PCI COURSE: SOUTH AFRICA, AUGUST 1988

by Dr. B. F. MCCULLOUGH

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

Summary of the PCI Course
on
Design of Concrete Roads: A Review of the 1986 AASHTO Guidelines

By
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The Center for Transportation Research
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of Civil Engineering

The primary purpose of this course is to present basic concepts and applications for the revised AASHTO Guide for design of pavement structures considering the following principles:

1) Introduction
2) Pavement design and management
3) General design concepts and input
4) Rigid pavement design procedure
5) Rehabilitation of flexible and rigid pavement with concrete overlays
6) Implementation guidelines

Each of these principles and the introduction session are discussed in more detail below.

The primary objective of the introduction session is to introduce the participants to the Guide, with the following secondary objectives:

1) Provide the student with background on the development of the Guide, organization of the material it contains and the individuals contributing to its development.
2) Provide a conceptual overview of the Guide and the revisions incorporated to provide the designer increased flexibility and capability in design.
3) Provide the FHWA's viewpoint on implementing the Guide.

In the following session we will discuss pavement design and management principles. The objective of this session will be to familiarize the participants with the overall content of the Guide with special emphasis on the new or modified procedures and concepts which have been added.

Emphasis will be given to the following items included in the Guide namely: Glossary of terms, Roadbed soil strength, Inclusion of environmental factors, Drainage, Pavement management, Reliability, and Life cycle costs. Each of the listed topics will be further illustrated by specific applications in each succeeding session.

The primary objective of the next session is to provide an understanding of the design inputs of a general nature, i.e. applicable to all pavement types. The secondary objective is to increase the students capability to develop specific general input information for a design problem.

Emphasis will be given to the analysis period, initial performance period, roadbed soil resilient modulus, terminal serviceability index, weighted resilient modulus concepts, reliability, roadbed swelling, roadbed frost heave, and pavement type. The approach used will be to explain the principles involved in developing the charts and their application. Next, the procedures will be illustrated in step-by-step applications to an example problems. Emphasis will also be given to explaining the new concepts.

The objective of session 4 is to describe concepts related to the use of the guide for the design of rigid pavements and to illustrate design procedures by example problems. The design procedure will encompass both the thickness design and horizontal dimensions such as joint spacing, reinforcement, etc. Explanations will emphasize the type of information required to design of pavement, sources of information and interpretation of results that apply to specific examples. The factors presented in Session 3 will be considered in discussing the design procedure. Specifically, the material will be covered as follows:

1) Specific rigid pavement input
2) Rigid pavement thickness design
3) Rigid pavement joint design
4) Rigid pavement reinforcement design
5) Example problems

Computer aided examples will be used to illustrate specific design procedures for new construction.

The 1986 Guide includes a procedure for evaluating existing pavements to determine overlay requirements. Session No. 5 will review concepts and illustrate procedures for estimating portland cement concrete overlay requirements.

The subjects to be covered in this session include the following; methodology, unit delineation, remaining life, flexible overlays on rigid existing, rigid overlays on rigid existing, rigid overlays on existing flexible, use of recycled materials, and use of milling procedures.

The primary objective of the final session is to encourage the attendees to implement the Guides and provide basic procedural guidelines for an agency to implement the new concepts. Illustrative examples of the procedures that may be used by the States will be provided. The basic problems will be defined, the agency needs will be outlined, the alternate approaches or solutions will be covered, a basic sample plan will be formulated to illustrate the concepts involved, and the need for implementation will be emphasized.

Session 1
Introduction

Objectives

The primary objective of this session is to introduce the participants to the Guide, with the following secondary objectives:

1. Provide the student with background on the development of the Guide, organization of the material it contains and the individuals contributing to its development.
2. Provide a conceptual overview of the Guide and the revisions incorporated to provide the designer increased flexibility and capability in design.
3. Provide the FHWA's viewpoint on implementing the Guide.

Outline

During this session, emphasis will be given to the following items:

1. An introduction of the instructors, students, and the course approach.
2. The agenda, objectives and scope of the sessions.
3. The background of Guide development. This will cover the organization, individual contributors, process, etc.
4. The FHWA viewpoint on implementation as to schedule and use in documenting designs (presentation by FHWA representative).
5. A slide presentation providing a conceptual review of the Guide. This will provide the student a short overview of the Guide with emphasis on the new concepts incorporated, philosophical considerations, the models used, and design comparisons.
6. A brief discussion of the limitations of various design methods will be provided so that a fair comparison can be made. The tendency is to critique the material at hand while holding a less perfect method as a reference.

COURSE APPROACH

1. Familiarize
   a. Basic Concepts & Procedures
   b. Application of Procedures
   c. Limitations

2. Implement
   a. Needs of Agency
   b. Mechanistic

3. Computer Program

TASK FORCE GUIDELINES

1. SS/Ai's from tests
2. Variability / Reliability
3. Emphasis on Reliability
4. Life cycle costs
5. Drainage
6. Provide for revisions
7. National & International in Scope
    a. Cities & Counties
    b. Other Agencies
    c. Other Countries
8. 2/3 Approval

HISTORICAL DEVELOPMENT OF GUIDES

1959 - Guidelines

1962 - Interim Guides

1972 - Revision of Guides (Blue Manual)
and NCHRP Report 128

1981 - Chapter III Revisions

1986 - Guide

LIMITATION OF GUIDE

1. Specific pavement materials and roadbed soil
2. Single environment
3. An accelerated two-year testing period extrapolated to a 10 - 20 designs
4. Operating vehicles with identical axle loads and configurations, as opposed to mixed traffic

GENERAL LIMITATIONS

1. Verification
2. Inadequate statistical data (reliability)
3. Definition of failure missing

DEVELOPMENT

NEW DESIGN TOOLS

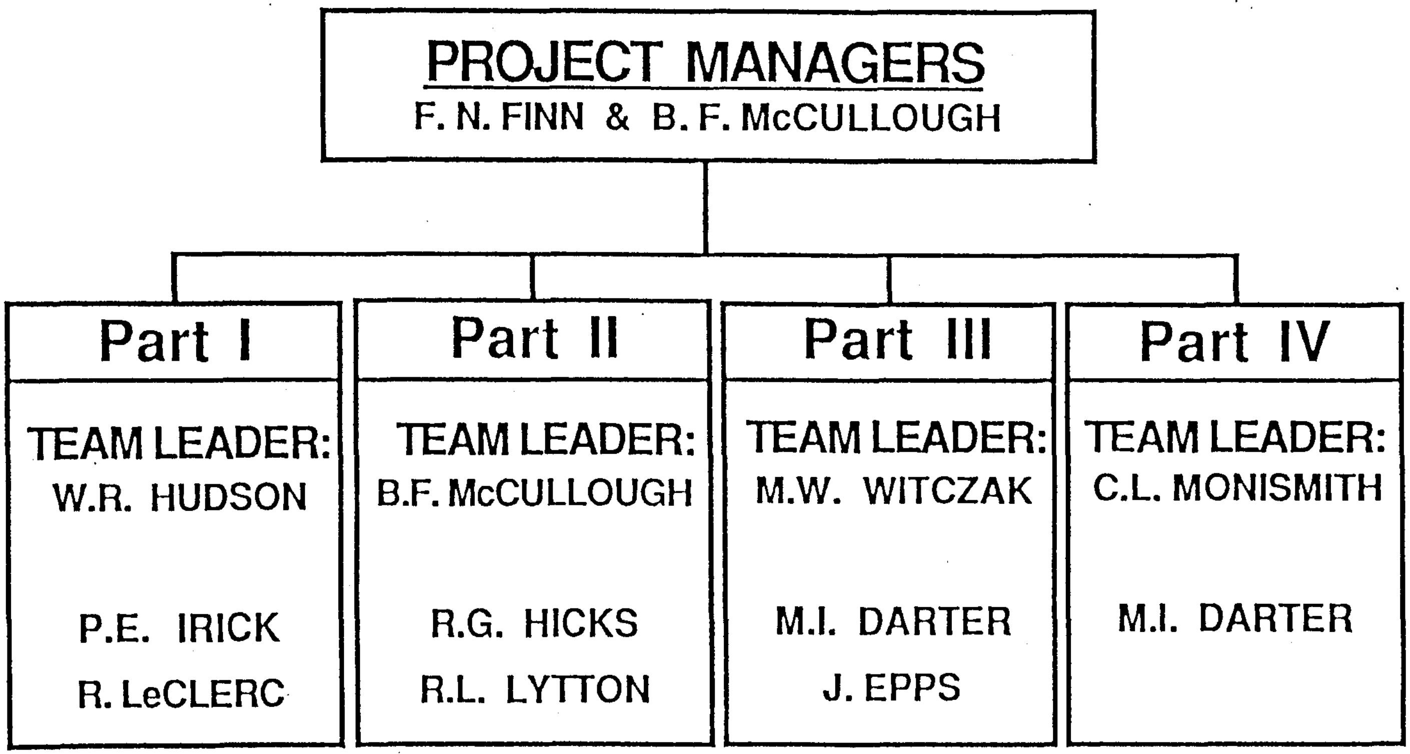
COMPARISONS

PHILOSOPHICAL APPROACHES

BASIC CONCEPTS

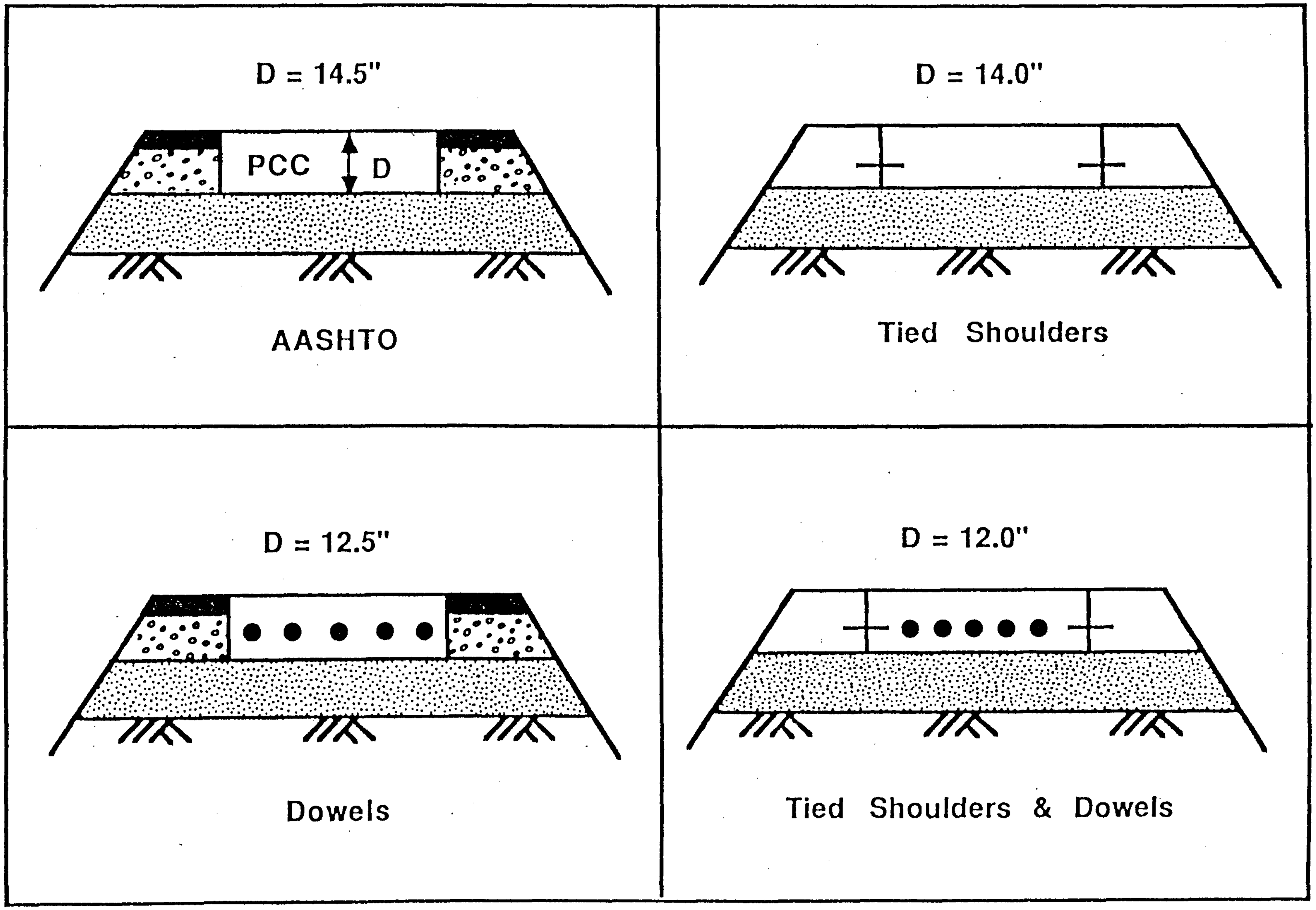
MODELS

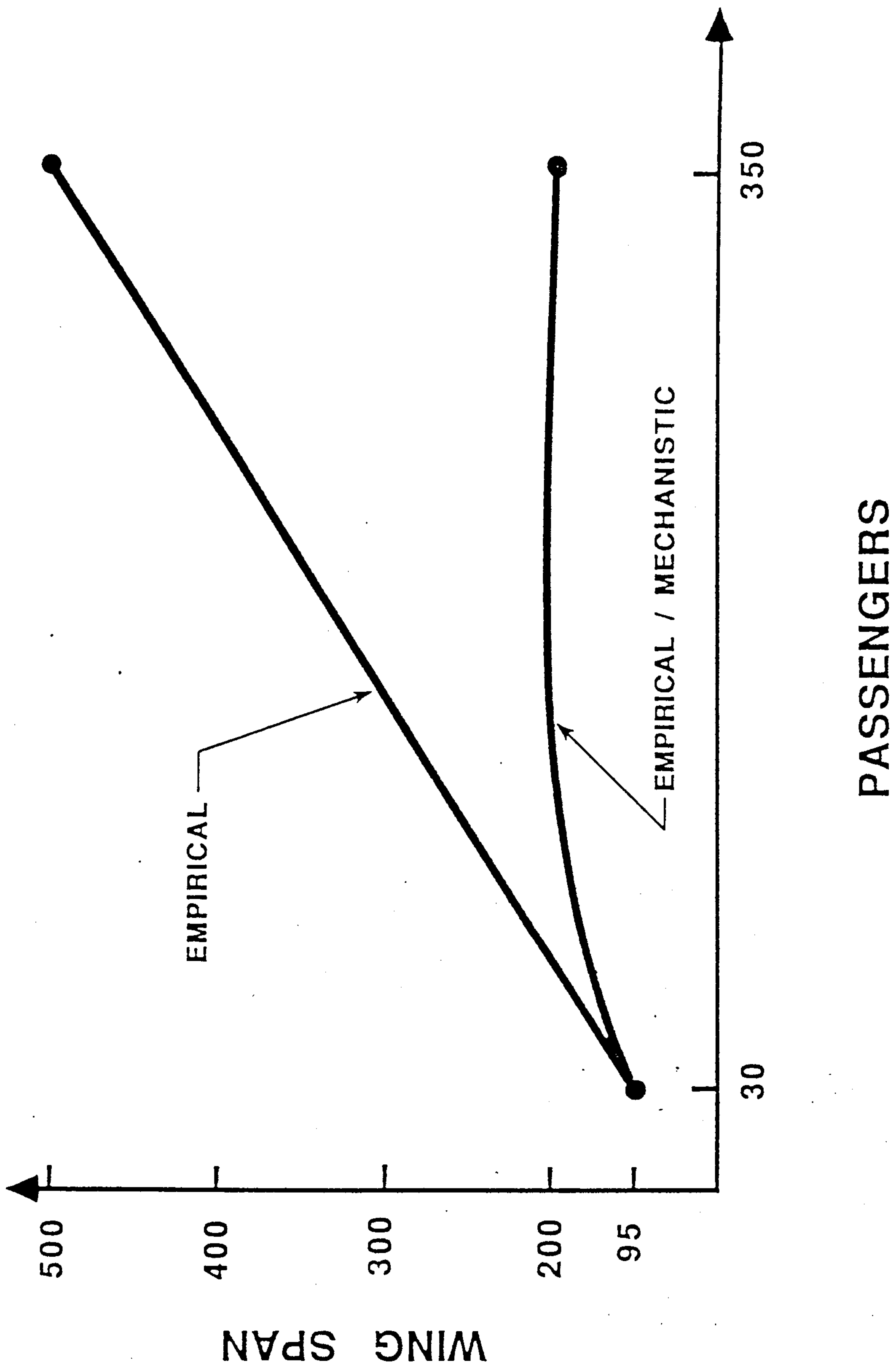
CONSULTANTS

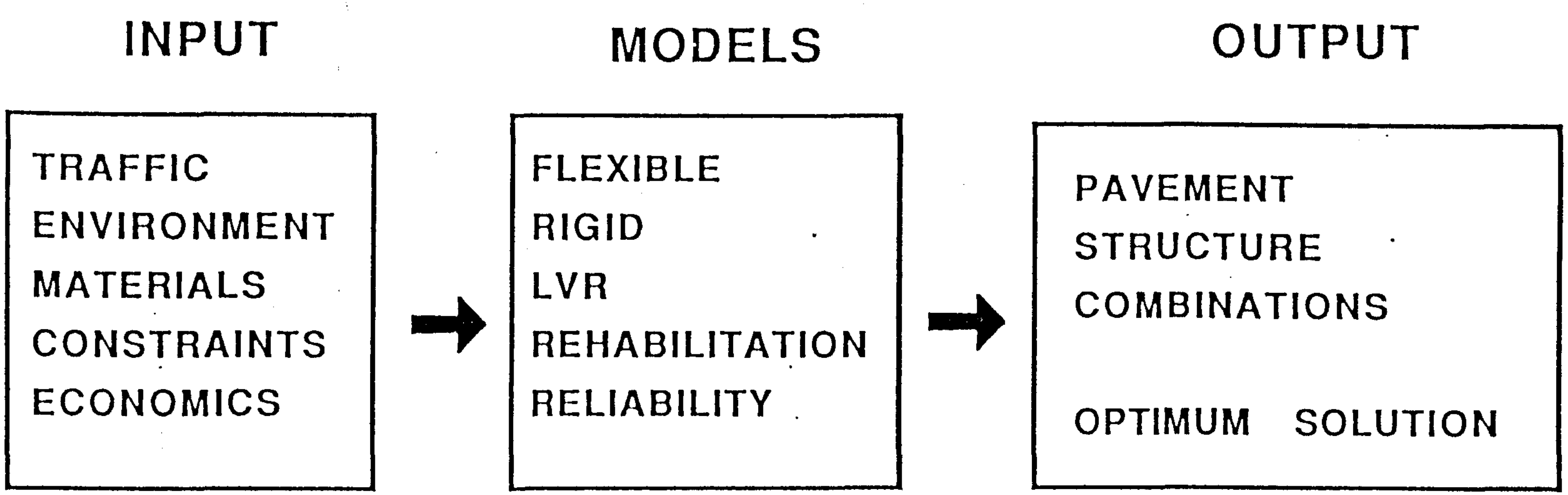


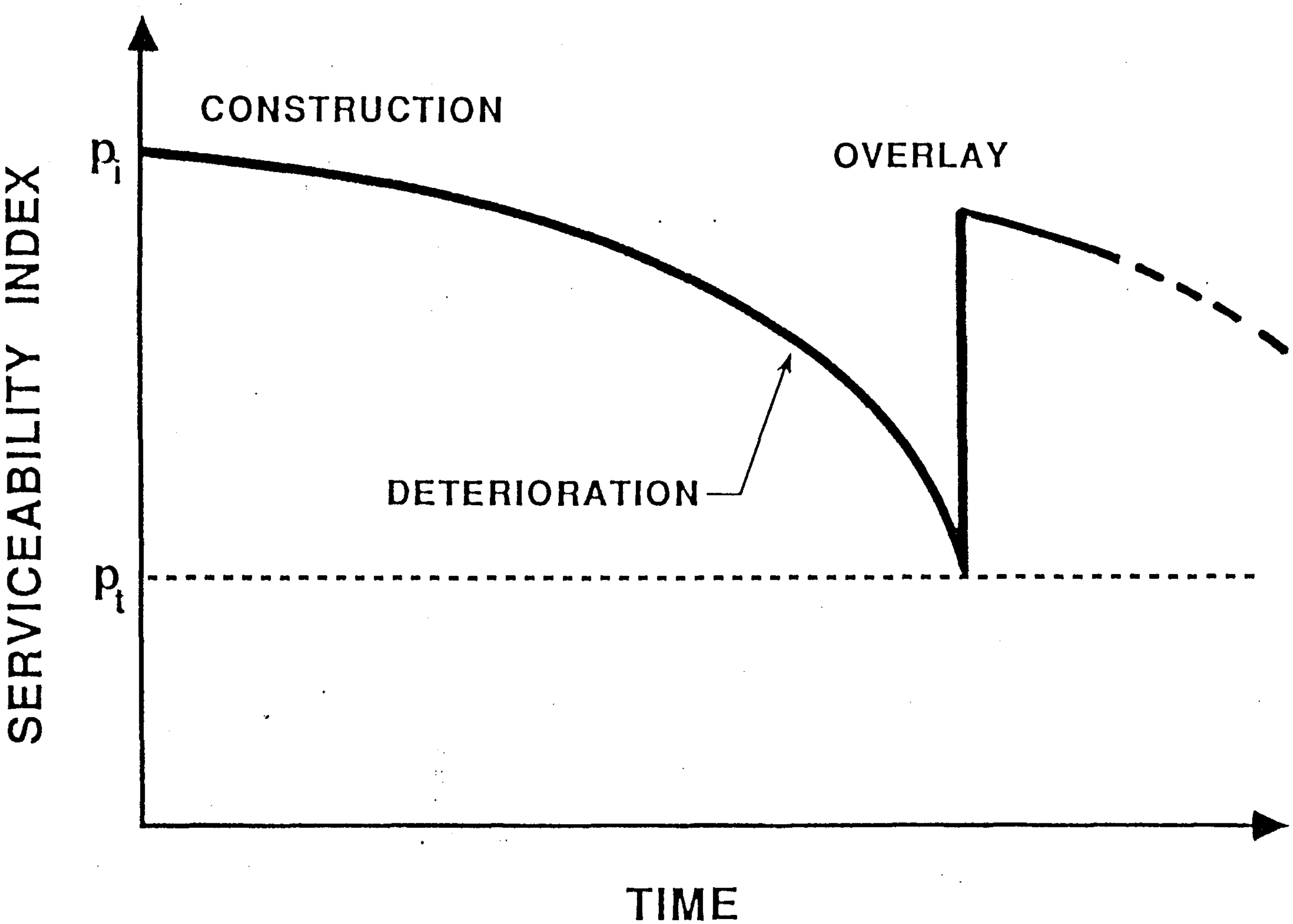
Improvements to the Guide

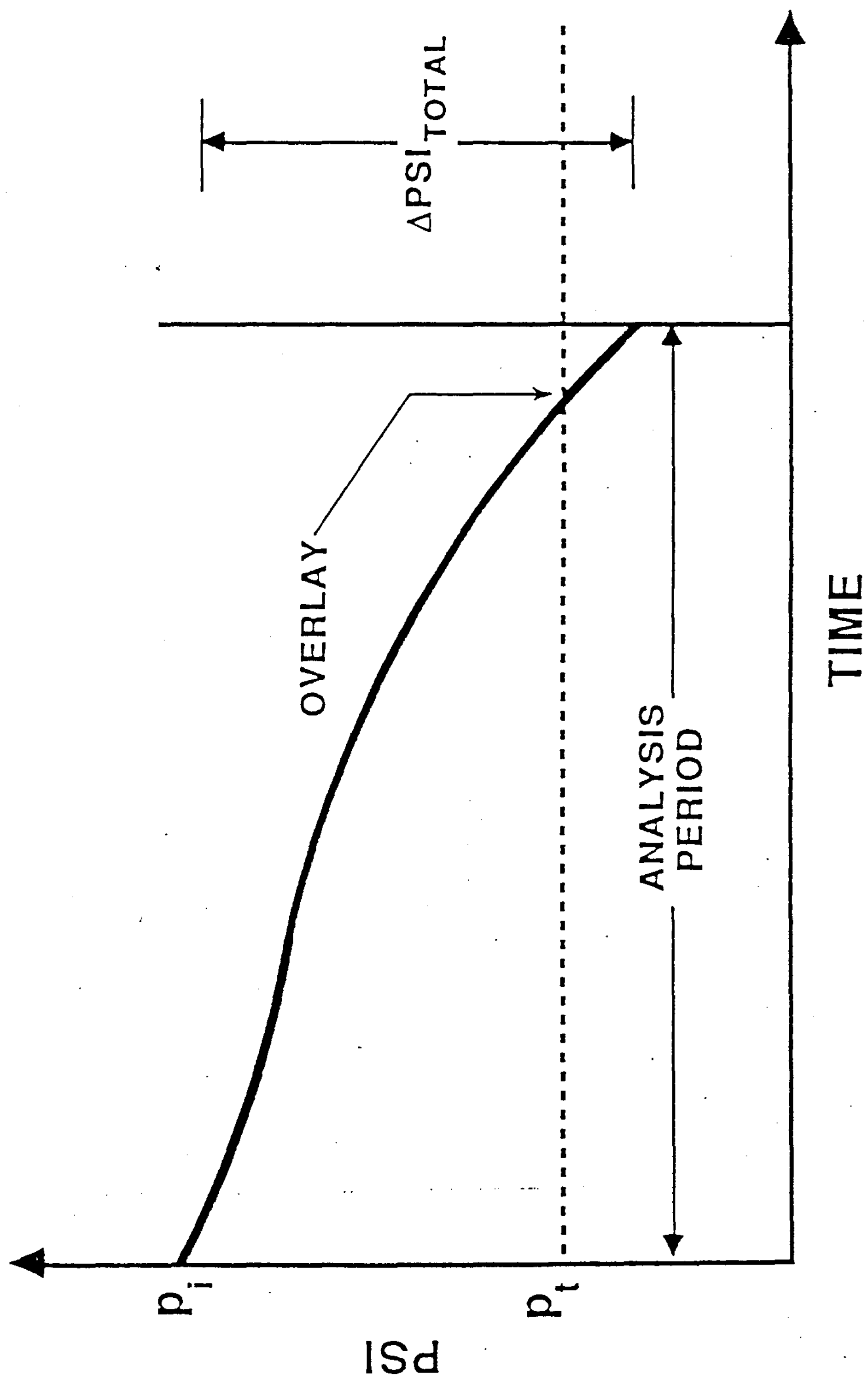
1. RELIABILITY
2. M_R FOR SOILS
3. M_R FOR LAYER COEFFICIENTS
4. DRAINAGE
5. ENVIRONMENT
6. LOAD POSITION
7. SUBBASE EROSION
8. LIFE CYCLE COSTS
9. REHABILITATION
10. PAVEMENT MANAGEMENT
11. LOAD EQUIVALENCIES
12. TRAFFIC DATA
13. LOW VOLUME ROADS
14. MECHANISTIC / EMPIRICAL DESIGN

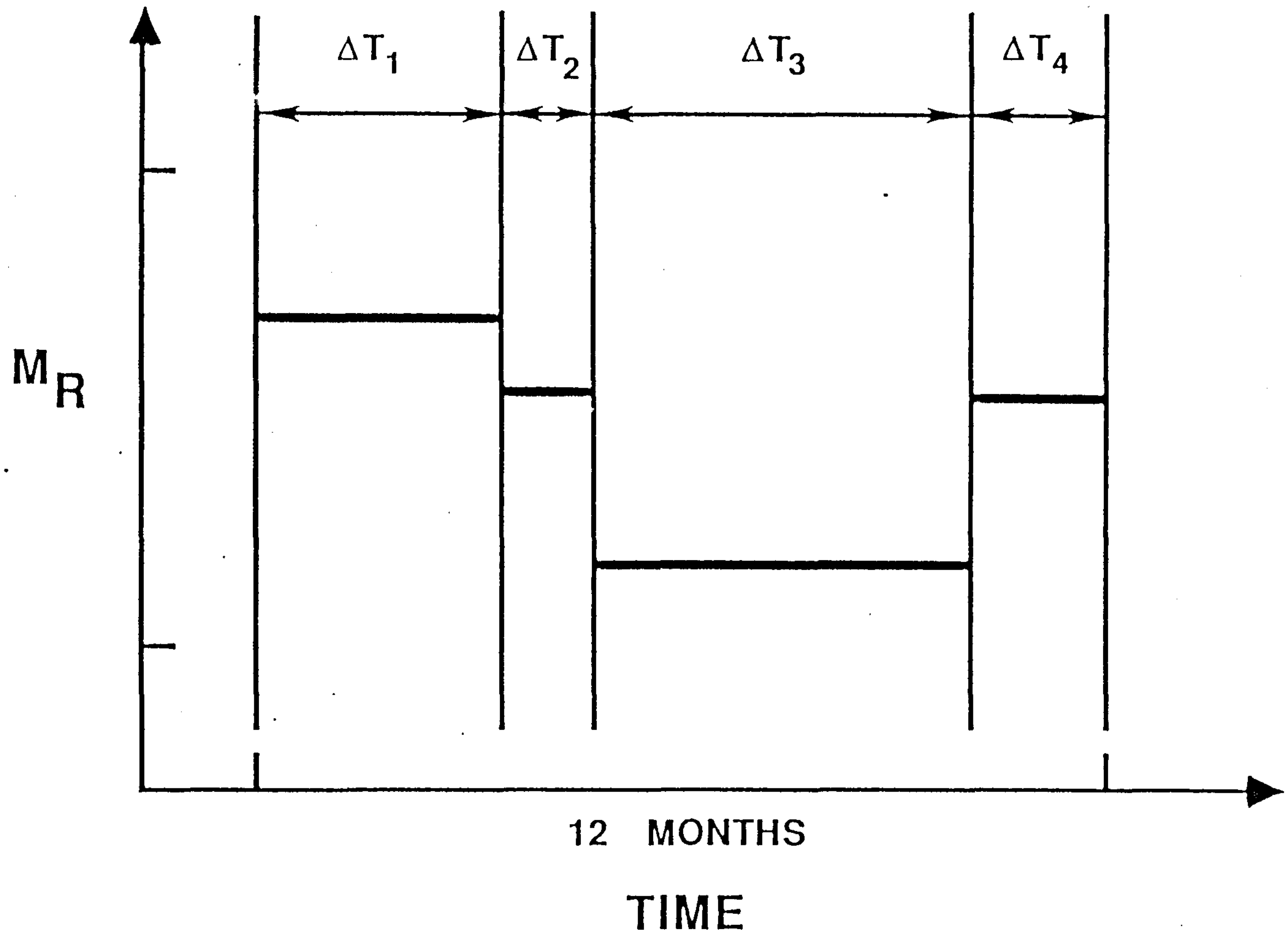

D = 14.5"
PCC
D
AASHTO
D = 14.0"
Tied Shoulders
D = 12.5"
Dowels
D = 12.0"
Tied Shoulders & Dowels

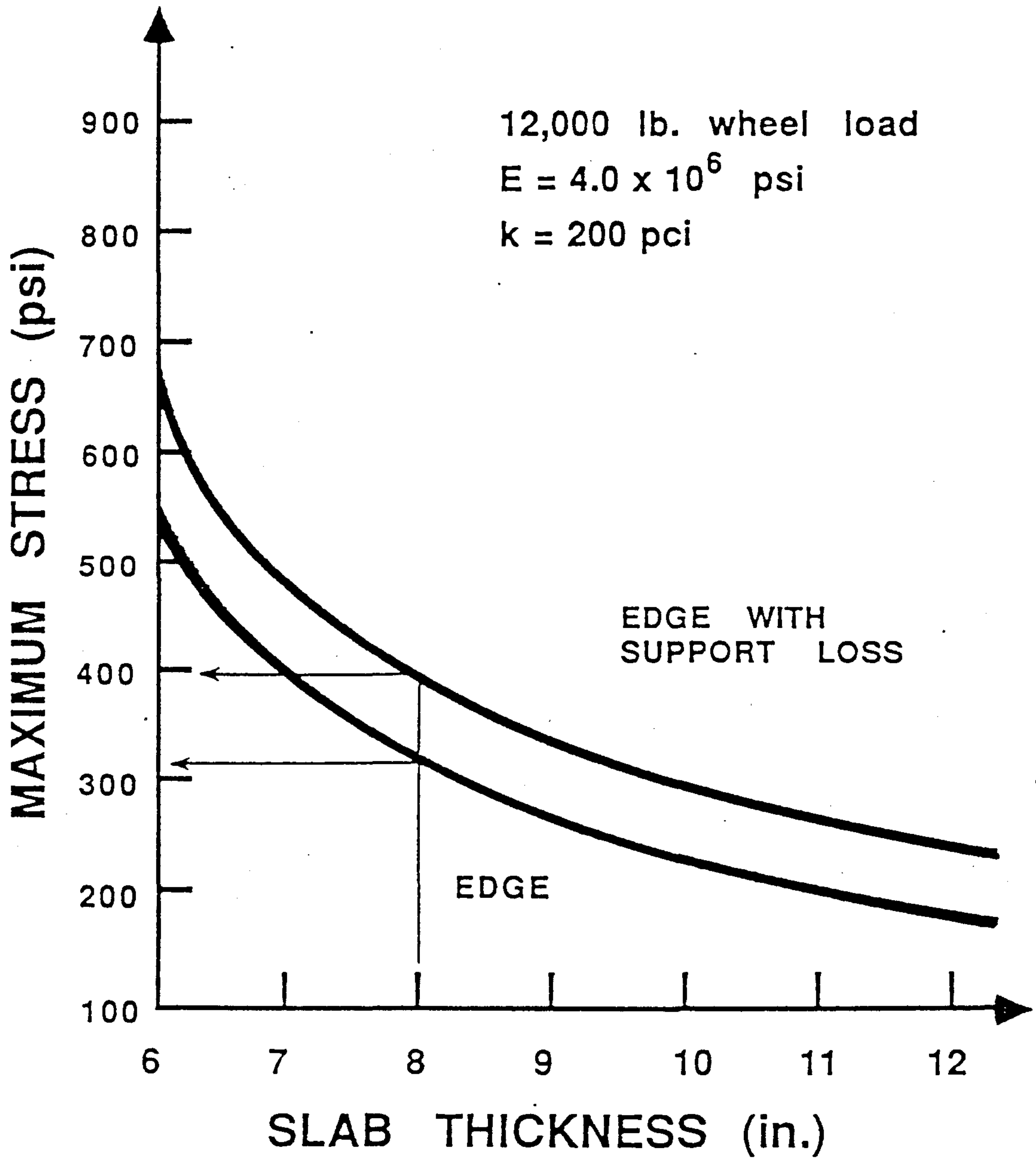

WING SPAN
500
400
300
200
95
30
350
PASSENGERS
EMPIRICAL
EMPIRICAL / MECHANISTIC

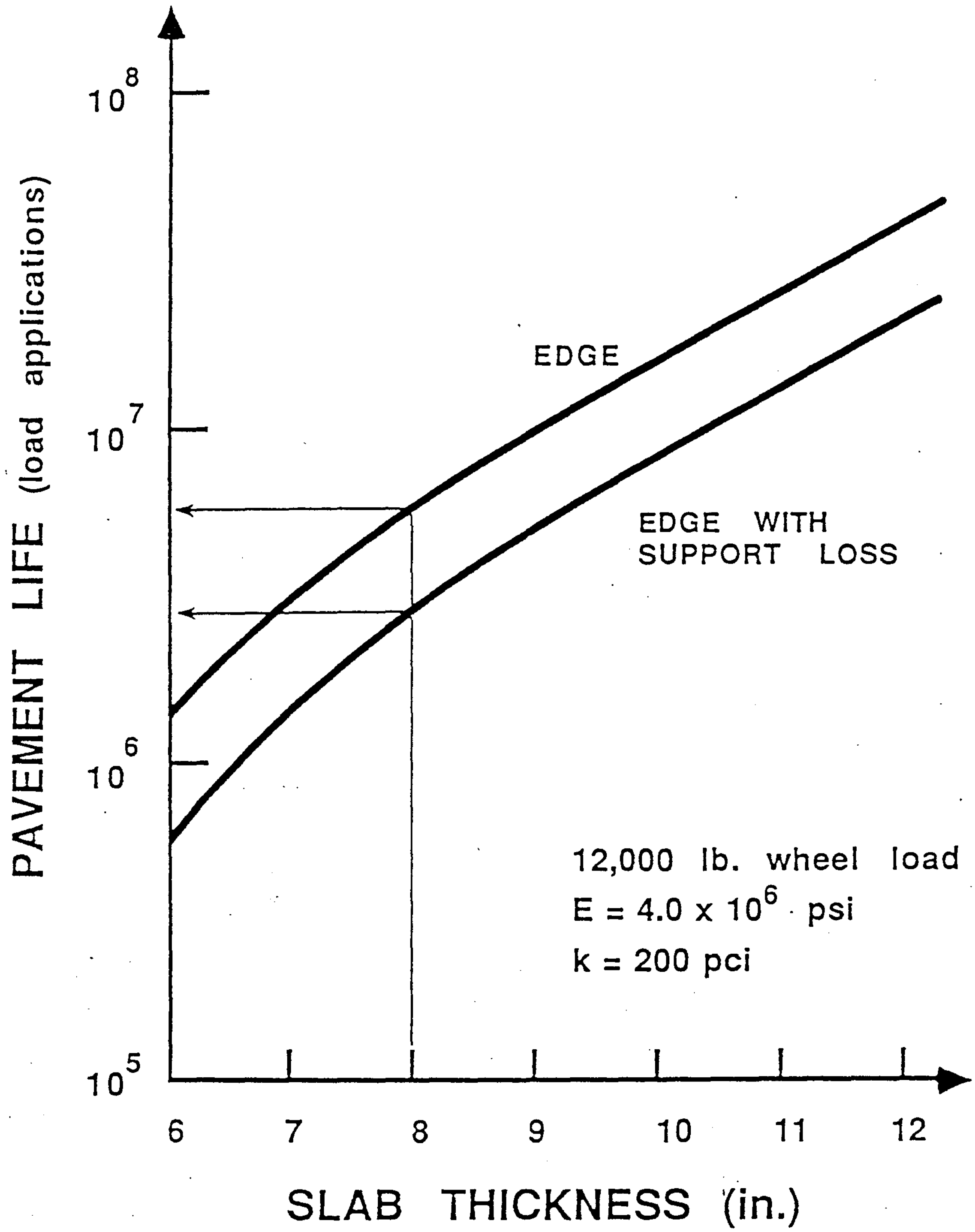

INPUT
TRAFFIC
ENVIRONMENT
MATERIALS
CONSTRAINTS
ECONOMICS
MODELS
FLEXIBLE
RIGID
LVR
REHABILITATION
RELIABILITY
OUTPUT
PAVEMENT
STRUCTURE
COMBINATIONS
OPTIMUM SOLUTION


CONSTRUCTION
OVERLAY
DETERIORATION
SERVICEABILITY INDEX
p_i
p_t
TIME

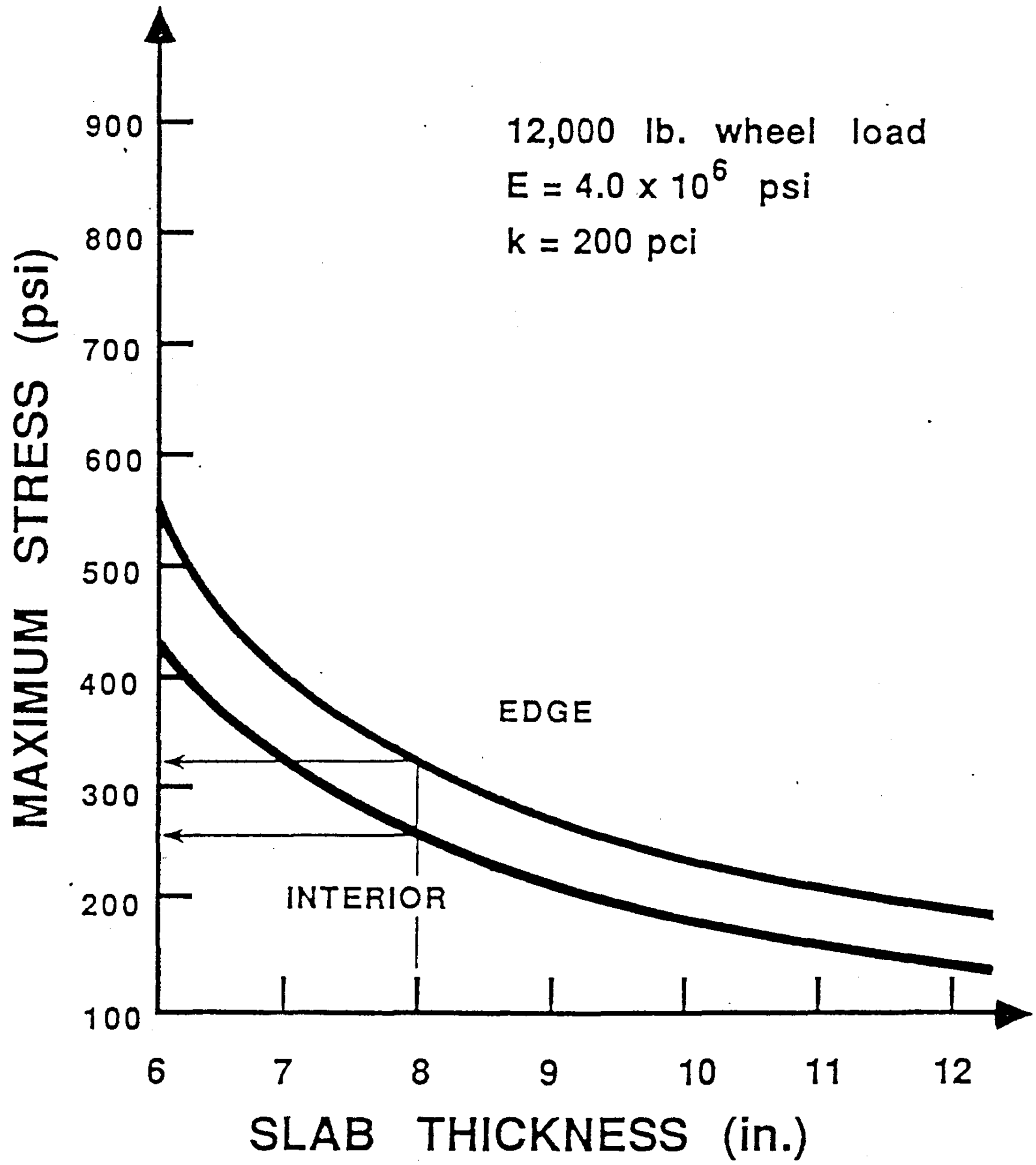

ΔPSI TOTAL
OVERLAY
ANALYSIS PERIOD
TIME
PSI
p_i
p_t

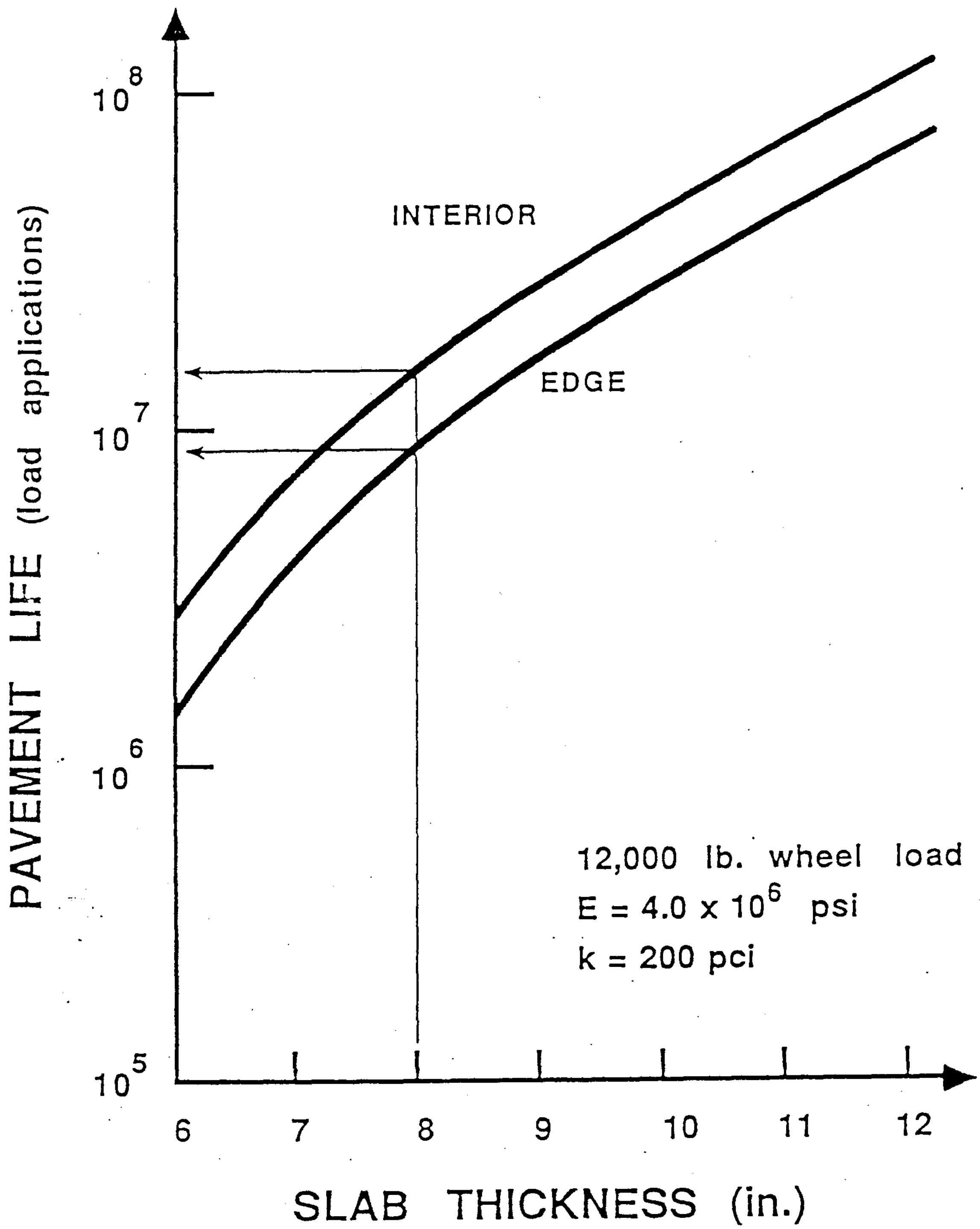

ΔT1
ΔT2
ΔT3
ΔT4
MR
12 MONTHS
TIME


12,000 lb. wheel load
E = 4.0 x 10^6 psi
k = 200 pci
MAXIMUM STRESS (psi)
900
800
700
600
500
400
300
200
100
EDGE WITH
SUPPORT LOSS
EDGE
6
7
8
9
10
11
12
SLAB THICKNESS (in.)

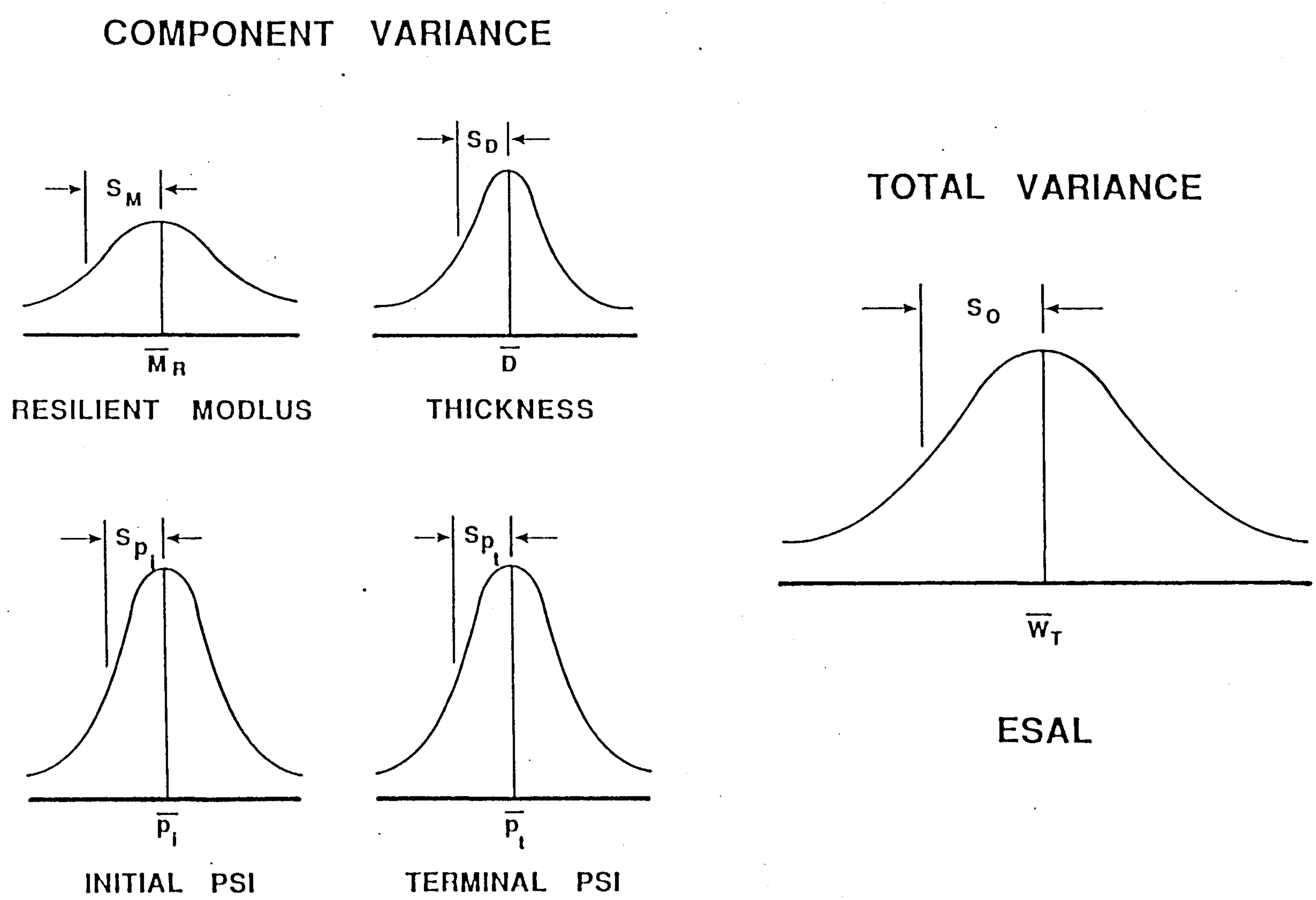


PAVEMENT LIFE (load applications)
10^8
10^7
10^6
10^5
EDGE
EDGE WITH SUPPORT LOSS
12,000 lb. wheel load
E = 4.0 x 10^6 psi
k = 200 pci
6
7
8
9
10
11
12
SLAB THICKNESS (in.)


12,000 lb. wheel load
E = 4.0 x 10^6 psi
k = 200 pci
MAXIMUM STRESS (psi)
900
800
700
600
500
400
300
200
100
EDGE
INTERIOR
6
7
8
9
10
11
12
SLAB THICKNESS (in.)



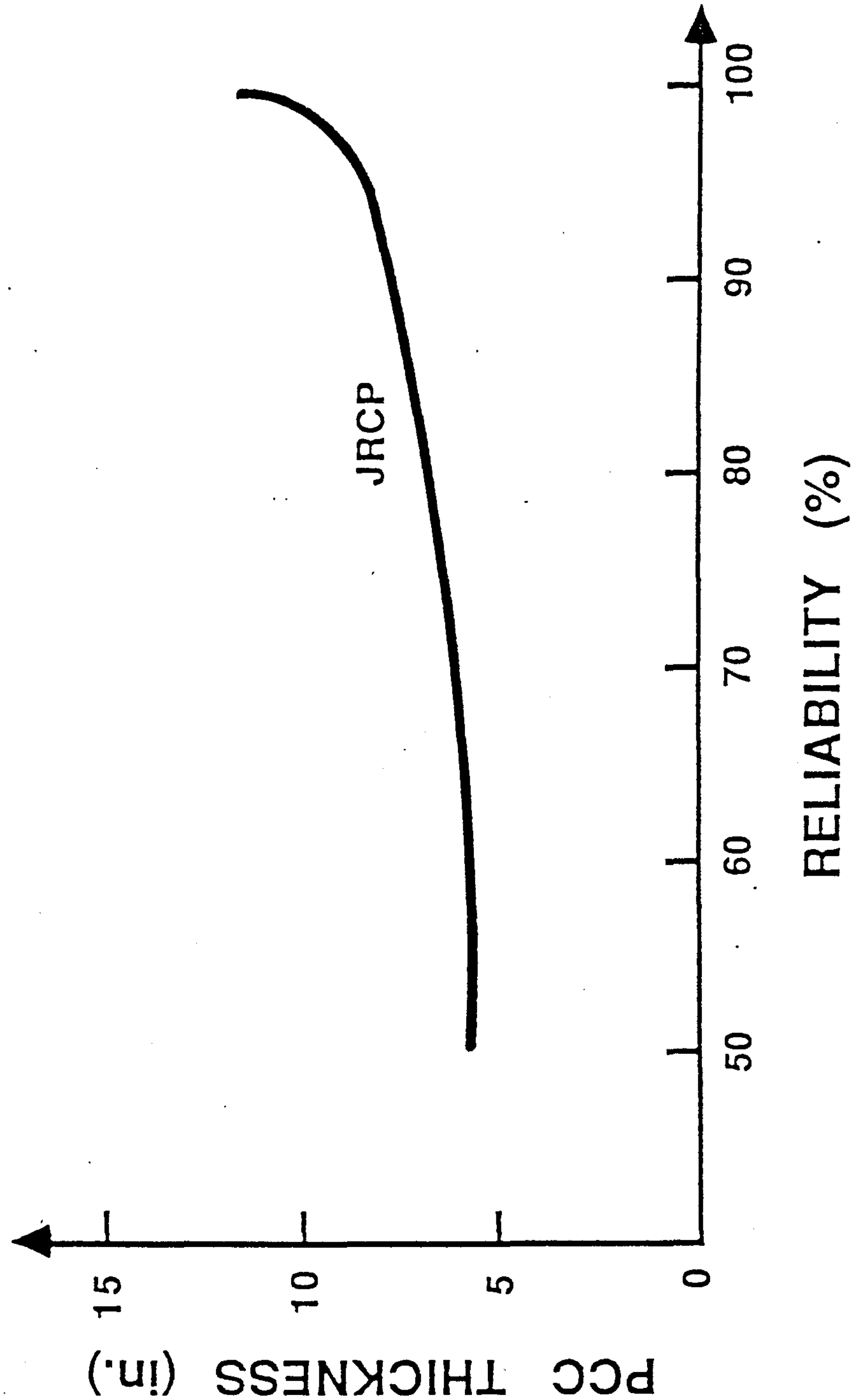
PAVEMENT LIFE (load applications)
10^8
10^7
10^6
10^5
INTERIOR
EDGE
12,000 lb. wheel load
E = 4.0 x 10^6 psi
k = 200 pci
6
7
8
9
10
11
12
SLAB THICKNESS (in.)


COMPONENT VARIANCE
S_M
M_R
RESILIENT MODLUS
S_D
D
THICKNESS
S_pi
p_i
INITIAL PSI
S_pt
p_t
TERMINAL PSI
TOTAL VARIANCE
S_O
W_T
ESAL

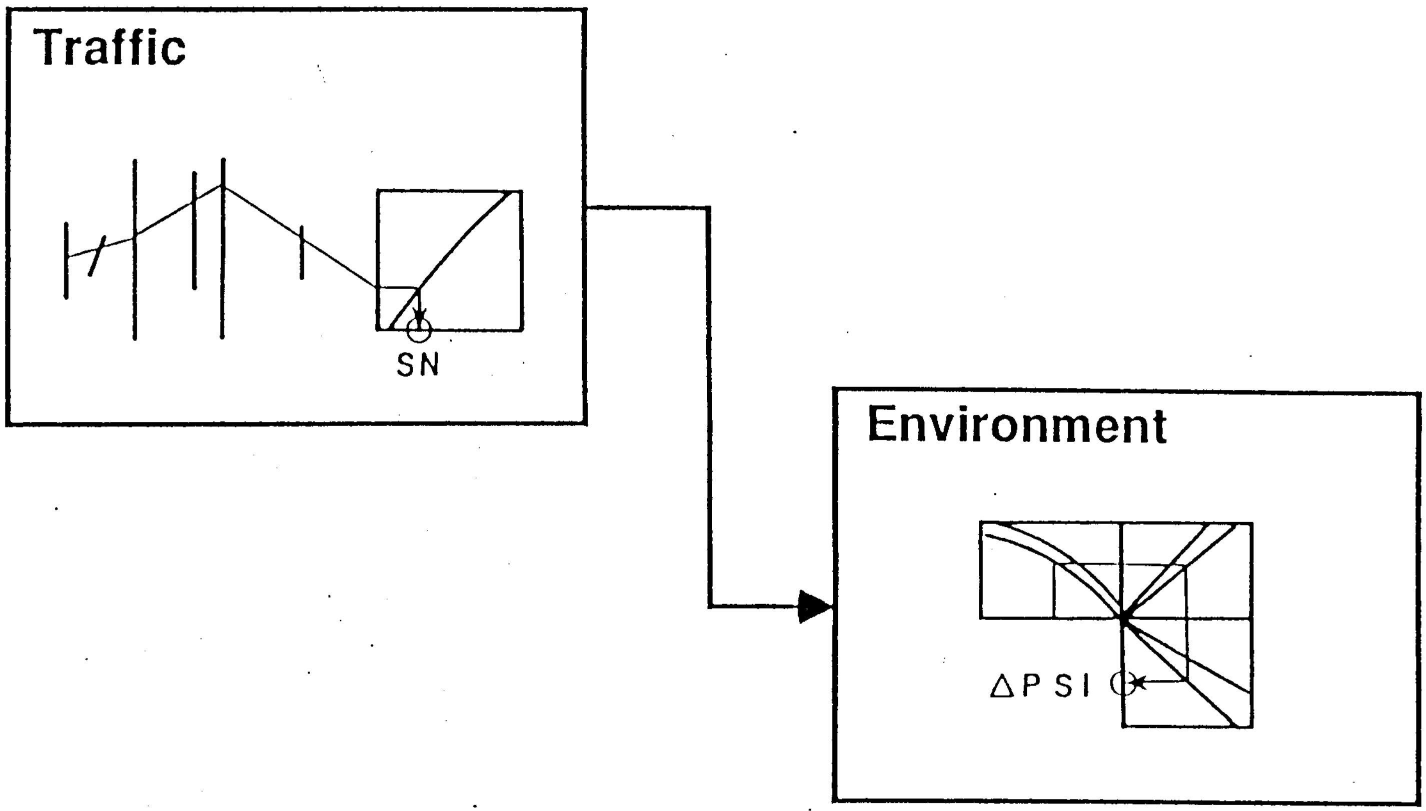
$$W_T = (10^{Z_R \cdot S_O}) \cdot w_T$$

$$W_T = F_R \cdot w_T$$

RELIABILITY	F_R	
	FLEXIBLE	RIGID
50	1.0	1.0
85	2.8	2.3
95	5.3	3.6
99	10.6	6.2


JRCP
RELIABILITY (%)
PCC THICKNESS (in.)
0
5
10
15
50
60
70
80
90
100

NOMOGRAPH



INPUT

– THICKNESS

- Time
- Traffic
- Reliability
- Environment
- PSI
- M_R
- Concrete properties

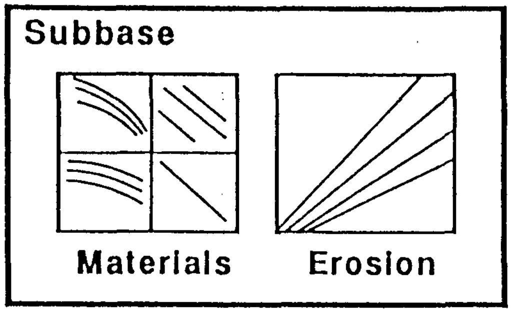
– CONFIGURATION

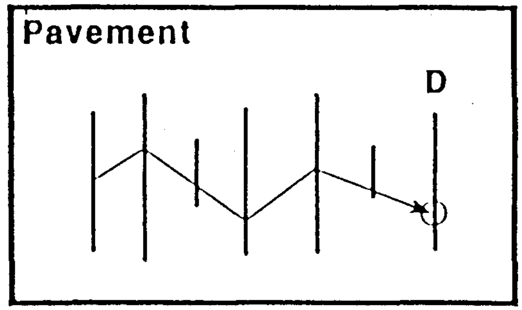
- Joints
- Reinforcement

Concrete properties
Steel properties
Subbase properties

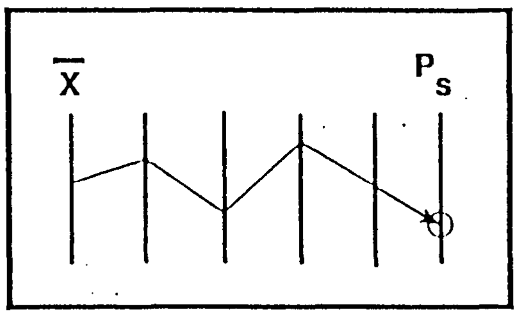
MODELS

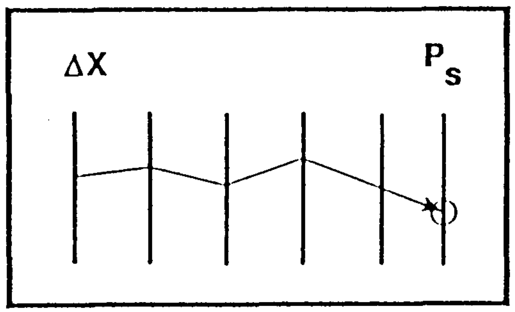
THICKNESS

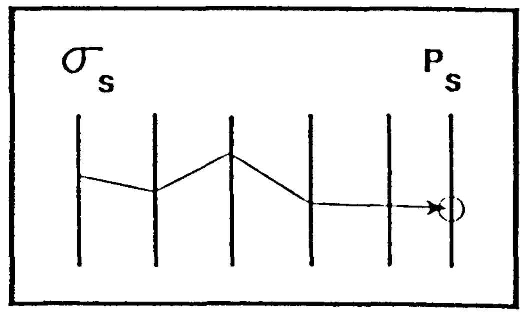




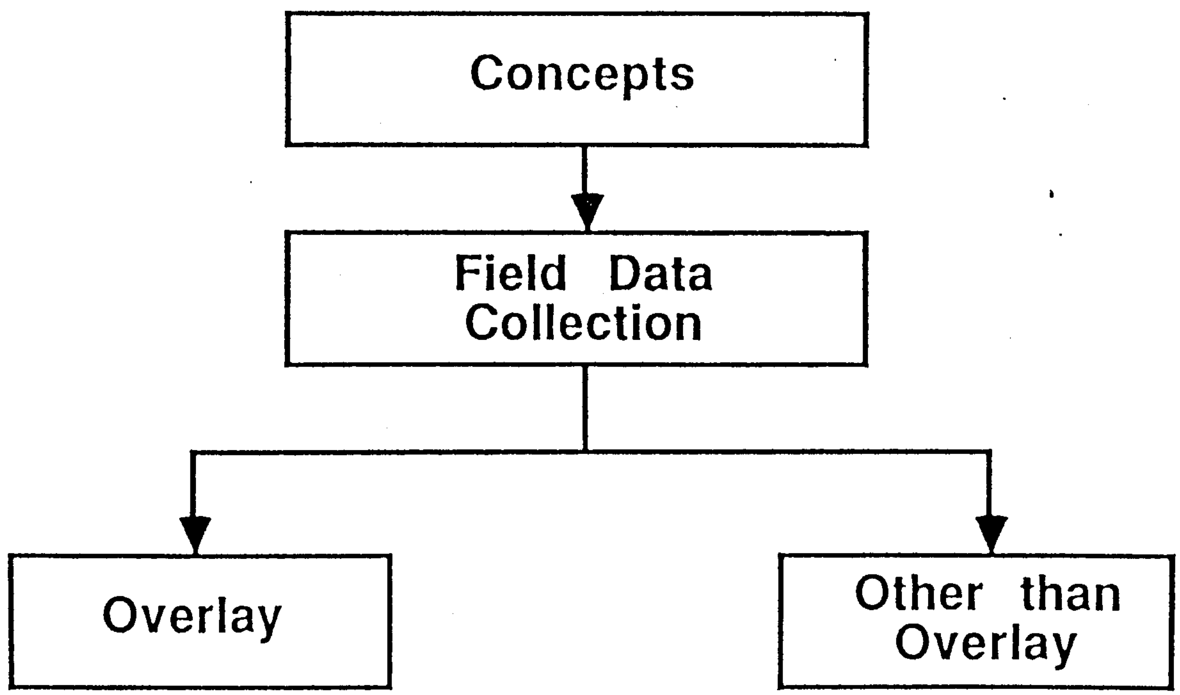
REINFORCEMENT

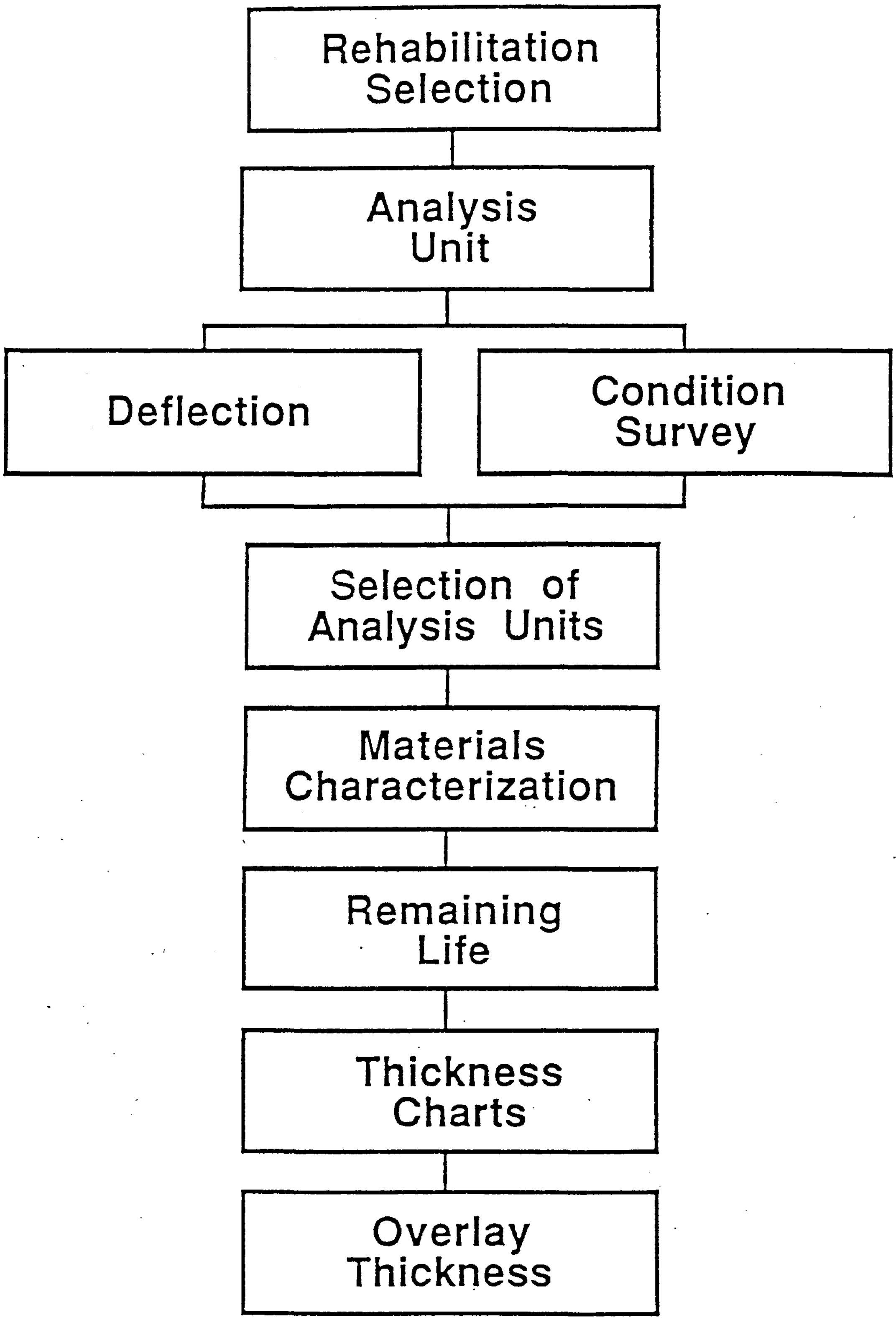






REHABILITATION




Rehabilitation Selection
Analysis Unit
Deflection
Condition Survey
Selection of Analysis Units
Materials Characterization
Remaining Life
Thickness Charts
Overlay Thickness

AASHTO Pavement Design Courses
FHWA Presentation

Subject: FHWA's Policy on Pavement Design and Rehabilitation

- FHWA published an Informational Notice in the Federal Register on April 24, 1985, outlining the FHWA rulemaking process and encouraging full and early public participation in the development of the new guide.

- Recently, AASHTO requested FHWA approval to allow the use of two new pavement guides on Federal-aid highway work (F. B. Francois' April 17 letter attached):

    1. "Guide for Design of Pavement Structures (1986)", and
    2. "Guidelines on Pavement Management (1985)."

- FHWA is developing a position on pavement design and rehabilitation to be published in the Federal Register.

- FHWA's proposed position on pavement design and rehabilitation includes:

    1. Adopt both AASHTO publications as "guides" and not as standards.
    2. It is desirable for each State to strengthen its pavement management program.
    3. It is desirable for each State highway agency to have a comprehensive engineering process for the selection and design of new pavement structures and rehabilitation strategies, and pavement management based on AASHTO and FHWA guidelines and local performance. Design criteria could be based on the new AASHTO Pavement Guide or other appropriate design guides, and performance experience in the State.
    4. It is desirable for each State to have a multi-disciplinary pavement team to evaluate pavement design and rehabilitation projects and to develop feasible alternatives.

- Both of the new AASHTO guides provides the users with flexibility. Therefore, each State's criteria and process may differ depending on climate, geography, materials, etc.

- FHWA will be working with each State in the development of its formal pavement design and rehabilitation process. Our goal is to find each State's process acceptable by July 1, 1988.

o Until our new pavement policy is adopted, we will continue to operate under our current policy which is:

- Our field offices will continue using the 1972 AASHTO Interim Guide for Design of Pavement Structures (Chapter III Revised 1981) as the basis to evaluate the structural adequacy for pavement designs regardless of the design procedures used by the State.
- Our field offices have been asked to consult with Headquarters regarding State requests to adopt the new Guide procedures prior to completion of the federal rulemaking process.

o When submitting designs under the new guide procedures during this interim period, it will expedite FHWA's review if the data needed to compare the design to the Interim Guide procedures are also submitted.

Reorganization

- Creation of a Pavement Division under Highway Operations with approximately 22 people ie. triple our current pavement staff.
- Division will be the primary focal point for pavement issues.
- Division made up of three teams: PM, PCC and AC.
- Pavement Management covers PMS as well as general pavement issues such as equipment, trucks, and tire pressures.
- The other two teams will concentrate on Design and Rehabilitation of flexible and rigid pavements.
- The reorganization plan will be implemented in August 1986.

Pavement Training

o Pavement Design Course (Four Days)

- Significant need for pavement training, particularly on the new AASHTO Pavement Design Guide.

- A comprehensive course on pavement design procedures including the new AASHTO guide.

o Study in Pavement Design, Rehabilitation, and Management Principles

- This is the second generation of the 6-week Pavement Management Course held at the University of Texas.

- Proposal is to contract for six 4-week sessions.

- Have not yet solicited for Request for Proposals.

- NHI annual call for training is in progress. Contact FHWA Division Office or NHI.

o <u>Techniques for Pavement Rehabilitation (3 1/2 Days)</u>

- This has been an extremely popular course now commonly known as Pavement 4R Course.
- 75 presentations have been given since January 1981 when course started.
- FHWA has 35 more presentations under contract that are available on request.
- Also, under consideration is the offering of 1-day modules on selected rehabilitation issues and techniques to States desiring specialized training. Interested States should contact the FHWA Division Office who will forward requests to the Washington Office.

o <u>Pavement Seminar for State Executive Officers (1 Day)</u>

- This is primarily a second generation of the joint AASHTO/FHWA Pavement Seminar for Chief Administrative Officers held late last year in Clearwater, Florida and San Diego, California.
- Material will be reorganized and aimed at the upper level of management.
- Work on this is just beginning and should be offered in 1987.

o <u>Pavement Rehabilitation and Design Teams</u>

- To help support States implementation of the new AASHTO Guide, we plan to expand the scope of our current Pavement Rehabilitation Design Team concept.
- To date the team has visited approximately 27 States.
- We will provide technical assistance to State highway agencies and FHWA division offices in implementing the New Guide.
- This team concept will not be to review the State and make criticisms, but to assist with various aspects of rehabilitation and implementation of design procedures. Provide an outside opinion.
- The team will be customized to fit the particular expertise needed.

SESSION 2

Session 2

Part I - Pavement Design and Management Principles

Objective

The objective of this session will be to familiarize the participants with the overall content of the Guide with special emphasis on the new or modified procedures and concepts which have been added.

Outline

Emphasis will be given to the following items included in the Guide:

1. Glossary of terms
2. Roadbed soil strength
3. Inclusion of environmental factors
4. Drainage
5. Pavement management
6. Reliability
7. Life cycle costs

Each of the above topics will be further illustrated by specific applications in each succeeding session.

References

Reading material for this session will be found in Part I, Chapters 1 through 5. All resourse material used in the presentation is included in the following pages.

Specific appendices of Part I (Vol I) which are related to this

Specific appendices of Part I (Volume I) which are related to this session include: Appendices A, B, D, E, F, and G. In Volume II, Appendices AA, BB, DD, EE, FF, GG, HH, and II provide additional information for subjects included in this session.

DESIGN CONSIDERATIONS

1. PAVEMENT PERFORMANCE
2. TRAFFIC
3. ROADBED SOIL
4. MATERIALS OF CONSTRUCTION
5. ENVIRONMENT
6. DRAINAGE
7. RELIABILITY
8. SHOULDER DESIGN
9. PAVEMENT MANAGEMENT
10. LIFE CYCLE COSTS

GLOSSARY OF TERMS
(PARTIAL)

ANALYSIS PERIOD - THE PERIOD OF TIME FOR WHICH THE ECONOMIC ANALYSIS IS TO BE MADE; ORDINARILY WILL INCLUDE AT LEAST ONE REHABILITATION ACTIVITY.

DRAINAGE COEFFICIENTS - FACTORS USED TO MODIFY LAYER COEFFICIENTS IN FLEXIBLE PAVEMENTS OR STRESSES IN RIGID PAVEMENTS AS A FUNCTION OF HOW WELL THE PAVEMENT STRUCTURE CAN HANDLE THE ADVERSE EFFECT OF WATER INFILTRATION.

EQUIVALENT SINGLE AXLE LOADS (ESAL'S) - SUMMATION OF EQUIVALENT 18000 POUND SINGLE AXLE LOADS USED TO COMBINE MIXED TRAFFIC TO DESIGN TRAFFIC FOR THE DESIGN PERIOD.

LAYER COEFFICIENT (A_1, A_2, A_3) - THE EMPIRICAL RELATIONSHIP BETWEEN STRUCTURAL NUMBER (SN) AND LAYER THICKNESS WHICH EXPRESSES THE RELATIVE ABILITY OF A MATERIAL TO FUNCTION AS A STRUCTURAL COMPONENT OF THE PAVEMENT.

LOW VOLUME ROADS - A ROADWAY GENERALLY SUBJECTED TO LOW LEVELS OF TRAFFIC; IN THIS GUIDE, STRUCTURAL DESIGN IS BASED ON A RANGE OF 18-KIP ESAL'S FROM 50,000 TO 1,000,000 FOR FLEXIBLE AND RIGID PAVEMENTS AND FROM 10,000 TO 1,000,000 FOR AGGREGATE SURFACED ROADS.

MODULUS OF SUBGRADE REACTION (K) - WESTERGAARD'S MODULUS OF SUBGRADE REACTION FOR USE IN RIGID PAVEMENT DESIGN (THE LOAD IN POUNDS PER SQUARE INCH ON A LOADED AREA OF THE ROADBED SOIL OR SUBBASE DIVIDED BY THE DEFLECTION IN INCHES OF THE ROADBED SOIL OR SUBBASE, PSI/IN.)

PAVEMENT PERFORMANCE - THE TREND OF SERVICEABILITY WITH LOAD APPLICATIONS.

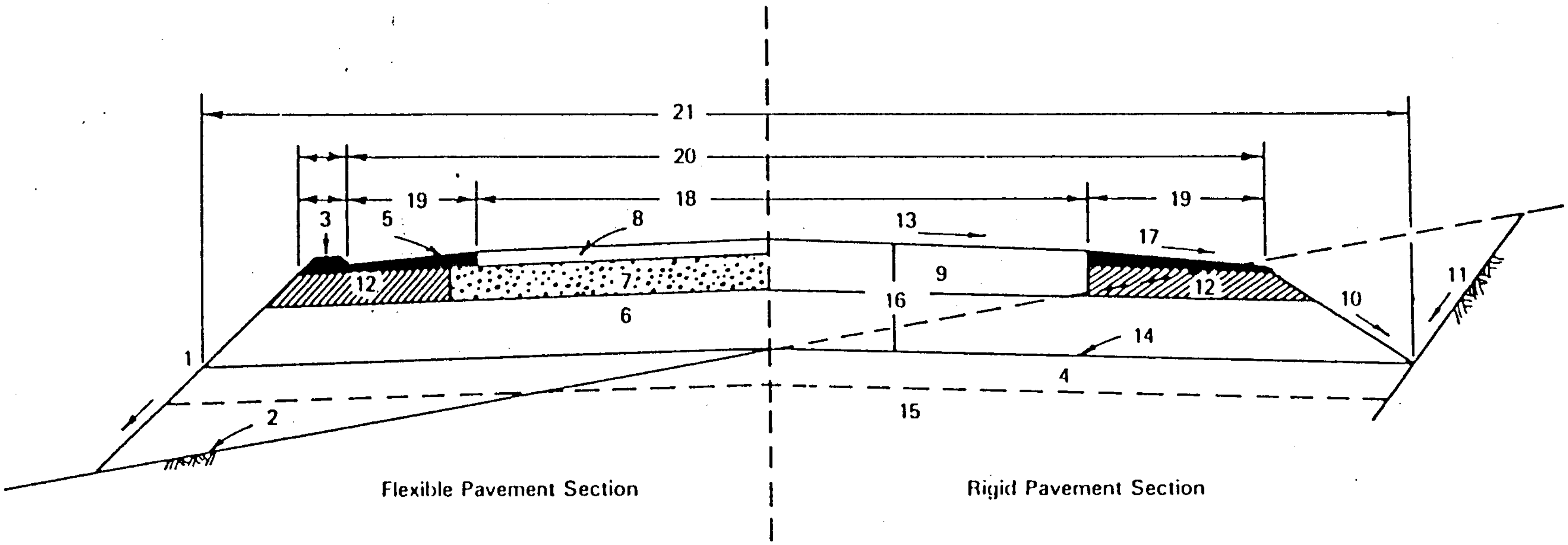
PERFORMANCE PERIOD - THE PERIOD OF TIME THAT AN INITIALLY CONSTRUCTED OR REHABILITATED PAVEMENT STRUCTURE WILL LAST (PERFORM) BEFORE REACHING ITS TERMINAL SERVICEABILITY; THIS IS ALSO REFERRED TO AS THE DESIGN PERIOD.

GLOSSARY OF TERMS
(PARTIAL)

RESILIENT MODULUS - A MEASURE OF THE MODULUS OF ELASTICITY OF ROADBED SOIL OR OTHER PAVEMENT MATERIAL.

ROADBED MATERIAL - THE MATERIAL BELOW THE SUBGRADE IN CUTS AND EMBANKMENTS AND IN EMBANKMENT FOUNDATIONS, EXTENDING TO SUCH DEPTH AS AFFECTS THE SUPPORT OF THE PAVEMENT STRUCTURE.

TRAFFIC EQUIVALENCE FACTOR (E) - A NUMERICAL FACTOR THAT EXPRESSES THE RELATIONSHIP OF A GIVEN AXLE LOAD TO ANOTHER AXLE LOAD IN TERMS OF THEIR EFFECT ON THE SERVICEABILITY OF A PAVEMENT STRUCTURE. IN THIS GUIDE, ALL AXLE LOADS ARE EQUATED IN TERMS OF THE EQUIVALENT NUMBER OF REPETITIONS OF AN 18-KIP SINGLE AXLE.

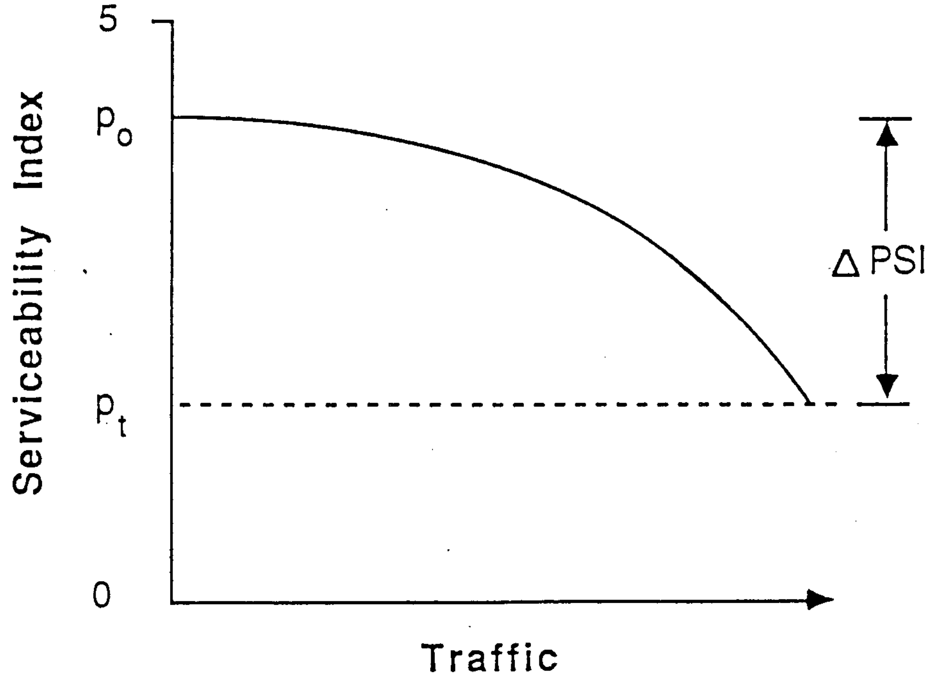


1 - FILL SLOPE
2 - ORIGINAL GROUND
3 - DIKE
4 - SELECTED MATERIAL OR PREPARED ROADBED
5 - SHOULDER SURFACING
6 - SUBBASE
7 - BASE COURSE
8 - SURFACE COURSE
9 - PAVEMENT SLAB
10 - DITCH SLOPE
11 - CUT SLOPE
12 - SHOULDER BASE
13 - CROWN SLOPE
14 - SUBGRADE
15 - ROADBED SOIL
16 - PAVEMENT STRUCTURE
17 - SHOULDER SLOPE
18 - TRAVEL LANES
19 - SHOULDER
20 - ROADWAY
21 - ROADBED

Note: See Figure 1.3 for examples of section with provision for subsurface drainage.

Structural Design Terms

Figure 1.1. Typical section for rigid or flexible pavement structure.



Criteria for selection of p_t :

p_t	% Stating Unacceptable
3.0	12
2.5	55
2.0	85

Table D.23. Worksheet for calculating 18-kip equivalent single axle load (ESAL) applications.

Analysis Period = 20 Years

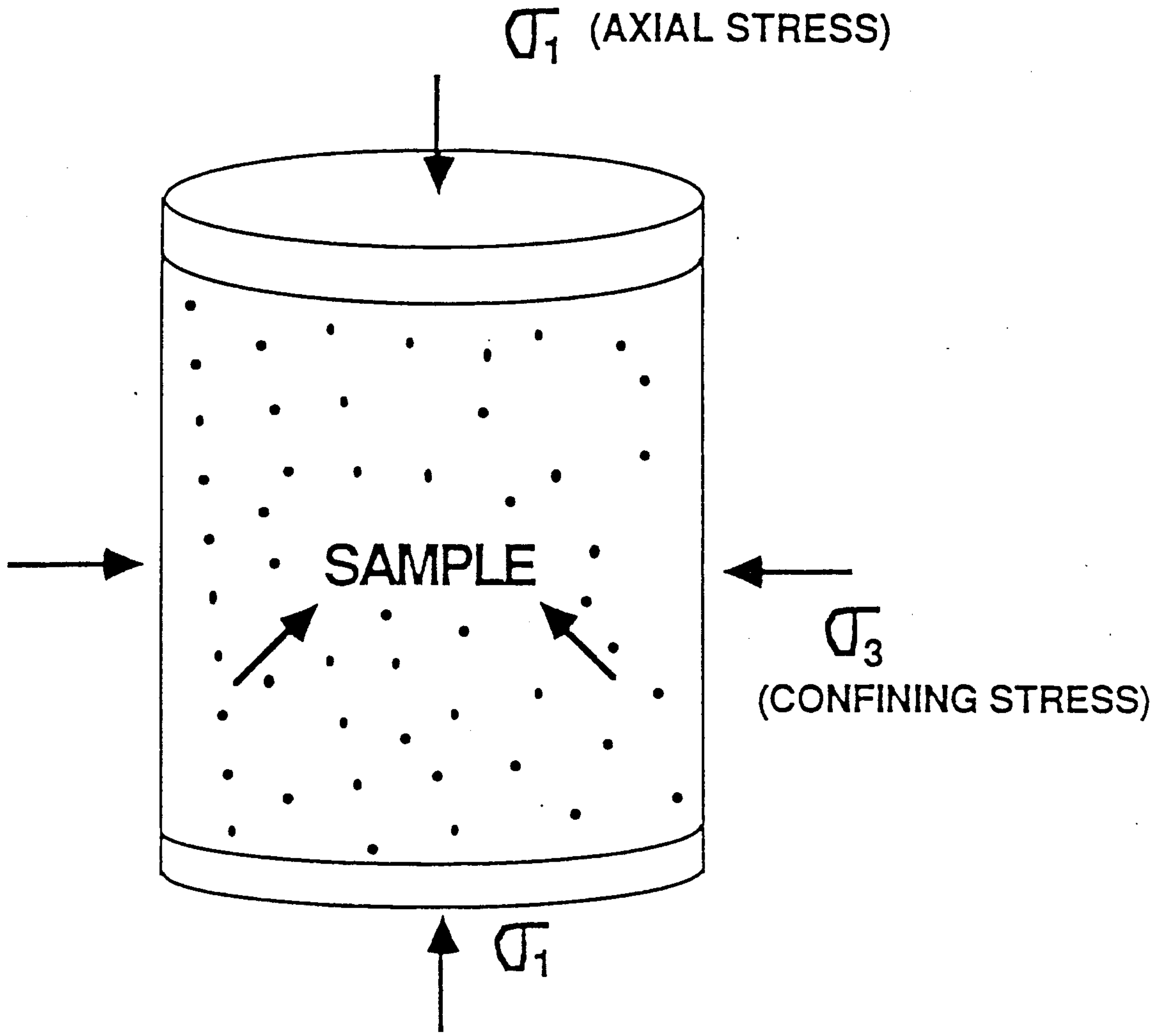
Location Example 3 Assumed SN or D = 9"

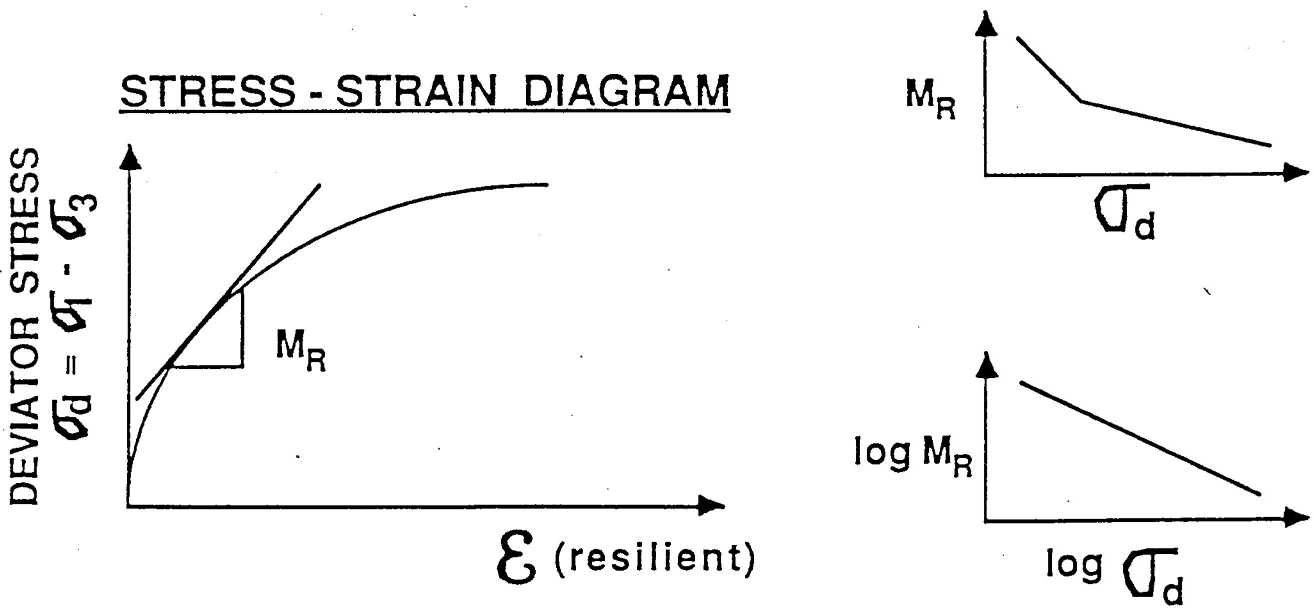
Vehicle Types	Current Traffic (A)	Growth Factors (B)	Design Traffic (C)	E.S.A.L. Factor (D)	Design E.S.A.L. (E)
		4%			
Passenger Cars	5,925	29.78	64,402,972	.0008	51,522
Buses	35	29.78	380,440	.6806	258,927
		4%			
Panel and Pickup Trucks	1,135	29.78	12,337,109	.0122	150,513
Other 2-Axle/4-Tire Trucks	3	29.78	32,609	.0052	170
2-Axle/6-Tire Trucks	372	29.78	4,043,528	.1890	764,227
3 or More Axle Trucks	34	29.78	369,570	.1303	48,155
All Single Unit Trucks					
		6%			
3 Axle Tractor Semi-Trailers	19	36.79	255,139	.8646	220,593
4 Axle Tractor Semi-Trailers	49	36.79	657,989	.6560	431,641
5 + Axle Tractor Semi-Trailers	1,880	36.79	25,245,298	2.3719	59,879,322 *
All Tractor Semi-Trailers					
		7%			
5 Axle Double Trailers	103	41.00	1,541,395	2.3187	3,574,033 *
6 + Axle Double Trailers	0	41.00			
All Double Trailer Combos.					
		6%			
3 Axle Truck-Trailers	208	36.79	2,793,097	.0152	42,455
4 Axle Truck-Trailers	305	36.79	4,095,647	.0152	62,254
5 + Axle Truck-Trailers	125	36.79	1,678,544	.5317	892,482
All Truck-Trailer Combos.					
All Vehicles	10,193		117,833,337	Design E.S.A.L.	66,376,294 **

* Note (1) These two categories account for 96 percent of total E.S.A.L.'s calculated in this example.

** Note (2) Unfactored for direction and lane distribution (multi-laned facility).

SCHEMATIC DIAGRAM OF RESILIENT MODULUS TEST (AASHTO T274)



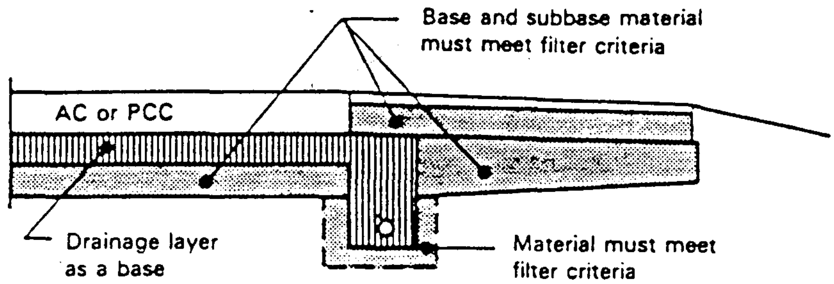


NEED FOR SUBSURFACE DRAIN

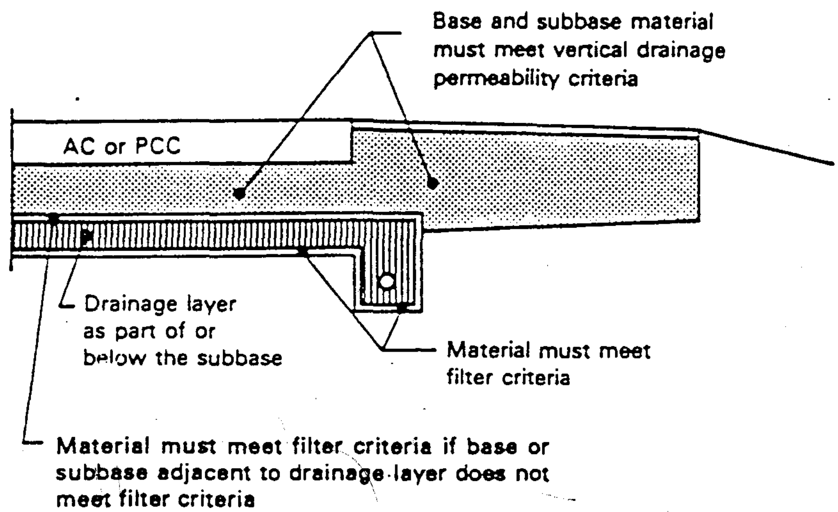
BASED ON:

- FREQUENCY OF RAINFALL
- AMOUNT OF RAINFALL
- QUANTITY OF WATER TO BE DRAINED
- THICKNESS OF DRAINAGE LAYER
- PERMEABILITY OF DRAINAGE LAYER
- HYDROSTATIC HEAD

A. Base is used as the drainage layer.*



B. Drainage layer is part of or below the subbase.

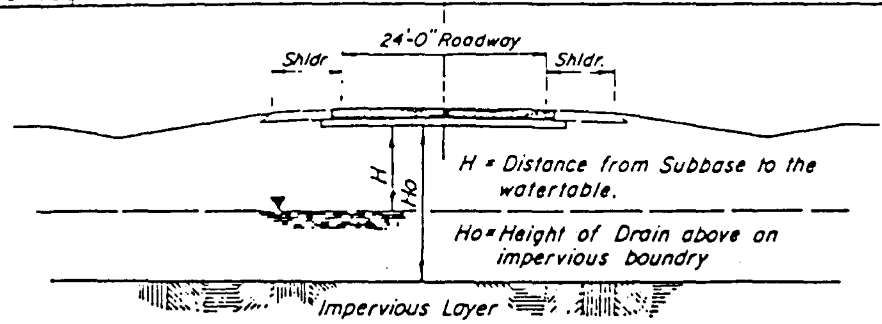


Note: Filter fabrics may be used in lieu of filter material, soil, or aggregate, depending on economic considerations.

* Generally preferred configuration.

Figure 1.3. Example of drainage layer in pavement structure (*11*).

Time required to drain 0.5 ft^3 of water / lineal foot of a 24' wide pavement



Ratio H/Ho	PERMEABILITY				
	10^{-3} CM/SEC 2.8 Ft./Day	10^{-4} CM/SEC 0.28 Ft./Day	10^{-5} CM/SEC 0.028 Ft./Day	10^{-6} CM/SEC 0.0028 Ft./Day	10^{-7} CM/SEC 0.00028 Ft./Day
0.0	Minutes	Hours	Days	Weeks	Months
0.1	108	18	7.4	10.6	24.8
0.2	54	9	3.8	5.3	12.4
0.3	36	6	2.5	3.6	8.3
0.4	27	4.5	1.9	2.6	6.2
0.5	24	3.8	1.5	2.1	5.0
0.6	21	3.0	1.3	1.8	4.1
0.7	18	2.6	1.1	1.5	3.5
0.8	15	2.2	0.9	1.3	3.1
0.9	13	2.0	0.8	1.2	2.8
1.0	10	1.8	0.7	1.1	2.5

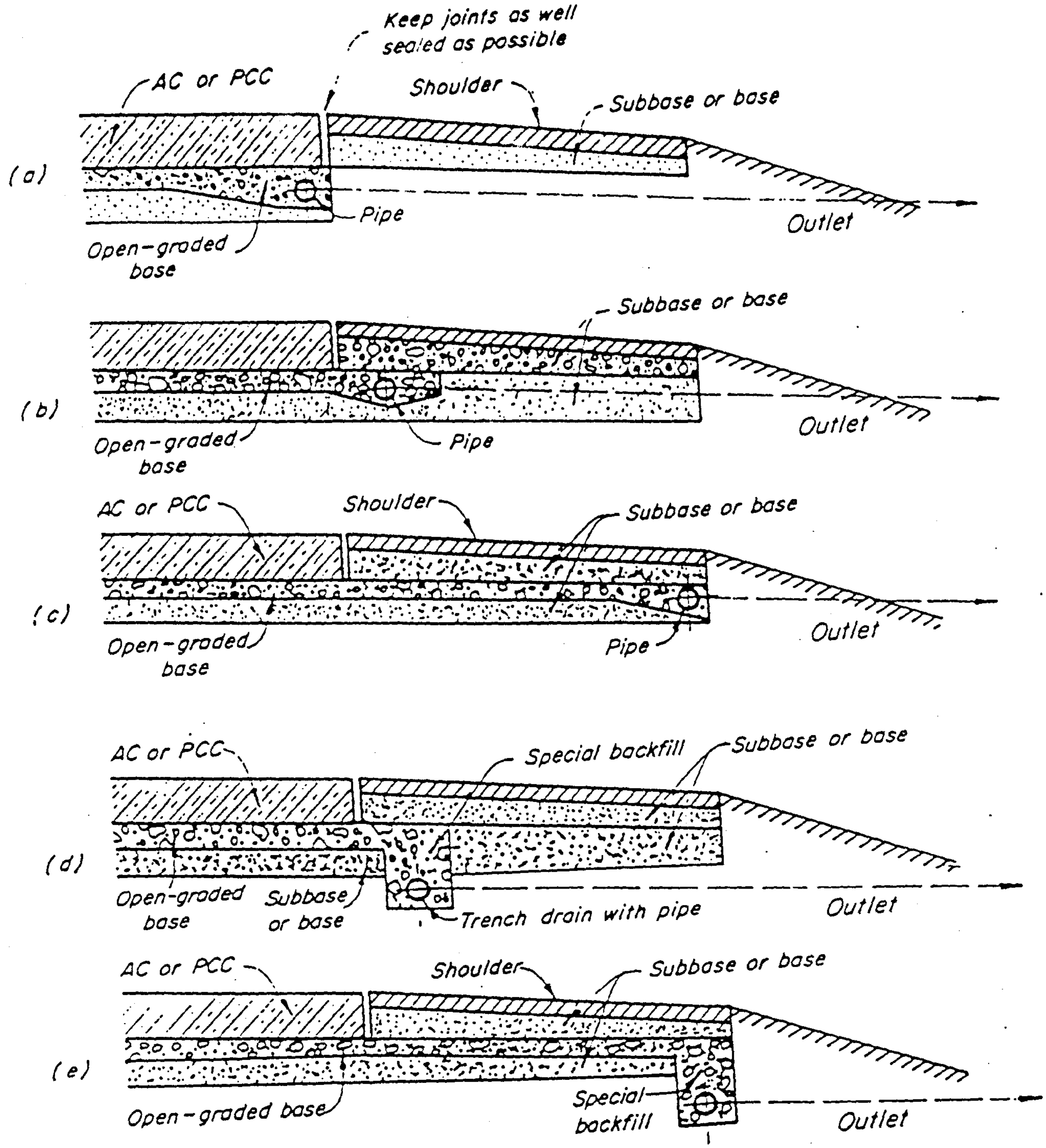
Chart Based on DARCYS LAW In Form of $0.5T = K \frac{H}{H_o} A$

T = Time (Days)
H = Hydraulic Head In Ft.
Ho = Depth of "Soil Reservoir" Overlying Impervious Layer, Ft..
A = Area, 24 $Ft.^2$

BASE DRAINAGE TIME VARIOUS SUBGRADE PERMEABILITY

Figure 7.

Note: Additional details regarding vertical drainage are provided in Volume 2, Appendix AA.



Typical details of outer edges of drainage systems.

OPEN GRADE BASE DESIGN

Figure 17.

Note: Additional details regarding drainage designs are provided in Volume 2, Appendix AA.

DRAINAGE FORMULA

$$t_{50} = (n_e * L^2) / [2 * K (H + L * TAN\alpha)]$$

WHERE:

t_{50} = TIME FOR 50 PERCENT OF UNBOUND WATER TO DRAIN (DAYS)

n_e = EFFECTIVE POROSITY (80 PERCENT OF ABSOLUTE POROSITY)

L = LENGTH OF FLOW PATH (FEET)

K = PERMEABILITY CONSTANT (FT/DAY), AND

H = THICKNESS OF DRAINAGE LAYER

TAN α = SLOPE OF THE BASE LAYER

. . . .

SLOPE OF BASE LAYER

$$S_1 = \sqrt{S_T^2 + S_L^2}$$

WHERE: S_T^2 = SLOPE IN TRANSVERSE DIRECTION

S_L^2 = SLOPE IN LONGITUDINAL DIRECTION

LENGTH OF FLOW PATH

$$L = W \sqrt{1 + (S_L / S_T)^2}$$

WHERE: W = WIDTH OF LANE(S)

QUANTITY OF WATER INFILTRATING PAVEMENT

$$Q_i = I_C \left[\frac{N_C}{W} + \frac{W_C}{WC_S} \right] + K_P$$

Q_i = DESIGN INFILTRATION RATE, $FT^3/DAY/FT^2$ OF DRAINAGE LAYER,

I_C = CRACK INFILTRATION RATE, FT^3/DAY/LINEAL FOOT OF CRACK - USE 2.4 UNLESS OTHER INFORMATION IS AVAILABLE

N_C = NUMBER OF CONTRIBUTING LONGITUDINAL CRACKS

W_C = LENGTH OF CONTRIBUTING TRANSVERSE CRACKS OR JOINTS

W = WIDTH OF BASE OR SUBBASE SUBJECTED TO INFILTRATION, FEET

WC_S = SPACING OF TRANSVERSE CRACKS OR JOINTS, FEET

K_P = COEFFICIENT OF PERMEABILITY THROUGH UNCRACKED PAVEMENT, FT^3/DAY/SQUARE FOOT OF PAVEMENT

NOTE: ALTERNATE VALUES FOR I_C MAY BE FOUND IN LITERATURE AND JUSTIFIED BASED ON LOCAL EXPERIENCE.

DRAINAGE EXAMPLE

$$t_{50} = (\eta_e * L^2) / 2 * K (H + L * TAN\alpha)$$

ASSUME:

η = .15

η_e = 0.8η = .12 PERCENT

L = 24 FEET

K = 1000 FT/DAY

H = 0.5 FT

TANα = 0.015 FOR 1 1/2 PERCENT TRANSVERSE

$$t_{50} = (.12 * 24^2) / (2 * 1000) (0.5 + 24 * 0.015)$$

$$= 69.12 / (2000) (0.86)$$

= .04 DAYS

= 1 HOUR

DRAINAGE PARAMETERS

QUALITY OF DRAINAGE	WATER REMOVED WITHIN	K,FT./DAY*
EXCELLENT	0.083 DAYS(2 HOURS)	1202
GOOD	1 DAY	100
FAIR	7 DAYS (1 WEEK)	14
POOR	30 DAYS (1 MONTH)	3
VERY POOR	—	—

* L = 24 FT.

H = 0.33 FT.

Table 1.1. Permeability of graded aggregates (11).

Percent Passing	Sample Number 1	2	3	4	5	6
¾ - inch sieve	100	100	100	100	100	100
½ - inch sieve	85	84	83	81.5	79.5	75
⅜ - inch sieve	77.5	76	74	72.5	69.5	63
No. 4 sieve	58.5	56	52.5	49	43.5	32
No. 8 sieve	42.5	39	34	29.5	22	5.8
No. 10 sieve	39	35	30	25	17	0
No. 20 sieve	26.5	22	15.5	9.8	0	0
No. 40 sieve	18.5	13.3	6.3	0	0	0
No. 60 sieve	13.0	7.5	0	0	0	0
No. 140 sieve	6.0	0	0	0	0	0
No. 200 sieve	0	0	0	0	0	0
Dry density (pcf)	121	117	115	111	104	101
Coefficient of permeability (ft. per day)	10	110	320	1,000	2,600	3,000

Note: Compare to criteria on page 2.17.

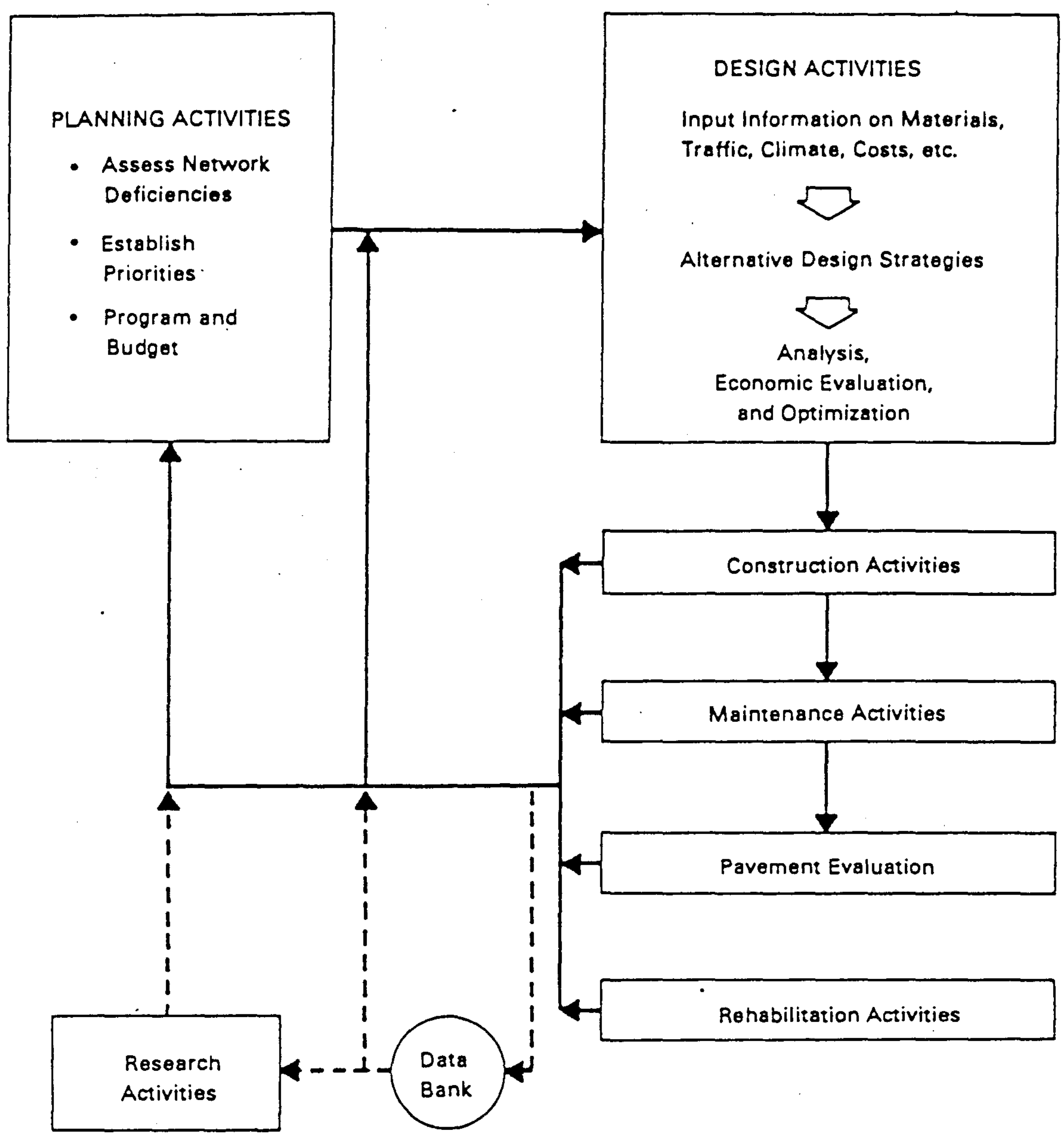


Figure 2.2. Major classes of activities in a pavement management system.

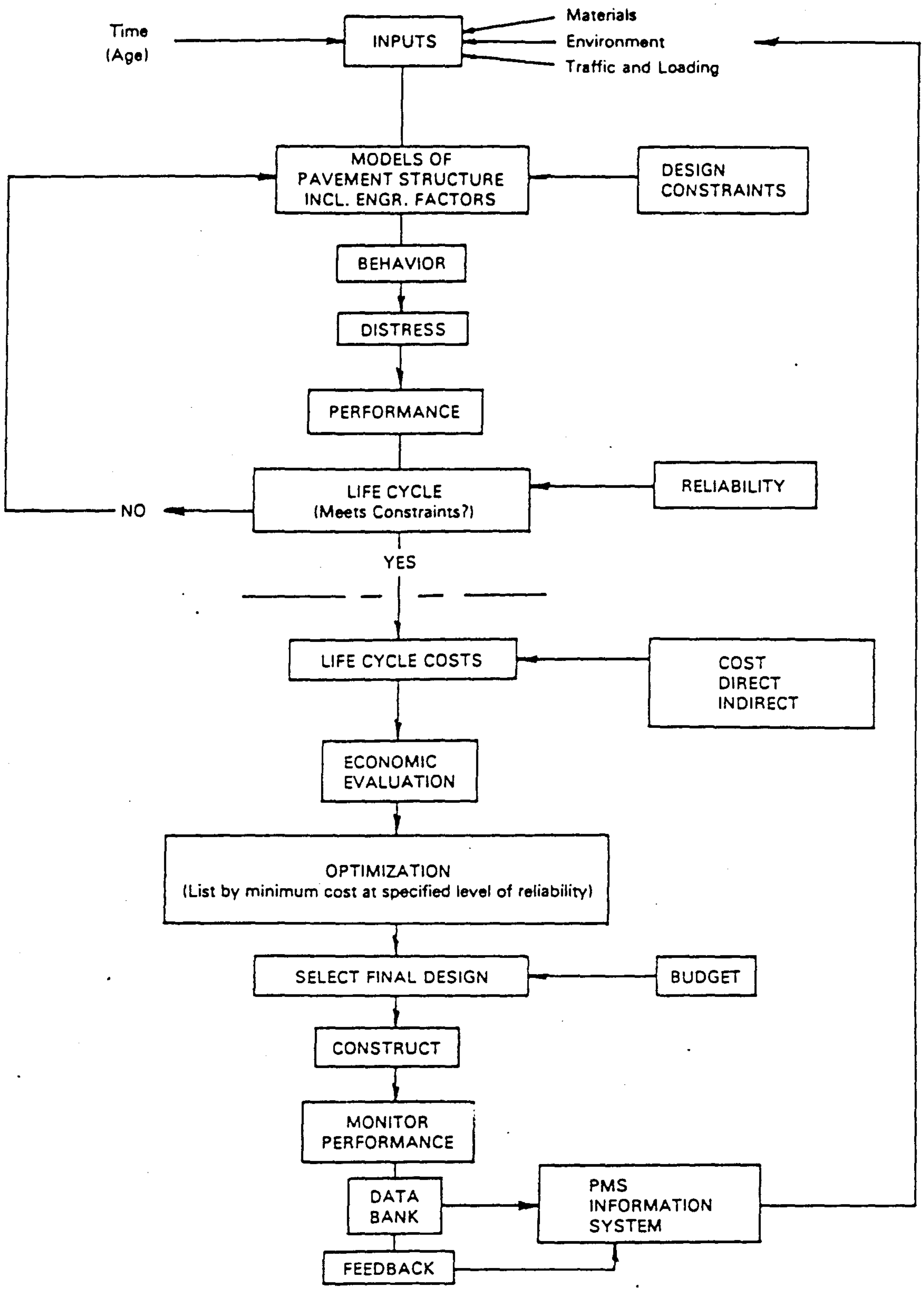


Figure 2.4. Flow diagram of a pavement management system.

LIFE CYCLE COSTS

1. SUMMARIZES ALL COSTS AND BENEFITS

   - ENGINEERING AND ADMINISTRATION
   - CONSTRUCTION
   - MAINTENANCE
   - USER
   - SALVAGE VALUE

2. ECONOMIC COMPARISON

   - PRESENT WORTH
   - EQUIVALENT UNIFORM ANNUAL COST
   - DISCOUNT RATE
   - ANALYSIS PERIOD

$$pwf_{i,n} = 1/(1+i)^n \quad (3.9.2)$$

where

$pwf_{i,n}$ = present worth factor for a particular i and n,

i = discount rate, and

n = number of years to when the sum will be expended, or saved.

$$TWPC_{x_1,n} = (ICC)_{x_1} + \sum_{t=0}^{t=1} pwf_{i,t} \left[(CC)_{x_1,t} + (MO)_{x,t} + (UC)_{x_1,t} \right] - (SV)_{x1,n} pwf_{i,n} \quad (3.9.3)$$

where

$TWPC_{x_1,n}$ = total present worth of costs for alternative x_1, for an analysis period of n years,

$(ICC)_{x_1}$ = initial capital costs of construction, etc., for alternative x_1,

$(CC)_{x_1,t}$ = capital costs of construction, etc., for alternative x_1, in year t, where t is less than n,

$pwf_{i,t}$ = present worth factor for discount rate, i, for t years,
= $1/(1+i)^t$,

$(MO)_{x_{1,t}}$ = maintenance plus operation costs for alternative x_1 in year t,

$(UC)_{x_1,t}$ = user costs (including vehicle operation, travel time, accidents, and discomfort if designated) for alternative x_1, in year t, and

$(SV)_{x_1,n}$ = salvage value, if any, for alternative x_1, at the end of the design period, n years.

LIFE CYCLE COST EXAMPLE

ASSUME:

INITIAL CONSTRUCTION COST:	$45.00/SQ.YD.
FIXED COSTS:	$15.00/SQ.YD.
ANNUAL MAINTENANCE YEAR 5	$ 0.02/SQ.YD.
ANNUAL INCREASE	$0.005/SQ.YD.
COST OF OVERLAY	$10.000/SQ.YD.
SALVAGE VALUE, 70%	$31.50
ANALYSIS PERIOD	15 YEARS
DISCOUNT RATE	4 PERCENT

YEAR	COST	PWF	PW
0	45	1.0	45.00
5	0.02*	0.806	0.02
6	0.025	0.775	0.02
7	0.030	0.745	0.02
8	0.035	0.716	0.03
9	0.040	0.689	0.03
10	10.000	0.662	6.62
15 (SV)	.70 x (45 + 10)	0.545	20.98

NPW = 51.74 - 20.98 = $30.76

* EQUIVALENT TO $141/LANE MILE

DEFINITION OF RELIABILITY

RELIABILITY IS THE PROBABILITY THAT A DESIGNED PAVEMENT SECTION WILL PERFORM SATISFACTORILY FOR THE TRAFFIC AND ENVIRONMENTAL CONDITIONS EXPERIENCED DURING THE DESIGN PERIOD.

INCORPORATION OF RELIABILITY INTO AASHTO PAVEMENT DESIGN GUIDE REPLACES (IN-PART):

* REGIONAL FACTOR IN FLEXIBLE PAVEMENT DESIGN (R TERM IN PERFORMANCE EQUATION)

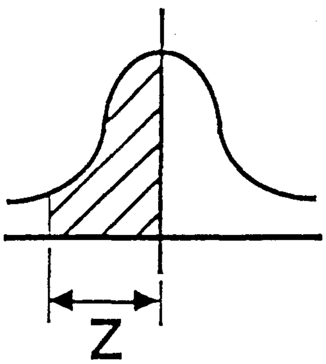
* WORKING STRESS IN RIGID PAVEMENT DESIGN ($f_t = S_c'/C$ IN PERFORMANCE EQUATION)

MAJOR SOURCES OF VARIATION THAT AFFECT PAVEMENT DESIGN AND/OR PERFORMANCE

* CONSTRUCTION (THICKNESSES, STRENGTHS, ETC.)
* ENVIRONMENT (SOIL, CLIMATE, ETC.)
* TRAFFIC FORECASTS (PROJECTIONS)
* PREDICTION ERROR (ERROR IN PERFORMANCE PREDICTION MODEL)

NOTE: THE ABOVE SOURCES OF VARIATION HAVE BEEN INCORPORATED IN THE RELIABILITY FACTOR FOR INITIAL DESIGN OR OVERLAYS.

USE OF MEAN (OR AVERAGE) VALUES FOR DESIGN



TEST NO.	S'_c (psi)
1	521
2	548
3	592
4	614
5	625
6	636
7	649
8	671
9	693
10	720

MEAN VALUE = **627**

σ = STD. DEV. = 62

90% CONF. LEVEL VALUE = **548**

$$(S'_c)_d = \text{MEAN VALUE} - Z(\sigma)$$

APPLIES TO ALL DESIGN FACTORS, INCLUDING :

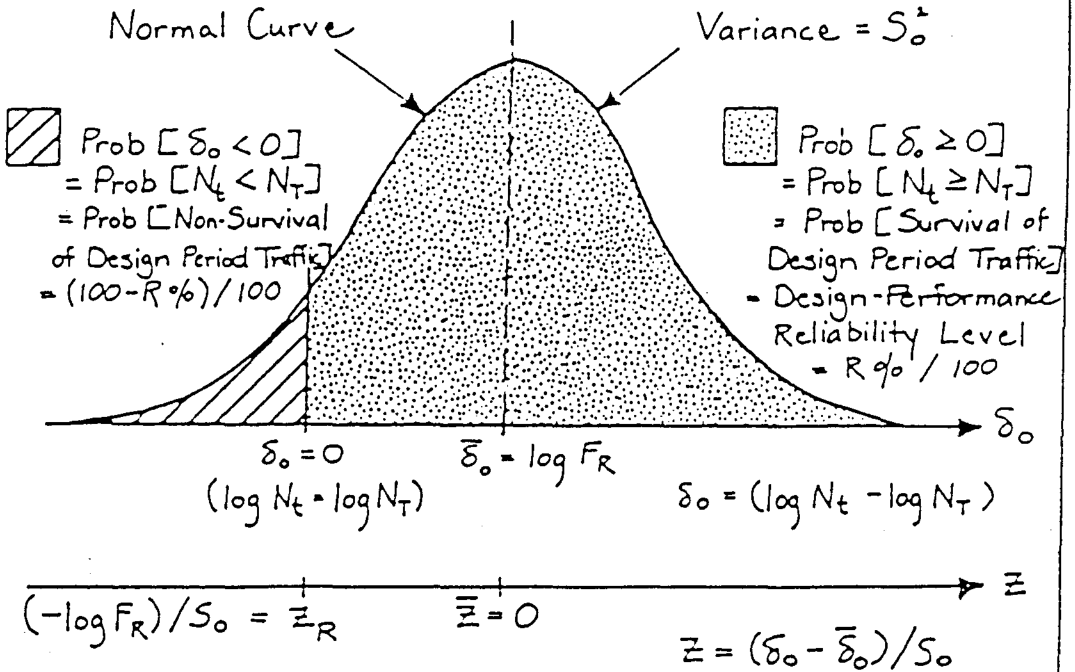
- TRAFFIC
- ROADBED SOIL STRENGTH
- PAVEMENT MATERIAL PROPERTIES
- LAYER THICKNESSES

Note: All input design factors must be based on average values with no adjustment based on distribution.

Table 2.2. **Suggested levels of reliability for various functional classifications.**

Functional Classification	Recommended Level of Reliability	
	Urban	Rural
Interstate and other freeways	85 - 99.9	80 - 99.9
Principal Arterials	80 - 99	75 - 95
Collectors	80 - 95	75 - 95
Local	50 - 80	50 - 80

Note: Results based on a survey of the AASHTO Pavement Design Task Force



$$\log F_R = -Z_R S_o$$

$$F_R = 10^{-Z_R S_o} = \text{Reliability Design Factor}$$

NOTE 1. The value of Z_R is determined by the value of R, and is obtained from standard normal curve area tables by entering (100 − R%)/100 for the tail area from $-\infty$ to Z_R.

NOTE 2. If $\log F_R = 0$, $Z_R = 0$, $F_R = 1$, and R = 50%. Thus the probability for design period survival is 50% if the traffic prediction (w_T) is substituted directly for W_t in the performance prediction (design) equation.

NOTE 3. For fixed R (hence fixed Z_R), F_R increases (or decreases) as $S_o = \sqrt{S_w^2 + S_N^2}$ increases (or decreases). F_R accounts for the <u>total chance variation</u> in traffic predictions <u>and</u> performance predictions.

RELIABILITY FACTOR FOR SPECIFIC LEVELS OF RELIABILITY

R	Z_R	S_O	$Z_R * S_O$	$10^{-Z_R * S_O}$	F_R	% INCREASE
50	0	0.34	0	1	1	---
						51
70	-.524	0.34	-.1782	1.51	1.51	
						25
80	-.841	0.34	-.2589	1.93	1.93	
						41
90	-1.282	0.34	-.4359	2.73	2.73	
						32
95	-1.64	0.34	-.5576	3.61	3.61	
						70
99	-2.32	0.34	-.7888	6.15	6.15	
						83
99.9	-3.09	0.34	-1.0506	11.24	11.24	

SESSION 3

Session 3

General Design Concepts and Input

Objective

The primary objective of this session is to provide an understanding of the design inputs of a general nature, i.e. applicable to all pavement types. The secondary objective is to increase the students capability to develop specific general input information for a design problem.

Outline

Emphasis will be given to the following items:

1. Analysis period
2. Initial performance period
3. Roadbed soil resilient modulus
4. Terminal serviceability index
5. Weighted resilient modulus concepts
6. Reliability
7. Roadbed swelling
8. Roadbed frost heave
9. Pavement type

The approach used will be to explain the principles involved in developing the charts and their application. Next, the procedures will be illustrated in step-by-step applications to an example problems. Emphasis will also be given to explaining the new concepts.

References

Reading material for this session will be found in Part II, Chapters 1 and 2. The following references will also be of assistance:

1. Van Til, C.J., McCullough, B.F., Vallerga, B.A. and Hicks, R.G., "Evaluation of AASHTO Interim Guides for Design of Pavement Structures," NCHRP Report 128, 1972.

2. Rada, Gonzalo and Witczak, M.W., "A Comprehensive Evaluation of Laboratory Resilient Moduli Results for Granular Material," TRB Paper, 1981.

3. McCullough, B.F. and Elkins, G.E., "CRC Pavement Design Manual," Austin Research Engineers, Inc., October 1979.

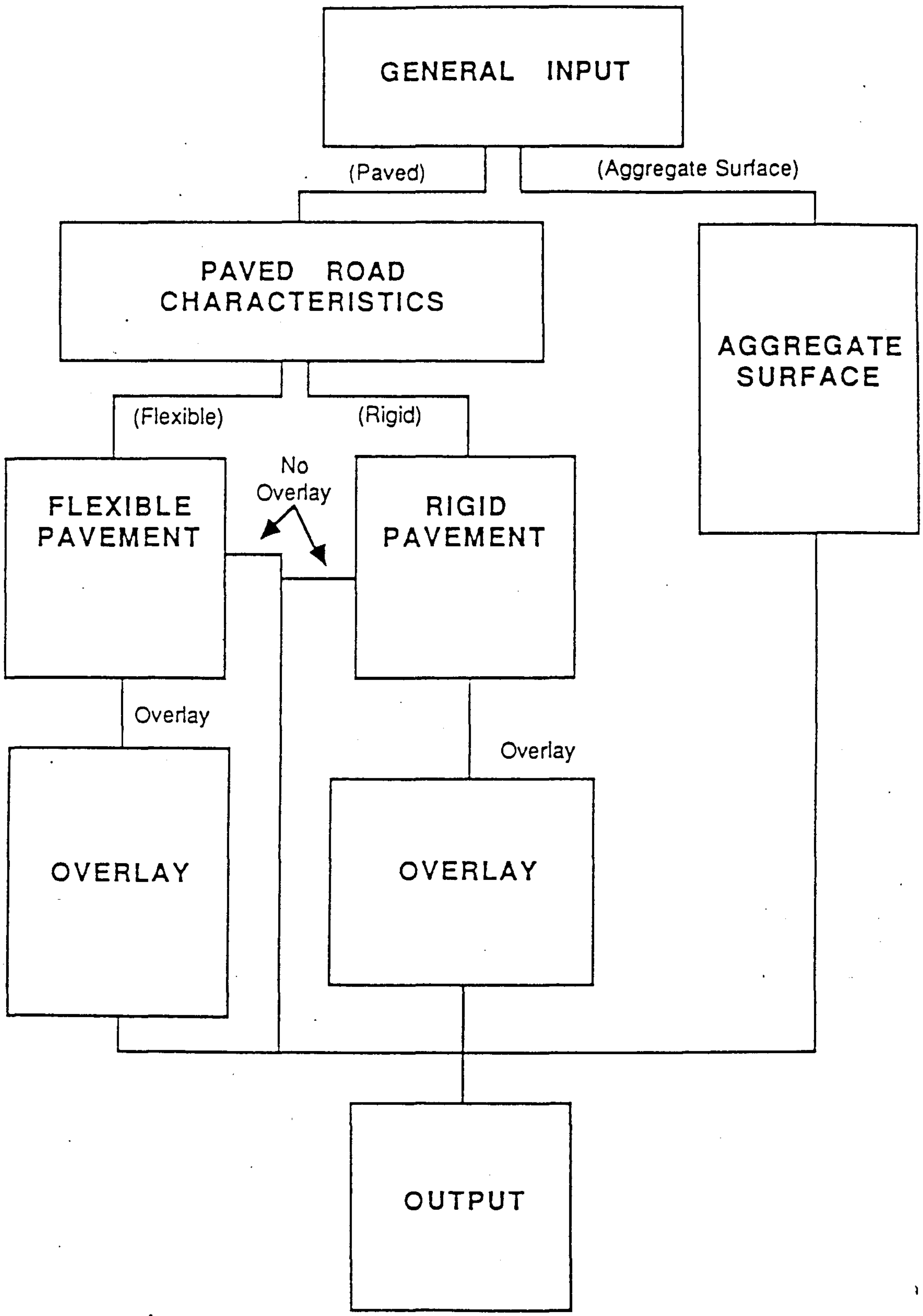
4. Carey, W. and Irick, P., "The Pavement Serviceability Performance Concept," Highway Research Record 250, 1980.

In addition to this material, Appendices EE, FF, HH, II, and MM of the Supplementary Information to the Guide will be used.

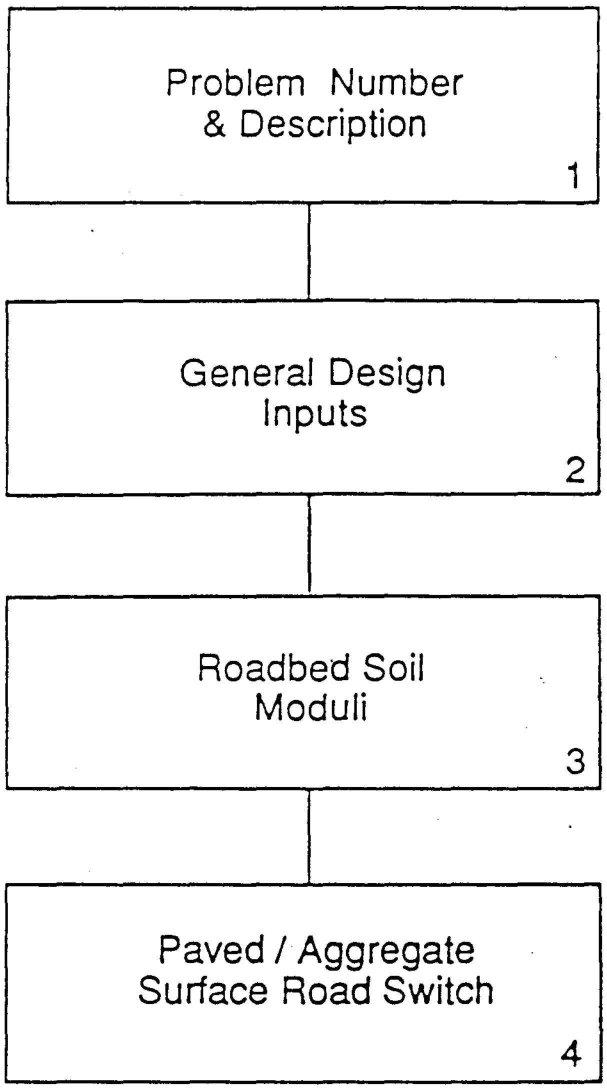
The following figures and tables in the Guide will be used during the presentation and are listed in the order of presentation: Table 2.1, page II-5 and II-6; Figure 1.5, page I-28; Figure 1.4, page I-25; Figure 2.3, page II-15; Figure 2.4, page II-16; Figure I-3, page I-10; Figure 1.2, page I-10; Figure G.3, page G-4; Figure G.4, page G.7; Figure G-7, page G-10; Figure G.8, page G-11; and Figure 2.2, page II-11.

The student should review these items in advance.

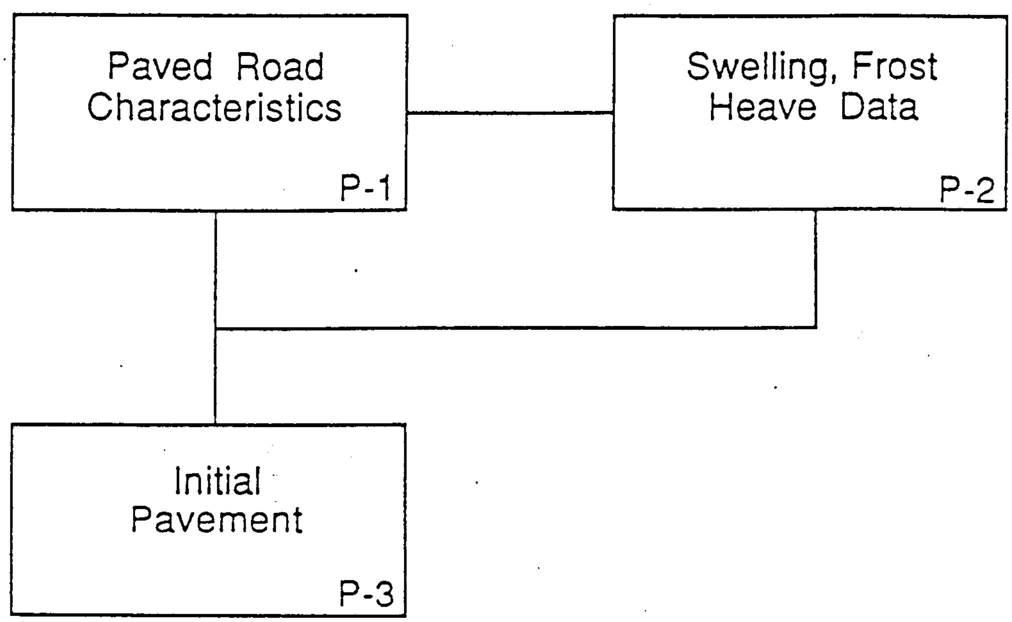
FLOW DIAGRAM OF SCREEN PROGRAM



GENERAL INPUT



PAVED ROAD CHARACTERISTICS



```
                         PSD-02
        AASHTO PAVEMENT STRUCTURAL DESIGN PROGRAM
                VERSION 02 - APR. 1986

                      Prepared For
         American Association of State Highway
            and Transportation Officials

                  Under Contract With
     National Cooperative Highway Research Program
            Transportation Research Board
              National Research Council
                NCHRP Project 20-7/28

                          By
         ARE Inc - Engineering Consultants


              Press Any Key to Continue ...
```

```
PSD-02

                    IMPORT/CREATE DATA FILE

        DATA FILE TO IMPORT . . . . . . . . . . . . . . STEVE.RR
          This allows the user to import and
          edit an existing data file.  This
          may be left blank if a new file is
          to be created.

        DATA FILE TO CREATE AND ANALYZE . . . . . . . . STEVE.RR
          If left blank, a default name
          (PSDTEMP.DAT) will be assumed.
```

```
PSD-02
                         PROBLEM NUMBER AND DESCRIPTION

        PROBLEM NUMBER . . . . . . . . . . . . . . . . .        200b

        PROBLEM DESCRIPTION
        EXAMPLE APPLICATION OF AASHTO PAVEMENT STRUCTURAL
        DESIGN PROGRAM - RIGID INITIAL WITH RIGID OVERLAY




   F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

```
PSD-02                                                        No.   200b
             * * *  GENERAL DESIGN INPUT REQUIREMENTS  * * *
        ANALYSIS PERIOD (YEARS) . . . . . . . . . . . . .          30.0
        DISCOUNT RATE (%) . . . . . . . . . . . . . . . .          4.00
        NUMBER OF TRAFFIC LANES (ONE DIRECTION) . . . . .             2
        LANE WIDTH (FEET) . . . . . . . . . . . . . . . .         12.00
        COMBINED WIDTH OF SHOULDERS (FEET, ONE DIRECTION)         16.00




   F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

PSD-02 No. 200b

*** ROADBED SOIL RESILIENT MODULI ***

Season No.	Resilient Modulus (psi)	Season No.	Resilient Modulus (psi)
1	6500	13	0
2	30000	14	0
3	2500	15	0
4	4000	16	0
5	4000	17	0
6	5000	18	0
7	5000	19	0
8	5000	20	0
9	5000	21	0
10	5000	22	0
11	6500	23	0
12	6500	24	0

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

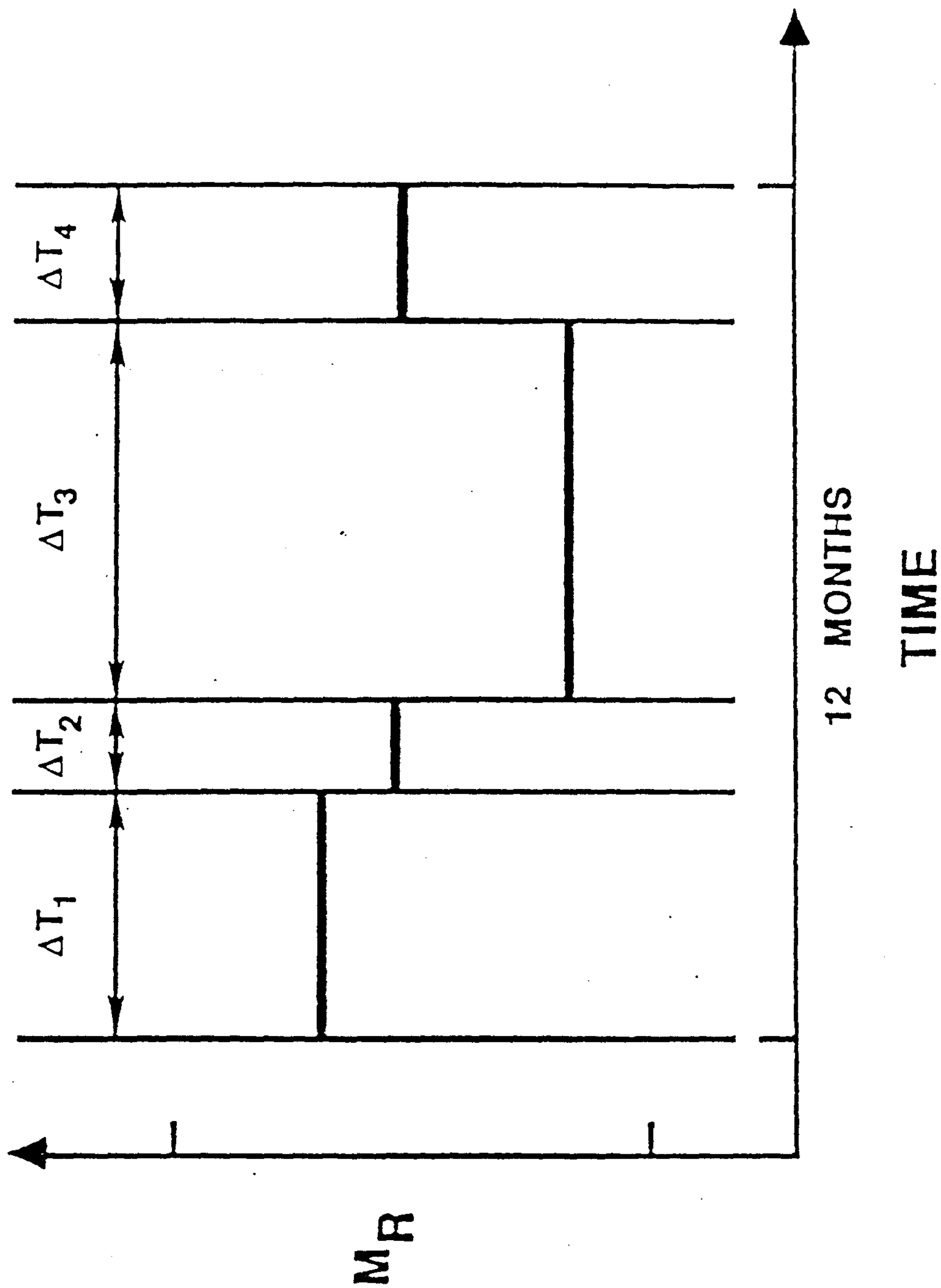
PSD-02 No. 200b

ROAD SURFACE
(P)aved or (A)ggregate . . . . P

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

REASONS FOR ADOPTING M_R

1. Not identified with any specific agency
2. Fundamental engineering property
3. Techniques currently available for characterizing M_R using NDT
4. M_R now a standard test procedure
5. If initial equipment investment is too high, possible to use correlation with other laboratory test
6. Favorable comparisons with other laboratory tests (U.S. Forest Service Study)
7. M_R test is not too complex; familiarity and experience should reduce current problems with application
8. Reservoir of information



ΔT_1
ΔT_2
ΔT_3
ΔT_4
12 MONTHS
TIME
M_R

Linear Damage Hypothesis:

$$(\text{Life}) \cdot \left[\frac{n_1}{(W_{18})_1} + \cdots + \frac{n_{12}}{(W_{18})_{12}} \right]$$

Uniform Monthly Traffic

$$n_{\text{Total}} \left[\frac{1}{(W_{18})_1} + \cdots + \frac{1}{(W_{18})_{12}} \right] \leqq 1$$

AASHO Equation :

$$W_{18} = SN^{k_1} \cdot (\, p_o \,,\, p_t \,,\, SN \,)^{k_2} \cdot M_R^{2.32}$$

Damage Equation :

$$n_T \, SN^{k_1} \cdot (\, p_o \,,\, p_t \,,\, SN)^{k_2} \left[\frac{1}{(M_R^{2.32})_1} + \cdots + \frac{1}{(M_R^{2.32})_{12}} \right] \geqq 1$$

Inherent Reliability of AASHTO Interim Guide

Flexible Pavements

50 % reliability

Rigid Pavements (assume $p_t = 2.5$)

Prior to 1981: $f_t = 0.75 \bullet S_c$

$\therefore W_{t'_{18}} = 0.374\, W_{t'_{18}}$

(corresponds to approx. 85% reliability)

Since 1981: $f_t = S_c / C$

- for $C = 1.33$ (same as $f_t = 0.75 \bullet S_c$)

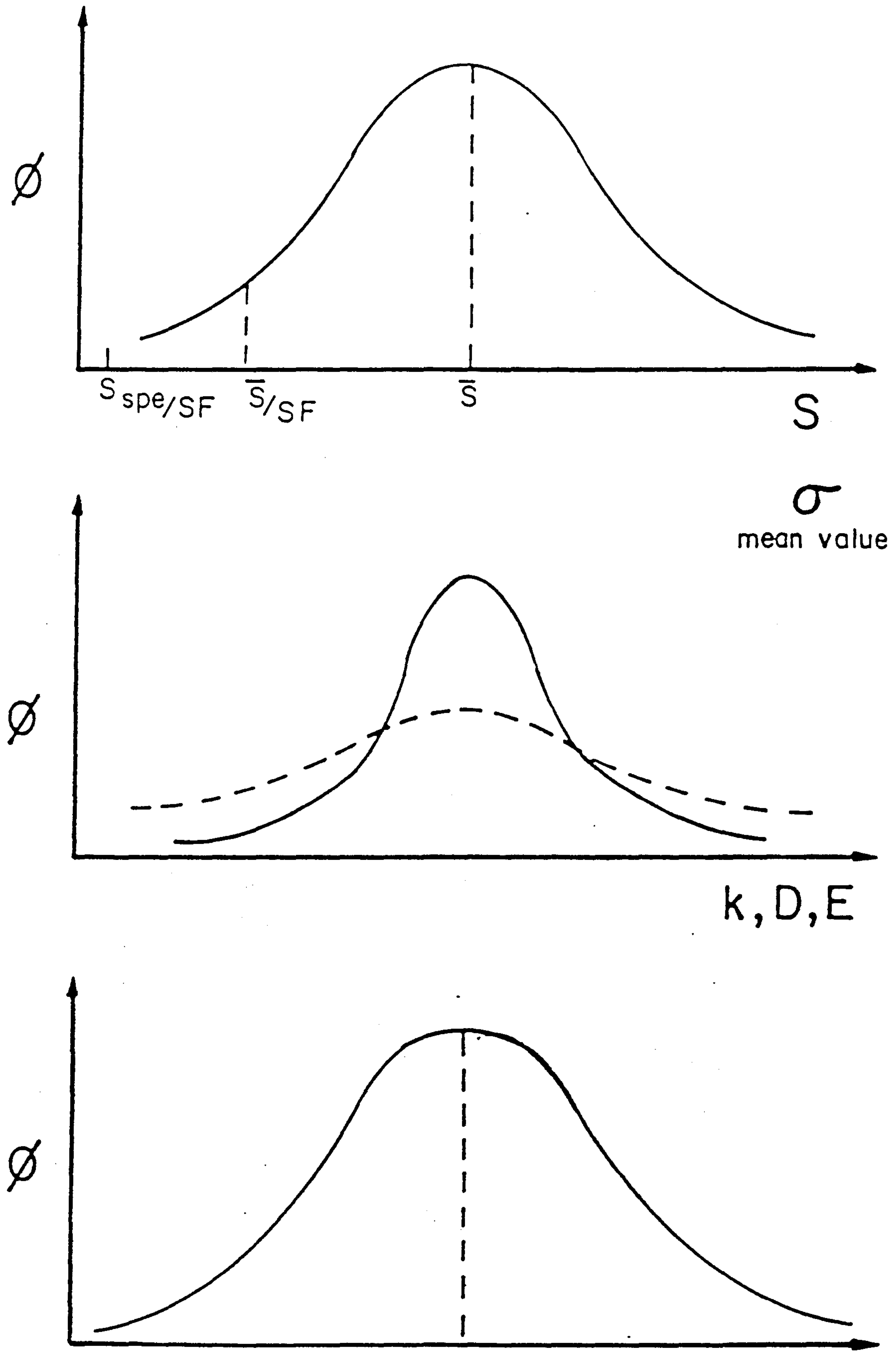
  $W_{t'_{18}} = 0.374\, W_{t'_{18}}$ (approx. 85%)

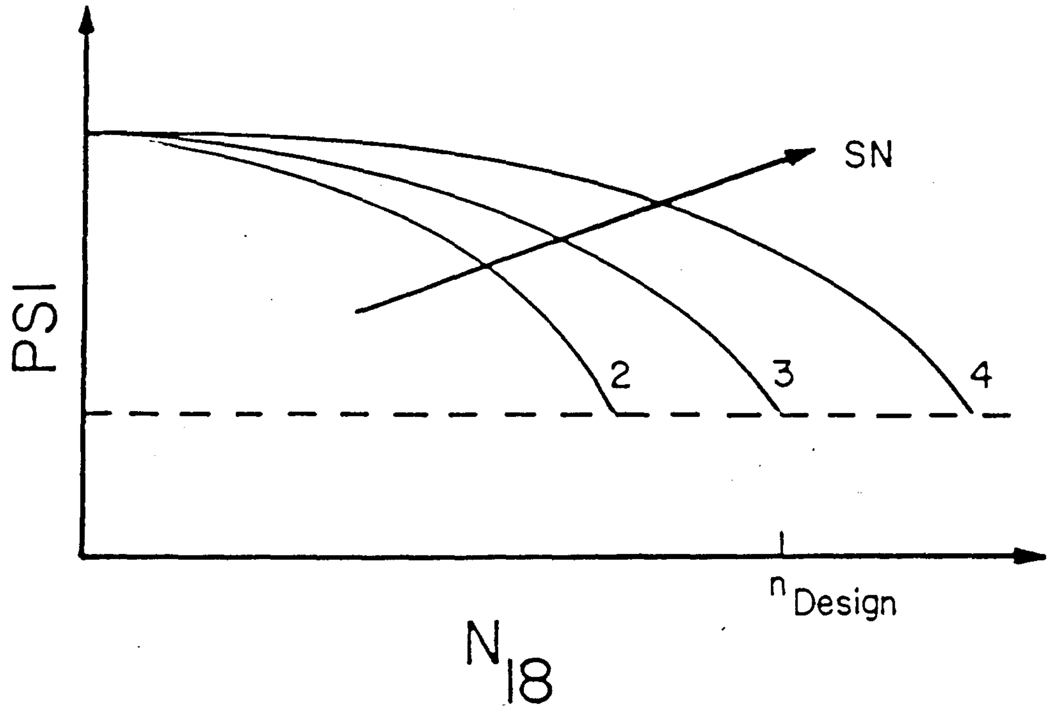
- for $C = 2.00$ ($f_t = 0.50 \bullet S_c$)

  $W_{t'_{18}} = 0.093\, W_{t'_{18}}$

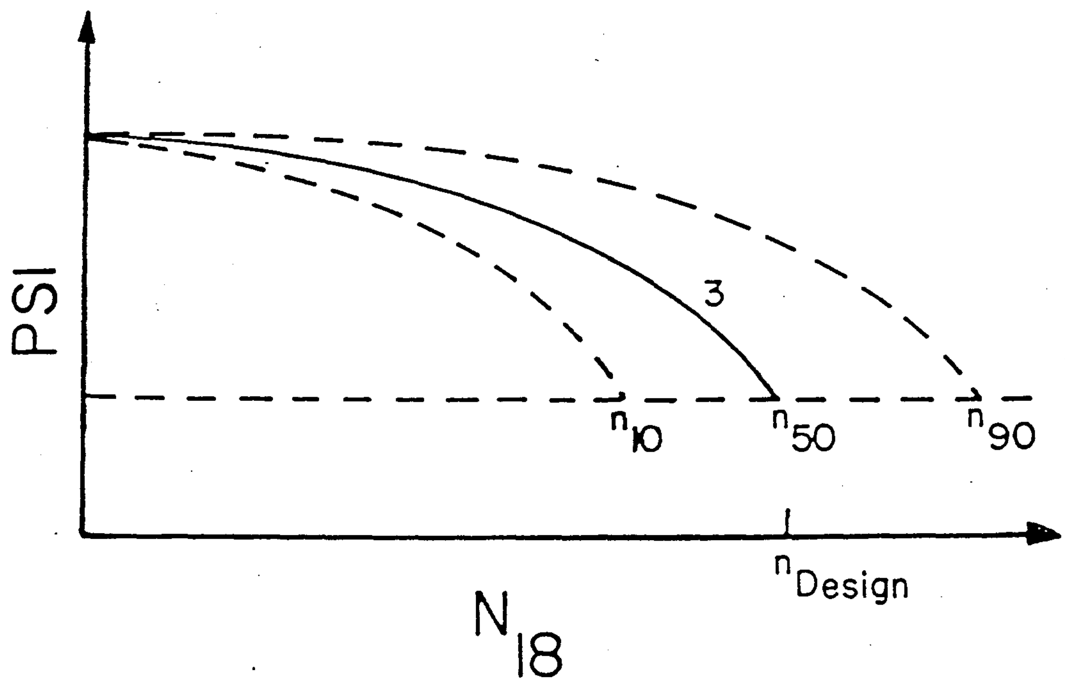
  (corresponds to approx. 98% reliability)

$N_{18} = f(S, k, D, \frac{1}{E})$ Predicted

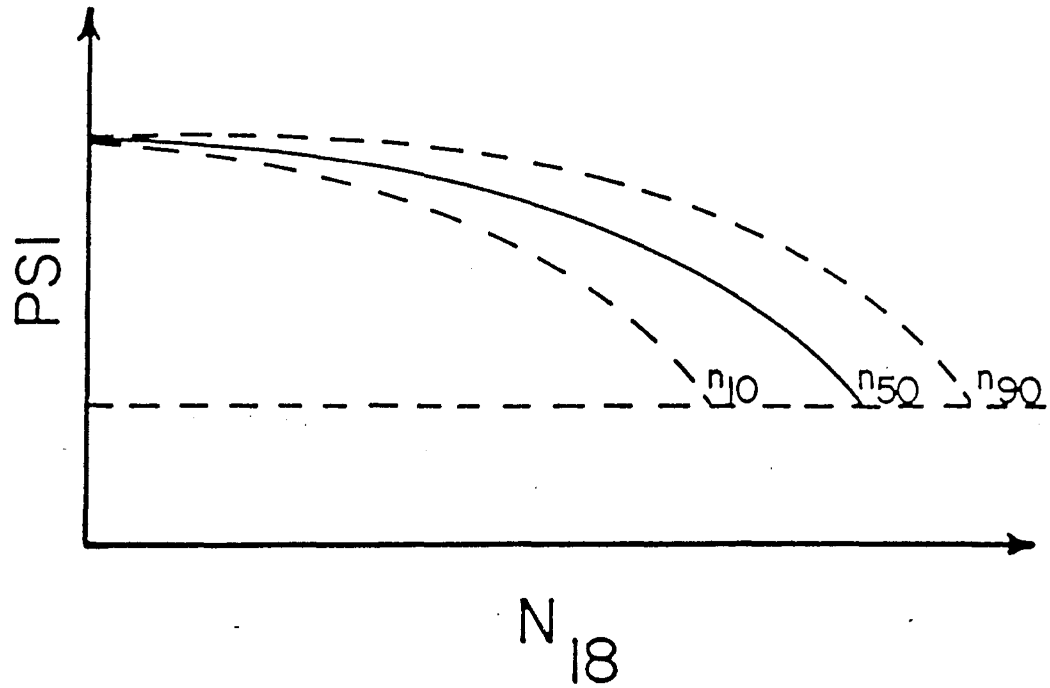


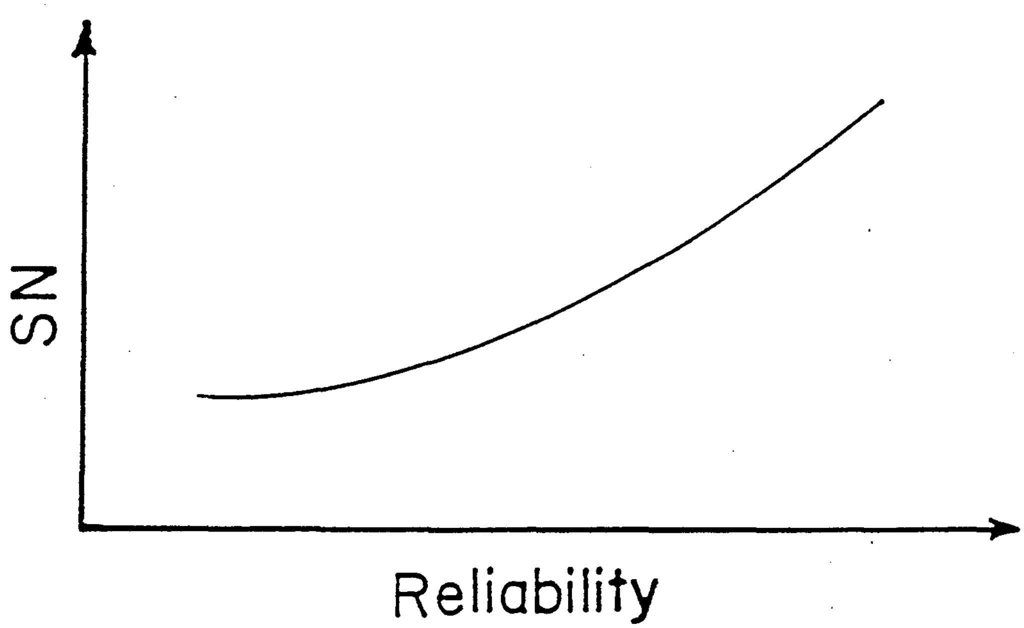


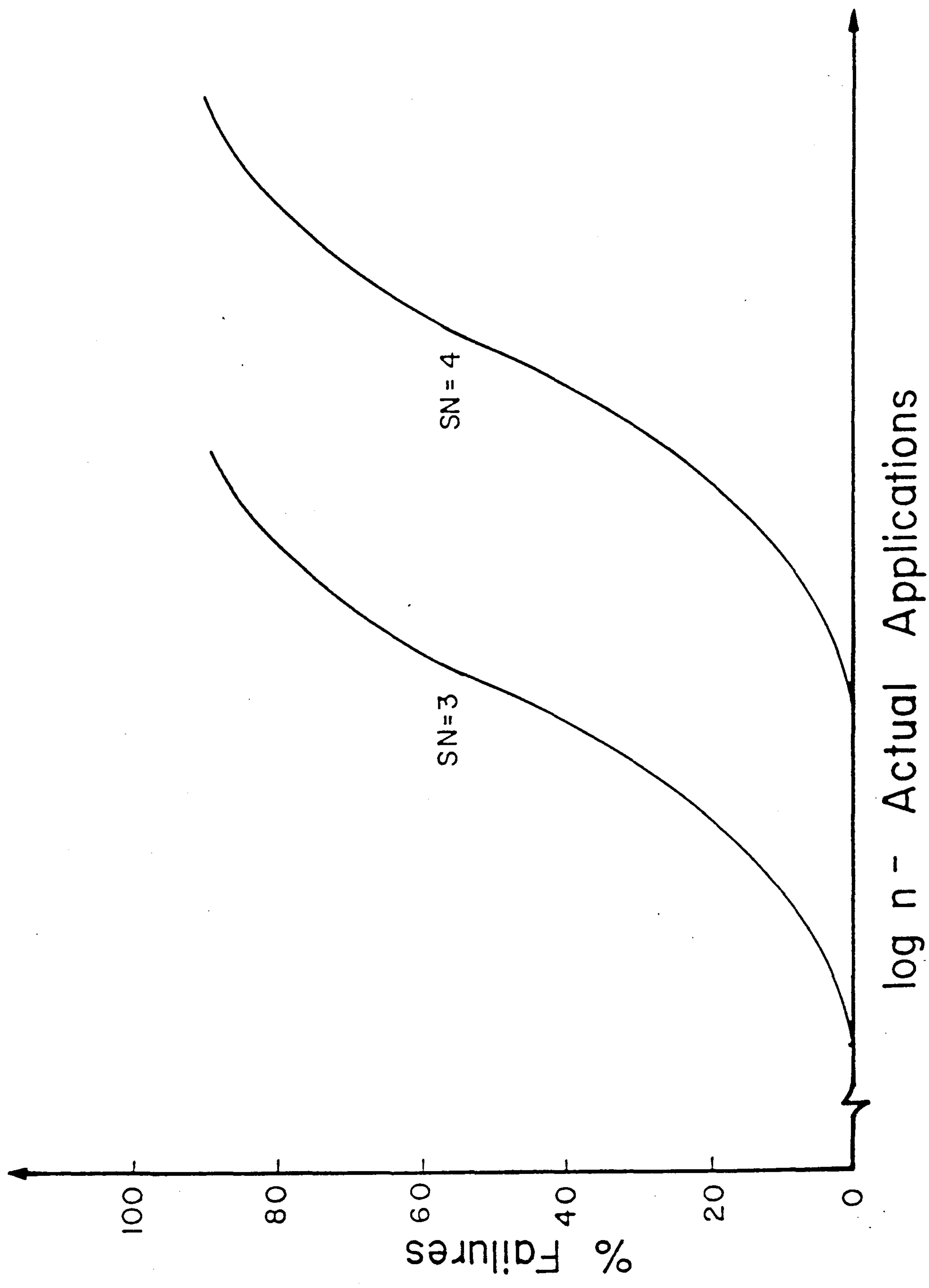
PSI
SN
2
3
4
n Design
N18

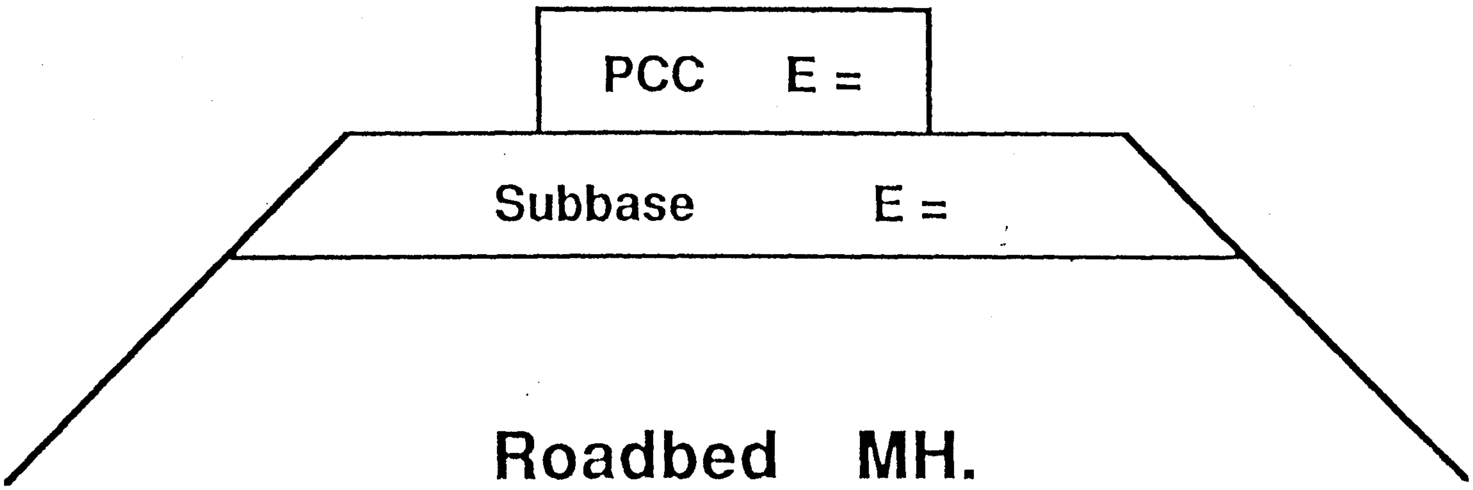


PSI
3
n10
n50
n90
n Design
N18


PSI
n_{10}
n_{50}
n_{90}
N_{18}


SN
Reliability


% Failures
100
80
60
40
20
0
SN=3
SN=4
log n - Actual Applications


PCC E =
Subbase E =
Roadbed MH.

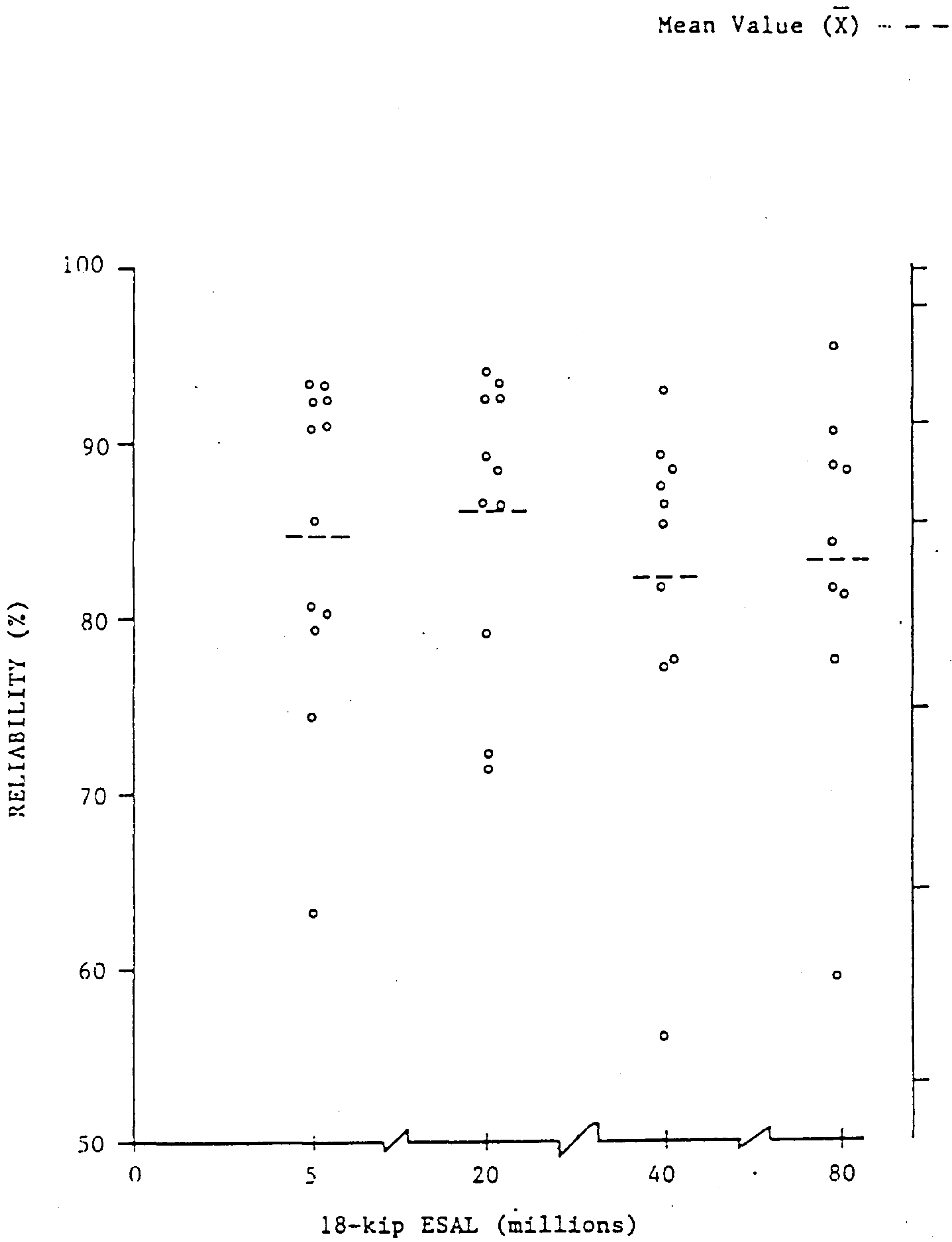


Figure II.3. Results of computed reliability in terms of the 18-kip ESAL design traffic in millions for a rural Interstate Highway using rigid pavements.

FUNCTIONAL CLASSIFICATION	RECOMMENDED LEVEL OF RELIABILITY	
	URBAN	RURAL
INTERSTATE, FREEWAYS	85 - 99.9	80 - 99.9
PRINCIPAL ARTERIES	80 - 99	75 - 95
COLLECTORS	80 - 95	75 - 95
LOCAL	50 - 80	50 - 80

ENVIRONMENTAL MODEL(S)

$$\Delta PSI = \Delta PSI_{Traffic} + \Delta PSI_{Envir.}$$

where: $\Delta PSI_{Traffic}$ = serviceability loss due to traffic which considers seasonal changes in subgrade support (i.e. resilient modulus, M_R).

$\Delta PSI_{Envir.}$ = serviceability loss due to subgrade swelling and frost heave.

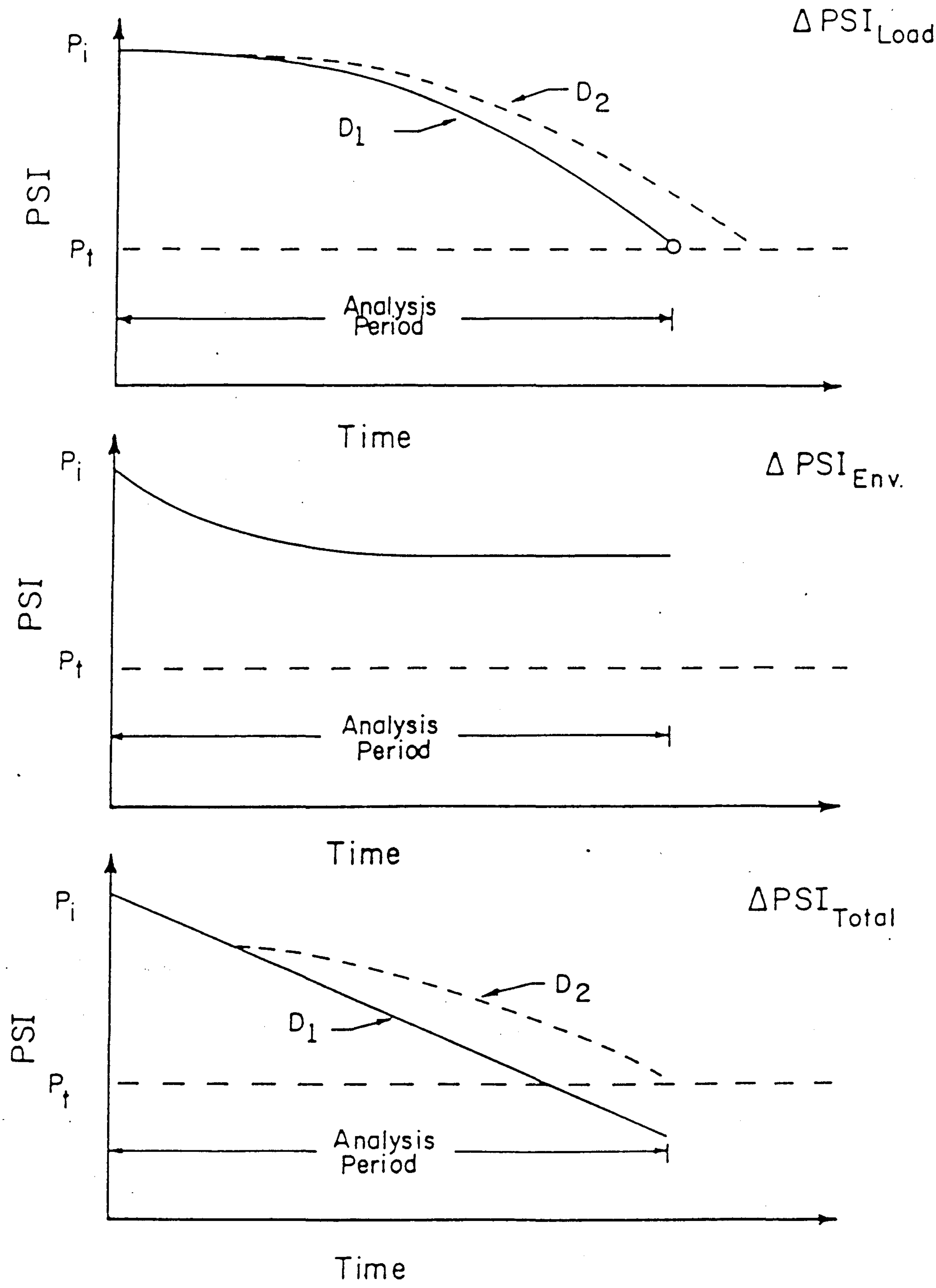
$$\Delta PSI_{Envir.} = \Delta PSI_{SW} + \Delta PSI_{FH} + \Delta PSI_{O}$$

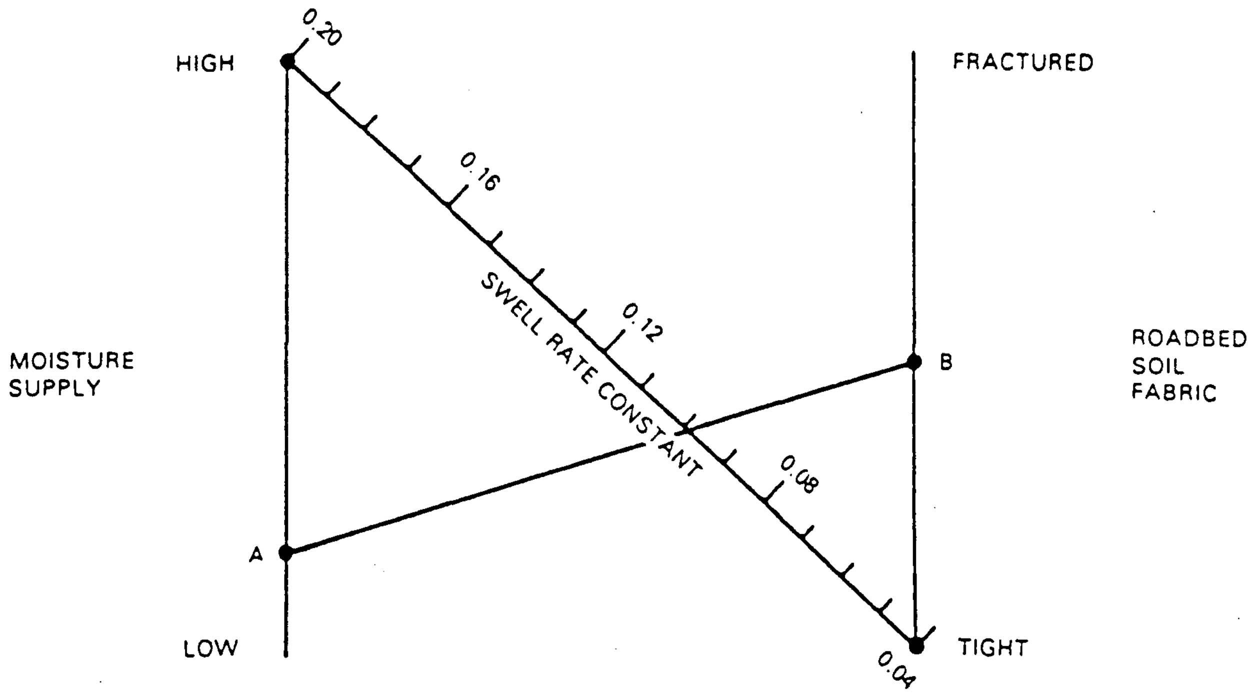
where:

ΔPSI_{SW} = serviceability loss due to subgrade swelling

ΔPSI_{FH} = serviceability loss due to frost heave

ΔPSI_{O} = serviceability loss due to others factors defined by the state e. g. "D cracking"


ΔPSI Load
P_i
P_t
PSI
D_1
D_2
Analysis Period
Time
ΔPSI Env.
P_i
P_t
PSI
Analysis Period
Time
ΔPSI Total
P_i
P_t
PSI
D_1
D_2
Analysis Period
Time



NOTES:

a) LOW MOISTURE SUPPLY:

Low rainfall
Good drainage

b) HIGH MOISTURE SUPPLY

High rainfall
Poor drainage
Vicinity of culverts, bridge abutments, inlet leads

c) SOIL FABRIC CONDITIONS (self explanatory)

d) USE OF THE NONOGRAPH

1) Select the appropriate moisture supply condition which may be somewhere between low and high (such as A).

2) Select the appropriate soil fabric (such as B). This scale must be developed by each individual agency.

3) Draw a straight line between the selected points (A to B).

4) Read swell rate constant from the diagonal axis (read 0.10).

Figure G.2. Nomograph for estimating swell rate constant, Part II (*1*).

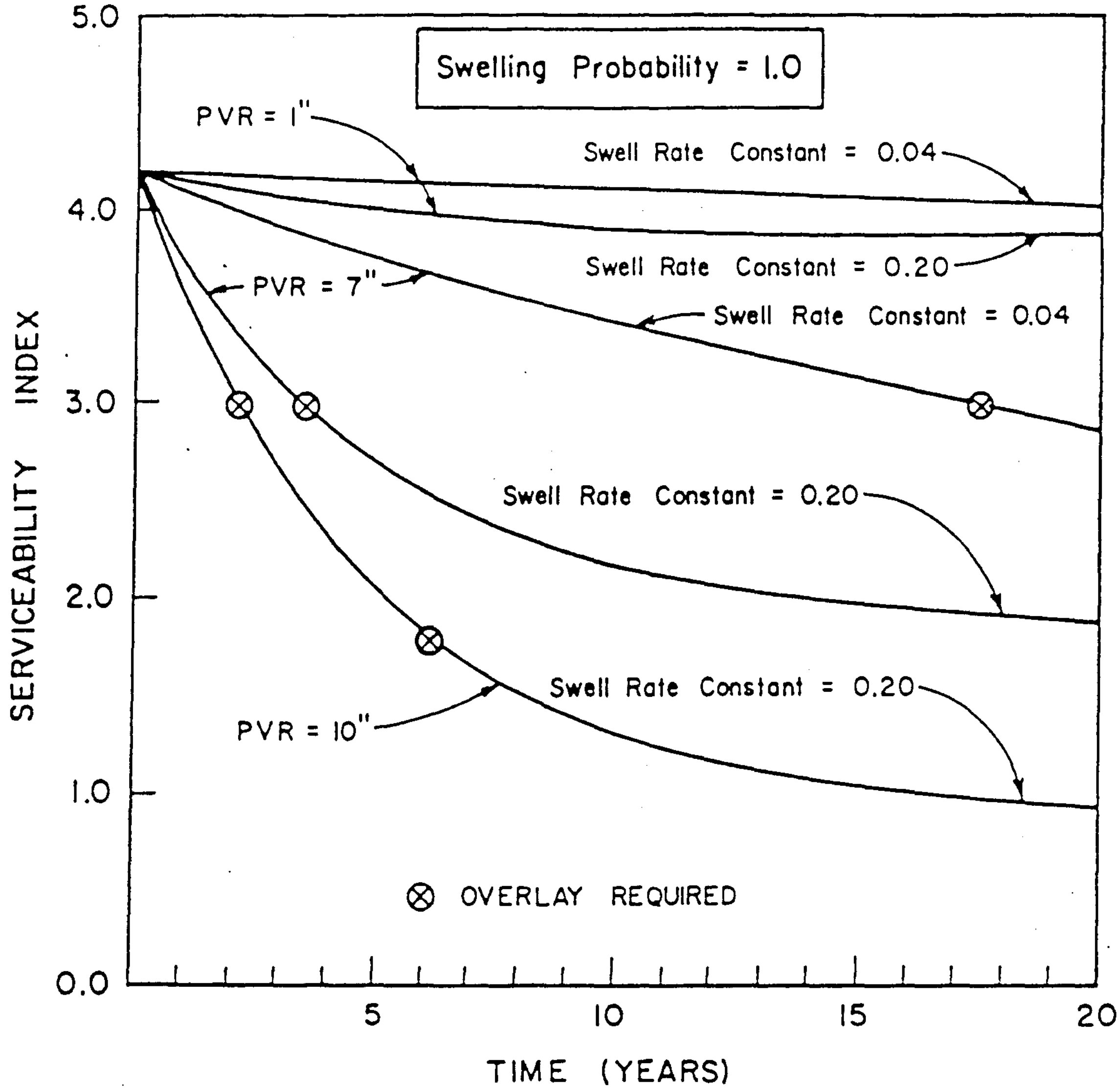
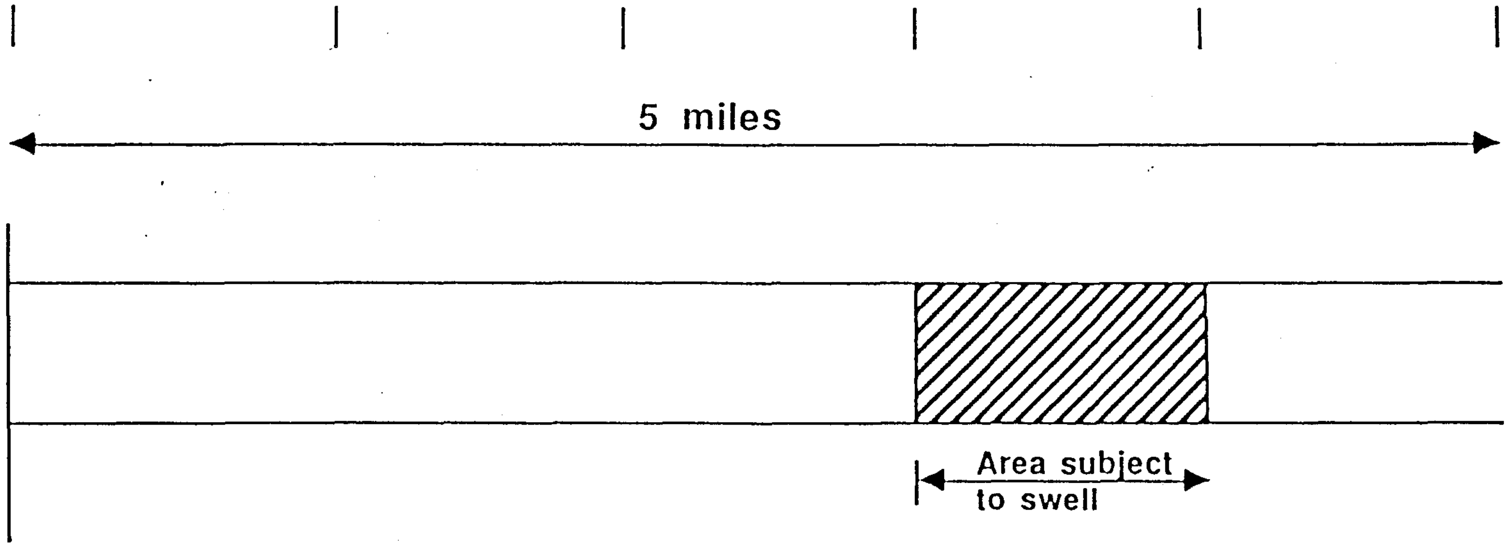


Figure 6.4: PERFORMANCE CURVES ILLUSTRATING SERVICEABILITY LOSS NOT CAUSED BY TRAFFIC



One Section:

$$P\{\text{ Swell }\} = \frac{1}{5} \times 100 = 20\%$$

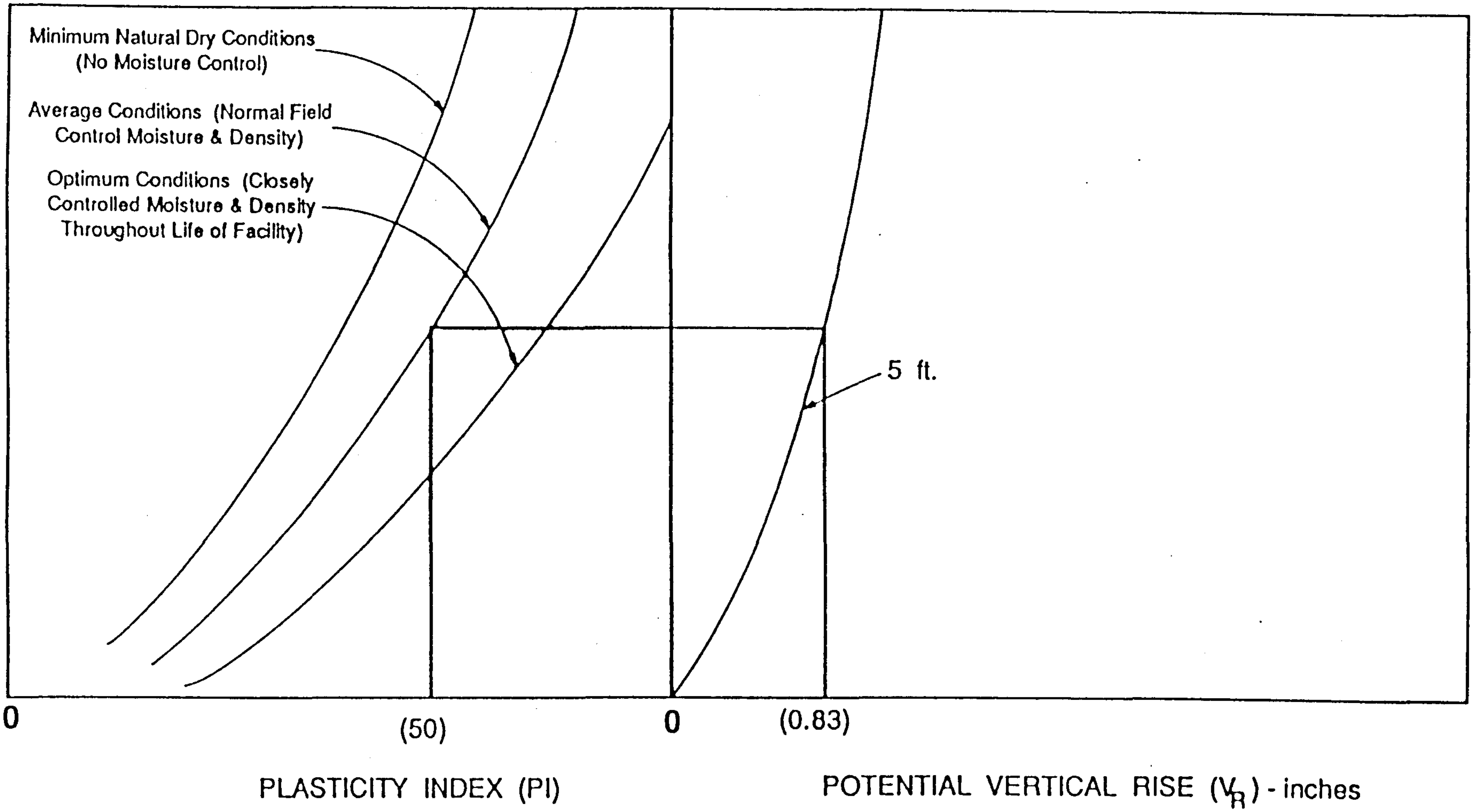
or

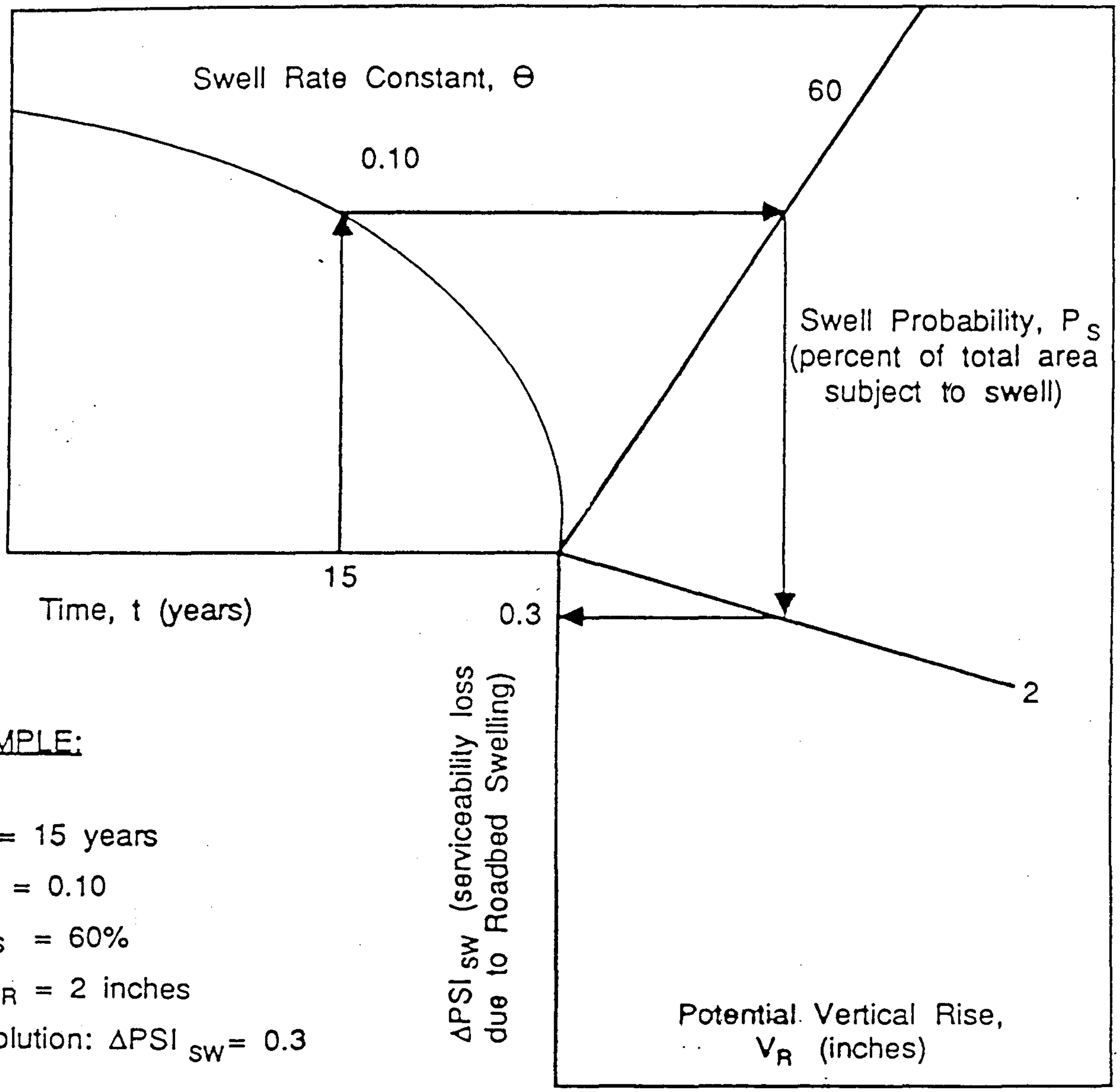
Three Sections:

$$P\{\text{ Swell }\} = \frac{0}{3} + 0\%$$

$$P\{\text{ Swell }\} = \frac{1}{1} = 100\%$$

$$P\{\text{ Swell }\} = \frac{0}{1} = 0\%$$


Minimum Natural Dry Conditions
(No Moisture Control)
Average Conditions (Normal Field
Control Moisture & Density)
Optimum Conditions (Closely
Controlled Moisture & Density
Throughout Life of Facility)
5 ft.
0
(50)
0
(0.83)
PLASTICITY INDEX (PI)
POTENTIAL VERTICAL RISE (V_R) - inches



<u>EXAMPLE:</u>

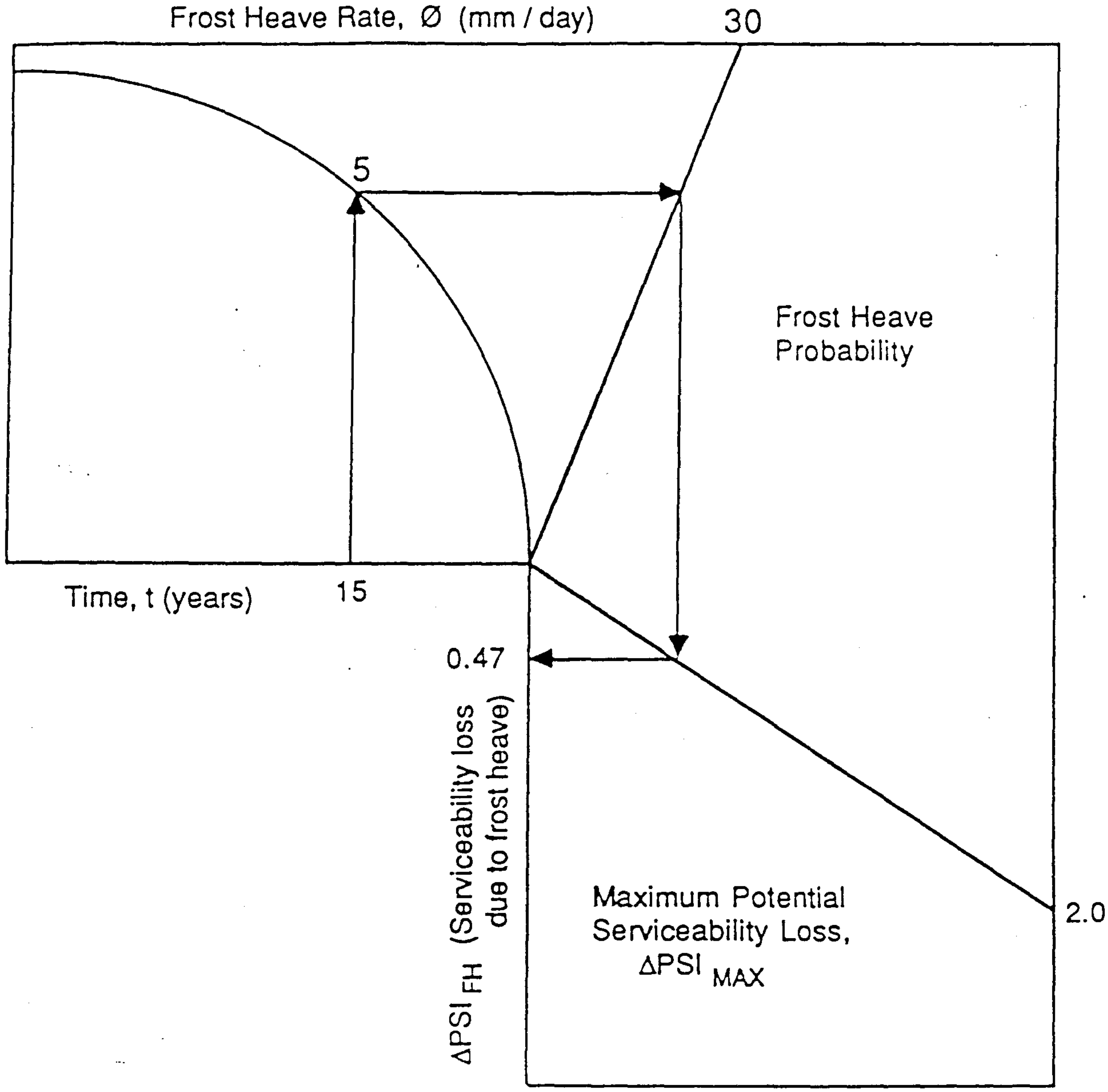
t = 15 years

Θ = 0.10

P_S = 60%

V_R = 2 inches

Solution: ΔPSI_{SW} = 0.3



EXAMPLE

t = 15 years

Ø = 5mm / day

P = 30%

ΔPSI_{MAX} = 2.0

Solution: ΔPSI_{FH} = 0.47

SESSION 4

Session 4

Rigid Pavement Design Procedures

Objectives

The objective of this session is to describe concepts related to the use of the guide for the design of rigid pavements and to illustrate design procedures by example problems. The design procedure will encompass both the thickness design and horizontal dimensions such as joint spacing, reinforcement, etc.

Outline

Explanations will emphasize the type of information required to design of pavement, sources of information and interpretation of results that apply to specific examples. The factors presented in Session 2 will be considered in discussing the design procedure. Specifically, the material will be covered as follows:

1. Specific rigid pavement input
2. Rigid pavement thickness design
3. Rigid pavement joint design
4. Rigid pavement reinforcement design
5. Example problems

Computer aided examples will be used to illustrate specific design procedures for new construction.

References

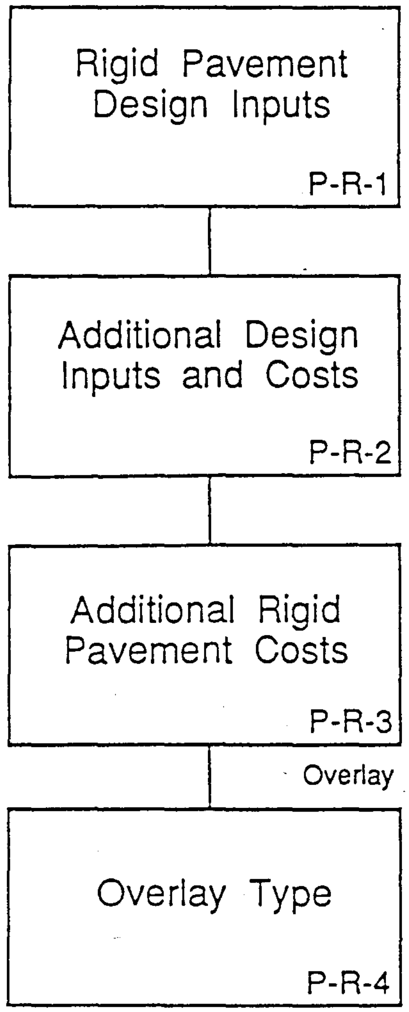
The information covered in this session is described in Part II of the Guides with emphasis on Sections 3.2, 3.3, 3.4, and 3.5.

Appendix I, Rigid Pavement Design Example will provide the guidelines for working specific examples. In addition, the supplementary Appendices HH, JJ, KK and LL provide additional information.

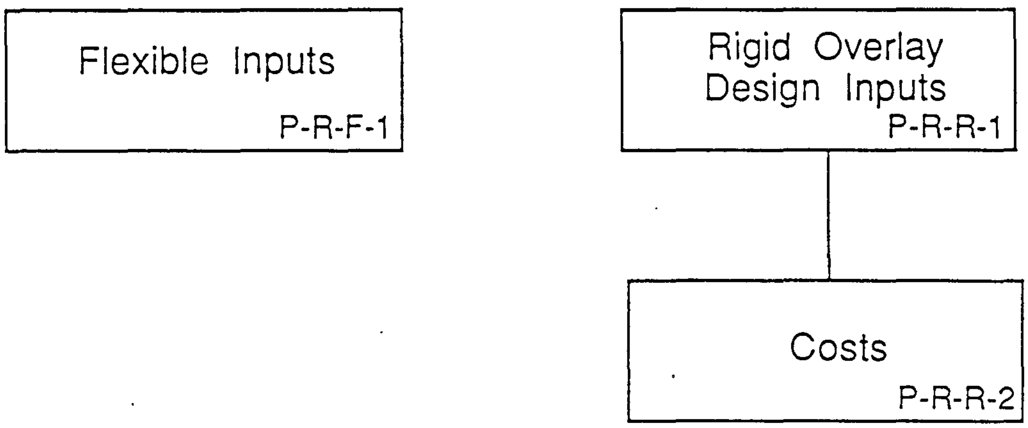
The following figures and tables in the Guide will be used during the presentation listed in the order of reference: Figure 2.1, page II-8; Figure 4.4, page I-61; Figure 3.3, page II-41; Figure 3.4, page II-42; Figure 3.5, page II-43; Figure 3.6, page II-44; Figure 3.7, page II-46; Figure 3.7, page II-47; Figure 3.8, page II-54; Figure 3.9, page II-57; Figure 3.10, pages II-59; Figure 3.11, page II-60; Figure 3.12, page II-61; Figure 3.13, pages II-66; Figure 3.14, page II-67; Table 3.2, page II-39; Table 2.7, page II-29; Table 3.3, page II-40; Table 2.6; page II-28; Table 2.5, page II-27; Table 3.4, page II-50; Table 2.8, page II-30; Table 3.5, pages II-55; Table 2.9 and 2.10, page II-31; Table 3.7, page II-62; Table 3.8, page II-63; and Table 3.9, page II-64.

The student should review these items in advance.

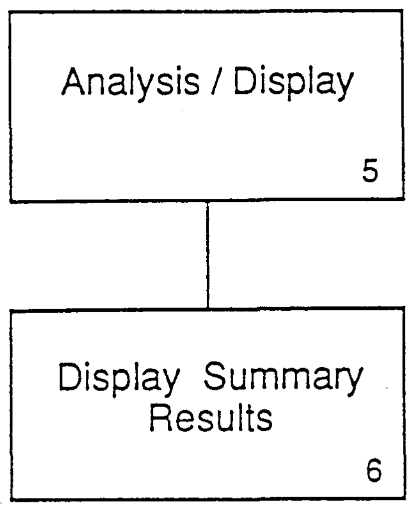
RIGID PAVEMENT



OVERLAY


Flexible Inputs
P-R-F-1
Rigid Overlay
Design Inputs
P-R-R-1
Costs
P-R-R-2

OUTPUT



```
                         PSD-02
          AASHTO PAVEMENT STRUCTURAL DESIGN PROGRAM
                VERSION 02 - APR. 1986

                     Prepared For
          American Association of State Highway
              and Transportation Officials

                  Under Contract With
        National Cooperative Highway Research Program
              Transportation Research Board
                National Research Council
                 NCHRP Project 20-7/28

                          By
           ARE Inc - Engineering Consultants


               Press Any Key to Continue ...
```

```
PSD-02

                   IMPORT/CREATE DATA FILE


     DATA FILE TO IMPORT . . . . . . . . . . . . . STEVE.RR
       This allows the user to import and
       edit an existing data file.  This
       may be left blank if a new file is
       to be created.

     DATA FILE TO CREATE AND ANALYZE . . . . . . . STEVE.RR
       If left blank, a default name
       (PSDTEMP.DAT) will be assumed.
```

PSD-02

PROBLEM NUMBER AND DESCRIPTION

PROBLEM NUMBER 200b

PROBLEM DESCRIPTION
EXAMPLE APPLICATION OF AASHTO PAVEMENT STRUCTURAL
DESIGN PROGRAM - RIGID INITIAL WITH RIGID OVERLAY

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

PSD-02 No. 200b

* * * GENERAL DESIGN INPUT REQUIREMENTS * * *

ANALYSIS PERIOD (YEARS) 30.0

DISCOUNT RATE (%) 4.00

NUMBER OF TRAFFIC LANES (ONE DIRECTION) 2

LANE WIDTH (FEET) 12.00

COMBINED WIDTH OF SHOULDERS (FEET, ONE DIRECTION) 16.00

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

PSD-02 No. 200b

* * * ROADBED SOIL RESILIENT MODULI * * *

Season No.	Resilient Modulus (psi)	Season No.	Resilient Modulus (psi)
1	6500	13	0
2	30000	14	0
3	2500	15	0
4	4000	16	0
5	4000	17	0
6	5000	18	0
7	5000	19	0
8	5000	20	0
9	5000	21	0
10	5000	22	0
11	6500	23	0
12	6500	24	0

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

PSD-02 No. 200b

ROAD SURFACE
(P)aved or (A)ggregate . . . . P

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

```
PSD-02                                                          No.   200b
           * * *  DESIGN INPUTS FOR FLEXIBLE AND RIGID PAVEMENTS  * * *

           DESIRED LEVEL OF RELIABILITY (PERCENT) . . . . .       90.00

           ROADBED SOIL SWELLING AND/OR FROST HEAVE
             Consider? (Y)es or (N)o . . . . . . . . . . . .          Y

      F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

```
PSD-02                                                          No.   200b
      * * *  INPUTS FOR ROADBED SOIL SWELLING AND/OR FROST HEAVE  * * *

          ROADBED SOIL SWELLING
            Potential Vertical Rise (inches) . . . . . . . .        1.20
            Swelling probability (percent) . . . . . . . . .          84
            Swell Rate Constant . . . . . . . . . . . . . . .      0.075

          FROST HEAVE
            Maximum Potential Serviceability Loss . . . . .         1.00
            Frost Heave Probability (percent) . . . . . . .           10
            Frost Heave Rate (mm/day) . . . . . . . . . . .        30.00

      F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

```
PSD-02                                                                No.    200b



        PAVEMENT TYPE
          (F)lexible or (R)igid . . . . . . . . . . . . .          R











     F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

```
PSD-02                                                                No.    200b
                   * * * RIGID PAVEMENT DESIGN INPUTS * * *
        PERFORMANCE PERIOD FOR INITIAL PAVEMENT (YEARS) .          15.0

        SERVICEABILITY INDEX
          After Initial Construction . . . . . . . . . .           4.50
          At End of Performance Period . . . . . . . . .           2.70

        TRAFFIC
          Growth Rate (percent per year) . . . . . . . .           2.00
          (S)imple or (C)ompound Growth  . . . . . . . .              C
          Initial Yearly 18-Kip ESAL (both directions) .        2400000
          Directional Distribution Factor (percent) . . .            50
          Lane Distribution Factor (percent) . . . . . .             85
          Calculated Total 18-KIip ESAL During the
            Analysis Period (in the design lane) . . . .       41379441

        OVERALL STANDARD DEVIATION (LOG REPETITIONS) . .          0.390



     F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

PSD-02 No. 200b

*** * * ADDITIONAL RIGID PAVEMENT DESIGN INPUTS * * ***
AND ASSOCIATED COSTS

SUBBASE	
Subbase Type	GRANULAR
Thickness (inches)	8.00
Elastic Modulus (psi)	30000
Unit Cost ($/CY)	17.00
Salvage Value (percent)	70
PORTLAND CEMENT CONCRETE SLABS	
Type of Construction	JRCP W/ TS
Approximate Slab Thickness (inches)	8.0
PCC Elastic Modulus (psi)	4500000
Average PCC Modulus of Rupture (psi)	800
Unit Cost of PCC ($/CY)	80.00
Salvage Value (percent)	20
STRUCTURAL CHARACTERISTICS	
Load Transfer Coefficient	2.60
Drainage Coefficient	1.05
Loss of Support Factor	0.50

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

PSD-02 No. 200b

*** * * ADDITIONAL RIGID PAVEMENT COSTS * * ***

OTHER CONSTRUCTION RELATED COSTS	
Shoulders, If Not Full Strength ($/linear ft) .	0.00
Drainage ($/linear ft)	8.00
Mobilization and other Fixed Costs ($/lin ft) .	10.00
MAINTENANCE COST	
Initial Year ($/lane mile)	-700.00
Yearly Increase ($/lane mile/year)	100.00

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

```
PSD-02                                                          No.    200b



        OVERLAY REQUIRED FOR REMAINING 15.0 YEARS
          (F)lexible or (R)igid . . . . . . . . . . . . .            R








    F1: HELP   F2: IMPORT/STORE   F3: ANALYZE/PRINT/EXIT   F4: DISPLAY RESULTS
```

```
PSD-02                                                          No.    200b
                   * * * RIGID OVERLAY DESIGN INPUTS * * *

        SREVICEABILITY INDEX
          After Overlay Construction  . . . . . . . . . .        4.50
          At End of Overlay Performance Period  . . . . .        2.50

        OVERLAY STANDARD DEVIATION (LOG REPETITONS) . . .       0.350

        STRUCTURAL CHARACTERISTICS & MATERIAL PROPERTIES
          Rigid Overlay Type . . . . . . . . . . . . . . . . JRCP W/ TS
          Minimum Thickness (inches)  . . . . . . . . . .        5.00
          PCC Elastic Modulus (psi)  . . . . . . . . . . .    4500000
          Average PCC Modulus of Rupture (psi)  . . . . .         800
          Load Transfer Coefficient . . . . . . . . . . .        2.60
          Bond Coefficient  . . . . . . . . . . . . . . .        1.00
          Drainage Coefficient  . . . . . . . . . . . . .        1.05
          Loss of Support Factor  . . . . . . . . . . . .        0.00



    F1: HELP   F2: IMPORT/STORE   F3: ANALYZE/PRINT/EXIT   F4: DISPLAY RESULTS
```

```
PSD-02                                                                  No.    200b
                     * * * RIGID OVERLAY COST INPUTS * * *

         OVERLAY CONSTRUCTION COSTS AND SALVAGE VALUE
           Unit Cost of Overlay Material ($/CY)  . . . . .        80.00
           Salvage Value (percent) . . . . . . . . . . . .           20
           Shoulders, If Different than Overlay ($/lin ft)         0.00
           Mobilization and Other Fixed Costs ($/lin ft) .         8.00

         OVERLAY MAINTENANCE COST
           Initial Year ($/lane mile)  . . . . . . . . . .      -700.00
           Yearly Increase ($/lane mile/year)  . . . . . .       100.00


    F1: HELP  F2: IMPORT/STORE  F3: ANALYZE/PRINT/EXIT  F4: DISPLAY RESULTS
```

```
              PERFORM ANALYSIS, PRINT RESULTS OR EXIT

         OPTIONS
            1. Perform Analysis
            2. Perform Analysis and Print Results
            3. Print Previous Results
            4. Return to Edit Session
            5. Exit

         Enter desired option . . . . . . . . . . . . . . . . . . .
```

PSD-02 SOLUTION FOR INPUT DATA FILE STEVE.RR

RIGID PAVEMENT STRUCTURAL DESIGN

Pavement Type	JRCP W/ TS
Required Thickness (in)	9.653
Performance Life (yrs)	15.0
18-kip ESAL Repetitions	17639270.

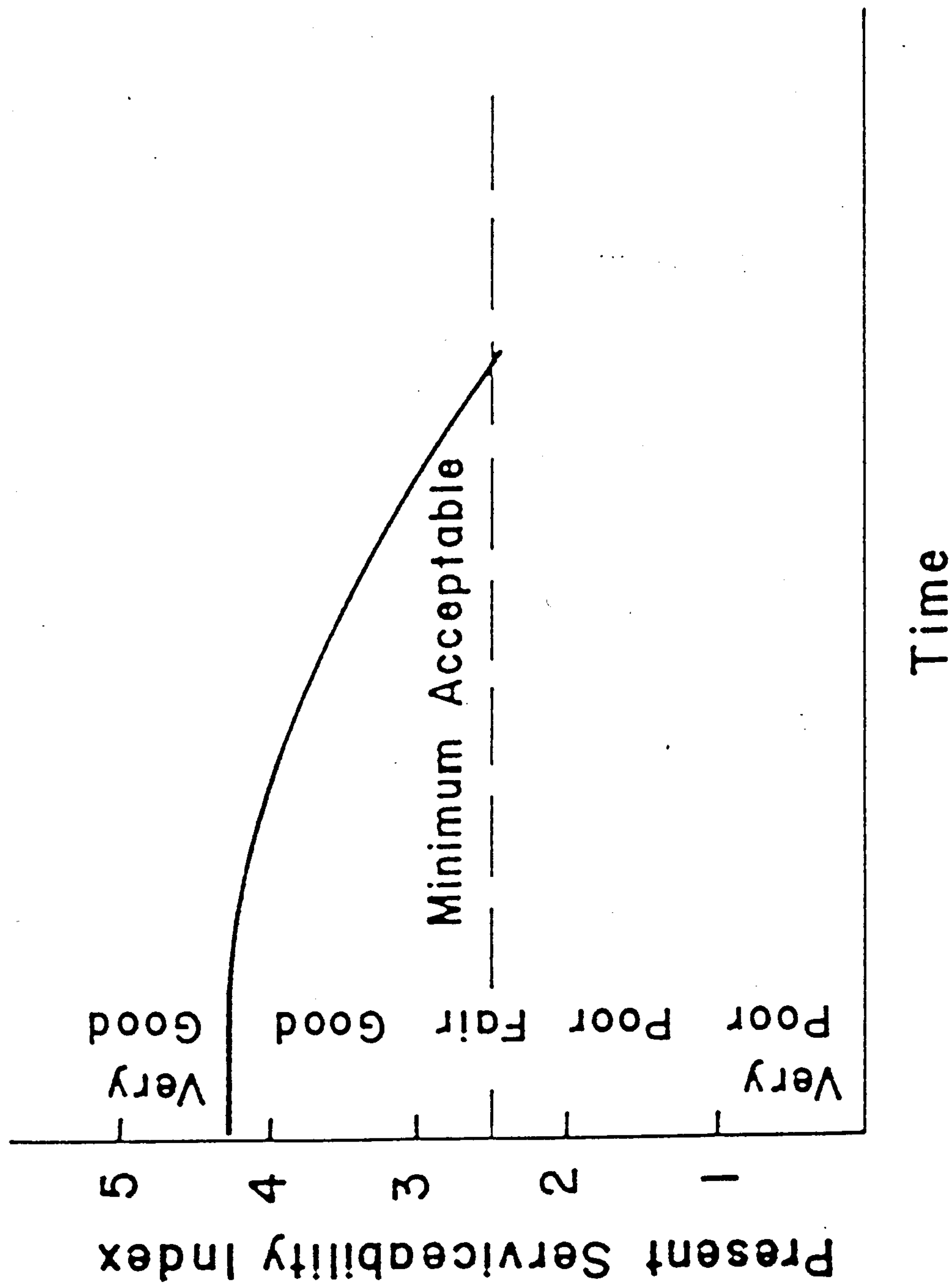
DESIGN FOR PROJECTED FUTURE OVERLAY

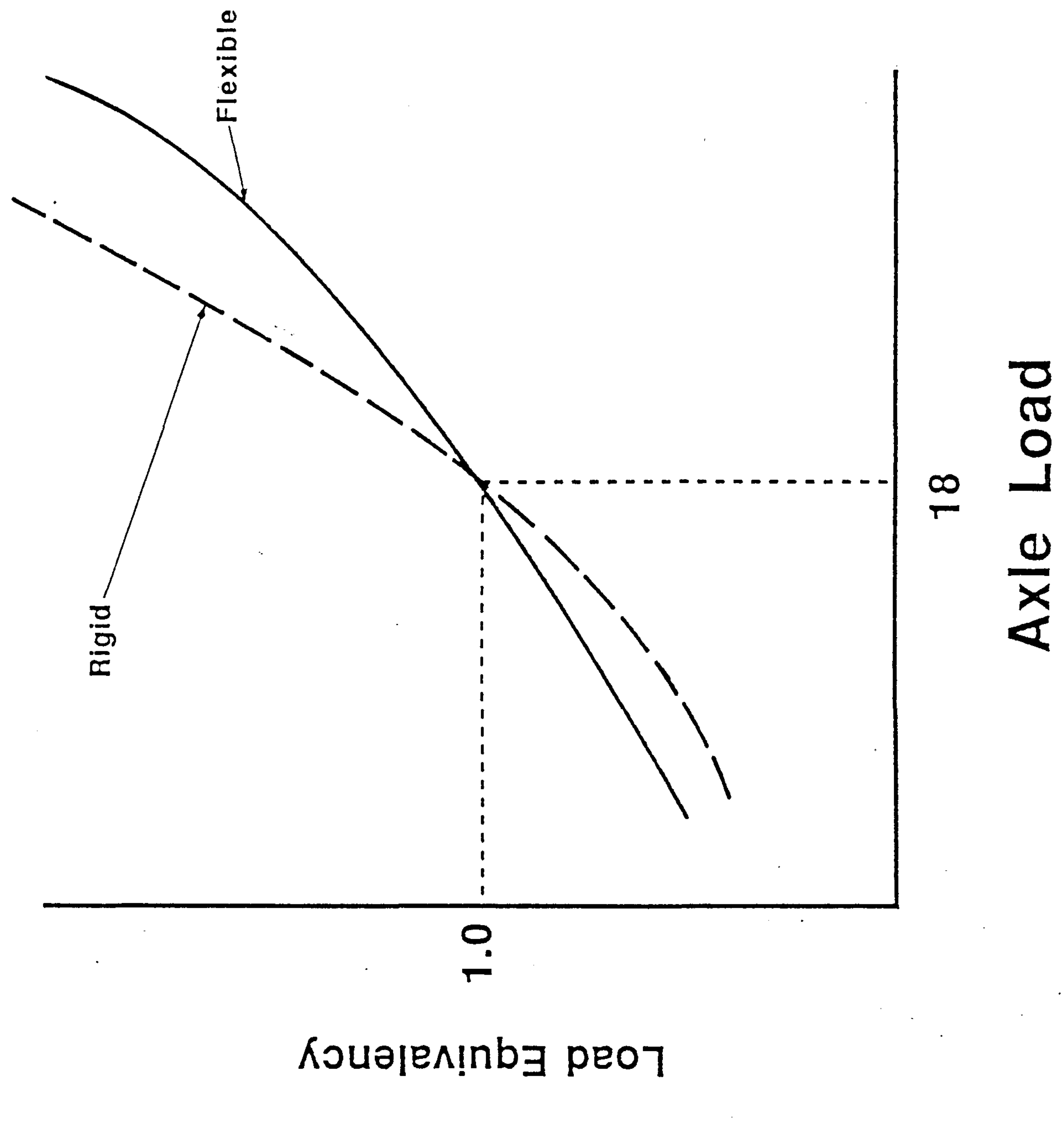
Overlay Type	JRCP W/ TS
Required Thickness (in)	5.000
Performance Life (yrs)	15.0
18-kip ESAL Repetitions	23740120.

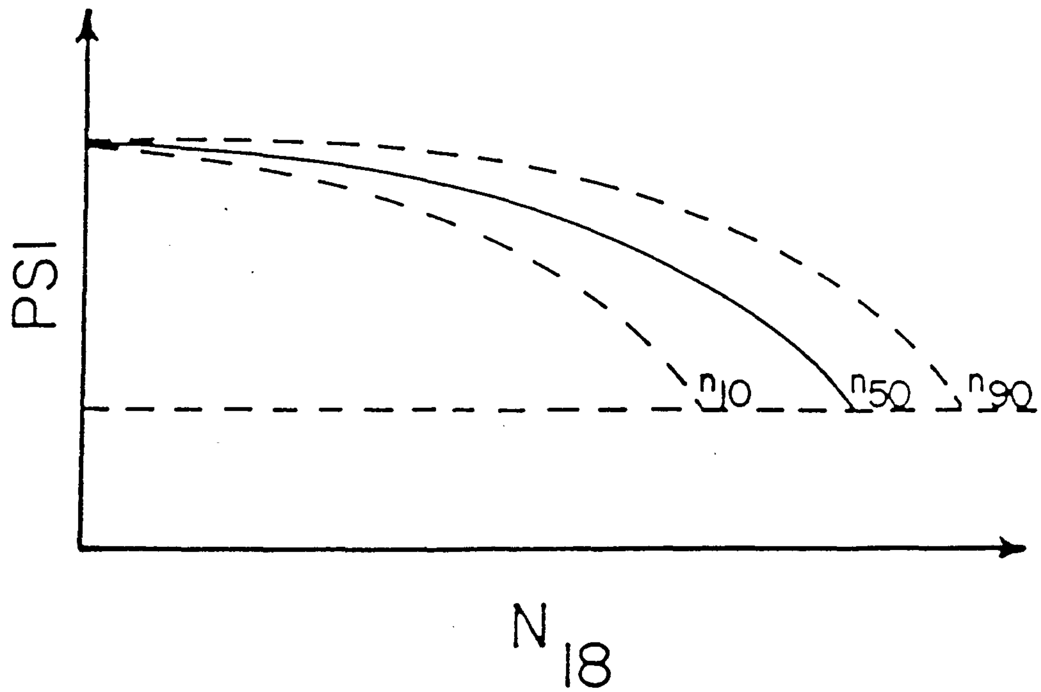
LIFE CYCLE COSTS ($/SY)

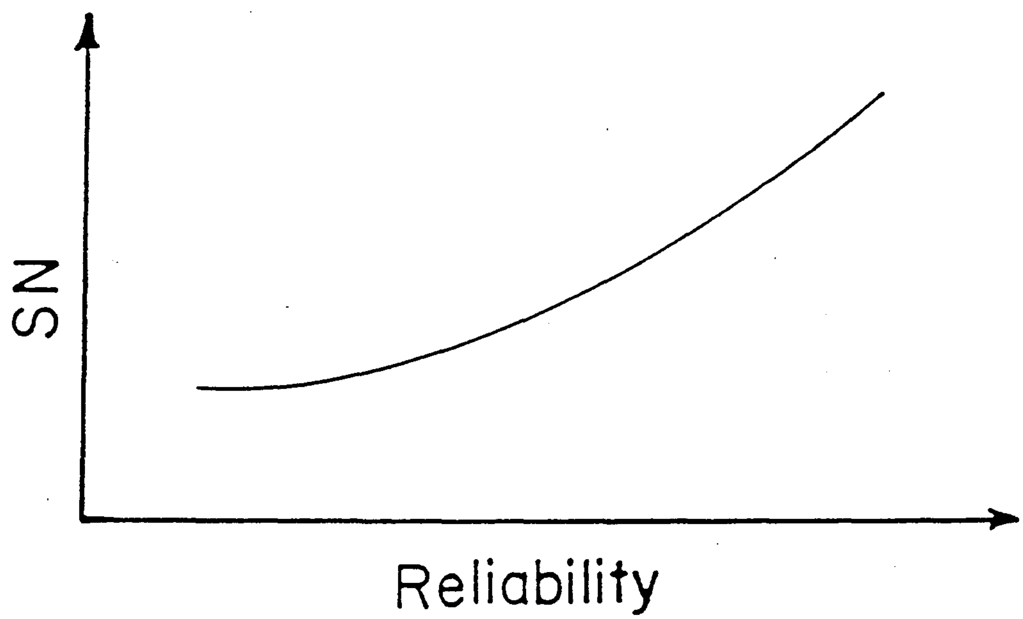
Initial Pavement	
Construction	48.80
Maintenance	.24
Salvage Value	-2.14
Overlay	
Construction	11.95
Maintenance	.13
Salvage Value	-.69
Net Present Value	58.29

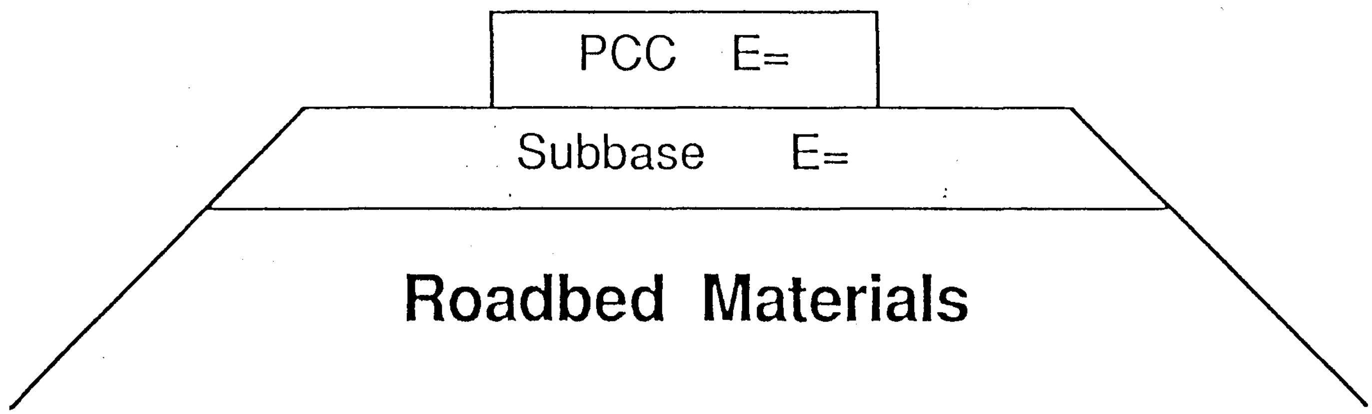
Press any key to continue...


Present Serviceability Index
5
4
3
2
1
Very Good
Good
Fair
Poor
Very Poor
Minimum Acceptable
Time


Flexible
Rigid
1.0
18
Axle Load
Load Equivalency


PSI
n10
n50
n90
N18


SN
Reliability


PCC E=
Subbase E=
Roadbed Materials

Flexible Pavements

$$\log_{10}W_{18} = 9.36 \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}[(4.2 - p_t)/(4.2 - 1.5)]}{0.40 + [1094/(SN + 1)^{5.14}]}$$

$$+ 2.32 \log_{10}MR - 8.07 \qquad 1.2.1$$

Rigid Pavements

$$\log_{10}W_{18} = 7.35 \log_{10}(D + 1) - 0.06 - \frac{\log_{10}[(4.5 - p_t)/(4.5 - 1.5)]}{1 + \dfrac{1.624 \times 10^7}{(D + 1)^{8.46}}}$$

$$+ (4.22 - 0.32p_t)\log_{10}\left[\left(\frac{S'_c}{215.63 \cdot J \cdot C_d}\right)\left(\frac{D^{.75} - 1.132}{D^{.75} - \dfrac{18.42}{(E_c/k)^{.25}}}\right)\right] \qquad 1.2.2$$

SUMMATION OF DAMAGE:

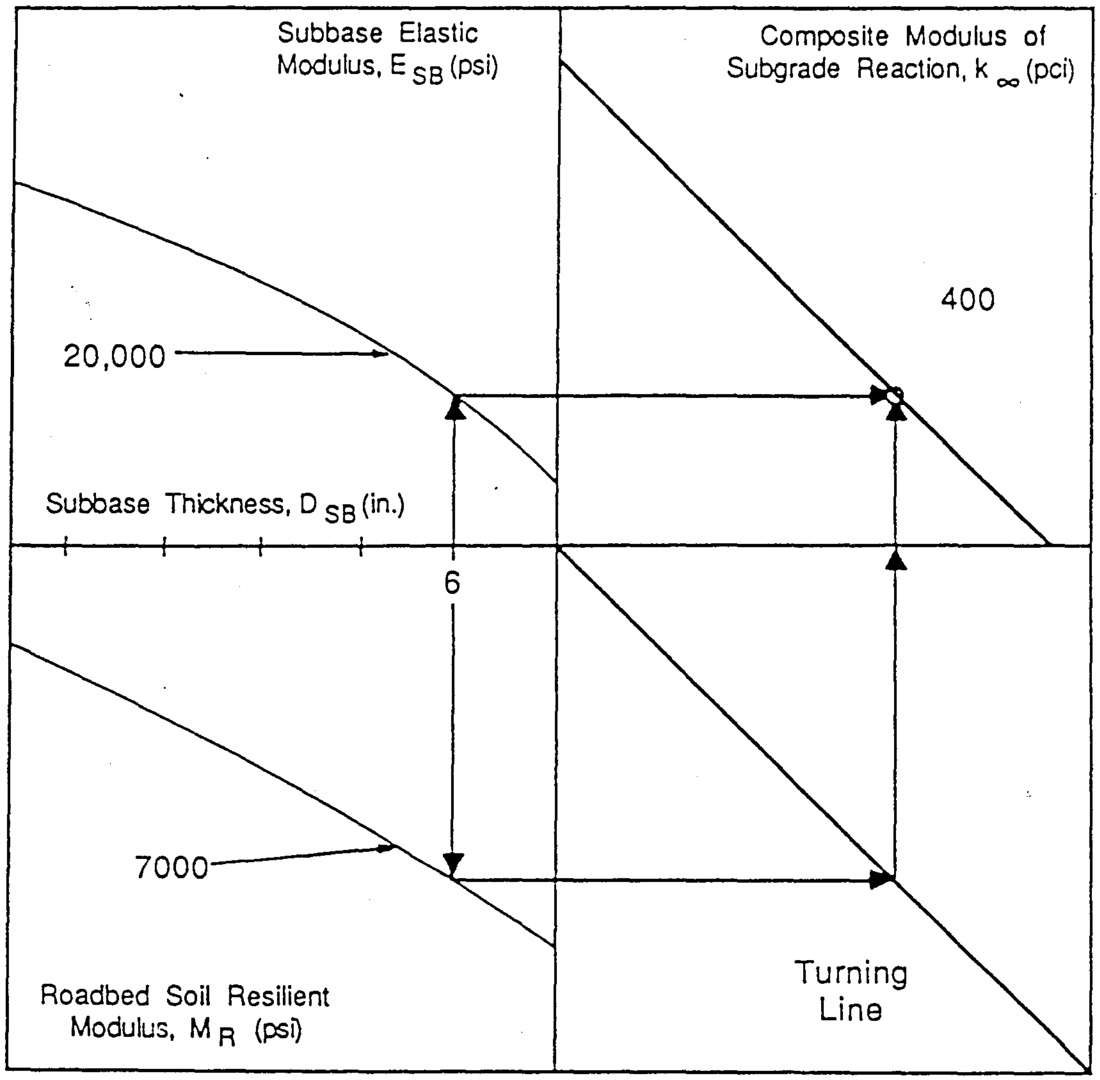
$$n_T \cdot \left(\frac{1}{(W_{18})_1} + \cdots + \frac{1}{(W_{18})_{12}} \right) \leq 1$$

RIGID EQUATION

$$W_{18-i} = \cdots C \left(\frac{D^{0.75} - 1.132}{K^{0.25}} \right)^{3.42} \cdots$$

RELATIVE DAMAGE

$$U = \frac{1}{\left(\frac{D^{0.75} - 1.132}{K^{0.25}} \right)^{3.42}}$$



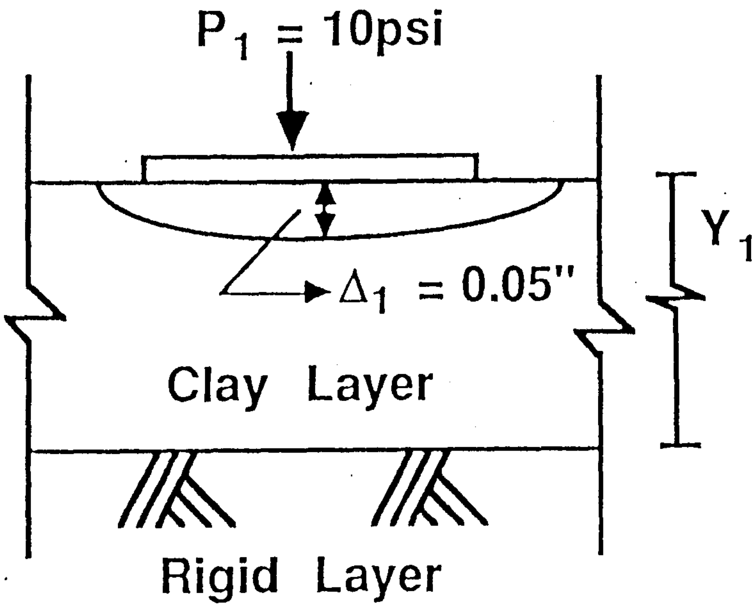
<u>EXAMPLE:</u>

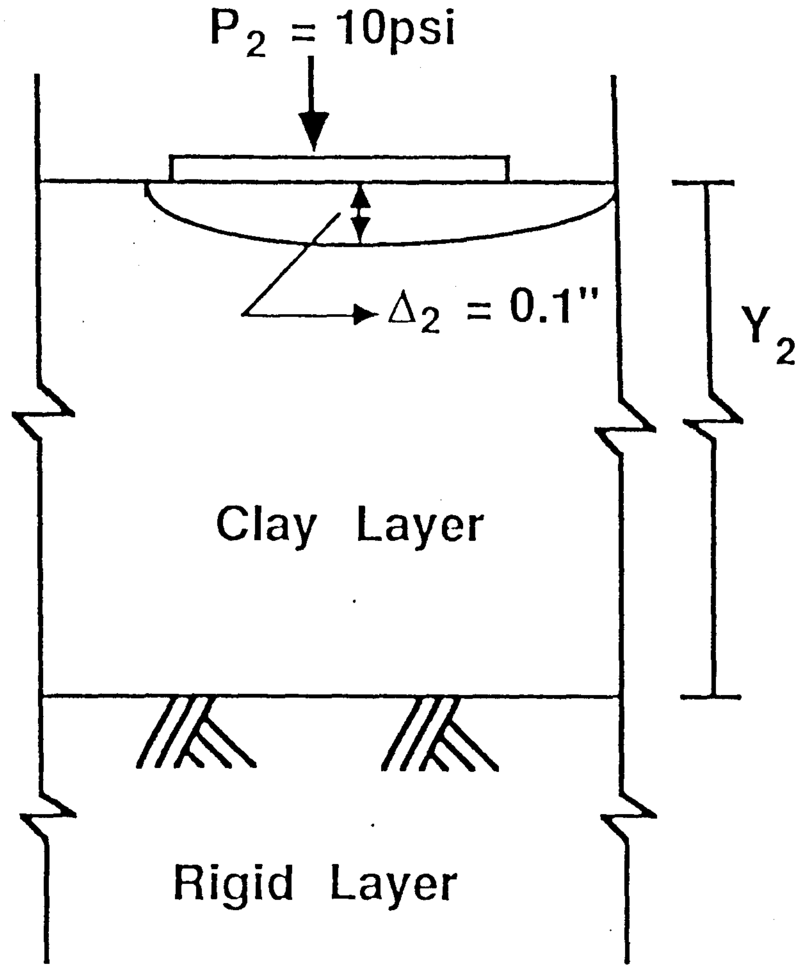
D_{SB} = 6 inches

E_{SB} = 20,000 psi

M_R = 7,000 psi

Solution: $k_\infty \doteq 400$ pci

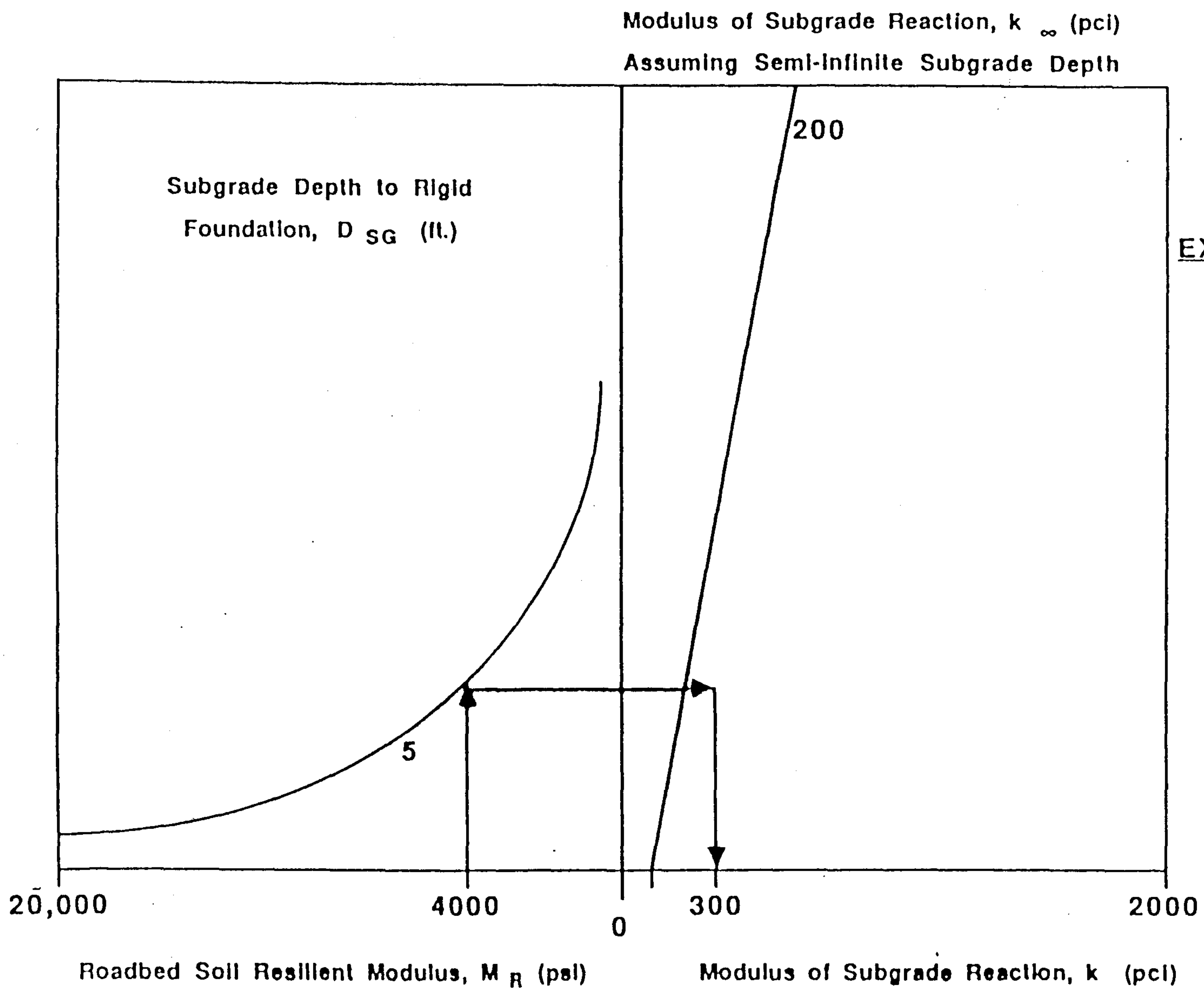




$$k_1 = \frac{10 \text{ psi}}{0.05 \text{ in.}} = 200 \text{ pci}$$

$$k_2 = \frac{10 \text{ psi}}{0.1 \text{ in.}} = 100 \text{ pci}$$

$$\therefore k_{Design} = k_{Chart} \bullet (Y_i)^c$$



EXAMPLE

M_R = 4000 psi

D_{SG} = 5 ft

k_∞ = 230 pci

Solution: k = 300 pci

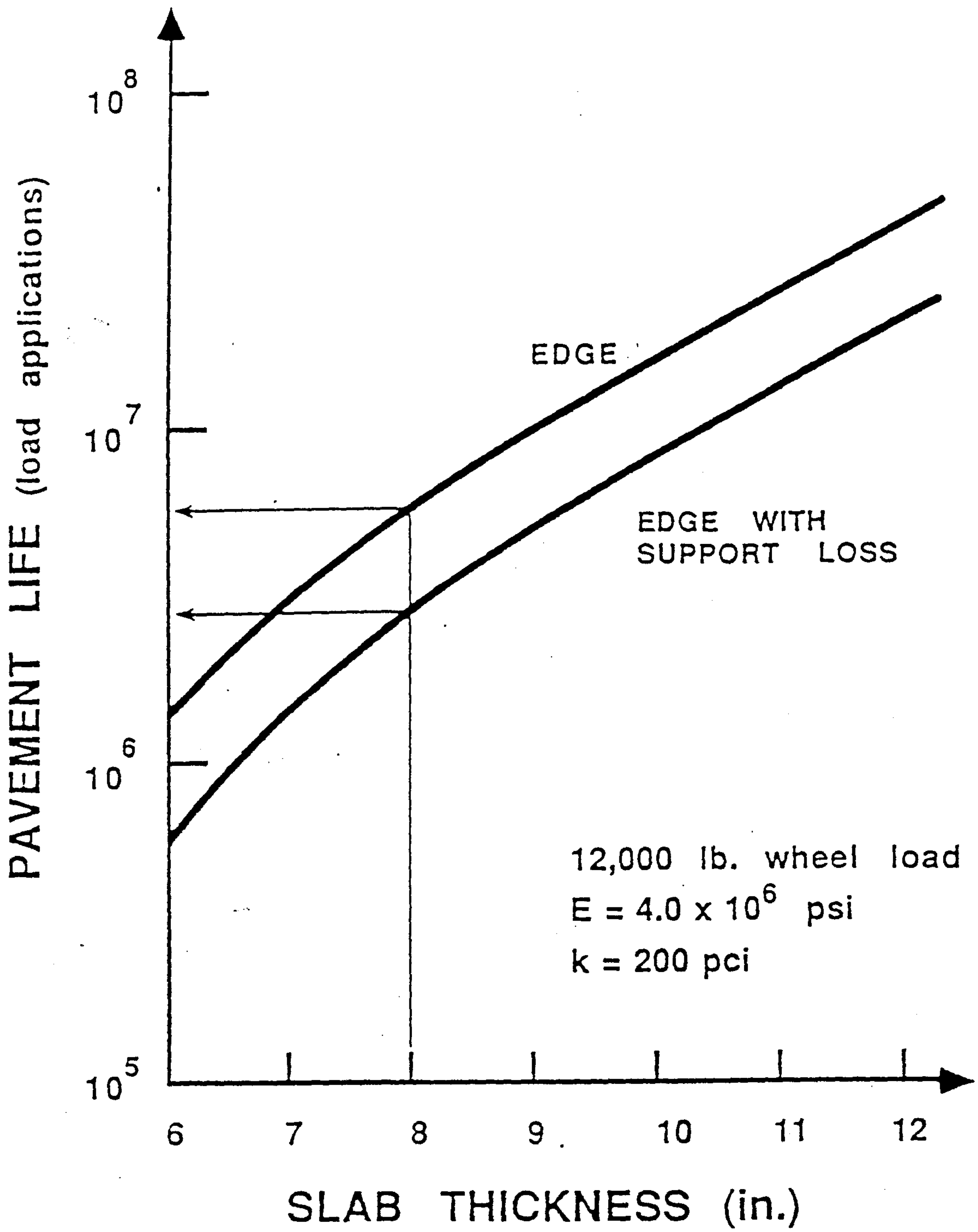
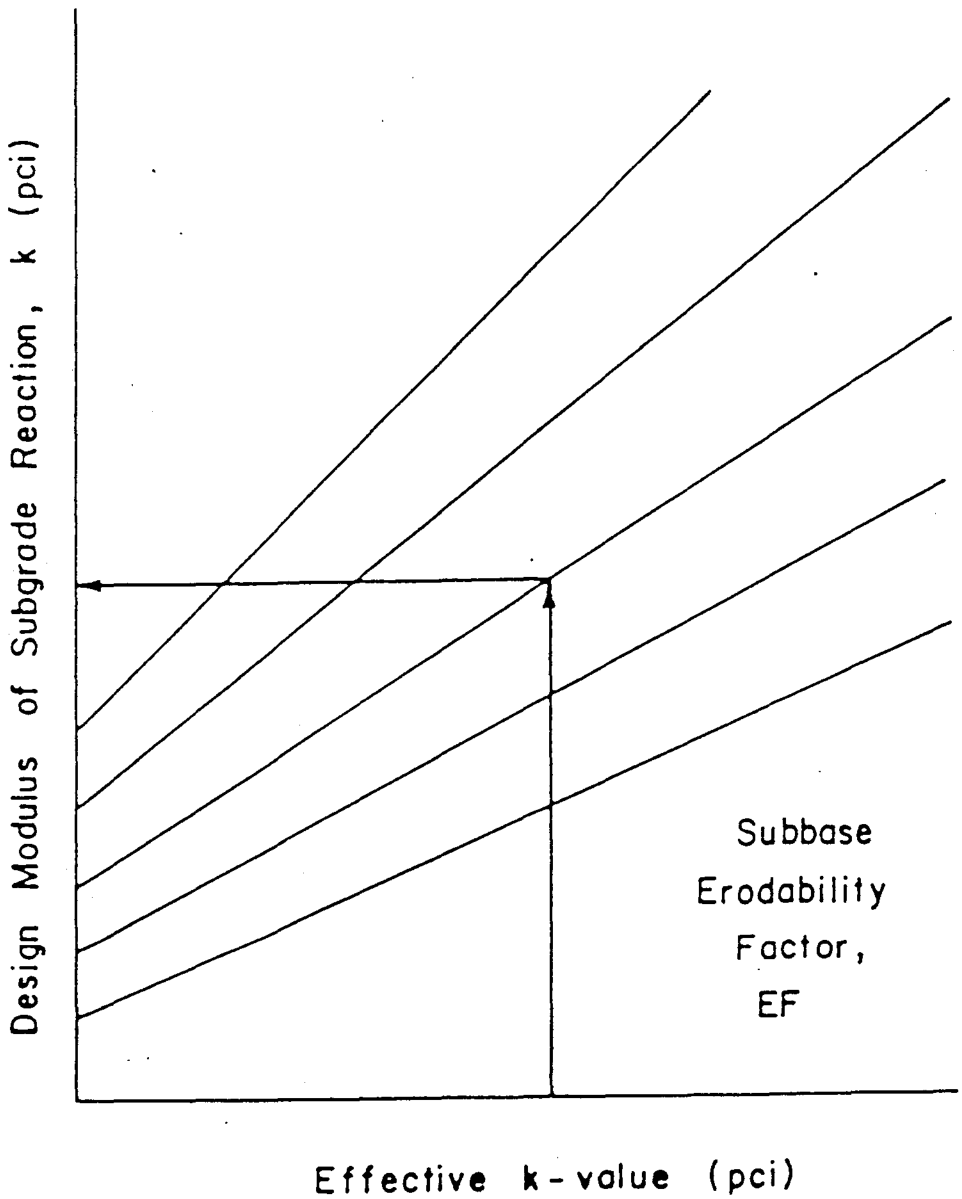

PAVEMENT LIFE (load applications)
10^8
10^7
10^6
10^5
EDGE
EDGE WITH SUPPORT LOSS
12,000 lb. wheel load
E = 4.0 x 10^6 psi
k = 200 pci
6
7
8
9
10
11
12
SLAB THICKNESS (in.)

Chart for Considering Effect of Erodability



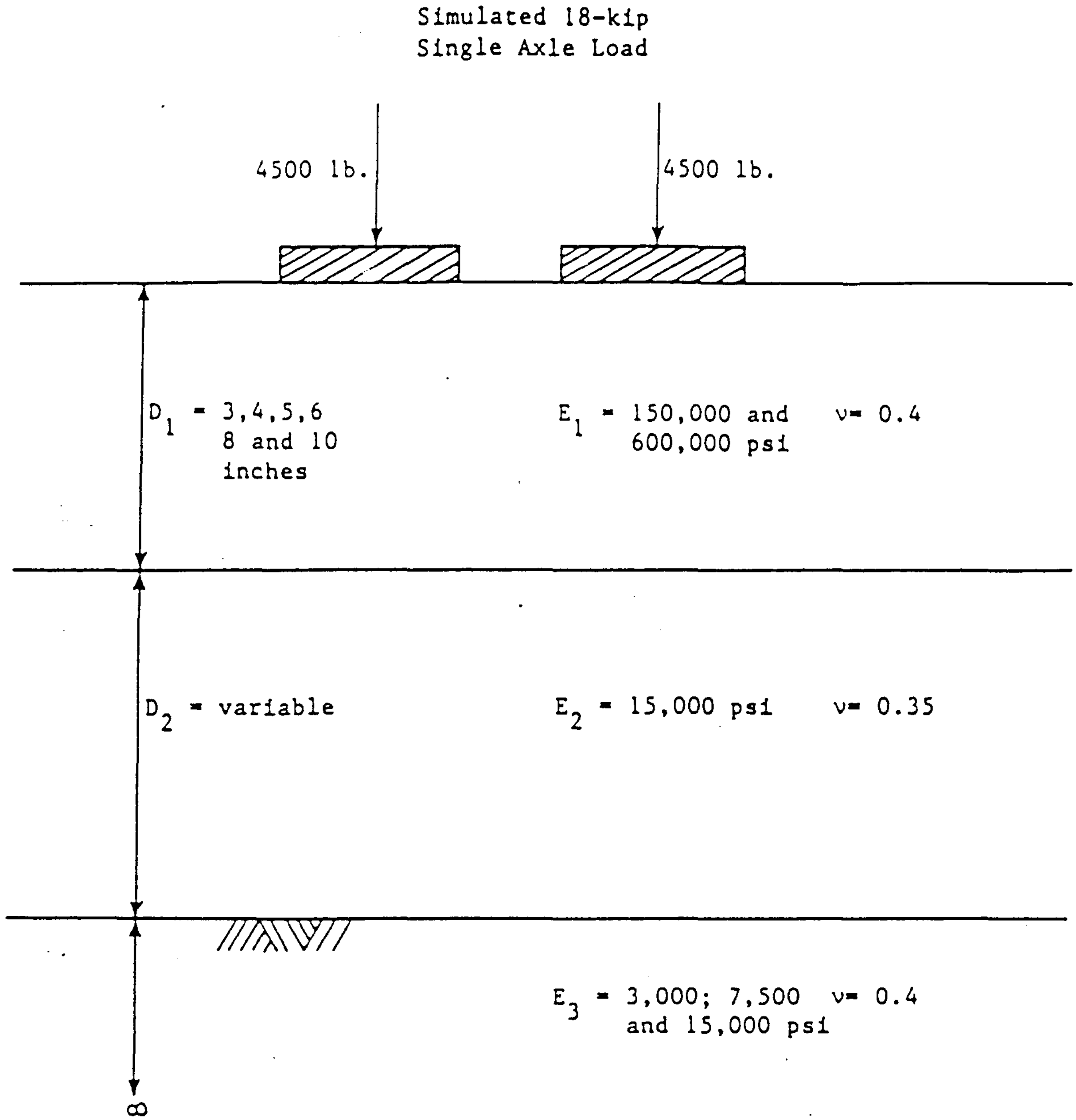
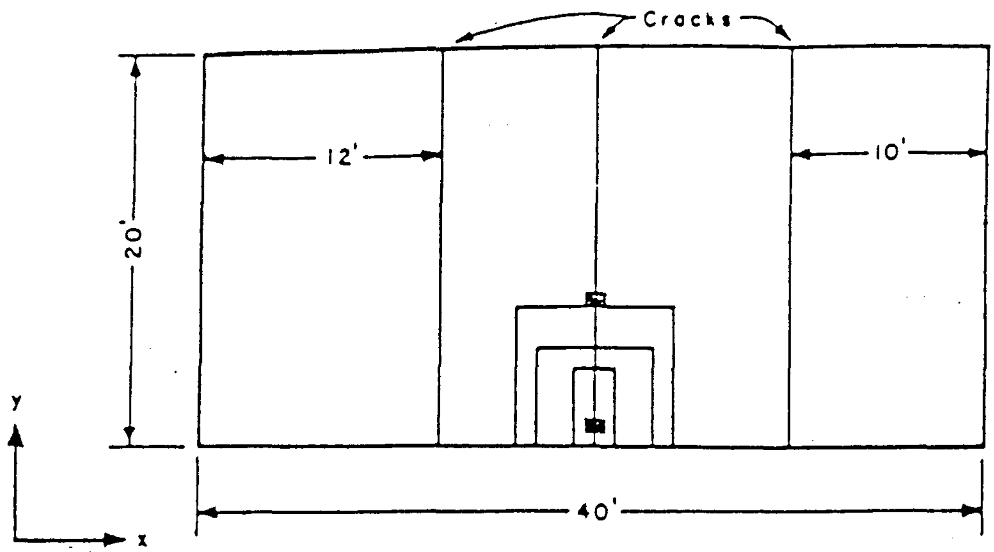


Figure FF.1. Cross sections analyzed to develop relationship between soil support value (S_1) and roadbed soil resilient modulus (E_3 or M_R).



Stiffness in x-Direction Reduced by 75% at the Cracks

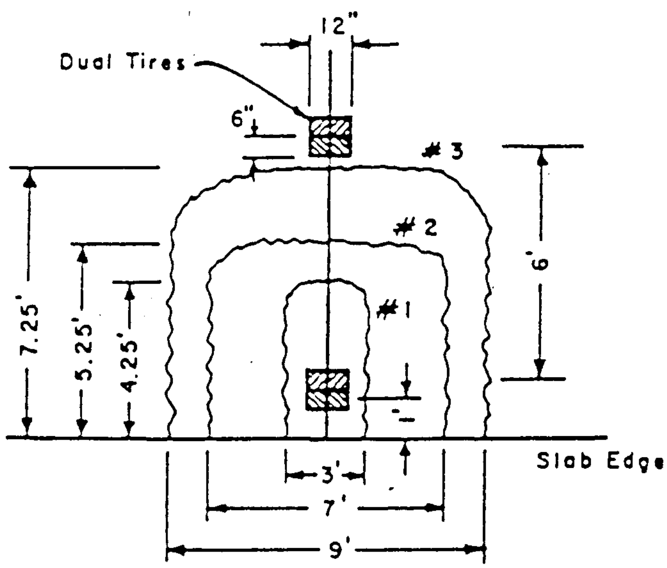
SLAB PROPERTIES

Thickness = 8"

Concrete Modulus = 5 x 10^6 psi

Poisson's Ratio = 0.25

4 Tires are 6000 lbs Each



Void Space	% Area of Slab	Loss of Support Factor
	0.00	0
# 1	1.59	1
# 2	4.59	2
# 3	8.16	3

Figure LL.2. Slab and support conditions for erodability analysis.

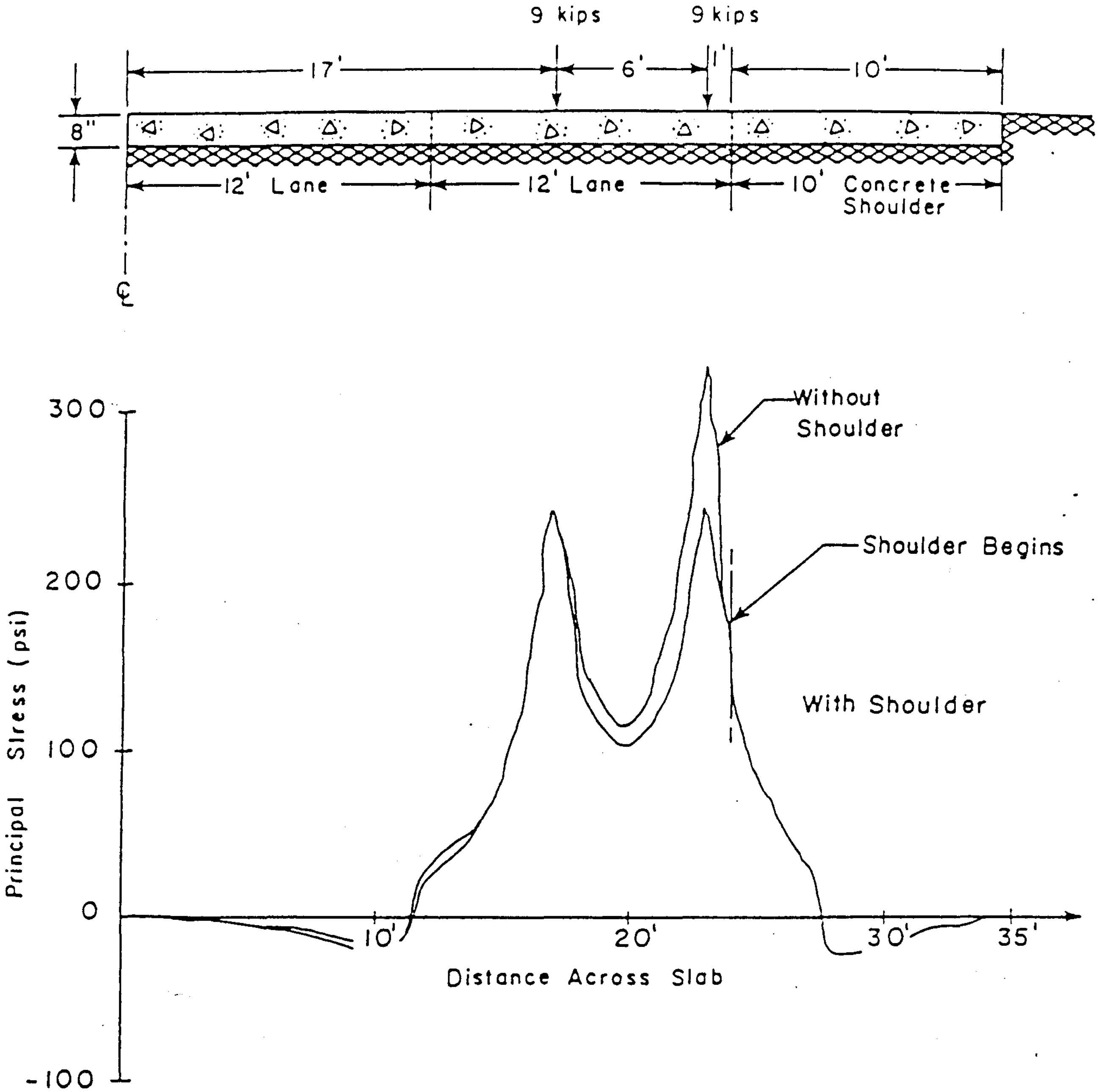
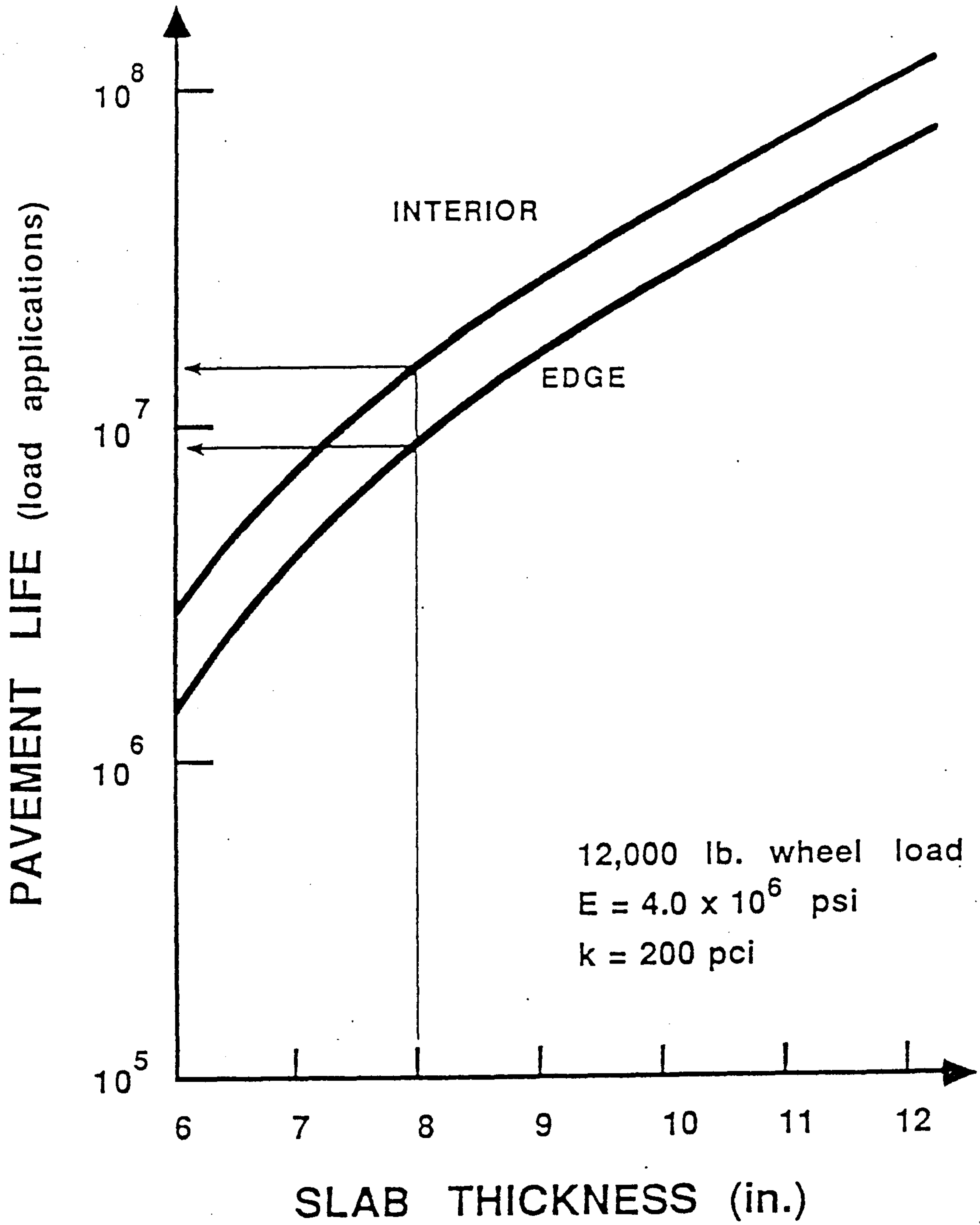
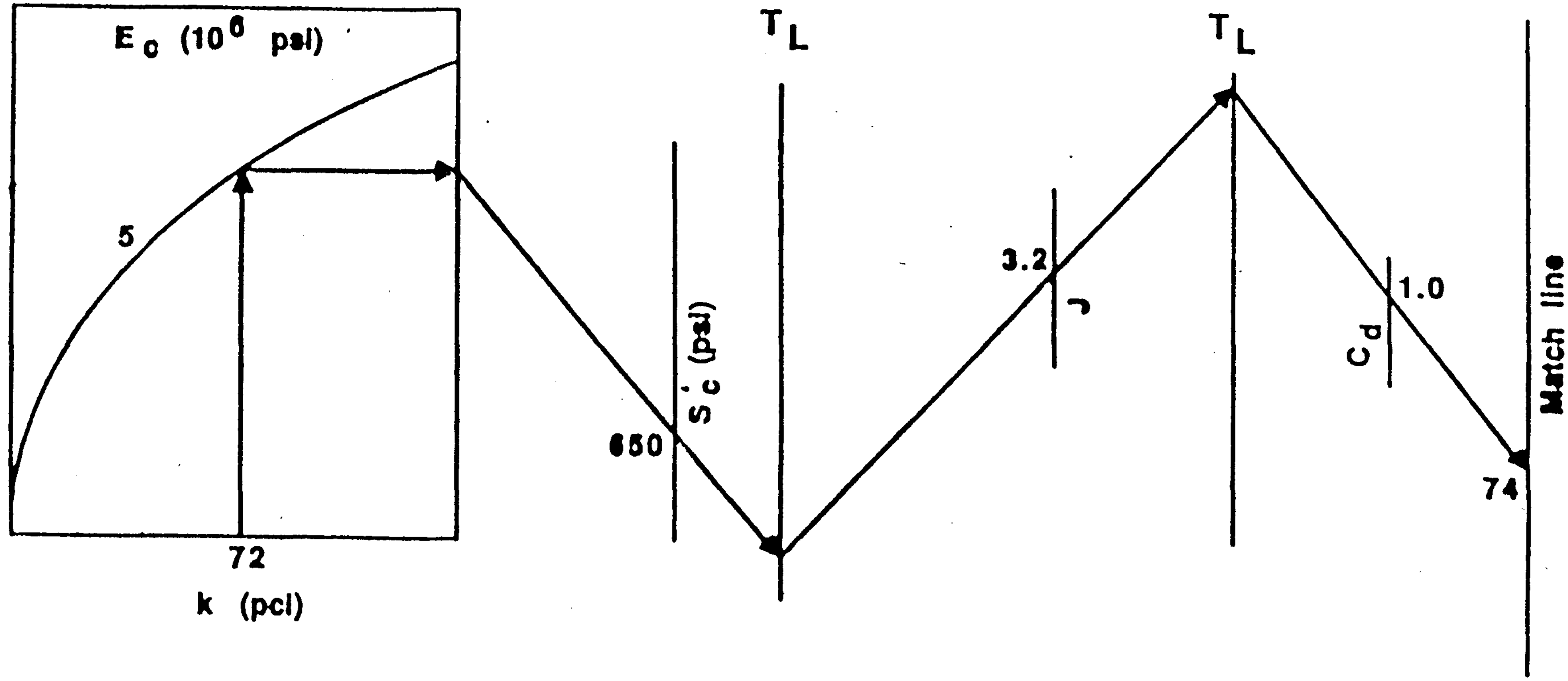


Figure KK.1. Transverse section and stress profile for 8-inch CRCP, with and without concrete shoulders. (7)



PAVEMENT LIFE (load applications)
10^8
10^7
10^6
10^5
INTERIOR
EDGE
12,000 lb. wheel load
E = 4.0 x 10^6 psi
k = 200 pci
6
7
8
9
10
11
12
SLAB THICKNESS (in.)



EXAMPLE

k = 72 pci

$E_c = 5 \times 10^6$ psi

S'_c = 650 psi

J = 3.2

C_d = 1.0

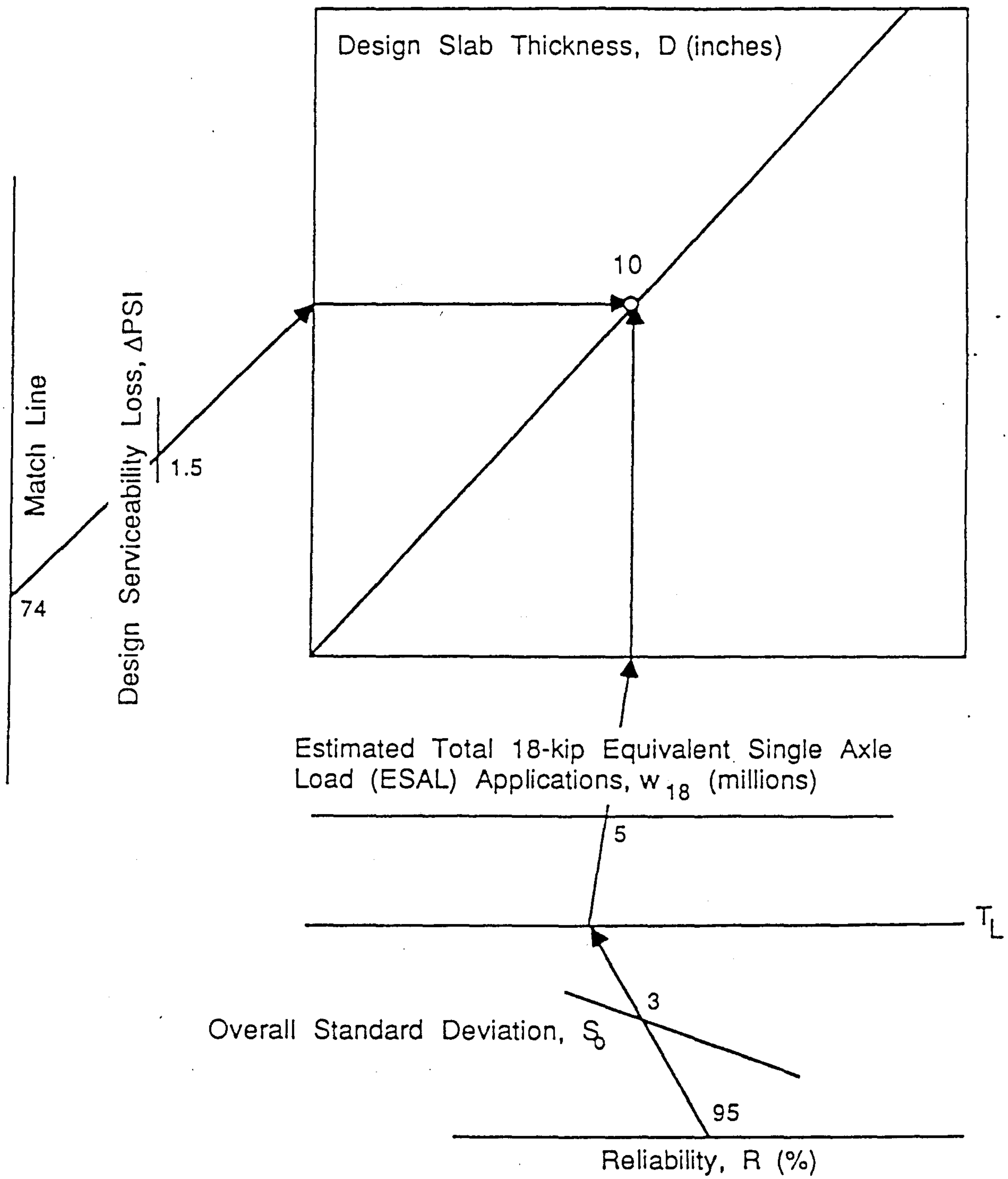
S_o = 0.29

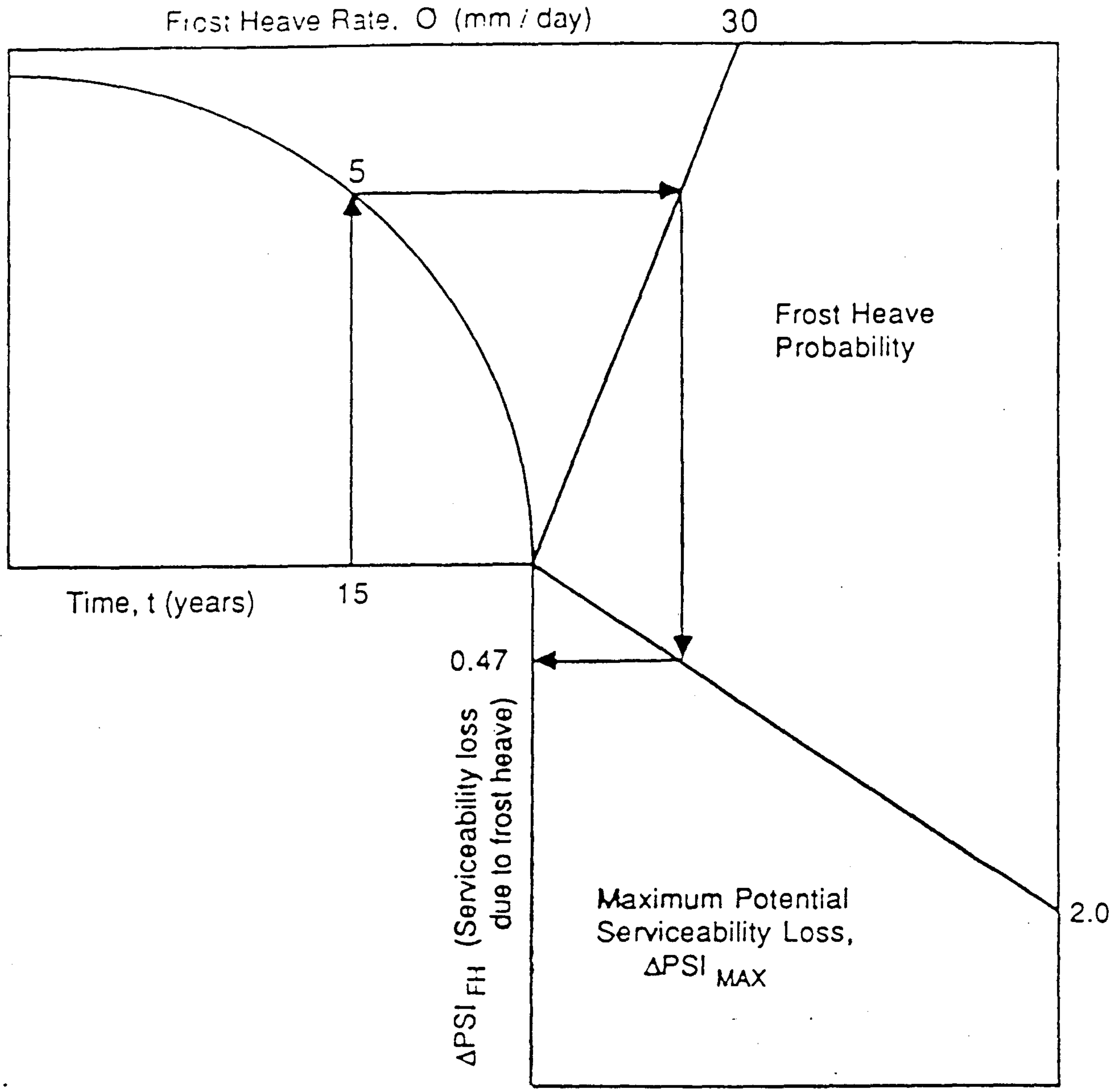
R = 95% (Z_R = -1.645

Δ PSI = 4.2-2.5 = 1.7

$W_{18} = 5.1 \times 10^6$ (18kip ESAL)

Solution: D = 10.0 inches (nearest half-inch, from segment 2)


Design Slab Thickness, D (inches)
10
Match Line
Design Serviceability Loss, ΔPSI
1.5
74
Estimated Total 18-kip Equivalent Single Axle Load (ESAL) Applications, w 18 (millions)
5
TL
3
Overall Standard Deviation, So
95
Reliability, R (%)



<u>**EXAMPLE**</u>

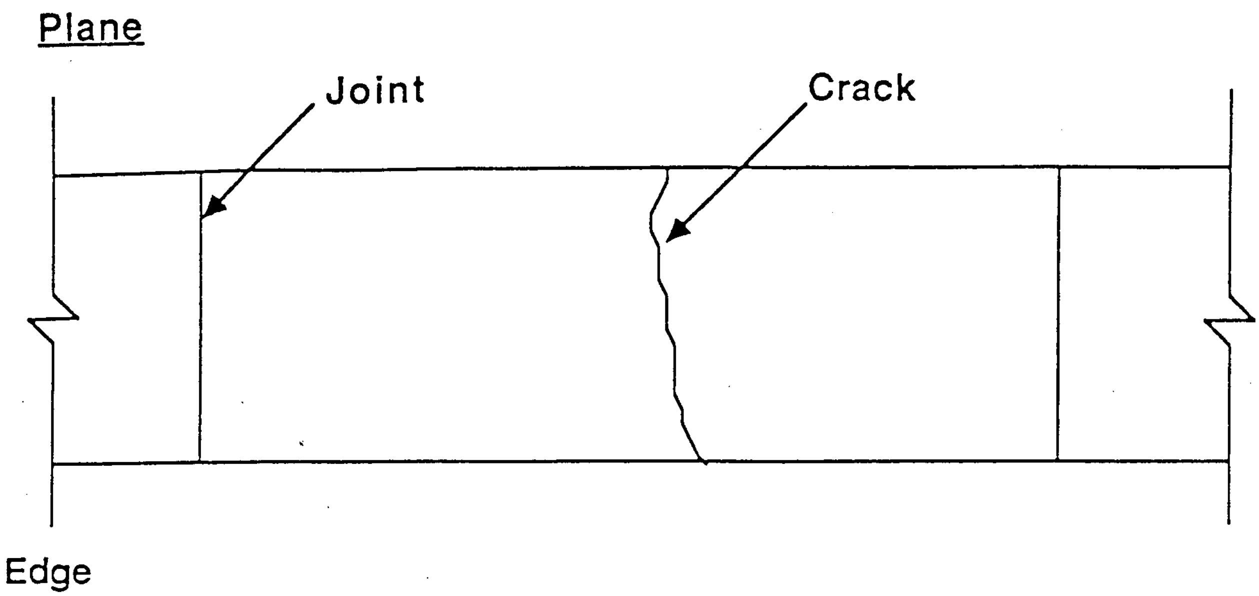
t = 15 years

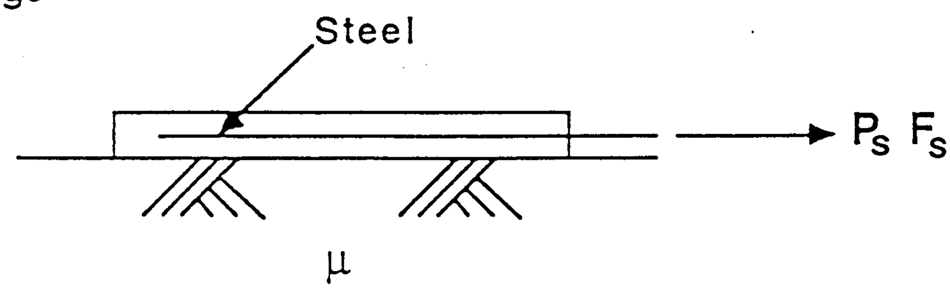
Ø = 5mm / day

P = 30%

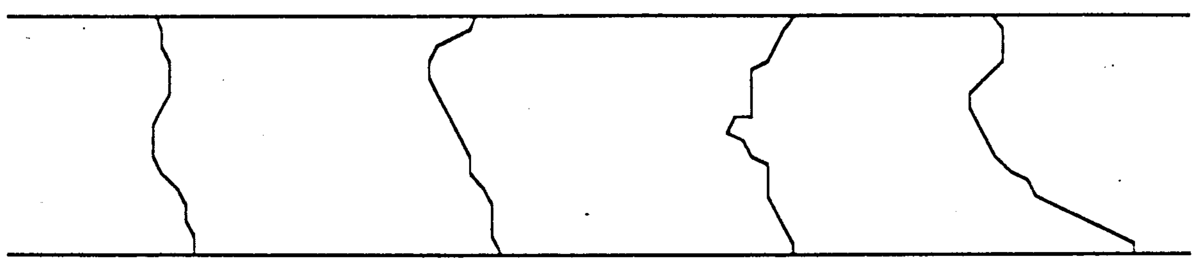
ΔPSI_{MAX} = 2.0

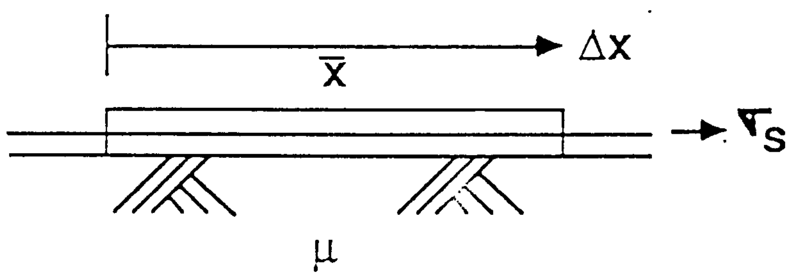
Solution: ΔPSI_{FH} = 0.47





$$F_s = F_{friction}$$





α_c , Z, f_F
α_s
d_B
f_s
ΔT

EXAMPLE

$\overline{X}$ = 3.5 ft.

α_s / α_c = 1.32

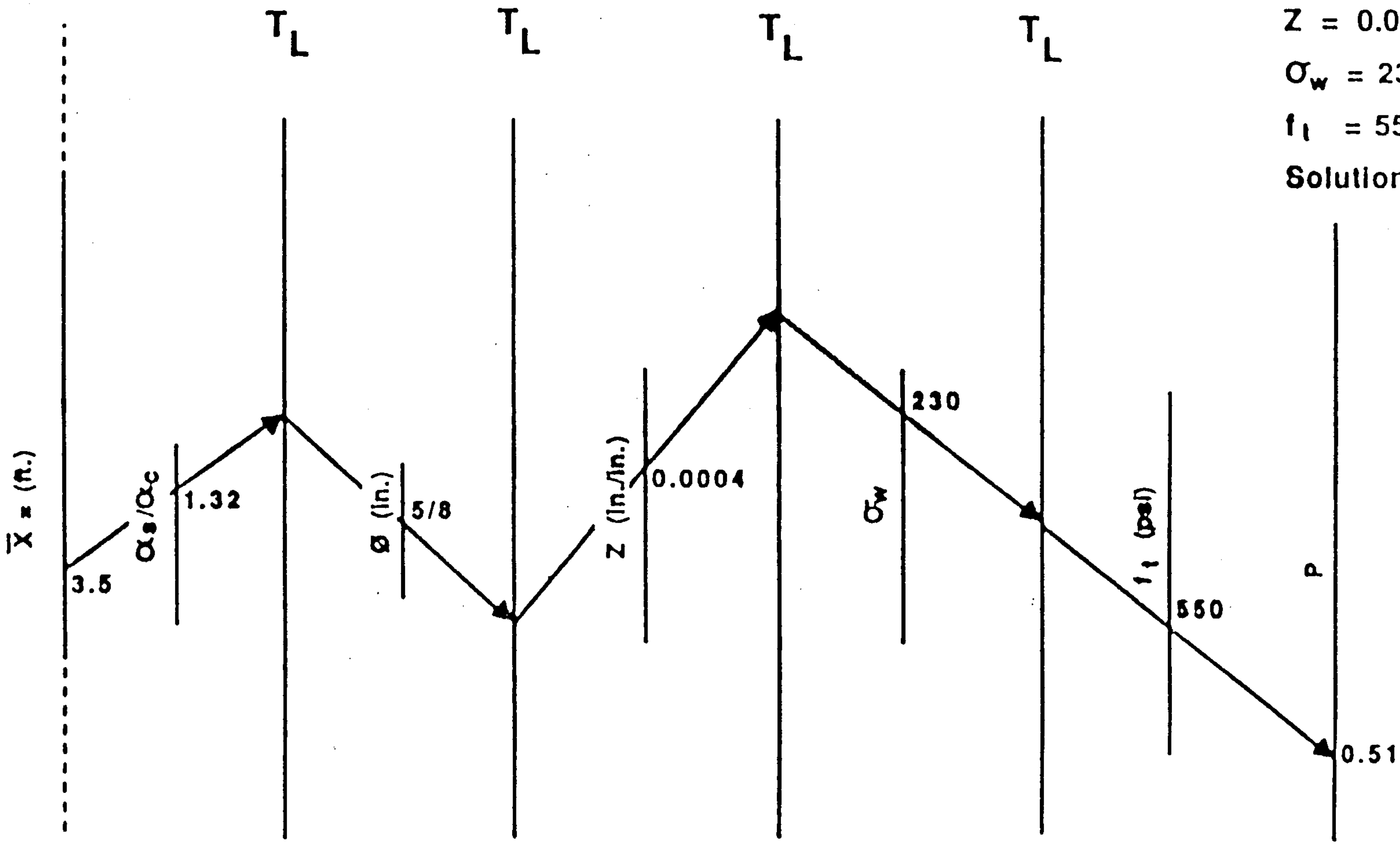
Ø = 5/8 in.

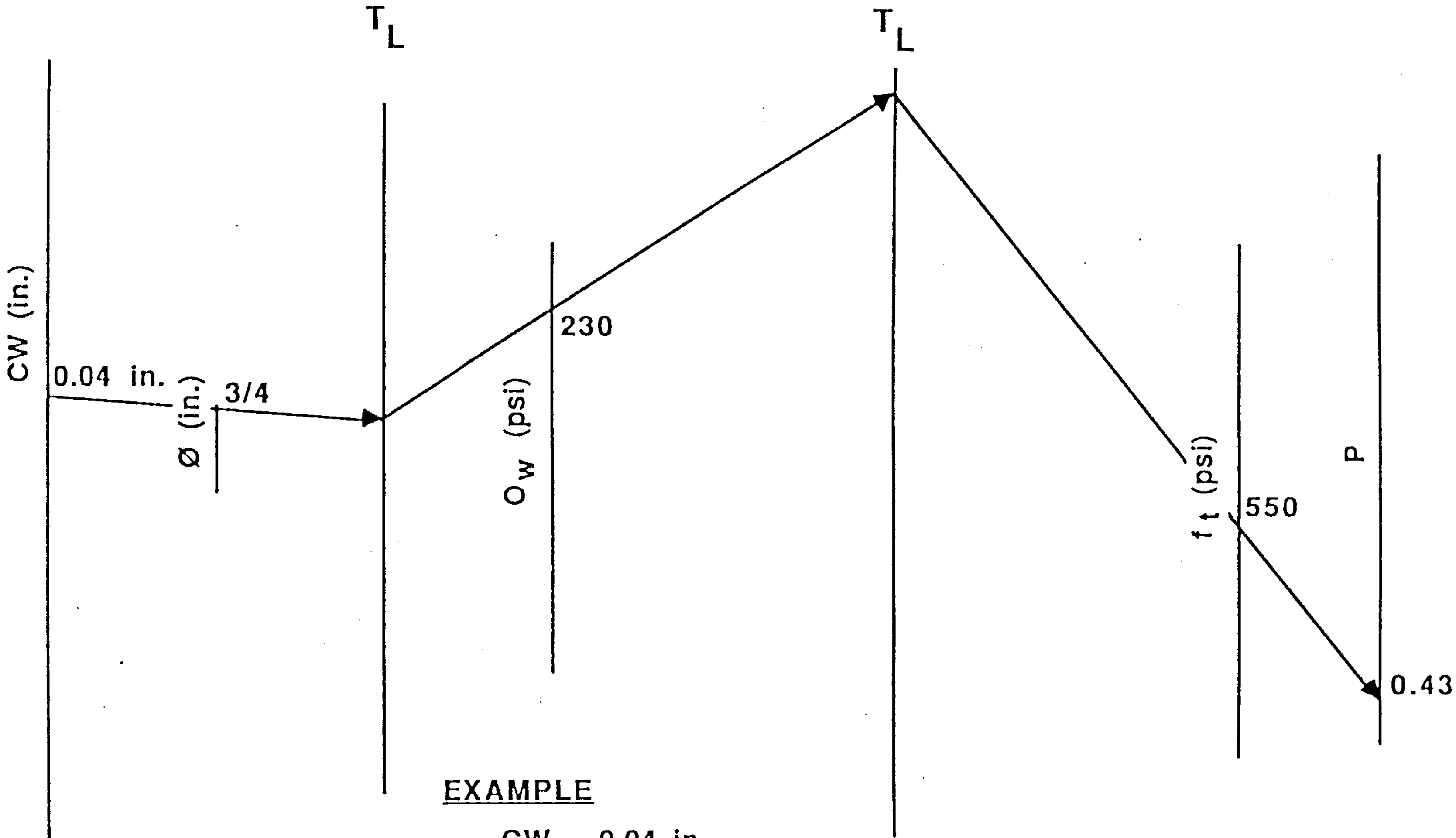
Z = 0.0004

σ_w = 230 psi

f_t = 550 psi

Solution: P = 0.51%





<u>EXAMPLE</u>

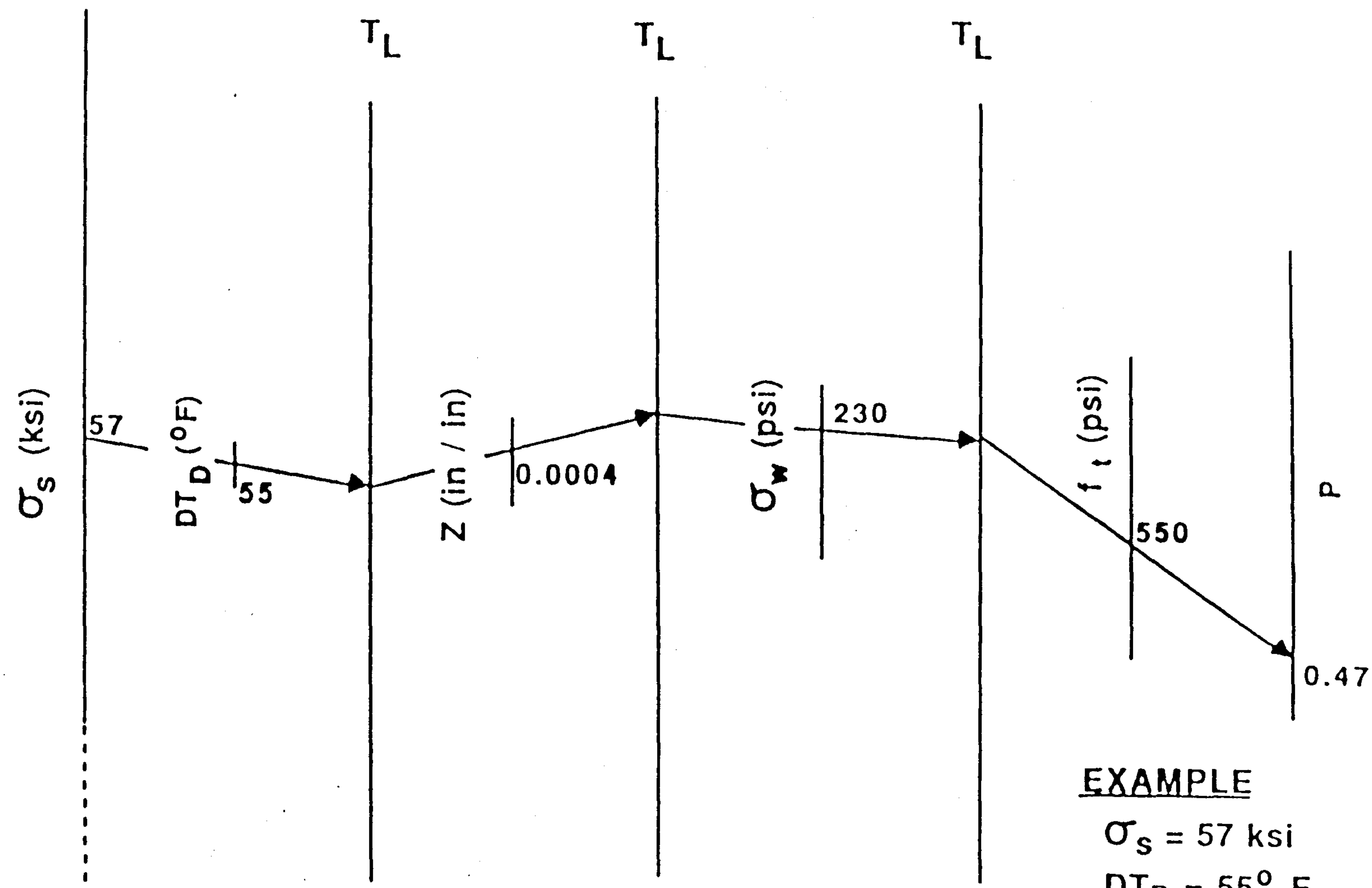
CW = 0.04 in.

Ø = 3/4 in.

O_W = 230 psi

f_t = 550 psi

Solution: P = 0.43%



EXAMPLE

σ_s = 57 ksi

DT_D = 55° F

Z = 0.0004

σ_w = 230 psi

f_t = 550 psi

Solution: P = 0.47%

SESSION 5

Session 5

Rehabilitation of Flexible and Rigid Pavements With Concrete Overlays

Objective

The objective of this session is to provide an understanding of the rigid pavement overlay design methodology. The intent to provide the student with both a basic understanding of the concepts involved as well as the techniques for solving his specific design problem.

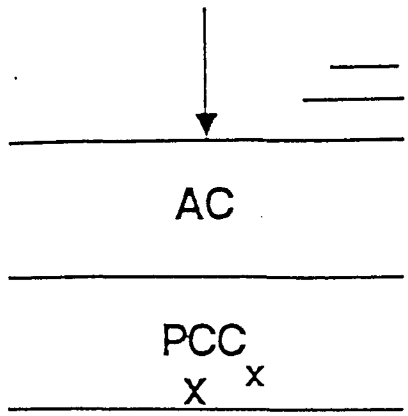
Outline

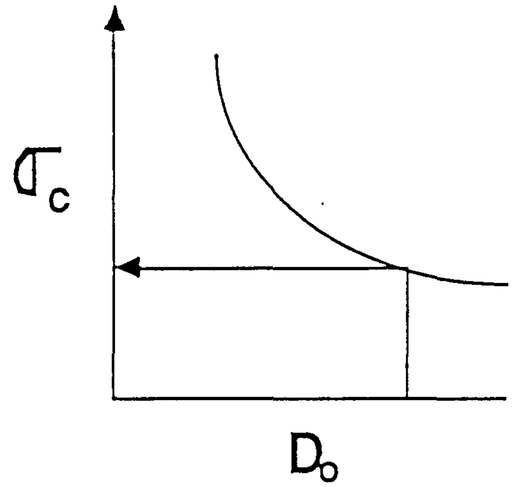
The subjects to be covered in this session include the following:

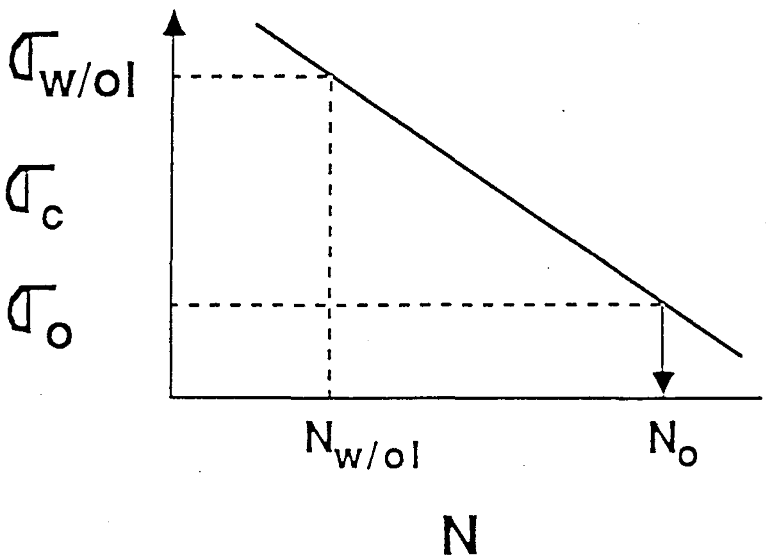
1. Methodology
2. A review of the unit delineation and remaining life concepts.
3. Rigid overlays on existing flexible overlays.
4. Use of recycled materials.
5. Use of milling procedures.

Reference

The material covered in this section is included in Part III, Chapter 5 with specific emphasis on sections 5.3.3 and 5.3.4. The material in Appendices M and N will also be used in the presentations.

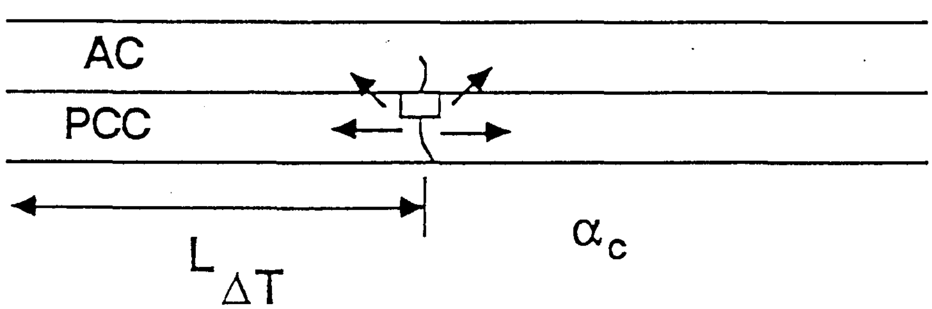






$$\frac{n_{w/ol}}{N_{w/ol}} + \frac{n_o}{N_o} \leq 1$$

$$R_L = 1 - \frac{n_{w/ol}}{N_{w/ol}}$$



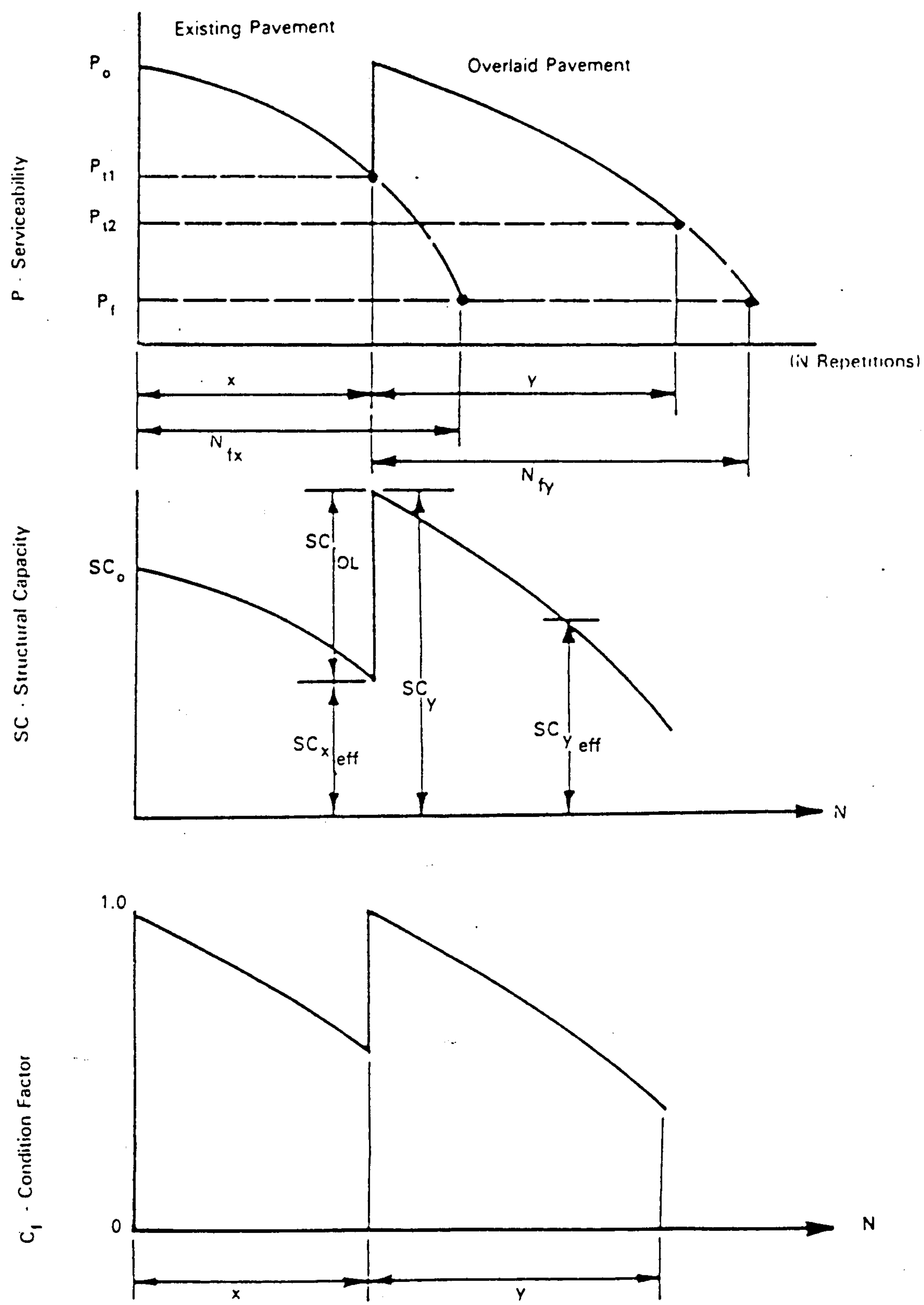


Figure 5.1. Relationship between serviceability—capacity condition factor and traffic.

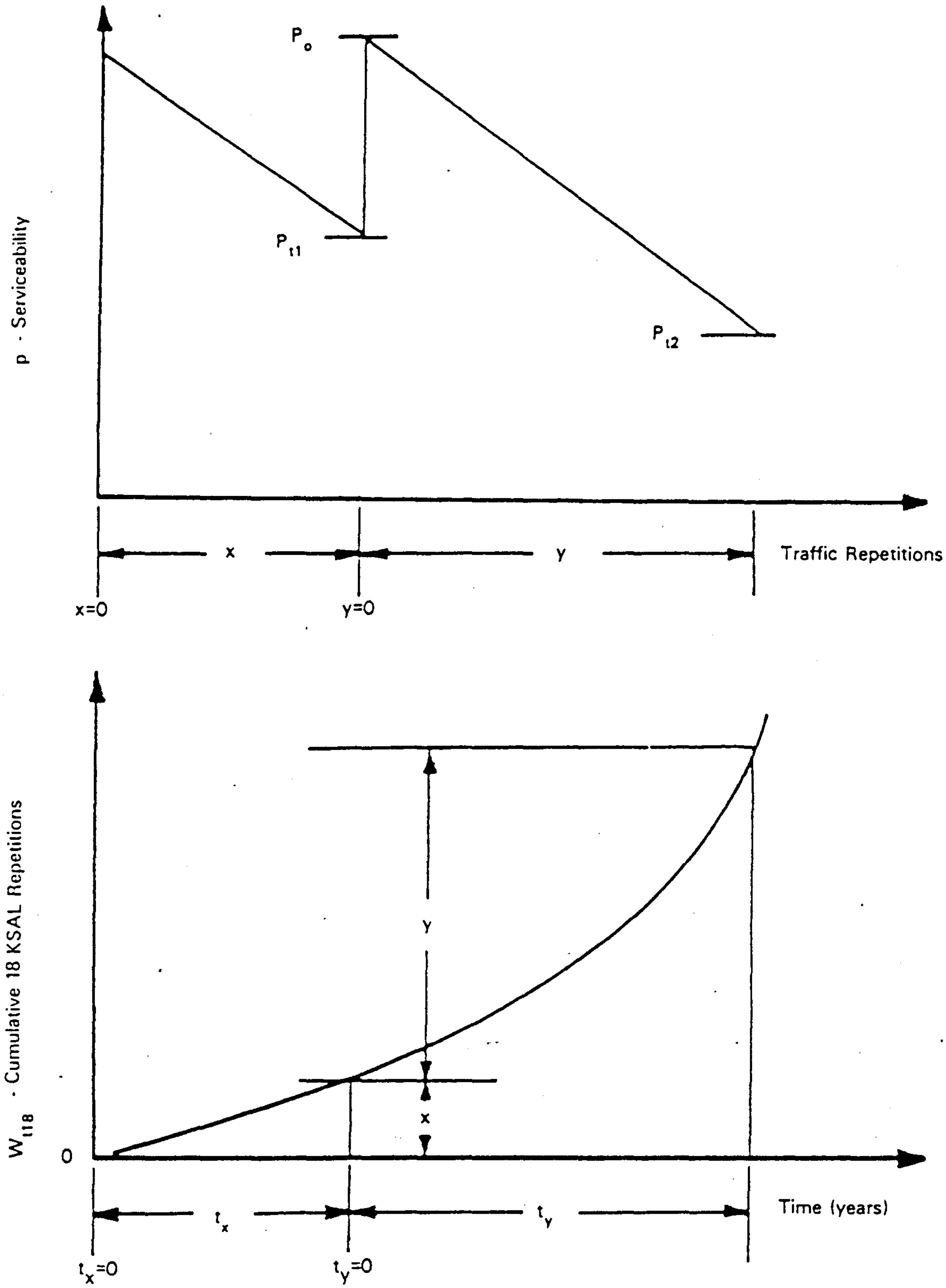


Figure 5.3. Appropriate serviceability—traffic repetition—time curves used in traffic analysis step.

Table 5.1. Specific overlay equation form utilized.

General Structural Capacity Form: $SC_{OL}^{n} = SC_{y}^{n} - F_{RL}(SC_{xeff})^{n}$

Type Overlay	Type Existing Pavement	Specific Equation	Conditions/Remarks
Flexible	Flexible	$SN_{OL} = SN_{y} - F_{RL}SN_{xeff}$	SC = SN; n = 1.0
Flexible	Rigid	$SN_{OL} = SN_{y} - F_{RL}SN_{xeff}$	SC = SN; n = 1.0 (see Section 5.3.3 for specific equations used)
Rigid	Flexible	$D_{OL} = D_{y}$ (see remarks)	Treat overlay analysis as new rigid pavement design using existing flexible pavement as new foundation (subgrade)
Rigid	Rigid	$D_{OL} = D_{y} - F_{RL}(D_{xeff})$	SC = D; n = 1.0 (Bonded Overlay)
		$D_{OL}^{1.4} = D_{y}^{1.4} - F_{RL}(D_{xeff})^{1.4}$	SC = D; n = 1.4 (Partial Bond Overlay)
		$D_{OL}^{2} = D_{y}^{2} - F_{LR}(D_{xeff})^{2}$	SC = D; n = 2.0 (Unbonded Overlay)

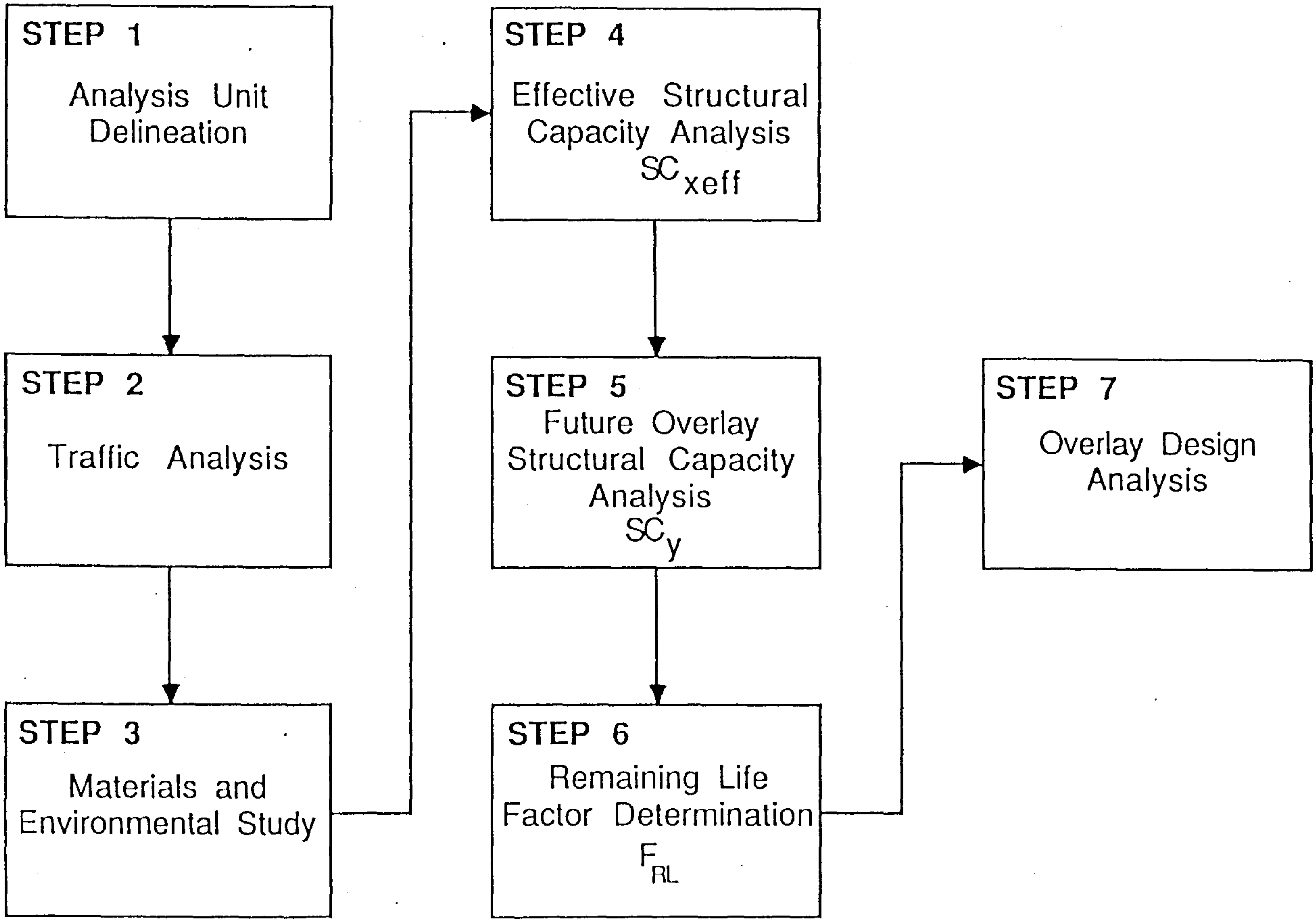


Figure 2.5. Required overlay design steps.

	② Traffic	③ Materials	④ (SC_{eff})	⑤ (SC_y)	⑥ (F_{RL})	⑦ O/L
	N_{fy} y			R_{LY}		
NDT		E_{PCC}	Fig. 5.8 $D_{eff} \rightarrow C_y$ Fig. 5.13		Fig. 5.17	Table 5.5
Traffic	N_{fx} X		$R_{LX} = (1 - \frac{X}{N_{fx}})$		"	"
Time	Ages		Fig. 5.14		"	"
PSI						
Condition		P_t	Fig. 5.15		"	"
		Table 5.3	Fig. 5.13		"	"

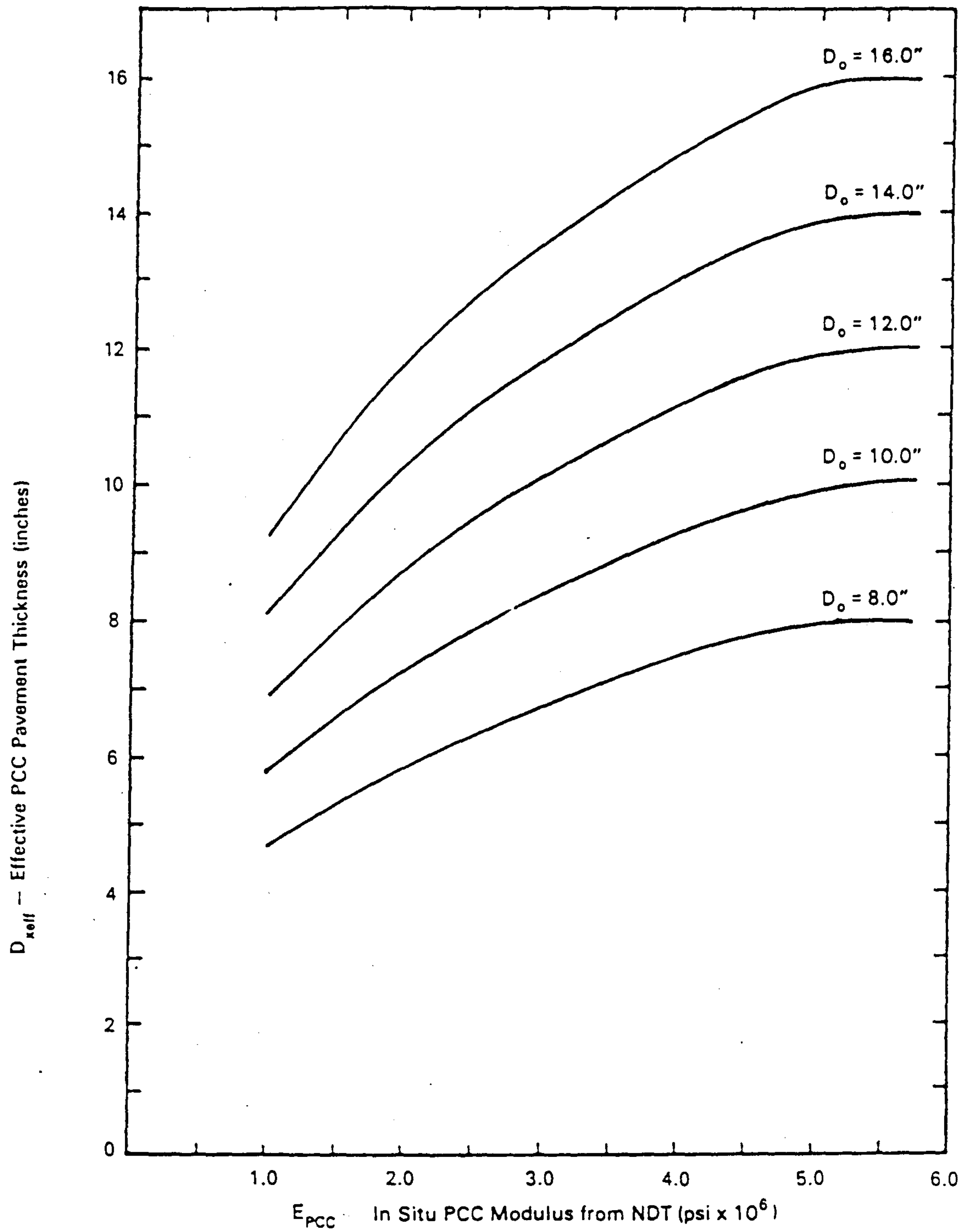


Figure 5.8. Determination of effective PCC structural capacity (thickness) from NDT-derived PCC modulus.

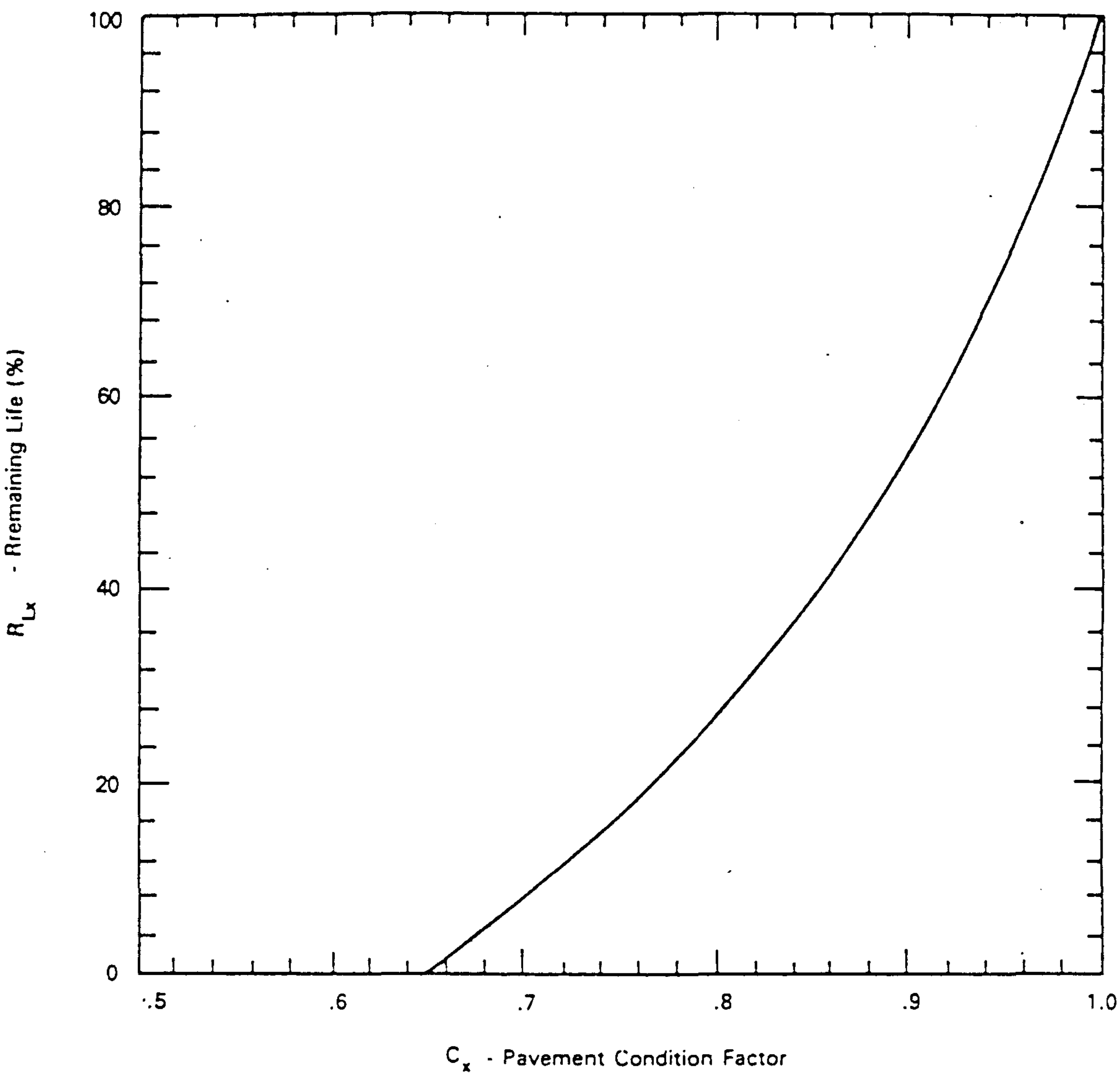


Figure 5.13. Remaining life estimate predicted from pavement condition factor.

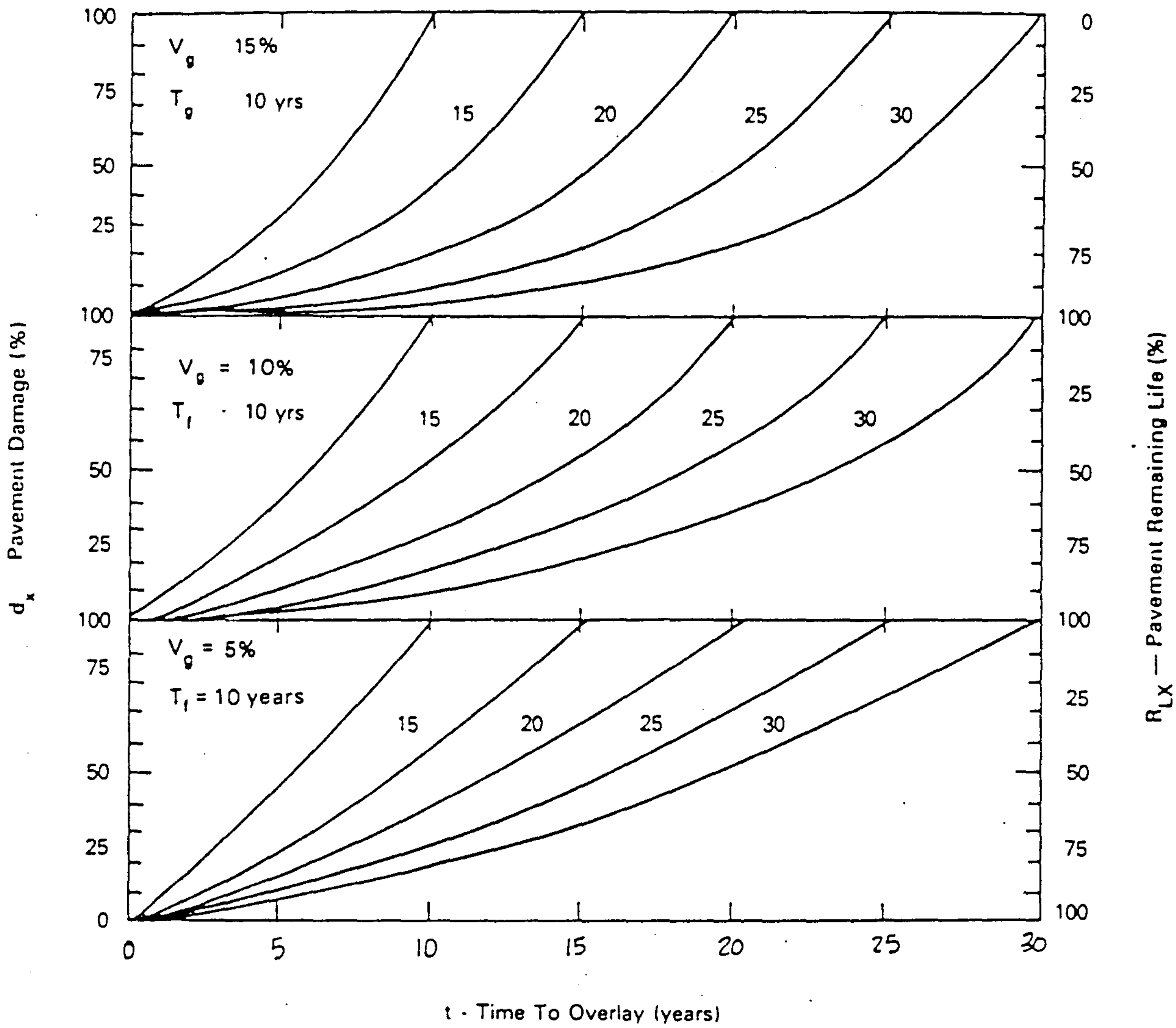


Figure 5.14. Remaining life estimate based on time considerations for various traffic growth rates.

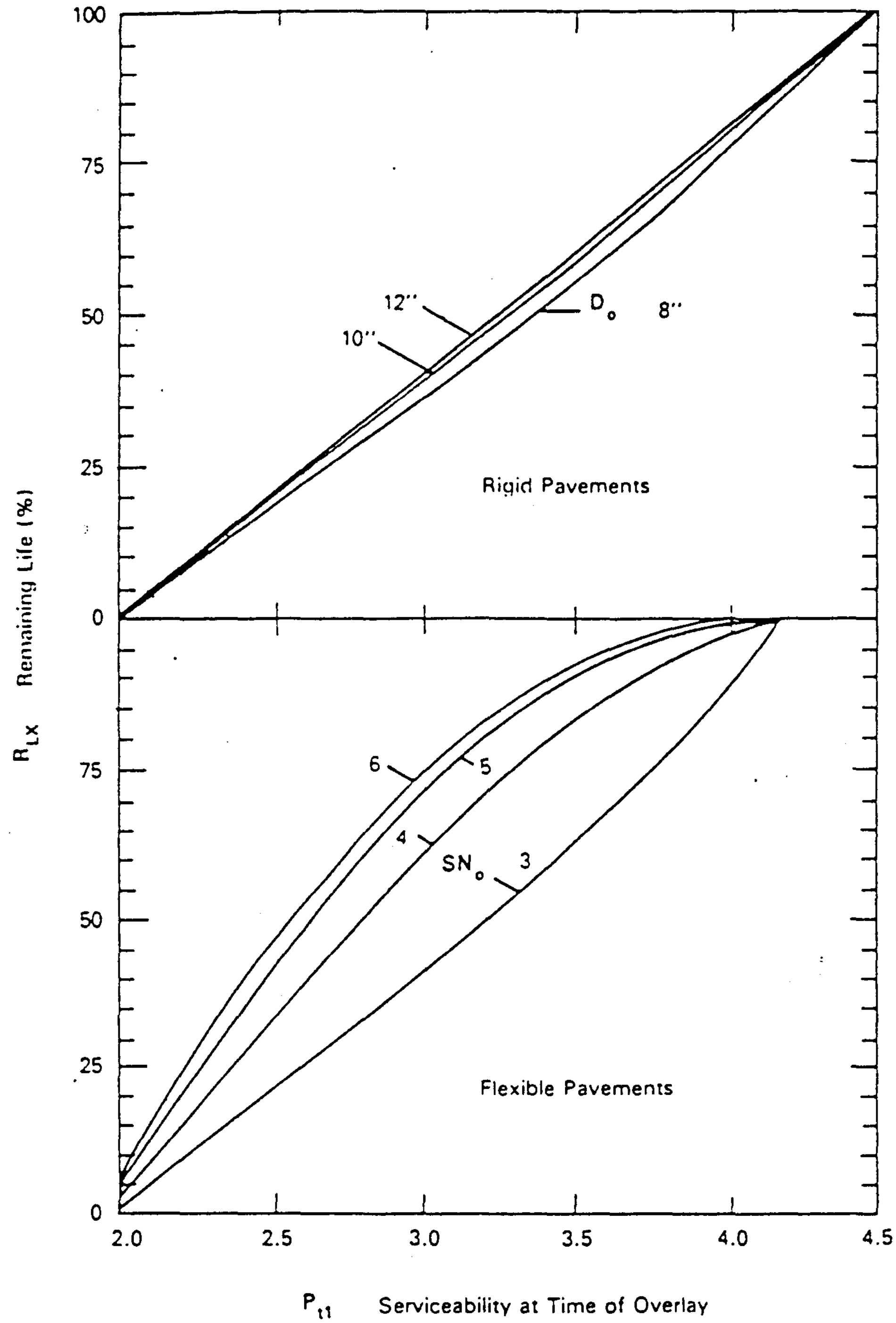


Figure 5.15. Remaining life estimate based on present serviceability value and pavement cross section.

Table 5.3. Summary of visual (C_v) and structural (C_x) condition values.

Layer Type	Pavement Condition	C_v Visual Condition Factor Range	C_x Struct Cond Factor Value
Asphaltic	1. Asphalt layers that are sound, stable, uncracked and have little to no deformation in the wheel paths	0.9-1.0	.95
	2. Asphalt layers that exhibit some intermittent cracking with slight to moderate wheel path deformation but are still stable.	0.7-0.9	.85
	3. Asphalt layers that exhibit some moderate to high cracking, have ravelling or aggregate degradation and show moderate to high deformations in wheel path	0.5-0.7	.70
	4. Asphalt layers that show very heavy (extensive) cracking, considerable ravelling or degradation and very appreciable wheel path deformations	0.3-0.5	.60
PCC	1. PCC pavement that is uncracked, stable and undersealed, exhibiting no evidence of pumping	0.9-1.0	.95
	2. PCC pavement that is stable and undersealed but shows some initial cracking (with tight, non working cracks) and no evidence of pumping	0.7-0.9	.85
	3. PCC pavement that is appreciably cracked or faulted with signs of progressive crack deterioration: slab fragments may range in size from 1 to 4 sq.yds., pumping may be present	0.5-0.7	.70
	4. PCC pavement that is very badly cracked or shattered into fragments 2-3 ft. in maximum size	0.3-0.5	.60
Pozzolanic Base/ Subbase	1. Chemically stabilized bases (CTB, LCF...) that are relatively crack free, stable and show no evidence of pumping	0.9-1.0	.95
	2. Chemically stabilized bases (CTB, LCF...) that have developed very strong pattern or fatigue cracking, with wide and working cracks that are progressive in nature: evidence of pumping or other causes of instability may be present	0.3-0.5	.60
Granular Base/ Subbase	1. Unbound granular layers showing no evidence of shear or densification distress, reasonably identical physical properties as when constructed and existing at the same "normal" moisture - density conditions as when constructed	0.9-1.0	.95
	2. Visible evidence of significant distress within layers (shear or densification), aggregate properties have changed significantly due to abrasion, intrusion of fines from subgrade or pumping, and/or significant change in in situ moisture caused by surface infiltration or other sources	0.3-0.5	.60

Special Notes:

1. The visual condition factor, C_v is related to the structural condition factor, C_x by:

$$C_v = C_x^2$$

2. The structural condition factor, C_x and *not* the C_v value, is the variable used in the structural overlay design equation (for all overlay-existing pavement types). It is defined by:

$$SC_{xeff} = C_x SC_o$$

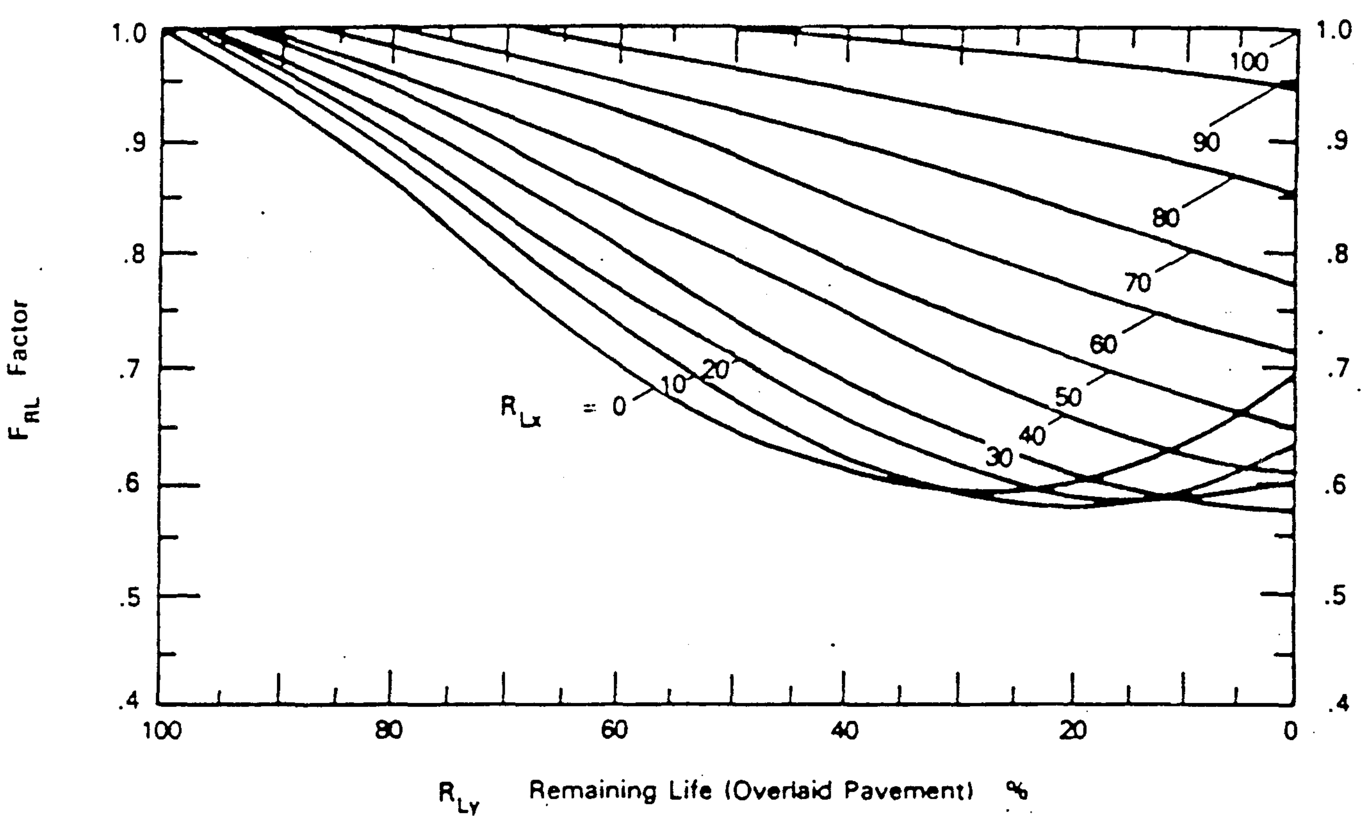


Figure 5.17. Remaining life factor as a function of remaining life of existing and overlaid pavements.

Table 5.5. Summary of overlay equations used in flexible overlay over existing rigid pavement analysis.

Major Overlay Condition	Specific Method Used	SN_{ol} Equation
Normal Structural Overlay	NDT Method 1	$SN_{ol} = SN_y - F_{RL}(0.8\ D_{xeff} + SN_{xeff-rp})$
	NDT Method 2	$SN_{ol} = SN_y - F_{RL} SN_{xeff}$
	Visual Condition Factor	$SN_{ol} = SN_y - F_{RL}(\ a_{2r} D_o\ +\ SN_{xeff-rp}$
Break-Seat Overlay	Estimating Nominal Crack Spacing	$SN_{ol} = SN_y - 0.7(\ 0.4\ D_o\ + SN_{xeff-rp})^*$
	Post Cracking NDT	
	(a)NDT Method 1	$SN_{ol} = SN_y - 0.7(\ a_{bs}\ D_o\ + SN_{xeff-rp})$
	(b) NDT Method 2	$SN_{ol} = SN_y - 0.7\ SN_{xeff}$

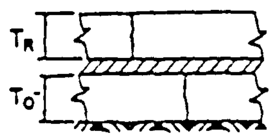
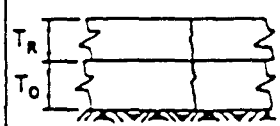
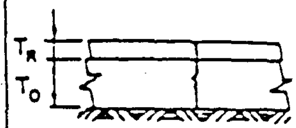
Special Note: The coefficient of D_o (ie.,0.4) actually varies from 0.35 for a nominal crack spacing of approximately 2.0 ft. to a value of 0.45 for a nominal crack spacing of approximately 3.0 ft.

Table 5.6. Minimum asphalt concrete structural overlay thickness for PCC Pavements (from the Asphalt Institute MS-17).

Existing PCC Slab Length (ft)	h_{ol} (min - inches) Maximum Annual Temperature Differential (°F)					
	30	40	50	60	70	80
10	4	4	4	4	4	4
15	4	4	4	4	4	4
20	4	4	4	4	5	5.5
25	4	4	4	5	6	7
30	4	4	5	6	7	8
35	4	4.5	6	7	8.5	*
40	4	5.5	7	8	*	*
45	4.5	6	7.5	9	*	*
50	5	7	8.5	*	*	*
60	6	8	*	*	*	*

*Alternate other than thickness of AC overlay should definitely be considered to minimize reflective cracking.

Table 5.8. Summary of concrete overlays on existing concrete pavements.

	UNBONDED OR SEPARATED OVERLAY	PARTIALLY BONDED OR DIRECT OVERLAY	BONDED OR MONOLITHIC OVERLAY
TYPE OF OVERLAY			
PROCEDURE	CLEAN SURFACE DEBRIS AND EXCESS JOINT SEAL PLACE SEPARATION COURSE-PLACE OVERLAY CONCRETE.	CLEAN SURFACE DEBRIS AND EXCESS JOINT SEAL AND REMOVE EXCESSIVE OIL AND RUBBER-PLACE OVERLAY CONCRETE	SCARIFY ALL LOOSE CONCRETE, CLEAN JOINTS, CLEAN AND ACID ETCH SURFACE - PLACE BONDING GROUT AND OVERLAY CONCRETE.
MATCHING OF JOINTS IN OVERLAY & PAVEMENT — LOCATION	NOT NECESSARY	REQUIRED	REQUIRED
MATCHING OF JOINTS IN OVERLAY & PAVEMENT — TYPE	NOT NECESSARY	NOT NECESSARY	REQUIRED
REFLECTION OF UNDERLYING CRACKS TO BE EXPECTED	NOT NORMALLY	USUALLY	YES
REQUIREMENT FOR STEEL REINFORCEMENT	REQUIREMENT IS INDEPENDENT OF THE STEEL IN EXISTING PAVEMENT OR CONDITION OF EXISTING PAVEMENT.	REQUIREMENT IS INDEPENDENT OF THE STEEL IN EXISTING PAVEMENT. STEEL MAY BE USED TO CONTROL CRACKING WHICH MAY BE CAUSED BY LIMITED NON-STRUCTURAL DEFECTS IN PAVEMENT.	NORMALLY NOT USED IN THIN OVERLAYS. IN THICKER OVERLAY STEEL MAY BE USED TO SUPPLEMENT STEEL IN EXISTING PAVEMENT.
T_R SHOULD BE BASED ON THE FLEXURAL STRENGTH OF	OVERLAY CONCRETE	OVERLAY CONCRETE	EXISTING CONCRETE
MINIMUM THICKNESS	6"	5"	1"
APPLICABILITY OF VARIOUS OVERLAY TYPES — STRUCTURAL CONDITION OF EXISTING PAVEMENT — NO STRUCTURAL DEFECTS C = 1.0*	YES	YES	YES
APPLICABILITY OF VARIOUS OVERLAY TYPES — STRUCTURAL CONDITION OF EXISTING PAVEMENT — LIMITED STRUCT. DEFECTS C = 0.75*	YES	ONLY IF DEFECTS CAN BE REPAIRED	ONLY IF DEFECTS CAN BE REPAIRED
APPLICABILITY OF VARIOUS OVERLAY TYPES — STRUCTURAL CONDITION OF EXISTING PAVEMENT — SEVERE STRUCT DEFECTS C = 0.35*	YES	NO	NO
APPLICABILITY OF VARIOUS OVERLAY TYPES — SURFACE CRACKS, SCALING, SPALLING AND SHRINKAGE CRACKS — NEGLIGIBLE	YES	YES	YES
APPLICABILITY OF VARIOUS OVERLAY TYPES — SURFACE CRACKS, SCALING, SPALLING AND SHRINKAGE CRACKS — LIMITED	YES	YES	YES
APPLICABILITY OF VARIOUS OVERLAY TYPES — SURFACE CRACKS, SCALING, SPALLING AND SHRINKAGE CRACKS — EXTENSIVE	YES	NO	YES

* C VALUES APPLY TO STRUCTURAL CONDITION ONLY, AND SHOULD NOT BE INFLUENCED BY SURFACE DEFECTS.

SESSION 6

Session 6

Implementation Guidelines

Objective

The primary objective of this session is to encourage the attendees to implement the Guides and provide basic procedural guidelines for an agency to implement the new concepts. Illustrative examples of the procedures that may be used by the States will be provided.

Outline

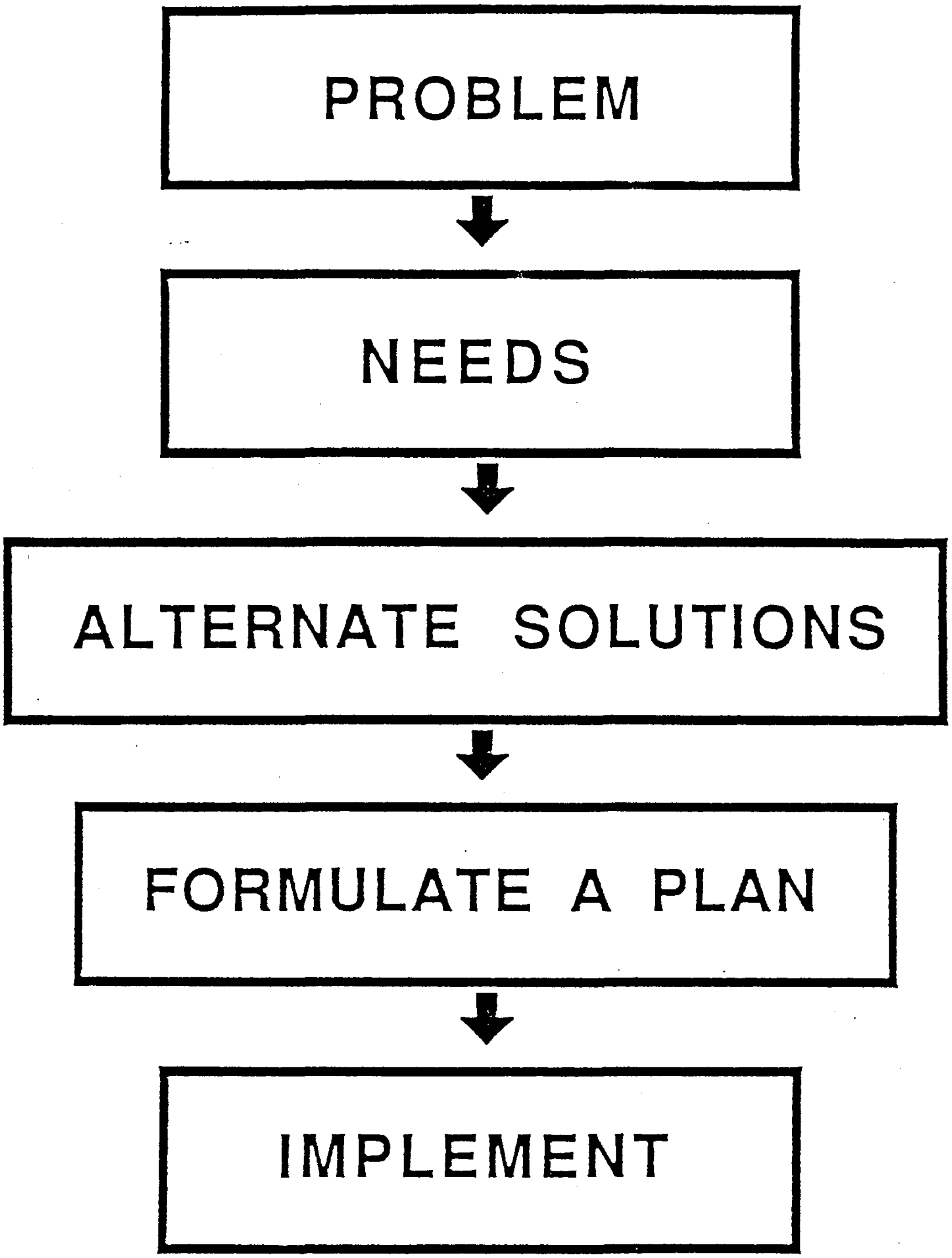
This session will be primarily covered by a slide show. The primary topics to be covered as to implementation are as follows:

1. The basic problems will be defined.
2. The agency needs will be outlined.
3. The alternate approaches or solutions will be covered.
4. A basic sample plan will be formulated to illustrate the concepts involved.
5. The need for implementation will be emphasized.

After the session closes, the student will be asked to complete and submit the training course evaluation form.

Reference

The reading assignment for supporting the information provided in this session will be the Preface and Executive Summary of the Guide.

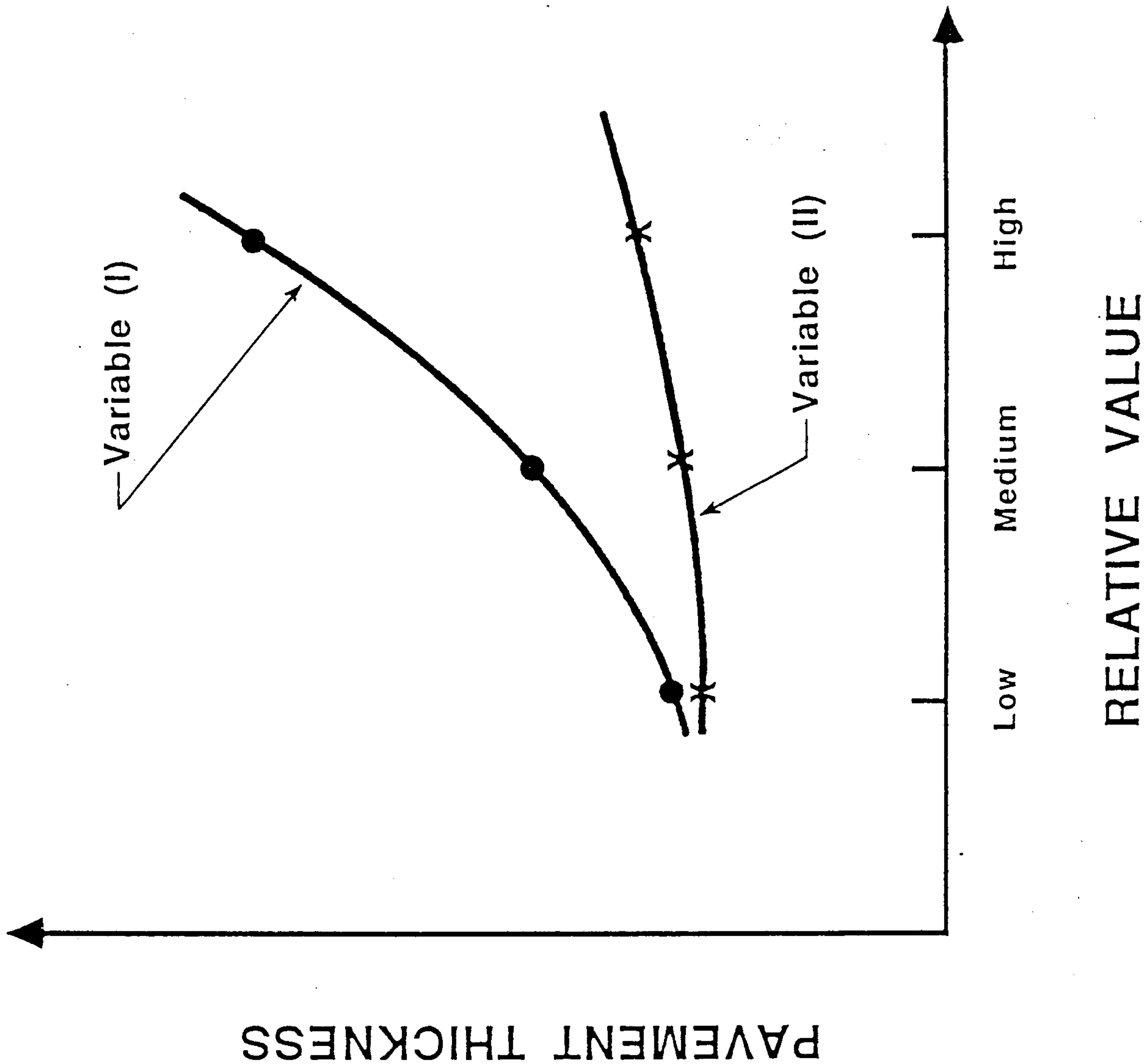

PROBLEM
NEEDS
ALTERNATE SOLUTIONS
FORMULATE A PLAN
IMPLEMENT

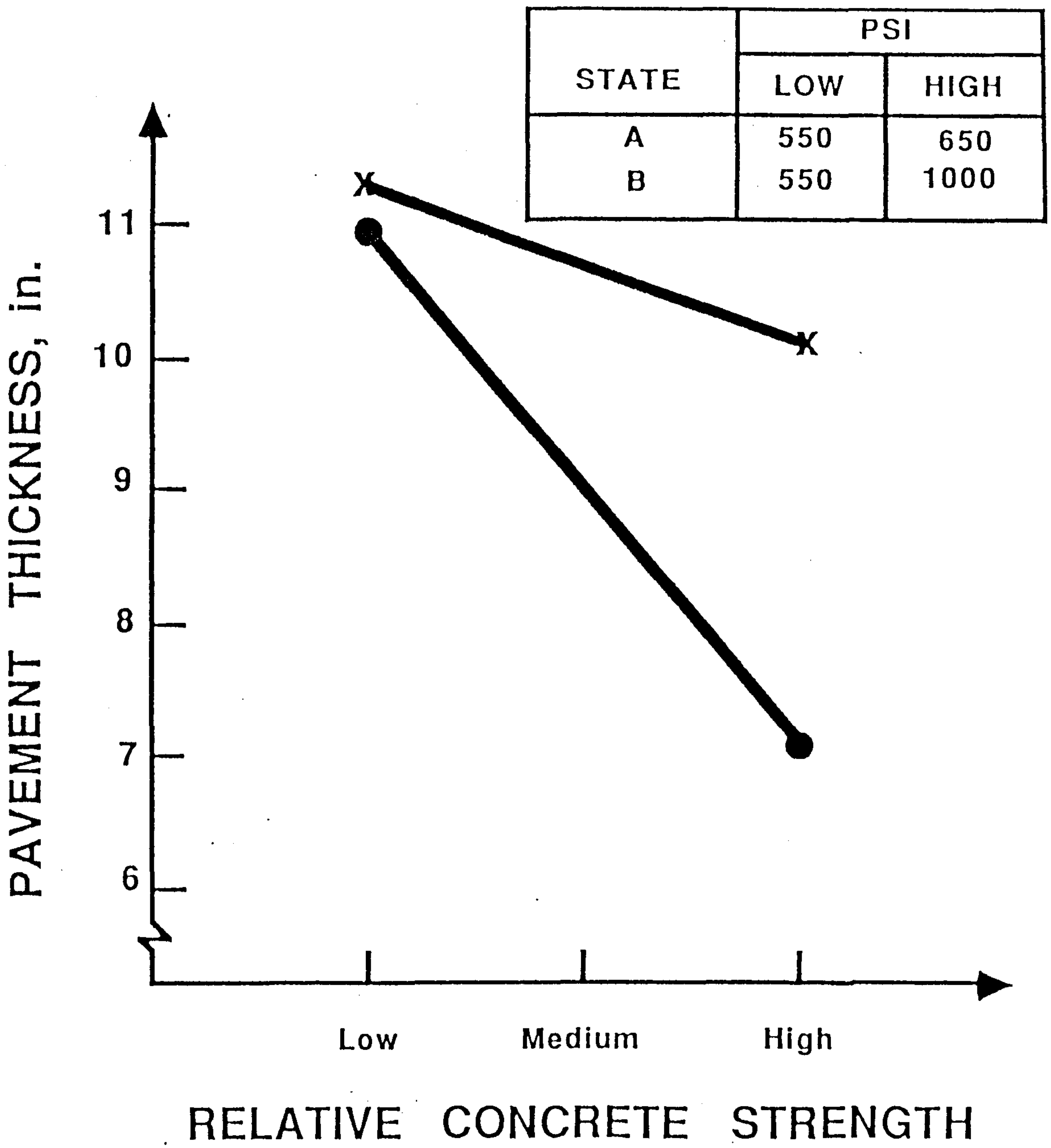
Improvements to the Guide

1. RELIABILITY
2. M_R FOR SOILS
3. M_R FOR LAYER COEFFICIENTS
4. DRAINAGE
5. ENVIRONMENT
6. LOAD POSITION
7. SUBBASE EROSION
8. LIFE CYCLE COSTS
9. REHABILITATION
10. PAVEMENT MANAGEMENT
11. LOAD EQUIVALENCIES
12. TRAFFIC DATA
13. LOW VOLUME ROADS
14. MECHANISTIC / EMPIRICAL DESIGN

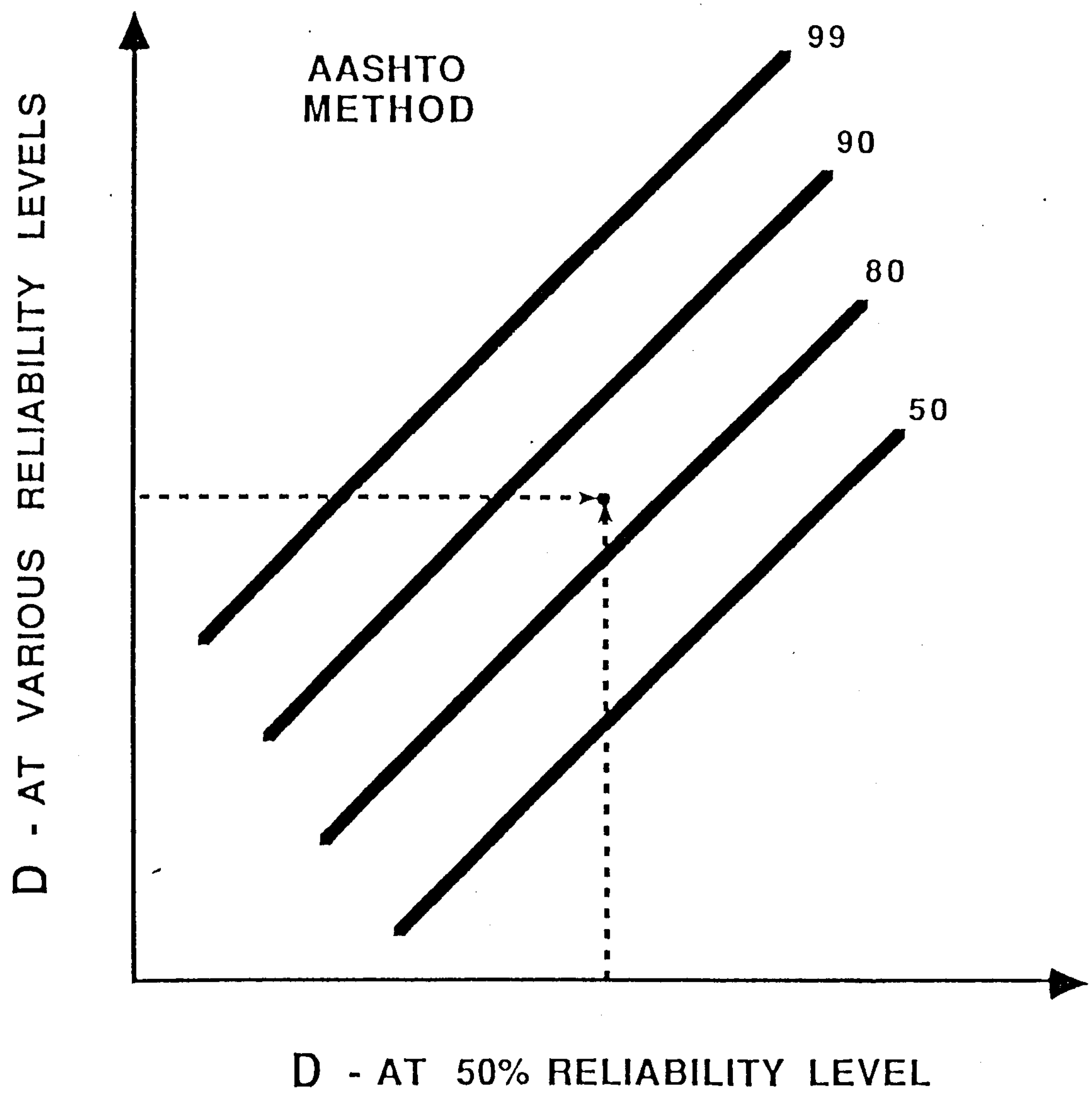
SENSITIVITY STUDY

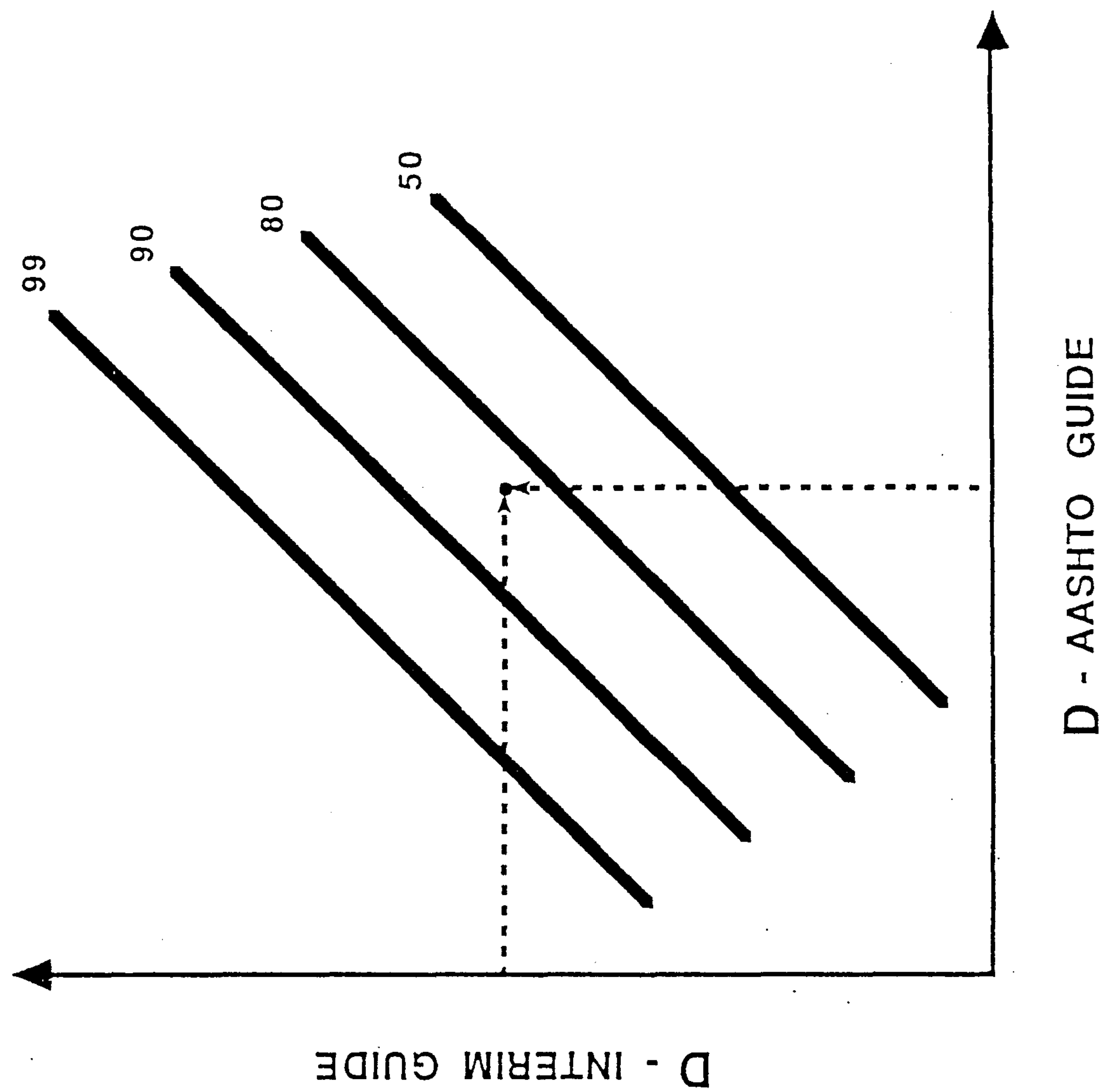
- Select panel
- Select range for each variable
- Solve for thickness (D)
- Plot graph of "D" vs. Variable range
- Prioritize in decreasing order of sensitivity
- Assess current knowledge
- Development program
    - Alter charts as needed
    - Characterization of variables
    - Commit resources on basis of priority / need


Variable (I)
Variable (II)
Low
Medium
High
RELATIVE VALUE
PAVEMENT THICKNESS

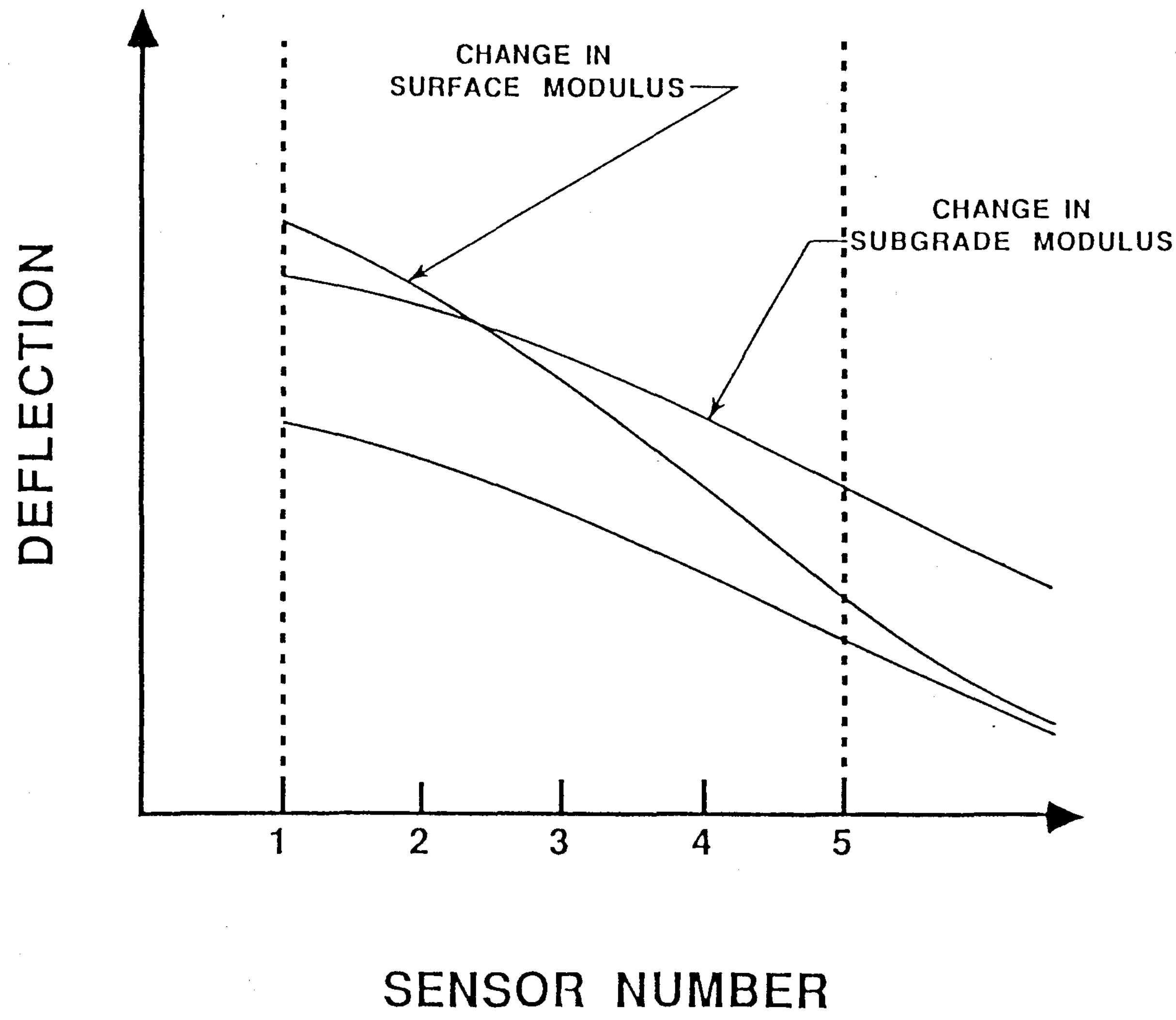


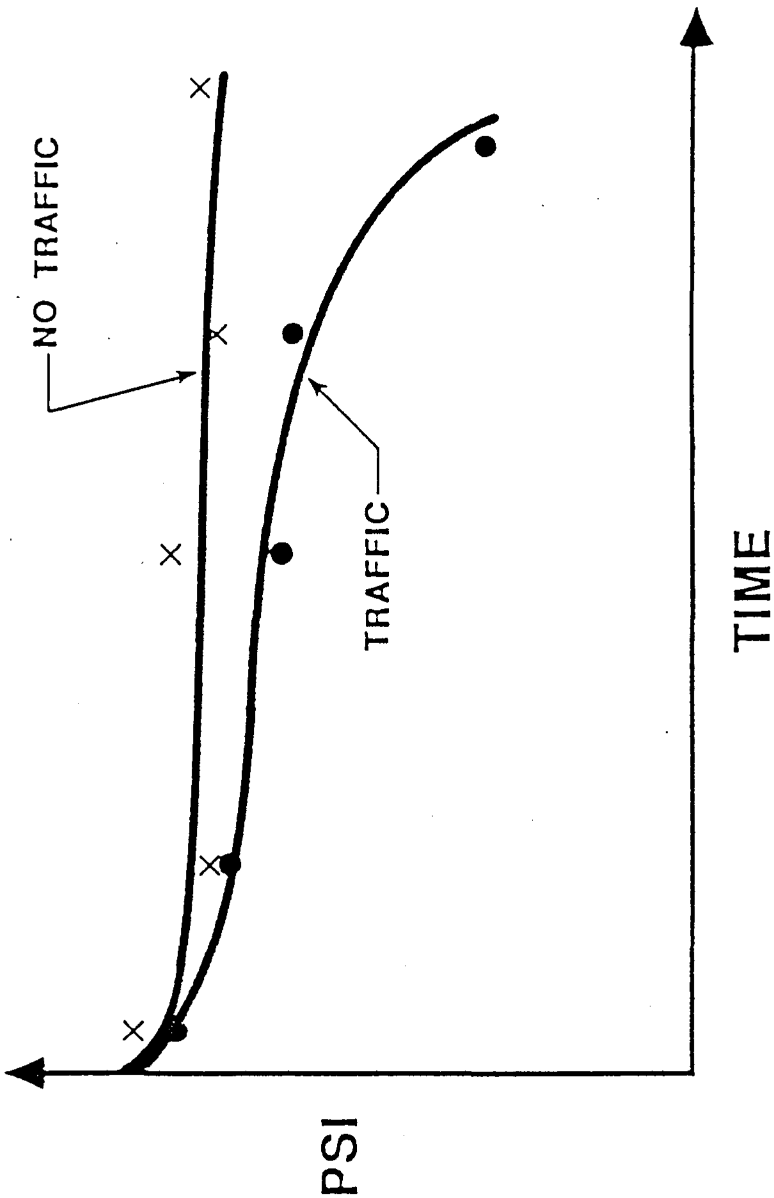
STATE
PSI
LOW
HIGH
A 550 650
B 550 1000
PAVEMENT THICKNESS, in.
11
10
9
8
7
6
Low
Medium
High
RELATIVE CONCRETE STRENGTH

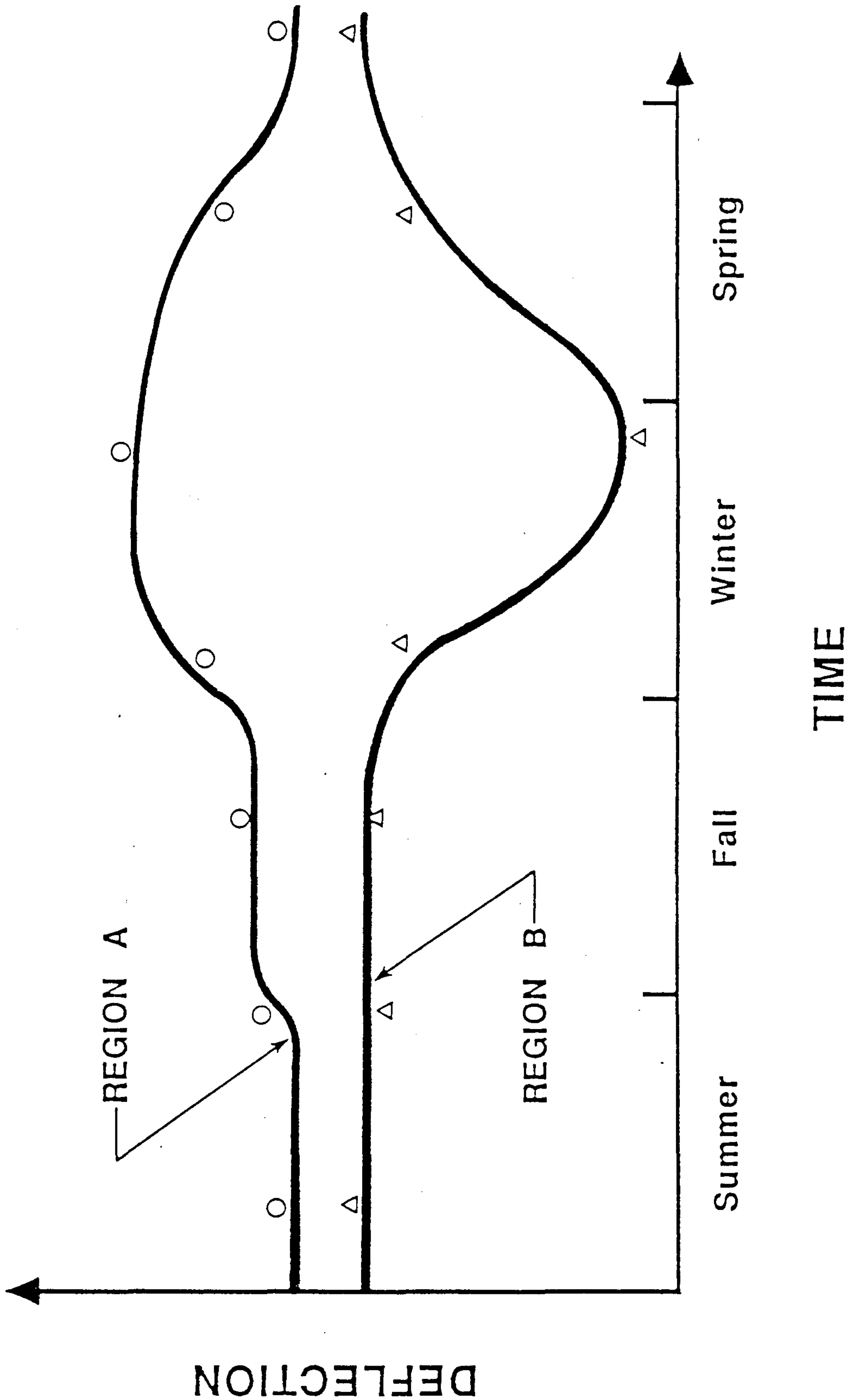

AASHTO
METHOD
99
90
80
50
D - AT VARIOUS RELIABILITY LEVELS
D - AT 50% RELIABILITY LEVEL


99
90
80
50
D - AASHTO GUIDE
D - INTERIM GUIDE

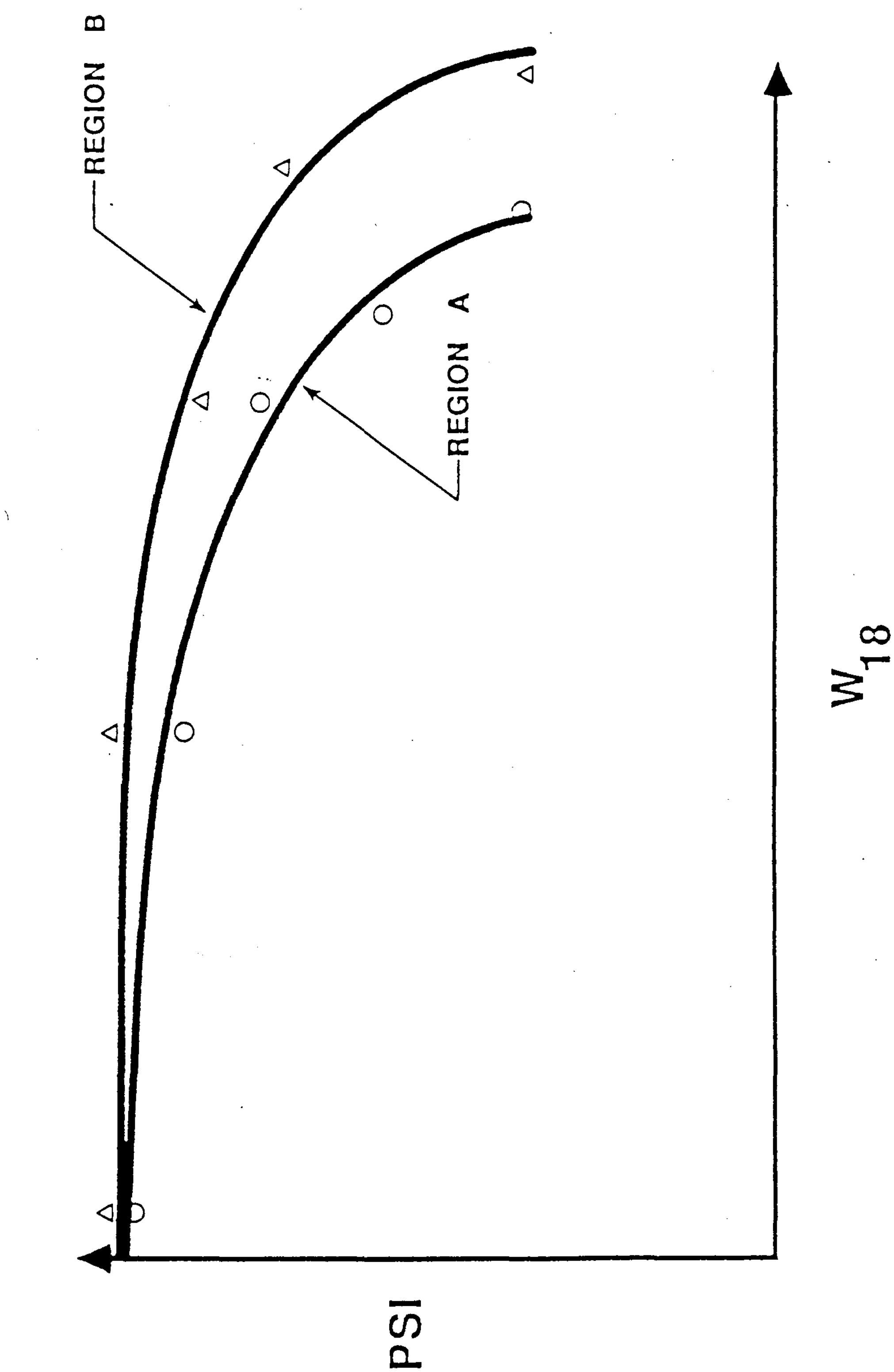
FUNCTIONAL CLASSIFICATION	RECOMMENDED LEVEL OF RELIABILITY	
	URBAN	RURAL
INTERSTATE, FREEWAYS	85 - 99.9	80 - 99.9
PRINCIPAL ARTERIES	80 - 99	75 - 95
COLLECTORS	80 - 95	75 - 95
LOCAL	50 - 80	50 - 80


CHANGE IN
SURFACE MODULUS
CHANGE IN
SUBGRADE MODULUS
DEFLECTION
1
2
3
4
5
SENSOR NUMBER

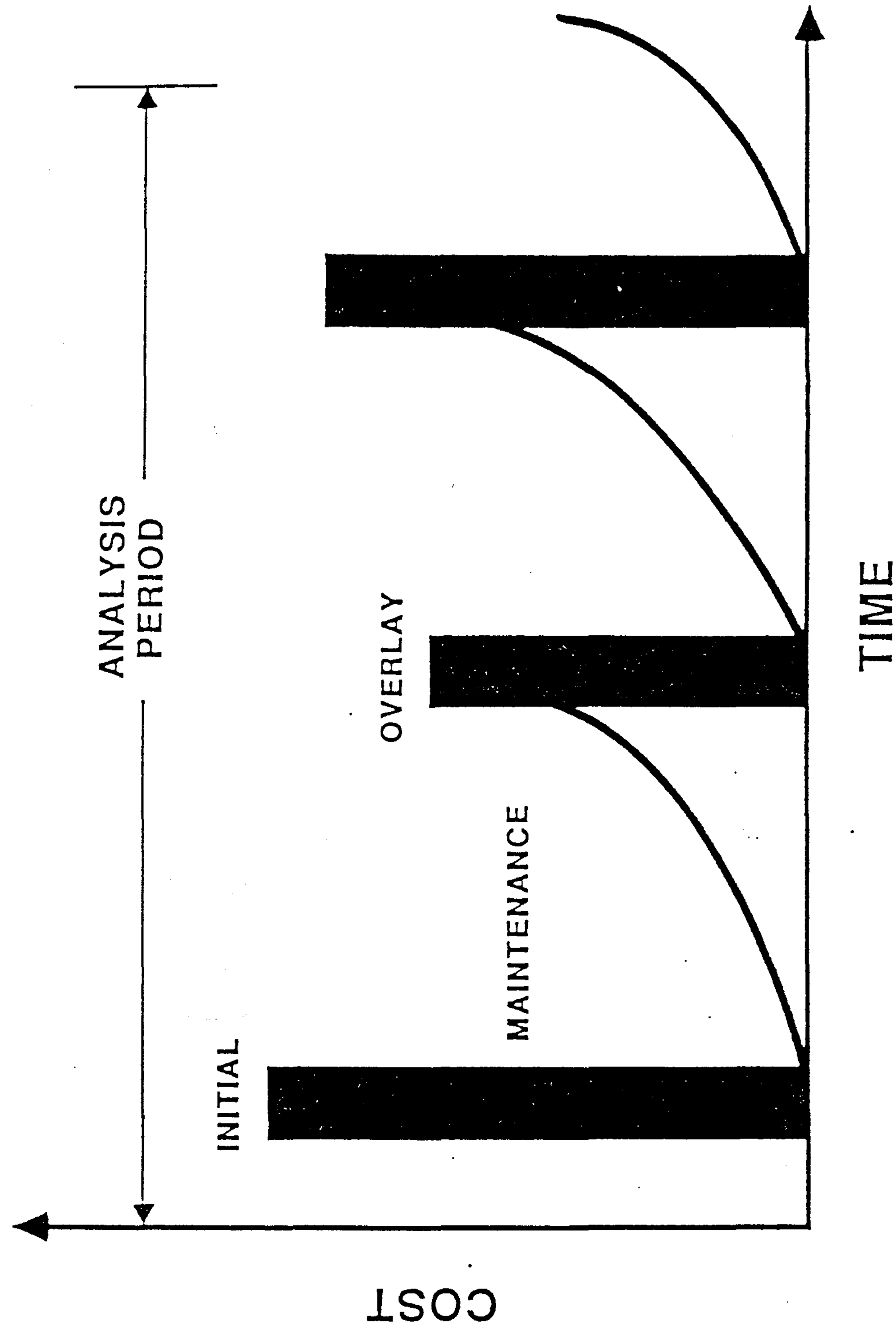

NO TRAFFIC
TRAFFIC
TIME
PSI

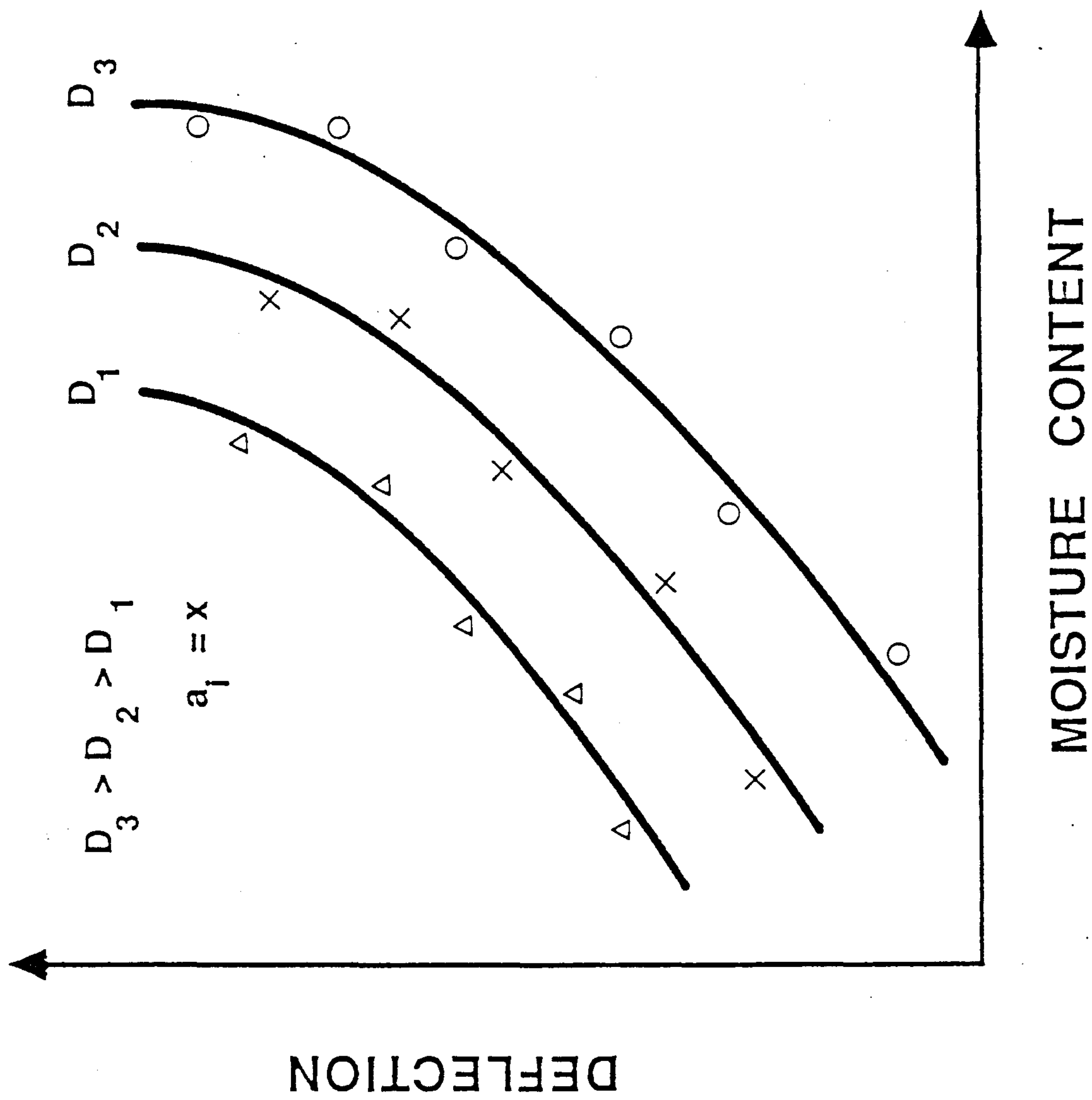


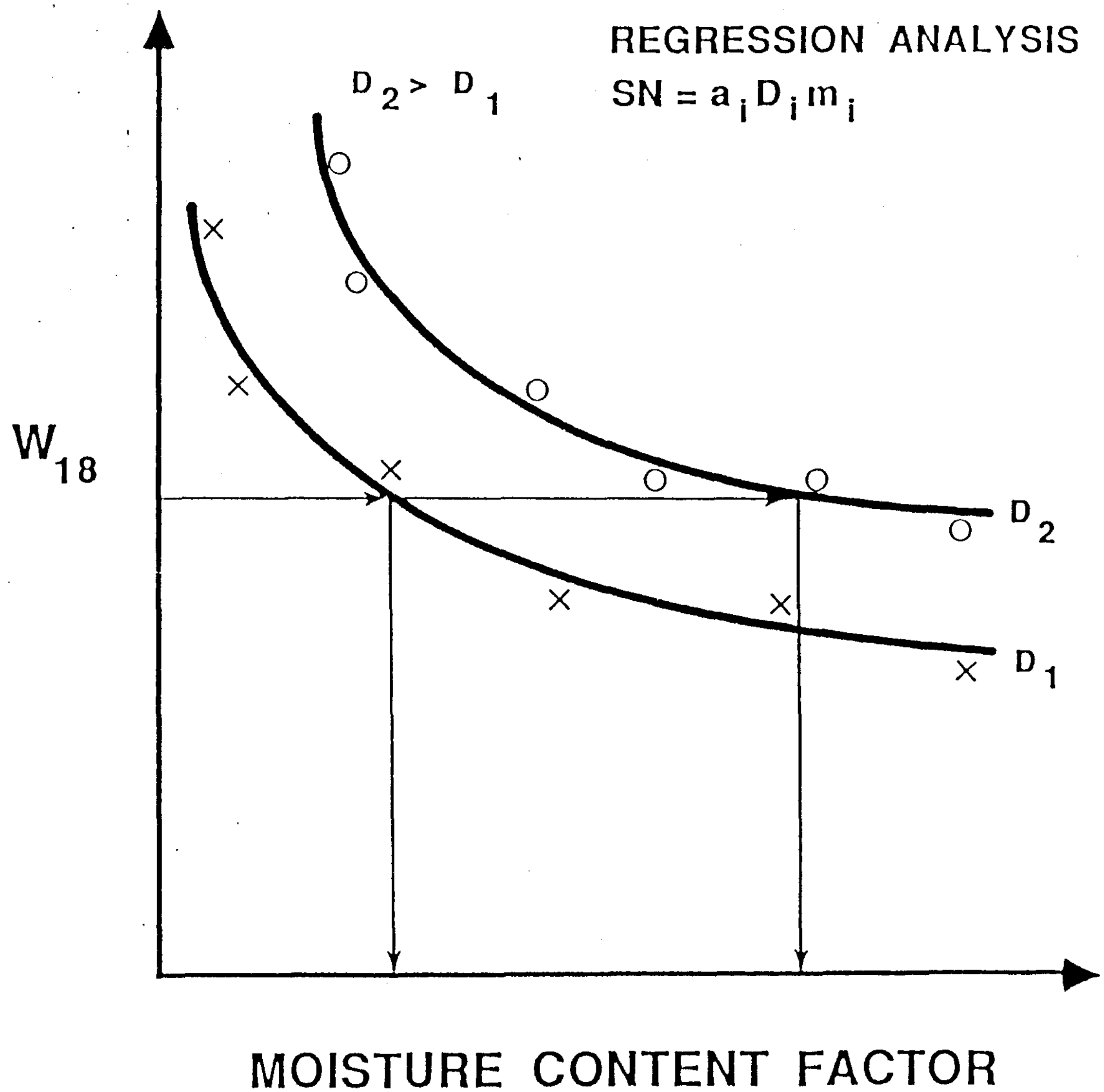
DEFLECTION
TIME
Summer
Fall
Winter
Spring
REGION A
REGION B



REGION B
REGION A
W_{18}
PSI


ANALYSIS PERIOD
INITIAL
MAINTENANCE
OVERLAY
TIME
COST


$D_3 > D_2 > D_1$
$a_i = x$
D_1
D_2
D_3
DEFLECTION
MOISTURE CONTENT


REGRESSION ANALYSIS
SN = a_i D_i m_i
D_2 > D_1
W_18
D_2
D_1
MOISTURE CONTENT FACTOR

AASHTO PAVEMENT DESIGN WORKSHOP

TRAINING COURSE EVALUATION FORM

Name (optional) ______________________________ Date __________

Job Responsibility ____

____

____

Instructions: Please complete the following questionnaire. Your responses will provide valuable feedback and will assist in planning subsequent course presentations.

Several items will be rated on a scale ranging from 1 to 7 and defined as follows:

1. Poor
2. Well below average
3. Below average
4. Average (acceptable)
5. Good
6. Very good
7. Excellent

Please circle the number which reflects your rating.

1. Please rate the course on its overall value and significance to you.

   1 2 3 4 5 6 7

Comments ____

____

____

2. Were the stated objectives of the course achieved?

   Very well ______ Reasonably well ______ No ______

3. The length of the course was:

   Much too long _____ Too long _____ About right ______

   Short ______ Very short ______

4. Should addition topics be covered, or should some topics be reduced or eliminated?

Comments ____

____

____

____

____

5. For the intended participant, the level of technical content was:

_______ extremely detailed

_______ somewhat detailed

_______ about right

_______ somewhat general

_______ extremely general

Comments ____

____

____

____

6. Please rate the visual aids. Poor Average Excellent

1 2 3 4 5 6 7

7. Would you recommend this course to your fellow workers? ______________

Why or why not? ____

____

____

8. What constructive suggestions would you offer for improvement of future presentations of this course? ______________________________

____

____

____

____

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____

____