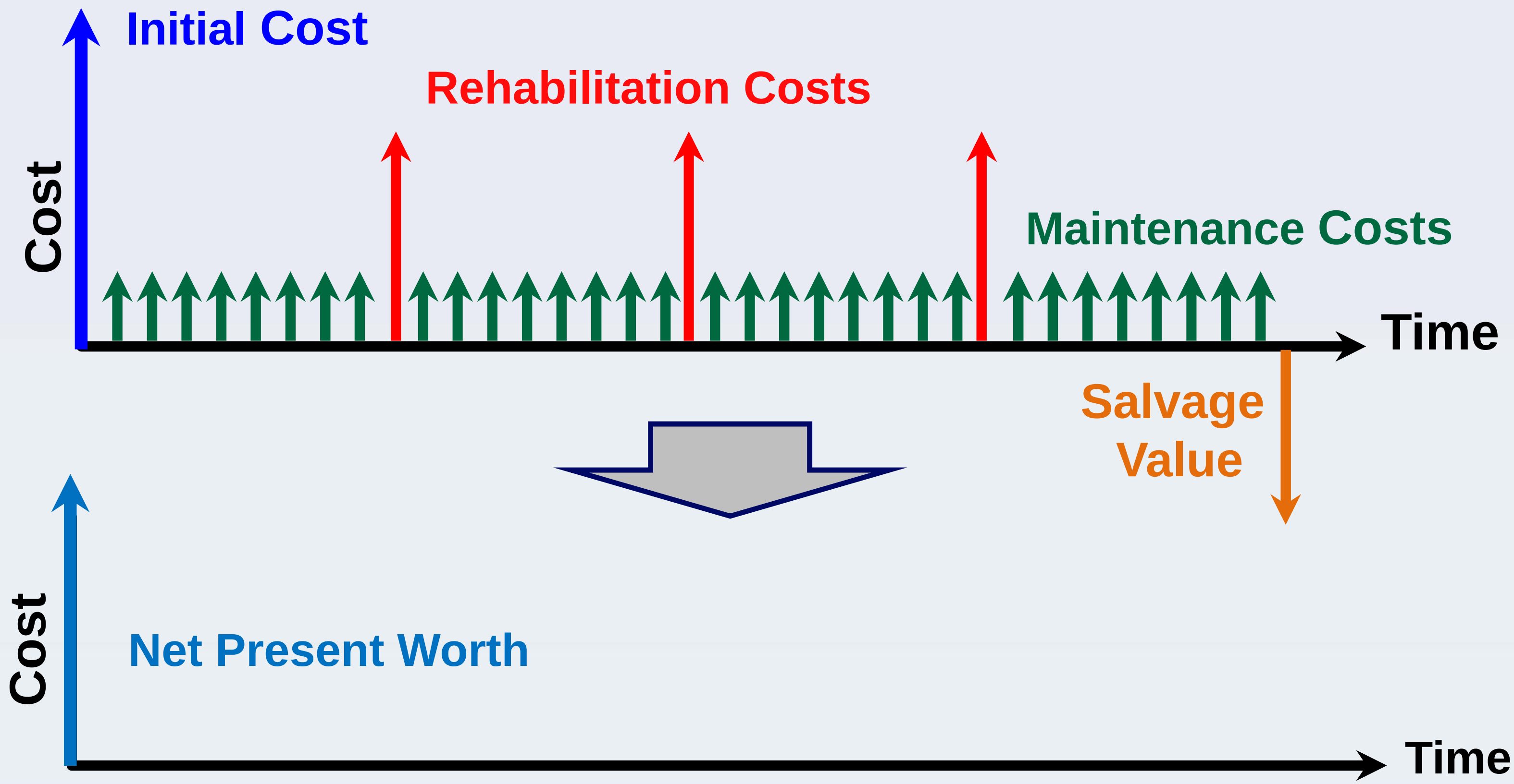
Depth ¼ - 1/3 pavement thickness

Now What?

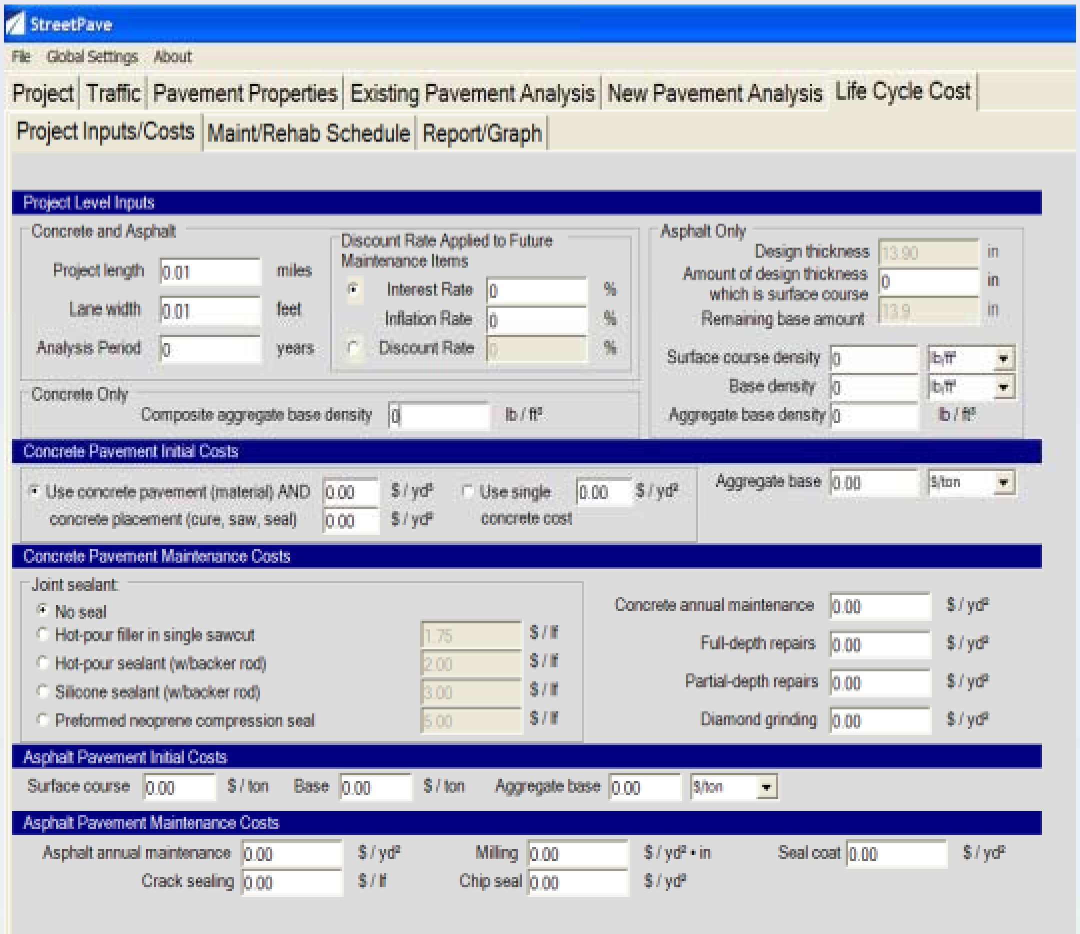
- With a baseline design as shown, these steps can optimize the pavement design:
  - Life cycle cost analysis.
  - Performance expectations.
  - Available budget.
  - Availability of qualified contractors.
  - Constructability.
  - User costs.

Life-Cycle Cost Analysis

Combines all present and future costs (benefits)



Life-Cycle Cost Analysis



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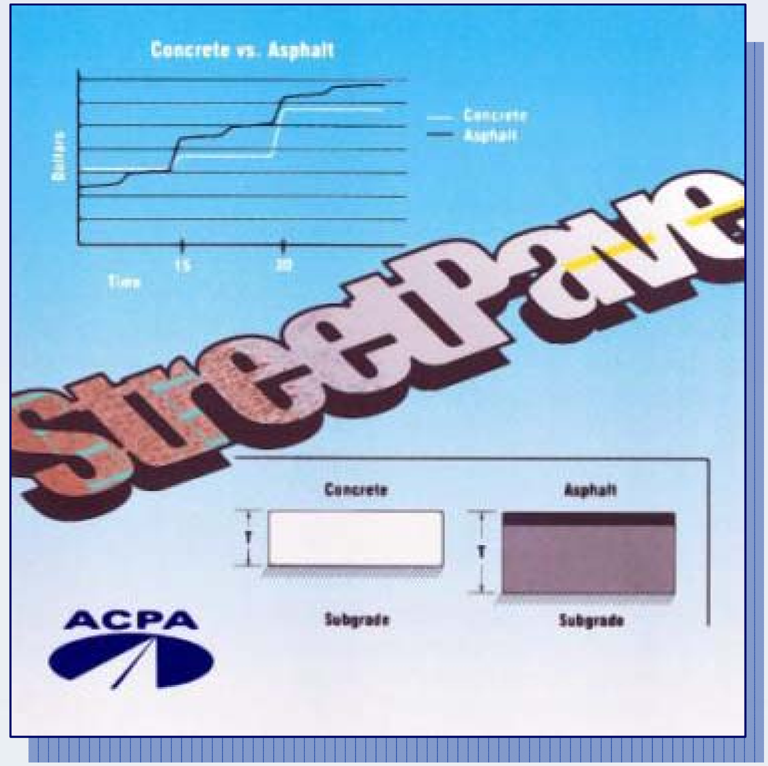
Finding StreetPave

Where to find StreetPave

- Available in two formats
  - Full-feature Windows® version in available from ACPA website at www.acpa.org/bookstore
  - Free, limited feature web-based version on ACPA's website at www.acpa.org/StreetPave/index.asp



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What's Next for StreetPave?

Watch for new version coming in the 4th Quarter 2010

- New capabilities for thin concrete overlays
- New sustainability inputs

Thank You!

More information at 847.966.2272 | www.acpa.org
888-84NRMCA (1.888.846.7622) | www.nrmca.org