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DOKUZ EYLUL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DESIGN OF THE FLEXIBLE HIGHWAY PAVEMENTS BY A COMPUTERIZED AASHTO METHOD

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ABSTRACT

Although it may vary form to country, highway construction investments constitute a high portion in rural transportation investments and expenditures. Especially, construction of the freeways may have even important negative impacts on the country's budget.

Today, the construction cost of the pavement of a rural highway represents about 60% of the total cost of the construction in Turkey. Hence, a very careful and realistic design of the pavement is indispensable for satisfactory performance as well as economical solutions.

At the beginning of a highway project, the priority for the design engineer is to take into consideration and to assure the required strength and load carrying capacity of the highway. In fact, there will always be different solutions or alternatives which may give satisfactory results, but only one of them will be the most economical solution.

For important roads, sometimes an increase of 1 cm in pavement thickness, or the use of one material instead of another may have an important effect on the total cost. Hence precision and trial of the different alternatives may lead to more economical solutions.

In this study, a computer aid design method based on ***AASHTO Guide*** procedures offers this opportunity to designer. The computer program presented in the study facilitates to obtain precise results and to test different data combinations.

First, ***AASHTO Method*** of design, revised again in 1986, is introduced and then above mention computer program developed for flexible highway pavements is presented in detail.

Computer program developed by the author minimized the assumptions thereby reducing technical and especially human errors. The use of the program shortens also the time for pavement design

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CHAPTER 1

INTRODUCTION PAVEMENT DESIGN PROCEDURES And AASHTO METHOD

1. Introduction And Background

1.1 General

1.1.1 Introduction

The determination of the highway pavement thickness has always been a problem for the transportation engineers.

The core of all methods used till now by designers are based on the consideration of the traffic, load and material characteristics. Some of these methods may be classified as following groups [(1)*] :

a) Methods based on *soil classification*, such as Group Index Method,

b) Methods based on *soil strength tests*, such as CBR (California Bearing Ratio) Method,

c) Methods based on *theoretic or semi-theoretic considerations* and laboratory tests, such as, triaxle test or Hveem Stabilometer Method,

d) Methods based on *the information obtained on the experiments and road tests,* such as TRRL Method in the England and **AASHTO** Method in USA.

It may be worthnoting to explain briefly some of these methods, especially the methods used extensively in other countries and in Turkey during last years.

a) Group Index Method: This method relies on the resistance of the subgrade soil which evaluated by the ***GI*** formulated as follow:

$$GI = 0.2 * a + 0.005 * a * c + 0.01 * b * d \qquad \textbf{Eq 1.1}$$

where

a and ***b*** are variables depending upon fines passing sieve,

c is ***a*** variable depending upon the likid limit and plastic limit of the soil, and

d depends on the plasticity index of the soil.

GI varies from 0 to 20. The smaller **GI** values are better for engineering purposes.

This method has some assumptions that the subgrade is compacted to 95 %, and base and subbase courses are compacted to 100 % of their **AASHTO** densities (standard proctor) and water table is kept at least at 90 to 120 cm below subgrade.

b) CBR Method: This method is based on **CBR** (California Bearing Ratio) penetration test and has a set of design charts based on field and laboratory investigations. After determining ***CBR*** values of subgrade, subbase and base course materials, the design chart given in **Figure 1.1** below is used to determine the thicknesses[(2)] :

* Numbers in parenthesis indicate the references given at the end of the text.

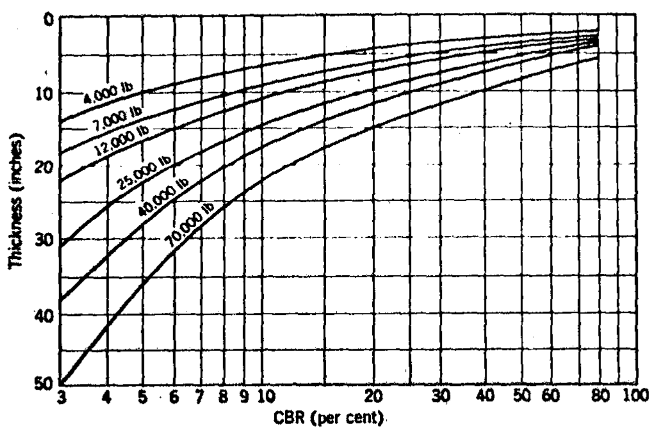


Figure 1.1 Chart to determine thicknesses of layers varying due to wheel load and **CBR** value [2]

It is important to note that the chart in figure is only an example and it may be modified in each country according to the regional conditions. The wheel loads on the curve are simple wheel loads. However, it is assumed that loads exceeding 9000 lbs are on duel-wheels.

From the curve, for a given wheel load, thickness above a layer can be determined when the chart is entered with the **CBR** value of that layer .

This method is still used in some countries, but its utilization in Turkey is limited to the flexible pavements with surface treatment.

Since they do not consider experience and environmental effects which affect the road as much as the other factors, these methods cannot be said to be realistic methods.

Here, **AASHTO** Method considering experience, road tests and environmental effects on a highly large scope is the main goal of this study.

1.1.2 Scope

The scope of this study is to introduce *the* **AASHTO** *Method* developed latest in 1986 and to present a computer program consisting procedures of this method being for flexible pavement.

The study were limited only by flexible pavement design and computer program preparation.

1.2 Content of study

This pavement structure design study provides a comprehensive set of procedures which can be used for the design and reconstruction of pavements; both flexible (asphaltic concrete surfaces) and aggregate-surfaced for low-volume roads. A glossary of terms, as used in this study, is provided in **Appendix A**. It is recognized that some of terms used herein may differ from those used in local practice.

It should be remembered that the total set of considerations required to assure reliable performance of a pavement structure will include many factors other than the determination of layer thickness of the structural components, such as material requirements, construction requirements and quality control.

Since these structural components are concepts which must be deeply examined, this study could not describe these subjects. It, therefore, was mentioned and described briefly anywhere in the study.

Chapters up to chapter 6 have been prepared as a summary background to assist the user in the proper interpretation of the design procedures. This chapter provides information of design considerations. ***Chapter 2*** provides a pavement design procedures. ***Chapter 3*** and ***Chapter 4*** provides overlay design in the scope of reconstruction and low-volume road design respectively. ***Chapter 5*** provides examples computed. ***Chapter 6*** presents a software consisting new pavement design and overlay construction. To help the user to be familiar names of functional parts of a road, a typical cross-section of a flexible and rigid pavement was presented in **Figure D-10.**

1.3 Design Consideration

The **AASHTO** Method of design provided in this study includes consideration of the following items [(3)*] :

a) Pavement performance,
b) Traffic,
c) Roadbed soil,
d) Materials of construction,
e) Environment,
f) Drainage,
g) Reliability.

Each of these factors is discussed in this chapter. It is worth noting again that the study (that this study summarizes **AASHTO** Method) describes and provides determinations of some factors, there are a number of considerations which are left to the user for final determination, e.g., drainage coefficients, environmental factors and terminal serviceability. The effect of seasonal varia* tions on material properties and careful evaluation of traffic for the designed project are details which the designer should investigate thoroughly.

The basic design equations used for flexible pavement are as follows:

$$\log_{10}(w_{18}) = Z_R * . S_o + 9.36 * \log_{10}(SN+1) - 0.20 \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{0.40 + \left(\frac{1094}{(SN+1)^{5.19}}\right)} + 2.32 * \log_{10}(M_R) + 8.07 \qquad \textbf{Eq. 1.2}$$

where **w_{18}** : predicted number of 18-kip equivalent single axle load applications,
Z_R : standard normal deviate,
S_0 : combined standard error of the traffic prediction and performance prediction,

* In the preparation of the text, Reference No: 3 was exhaustively used.

ΔPSI: difference between the initial design serviceability index, **Po**, and the design terminal serviceability index, **Pt**,

and **M_R** : resilient modulus (psi).

SN is equal to the structural number indicative of the total pavement thickness required.

$$SN = a_1 * D_1 + a_2 * D_2 * m_2 + a_3 * D_3 * m_3 \qquad \textbf{Eq 1.3}$$

where

a_i = i th layer coefficient,
D_i = i th layer thickness (inches) and
m_i = i th layer drainage coefficient.

The design nomograph presented in **Appendix D, Figure D-9**, solves this equation for the structural number **(SN)** for flexible pavements. The structural number is an abstract number expressing the structural strength of a pavement required for a given combinations of soil support *(**M_R**)*, total traffic expressed in equivalent 18-kip single axle loads, terminal serviceabilty, and environment. The required **SN** must be converted to actual thickness of surfacing, base and subbase courses, by means of appropriate layer coeffcients representing the relative strength of the construction materials.

In effect, the layer coefficient are based on the elastic moduli **M_R** and have been determined based on stress and strain calculations in a multilayered pavement system. Using these concepts, the layer coeffecient may be adjusted, increased, or strain required to provide comparable performance. **Chapter 2** details how each of the design considerations are to be treated in selecting the SN value and how to decompose **SN** into layers according to material properties and function, i.e., surface, base, subbase and so forth,

It is important to recognize that equation above were derived from empirical information obtained at the **AASHTO** Road Test.

1.4 Pavement Performance

The structural performance of a pavement relates to its physical consideration, i,e., occurance of cracking, faulting, raveling, etc. But the functional performance of a pavement concerns how well the pavement serves the user.

In order to qualify this the *'serviveability performance'* concept was developed by the **AASHTO** Road Test staff. An explanation of the concept herein seems worthwhile. The serviceability-performance concept is based on five fundamental assumptions,summarized as follows:

a) Highways are for the comfort and convenience of the travelling public (user),
b) Comfort, or riding quality, is a matter of subjective responce or the opinion of user.
c) Serviceability can be expressed by the mean of the ratings given by all highway users.
d) There are physical characteristics of a pavement which can be measured objectively and which can be related to subjective evaluations. This procedure produces an objective serviceability index.
e) Performance can be represented by the serviceability history of a pavement.

The serviceability of a pavement is expressed in terms of the present serviceability index **(PSI)**. The **PSI** is obtained from measurements of roughness and distress, e.g., cracking, patching and rut depth (flexible), at a particular time during the service life of the pavement. Roughness is the dominant factor in estimating the **PSI** of a pavement. Thus, a reliable method for measuring roughness is important, for the design of pavements, the change in roughness will control the life cycle of pavements. In this regard, the quality of construction will influence performance and the life cycle of the designed pavement. The initial pavement smoothness is an important design consideration. For example, the life cycle of a pavement initially constructed with a smoothness or **PSI** of 4.5 will have significantly longer life cycle than one constructed to a **PSI** of 4.0. Thus, quality control in the construction of a pavement can have a beneficial impact on performance (life cycle).

The scale for **PSI** ranges from 0 to 5, with a value of 5 representing the highest index of serviceability. For design it is necessary to select both an initial and terminal serviceability index. The initial serviceability index (**P_i**) is an estimate by the user of what the **PSI** will be immediately after construction. Values of **Pi** established for **AASHTO** Road Test conditions were 4.2 for flexible pavements and 4.5 for rigid pavements.

The terminal serviceability index (**P_t**) is the lowest acceptable level before resurfacing or reconstruction becomes necessary for the particular class of highway. An index of 2.5 or 3.0 is often suggested for use in the design of major highways, and 2.0 for highways with a lower classification. For relatively minor highways, where economic considerations dictate that initial expenditures be kept low, a **Pt** of 1.5 may be used.

The major factors influencing the loss of serviceability of a pavement are traffic, age and environment. Each of these design requirements included in **AASHTO** Guide.

An effort is met to account for the effects of environment on pavement performance in situations where swelling clay or frost heave are encountered. Thus, the total change in **PSI** at any time can be obtained by summing the damaging effects of traffic, swelling clay and/or frost heave, as shown in equation below and illustrated in **Figure D-11.**

$$\Delta PSI = \Delta PSI_{\text{traffic}} + \Delta PSI_{\text{swell/frost heave}} \qquad \textbf{Eg 1.4}$$

where

ΔPSI : total loss of serviceabilty,
$\Delta PSI_{traffic}$: serviceabilty loss due to traffic (ESAL's) and
$\Delta PSI_{swell/frost\ heave}$: serviceability loss due to swelling and/or frost heave of roadbed soil.

It can be noted in **Figure D-11** that effect of swelling soils or frost heave is to reduce the predicted service life of the pavement. The **AASHTO** Guide does not recommend increasing pavement structural thickness to offset the serviceability loss due to swelling soils; but it is feasible, however, to control frost heave by increasing the thickness of non-frost-susceptible material.

In many swelling situations, it may be possible to reduce to acceptable limits the effect of swelling soil by stabilization of the expensive soil. When experience indicates this is a viable procedure, it is not necessary to estimate the effect of swelling soil on the life cycle.

The predicted effect of frost heave is based on a limited amount of information in the literature. The most accepted procedure to minimize the effect of frost heave is to replace the frost-susceptible material with non-frost-susceptible material to a depth of one-half or more of the frost depth. If agency design procedures include provisions to mitigate the detrimental effects of frost, the serviceability loss due to frost heave should be ignored, i.e., assumed to be zero.

1.5 Traffic

The results of the **AASHTO** Road Test have shown that the damaging effect of the passage of an axle load can be represented by a number of 18-kip equivalent single axle loads or ESAL's. For example, one application of a 12-kip single axle was found to cause damage equal to approximately 0.23 applications of an 18-kip single axle load, and four applications of a 12-kip single axle were required to cause the same damage (or reduction in serviceability) as one application of an 18-kip single axle. This concept has been applied to the design equations and nomographs. The determination of design ESAL's is a very important consideration for the design of pavement structures.

Available load equivalency factors are considered the best available of the present time, representing information derived from the present time, representing information derived from the **AASHTO** Road Test. The empirical observations on the Road Test covered a range of axle loads from 2 to 30-kips on single axles and 24 to 48 kips on tandem axles.

Since pavements, new or rehabilitated, are usually designed for period ranging from 10 years to 20 years or more, it is necessary to predict the ESAL's for this period of time, i.e., the performance period. Performance period is defined as the period of time that an initial (or rehabilitated structure) will last before reaching its terminal serviceability. The ESAL's for the performance period represent the cumulative number from the time the roadway is opened to traffic to the time when the serviceability is reduced to a terminal value (e.g., **Pt** equal 2.5 or 2.0). If the traffic is under estimated, the actual time to **Pt** will probably be less than the predicted performance period, thereby resulting in increased maintenance and rehabilitation costs. The max. performance period to be used in designing for a particular pavement should reflect engineer or agency experience.

The equivalent loads derived from many traffic prediction procedures represent the totals for all lanes for both directions of travel. This traffic must be distributed by direction and by lanes for design purposes. Directional distribution is usually made by assigning 50 percent of the traffic to each direction, unless available measured traffic data warrant some other distribution. In regard to lane distribution, 100 percent of the traffic in one direction is often assigned to each of the lanes in that direction for purposes of structural design if measured distribution are not available.

Prediction of future traffic are often based in post traffic history. Several factors can influence such predictions. For purposes of pavement structure design, it is necessary to estimate the cumulative number of 18-kip equivalent single axle loads (ESAL's) for the performance period. The number of ESAL's may or may not be proportional to the average daily traffic. Truck traffic is the essential information required to calculate ESAL's; it is therefore very important to correctly estimate future truck traffic for the facility during the performance period.

Traffic may remain constant, or increase according to a straight line or at an accelerating (exponential) rate. In most cases, highways classified as principal arterial or interstate will have exponential growth. Traffic on some minor arterial or collector-type highways may increase along a straight line, while traffic on some residential streets may not change becouse the use remains constant. Thus, the designer must make provision for growth in traffic from the time of the last traffic count or weighing through the performance period selected for the projected under consideration.

The load equivalency factor increases approximately as a function of the ratio of any given axle load to the standard 18-kip single axle load raised to the fourth power. For example, the load equivalency of a 12-kip single axle lis given as 0.19 while the load equivalency for 20-kip single axle is 1.51. Thus the 20-kip load is 8 times as damaging as the 12-kip load, i.e., (20-12) . This relationship will vary depanding on the structural number and terminal serviceability.

The reliability factor, that will be included in this study, has been developed to provide consideration of uncertainties in both traffic predictions and performance predictions. The standard deviation of the relationship between predicted and actual traffic has been reported to be on the order of 0.2. In effect, the actual traffic may be 1.6 (one standard deviation) to 4.0 times (three standard deviations) as much as predicted.

The experimental design at the **AASHTO** Road Test included a wide range. However, the applied load were limited to a maximum of 1.114.000 axle applications for those sections which survived the full trafficking period. Thus the maximum number of 18-kip equivalent single axle loads (ESAL's) applied to any test section was approximately one million. However, by applying the concept of equivalent loads to test sections subjected to only 30-kip single axle loads, for example, it is possible to extend the findings to 8 10^6 ESAL's. Use of any design ESAL's above
8 10^6 requires extrapolation beyond the equations developed from the Road Test results.

1.6 **Roadbed Soil**

The definitive material property used to characterize roadbed soil for pavement design in **AASHTO** Guide is the resilient modulus (**M_R**). The procedure for determination of **M_R** is given ***AASHTO** Test Method T274.* The resilient modulus is a measure of the elastic property of soil recognizing certain nonlinear characteristics. The resilient modulus can be used directly for the design of flexible pavements.

It is recognized that TCK regional highway agencies as many ones do not have equipment for performing the resilient modulus test. Therefore, suitable factors are reported which can be used to estimate **M_R** from standard **CBR**, **R-value**, and soil index test results or values. The development of these factors is based on agencies of the knowledge correlations. It is strongly recommended that user agencies acquire the necessary equipment to measure **M_R**.

A range of soil types, saturation and densities should be included in the testing program to identify the main effects. *Heukelam* and *Klomp* have reported correlations between the Corps. of Engineers **CBR** and the in situ modulus of soil as below:

$$M_R(psi) = 1500 * CBR \qquad \textbf{Eq 1.5}$$

The data from which this correlation was developed ranged from 750 to 3000 times **CBR** but relationship above has been used extensively and is considered reasonable for fine-grained soil with a soaked **CBR** of 10 or less. The **CBR** here should correspond to the expected field density.

Similar relationship have also been developed by the Asphalt Institute which relate **R-value** to **M_R** as follows:

$$M_R(psi) = A + B * (R\text{-}Value) \qquad \textbf{Eq 1.6}$$

where

A = *772* to *1155* and
B = *369* to *555*.

For the purposes of this study, the following correlation may be used for fine-grained soils (**R-value** less than or equal to 20).

$$M_R = 1000 + 555 * (\text{R-Value}) \qquad \textbf{Eq 1.7}$$

This discussion summarizes estimates for converting **CBR** and **R-Value** to a resilient modulus for roadbed soil. Similar information is provided for granular materials in next section *'Materials Of Flexible Pavement Construction'*.

It must not be forgotten that if the specified density is used in project, it must be attended during construction by compaction adjustment.

1.7 Materials Of Flexible Pavement Construction

For flexible pavements, it may be necessary to convert **CBR** or **R-Value** information to resilient modulus, M_R. In the absence of correlations, the following correlations are provided for unbound granular materials (base and subbase):

Table 1.1 Correlations between MR and θ (stress state)*

θ (psi)	M_R (psi)
100	740 * CBR or 1000 + 780 * R
30	440 * CBR or 1000 + 450 * R
20	340 * CBR or 1000 + 350 * R
10	250 * CBR or 1000 + 250 * R

where θ : sum of the principal stresses, $\sigma_1+\sigma_2+\sigma_3$;

Referring to *AASHTO Test T274*, this corresponds to $\sigma_d + 3\,\sigma_3$ when $\sigma_d = \sigma_1 - \sigma_3$.

The strength of the granular base or subbase is related to the stess state which will occur under operating conditions. The sum of the principals stresses, θ, is a measure of the stress state, which is a function of pavement thickness, load, and the resilient modulus of each layer. As design engineers become increasingly familiar with these parameters, it will be possible to determine the stress state from a layered systems. However, if such information is not available, estimates of resilient modulus values provided in previously in **Section 1.6** may be used.

As shown in **Figure D-10,** flexible pavements generally consist of a prepared roadbed underlying layers of subbase, base and surface courses.

1.7.1 Prepared Roadbed

The prepared roadbed is a layer of compacted roadbed soil or select borrow material which has been compacted to a specified density.

* AASHTO Interim Guide

1.7.2 Subbase Course

The subbase course is the portion of the flexible pavement structure between the roadbed soil and base course. It usually consists of a compacted layer of granular material, either treated or untreated, or of a layer of a soil treated with a suitable admixture. The subbase material should be of significantly better quality than the roadbed soil. Becquse lower quality materials may be used in the lower layers of a flexible pavement structure, the use of a subbase course is often the most economical solution for construction of pavements over poor roadbed soils. For use in flexible pavement design procedure, subbase material requires the use of a layer coefficient ($\mathbf{a}_3$) in order to convert its actual thickness to a structural number (**SN**) which will be mentioned later. Untreated aggregate subbase should be compacted to 95 percent of maximum laboratory density or higher or the equivalent.

Subbase courses may have also additionally functions, such as:

a) preventing the intrusion of fine-grained roadbed soils into base courses,
b) minimize the daamge effects of frost action,
c) preventing the accumulation of free water within or below the pavement structure,
d) providing a working platform for construction equipment, that may be important when roadbed soil cannot provide the necessary support.

1.7.3 Base Course

The base course is the portion of the pavement structure immediately beneath the surface course. It is constructed on the subbase course. Its major function in the pavement is structural support. It usually consists of aggregate such as, crushed stone, crushed slag, crushed gravel and sand or combination of these materials. It may be used untreated or treated with suitable stabilizing admixtures, such as, portland cement, asphalt, lime, cement-flyash and lime-flyash, i.e., pozzolonic stabilized bases. Specifications for base course materials are generally considerably more stringent than for subbase materials in requirements for strength, plasticity and gradation.

When utulizing pozzolonic stabilized bases under a relatively thin asphaltic wearing surface, it can usually be expected that uncontrolled transverse reflection cracks will occur in the surface in a relatively short period of time, e.g., 1 to 3 years.

Untreated aggregate base should be compacted to at least 95 percent of maximum laboratory density based on *AASHTO Test T180, Method* D, or the equivalent.

For use in the design procedure for flexible pavements, base material must be represented by a layer coefficient ($\mathbf{a}_2$) in order that its actual thickness may be converted to a structural number.

1.7.4 Surface Course

The surface course of a flexible structure consists of a mixture of mineral aggregates and bituminous materials placed as the upper course and usually constructed on a base course. In addition to its major function as a structural portion of the pavement, it must also be designed to resist the abrasive forces of traffic, to reduce the amount of surface water penetrating the pavement, to provide a skid-resistance surface, and to provide a smooth and uniform rigid surface.

The use of laboratory design procedure is essential to ensure that a mixture will be satisfactory. Dense-graded aggregates with a maximum size of about 1 inch are most commonly specified for surface courses for highways. Surface courses are usually prepared by hot plant mixing with an asphalt cement, but satisfactory performance has also been obtained by cold plant mixing, or even mixing in-place, with liquid asphalts or asphalt emulsions. Hot plant mixes, e.g., asphalt concrete, are recommended for use on all moderate to heavily trafficked highways.

Construction specifications usually require that a bituminous material be applied on untreated aggregate base course as a prime coat, and on treated base courses and between layers of the surface course to serve as a tack coat.

It is particularly important that surface courses be properly compacted during construction. Improperly compacted surface courses are more likely to exhibit a variety of types of distress that tend to reduce the life and overall level of performance of the pavement. Theoritical maximum densities of 92 percent or more are sometimes specified for dense-graded mixes.

For use in design procedure, **Figure D-4** will be used to determine structural coefficients of upper layers over base course.

1.8 Environment

There are two main environmental factor that are considered with regard to pavement performance and pavement structure design. Specifically, these are temperature and rainfall.

Temperature will affect the creep properties of asphalt concrete, thermal-induced stresses in asphalt concrete, contraction and expansion of portland cement concrete, and freezing and thawing of roadbed soil.

Rainfall, if allowed to penetrate the pavement structure or roadbed soil, will influence the properties of these materials. Freezing and thawing of roadbed soil has traditionally been a major concern of pavement designers.

Frost heaving of soil within or beneath a pavement is caused by the accumulation of ice within the larger soil voids and, usually, a subsequent expansion to form continues ice lenses, layers, veins, or other ice masses.

Thawing can proceed from the top downward, from the bottom upward or both, that this depends on the pavement surface temperature.

In summary, frost action due to freezing temperatures in soil, can cause both heaving and thaw-weakening. Laboratory tests and field evaulations indicate that the retained modulus during the thaw-weakening period may be 20 to 50 percent of the normal modulus obtained during the summer and fall periods. Note that the modulus is related to **CBR**, **R-value**, or plate bearing value and, hence, experience with these types of strought tests can be used to infer the seasonal effects on the modulus.

In addition to these effects, swelling and frost heave will be mentioned at next chapter to put into design procedure.

1.9 Drainage

Drainage of water from pavements has always been an important consideration in road design;however,current methods of design have often resulted in base courses that do not drain well. Water enters the pavement structure in many ways, such as, through cracks, joints, or pavement infiltration, or as groundwater from an interrupted aquifier, high water table or localized spring.

Drainage effects are directly considered in terms of the effect of moisture on roadbed soil and base strength in the swelling and frost heave consideration.

For new design, the effect of drainage by modifying the structural layer cefficient as a function of:

a) the quality of drainage (e.g., the time required for the pavement to drain), and

b) the percent of time the pavement structure is exposed to moisture levels approaching saturation.

1.10 Reliability

The reliability of a pavement design-performance process is the probability that a pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the performance period (= design period).

The reliability equation is assumed to be an explicit mathmatical formula for predicting the number of *ESAL* (w_{18}) that the any section of road can withstand before it reaches a specified terminal level of serviceability (**P_t**). Reliability design factor, F_R, is composed of four categories as below:

a) pavement structure factors, such as, subbase thickness,
b) roadbed soil factors, such as, roadbed soil resilient modulus,
c) climate-related factors, such as, drainage coefficients, and
d) pavement condition factors, such as, terminal ***PSI.***

In this study, instead of detaily explanation of F_R, only a simple formula presented below and **Table D-3** was presented due to being extensive scope.

$$Z_R = (-\log F_R) / S_O \qquad \textbf{Eq 1.8}$$

where Z_R : standard normal deviate
S_O : overall standard deviation.

S_O and F_R provide for all chance variation in the design-performance process and at a known level of reliability.

Table D-3 gives the standard normal deviate, Z_R , corresponding to selected levels of reliability.

In summary, S_O expresses the variance in the future traffic projections and performance prediction in reliability scope.

1.10.1 Selection Of Overall Standard Deviation

a) The estimate overall standard deviation for the case where the varianced of projected future traffic is considered (along with the other variances associated with the revised pavement performance models) is 0.44 for flexible pavements.

b) The estimated overall standard deviation for the case when the variance of projected future traffic is not considered (and the other variances associated with the revised pavement performance models are) is 0.40 for flexible pavements.

c) The range of S_0 value is based on the values identified below:
0.40 - 0.50 (flexible pavements)

It is to recognize that inherent in the **So** values, identified in **(a)** and **(b)** above, is a means for the user to specify an overall standard deviation **(S_0)** which better represents his ability to project future 18-kip ESAL traffic. If, becouse of an extensive traffic count and weigh-in-motion program of **AASHTO**, an engineer or any agency is capable of projecting future traffic better and therefore has a lower traffic variance, then that state might use an **So** value somewhere between the values identified in **(a)** and **(b).** For example, for flexible pavements, where S_O (low) is 0.44 and S_O (high) is 0.49, a value of 0.47 or 0.48 could be used.

1.10.2 Selection Of Reliability Level

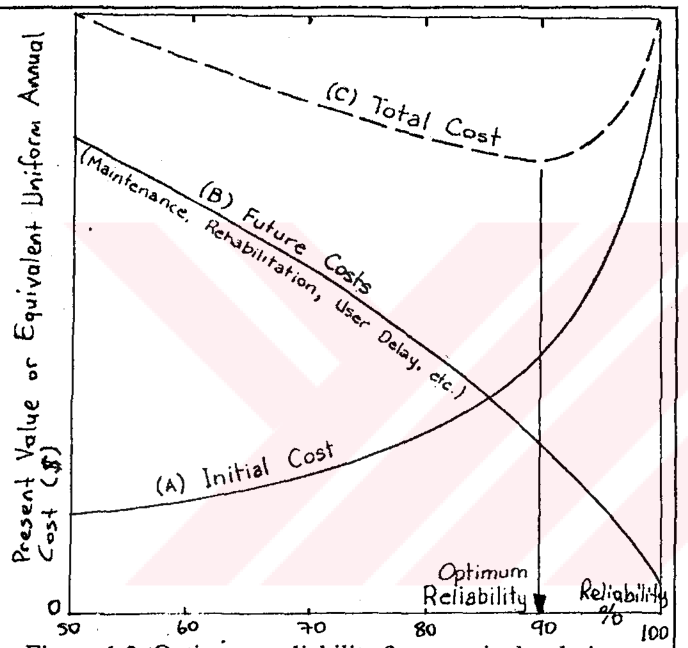


Figure 1.2 Optimum reliability for a particular design project

The selection of an appropriate level of reliability for the design of a particular facility depends primarily upon the projected level of usage and the consequences (risk) associated with constructing an initially thinner pavement structure. If a facility is heavily trafficked, it may be undesirable to have to close or even restrict its usage at future dates becouse of the higher levels of distress, maintenance, and rehabilitation associated with an inadequate initial thickness. On the other hand, a thin initial pavement (along with the heavier maintenance and rehabilitation levels) may be acceptable, if the projected level of usage is such that fewer conflicts can be expected. Figure below provides a graph illustrating the concept behind this detailed approach to identifying an optimum level of reliability for a particular design project.

It should be recognized that this optimum reliability is applicable only to the level of usage and consequences (risk) of failure associated with a particular project. Although other design projects may have the some level of usage, varying soil and environmental conditions may affect the level of risk and, therefore, the optimum reliability.

1.10.3 Reliability And Stage Construction Alternatives

When considering reliability in stage construction or 'planned rehabilation' design alternatives, it is important to consider the effects of compound reliability. Unless this is recognized, the overall reliability of say a 2-stage strategy (each stage designed for a 90 percent reliability level) should be 0.90 * 0.90 or 81 percent. Such a strategy could not be compared equally with a single-stage strategy designed for 90 percent reliability. For cases where the initial design period is less than the desired analysis period, stage construction or planned rehabilition is required (for the deisgn strategy to last the analysis period) and the definition of reliability must be expanded to include the uncertainty associated with the additional stage(s). Assuming that the probability of one stage lasting its design period is independent of that of another stage, the probability or overall reliability that all stages will last their design periods (or that the strategy will last the entire analysis period) is the product of the individual stage reliabilities.

Thus, in order to achieve a certain overall design reliability **($R_{overall}$)** in a particular design strategy, the following equation should be applied to establish the individual reliability **(R_{stage})** required to design each stage:

$$R_{stage} = (R_{overall})^{1/n}$$

Where **(n)** is equal to the number of stages including that of the initial pavement structure.

CHAPTER 2

PAVEMENT DESIGN PROCEDURES FOR NEW CONSTRUCTION

2.1 Background

One of the major objectives of the **AASHTO** Road Test was to provide information that could be used in developing pavement design criteria and pavement design procedures.

AASHTO *Interim Guide,* edited once again in 1986, contains following modifications to the old versions, for the flexible pavement design procedures:

a) The soil support number is replaced by the resilient modulus to provide a rational testing procedure that may be used by an agency to define the material properties.

b) The layer coefficients for the various materials are defined in terms of resilient modulus as well as standard methods *(* **CBR** *and* **R-Value***).*

c) The environmental factors of moisture and temperature are objectively included in the Guide so that environmental considerations could be rationally accounted for in the design procedure.

d) Reliability is introduced to permit the designer to use the concept of risk analysis for various classes of roadways.

e) Stage construction (i.e., planned rehabilitation) design procedures are incorporated.

2.2 Scope

The procedure contained here is basically an extension of the 'algorithms originally developed from *the* **AASHTO** *Road Test.* As a new concept, stage construction is presented to provide the designer with the option of examining numerous alternatives for selection of an optimum pavement design strategy for a facility.

This part also permits the designer to account for pavement serviceability loss resulting from both traffic loads and environment. The environmental aspects are considered in terms of both their direct and indirect effects on the serviceability index. The direct environmental effects are in terms of swelling and frost heave of the roadbed soil, while the indirect effects are in terms of the seasonal variation of material properties and their impact on traffic load associated serviceability loss. The designer has the option of not considering either of these environmental factors, if so desired.

2.3 Design Variables

2.3.1 Time Constraints

Consideration the dimension of time constraints is required for both highway and low-volume road design. Time constraints permit the designer to select from strategies ranging from the initial structure lasting the entire analysis period (i.e., performance period equals the analysis period) to stage construction with an initial structure and planned overlays.

2.3.1.1 **Performance Period**

This refers to the period of time that an initial pavement structure will last before it needs rehabilitation. It can also be explained that performance period is equivalent to the time elapsed as a new , constructed , or rehabilitated structure deteriorates from its initial serviceability to its terminal serviceability.

The minimum performance period is the shortest amount of time a given stage should last. For example, it may be desirable that the initial pavement structure last at least 10 years before some major rehabilitation operation is performed.

The maximum performance period is the maximum practical amount of time that the user can expect from a given stage. For example, experience has shown in areas that pavements originally designed to last 20 years required some type of rehabilitation or resurfacing within 15 years after initial construction. This limiting time period may be the result of **PSI** *loss* due to environmental factors, disintegration of surface, etc. The selection of longer time periods than can be achieved in the field will result in unrealistic designs.

2.3.1.2 **Analysis Period**

This refers to the period of time for which the analysis is to be conducted, i.e., the length of time that any design strategy must cover. Because of the consideration of the maximum performance period, it may be necessary to consider and plan for stage construction (i.e., an initial pavement structure followed by one or more rehabilitation operations) to achieve the desired analysis period. **Table 2.1** is general guideline.

Table 2.1 Analysis period due to highway classifications *

Highway Condition	Analysis Period (years)
High Volume Urban	30 - 50
High Volume Rural	20 - 50
Low Volume Paved	15 - 25
Low Volume Aggregate Surfaced	10 - 20

2.3.2 **Traffic**

The design procedures for both highways and low-volume roads are all based on cumulative expected 10-kip equivalent single axle loads (ESAL) during the analysis period ($\mathbf{w}_{18}$).

For any design stuation in which the initial pavement structure is expected to last, the analysis period without any rehabilitation or resurfacing, all that is required is the total traffic over the analysis period., If, however, stage construction is considered, i.e., rehabilitation or resurfacing is anticipated (due to lack of initial funds, roadbed swelling, frost heave, etc.), then the user must prepare a graph of cumulative 18-kip ESAL traffic versus time, as illustrated in **Figure D-1**. This will be used to separate the cumulative traffic into the periods (stages) during which it is encountered.

The predicted traffic furnished by the planning group is generally the cumulative 18-kip ESAL axle applications expected on the highway , wher[1] eas the designer requires the axle applications in

* Aashto Interim Guide

the design lane. Thus, unless specifically furnished, the designer must factor the design traffic by direction and then by lanes (if more than two). The following equation may be used to determine the traffic (W_{18}) in the design lane:

$$W_{18} = D_D * D_L * w_{18} \qquad \textbf{Eq 2.1}$$

where

D_D **:** a directional distribution factor, expressed as a ratio, that accounts for the distribution of *ESAL* units by direction, e.g., *east-west, north-south*, etc.,

D_L **:** a lane distribution factor, expressed as a ratio, that accounts for distribution of traffic when two or more lanes are available in one direction,

w_{18} **:** the cumulative two-directional 18-kip ESAL units predicted for a specific section of highway during the analysis period as explained in **Chapter 1.**

Although the $\mathbf{D_D}$ factor may vary from 0.3 to 0.7, but is generally 0.5 (50 %) for most highways, depending on which direction is *loaded* and which is *unloaded*. For the $\mathbf{D_L}$ factor, the following table may be used as a guide:

Table 2.2 Percent of 18-kip ESAL in each direction,

No of Lanes in each direction	Percent of 18-kip ESAL in design lane
1	100
2	80 - 100
3	60 - 80
4	50 - 75

2.3.3 <u>Reliability</u>

Basically, it is a means of incorporating some degree of certainty into the design process to ensure that the various design alternatives will last the analysis period. The reliability design factor accounts for chance variations in both traffic prediction ($\mathbf{w_{18}}$) and the performance prediction ($\mathbf{W_{18}}$)and therefore provides a predetermined level of assurance **R** that pavement sections will survive the period for which they were designed.

Generally, as the volume of traffic, difficulty of diverting traffic, and public expectation of availability increases, the risk of not performing to expectations must be minimized. This accomplished by selecting higher levels of reliability. **Table D-1** presents recommended levels of reliability for various functional classifications. Note that the higher levels corresponds to the facilities which receive the most use, while the lowest level, 50 percent, corresponds the local roads.

Application of reliability concept requires the following steps:

1) Define the functional classification of the facility and determine whether a rural or urban condition exists.

2) Select a reliability level from the range given in **Table D-1.** The greater the value of reliability, the more pavement structure required.

3) A standard deviation (**S_0**) should be selected that is representative of local conditions.

Values of **S_0** developed in ***AASHTO** Road Test* did not include traffic error. However, the performance prediction error developed at the Road Test was 0.35 for flexible pavements. This corresponds to a total standard deviation for traffic of *0.45* for *flexible pavements*.

2.3.4 **Environmental Effects**

The environment can affect the pavement performance in several ways. Temperature and moisture changes can have an effect on the strength, durability, and load-carrying capacity of the pavement and roadbed materials. Another major environmental impact is the direct effect roadbed swelling, pavement blowups, frost heave, disintegration, etc., can have on loss of riding quality and serviceability. This study provides only the criteria necessary for quantifying the input requirements for evaluating roadbed swelling and frost heave. If either of these can lead to a significant loss in serviceability or ride quality during the analysis period then it (they) should be considered in the design analysis for all pavement structural type, except perhaps aggregate-surfaced roads.

The objective of this step is to produce a graph of serviceability loss versus time, such as that illustrated in **Figure D-2.** The chart may be used to estimate the serviceability loss at intermediate periods, e.g., at 13 years, the loss is 0.73 in the example figure. Obviously, if only swelling or only frost heave is considered, there will be only one curve on the graph.

2.3.4.1 **Roadbed Swelling**

To generate the swelling curve, it is first necessary to estimate three variables which affect the rate and potential magnitude of serviceability loss due to swelling :

a) Swell Rate Constant,

b) Potential Vertical Rise, and

c) Swell Probability.

Note that, swelling need only be considered for fine-grained soils such as clays and silts, but all clays and silts are not swelling materials.

a) The Swell Rate Constant (**θ**) is a factor used to estimate the rate of which swelling will take place. This constant can vary anywhere between 0.04 and 0.20. A higher value should be used when the soil is exposed to a large moisture supply from either high rainfall, poor drainage, or other sources of moisture. Lower values should be used when the roadbed has less access to moisture. **Figure B-*1*** provides a chart for subjectively estimating the rate of roadbed soil swelling, considering the available moisture supply and the fabric of roadbed soil.

b) The Potential Vertical Rise (**V_R**) represents the amount of vertical expansion that can occur in the roadbed soil under extreme swell conditions (i.e., high plasticity and extended moisture availability. The designer may obtain Vr from laboratory test results, an empirical procedure, or by experience. **Figure B-2** provides a chart that can be used to estimate the Vr at a particular location given the swelling layer's plasticity index *(ASTM Test No D424)*, moisture condition, and overall thickness of the layer. The moisture condition is a subjective decision based on an estimate of how close the soil moisture conditions during construction or to the in situ moisture conditions at a later date.

c) Swell Probability **(P_S)** represents the proportion (expressed as a percent) of the project length that is subject to swell. The probability of swelling at a given location is considered to be 100 percent if the roadbed soil plasticity index *(AASHTO T90)* is greater than 30 and the layer thickness is greater than 2 feet (or if the $\mathbf{V_R}$ is greater than 0.20 inches). If the project length is separated into swelling and nonswelling materials and they are treated separately, then a probability of 100 percent is used for the swelling sections.

Figure B-3 presents swelling curve accomplished by solving the swelling serviceability loss equation below:

$$\Delta PSI_{SW} = 0.00335 * V_R * P_S * (1-e^{-0 * t}) \qquad \textbf{Eq 2.2}$$

Moisture condition (or supply) refers to the availability of moisture for roadbed soil absorption and $\mathbf{V_R}$ represents the potential vertical rise at a given site as determined from **Figure B-3.** Soil fabric represents the capability of moisture to infiltrate the soil; most fine-grained soils beneath a pavement are neither fractured nor extremely tight. Note that roadbed thickness represents the thickness of the layer subject to swell, for thickness greater than 30 feets, use 30 feets. A simple example is presented in **Figure B-3.**

2.3.4.2 **Frost Heave**

The frost heave phenomenon is very similar to roadbed swelling that it can result in a significant loss of road serviceability due to differential expansion (the differential values of expansion are of interest not the total value). Frost heave occurs when free water in the roadbed soil collects and freezes to form ice lenses. Obviously, frost heaving will not be a problem in areas which are arid or have a minimum frost penetration into the roadbed. Frost heaving can also be minimized by providing drainage to reduce the availability of free water.

There are three factor for frost heave:

a) Frost heave rate,
b) Maximum potential serviceability loss due to frost heave,
c) Frost heave probability.

a) Frost Heave Rate (∅) defines the rate of increase of frost heave roughness (in millimeter per day). The rate of heave depends on the type of roadbed material and its percentage of fine-grained material. **Figure C-*1*** presents a chart that may be used to estimate the rate of heave based on the roadbed soil's *Unified Soil Classification* and percent (by weight) of material finer than 0.02 mm (**AASHTO** T88). After determining material type and the percentage of material weight finer than 0.02 mm, give percentage of soil on the horizontal scale through the material type on the chart and read the average rate of heave not overflowing the frost susceptibility classifications limits. The number determined can vary due to difference of high and low limits of frost susceptibility classifications. For example, let material percentage finer than 0.02 mm and material type be 7 mm and silty gravels' respectively. And let frost susceptibility classification be *Low*'. A number varying between 1 and 2 mm/day from example **Figure C-1** can be read. Thus, average of these values can be used for computation.

b) The Maximum Potential Serviceability Loss **(ΔPSI_{max})** ***Due To Frost Heave*** is dependent on the quality of drainage and depth of frost penetration. **Figure C-2** can be used to estimate this value. **Table D-5** can be used as a guide.

c) Frost Heave Probability **(P_f)** should basically be the designer's estimate of percent area of the project that will experience frost heave. Obviously, this is affected by several factors including the extent of frost-susceptible roadbed material, moisture availability, drainage quality, number of freeze-thaw cycles during the year, and depth of frost penetration. **Figure C-3 as Figure B-3** presents frost heave curve accomplished by solving the frost heave serviceability loss equation below:

$$\Delta PSI_{fh} = 0.01 * P_f * \Delta PSI_{max} * (1-e^{(-0.02*\varnothing*t)}) \quad \textbf{Eq 2.3}$$

The time, **t,** used in **Figure B-3** and **Figure C-3** should be equal to the analysis period. For stage construction and rehabilitation strategies, the performance period is used. The frost heave serviceability loss curve should then be combined with the swelling serviceability loss curve (if applicable) to produce a total serviceability loss versus time curve as in **Figure D-2.** Thus, curve will then be used as a component of the design procedure. A simple example for frost heave is presented in **Figure C-3.**

2.4 <u>Serviceability</u>

The serviceability of a pavement is defined as its ability to serve the type of traffic (automobiles and trucks) which use the facility. The primary measure of serviceability is the *Present Serviceability Index* **(PSI)**', which ranges from 0 (impossible road) to 5 (perfect road). The basic design philosophy of **AASHTO** Guide is the serviceability-performance concept, which provides a means designing a pavement based on a specific total traffic volume and a minimum level of serviceability desired at the end of performance period.

Selection of the lowest allowable **PSI** or terminal serviceability index P_t is based on the lowest index that will be tolerated before rehabilitation, resurfacing or reconstruction becomes necessary. An index of 2.5 or higher is suggested for design period or the total traffic volume, rather than by designing for a terminal serviceability less than 2.0.

Once P_o and P_t are established equation below should be applied to define the total change in serviceability index:

$$\Delta PSI = P_o - P_t \quad \textbf{Eq 2.4}$$

It should be recognized that the P_o values observed at the **AASHTO** Road Test was 4.2 for flexible pavements.

2.5 Material Properties For Structural Design

2.5.1 Effective Roadbed Soil Resilient Modulus

Effective roadbed resilient modulus is established which is equivalent to the combined effect of all the seasonal modulus values. For roadbed materials, laboratory resilient modulus tests *(AASHTO T274)* should be performed on representative samples in stress and moisture conditions simulating those of the roadbed soil for spring-thaw or winter-frozen conditions, then, for extreme cases, practical values of resilient moduli of 20.000 to 50.000 psi may be used for frozen conditions , and for spring-thaw conditions, the retained modulus may be 20 to 30 percent of the normal modulus during the summer and fall periods.

Two different procedures for determining the seasonal variation of the modulus are offered as guidelines. One method is to obtain a laboratory relationship between resilient modulus and moisture content. Then with an estimate of the in situ moisture content of the soil beneath the pavement, the resilient modulus for each of the seasons may be estimated. Besides defining the seasonal moduli, it is also necessary to separate the year into the various component time intervals during which different moduli are effective. In making this breakdown, it is not necessary to specify a time interval of less than one-half month for any given season.

The length of the seasons and the seasonal roadbed resilient moduli are all that is required in terms of roadbed support for the design of rigid pavements and aggregate-surfaced roads. For the design of flexible pavements, however, the seasonal data must be translated into the effective roadbed soil resilient modulus described earlier. This is accomplished with the aid of the chart in **Figure D-3.**

Since a mean value of resilient modulus is used, design sections with coefficient of variations greater than 0.15 (within a season) should be subdivided into smaller sections. For example, if the mean value of resilient modulus is 10.000 psi, then approximately 99 percent of the data should be in a range of 5.500 to 14.500 psi.

The first step of this process is to enter the seasonal moduli in their respective time periods. If the smallest season is one-half month, then all seasonal must be defined in terms of half months and each of the all seasons must be defined in terms in terms of whole months and only one box per month may be filled in.

The next step is to estimate the relative damage **(U_f)** values corresponding to each seasonal modulus. This is done using the vertical scale or the corresponding equation shown in **Figure D-3.** For example, the relative damage corresponding to a roadbed soil resilient modulus of 4.000 psi is 0.51.

Next, the **U_f** values should all be added together and divided by the number of seasonal increments (12 or 24) to determine the average relative damage. The effective roadbed soil resilient modulus **(M_R)**, then, is the value corresponding to the average relative damage on the **M_R - U_f** scale. **Figure D-3** provides an example of the application of the **M_R** estimation process.

2.6 Pavement Structural Characteristics

There are many types of material properties and laboratory test procedure for assessing the strength of pavement structural materials. Elastic modulus is a fundamental engineering property of any paving or roadbed material. The strength of the material is important. In addition to stiffness, and future mechanistic-based procedures may reflect strength as well as stiffness in the material characterization procedures.

It is important note that, although resilient modulus can apply to any type of material, the notation $\mathbf{M_R}$ as used in this study applies only to the roadbed soil. Different notations are used to express the moduli for subbase ($\mathbf{E_{SB}}$), base ($\mathbf{E_{BS}}$), asphalt concrete ($\mathbf{E_{AC}}$) and Portland cement concrete ($\mathbf{E_C}$).

The procedure for estimating the resilient modulus of a particular pavement material depends on its type. Relatively low stiffness materials, such as natural soils, unbound granular layers, and even stabilized layers and asphalt concrete, should be tested using the resilient modulus test method (**AASHTO** *T274*). Alternatively, the bound or higher stiffness materials, such as stabilized bases and asphalt concrete, may be tested using the repeated-load indirect tensile test *(ASTM D4123)*. It is difficult to measure the modulus using the indirect tensile apparatus for Portland cement concrete and base materials stabilized. For these, *ASTM C469*, is recommended.

The elastic modulus for any type of material may also be estimated using correlations developed by some agencies. For normal Portland cement concrete, the following correlation by **American Concrete Institute** is recommended:

$$E_C = 57000 * (f'_C)^{0.5} \qquad \textbf{Eq 2.5}$$

where E_C : PCC elastic modulus (in psi),
$f'c$: PCC compressive strength (in psi), using *AASHTO T22, T140* or *ASTM C39*.

2.6.1 Layer Coefficients

This section describes a method for estimating the *AASHTO Structural layer coefficients* (**a_i** *values)* required for standard flexible pavement structural design. A value for this coefficient is assigned to each layer material in the pavement structure in order to convert actual layer thicknesses into structural number **(SN).** This layer coefficient expresses the empirical relationship between **SN** and thickness and is a measure of the relative ability of material to function as a structural component of the pavement. The following general equation for structural number reflects the relative impact of the layer coefficients (**a_i**) and thickness (**D_i**):

$$SN = \sum_{i=1} a_i * D_i \qquad \textbf{Eq 2.6}$$

Although the elastic (resilient) modulus has been adopted as the standard material quality measure, it is still necessary to identify (corresponding) layer coefficients because of their treatment in the structural number design approach. Though there are correlations available to determine the modulus from tests, such as **R-value**, the procedure recommended is direct measurement using ***AASHTO Method T274*** (subbase and unbound granular materials) and *ASTM D4123* for asphalt concrete and other stabilized materials. The discussion of how these coefficients are separated into five categories, depending on the type and function of the layer material. These are asphalt concrete, granular subbase, cement treated, and bituminous base. Other materials, such as, lime, lime flyash, and cement flyash are acceptable materials, and agency should develop charts

a) Asphalt Concrete Surface Course : **Figure D-4** provides a chart that may be used to estimate the structural layer coefficient of a dense-graded asphalt concrete surface course based on its elastic (resilient) modulus (E_{AC}) at 20°C. Caution is recommended for modulus values above 450.000 psi.

b) Granular Base Layers **: Figure D-5** provides a chart that may be used to estimate a structural layer coefficient, $\mathbf{a_2}$, from one of three different laboratory test results on a granular base material, including base resilient modulus, E_{BS}. The **AASHTO** Road Test basis for these correlations is:

$a_2 = 0.14$ $E_{BS} = 30.000$ psi *CBR* = *100* (approx.) ***R-Value*** = *85* (approx.)

The following relationship may be used in lieu of **Figure D-5** for granular base material form its elastic (resilient) modulus, $\mathbf{E_{BS}}$:

$$a_2 = 0.249 * (\log 10\ E_{BS}) - 0.797 \quad \textbf{Eq 2.7}$$

Table 2.3 k_1 and k_2 values varying due to moisture condition			
	MOISTURE CONDITION	k_1*	k_2*
	DRY	6.000-10.000	0.5-0.7
BASE	DAMP	4.000-6.000	0.5-0.7
	WET	2.000-4.000	0.5-0.7
	DRY	6.000-8.000	0.4-0.6
SUBBASE	DAMP	4.000-6.000	0.4-0.6
	WET	1.500-4.000	0.4-0.6

For aggregate base layers, E_{BS}, is a function of the stress state θ within the layer and is normally given the relation:

$$E_{BS} = k_1 * \theta^{k_2}$$

where

θ**:** stress state or sum of principal stresses $\sigma_1 + \sigma_2 + \sigma_3$ (psi)

k_1 , k_2 **:** regression constants which are a function of material type.

Typical values for base materials are: $\mathbf{k_1}$: 3000 to 8000 $\mathbf{k_2}$: 0.5 to 0.7

If it is possible that $\mathbf{M_R = k_1\, \theta^{k_2}}$ and for $\mathbf{k_1}$ and $\mathbf{k_2}$ table above can be used for unbound base and subbase materials.

c) Granular Subbase Layers : **Figure D-8** provides a chart that may be used to estimate a structural layer coefficient, $\mathbf{a_3}$, from one of three different laboratory results on a granular subbase material, including subbase resilient modulus, E_{SB}. The **AASHTO** Road Test basis for these correlation is :

$\mathbf{a_3}$: 0.11 $\mathbf{E_{SB}}$: 15.000 psi **CBR** : *30* (approx.) **R-Value :** *60* (approx.)

The $\mathbf{E_{SB}}$ versus a*a3* relationship similar to that for granular base materials is as follow:

$$a_3 = 0.227 * (\log 10 E_{SB}) - 0.839 \quad \textbf{Eq 2.9}$$

For aggregate subbase layers, $\mathbf{E_{SB}}$, is affected by stress state O in a fashion similar to that for the base layer. Typical values for $\mathbf{k_1}$ range 1500 to 6000, while $\mathbf{k_2}$ varies from 0.4 to 0.6. Also table above can be used for subbase layer.

d) Cement-Treated Bases: **Figure D-6** provides a chart that mat be used to estimate the structural layer coefficient, $\mathbf{a_2}$, for cement-treated base material either its *Elastic Modulus*, $\mathbf{E_{BS}}$, or, alternatively, its *7-day Unconfined Compressive Strength (ASTM D1633)*.

e) Bituminous-Treated Bases: **Figure D-7** presents a chart that may be used to estimate $\mathbf{a_2}$ for a bituminous-treated base material from either its *Elastic Modulus*, $\mathbf{E_{BS}}$, or, alternatively *Marshall Stability (AASHTO T245, ASTM D1559).*

2.6.2 **Drainage**

This section describes the selection of inputs to treat the effects of certain levels of drainage on predicted pavement performance.

Note that guidance is not provided here any detailed drainage designs or construction methods. It is up to the design engineer to identify what level (or quality) of drainage is achieved under a specific set of drainage conditions. **Table D-5** is the general definitions corresponding to different drainage levels from the pavement structure.

The treatment for the expected level of drainage for a flexible pavement is through the use of modified layer coefficients (e.g., a higher effective layer coefficient would be used for improved drainage conditions). The factor modifying the layer coefficient is referred to as an $\mathbf{m_i}$ value and has been integrated into the structural number SN equation along with layer coefficient ($\mathbf{a_i}$) and thickness ($\mathbf{D_i}$); Thus,

$$SN = a_1 * D_1 + a_2 * D_2 * m_2 + a_3 * D_3 * m_3 \quad \textbf{Eq 2.10}$$

Note that the possible effect of drainage on the asphalt concrete surface course is not considered. **Table D-2** presents the recommended $\mathbf{m_i}$ values as a function of the quality of drainage and the percent of time during the year the pavement structure would normally be expressed to moisture levels approaching saturation.

Finally, it is also important to note that these values apply only to the effects of drainage on untreated base and subbase layers. Although improved drainage is certainly beneficial to stabilized or treated materials, the effects on performance of flexible pavements are not as profound as those quantified in **Table D-2**. As a basis for comparison, the $\mathbf{m}_i$ value for conditions at the AASHTO Road Test is 1.0.

2.7 Flexible Pavement Design

This section describes the application of design procedures for flexible pavements. Flexible pavement design includes asphalt concrete (A_C) surfaces and surface treatments **(ST).** Design approach permits both traffic and environmental loss of serviceability to be taken into account. If the designer desires that only the serviceability loss due to traffic be considered, then *Section 2.7.3* may be ignored.

The basic concept of design for flexible pavement is to first determine the required thickness based on the level of traffic. The associated performance period is then corrected for any environmental-associated losses of serviceability. A stage construction option is provided to allow the designer to consider planned rehabilitation for either environmental or economic reasons. Thus, numerous strategies for original design thickness and subsequent rehabilitation may be developed.

Design is first based on identifying a flexible pavement structural number **SN** to withstand the projected level of axle load traffic.

2.7.1 Determination Required Structural Number

Figure D-9 presents the nomograph recommended for determining the design structural number **(SN)** required for specific conditions, including

a) the estimated future traffic, $\mathbf{W}_{18}$, for the performance period,
b) the reliability, **R**, which assumes all input is at average value,
c) the overall standard deviation, $\mathbf{S_0}$,
d) the effective resilient modulus of roadbed material, $\mathbf{M}_R$, and
e) the design serviceability loss, Δ **PSI** = $\mathbf{P_0 - P_t}$.

A simple example is presented in this figure.

2.7.2 Stage construction

Experience has shown that regardless of the strength (or load-carrying capacity) of a flexible pavement, there may be a maximum performance period associated with a given initial structure which is subjected to some significant level of truck traffic. Obviously, if the analysis period is 20 years (or more) and this practical maximum performance period is less than 20 years, there may be a need to consider stage construction (i.e., planned rehabilitation) in the design analysis. If stage construction alternatives are to be considered, it is important to check the constraint on minimum performance period within the various candidate strategies. It is also important to recognize the need to compound the reliability for each individual stage of the strategy. For example, if each stage of 3-stage strategy (an initial pavement with two overlays) has a 90 percent reliability, the overall reliability of the design strategy is 0.90 * 0.90 * 0.90 or 72.9 percent. Conversely, if an overall reliability of 95 percent is desired, the individual reliability for each stage must be $(0.95)^{1/3}$ or 98.3 percent. It is important to recognize compound of reliability may be severe for stage construction, and later opportunities to correct problem areas may be considered.

To evaluate stage construction alternatives, the user should refer to **Chapter 3** which addresses pavement rehabilitation.

2.7.3 Roadbed Swelling And Frost Heave

If either swelling and frost heave are to be considered in terms of their effects on serviceability loss and the need for future overlays, then the following procedure should be applied. It does require the plot of serviceability loss versus time as in **Figure D-2.**

The procedure for considering environmental serviceability loss is similar to the treatment of stage construction strategies because of the planned future needed for rehabilitation. In the stage construction approach, the structural number of the initial pavement is selected and its corresponding performance period (service life) determined. An overlay (or series of overlays) which will extend the combined performance periods past the desired analysis period is then identified. The difference in the stage construction approach when swelling and/or frost heave are considered is that an iterative process is required to determine the length of the performance period for each stage of the strategy. The objective of this iterative process is to determine when the combined serviceability loss due to traffic and environment reaches the terminal level. It is described with the aid of **Table C-1.**

Step 1: Select an appropriate structural number SN, for the initial pavement. Because of the relatively small effect the structural number has an minimizing swelling and frost heave, the maximum initial **SN** recommended is that derived for conditions assuming no swelling or frost heave. For example, if the desired overall reliability is 90 % (since an overlay is expected, the design reliability for both the initial pavement and overlay is 90½ = 95 %), the effective roadbed soil modulus is 5.000 psi, the initial serviceability is 2.5, and a 15-year performance period (along with a corresponding 5 million 18-kip ESAL application) for the initial pavement is assumed, the maximum **SN** (determined from **Figure D-9)** that should be considered for swelling/frost heave condition is 4.4. Anything loss than a *SN* of 4.4 may be appropriate, so long as it does not violate the minimum performance period.

Step 2: Select a trial performance period that be expected under the swelling/frost heave conditions anticipated and enter in *Column 2.* This number should be less then the maximum possible performance period corresponding to the selected initial pavement structural number. In general, the greater the environmental loss, the smaller the performance period will be.

Step 3: Using the graph of cumulative environmental serviceability loss versus time developed as in **Figure D-2**, estimate the corresponding total serviceability loss due to swelling and frost heave **($PSI_{sw,fh}$)** that can be expected for the trial period from *Step 2,* and enter in *Column 3.*

Step 4: Subtract this environmental serviceability loss *(Step 3)* from the desired total serviceability loss (4.4 - 2.5 = 1.9 is used in the example) to establish the corresponding traffic serviceability loss. Enter result in *Column 4.*

$\Delta PSI_{TR} = \Delta PSI - \Delta PSI_{SW,fh}$ **Eq 2.11**

Step 5: Use **Figure D-9** to estimate the allowable cumulative 18-kip ESAL traffic corresponding to the traffic serviceability loss determined in *Step 4* and enter in *Column 5*. Note that it is important to use the same levels of reliability, effective roadbed soil resilient modulus, and initial structural number when applying the flexible pavement chart to estimate this allowable traffic.

Step 6: Estimate the corresponding year at which the cumulative 18-kip ESAL traffic (determined in *Step 5*) will be reached and enter in *Column 6*. This should be accomplished with the aid of the cumulative traffic versus time plot developed as in **Figure D-1** example.

Step 7: Compare the trial performance period with that calculated in *Step 6*. If the difference is greater than 1 year, calculate the average of two and use this as the trial value for the start of next iteration (return to *Step 2*). If the difference is less than 1 year, convergence is reached and the average is said to be the predicted performance period of the initial pavement structure corresponding to the selected initial **SN.** In the example, convergence was reached after three iterations and the predicted performance period is about 8 years.

The basis of this iteratic process is exactly the same for the estimation of the performance period of any subsequent overlays. The major difference in actual application are that the overlay design methodology presented in **Chapter 3** is used to estimate the performance period of the overlay and any swelling and/or frost heave losses predicted after overlay should restart and then progress from the point in time when the overlay was placed.

2.7.4 Selection Of Layer Thicknesses

Once the design structural number **SN** for an initial pavement structure is determined, it is necessary to identify a set of pavement layer thickness which, when combined, will provide the load-carrying capacity corresponding to the design **SN.** The equation 2.10 provides the basis for converting **SN** into actual thicknesses of surfacing, base and subbase:

$$SN = a_1 * D_1 + a_2 * D_2 * m_2 + a_3 * D_3 * m_3$$

where a_1, a_2, a_3 : layer coefficients representative of surface, base and subbase courses, respectively,

D_1, D_2, D_3 : actual thicknesses (in inches) of surface, base and subbase courses, respectively,

m_2, m_3: drainage coefficients for base and subbase layers, respectively.

The **SN** equation does not have a single unique solution; i.e., there are many combinations of layer thicknesses that are satisfactory solutions. The thickness of the flexible pavement layers should be rounded to the nearest ½ inch. When selecting appropriate values for the layer thicknesses, it is necessary to consider their cost effectiveness along with the construction and maintenance constraints in order to avoid the possibility of producing an impractical design. From a cost-effective view, if the ratio of costs for layer 1 to layer 2 is less than the corresponding ratio of layer coefficients times the drainage coefficient, then the optimum economical design is on where the minimum base thickness is used.

Since it is generally impractical and uneconomical to place surface, base or subbase courses of less than some minimum thickness, the **Table D-4** is provided as minimum practical thicknesses for each pavement courses.

Individual agencies should also establish the effective thickness and layer coefficients of both single and double surface treatments. The thickness of the surface treatment layer may be negligible in computing **SN**, but its effect on the base and subbase properties may be large due to reductions in surface water entry.

2.7.5 Layered Design Analysis

It should be recognized that, for flexible pavements, the structure is a layered system and should be designed accordingly. First, the structural number required over the roadbed soil should be computed. In the same way, The structural number required over the subbase layer and base layer should also be computed, using the applicable strength values for each.

By working with differences between the computed **SN** numbers required over each layer, the maximum allowable thickness of any given layer can be computed. For example, the maximum allowable **SN** for the subbase material would be equal to the **SN** required over the subbase subtracted from the SN required over the roadbed soil. In a like manner, the structural numbers of the other layers may be computed. The thicknesses for the respective layers may be determined as indicated on **Figure D-18.**

It should be recognized that this procedure should not be applied to determine the **SN** required above subbase or base materials having a modulus greater than 40.000 psi. For such cases, layer thicknesses of materials above the high' modulus layer should be established based on cost effectiveness and minimum practical thickness considerations.

CHAPTER 3

PAVEMENT DESIGN PROCEDURE FOR RECONSTRUCTION WITH OVERLAY

The basic equation for determining the required **SN** value due to a flexible overlay over an existing flexible pavement is shown below, required thickness of asphaltic overlay, $\mathbf{h_{OL}}$, can be found from this formula:

$$h_{OL} = SN_{OL}/a_{OL} = (SN_y - F_{RL} * SNxeff)/a_{OL} \qquad \textbf{Eq 3.1}$$

where

SNy: the total structural capacity required to support the overlay traffic over existing subgrade (foundation) conditions,

FRL: the remaining life factor which accounts for damage of the existing pavement as well as the desired degree of damage to the overlay at the end of the overlay traffic. It is always less than or equal to a value of 1.0.

SNxeff: the effective structural capacity of the existing pavement immediately prior to the time of the overlay, and has reflected the damage to that point in time,

a_{OL}: the structural layer coefficient of the overlay material,

SN_{OL}: structural number of the required asphalt concrete overlay.

Step 1 : First, compute the service life of initial pavement as described in *Section 2.7*, new construction pavement procedures. Obviously, it must be the sane as maximum performance period or less than this due to considering swelling and frost heave.

Step 2 : Second, determine the traffic that will be carried by overlay. This is the difference between traffic numbers corresponding the times that are new computed maximum performance period and analysis period. **Figure D-1** can be used to determine the remaining 18-kip ESAL traffic that will be carried by overlay.

Step 3 : Next, determine the $\mathbf{SN_y}$ which is structural number required for a *'new'* pavement to carry the estimated future traffic for prevailing roadbed soil support conditions. This is determined using **Figure D-9** with input parameters associated with the design of new pavement to last the remaining time of analysis period which is determined in the first step. The cumulative 18-kip ESAL traffic $\mathbf{(W_{18})}$ is the difference traffic between at the beginning of overlay and at the end of overlay meaning at the same time traffic corresponding maximum performance period (computed for new construction) and analysis period. For $\mathbf{SN_y}$ determination, design serviceability loss **(Δ PSI)** must be first computed. This can be gotten using **Figure D-2** prepared for new construction before. The serviceability loss due to environment is the loss difference between those corresponding new maximum performance period and analysis period.

$$\Delta PSI_{TR} = \Delta PSI - \Delta PSI_{sw,fh} \qquad \textbf{Eq 2.11}$$

$$\Delta PSI = P_o - P_t \qquad \textbf{Eq 3.2}$$

$$\Delta PSI_{sw,fh} = \Delta PSI_{AP} - \Delta PSI_{PP} \qquad \textbf{Eq 3.3}$$

where

ΔPSI_{Ap}: loss of serviceability corresponding to the analysis period,

ΔPSI_{pp}: loss of serviceability corresponding to the computed performance period.

Thus, the resulting $\mathbf{SN_y}$ can be computed using parameters, overall standard deviation $(\mathbf{S_0})$, the second stage reliability (**R** from $\mathbf{R}^{1/n}$ computed for new pavement construction before), the effective roadbed resilient modulus $(\mathbf{M_R})$ and loss due to traffic ($\Delta \mathbf{PSI_{TR}}$ computed above).

Step 4 *:* Compute F_{RL}. This is established based on the estimated remaining life $(\mathbf{R_{Lx}})$ of the original pavement at the time of overlay and the estimated remaining life $(\mathbf{R_{Ly}})$ of the overlay when it reaches its design terminal serviceability:

a) From **Figure D-13**, for a $\mathbf{SN_0}$ (the structural number of the original pavement) and a terminal serviceability (at the time of overlay), the value of $\mathbf{R_{Lx}}$ is computed. Note that in comparing serviceability to traffic repetitions, several serviceability values should be considered:

P_0 : Initial serviceability of the original pavement or the overlaid pavement when constructed,

P_{t1} : Terminal serviceability of the existing pavement immediately prior to the ovarlay,

P_{t2}: Terminal serviceability desired with the overlaid pavement after the overlay traffic has been applied, and

P_f : The ultimate failure serviceability for any pavement type corresponding to a completely damaged (failed) pavement.

In **Figure D-13**, $\mathbf{P_{t1}}$ symbolizes the expression above.

It is not essential that $\mathbf{P_{t1}}$ must be equal to $\mathbf{P_{t2}}$ since serviceability at the time of ovarlay and serviceability at the end of overlay period are input considerations of designer. For this overlay method, failure serviceability is $\mathbf{P_f}$=*2.0*. Therefore, when a pavement serviceability reaches a $\mathbf{P_f}$=*2.0,* the pavement is said to be 100 percent damaged with no remaining life. Since this is subjective value, pavements with more than 100 percent damage or negative remaining life may occur. This is not alarm the user once the relative basis of damage and remaining life is understood. Expressions are symbolized in **Figure D-19 (a).**

b) From **Figure D-9**, estimate the future 18-kip ESAL traffic $(\mathbf{N_{fy}})$ to ultimate failure (i.e., when serviceability drops to $\mathbf{P_f}$ of 2.0 and remaining life is zero). This is based on the same input parameters used to estimate $\mathbf{SN_y}$, except the serviceability loss used as input to the design chart includes the loss due to roadbed swelling.

$$\Delta PSI_{TR} = (P_0 - P_t) - \Delta PSI_{sw,fh} \qquad \textbf{Eq 2.11}$$

c) Estimate the future traffic ***(y)*** to a terminal serviceability, and then the estimated remaining life **(R_{Ly})** of the overlay when it reaches **Pt.**

R_{Ly} = (Nfy -y)/Nfy (convert it as a percentage) **Eq 3.4**

d) Thus, by applying the above estimates of **R_{Lx}** and **R_{Ly}** in the graph from **Figure D-12,** estimate the remaining life factor **F_{RL}**.

<u>Step 5</u> : The last factor to be estimated before the required overlay structural number can be determined is the effective structural number **(SN_{xeff})** of the original pavement at the time of overlay. Since this represents the design for an overlay, the time of maximum performance period computed after initial pavement construction, SNxeff must be approximated using the following relationship:

$$SN_{xeff} = C_X * SN_O \qquad \textbf{Eq 3.5}$$

where

SN_O : structural number of original pavement, and

C_X : pavement condition factor.

The latter term, **C_X**, is estimated based on the remaining life **R_{Lx}** of original pavement at the time of the overlay.

Referring to **Figure D-14, C_X** is estimated corresponding to **R_{Lx}**. Thus, the effective structural number can be computed.

Inserting the values for **SN_y, F_{RL}** and **SN_{xeff}** into the overlay design equation results in a required overlay structural number **(SN_{OL})**.

This translates into a design asphalt overlay thickness of

$$D_{OL} = SN_{OL} / a_{OL} \text{ (inches).} \qquad \textbf{Eq 3.6}$$

CHAPTER 4

LOW-VOLUME ROAD DESIGN

This chapter covers the design of low-volume roads for two surface types using procedure based on design charts (nomographs) and design catalogs. For surface treatment or chip seal pavement structures, the procedures for flexible pavements may be used.

Since many city streets and country roads that full under the low-volume category may still carry significant levels of truck traffic, the maximum number of 18-kip ESAL applications considered for flexible pavements is 700.000 to 1 million. The practical minimum traffic level that can be considered for any flexible pavement during a given performance period is about 50.000 18-kip ESAL applications. For the aggregate-surfaced (gravel) roads used for many country and forest roads, the maximum traffic level considered is 100.000 18-kip ESAL applications, while the practical minimum level (during a single performance period) is 10.000.

4.1 Flexible Pavements

The low-volume road design chart procedures for flexible pavements are basically the same as those for highway pavement design. The primary difference in the design for low-volume roads is the level of reliability that may be used. Because of their relative low usage and the associated low level of risk, the level of reliability recommended for low-volume road design is 50 percent. The designer may, however, design for higher levels of 60 to 80 percent, depending on the actual projected level of corridor, etc.

If, in estimating an effective resilient modulus of the roadbed material (**M_R**), it is not possible to determine the lengths of the seasons or even the seasonal roadbed soil resilient moduli, **Table D-6** provides roadbed soil resilient modulus values that may be used for low-volume road design classifying the general quality of the roadbed material as a foundation for the pavement structure.

4.2 Aggregate-Surfaced Roads

The basis for treating the effects of seasonal moisture changes on roadbed soil resilient modulus, **M_R**, is the same for aggregate-surfaced road design as it is for flexible pavement design.

Unlike the flexible pavement design procedures, however, the design chart-based procedure for aggregate-surfaced roads requires a graphical solution. It is important to note that the effective modulus of the roadbed soil developed for flexible pavement design should not be used in lieu of the procedure described here.

The primary design requirements for aggregate-surfaced roads include:

a) the predicted future traffic, **w_{18}** (section 2.3.2), for the period,
b) the lengths of the seasons (section 2.5.1),
c) seasonal resilient moduli of the roadbed soil (section 2.5.1),
d) elastic modulus, **E_{BS}** (psi) of aggregate base layer (section 2.6),
e) elastic modulus, **E_{SB}** (psi) of aggregate subbase layer (section 2.6),
f) design serviceability loss, **Δ PSI** (section 2.4),

g) allowable rutting, **RD** (inches) in surface layer.

It is important to explain *the allowable rutting* **(RD)** because of using this criteria in the procedure:

In **AASHTO** Guide, rutting is considered only as a performance criterion for aggregate-surfaced roads. Although rutting is a problem with asphalt concrete surface pavements, no design model suitable for incorporation into **AASHTO** Guide is available ta this time. It is important to note that the rut depth failure predicted by the aggregate-surfaced road model does not refer to simple surface rutting (which can be corrected by normal blading operations), but to serious rutting associated with deformation of the pavement structure.

The allowable rut depth for an aggregate-surfaced road is dependent on the average daily traffic. Typically, allowable rut depths range from 1.0 to 2.0 inches for aggregate-surfaced roads.

These design requirements itemized above are used in conjunction with the computational chart in example **Table D-7** and the design nomographs for serviceability **(Figure D-16)** and rutting **(Figure D-15).** *Design procedure ýs as fallow:*

Step 1 **:** Select four levels of aggregate base thickness, $\mathbf{D_{BS}}$, which should bound the probable solution. For this, four separate tables, identical to **Table D-7**, should be prepared.

Enter each of the four trial base tables ($\mathbf{D_{BS}}$ *8* inches is used in the example).

Step 2 **:** Enter the design serviceability loss as well as the allowable rutting in the appropriate boxes of each of the four tables.

Step 3 **:** Enter the appropriate seasonal resilient (elastic) moduli of the roadbed **($\mathbf{M_R}$)** and aggregate base material, $\mathbf{E_{BS}}$ (psi), in *Column 2 and 3,* respectively, of **Table D-7.** The base modulus values may be proportional to the resilient modulus of the roadbed soil during a given season. A constant value of 30.00 psi was used in the example, however, since a portion of aggregate base material will be converted into an equivalent thickness of subbase material (which will provide some shield against the environmental moisture effects).

Step 4 **:** Enter the seasonal 18-kip ESAL traffic in *Column 4* of **Table D-7**. Assuming that truck traffic is distributed evenly throughout the year, the lengths of the seasons should be used to proportion the total projected 18-kip ESAL traffic to each season. If the road is load-zoned (restricted) during certain critical periods, the total traffic may be distributed only among those seasons when truck traffic is allowed.

Step 5 **:** Within each of the four tables, estimate the allowable 18-kip ESAL traffic for each of the four seasons using the serviceability-based nomograph in **Figure D-16** and enter in *Column 5.* If the resilient modulus of the roadbed soil (during the frozen season) is such that the allowable traffic exceeds the upper limit of the nomograph, assume a practical value of 500.000 18-kip ESAL.

Step 6 **:** Within each of the four tables, estimate the allowable 18-kip ESAL traffic for each of the four seasons using the rutting-based nomograph in **Figure D-15,** and enter *Column 7.* Again, if the resilient modulus of the roadbed soil is such that the allowable traffic exceeds the upper limit if the nomograph, assume a practical value of 500.000 18-kip ESAL.

Step 7 : Compute the seasonal damage values in each of the four tables for the serviceability criteria by deviding the projected seasonal traffic *(Column 4)* by the allowable traffic in that season *(Column 5)*. Enter these seasonal damage values in *Column 6* of **Table D-7** corresponding serviceability criteria. Next, follow these same instructions for rutting criteria, i.e., divide *Column 4* by *Column 7* and enter in *Column 8*.

Step 8 : Compute the total damage for both the serviceability and rutting criteria by adding the seasonal damages When this is accomplished for all four tables corresponding to the four trial base thickness, a graph of total damage versus base layer thickness should be prepared. The average base layer thickness, D_{BS} required is determined by interpolating in this graph for a total damage equal to 1.0. **Figure D-20** provides an example in which the design is controlled by the serviceability criteria, D_{BS} is equal to 10 inches.

Step 9 : The base layer thickness determined in the last step should be used for design if the effects of aggregate loss are negligible. If, however, aggregate loss is significant, then design thickness is determined using the following equation:

$$D_{BS} = D_{BS} + (0.5 * GL)$$ **Eq 4.1**

where

GL : total estimated aggregate (gravel) loss (in inches) over the performance period.

Aggregate loss due to traffic and erosion is an additional concern for aggregate-surfaced roads. When aggregate loss occurs, the pavement structure becomes thinner and the load-carrying capacity is reduced. This reduction of the pavement structure thickness increases the rate of surface deterioration.

To treat aggregate loss in the procedure, it is necessary to estimate the total thickness of aggregate that will be last during the design period, and the minimum thickness of aggregate that is required to keep a maintainable working surface for the pavement structure.

Note that there is very little information available today to predict the rate of aggregate loss. Below is an example of a prediction equation developed with limited data on sections experiencing greater than 50 percent truck traffic:

$$GL = 0.12 + 0.1223\ (LT)$$ **Eq 4.2**

where

LT : number of loaded trucks in thousands.

A second equation, which was developed from a recent study in Brazil on typical rural sections, can be employed by the user to determine the input for gravel loss:

$$GL = (B/25.4)/(0.0045 * LADT + 3380.6/R + 0.467 * G)$$ **Eq 4.3**

where

GL : aggregate loss, in inches, during the period of time being considered,
B : number of bladings during the period of time being considered,
LADT : average daily traffic in design lane (for one-lane road use total traffic in both directions),

R : average radius of curves, in feet,
G : absolute value of grade, in percent.

Another equation, developed through a British study done in Kenya, is more applicable to areas where there is very little truck activity and thus the facility is primarily used by cars. Since the equation below is for annual gravel loss, the total gravel loss **(GL)** would be estimated by multiplying by the number of years in the performance period:

$$AGL = [T^2/(T^2+50)]*f*(4.2 + 0.092 * T + 0.0889 * R^2 + 1.88\ VC) \quad \textbf{Eq 4.4}$$

where

AGL : annual aggregate loss, in inches,
T : annual traffic volume in both directions, in thousands of vehicles,
R : annual rainfall, in inches,
VC : average percentage gradient of the road,
f : 0,037 for lateritic gravels,
0.043 for quartzitic gravels,
0.028 for volcanic gravels,
0.059 for coral gravels.

It should be noted that there are serious drawbacks with all the equations shown here; therefore, whenever possible, local information about aggregate loss should be used as input to the procedure.

Going on computation of $\mathbf{D_{BS}}$;

If, for example, the total estimated gravel loss was 2 inches and the average base thickness required was 10 inches, the design thickness of the aggregate base layer would be

$$D_{BS} = D_{BS} + (0.5 + GL) = 10 + (0.5 * 2) = 11 \text{ inches}$$

<u>Step</u> <u>10</u> : The final step of the design chart procedure for aggregate-surfaced roads is to convert a portion of the aggregate base layer thickness to an equivalent thickness of subbase material. This is accomplished with the aid of **Figure D-17.** Select the final base thickness desired, $\mathbf{D_{BSf}}$ (6 inches is used in the example). Draw a line to the estimated modulus of the subbase material, $\mathbf{E_{SB}}$ (15.000 psi is used in the example). Go across and through the scale corresponding to the reduction in base thickness, $\mathbf{D_{BSi}}$-$\mathbf{D_{BSf}}$ (11 minus 6 equal to 5 inches is used in the example). Then, for the known modulus of the base material, $\mathbf{E_{BS}}$ (30.000 psi in the example), determine the required subbase thickness, $\mathbf{D_{SB}}$ (8 inches)

CHAPTER 5

EXAMPLES

In this chapter, a detailed example is presented, and then a few more are presented additionally giving only input and output values.

5.1 Flexible Pavement Design Example

This example is provided to illustrate the flexible pavement design procedure presented in *section 2.7.* The design requirements for this example are described here in the same order.

Time Constraints: The analysis period selected for this deign example is 20 years and the maximum performance period (or service life) selected for the initial flexible pavement structure is 15 years. Thus, it will be necessary to consider stage construction (i.e., planned rehabilitation) alternatives to develop design strategies which will last the analysis period.

Traffic: Based on average daily traffic and axle weight data from the planning group, the estimated two-way 18-kip equivalent single axle load *(ESAL)* applications during the first year of the pavement life is 2.5 10^6 and the projected (compound) growth rate is 3 percent per year. The directional distribution factor D_L for facility (assume three lanes in on direction) is 80 percent. Thus, the traffic during the first year (in the design lane) is (2.5 10^6)*(0.80)*(0.50) or 1.0 10^6 18-kip ESAL applications. **Figure D-1** provides a plot of the cumulative 18-kip ESAL traffic over the 20-year analysis period. The curve and equation for future traffic **(w_{18})** are reflective of the assumed exponential growth rate **(g)** of 3 percent.

Reliability: A 90 % overall reliability level was selected for design because of being heavily trafficked state highway and being in a rural situation where daily traffic volumes should never exceed half of its capacity. This means that for a two-stage strategy (initial pavement plus one overlay), the design reliability for each stage must be 0.90 ½ or 95 percent. Similarly, for three-stage strategy (initial pavement plus two overlays) the design reliability for all three stages must be $0.90^{1/3}$ or 96.5 percent. Another criteria required for the consideration of reliability is the overall standard deviation **(S_0)**. In this example problem 0.35 of **(S_0)** will be used.

Environmental Impacts: The roadbed soil is considered to be a highly active swelling clay. Because of this, a drainage system will be constructed which is capable of removing excess moisture in less than 1 day. The duration of below-freezing temperatures in this environment, however, is not sufficient to result in any problems with frost heaving. Average plasticity index **PI** is above 40 and because of the plan to construct a *'good'* drainage system, the future moisture conditions are considered to be *'optimum'* throughout the project length.

Assuming roadbed soil have a tight fabric and since **PI** is greater than 40, swell rate constant was determined as 0.075 and potential vertical rise *V_R* was determined as 1.2 inches using **Figure B-2.**

The swell probability is simply the percent of the length of the project which has a potential vertical rise greater than 0.2 inches, assuming 10.100 feet out of the total 12.000 have a V_R greater than 0.2 inches, thus the swelling probability is 84 %.
Using *Figure B-3,* 0.20 can be plotted to use determination of thicknesses.

Serviceability: Based on the traffic volume and functional classification of the facility *(6-lane state highway)* a terminal serviceability $\mathbf{P_t}$ of 2.5 was selected, and the initial serviceability $\mathbf{P_0}$ of 4.6 was selected. Thus

$$\Delta PSI = Po - Pt = 4.6 - 2.5 = 2.1$$

Effective Roadbed Soil Resilient Modulus: **Figure D-3** summarizes the data used to characterize the effective resilient modulus of the roadbed soil. Individual moduli are specified for 24 half-month intervals to define the seasonal effects. These values are also reflective of the roadbed support that would be expected under the improved moisture conditions provided by the *'good'* drainage system.

Roadbed Moisture Condition	Roadbed Soil Resilient
	Modulus (psi)
Wet	5.000
Dry	6.500
Spring-Thaw	4.000
Frozen	20.000

The frozen season *(from mid-January to mid-February)* is 1 month long , the spring-thaw season *(mid-February to March)* is 0.5 months long, the wet periods *(March through May* and *mid-September through mid-November)* total 5 months, and the dry periods *(June through mid-September* and *mid-November through mid-January)* total 5.5 months. Application of the effective roadbed soil $\mathbf{M_R}$ estimation procedure results in a value of 5.700 psi.

Pavement Layer Materials Characterization: Three types of pavement materials will constitute the individual layers of the structure. The moduli for each, determined using the recommended laboratory test procedures, are as follows:

Asphalt Concrete : E_{AC}=400.000 psi,
Granular Base : E_{BS}=30.000 psi,
Granular Subbase : E_{SB}=11.000 psi.

Layer Coefficients: The structural layer coefficients **(ai-values)** corresponding to the moduli defined in the previous section are as follows:

Asphalt Concrete : a_1=0.42 **(Figure D-4),**
Granular Base : a_2=0.14 **(Figure D-5),**

Granular Subbase : a_3=0.08 **(Figure D-8).**

Drainage Coefficients: The drainage coefficients **(m-values)** corresponding to the granular base and subbase materials for a *'good'* drainage system (i.e., water removed within 1 day) is 1.20, (The **range in Table D-2,** for 1 to 5% moisture exposure time is 1.15 to 1.25).

5.1.1 Development Of Initial Stage

Since the estimated maximum performance period (15 years) is less than the design analysis period (20 years) any initial structure selected will require an overlay to last the analysis period. The thickest recommended initial structure (evaluated here) is that corresponding to the maximum 15-year performance period . Thinner initial structure , selected for the purpose of life-cycle cost analysis, will require thicker overlays (at an earlier date) to last the same analysis period.

Using $\mathbf{M_R}$ of 5700 psi, *R* of 95 %, **So** of 0.35, **Δ PSI** of 2.1 and the cumulative traffic at the max. performance period 18.6 10^6 18-kip ESAL (from **Figure D-1** for a time of 15-year), form **Figure D-9,** max. initial structural number *SN* of 5.6 is computed. Because of serviceability loss due to swelling, however, an overlay will be required before the end of the 15-year design performance period. Using the step-by-step procedure described in section 2.7, the service life that can actually be expected is about 13 years, see **Table D-8.** Thus, the overlay that must be designed will need to carry the remaining 18-kip ESAL traffic over the last 7 years of the analysis period.

Next, solve for the *SN* required above the base material by applying **Figure D-9** using the resilient modulus of base material (rather than the effective roadbed soil resilient modulus). Values of $\mathbf{E_{BS}}$ equal to 30.000 psi, first stage reliability **R** equal to 95%, $\mathbf{W_{18}}$ equal to 16.0 10^6 and $\mathbf{\Delta PSI_{TR}}$ equal to 1.89 (the latter two are form **Table D-8**) result in an 3.2. Thus the asphalt concrete surface thickness required is

$$D_1^* = SN_1 / a_1 = 3.2 / 0.42 = 7.6 \text{ (or 8 inches)}$$

$$SN_1^* = a_1 * D_1^* = 0.42 * 8 = 3.36$$

Similarly, using the subbase modulus of 11.000 psi as the effective roadbed soil resilient modulus, $\mathbf{SN_2}$ is equal to 4.5 and the thickness of base material required is

$$D_2^* \quad (SN_2 - SN_1^*) / (a_2 * m_2)$$

$$= (4.5 - 3.36) / (0.14*1.20) = 6.8 \text{ (or 7 inches)}$$

$$SN_2^* = 7 * 0.14 * 1.20 = 1.18$$

Finally, the thickness of subbase required is :

$$D_3^* = (SN_3 - (SN_1^* + SN_2^*)) / (0.08 * 1.20) = 11 \text{ inches.}$$

5.1.2 **Development Of Overlay Design**

In this section an overlay example is presented based on the previous example computed to determine initial layer thicknesses.

Since the initial pavement structure in this design example has a service of only 13 years, the overlay that should be determined for life-cycle cost analyses must last 7 years and carry the remaining 18-kip ESAL traffic thickness design for this overlay is accomplished using an adaptation of the overlay design procedure described in *Chapter 3*. The equation to be used to solve as follow:

$$SN_{OL} = SNy - (F_{RL} * SNxeff)$$

SN_y is determined using **Figure D-9** with input parameters associated with the design of a new pavement to last the remaining 7 years of analysis period. The cumulative 18-kip ESAL traffic **(W_{18})** between years 13 and 20 is 11.3 10^6 (from **Figure D-1**), the second stage reliability **R** is 95%, **So** is 0.35, **M_R** is 5.700 psi. The serviceability loss due to traffic **(ΔPSI_{TR})**, which is used as input to **Figure D-9** is equal to the design serviceability loss *(PSI)* less than the serviceability loss due to environment, in this case, only swelling **(Δ PSI_{SW})**.

$\Delta PSI_{TR} = \Delta PSI - \Delta PSI_{SW}$ Since,
$\Delta PSI = P_O - P_t = 4.6 - 2.5 = 2.1$ and
$\Delta PSI_{SW} = 0.26$ (**Figure D-21,** year 20) - 0.21 (year 13) = 0.05

The serviceability loss due to traffic is:

$\Delta PSI_{TR} = 2.1 - 0.05 = 2.05$ Thus, the resulting **SNy** from **Figure D-9** is 5.2.

The remaining life factor F_{RL} is established based on the estimated remaining life R_{Lx} of the original pavement at the time of overlay and the estimated remaining life R_{Ly} of the overlay when it reaches its design terminal serviceability of 2.5.

a) From **Figure D-13,** for an **SN_O** (the structural number of the original pavement) equal to 5.6 and terminal serviceability (at the time of overlay) of 2.5, the value of R_{Lx} is 42 percent.

b) From **Figure D-9,** the estimated future 18-kip ESAL traffic N_{Fy} to ultimate failure (i.e., when the serviceability drops to 2.0 and remaining life is zero) is 17.0 10^6 18-kip ESAL. This is based on the same input parameters used to estimate **SN_y,** except the serviceability loss used as input to the design chart includes the loss due to roadbed swelling.

$\Delta PSI_{TR} = (4.6 - 2.0) - 0.05 = 2.55$

Since the estimated future traffic **(y)** to a terminal serviceability of 2.5 is 11.3 10^6 18-kip ESAL, the estimated remaining life R_{Ly} of the overlay when it reaches **P_t** equal 2.5 is:

$R_{Ly} = (N_{Fy} - y) / N_{Fy} = (17\ 10^6 - 11.3\ 10^6) / 17\ 10^6 = 0.335 = 33.5\ \%$

Thus, by applying the above estimates of $\mathbf{R_{Lx}}$ and $\mathbf{R_{Ly}}$, in the graph form **Figure D-12,** the remaining life factor $\mathbf{F_{RL}}$ is 0.72.

The last factor to be estimated before the required overlay structural number can be determined is the effective structural number $\mathbf{SN_{xeff}}$ of the original pavement at the time of overlay. Since this represents the design for an overlay 13 years after initial pavement construction, $\mathbf{SN_{xeff}}$ must be approximated using the following relationship.

$$SN_{xeff} = C_x * SN_o$$

where

SN_o : structural number of original pavement (5.6), and

C_x : pavement condition factor.

The latter term, $\mathbf{C_x}$, is estimated based on the remaining life $\mathbf{R_{Lx}}$ of the original pavement at the time of the overlay. From **Figure D-14,** (with $\mathbf{R_{Lx}}$ equal to 42 %), $\mathbf{C_x}$ is 0.86. Thus, the effective structural number is :

$$SN_{xeff} = 0.86 * 5.6 = 4.82$$

Inserting the values for $\mathbf{SN_y}$, $\mathbf{F_{RL}}$ and $\mathbf{SN_{xeff}}$ into the overlay design equation results in a required overlay structural number of

$$SN_{OL} = 5.2 - (0.72 * 4.82) = 1.73$$

This translates into a design asphalt concrete overlay thickness of

$$D_{OL} = SN_{OL} / a_{OL} = 1.73 / 0.42 = 4.1 \text{ inches.}$$

5.1.3 <u>Summary Of Design Strategy</u>

The first stage or initial pavement structure has an **SN** of 5.6 which was broken down into the following layer thickness:

Asphalt Concrete :	8 inches,
Granular Base :	7 inches,
Granular Subbase :	11 inches.

This structure will last approximately 13 years and carry about 16 million 18-kip ESAL applications. It will require a 4-inch asphalt concrete overlay to last the remaining 7 years of the 20-year analysis period. During those 7 years, the overlaid structure will carry about 11 million 18-kip applications.

Note that if the designer requires 3-stage construction (this means one initial pavement structure plus two overlays for rehabilitation), Reliability **R** equals $\mathbf{R}^{1/3}$ and lifetime of first overlay is needed to last:

For example, let max. performance period be as 13 years corresponding to **R** (which equals $\mathbf{R}^{1/3}$) and let us assume first overlay to last 4 years. In this case, the construction time of first overlay is after 13 years and of second overlay is after 17 years. Figures must be used considering this situation.

5.2 Computed Examples

In this section, some examples will be presented to compare. Note that some input data were assumed to be constant to be able to compare the results. Plots of serviceability and cumulative 18-kip ESAL traffic of examples are presented in **Figure 5.1** and **Figure 5.2.**

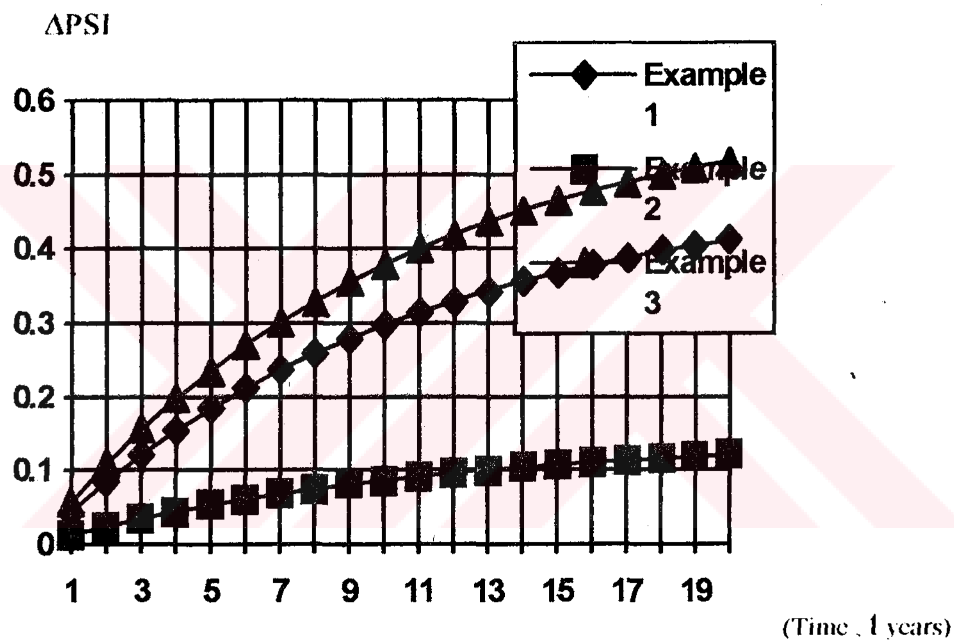


Figure 5.1 Total serviceability loss due to swelling and frost heave for examples.

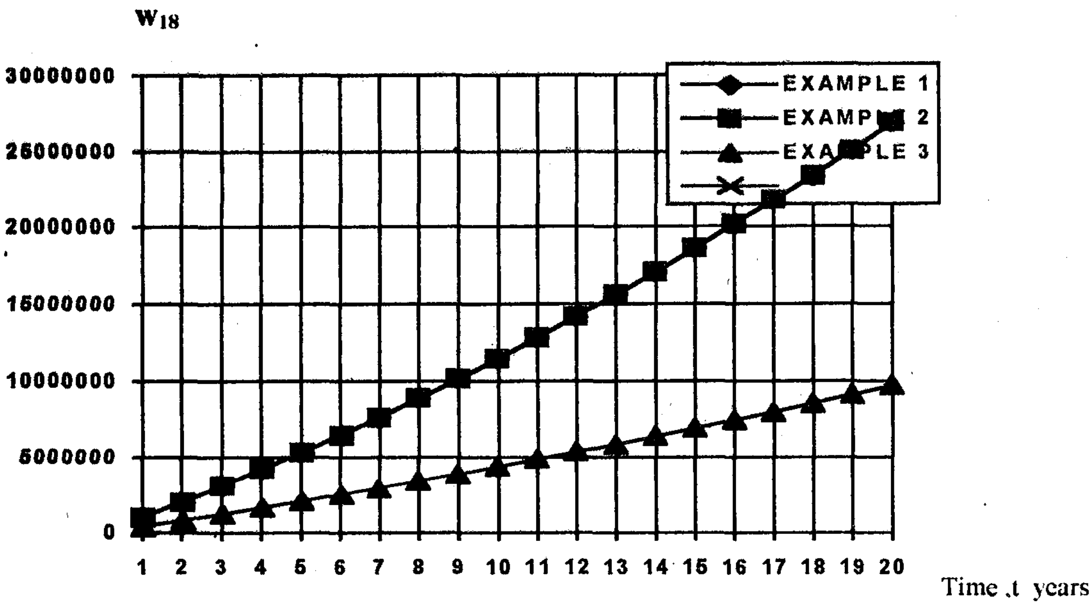


Figure 5.2 Cumulative 18-kip ESAL traffic versus time for examples

EXAMPLE 1

Reliability Factor	95 %
Analysis Periad	20 year
Maximum Performance Period	15 year
Initial Serviceability	4.6
Terminal Serviceability	2.5
Overall Standard Deviation	0.45
Exponential Growth Rate	3.0 %
18-kip ESAL Trafiic	$2.5\ 10^6$
Directional Distribution Factor	50 %
Lane Distribution Factor	80 %
Stage Strategy Number	2
Moisture Supply	25 %
Roadbed Soil Fabric	25 %
Swell Rate Constant	0.08
Plasticity Index	45
Moisture Condition	Average
Layer Thickness	10 feet
Potential Vertical Rise	1.225 inches
Swelling Probability	20 %
Depth of Frost Penetration	5.0 feet
Frost Heave Rate	5.0 mm/day
Maximum Serviceability Loss	2.0
Drainage Quality	Poor
Frost Heave Probability	20 %

LAYER NAME	STRENGTH PARAMETER	PARAMETER VALUE	VALUES CONVERTED TO ELASTICITY OF MODULUS
Subgrade	CBR	4 %	6.000 psi
Subbase Course	CBR	30 %	14.800 psi
Base Course	CBR	90 %	29.000 psi
Binder Course	Elasticity of M.	300.000 psi	300.000 psi

Standard Normal Deviate : ZR = -1.968			
LAYER NAME	STRUCTURAL COEFFICIENT	STRUCTURAL NUMBER	DRAINAGE COEFFICIENT
Subgrade		5.9	
Subbase C.	0.110	4.4	1.0
Base C.	0.137	3.4	1.0
Binder C.	0.370		1.0

ITERATIO NNO	Trial Performanc ePeriod	Serviceability Loss Due To Swelling And Frost Heave	Corresponding ServiceabilityL oss Due to Traffic	Allowable Cumulative Traffic	Corresponding Performance Period
1	13	0.3441	1.7559	11080000	9.71
2	11.35	0.3200	1.7800	11425000	9.97
3	10.66	0.3100	1.7900	11568000	10.08
4*	10.37				

*Convergence achieved after 3 iterations.

Thickness determination:

$D_1^* = 3.4 / 0.37 = 9.19 \sim 9.5$ inches (Binder Course)

$SN_1^* = a_1 * D_1^* = 0.37 * 9.5" = 3.52 > 3.4$

$D_2^* = (4.4 - 3.52) / (0.137 * 1.00) = 6.42 \sim 6.5"$ inches (Base Course)

$SN_2^* = a_2 * D_2 * m_2 = 0.137 * 6.5 * 1.0 = 0.89$

$D_3^* = (SN_3^* - (SN_1^* + SN_2^*)) / (a_3 * m_3) = (5.9 - (3.52 + 0.89)) / (0.11 * 1.0) = 13.55 \sim 14$ inches (Subbase C.)

Total Thickness over subgrade : 9.45 + 6.5 + 14 = 30 inches = 76.20 cm

Overlay Thickness:

Elasticity Modulus of Overlay = 300.000 psi

Remaining Time = 20 - 10.37 = 9.63 years

Cumulative Traffic = 26870374 - 11961128 = 14909246
$\Delta PSI_{SW,FR}$ = 0.411 (year 20) - 0.296 (year 10.37) = 0.115
Resulting SNy = 5.9 ----> Rlx = 47 %
ΔPSI_{TR} = (4.6 - 2.0) - 0.115 = 2.485

Estimated Future Traffic = 24023863
Rly = (NFy - y)/NFy = (24023863 - 14909246)/24023863 = 0.38 (38 %)
F_{RL} = 0.735 , Cx = 0.88, Snxeff = 0.88 * 5.9 =5.19
SN_{OL} = 5.9 - (0.735 * 5.19) = 2.09 $D_{OL} = SN_{OL} / a_{OL}$ = 2.09 / 0.37 = 5.64 " inches (Overlay Thickness)

EXAMPLE 2

Reliability Factor	90 %
Analysis Periad	20 year
Maximum Performance Period	15 year
Initial Serviceability	4.6
Terminal Serviceability	2.5
Overall Standard Deviation	0.45
Exponential Growth Rate	3.0 %
18-kip ESAL Trafiic	2.5 10^6
Directional Distribution Factor	50 %
Lane Distribution Factor	80 %
Stage Strategy Number	3
Moisture Supply	35 %
Roadbed Soil Fabric	30 %
Swell Rate Constant	0.095
Plasticity Index	35
Moisture Condition	Minimum
Layer Thickness	5 feet
Potential Vertical Rise	0.700 inches
Swelling Probability	60 %

LAYER NAME	STRENGTH PARAMETER	PARAMETER VALUE	VALUES CONVERTED TO ELASTICITY OF MODULUS
Subgrade	Elasticity of M.	6000 psi	6000 psi
Subbase Course	Elasticity of M.	15000 psi	15000 psi
Base Course	Elasticity of M.	40000 psi	40000 psi
Binder Course	Elasticity of M.	400000 psi	400000 psi

Standard Normal Deviate : ZR = -1.822

LAYER NAME	STRUCTURAL COEFFICIENT	STRUCTURAL NUMBER	DRAINAGE COEFFICIENT
Subgrade		5.8	
Subbase C.	0.109	4.3	1.0
Base C.	0.169	3.1	1.0
Binder C.	0.420		1.0

ITERATIO NNO	Trial Performanc ePeriod	Serviceability Loss Due To Swelling And Frost Heave	Corresponding ServiceabilityL oss Due to Traffic	Allowable Cumulative Traffic	Corresponding Performance Period
1	13	0.100	2.00	15119664	12.65
2	12.85	0.099	2.001	15136385	12.67
3*	12.75				

*Convergence achieved after 2 iterations.

Thickness determination:

$D_1^* = 3.1 / 0.42 = 7.38 \sim 7.5$ inches (Binder Course)

$SN_1^* = a_1 * D_1^* = 0.42 * 7.5" = 3.15 > 3.1$

$D_2^* = (4.3 - 3.15) / (0.169 * 1.00) = 6.8 \sim 7"$ inches (Base Course)

$SN_2^* = a_2 * D_2 * m_2 = 0.169 * 7 * 1.0 = 1.18$

$D_3^* = (SN_3^* - (SN_1^* + SN_2^*)) / (a_3 * m_3) = (5.8 - (3.15+1.18)) / (0.109 * 1.0) = 13.49 \sim 13.5$ inches (Subbase C.)

Total Thickness over subgrade : 7.5 + 7 + 13.5 = 28 inches = 71.12 cm

<u>*EXAMPLE 3*</u>

Reliability Factor	90 %
Analysis Periad	20 year
Maximum Performance Period	15 year
Initial Serviceability	4.6
Terminal Serviceability	2.5
Overall Standard Deviation	0.45
Exponential Growth Rate	2.0 %
18-kip ESAL Trafiic	$1.0\ 10^6$
Directional Distribution Factor	50 %
Lane Distribution Factor	80 %
Stage Strategy Number	2
Depth of Frost Penetration	5.0 feet
Frost Heave Rate	5.0 mm/day
Maximum Serviceability Loss	2.0

Drainage Quality	Poor
Frost Heave Probability	30 %
Swelling Probability	60 %

LAYER NAME	STRENGTH PARAMETER	PARAMETER VALUE	VALUES CONVERTED TO ELASTICITY OF MODULUS
Subgrade	R - Value	9	5995 psi
Subbase Course	R - Value	60	14400 psi
Base Course	Unconfined C. Str.	200	525000 psi
Binder Course	Elasticity of M.	350000 psi	350000 psi

Standard Normal Deviate : ZR = -1.633			
LAYER NAME	STRUCTURAL COEFFICIENT	STRUCTURAL NUMBER	DRAINAGE COEFFICIENT
Subgrade		5.0	
Subbase C.	0.105	3.7	1.0
Base C.	0.125	0.8	1.0
Binder C.	0.390		1.0

ITERATIO NNO	Trial Performanc ePeriod	Serviceability Loss Due To Swelling And Frost Heave	Corresponding ServiceabilityLoss Due to Traffic	Allowable Cumulative Traffic	Corresponding Performance Period
1	13	0.436	1.66	4195301	9.62
2	11.31	0.406	1.69	4347907	9.94
3	10.62	0.392	1.71	4420055	10.08
4	10.35	0.386	1.71	4451158	10.15
5*	10.25				

*Convergence achieved after 4 iterations.

Thickness determination:

$D_1^* = 0.8 / 0.39 = 2.05 \sim 2.5$ inches (Binder Course)

$SN_1^* = a_1 * D_1^* = 0.39 * 2.5" = 0.98 > 0.8$

$D_2^* = (3.7 - 0.98) / (0.125 * 1.00) = 21.76 \sim 22"$ inches (Base Course)

$SN_2^* = a_2 * D_2 * m_2 = 0.125 * 22 * 1.0 = 2.75$

$D_3^* = (SN_3^* - (SN_1^* + SN_2^*)) / (a_3 * m_3) = (5.0 - (2.755 + 0.98)) / (0.105 * 1.0) = 12.1 \sim 12.5$ inches (Subbase C.)

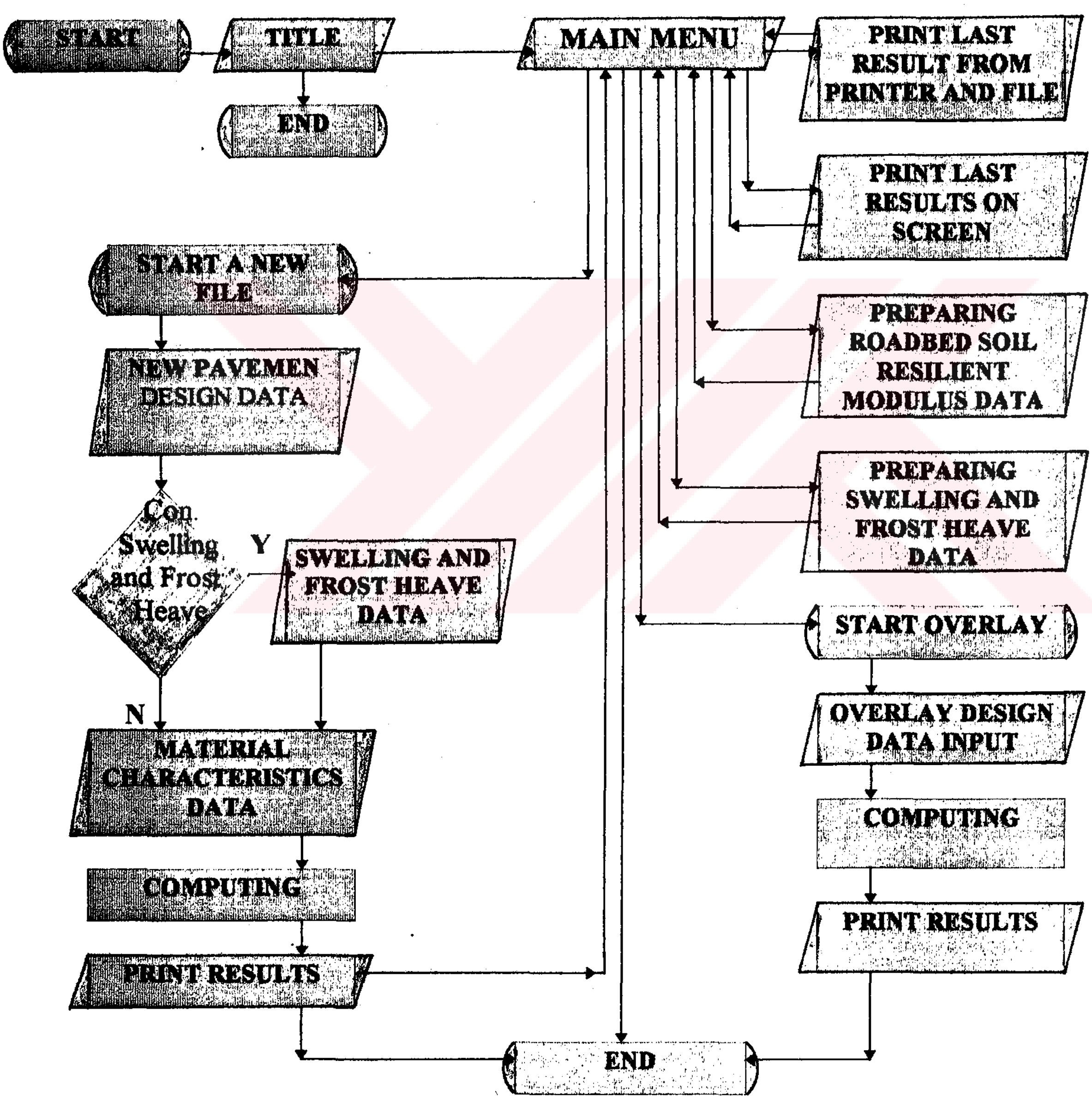
Total Thickness over subgrade : 2.5 + 22 + 12.5 = 37 inches = 93.98 cm

CHAPTER 6

COMPUTER PROGRAM AND UTILIZATION MANUAL

6.1 General Introduction

In this chapter, a serviceable personal computer-based program has been developed, to facilitate the utilization of the AASHTO Design procedure for flexible highway pavements. Flow-chart of the program is as follows:



The use of the computer program has reduced many data reading in figures, nomographs and charts. Results obtained are very close to the values calculated by hand due to lack of assumptions and rounding some values.

6.2 Hardware and Software Requirements

A **720 K**, 3½ inches diskette 🖫 containing the program, *'readme.1st'* file (first instructions file) and some other operation files were presented with this study.

'aashto.exe' program is designed to operate on IBM** compatible personal computers using MS DOS* disk operation systems. A minimum of ***256 K RAM*** (random access memory) is enough on the mainboard for successful operation of the program, and ***VGA 640x480*** resolution graphics card is needed to display the screens. Because of designing for ***VGA Graphics Card*** and using only graphic screens, this is strictly required. The operation of the program can be speeded up by employing a hard disk instead of the diskette. Speed of the program may vary from computer to computer due to Computer *CPU* speed. A hard copy of results for any given problem can be obtained from a suitable printer by choosing inside program.

6.3 Utilization of the Program

As described above, in diskette, only *'aashto.exe'* file runs to perform the pavement design. *'egavga.bgi'* and *'aashto.def'* files are needed to perform together.

After having run the *aashto.exe* file in *DOS* disk operation system, a sequence of screens appear on monitor screen. The table of screens is shown in ***APPENDIX F.*** First screen is text screen. This phase also controls the directory path being worked in and PC Graphics Card' Type. In case of any malfunction, a screen warning is met.

Some instructions appear on screens. It, therefore, is important to follow screens and prompts warning the user. During first two screens appear, The user can quit at any time pressing *ESC* key on keyboard. Pressing **H** brings help screens.

Main Menu consists of 7 items. These are as follows:

1- Thickness Determination For Initial Pavement
2- Changing Data And Thickness ReDetermination
3- Thickness Determination For Overlay
4- Preparing Swelling And Frost Heave Data
5- Preparing Roadbed Resilient Modulus Data
6- Printing Again Last results On Screen
7- Print Last Results From Printer And To File

The user must choose first item pressing *1* key to compute thicknesses of layers of a new project entering new data. choosing this item brings 3 screens to give new data.

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* MS DOS is registered trade mark of Microsoft Co.
** IBM is registered trade mark of International Buisiness Machines Co.

Item 2 is the item by which the user can change data of an existing pavement and compute again in a short time. this item's screens are the same as those of item 1.

Item 3 is for overlay requirement. This brings a screen **(screen F-7)** only asking one question. This item does not perform any function before not entering data for a new pavement design.

Item 4 brings a screen to prepare a table to use in design. The user can print this screen using 'print screen' key on keyboard by means of DOS. This item has not got any function differing this performing.

Item 5, as *4,* differs only to prepare roadbed resilient modulus data.

Choôsing *6* prints last computed results on screen again.

And choosing 7 prints last computed results to file and from printer at the same time.

a) ITEM 1 *(Thickness Determination For Initial Pavement):* Selecting this item brings a new screen *(screen F-3)*. A prompt above asks the user press a key to start entering data. The user may call help pressing H or start pressing any key other than *H* at this phase. After this a sequence of question prompts appears below:

Prompt: File Name To Open (Without Extension): This question asks the user give a name if he/she wants a hard copy as a file to copy input and output data in it. The user can give up to 8 letters. If it is left blank, a default is 'aashto++' whose last two character are randomized.

Prompt: Reliability Factor(50..99.99) <90>: The user must here give desired level of reliability as percent from 50 to 99.99. It can be a real or integer value. 90 is assumed if he/she leaves blank . Use **Table D-1** for help.

Prompt: Analysis Period (0..60 year) <20>: This is refers to the period of time , for which the analysis is to be conducted, i.e., the length of time that any design strategy must cover. The user can use **Table 2.1** for help. Leaving blank will be considered as 20.

Prompt: Maximum Possible Performance Period (0..50 year) <15>: This is the maximum practical amount of time that the user can expect from a given stage. It is clear that it must be less than 'Analysis Period'. Analysis period is assumed if the user leaves blank.

Prompt: Initial Serviceability (0..5) <4.5>: This is the level of serviceability desired at the beginning of performance period. Leaving blank is assumed as 4.5.

Prompt: Terminal Serviceability (0..5) <2.5>: It expresses minimum level of serviceability desired at the end of the performance period. It must be less than the initial serviceability and is limited by this value, and seen in question prompt at the same time. Leaving blank is assumed as 2.5.

Prompt: Stage Strategy Number (1..3) <2>: It expresses stage construction, i.e., 2 means an initial pavement plus one overlay. Leaving blank is assumed as 2.

Prompt: Overall Standard Deviation (0..1) <0.45>: This is chance variation in the traffic prediction of a given traffic loading. The user can give 0.35 for rigid pavements, 0.45 for flexible pavements. 0.45 is default value.

Prompt: Estimated 18-kip ESAL (0..10E+7) <1E+7> : This is the cumulative two-directional **18-kip ESAL** units predicted for a specific section of a highway during the analysis period. It is limited **by max.** 100.000.000 and assumed as 1.000.000 repetitions if it is left blank.

Prompt: Directional Dist. Factor (0..100) <50>: Directional distribution factor is expressed as a ratio that accounts for the distribution of ESAL units by direction, e.g., east-west, north-south, etc. Leaving blank is assumed as 50.

Prompt: Lane Dist. Factor (50..100) <50>: Lane distribution factor is expressed as a ratio that accounts for the distribution of traffic when two or more lanes are available in one direction. Use the **Table 2.2** for help:

Prompt: Exponential Growth Rate (-20..20) <0.0001>: The user must here give a value that reflects the probable growth rate of traffic using the facility based on previous experience and judgement. Negative value is also possible. Note that ***Compound Growth*** rate was used as a type of growth rate. 0.0001 is default value.

After these question prompts, it is possible to re-input these data pressing ESC key or the user can answer prompt *'Consider Swelling And Frost Heave (Yes/No):'* pressing *Y* or *N* key or *H* to call help. Pressing *H* calls help screens, *Y* brings swelling and frost heave data input phase screen and *N* key omits this phase and calls material characteristics data input phase. If *Y* key is pressed, a new screen and a prompt as *'<Any Key To Continue>'* appears. At this time the user can press *H* for help screens. Next prompts are as follows:

Prompt: Consider Only Swelling, Only Frost H. or Both (S/F/B) <Both> : This prompt asks the user which environmental effect he/she will select. Pressing *S* selects swelling, pressing *F* selects frost heave, and *B* or *<Enter>* selects both swelling and frost heave.

Prompt: Moisture Supply (0.100 %) <20>: This is percentage which shows the moisture degree. **See Figure B-1** for help. Value must be integer. In case of blank input, 50 is assumed.

Prompt: Roadbed Soil Fabric (0..100 %) <20>: This is also percentage which shows the fabric of the roadbed soil. See **Figure B-1** for help. Value must be an integer and 50 is assumed if left blank.

Prompt: Moisture Condition (M/A/O) <Average> : The user must here give the capital letters of moisture conditions. Moisture condition is the subjective decision based on an estimate of how close the soil moisture conditions during construction are to the in situ moisture conditions at a later date. See **Figure B-2** for help.

Prompt: Plasticity Index (20..80) <40> : This variable is the plasticity index of subgrade soil at a particular location. It is necessary for potential vertical rise computation. Limits will vary due to moisture condition given above. See **Figure B-2** for help.

Prompt: Layer Thickness (2/5/10/15/20/25/30/31..100) <2>: This expresses thickness of layer which is under penetration. The user can select only the numbers above. In case of blank input, 2 is assumed. See **Figure B-2** for help.

Prompt: Swell Probability (0..100) <20>: Swell probability is expressed as a percentage representing the proportion of the project length that is subject to swell.

Prompt: Frost Heave Rate (0..30 mm/day) <2>: Frost heave rate defines the rate of increase of the frost heave roughness (in millimeter per day). The user can use **Figure C-1** for help. Detailed information to use this figure is explained in previous chapters. Default value is 5 mm/day.

Prompt: Depth of Frost Penetration (1..10 ft) <2>: This is for maximum serviceability loss computation. It is expressed in feet. Default value is 5 feet.

Prompt: Drainage Quality (Vp/P/F/G/E) <Poor> : This expresses the quality of the drainage. Use **Table D-5** to decide: The user must press the first letters of the drainage qualities to select. Default quality is *Poor* Drainage quality.

Prompt: Frost Heave Probability (0..100 %) <20>: This should be the user's estimation of the percent area of the project that will experience frost heave. Default value is 50 percent.

After all these data inputs, the user can re-input all these data pressing **ESC** key or continue pressing other than **ESC** key. Next screen is the material characteristics data inputs phase screen.
First prompt *<Any Key To Continue>* on material characteristics data input screen **(Screen F-5)** as previous screens asks the user press a key. **H** key calls help screens but others are starter to continue data inputting.

Prompt: How Many Layers Are There Over Base Course (0..4) <1>?: This prompt asks the user give number of the layers which will be constructed over base course, such as binder course, surface course ...etc. The user can give number up to 4. This means 4 more layers can be constructed over base course except for overlay. Answer to this prompt brings next prompts. Default value is 1.

Prompt: 4. Layer name : The user here gives names of these layers. If he/she gives 0 (zero) answer to previous prompt, this prompt is omitted. Note that names of the first three layers are constant, named as *Subgrade*, *Subbase C.*, *Base C.*, respectively. 4. and 5. layer names are '*Binder C.*' and '*Surface C.*' respectively if they are left blank. After name inputs, next prompts ask the user strength parameters of these layers.

Prompt: Subgrade Strength Parameter:
CBR, R (if <20) or Elasticity of Modulus (C/R/E) <E>:
This prompt asks the user which kind of strength parameter he/she will use to characterize strength of the subgrade. R-value can be used if it is less than 20 due to **AASHTO Guide** suggestion. One of ***C***, ***R*** or ***E*** is an answer. Default is E.

__Prompt:__ Subbase Strength Parameter:

CBR, R or Elasticity of Modulus (C/R/E) <E>:

This is the same as previous prompt but asks theuser the strength parameter of the subbase course.

__Prompt:__ Application Type Base Course:

Cement Treated, Bituminous Treated, Granular (C/B/G) <G>:

This prompt asks the user the type of application to construct base course. The user can give ***C, B*** or *G hot* keys. Prompts in case of each choice:

In case of ***C*** choice:

__Prompt:__ Base Strength Parameter:

Unconfined Compressive Strength or Modulus (U/M):

The user here select the type pressing ***U*** or ***M*** hot keys.

In case of ***B*** choice:

__Prompt:__ Base Strength Parameter:

Marshall Stability or Modulus (S/M):

S means Marshall Stability, *M* means Modulus (=elasticity of modulus) type.

In case of ***G*** choice:

__Prompt:__ Base Strength Parameter:

CBR or Elasticity of Modulus (C/E):

C express **CBR**, ***E*** elasticity of modulus.

Note that all these data are needed for structural coefficient and $\mathbf{M_R}$ in main equation computation. In case of selecting **CBR, R-Value, Unconfined Compressive Strength, Marshall Stability,** these strength parameters are translated into elasticity of modulus for $\mathbf{M_R}$ computation. Strength parameter for upper layers (if existing) is assumed to be elasticity of modulus.

After these data, next prompts ask the magnitudes of these layer strength parameters.

__Prompt:__ Their Magnitude:

1. Layer Value: Prompt is repeated for other layers. Note that the layer value the user will give refers to strength parameter of that layer.

__Prompt:__ Drainage Coefficients of layers over subgrade (0.4.. 1.4) <1.0>:

Subbase C. Drainage Coefficient:

__Prompt:__ Base C. Drainage Coefficient:

__Prompt:__ (names) *Drainage Coefficient:*

.

.

.

These prompts ask the user give drainage coefficient of the first three layers over subgrade. Program assumes 1.0 as drainage coefficient of layers above the first three layers except for subgrade.

At the end of this phase, you can re-input these data by **ESC** key or any other key to start computing answering to prompt < *Any Key To Start Computing* >.

Next Screen, in case that the user wants to continue, an output screen appears **(Screen F-6).** At the beginning of this phase a prompt appears over screen warning the user to wait due to running. This waiting time varies due to computer CPU type and due to that if a math. processor exists or not. When computing ended, results appear in column order on this screen. First column presents the names, second the structural coefficients, third the structural numbers and fourth layers thicknesses computed. Additionally, first of last two line expresses new maximum performance period computed. This value may be less than the first maximum performance period due to swelling and frost heave consideration. Second line expresses the time difference between analysis period and maximum performance period. If swelling and frost heave is considered, it is clear that difference will increase and an overlay will be necessary for this time. Note that a typical cross-section of a flexible pavement appears on the output screen. This cross-section is only symbolical.

After having seen the results, the user can return to main menu pressing **ESC** key or print results by means of printer to get a hard copy pressing **P** key or copy results to a file pressing **F** hot key.

b) __ITEM 2__ *(Changing Data And Thickness ReDetermination):* Selecting this item brings screens as those of ***ITEM 1.***

First question asks the user the name of file (without any extension) which he/she computed before and printed to a file with '.out' extension named. If he/she gives an invalid or absent file name, the program opens 'aashto.def' file having default values.

Second question asks the user to press a key or **H** for help. Third question asks the user give a name that will be appointed to output file. Next question asks the user which factor will be changed requiring only its item number. Leaving blank omits next phase asking before whether he/she will consider swelling and/or frost heave. If answer is yes **(Y),** swelling and frost heave data input phase screen appears, otherwise, material characteristics data input phase screen appears. All these phases have the same law to input data as seen in *ITEM 1.* After these phases, the program starts computation. Results are in the same order as that of *ITEM 1.*

c) __ITEM 3__ *(Thickness Determination For Overlay):* Selecting this item brings overlay design phase screen **(Screen F-7).** On this screen a prompt as < *Any Key To Continue* > appears as ones seen on previous data input screens. Here, the user can press **H** key for help or any other key to start giving data.

Prompts here changes depending upon the stage strategy number. If stage strategy is selected 1, this is to say that overlay is not required. So, overlay design phase cannot be called warning the user with a prompt on main menu screen. In case of selecting stage strategy number as 2, this means 1 initial pavement structure plus one overlay. Otherwise, in case of selecting 3, it means one pavement structure and 2 overlays over this structure.

Selecting 2 brings only one prompt that is as follow:

__Prompt:__ First Stage Overlay Material Elasticity of Modulus:

This prompt asks the user give elasticity modulus of overlay material. This can be given as that of upper layer of initial structure and is limited with max. *500000* psi. After giving value, program runs and computes structural number, structural coefficient and thickness of overlay and prints them on screen together values of initial pavement structure. At this stage, as previous ones, the user can use **ESC, P, F,** or **H** hot keys for their function. Note that overlay is designed for the time that is difference between analysis period and new computed max. performance period. Note that this will be less than first number given at general data phase if swelling and frost heave is considered.

For example, let analysis period be 25 years and max. possible performance period be 15 years and assume that maximum performance period was computed 13 years. In this case, overlay is designed for remaining 25-13=12 years.

Selecting 3 as stage strategy number brings 3 prompts. First two ask the elasticity modulus of two overlay and the other asks lifetime of first overlay. Note that first overlay lifetime is limited 1 year and 1 year less than difference between analysis period and maximum performance period just computed. To give an example: If analysis period and max. possible performance period were selected 25 and 15 years respectively and new max. performance period was computed as 13 years. In this case, the life time of first overlay is limited with minimum 1 year and maximum 25-13-1=11 years. If the user select 10 years as lifetime of first overlay, the lifetime of second overlay is 25-(13+10)=2 years automatically.

After giving data, program runs and computes structural numbers, structural coefficients and thicknesses of both overlay and prints them on screen with values of initial structure layers.

d) __ITEM 4__ (Preparing Swelling And Frost Heave Data): Selecting this item brings only one screen. At this stage, the user can call help with **H** key or any other key to continue data input sequence. Prompt sequence is as follows:

__Prompt:__ Section Length (ft) (0..1000): The user here give the section length of the road which he/she separated in sections being influenced by swelling and frost heave. It is limited by 0 and 1000 ft.

__Prompt:__ Roadbed Thickness (0..1000): This is the thickness of roadbed section whose length the user gave before. It is limited by 0 and 1000 ft as previous data.

__Prompt:__ Soil plasticity Index (20..80): This is plasticity index of samples taken at each bore hole in the section. It is limited by 20 and 80.

Prompt: Moisture Condition (M A O): The user here gives the moisture condition for each bore hole pressing **M, A, O** key where **M** means 'Minimum', **A** means 'Average' and **O** means 'Optimum'.

After data input, the user can return to main menu screen pressing **ESC** hot key.

***e) ITEM 5** (Preparing Roadbed Resilient Modulus Data):* This item calls only one screen as ITEM 4. The user can require help at the beginning pressing **H** key. Prompts appearing at this phase are as follows:

Prompt: Roadbed Resilient Modulus (0..30000) psi: The user here gives the roadbed resilient modulus of the section in climatic condition of that month. Months is devided two halves.

Prompt: Relative Damage Uf (0..1000): This is relative damage factor computed using roadbed resilient modulus and equation on **Figure D-3.**

At the end of this phase, a prompt appears above showing average relative damage. Giving roadbed resilient modulus after using equation, the user can print using *'printscreen'* key. **ESC** key quits this phase and return main menu screen.

***f) ITEM 6** (Printing Again Last Results On Screen)* This item calls back new pavement design output phase screen **(Screen F-6).** The user can use functional keys such as **ESC, H, F, P** for any requirements, also here.

***g) ITEM 7** (Printing Last Results From Printer And To File)* This item prints last new pavement design outputs in a file whose name has been given before and from printer. The user should control that printer is on. Otherwise, a malfunction occurs.

Note that an output file is presented at the end of section 2.3 of this chapter.

6.4 Some Points in the Program to Consider

Followings are some points the user must consider:

a) In program, the user meets questions as in such a format below: For example,

'Exponential Growth Rate (-20..20) < 0.0001 > :'

Question Expression — Limitation — Default Value

-20 means minimum value the user is permitted to give.
20 means maximum value the user is permitted to give.

0.0001 means default value that will be processed if the user leaves blank as an answer to the question.

b) The user must control the printer before he/she chooses ***ITEM 7*** on main menu screen **(Screen F-2)** or on initial pavement design output phase **(Screen F-6).** Because this is not a professional program , in case of any wrong answer, the process may end with a *'Run-Time Error'* and he/she may not call program back at any phase he/she is.

c) The user must pay attention to give answer and values in accord to perform analysis without fault. He/she, therefore, should decide and prepare data that he/she will give before starting the program.

d) The user should answer *'File Name To Open'* on initial pavement design screen **(Screen F-3)** giving a name without any extension. The program assumes the extension as *'.out'*. The user can see the content of these files by means of any editor program.

e) Help requirement is possible only at the beginning and at the end of each phase, for example, help for swelling and frost heave can be called only if the prompt *'H to help'* appears.

f) Giving an answer, such as 12.3, can appear on the screen as *1.23E+01*. It is clear that this is equal to 12.3 as known. This is valid also for output values.

g) Choosing **ITEM 3, 6, 7** on main menu screen may brings a prompt as *'No New Data Have Been Given In Yet'* if the user have not given any data for a new pavement design. It means, the user must select ITEM 1 first before these items are executed.

h) It is clear that Terminal Serviceability value (initial pavement design phase) must be less than the initial serviceability value. The minimum limit of the terminal serviceability is the initial serviceability value. So, the maximum limit of the terminal serviceability in question prompt will be changed depending upon the initial serviceability that the user has given before.

i) All data are limited as possible as they can be in case of that the user may give invalid values. But a combination of these data may not well-combined. So, it is important to prepare a well combination for trusty, not to get abnormal results.

j) In case of any improper answer to questions, program warns the user prompting blue texts above, i.e., if a real value instead of an integer that question requires is given, a prompt as ***'<* *NUMERIC , INTEGER VALUE and IN LIMITS REQUESTED * '* appears. In this case, prompts live for only ⌛ 2 seconds and then disappear. But on the main menu screen, life time of prompts is ⌛ 3 seconds which the user can read the prompt easily.
Please wait during this time.

6.5 Program Content

The Program was prepared in pieces whose file names are *'aashto', 'compute', 'screens', 'datastor', ' helps', 'inputs', 'outputs' and 'warnings'. AASHTO* file consists of main oriented Pascal commands but other are 'unit' files meaning aid files in Turbo Pascal * programming language. Below is the list of the files whose contents are expressed:

a) 'aashto.pas' consists of main menu orientation and the general management file.

b) 'compute.pas' consists of computing process. It computes the structural number, structural coefficients, and layer thicknesses.

c) 'datastor.pas' consists of function which stores all static data and temporary variables and values.

d) 'helps.pas' consists of all help screens when they are required.

e) 'inputs.pas' file is the file in which all individual data are input.

f) 'screens.pas' file consists of all screens printed on monitor when the program is running.

g) 'warnings.pas' consists of all prompts warning the user after any improper value input or requirement.

Note that content of all these files is listed in **APPENDIX H .**

6.6 Introduction To Turbo Pascal Programming Language

Pascal programming language was approved by Niklaus Writh as an extension of ALGOL Programming language. It has been approved year by year and been very popular programming language used by many young programmers and users.

Turbo Pascal, used in this program, is the registered mark of Borland International which approved this version (6.0) in last years and put on the market new (7.0) version.

Turbo Pascal is neither a very complex language as Turbo C++, Assembler or Machine Language nor a very basic language as Basic. This property of language has increased its popularity, and it is used in large and complex program preparing.

6.7 Computed Examples

Here are the some examples solved using the program. some of them were solved considering swelling and frost heave, some of them not. Additionally, the user will find a few examples overlay design required.

* Turbo Pascal is registered trade mark of Borland International.

♣ FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM ♣	MAY 11/1994
♣INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK *1♣	[Filename].aashto15 *2
NOTE :	
Maximum Possible Performance Period (year) :	15
Analysis Period (year) :	20
Initial Serviceability :	4.5999999999854481E+0000
Terninal Serviceability :	2.5000000000000000E+0000
Stage Strategy Number :	2
Overall Standard Deviation :	3.4999999999909051E-0001
Estimated 18 kip Single Axle Load :	2.5000000000000000E+0006
Directional Distribution Factor (%)	50
Lane Distribution Factor (%)	80
Exponential Growth Rate (%)	1.0000000000000000E+0000
Reliability Factor (%)	9.0000000000000000E+0001
♣ SWELLING & FROST HEAVE DATA BLOCK *3 ♣	Only SWELLING Considered *4
Moisture Supply (%)	20
Roadbed Soil Fabric (%)	20
Plasticity Index	44
Moisture Condition	Average
Layer Thickness (inc)	2
Swell Probability (%)	80
Frost Heave Rate (mm/day)	0.0000000000000000E+0000
Depth of Frost Penetration (feet)	0.0000000000000000E+0000
Drainage Quality	
Frost Heave Probability (%)	0

♣ PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK *5 ♣

LAYER NAMES *6	STRENGTH PARAMETER *7	MAGNITUDE *8	DRAINAGE C.*9
Subgrade	Elasticity of Modulus	5700	1.0000E+0000
Subbase C.	Elasticity of Modulus	11000	1.0000E+0000
Base C.	Elasticity of Modulus	30000	1.0000E+0000
Binder C.	Elasticity of Modulus	400000	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000

♣ INITIAL PAVEMENT OUTPUT BLOCK *10 ♣

STRUCTURAL Co. *11	STRUCTURAL No.*12	LAYER THICK *13	CONVERTED VALUE *14
0.000000000E+0000	5.540000000E+0000	0.000000000E+0000	5700
7.839613953E-0002	4.500000000E+0000	1.326595934E+0001	11000
1.378031924E-0001	3.190000000E+0000	9.506310721E+0000	30000
4.192476401E-0001	1.150000000E+0000	7.608868111E+0000	400000
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0

*15 New Max. Performance Period 1.44E+0001 Computed. After This Time An Overlay Necessary For 5.57E+0000 Years.

#2. STAGE OVERLAY STRUCTURE DATA BLOCK *16#			Required *17	
LAYER N*18	MR *19	STRUCTURAL Co. *20	STRUCTURAL NUM.*21	LAYER THICK. *22
OVERLAY 1	300000	3.5988539394E-0001	1.8292929999E+0000	5.082987614E+0000
OVERLAY 2.	0	0.0000000000E+0000	0.0000000000E+0000	0.000000000E+0000

*23 First Overlay is Necessary After 1.4E+0001 Years Over Initial Layers.

NOTE THAT

*1 is the block where all main data were listed.
*2 is the name of this file which is given in program by the user.
*3 is the block where SWELLING and FROST HEAVE data were listed (with positive numbers if considered).
*4 shows whether Swelling or/and Frost Heave is considered or not, or which one is considered.
*5 is the block where all main material properties data were listed.
*6 is the block where all layer names were listed.
*7 is the block where the strength parameter of each layer is given. These are the parameters the user uses to find layer coefficients at charts.
*8 shows strength parameter magnitudes of each layer. For example, if R-Value is shown for subbase in Block <7>, this value may vary 1 to 85 or 90 limited in layer coefficient charts.
*9 is the block where drainage coefficient of each layer is listed varying 0.6 to 1.4.
*10 is the block presenting results after program running.
*11 is the block where structural coefficient of each layer is listed.
*12 is the block where structural number of each layer is listed.
*13 is the block where layer thicknesses are listed in inches.
*14 is the block where strength parameter of each layer is converted in modulus to use in computation. For example, if CBR is given as the strength parameter of subbase, a 24 CBR magnitude, shown, is used in computation as 13500 psi modulus being converted.
*15 is the block presenting max. performance period after computing. The number will be less than max. possible performance period if Swelling or/and Frost Heave is considered.
*16 is the block presenting overlay thickness and propreties.
*17 shows if overlay computation is required or not.
*18 shows the layer name of each overlay, standard as Overlay 1 and 2
*19 shows the elasticity modulus of each overlay. Note that if 1 overlay is required, values of second overlay will be zero.
*20 shows the structural coefficient of each overlay.
*21 shows the structural number of each overlay.
*22 shows the layer thickness of each overlay in inches.
*23 shows the year which first overlay must be constructed.
*24 shows the year which second overlay must be constructed (if required).

* Example output printed from Printer.

♣ FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM ♣	MAY 22/1994

♣ INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK ♣	[Filename]:aashto36
NOTE :	
Maximum Possible Performance Period (year) :	15
Analysis Period (year) :	20
Initial Serviceability :	4.59999999999854481E+0000
Terminal Serviceability :	2.50000000000000000E+0000
Stage Strategy Number :	3
Overall Standard Deviation :	4.49999999999818101E-0001
Estimated 18 kip Single Axle Load :	2.50000000000000000E+0006
Directional Distribution Factor (%) :	50
Lane Distribution Factor (%) :	80
Exponential Growth Rate (%) :	3.00000000000000000E+0000
Reliability Factor (%) :	9.00000000000000000E+0001

♣ SWELLING & FROST HEAVE DATA BLOCK ♣	Not Considered
Moisture Supply (%) :	0
Roadbed Soil Fabric (%) :	0
Plasticity Index :	0
Moisture Condition :	
Layer Thickness (inc) :	0
Swell Probability (%) :	0
Frost Heave Rate (mm/day) :	0.00000000000000000E+0000
Depth of Frost Penetration (feet) :	0.00000000000000000E+0000
Drainage Quality :	
Frost Heave Probability (%) :	0

♣ PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK ♣

LAYER NAMES	STRENGTH PARAMETER	MAGNITUDE	DRAINAGE C.
Subgrade	Elasticity of Modulus	5000	1.0000E+0000
Subbase C.	Elasticity of Modulus	10000	1.0000E+0000
Base C.	Elasticity of Modulus	30000	1.0000E+0000
Bin. Tab.	Elasticity of Modulus	400000	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000

♣ INITIAL PAVEMENT OUTPUT BLOCK ♣

STRUCTURAL Coef.	STRUCTURAL No.	LAYER THICK.	CONVERTED VALUE
0.000000000E+0000	6.200000000E+0000	0.000000000E+0000	5000
6.900000000E-0002	5.020000000E+0000	1.710144928E+0001	10000
1.378031924E-0001	3.490000000E+0000	1.110279068E+0001	30000
4.192476401E-0001	1.300000000E+0000	8.324435645E+0000	400000
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0

*** New Max. Performance Period 1.50E+0001 Computed. After This Time An Overlay Necessary For 5.00E+0000 Years.

♣ 2. STAGE OVERLAY STRUCTURE DATA BLOCK ♣	Required

LAYER NAME	MR (psi)	STRUCTURAL Coef.	STRUCTURAL NUM.	LAYER THICK.
OVERLAY 1	350000	3.9056528802E-0001	1.1031624998E+0000	2.824527764E+0000
OVERLAY 2	350000	3.9056528802E-0001	1.1531624998E+0000	2.952547334E+0000

*** First Overlay is Necessary After 1.5E+0001 Years Over Initial Layers.
*** Second Overlay is Necessary After 1.8E+0001 Years Over First Overlay.

♣ FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM ♣	MAY 22/1994
♣ INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK ♣	[Filename]:aashto85
NOTE :	
Maximum Possible Performance Period (year) :	15
Analysis Period (year) :	20
Initial Serviceability :	4.5999999999854481E+0000
Terninal Serviceability :	2.5000000000000000E+0000
Stage Strategy Number :	2
Overall Standard Deviation :	4.4999999999818101E-0001
Estimated 18 kip Single Axle Load :	1.0000000000000000E+0006
Directional Distribution Factor (%) :	50
Lane Distribution Factor (%) :	80
Exponential Growth Rate (%) :	3.0000000000000000E+0000
Reliability Factor (%) :	9.0000000000000000E+0001
♣ SWELLING & FROST HEAVE DATA BLOCK ♣	Not Considered
Moisture Supply (%) :	0
Roadbed Soil Fabric (%) :	0
Plasticity Index :	0
Moisture Condition :	
Layer Thickness (inc) :	0
Swell Probability (%) :	0
Frost Heave Rate (mm/day) :	0.0000000000000000E+0000
Depth of Frost Penetration (feet) :	0.0000000000000000E+0000
Drainage Quality :	
Frost Heave Probability (%) :	0

*This and following example outputs are file outputs.

PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK			
LAYER NAMES	STRENGTH PARAMETER	MAGNITUDE	DRAINAGE C.
Subgrade	Elasticity of Modulus	5500	1.0000E+0000
Subbase C.	Elasticity of Modulus	12000	9.5000E-0001
Base C.	Elasticity of Modulus	25000	9.5000E-0001
Binder C.	Elasticity of Modulus	350000	1.1000E+0000
		0	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000

INITIAL PAVEMENT OUTPUT BLOCK			
STRUCTURAL Coef.	STRUCTURAL No.	LAYER THICK.	CONVERTED VALUE
0.000000000E+0000	5.210000000E+0000	0.000000000E+0000	5500
8.697414285E-0002	4.050000000E+0000	1.403926031E+0001	12000
1.180870622E-0001	3.140000000E+0000	8.111767023E+0000	25000
3.905652880E-0001	1.110000000E+0000	7.308753599E+0000	350000
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0

*** New Max. Performance Period 1.50E+0001 Computed. After This Time An Overlay Necessary For 5.00E+0000 Years.

2. STAGE OVERLAY STRUCTURE DATA BLOCK		Required		
LAYER NAME	MR (psi)	STRUCTURAL Coef.	STRUCTURAL NUM.	LAYER THICK.
OVERLAY 1	300000	3.5988539394E-0001	1.6767247499E+0000	4.659051960E+0000
OVERLAY 2	0	0.0000000000E+0000	0.0000000000E+0000	0.000000000E+0000

*** First Overlay is Necessary After 1.5E+0001 Years Over Initial Layers.

FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM	MAY ../1994
INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK	[Filename] example1
NOTE	
Maximum Possible Performance Period (year)	15
Analysis Period (year)	20
Initial Serviceability	4.5999999999854481E+0000
Terninal Serviceability	2.5000000000000000E+0000
Stage Strategy Number	2
Overall Standard Deviation	4.4999999999818101E-0001
Estimated 18 kip Single Axle Load	2.5000000000000000E+0006
Directional Distribution Factor (%)	50
Lane Distribution Factor (%)	80
Exponential Growth Rate (%)	3.0000000000000000E+0000
Reliability Factor (%)	9.0000000000000000E+0001

SWELLING & FROST HEAVE DATA BLOCK	Only SWELLING Considered
Moisture Supply (%)	40
Roadbed Soil Fabric (%)	30
Plasticity Index	40
Moisture Condition	Optimum
Layer Thickness (inc)	10
Swell Probability (%)	30
Frost Heave Rate (mm/day)	0.0000000000000000E+0000
Depth of Frost Penetration (feet)	0.0000000000000000E+0000
Drainage Quality	
Frost Heave Probability (%)	0

PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK

LAYER NAMES	STRENGTH PARAMETER	MAGNITUDE	DRAINAGE C.
Subgrade	Elasticity of Modulus	5500	1.0000E+0000
Subbase C.	Elasticity of Modulus	12000	1.0000E+0000
Base C.	Unconfined Compressive Strength	190	1.0000E+0000
ANY LAYER	Elasticity of Modulus	400000	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000

INITIAL PAVEMENT OUTPUT BLOCK

STRUCTURAL Coef.	STRUCTURAL No.	LAYER THICK.	CONVERTED VALUE
0.000000000E+0000	5.880000000E+0000	0.000000000E+0000	5500
8.697414285E-0002	4.610000000E+0000	1.460204100E+0001	12000
1.260000000E-0001	1.100000000E+0000	2.494153380E+0001	525000
4.192476401E-0001	1.250000000E+0000	3.500000000E+0000	400000
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0

*** New Max. Performance Period 1.47E+0001 Computed. After This Time An Overlay Necessary For 5.28E+0000 Year..

♣ 2. STAGE OVERLAY STRUCTURE DATA BLOCK ♣	Not Required

LAYER NAME	MR (psi)	STRUCTURAL Coef.	STRUCTURAL NUM.	LAYER THICK.
OVERLAY 1	0	0.0000000000E+0000	0.0000000000E+0000	0.000000000E+0000
OVERLAY 2	0	0.0000000000E+0000	0.0000000000E+0000	0.000000000E+0000

♣ FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM ♣	MAY 22/1994
♣ INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK ♣	[Filename]:example2
NOTE :	
Maximum Possible Performance Period (year) :	15
Analysis Period (year) :	20
Initial Serviceability :	4.5999999999854481E+0000
Terminal Serviceability :	2.5000000000000000E+0000
Stage Strategy Number :	3
Overall Standard Deviation :	4.4999999999818101E-0001
Estimated 18 kip Single Axle Load :	2.5000000000000000E+0006
Directional Distribution Factor (%)	50
Lane Distribution Factor (%)	80
Exponential Growth Rate (%) :	3.0000000000000000E+0000
Reliability Factor (%) :	9.0000000000000000E+0001
♣ SWELLING & FROST HEAVE DATA BLOCK ♣	Both Considered
Moisture Supply (%) :	30
Roadbed Soil Fabric (%) :	30
Plasticity Index :	45
Moisture Condition :	Average
Layer Thickness (inc) :	20
Swell Probability (%) :	30
Frost Heave Rate (mm/day) :	2.0000000000000000E+0000
Depth of Frost Penetration (feet) :	2.0000000000000000E+0000
Drainage Quality :	Good
Frost Heave Probability (%) :	25

♣ PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK ♣			
LAYER NAMES	**STRENGTH PARAMETER**	**MAGNITUDE**	**DRAINAGE C.**
Subgrade	CBR (California Bearing Ratio)	4	1.0000E+0000
Subbase C.	CBR (California Bearing Ratio)	35	1.0000E+0000
Base C.	Marshall Stability	1400	1.0000E+0000
Asinma T.	Elasticity of Modulus	300000	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000

♣ INITIAL PAVEMENT OUTPUT BLOCK ♣			
STRUCTURAL Coef.	**STRUCTURAL No.**	**LAYER THICK.**	**CONVERTED VALUE**
0.000000000E+0000	5.870000000E+0000	0.000000000E+0000	6000
1.118867658E-0001	4.340000000E+0000	1.367453951E+0001	15450
2.750000000E-0001	1.430000000E+0000	1.058181818E+0001	300000
3.598853939E-0001	1.430000000E+0000	3.973487183E+0000	300000
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0

*** New Max. Performance Period 1.30E+0001 Computed. After This Time An Overlay Necessary For 6.97E+0000 Years.

♣ 2. STAGE OVERLAY STRUCTURE DATA BLOCK ♣		Required		
LAYER NAME	**MR (psi)**	**STRUCTURAL Coef.**	**STRUCTURAL NUM.**	**LAYER THICK.**
OVERLAY 1	400000	4.1924764014E-0001	1.2343000249E+0000	2.944084848E+0000
OVERLAY 2	400000	4.1924764014E-0001	1.3143000249E+0000	3.134902857E+0000

*** First Overlay is Necessary After 1.3E+0001 Years Over Initial Layers.
*** Second Overlay is Necessary After 1.7E+0001 Years Over First Overlay.

♦ FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM ♦	MAY 22/1994
♦ INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK ♦	[Filename]:example3

NOTE :	
Maximum Possible Performance Period (year) :	15
Analysis Period (year) :	20
Initial Serviceability :	4.5999999999854481E+0000
Terminal Serviceability :	2.5000000000000000E+0000
Stage Strategy Number :	2
Overall Standard Deviation :	4.4999999999818101E-0001
Estimated 18 kip Single Axle Load :	1.0000000000000000E+0006
Directional Distribution Factor (%)	50
Lane Distribution Factor (%) :	80
Exponential Growth Rate (%) :	2.0000000000000000E+0000
Reliability Factor (%) :	9.0000000000000000E+0001

♦ SWELLING & FROST HEAVE DATA BLOCK ♦	Only FROST H. Considered
Moisture Supply (%) :	0
Roadbed Soil Fabric (%) :	0
Plasticity Index :	0
Moisture Condition :	
Layer Thickness (inc) :	0
Swell Probability (%) :	0
Frost Heave Rate (mm/day) :	2.0000000000000000E+0000
Depth of Frost Penetration (feet)	2.0000000000000000E+0000
Drainage Quality	Excellent
Frost Heave Probability (%) :	40

♦ PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK ♦

LAYER NAMES	STRENGTH PARAMETER	MAGNITUDE	DRAINAGE C.
Subgrade	Elasticity of Modulus	5700	1.0000E+0000
Subbase C.	Elasticity of Modulus	11000	1.0000E+0000
Base C.	Elasticity of Modulus	30000	1.0000E+0000
ANY	Elasticity of Modulus	400000	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000
		0	1.0000E+0000

♦ INITIAL PAVEMENT OUTPUT BLOCK ♦

STRUCTURAL Coef.	STRUCTURAL No.	LAYER THICK.	CONVERTED VALUE
0.000000000E+0000	5.100000000E+0000	0.000000000E+0000	5700
7.839613953E-0002	4.120000000E+0000	1.250061554E+0001	11000
1.378031924E-0001	2.900000000E+0000	8.853205636E+0000	30000
4.192476401E-0001	1.020000000E+0000	6.917152829E+0000	400000
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0
0.000000000E+0000	0.000000000E+0000	0.000000000E+0000	0

*** New Max. Performance Period 1.45E+0001 Computed. After This Time An Overlay Necessary For 5.50E+0000 Years.

♦ 2. STAGE OVERLAY STRUCTURE DATA BLOCK ♦	Not Required

LAYER NAME	MR (psi)	STRUCTURAL Coef.	STRUCTURAL NUM.	LAYER THICK.
OVERLAY 1	0	0.0000000000E+0000	0.0000000000E+0000	0.000000000E+0000
OVERLAY 2	0	0.0000000000E+0000	0.0000000000E+0000	0.000000000E+0000

CHAPTER 7

CONCLUSIONS And SUGGESTIONS FOR FURTHER STUDIES

The computer program presented in previous chapterswas based on **AASHTO Guide** for the design of pavement structure. It can be said that this approach of method of design considers highly realistic factors, such as, environmental effects, material properties, traffic effects, future traffic estimation ...etc, especially, environmental effects including both swelling and frost heave affecting the highway performance and life negatively.

Overlay design consideration in the *Guide* prevents unnecessary initial layer thickness which will serve future traffic offering more economical solutions.

Computer program prepared in accordance with the **AASHTO Guide** gives realistic solutions and yields the results in a shorter time avoiding trial approaches.

In this study, the major goal was to introduce the recently developed **AASHTO Guide** for the design of flexible pavements and to prepare a computer program to facilitate and accelerate the design with the possibility of using different data combinations.

This study introduced only flexible pavement and overlay design procedures scanning and filtering the related parts of the *Guide*, and software is prepared in this scope.

Any further study on this subject should be oriented by adapting the procedures and data to the local conditions in Turkey. Also rigid pavement design procedures should be included in the study and the software should be developed considering these procedures.

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APPENDIX A

GLOSSARY OF TERMS

Analysis Period: The period time for which the economic analysis is to be made; ordinarily will include at least one rehabilitation activity.

Base Coarse: The layer or layers of specified or selected material of designed thickness placed on a subbase or subgrade to support a surface coarse.

Drainage Coefficient: Foctors 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: Summation of equivalent 18000-pound single axle loads used to combine mixed traffic for the design period.

Flexible Pavement: A pavement structure which maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction, and cohesion for stability.

Initial Serviceability: The highest index that the user of road will be able to accept this road perfect after being put into service.

Layer Coefficient: The emperical relationship between structural number and layer thickness which expresses the relative ability of a material to function as a structural component of the pavement.

Low-Volume Road: road generally subjected to low levels of traffic; in **AASHTO Guide**, structural design is based on a range of 18-kip ESAL`s from 10000 to 100000 repetations for aggregate-surfaced roads.

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.

Presented Serviceability Index: A number derived by formula for estimating the serviceability rating from measurements of certain physical features of the pavement.

Reliability: It is a means of incorporating some degree of certainty in to the design process to esure that the various design alternatives will last the analysis period.

Resilient Modulus: A measure of the modulus of elasticity of roadbed soil or other pavement material.

Rigid Pavement: A pavement structure which distributes loads to the subgrade, having as one coarse a portland cement concrete slab of relatively high-bending resistance.

Roadbed: The graded portion of a highway between top and side slopes, prepared as a foundation for the pavement structure and shoulder.

Structural Number: An index number derived from an analysis of traffic, roadbed soil conditions, and environment which may be converted to thickness of flexible pavement layers through the use of suitable layer coefficients related to the type of material being used in each layer of the pavement structure.

Subbase: The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base coarse (or in the rigid pavements, the portland cement concrete slab).

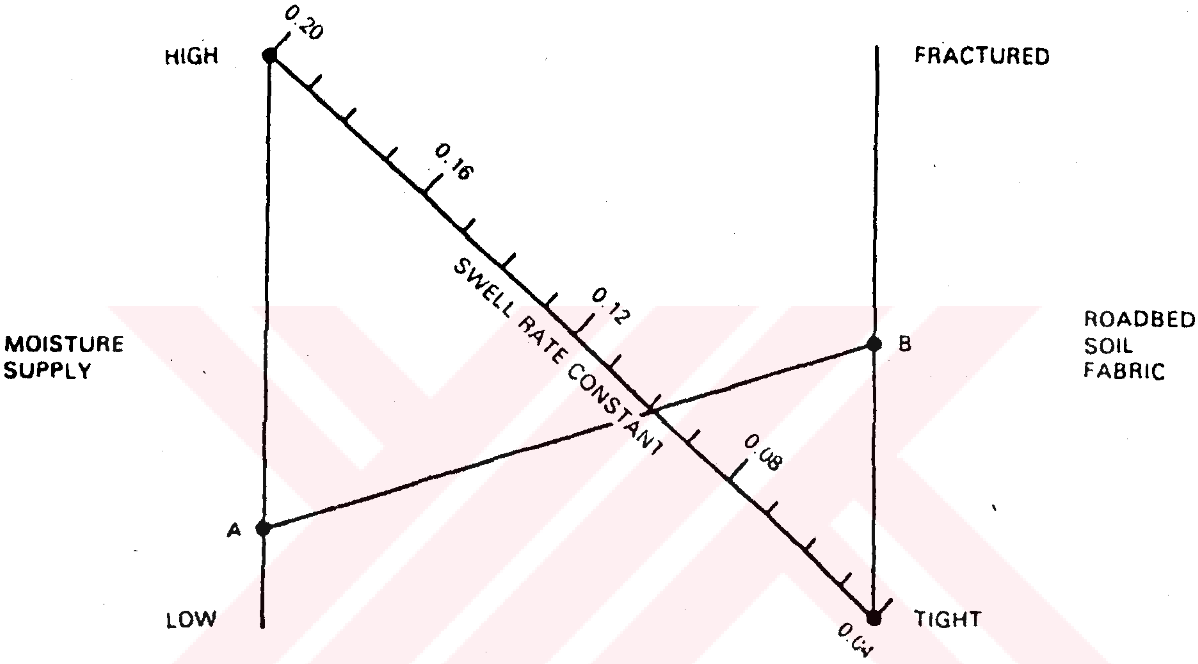
Subgrade: The top surface of a roadbed upon which the pavement structure and shoulders are constructed.

Surface Coarse: One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegration effects of climate. The top layer of flexible pavements is sometimes called `wearing coarse`.

Terminal Serviceability: The lowest index that will be tolerated before rehabilitation, or reconstruction becomes necassary.

APPENDIX B

FIGURES AND TABLES OF SWELLING TREATMENT



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

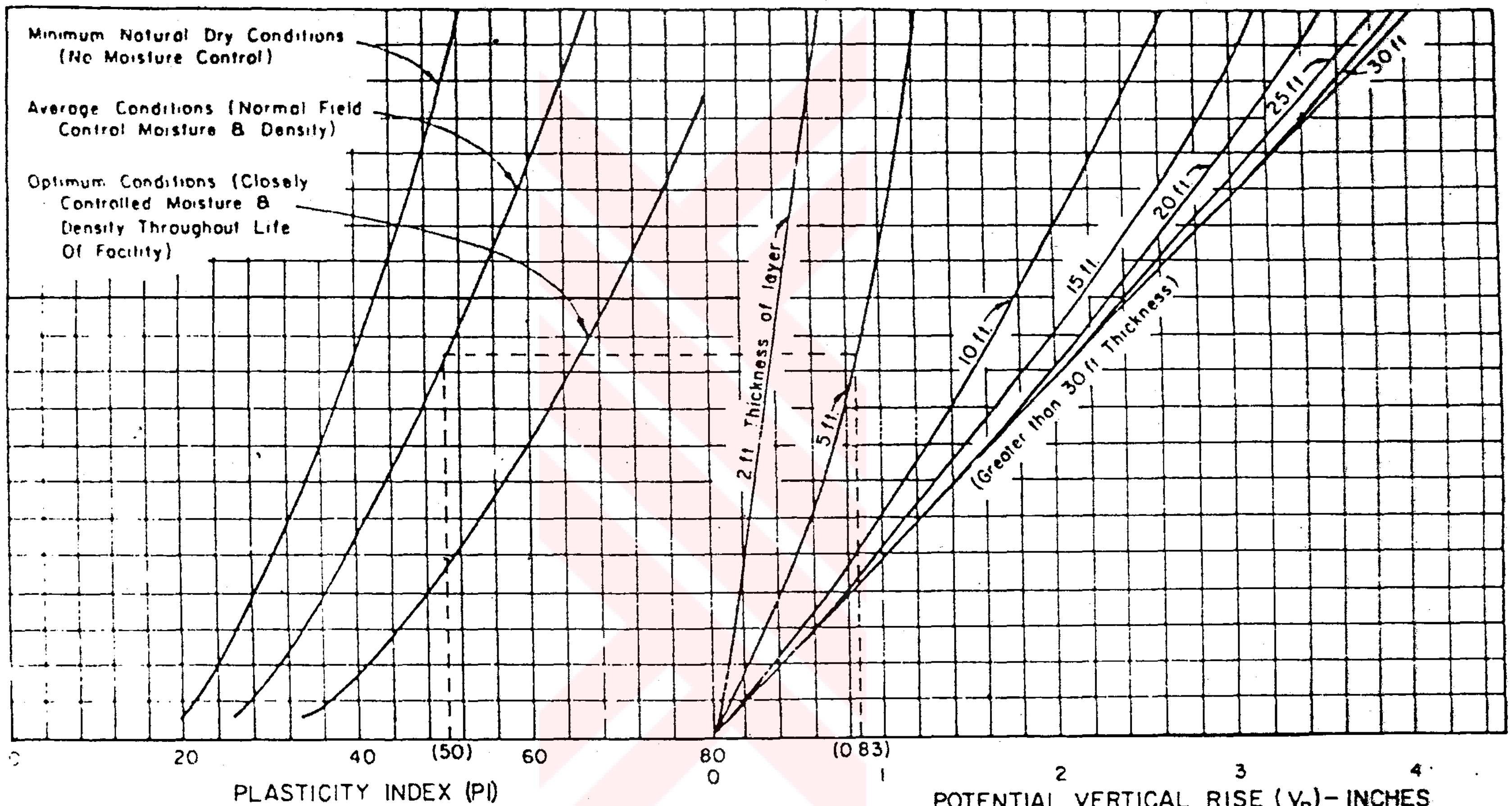
1) Select the appropriate moisture supply condition which may be somewhere between low and high (such as A).

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 B-1 Nomograph For Estimating Swell Rate Constant



NOTES

1. This figure is predicated upon the following assumptions:
   a. The subgrade soils for the thickness shown all are passing the No. 40 mesh sieve.
   b. The subgrade soil has a uniform moisture content and plasticity index throughout the layer thickness for the conditions shown.
   c. A surcharge pressure from 20 inches of overburden (± 10 inches will have no material effect).
2. Calculations are required to determine V_R for other surcharge pressures.

Figure B-2 Chart For Estimating the appropriate potential vertical rise of natural soils.

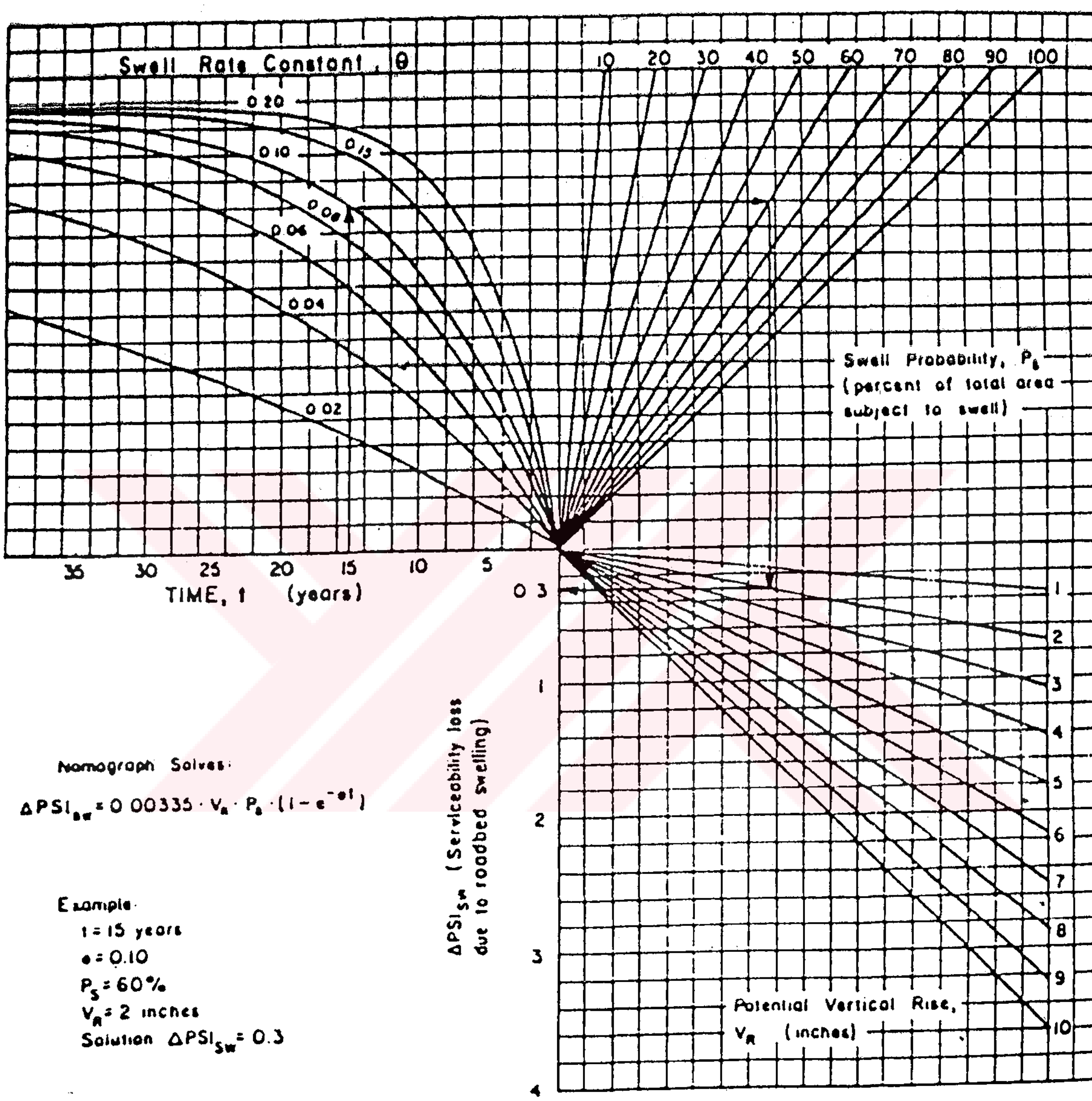


Figure B-3 Chart For Estimating Serviceability Loss Due To Roadbed Swelling

APPENDIX C

FIGURES AND TABLES OF FROST HEAVE TREATMENT

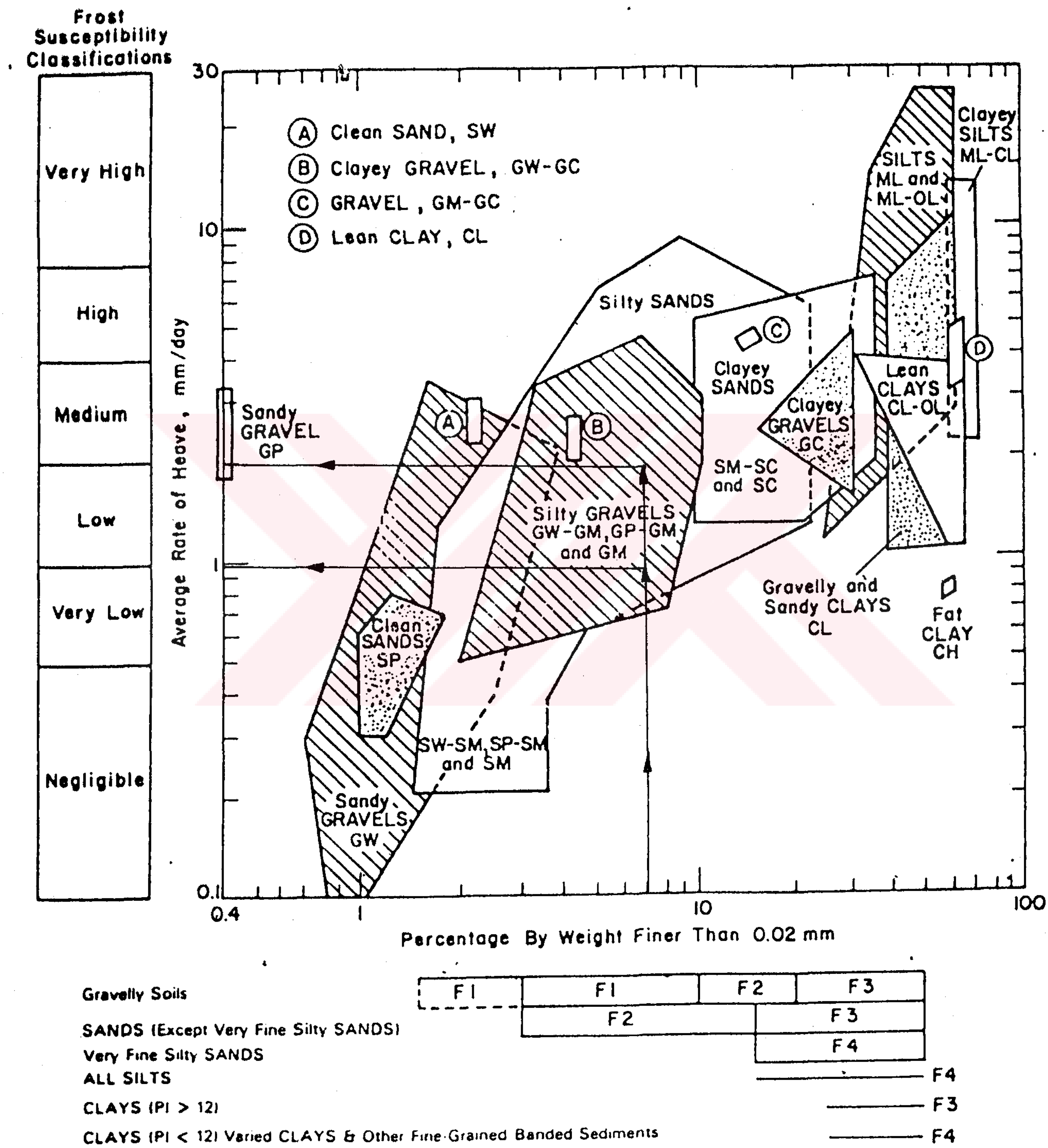


Figure C-1 Chart For Estimating Frost Heave Rate For A Roadbed

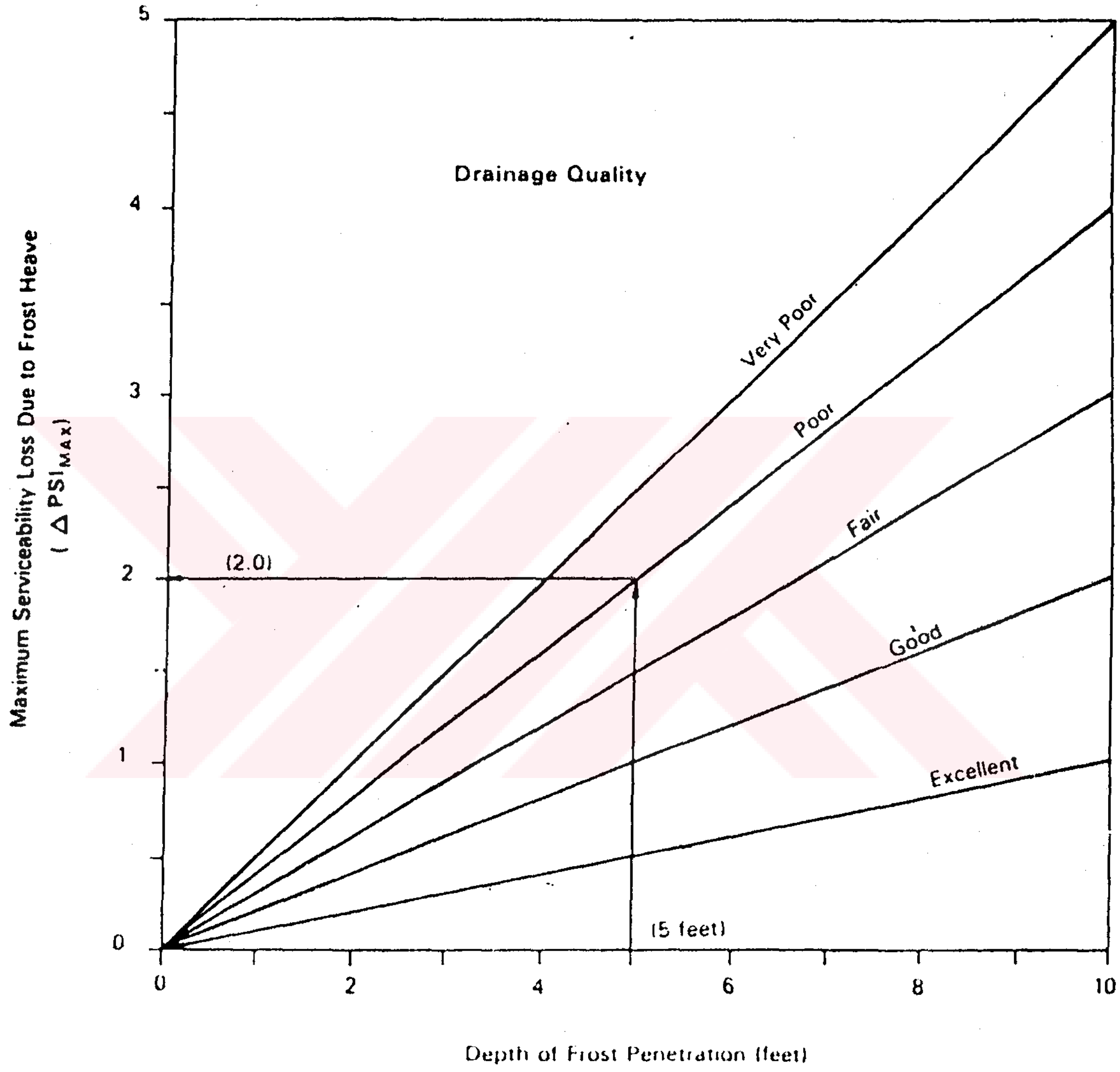


Figure C-2 Graph For Estimating Maximum Serviceability Loss Due To Frost Heave

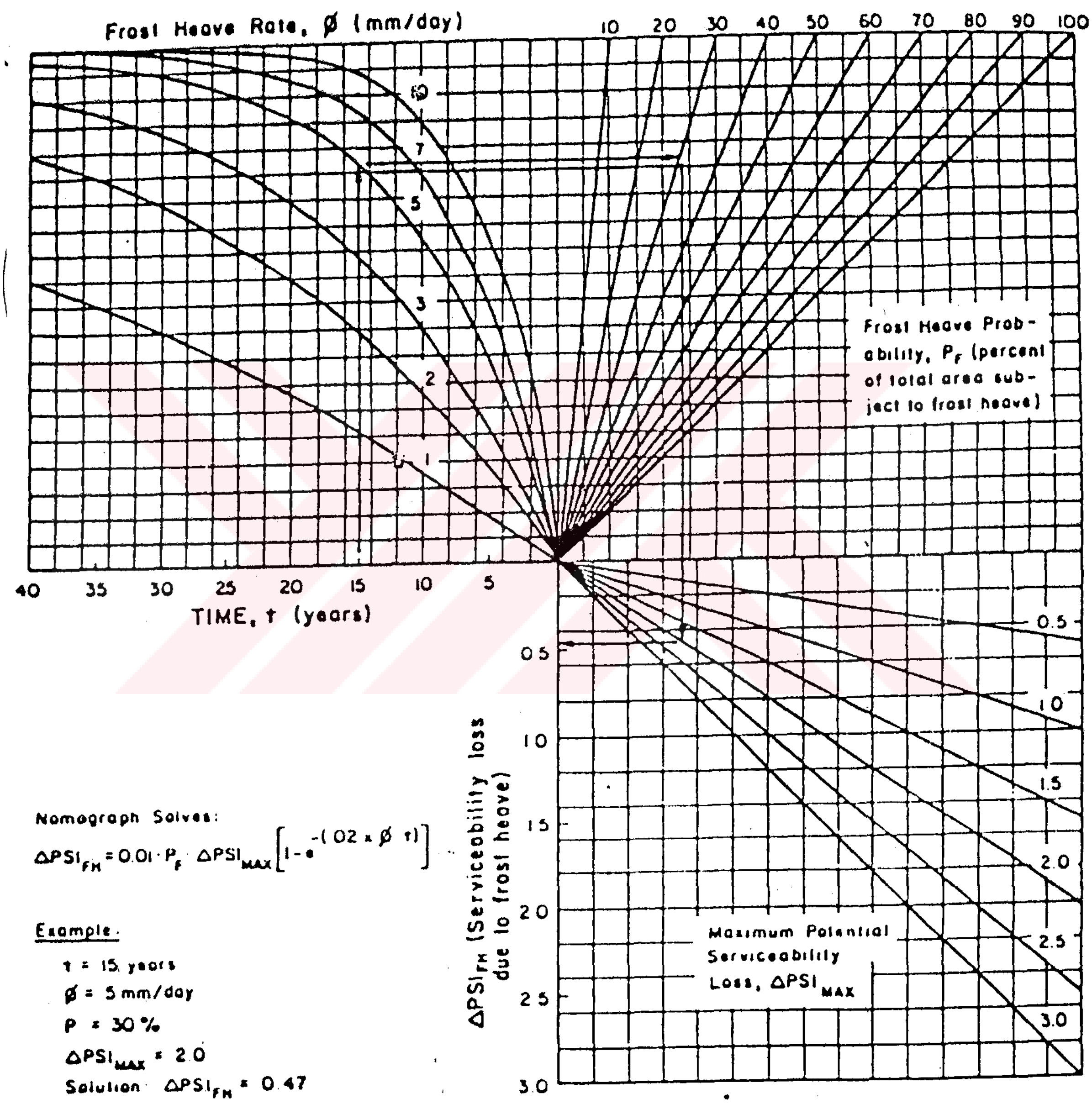


Figure C-3 Chart For Estimating Serviceability Loss Due To Frost Heave

Table C-1 Example Of Process Used To Predict The Performance Period Of An Initial Pavement Structure Considering Swelling And/Or Frost Heave

Initial SN: 4.4
Maximum Possible Performance Period (years): 15
Design Serviceability Loss. PSI=Po-Pt=4.4-2.5=1.9

(1) Iteration No	(2) Trial Per. Per (years)	(3) Total Service. Loss Due Swelling And Frost Heave PSIsw,fh	(4) Corresponding Serviceability Loss Due To Traffic PSItr	(5) Allowable Cumulative Traffic (18-kip) ESAL	(6) Corresponding Performance Period (years)
1	13.0	0.73	1.17	$2.0\ 10^6$	6.3
2	9.7	0.63	1.27	$2.3\ 10^6$	7.2
3	8.5	0.56	1.34	$2.6\ 10^6$	8.2

Clumn No	Description Of Procedures
2	Estimated by the designer (step 2)
3	Using estimated value from column 2 with **Figure D-2**, the total serviceability loss due to swelling and frost heave is determined (step 3)
4	Subtract environmental serviceability loss (column 3) from design total serviceability loss to determine corresponding serviceability loss due to traffic.
5	Determine form **Figure D-9** keeping all inputs constant (except for use of traffic serviceability loss from column 4 and applying the chart in reverse (step 5)
6	Using the traffic from column 5, estimate net performance period from **Figure D-1** (step 6)

APPENDIX D

FIGURES AND TABLES OF DESIGN PROCEDURES

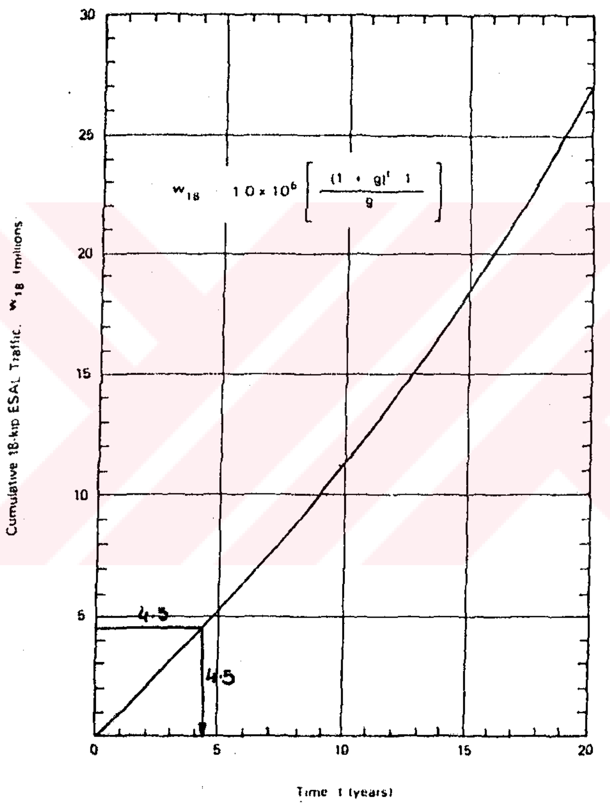


Figure D-1 Example plot of cumulative 18-kip ESAL traffic versus time for assumed conditions.

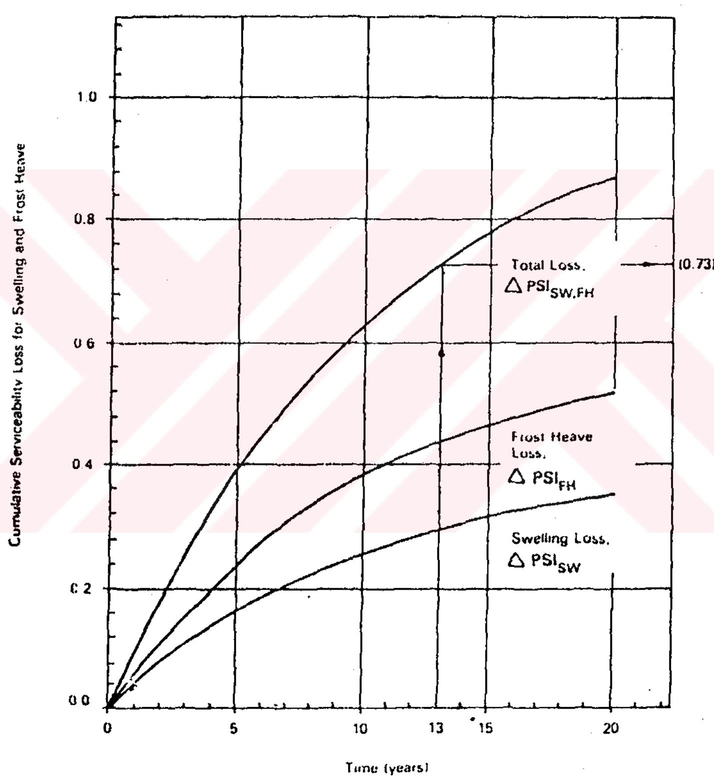
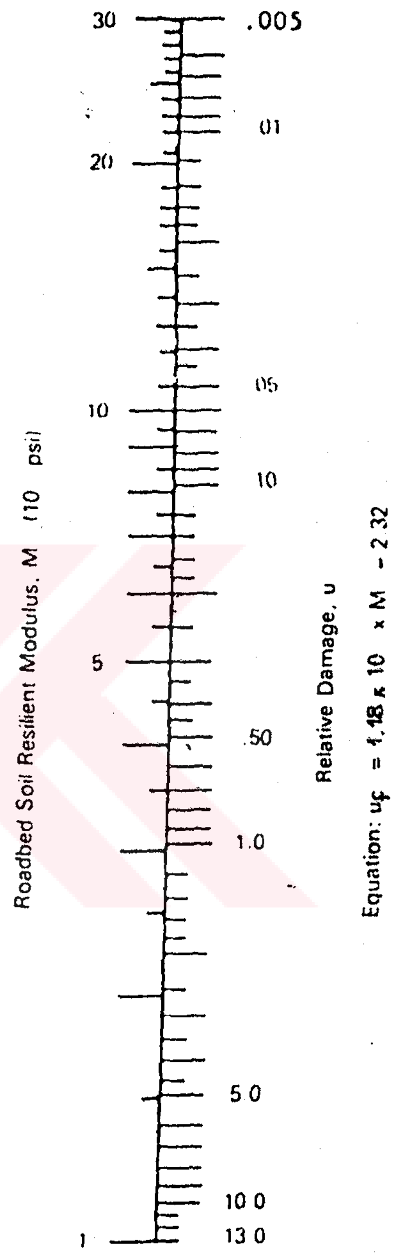


Figure D-2 A conceptual example of the environmental serviceability loss versus time graph that may be developed for a specific location

Month	Roadbed Soil Modulus, M_R (psi)	Relative Damage u_f
Jan	6,500	0.167
	20,000	0.012
Feb	20,000	0.012
	4,000	0.515
Mar	5,000	0.307
	5,000	0.307
Apr	5,000	0.307
	5,000	0.307
May	5,000	0.307
	5,000	0.307
June	6,500	0.167
	6,500	0.167
July	6,500	0.167
	6,500	0.167
Aug	6,500	0.167
	6,500	0.167
Sept.	6,500	0.167
	5,000	0.307
Oct.	5,000	0.307
	5,000	0.307
Nov.	5,000	0.307
	6,500	0.167
Dec	6,500	0.167
	6,500	0.167
Summation: Σu_f =		5.446



Average: $\bar{u}_f = \frac{\Sigma u_f}{n} = \frac{5.46}{24} = 0.227$

Effective Roadbed Soil Resilient Modulus, M_R (psi) = 5,700 (corresponds to $\bar{u}_f$)

Figure D-3 Example chart for estimating effective roadbed soil resilient modulus for flexible pavements designed using the serviceability criteria

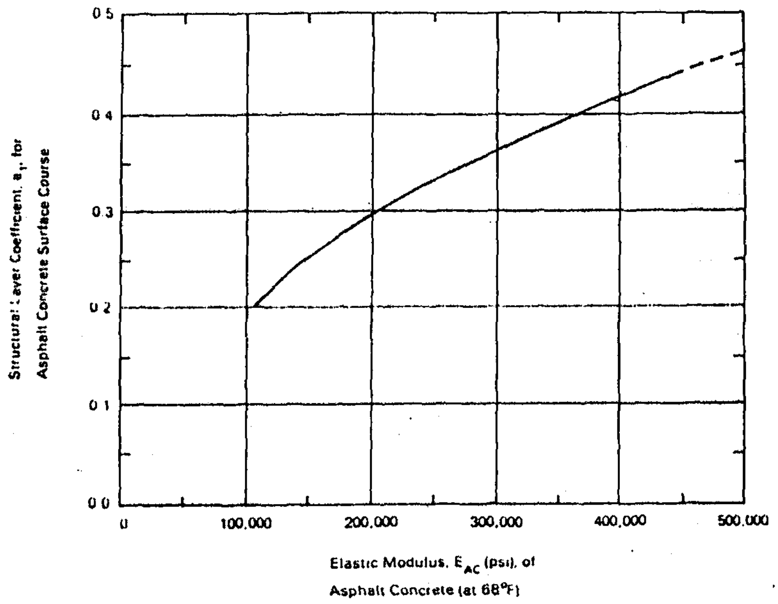


Figure D-4 Chart for estimating structural layer coefficient of dense-graded asphalt concrete based on the elastic (resilient) modulus

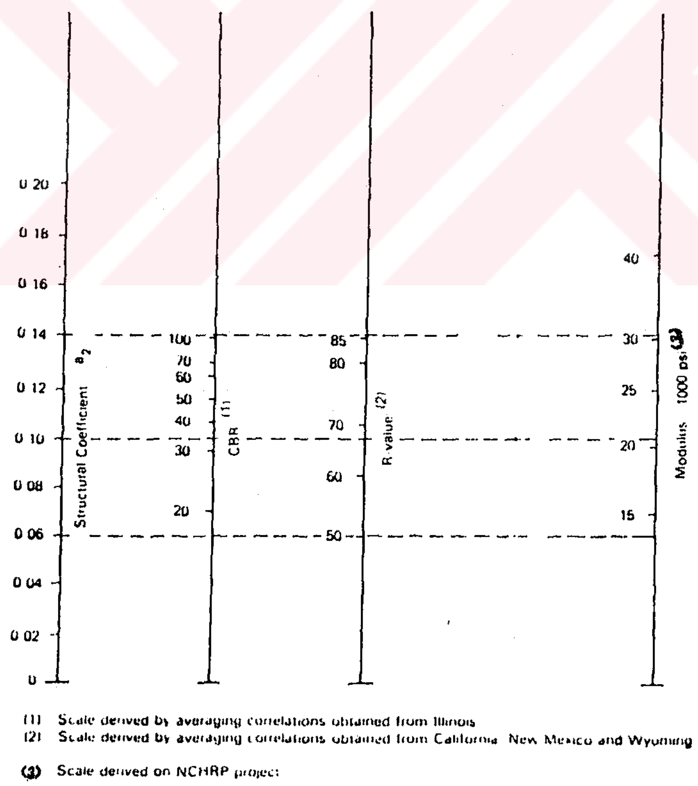


Figure D-5 Variation in granular base layer coefficient (a2) with various base strength parameters

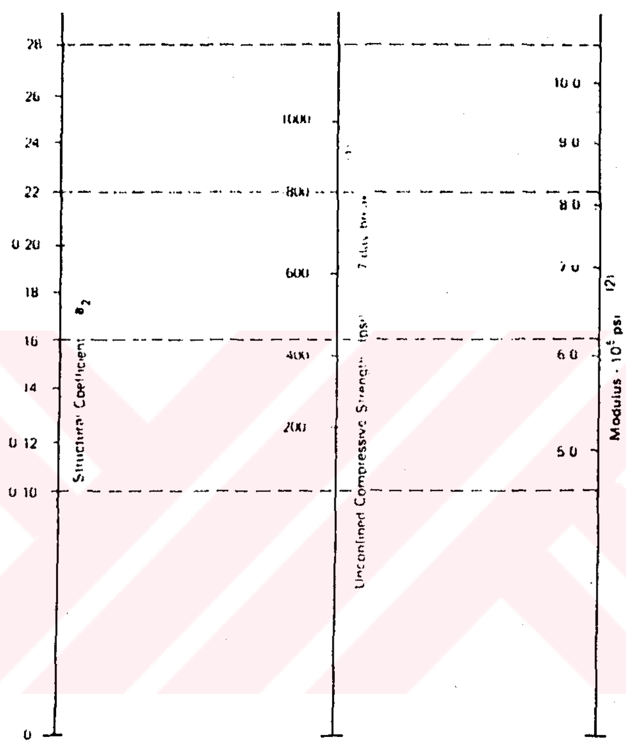


Figure D-6 Variation in **(a2)** for cement-treated bases with base strength parameter

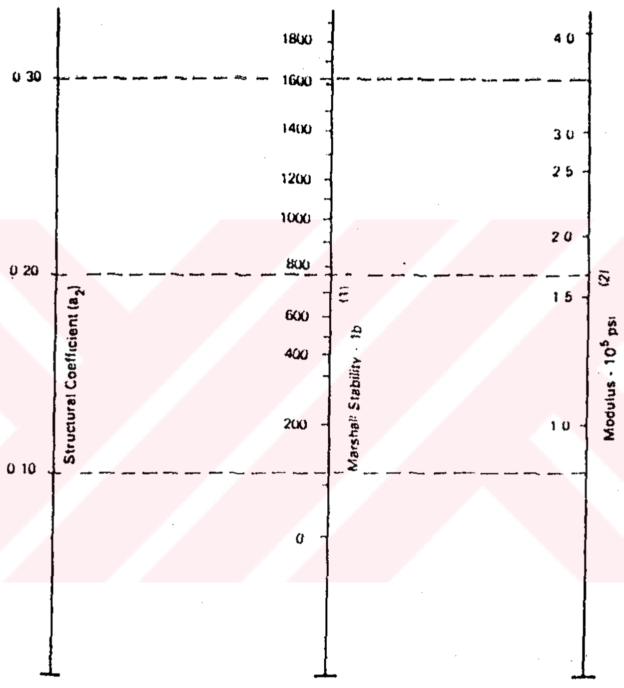
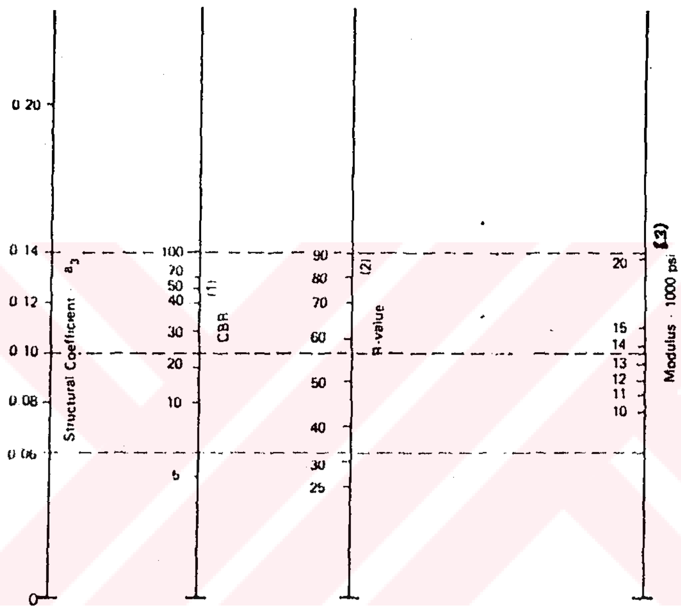


Figure D-7 Variation in (**a2**) for bituminous-treated bases with base strength parameter



(1) Scale derived from correlations from Illinois

(2) Scale derived from correlations obtained from The Asphalt Institute, California, New Mex'`o and Wyoming.

(3) Scale derived on NCHRP project

Figure D-8 Variation in granular subbase layer coefficient (a_3) with various subbase strength parameter

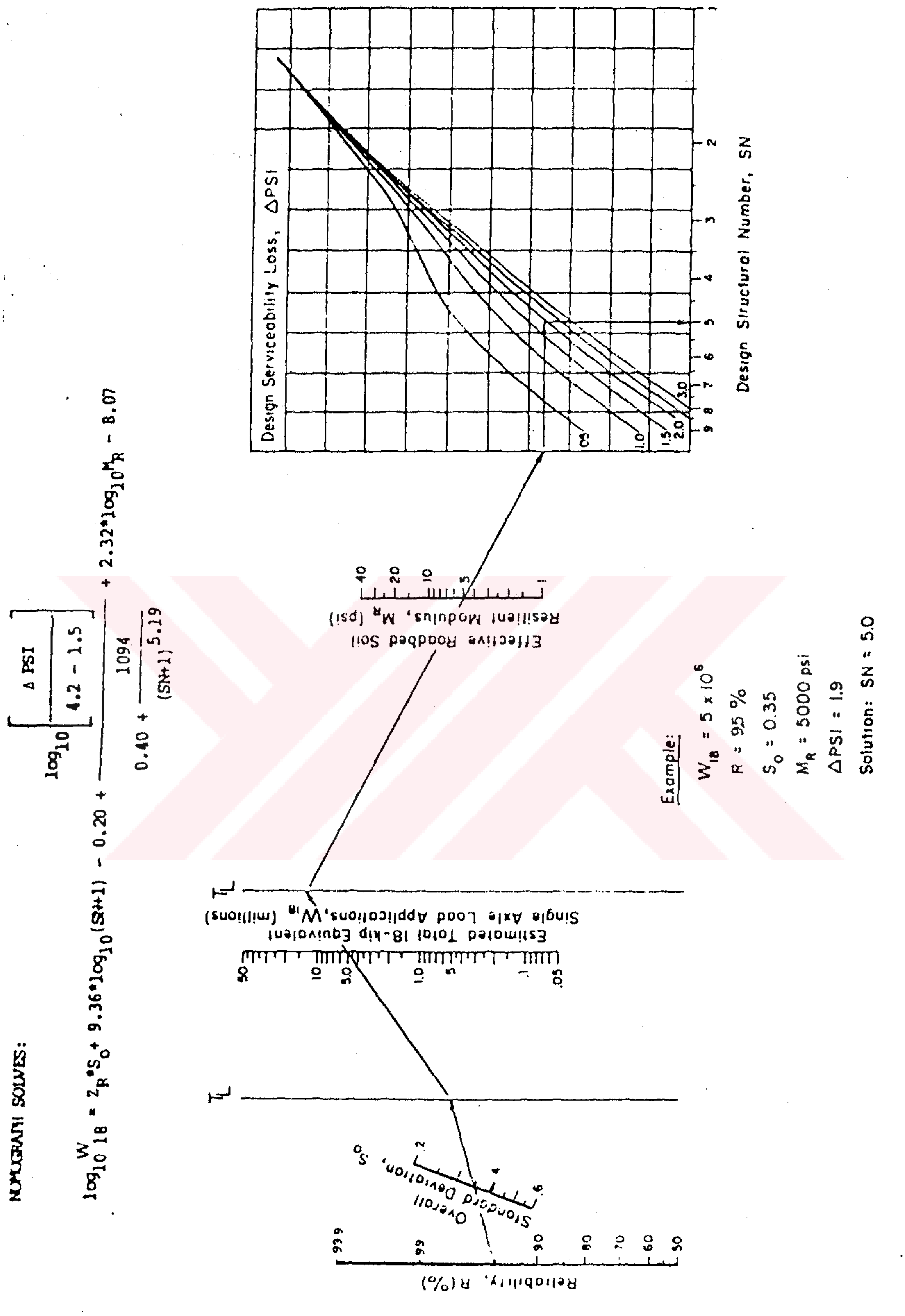


Figure D-9 Design chart for flexible pavements based on using mean value for each input

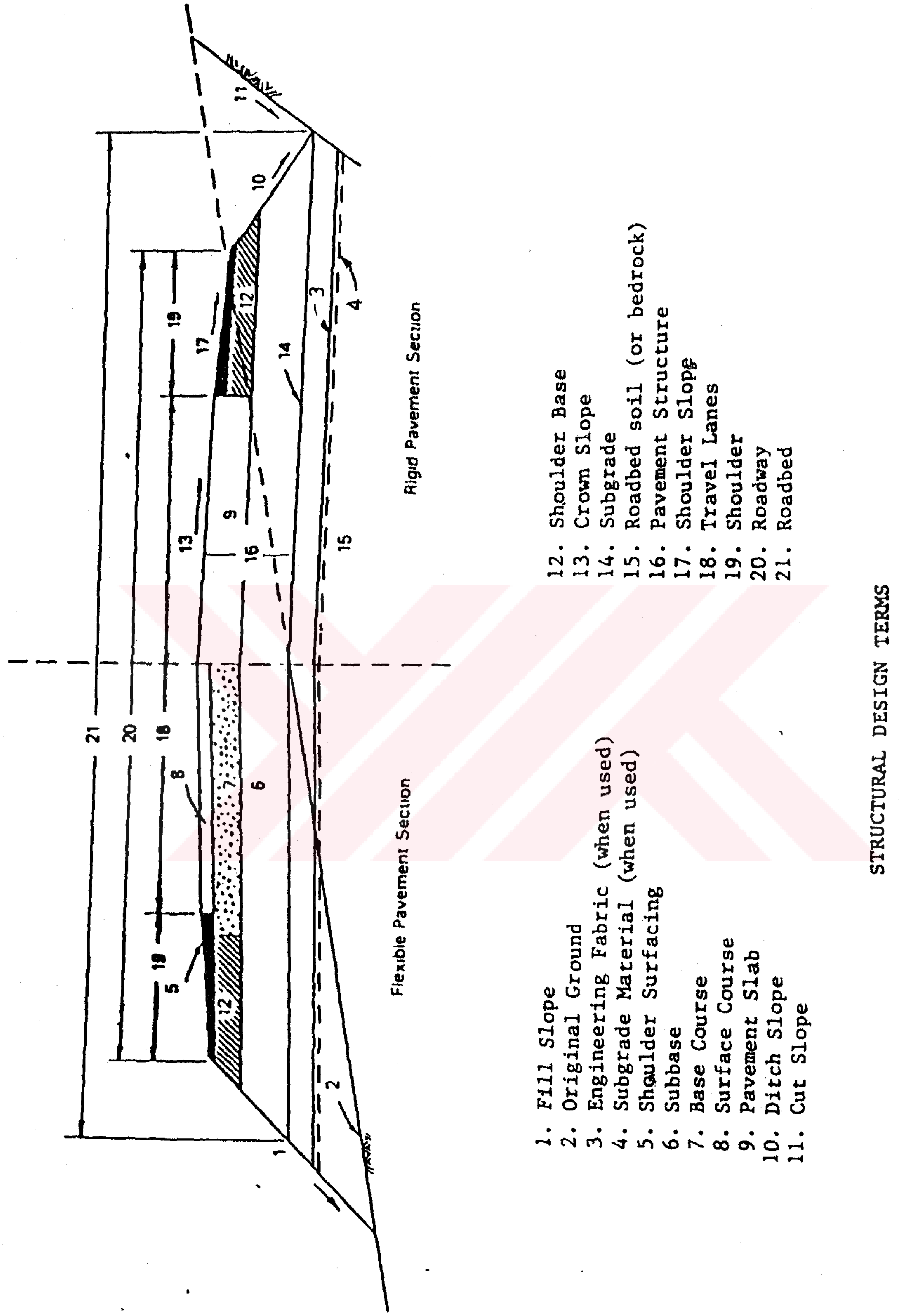


Figure D-10 Typical section of a highway consisting rigid and flexible pavement structure[4]

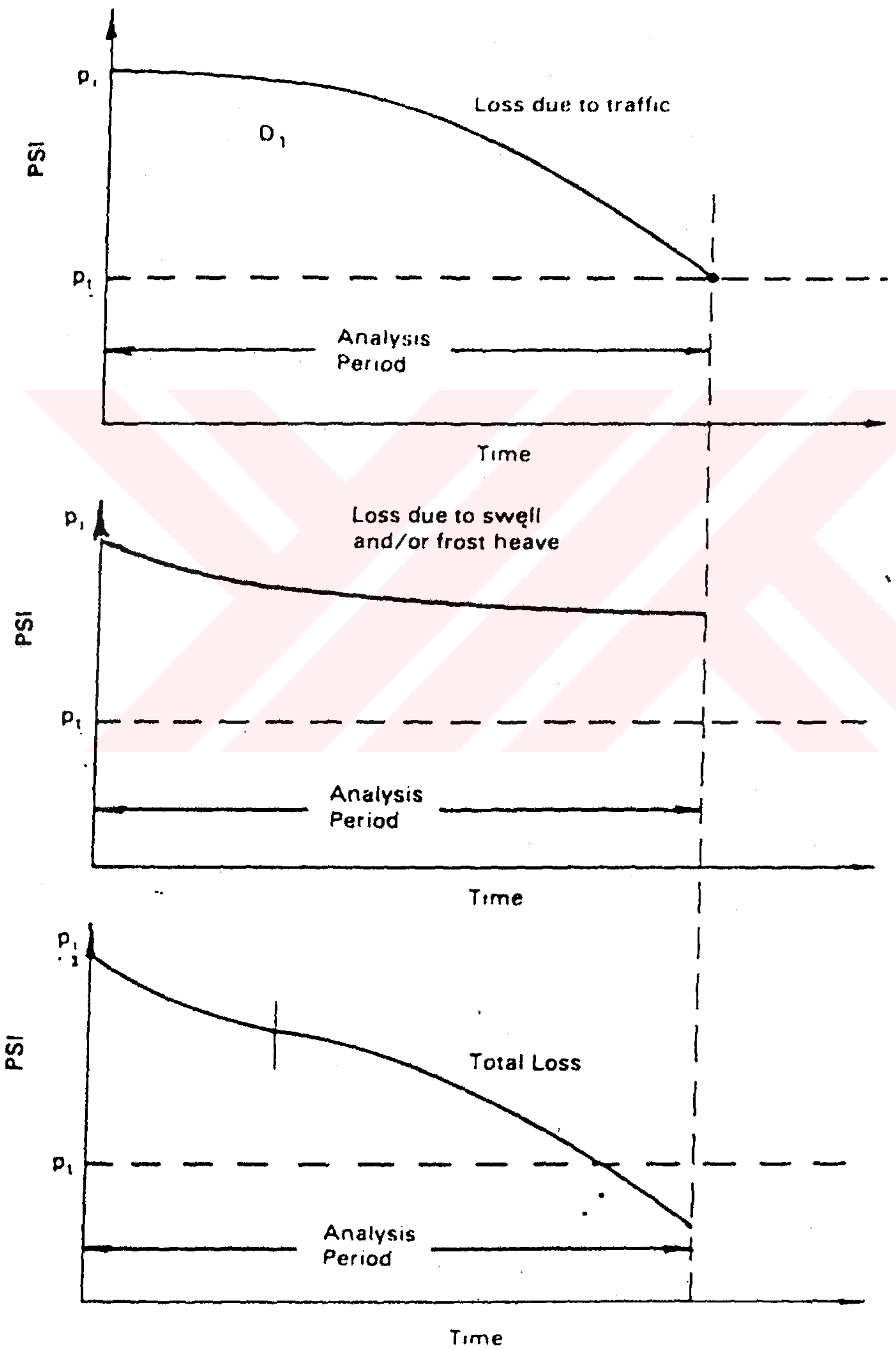


Figure D-11 Pavement Performance Trends

D10

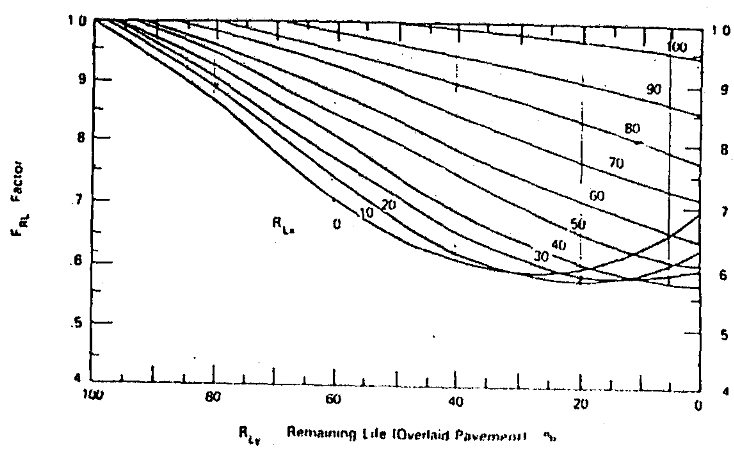


Figure D-12 Remaining life factor as a function of remaining life of existing and overlaid pavements

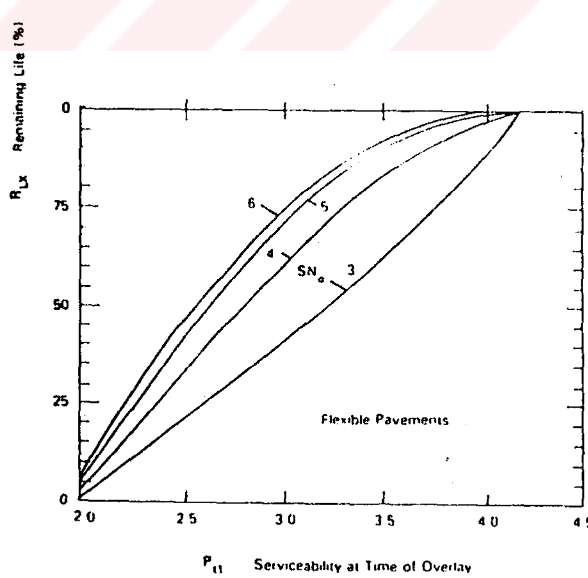


Figure D-13 Remaining life estimate based on present serviceability value and pavement cross section.

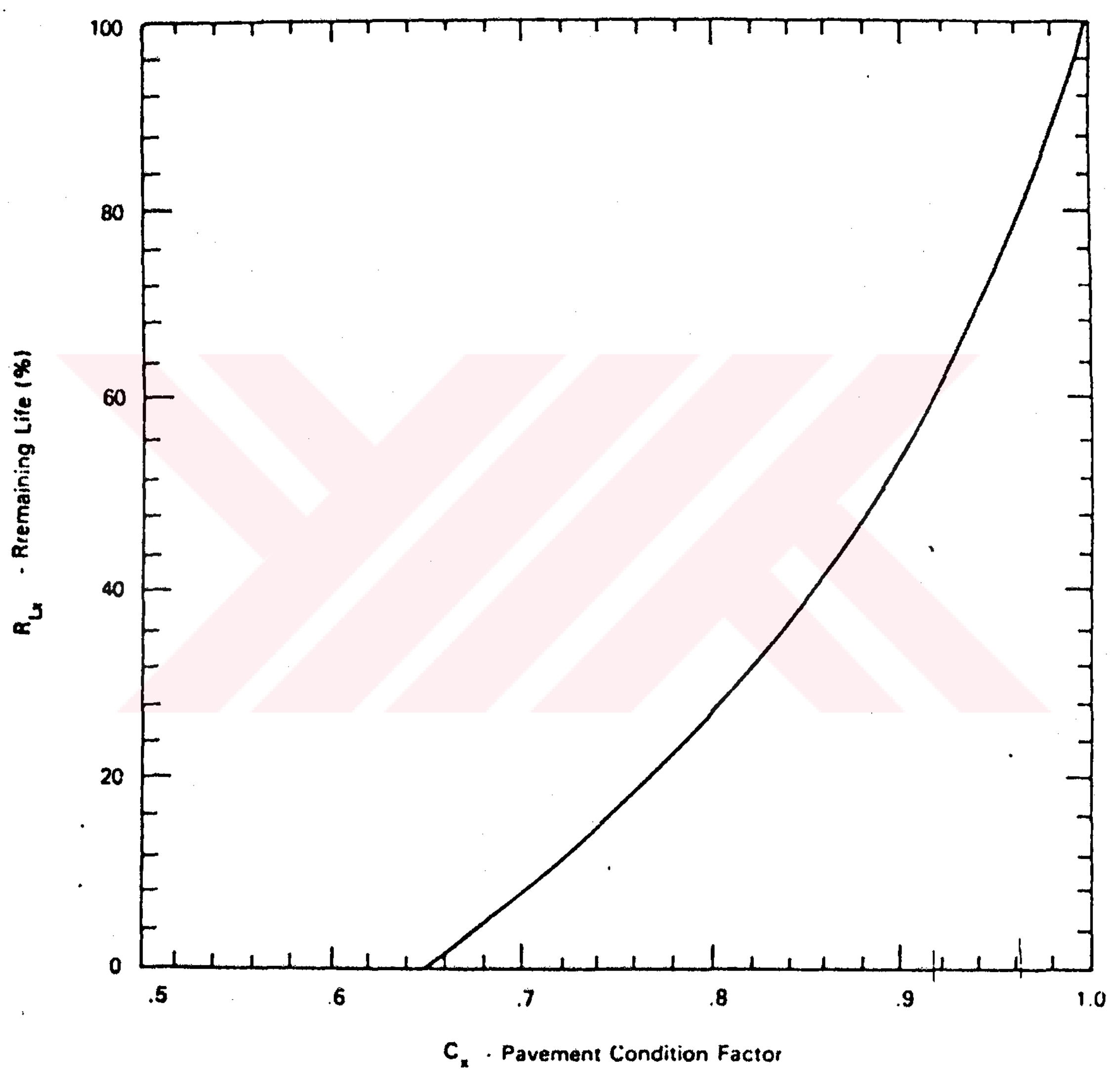


Figure D-14 Remaining life estimate predicted from pavement condition factor

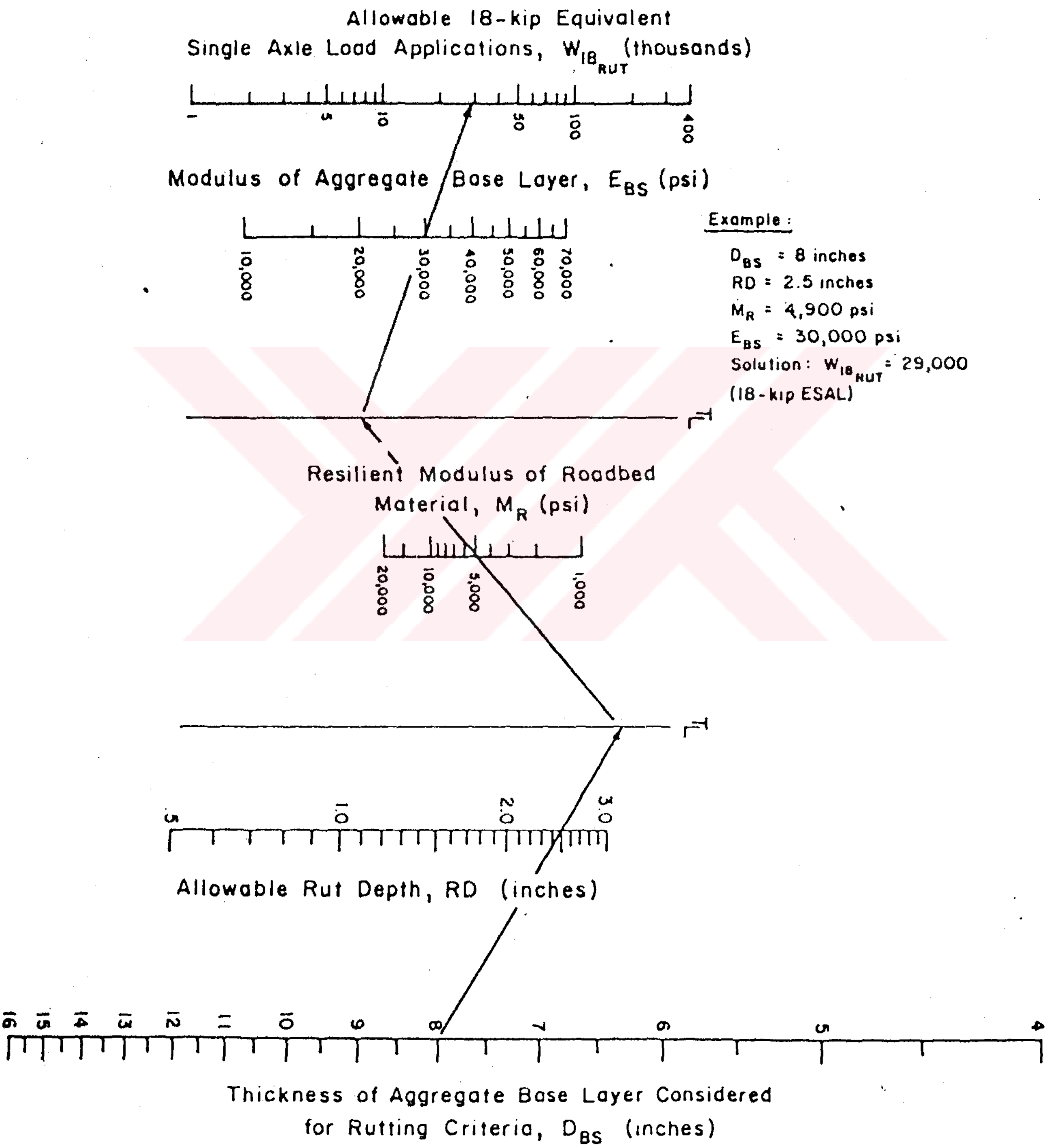


Figure D-15 Design chart for aggregate-surfaced roads considering allowable rutting

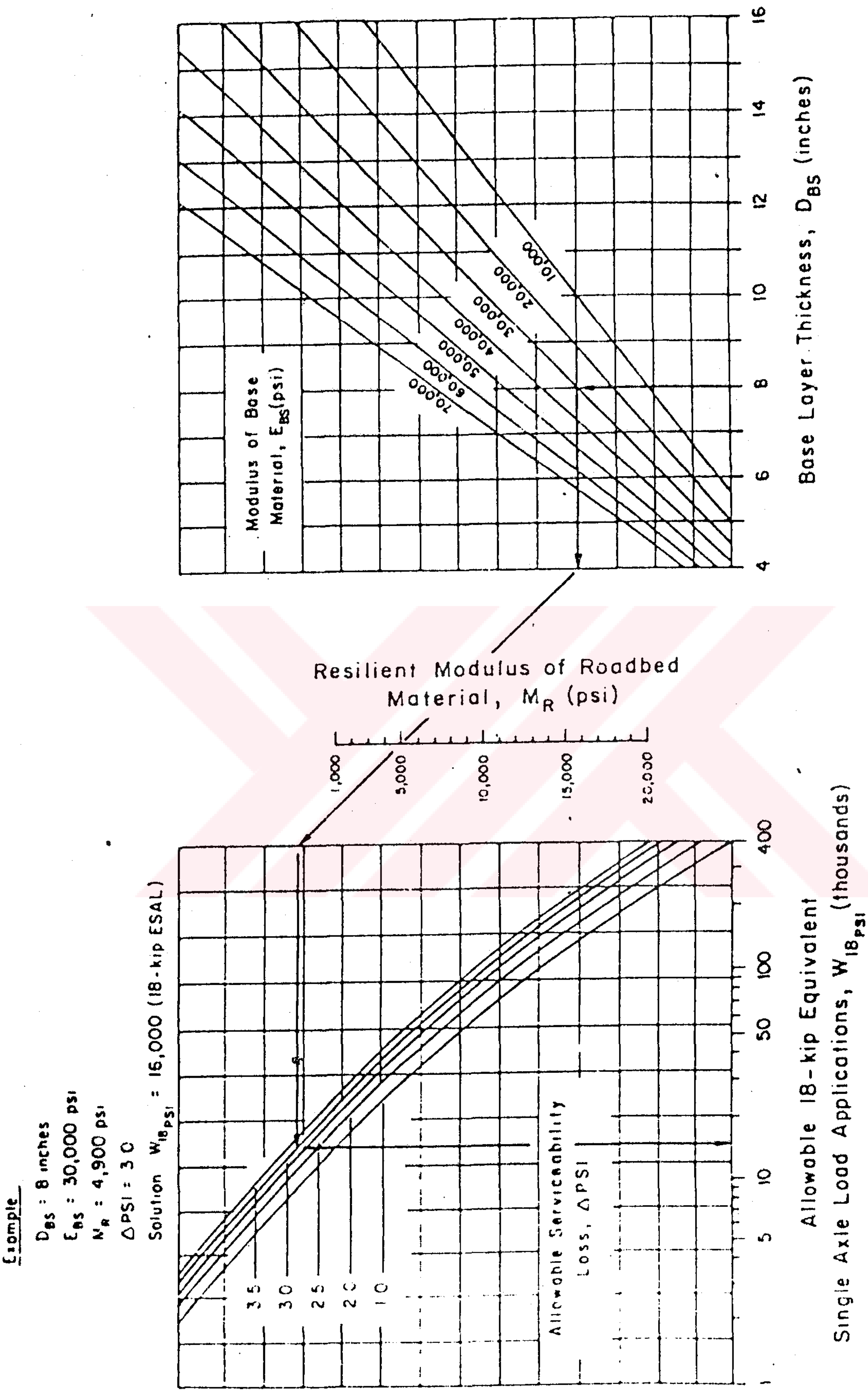


Figure D-16 Design chart for aggregate-surfaced roads consideringallowable serviceability loss

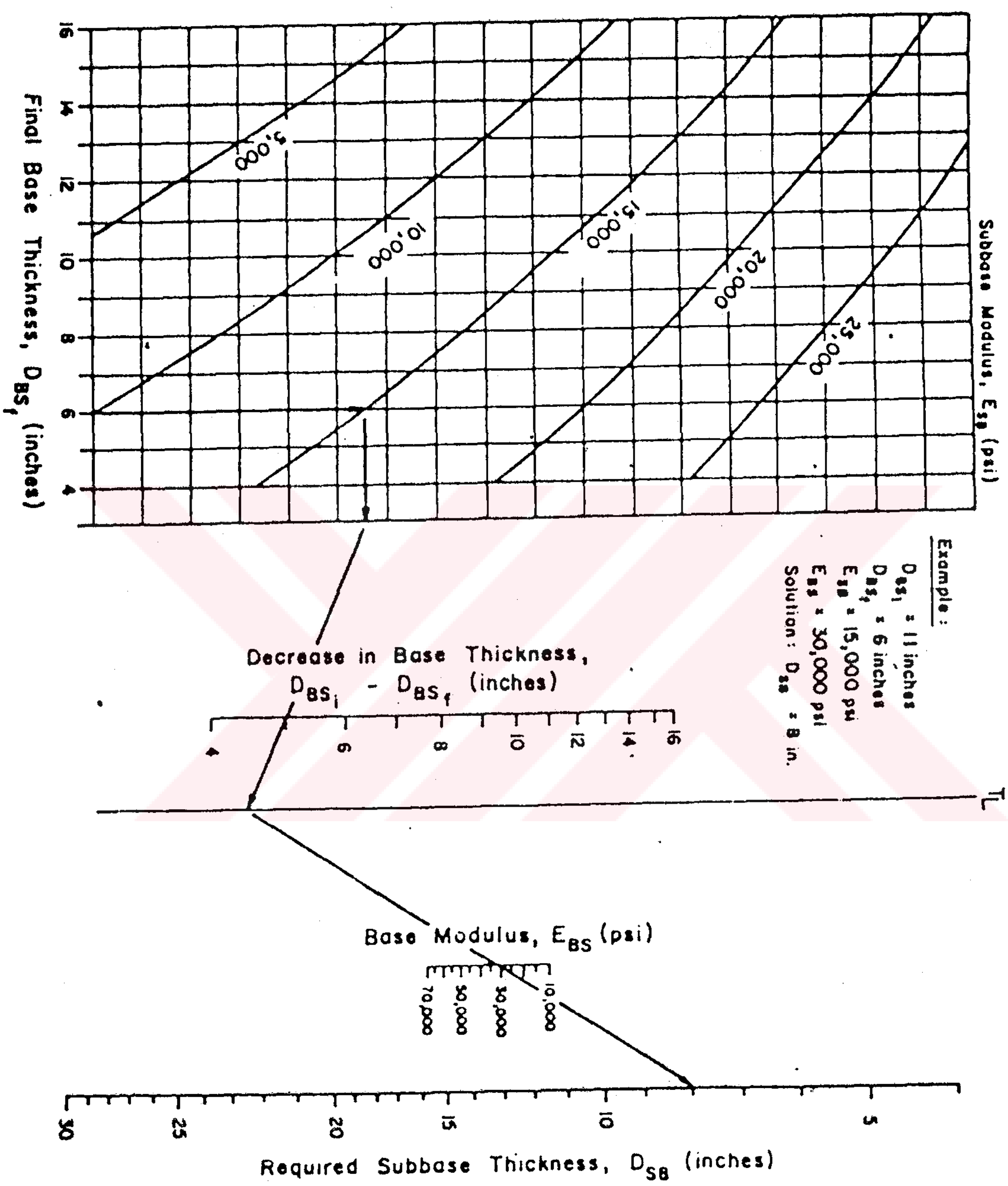
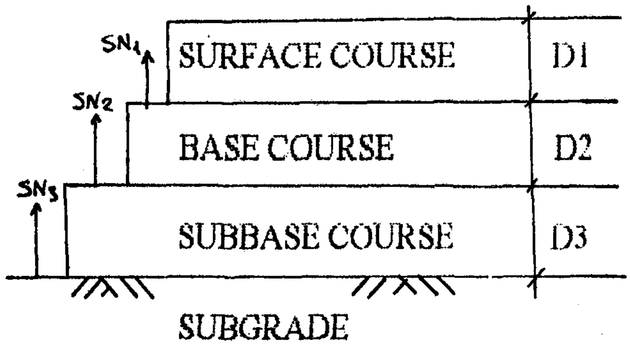


Figure D-17 Chart to convert a portion of the aggregate base layer thickness to an equivalent thickness of subbase



$D_1^* \geq SN_1 / a_1$ $SN_1^* = a_1 * D_1^* \geq SN_1$ $D_2^* \geq (SN_2 - SN_1^*) / (a_2 * m_2)$

$SN_1^* + SN_2^* \geq SN_2$ $D_3^* \geq (SN_3 - (SN_1^* + SN_2^*)) / (a_3 * m_3)$

a) a, D, m and SN are as defined in the text and or minimum required values
b) An asteriks with D or SN indicates that it represents the value actually used, which must be equal to or greater than the required value

Figure D-18 Procedure for determining thickness of layers using a layered analysis approach

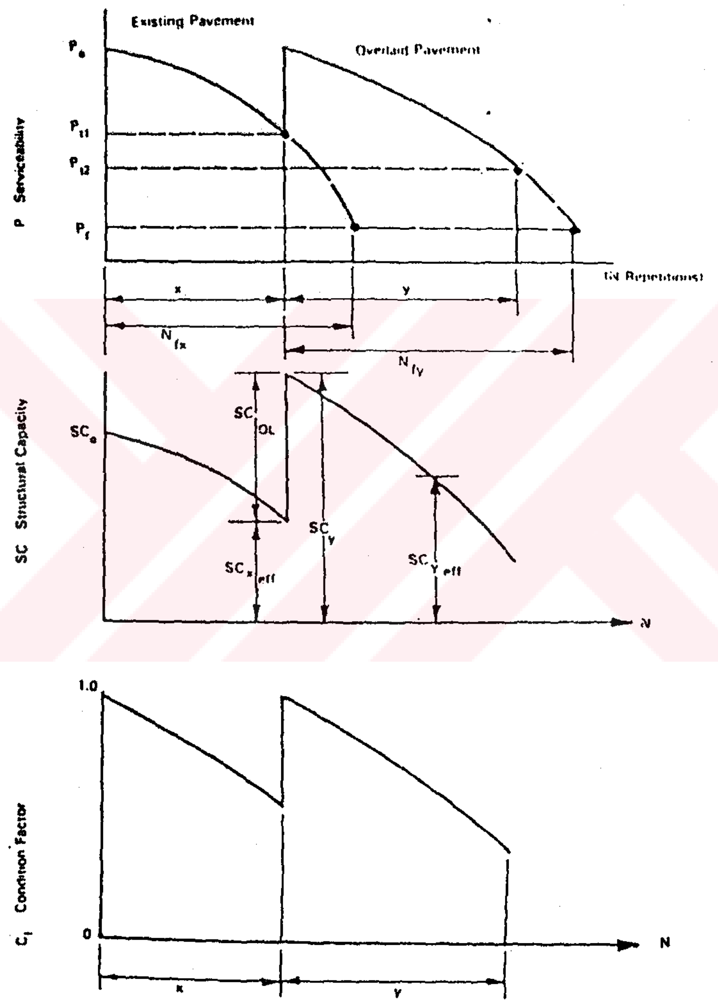


Figure D-19 Relationship between serviceability-capacity condition factor and traffic

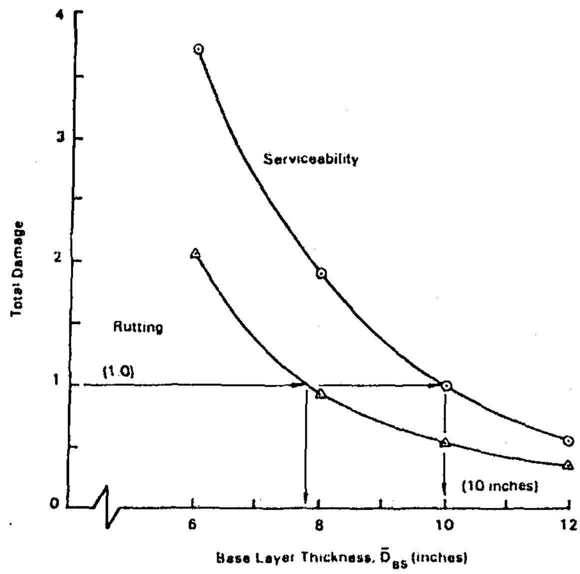


Figure D-20 Example growth of total damage versus base layer thickness for both serviceability and rutting criteria

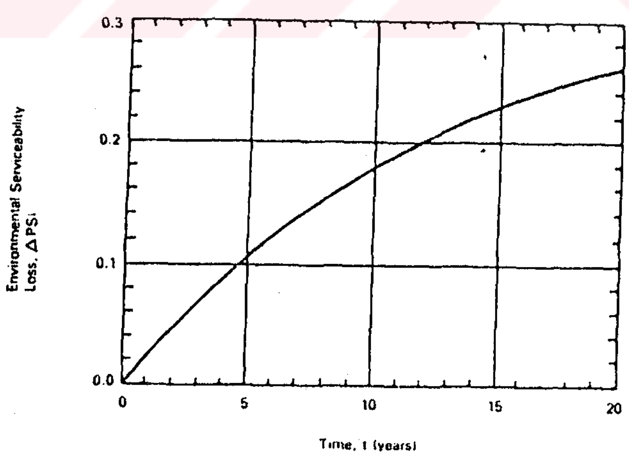


Figure D-21 Graph of example environmental serviceability loss versus time for swelling conditions considered

Table D-1 Suggested Levels of reliability for various functional classification

Functional Classification	*Recommended Level of Reliability*	
	Urban	Rural
Interstate andOther 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		

Table D-2 Recommended mi values for modifying for modifying structural layer coefficient of untreated base and subbase materials in flexible pavements

	Percent of time pavement structure is exposed to moisture levels approaching saturation			
DRAINAGE QUALITY	Loss Than 1 %	1-5 %	5-25 %	Greater Than 25 %
Excellent	1.40-1.35	1.35-1.30	1.30-1.20	1.20
Good	1.35-1.25	1.25-1.15	1.15-1.00	1.00
Fair	1.25-1.15	1.15-1.05	1.00-0.80	0.80
Poor	1.15-1.05	1.05-0.80	0.80-0.60	0.60
Very Poor	1.05-0.95	0.95-0.75	0.75-0.40	0.40

Table D-3 Standard Normal Deviate (Z_R) Values Corresponding To Selected Levels Of Reliability

Reliability R (%)	*Standard Normal Deviate,* Z_R
50	-0.000
60	-0.253
70	-0.524
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
96	-1.751
97	-1.881
98	-2.054
99	-2.327
99.9	-3.090
99.99	-3.750

Table D-4 Minimum Practical Thickness For Each Pavement Course

Minimum Thickness (inches)		
Traffic, ESAL's	Asphalt Concrete	Aggregate Base
Less than 50.000	1.0 (or surface treated)	4
50.000 -150.000	2.0	4
150.001-500.000	2.5	4
500.001-2.000.000	3.0	6
2.000.001-7.000.000	3.5	6
Greater than 7.000.000	4.0	6

Table D-5 The general definations corresponding to different drainage levels from the pavement structure

Quality Of Drainage	*Water Removed Within*
Excellent	2 Hours
Good	1 Day
Fair	1 Week
Poor	1 Month
Very Poor	Water will not Drain

Table D-6 Suggested seasonal roadbed soil resilient moduli M_R (psi), as a function of the relative quality of the roadbed material

Relative Quality of Roadbed Soil	Season (Roadbed Soil Moisture Condition)			
	Winter (Roadbed Frozen)	Spring-Thaw (Roadbed Saturated)	Spring/Fall (Roadbed Wet)	Summer (Roadbed Dry)
Very Good	20,000*	2,500	8,000	20,000
Good	20,000	2,000	6,000	10,000
Fair	20,000	2,000	4,500	6,500
Poor	20,000	1,500	3,300	4,900
Very Poor	20,000	1,500	2,500	4,000

*Values shown are Resilient Modulus in psi

Table D-7 Example application of chart for computing total pavement damage (for both serviceability and rutting criteria) based on a trial aggregate base thickness

TRIAL BASE THICKNESS, D_{BS} (Inches) 8				Serviceability Criteria Δ PSI = 3.0		Rutting Criteria RD(inches) = 2.5	
(1) Season (Roadbed Moisture Condition)	(2) Roadbed Resilient Modulus, M_R(psi)	(3) Base Elastic Modulus, E_{BS}(psi)	(4) Projected 18-kip ESAL Traffic, w_{18}	(5) Allowable 18-kip ESAL Traffic, $(W_{18})_{PSI}$	(6) Seasonal Damage, $\frac{w_{18}}{(W_{18})_{PSI}}$	(7) Allowable 18-kip ESAL Traffic, $(W_{18})_{RUT}$	(8) Seasonal Damage $\frac{w_{18}}{(W_{18})_{RUT}}$
Winter (Frozen)	20,000	30,000	4,400	400,000	0.01	130,000	0.03
Spring-Thaw (Saturated)	1,500	30,000	2,600	4,900	0.53	8,400	0.31
Spring/Fall (Wet)	3,300	30,000	7,000	8,400	0.83	20,000	0.35
Summer (Dry)	4,900	30,000	7,000	16,000	0.44	29,000	0.24
		Total Traffic =	21,000	Total Damage =	1.81	Total Damage =	0.93

Table D-8 Reduction in performance period (service life) of initial pavement ariving from swelling considerations

Initial SN 5.6
Maximum Possible Performance Period (years) 15
Design Serviceability Loss, $\Delta PSI = p_o - p_t$ = 4.6 - 2.5 = 2.1

(1) Iteration No.	(2) Trial Performance Period (Years)	(3) Serviceability Loss Due to Swelling ΔPSI_{SW}	(4) Corresponding Serviceability Loss Due to Traffic ΔPSI_{TR}	(5) Allowable Cumulative Traffic (18-kip ESAL)	(6) Corresponding Performance Period (Years)
1*	13	0.21	1.89	16.0×10^6	13.2

*Convergence achieved after only one iteration.

APPENDIX E

LIST OF TEST PROCEDURES

1- CBR, California Bearing Ratio *(ASTM D1883, AASHTO T193, Milstd 621 A):* To determine the load-bearing capacity. The results are used to appropriate the resilient modulus.

2- Marshall Stability *(ASTM D1559, AASHTO T245):* To determine the plastic flow rate of bituminous mixtures.

3- Plasticity Index *(ASTM D424, AASHTO T 90):* To find the range of water content s over which the soil is in a plastic state.

4- Resilient Modulus of Asphalt Concrete From Diametral Strain *(ASTM D4123):* To estimate the modulus of asphalt concrete and other relatively low-strength materials under simulated field-loading conditions.

5- Roadbed Resilient Modulus *(M_R) (AASHTO T274):* To determine the roadbed resilient modulus of the elastic property of soil.

6- R-Value *(ASTM D2844, AASHTO T190):* To determine the load-bearing capacity of a material.

7- Unconfined Compressive Strength:

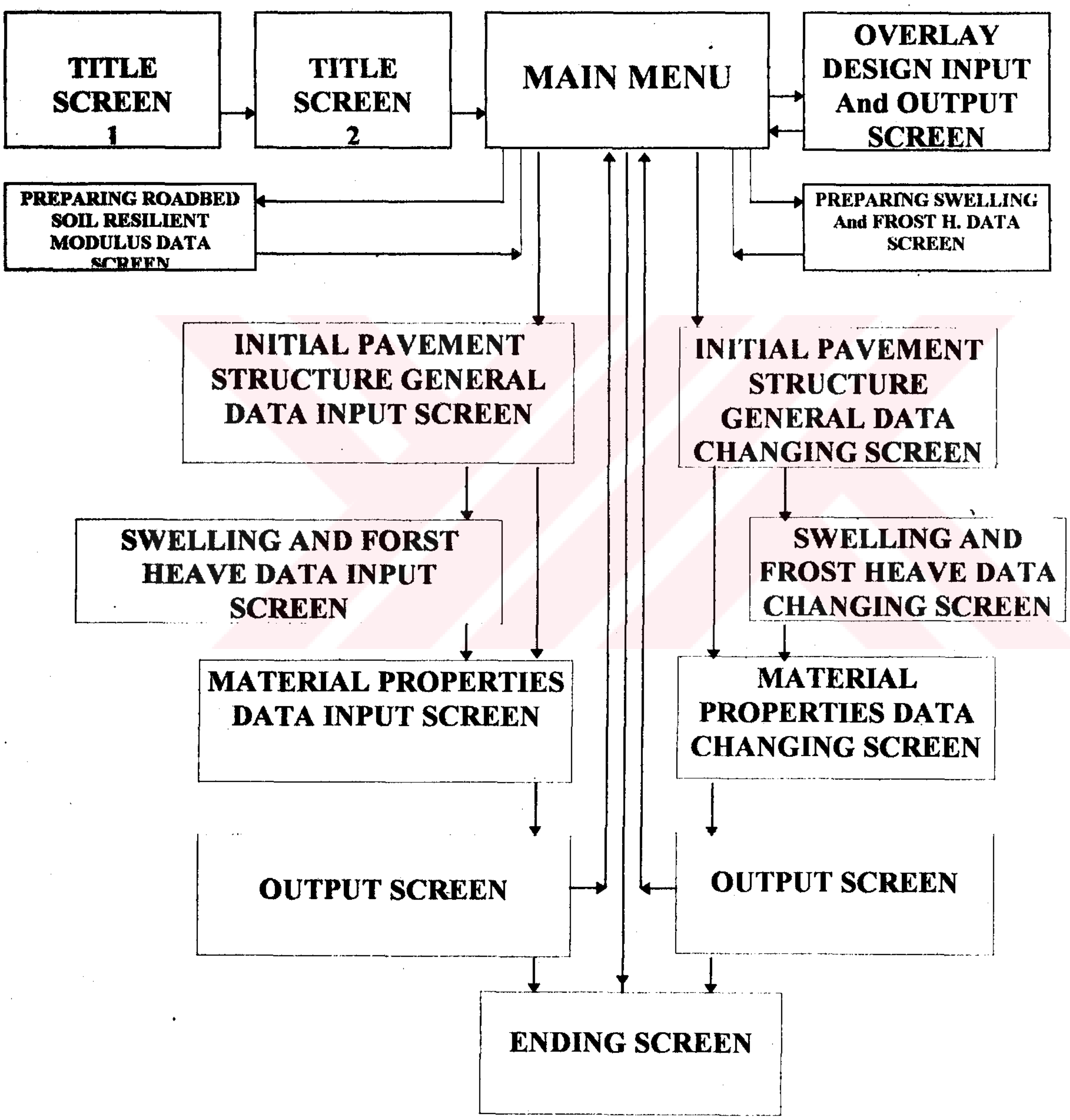
a) For cohesive soils (ASTM D2166, AASHTO T208)

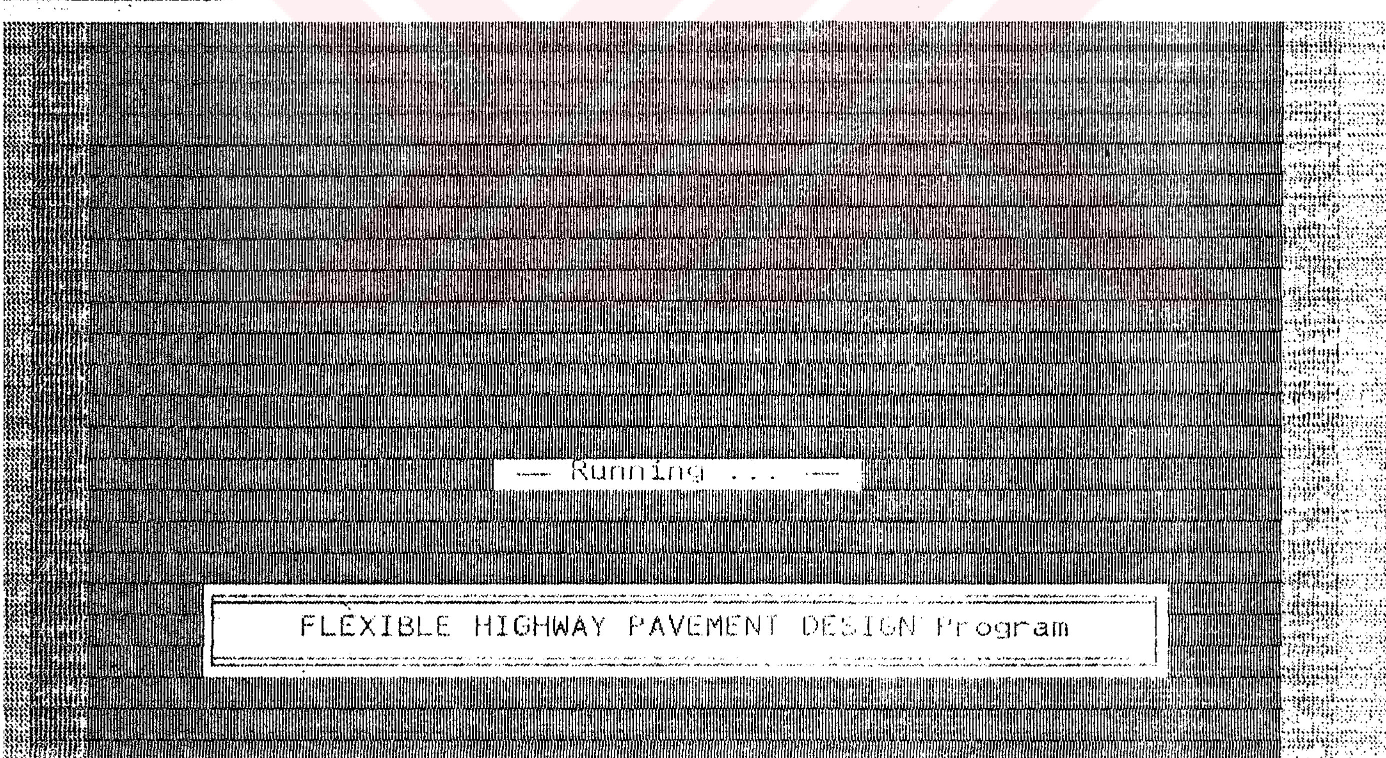
b) For cement-treated materials (ASTM D1633): To find the unconfined compressive strength of soils using molded cylinders as test speciments.

APPENDIX F

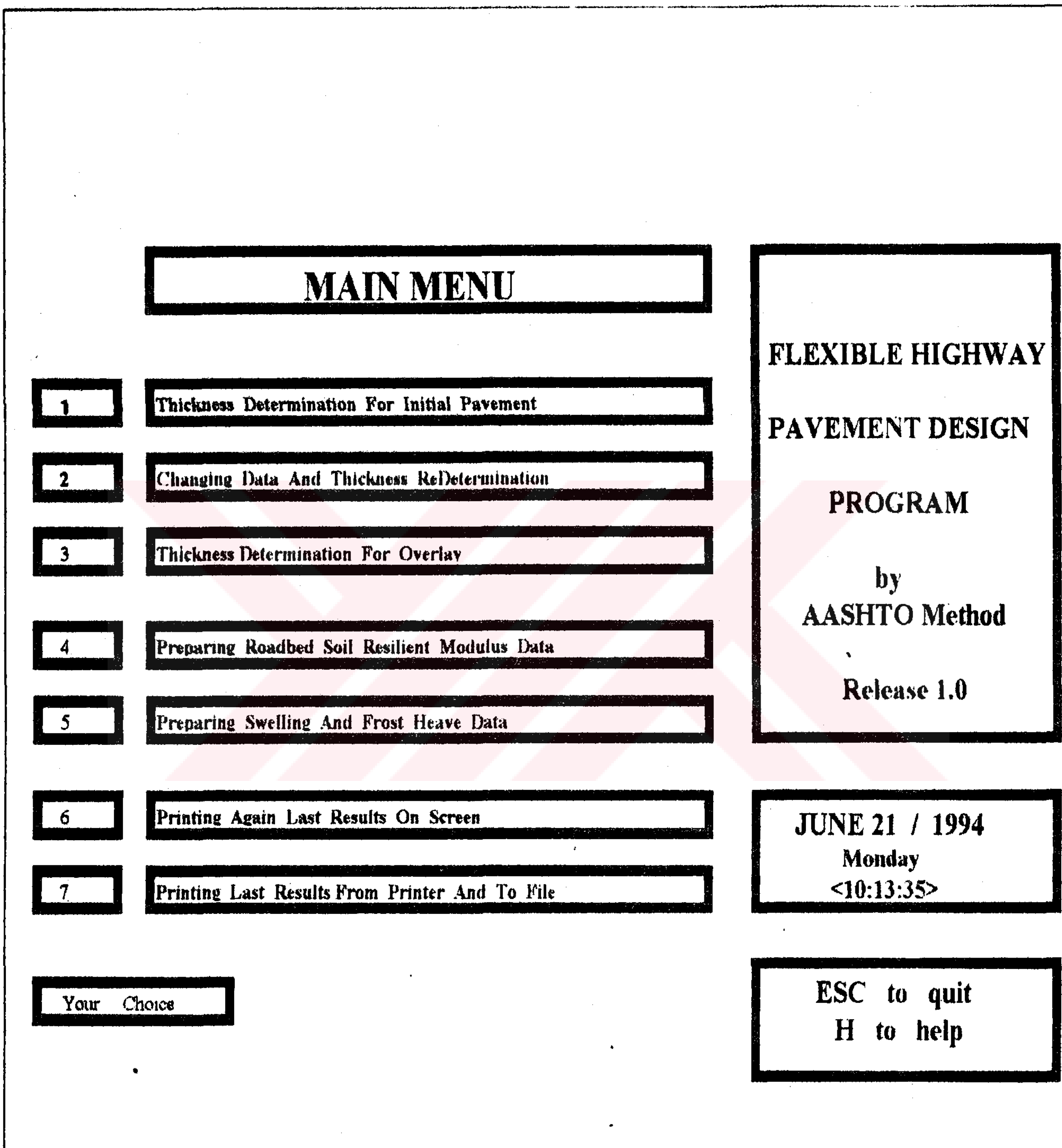
SCREENS APPEARING WHEN THE PROGRAM IS RUNNING

Below is the micro flow-chart illustrating the sequence of the input, control and output screens in program. Note that all input screens can call a help screen.

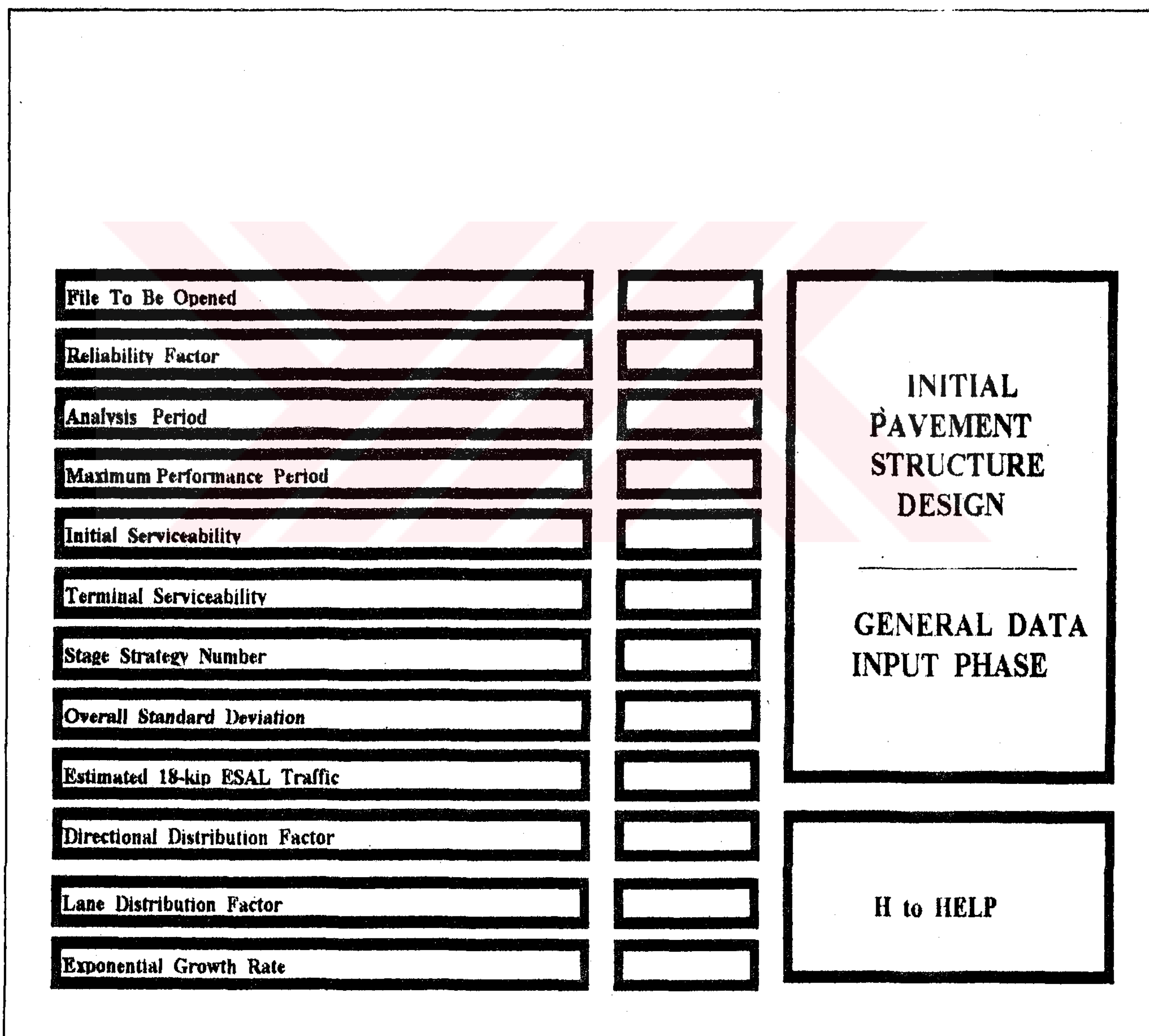




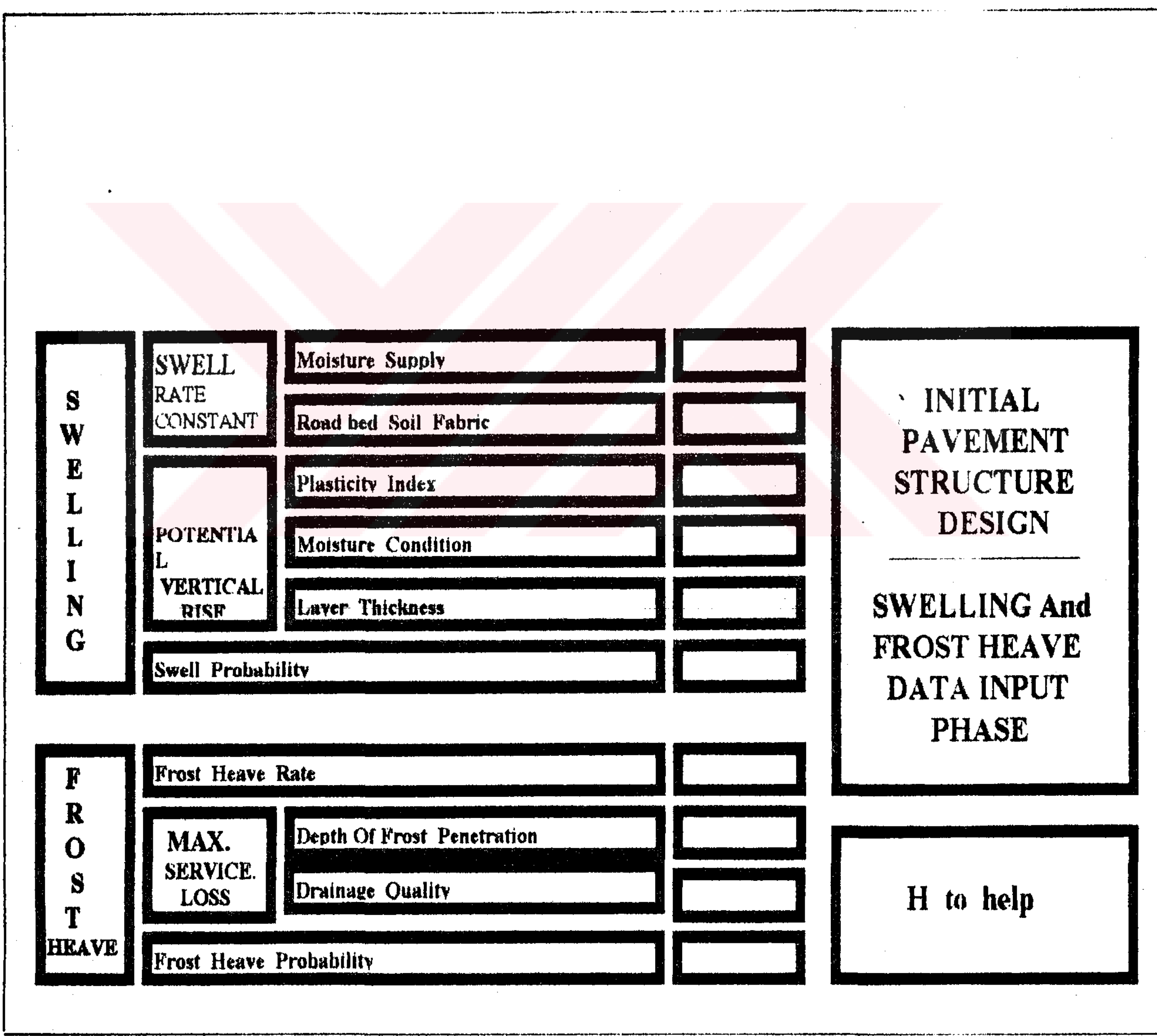
Screen F-1 Title and PC Graphics Card control screen.



Screen F-2 Main Menu screen.

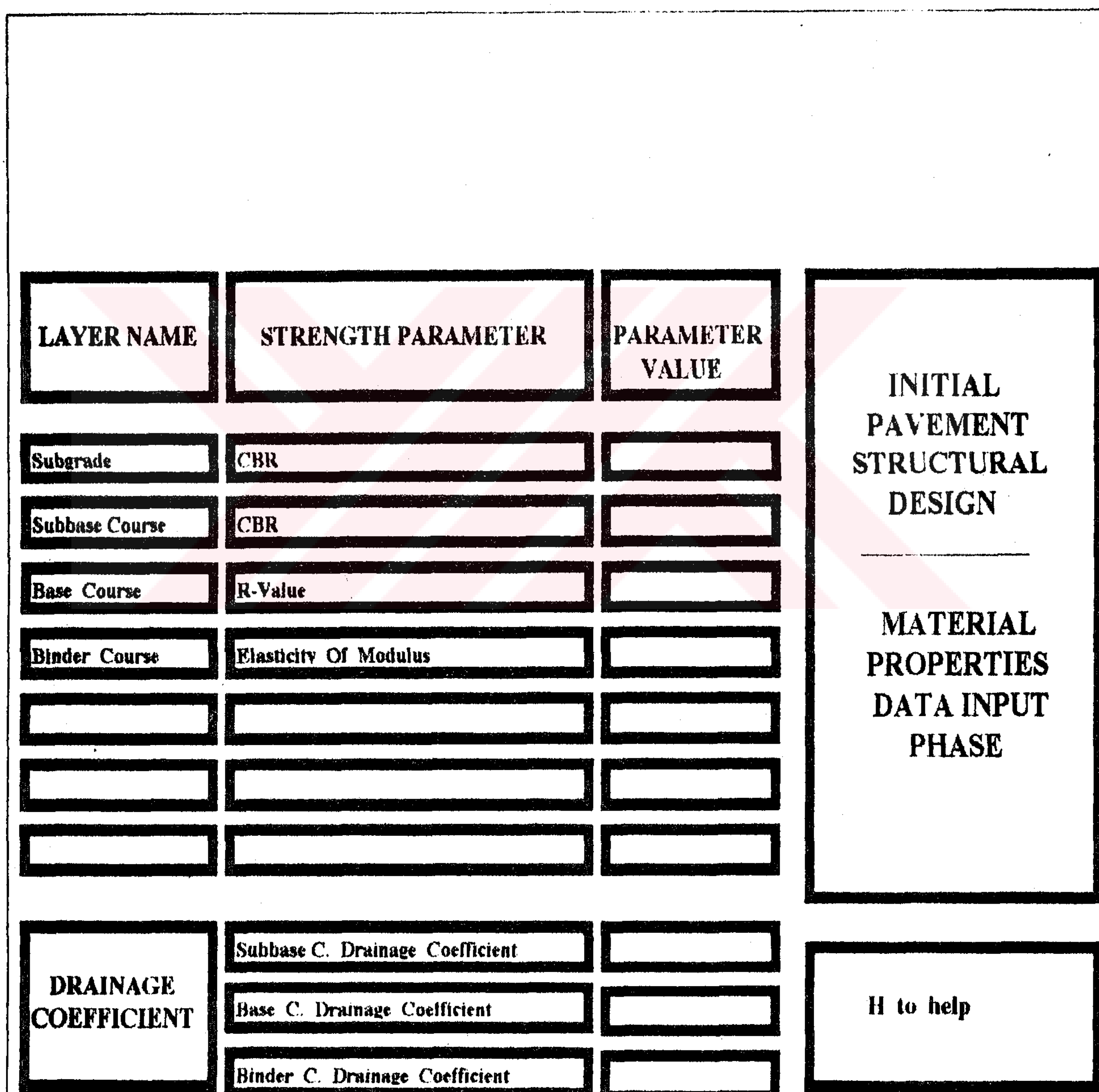


Screen F-3 Initial pavement design, general data input screen.

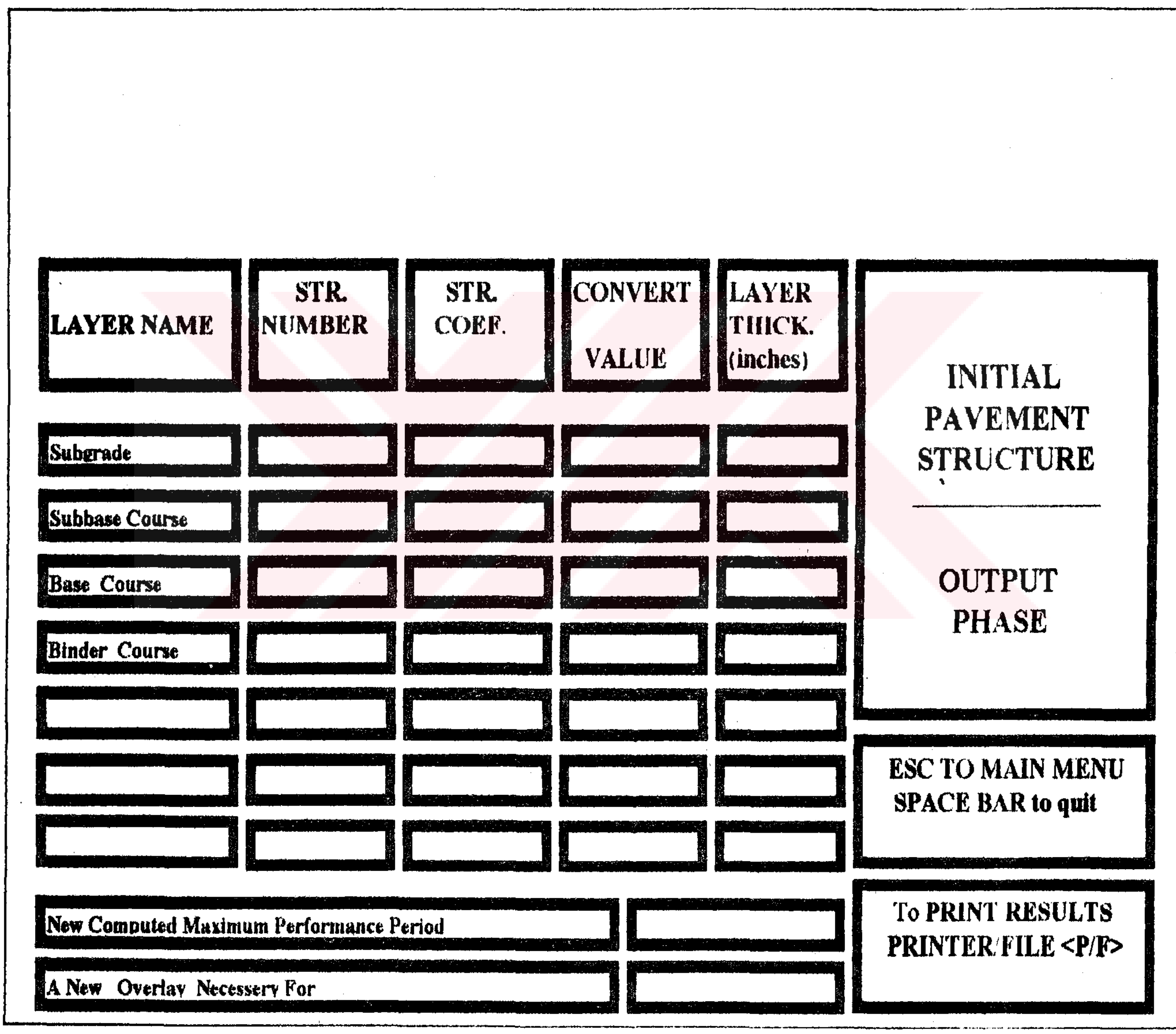


Screen F-4 Swelling and Frost heave data input screen

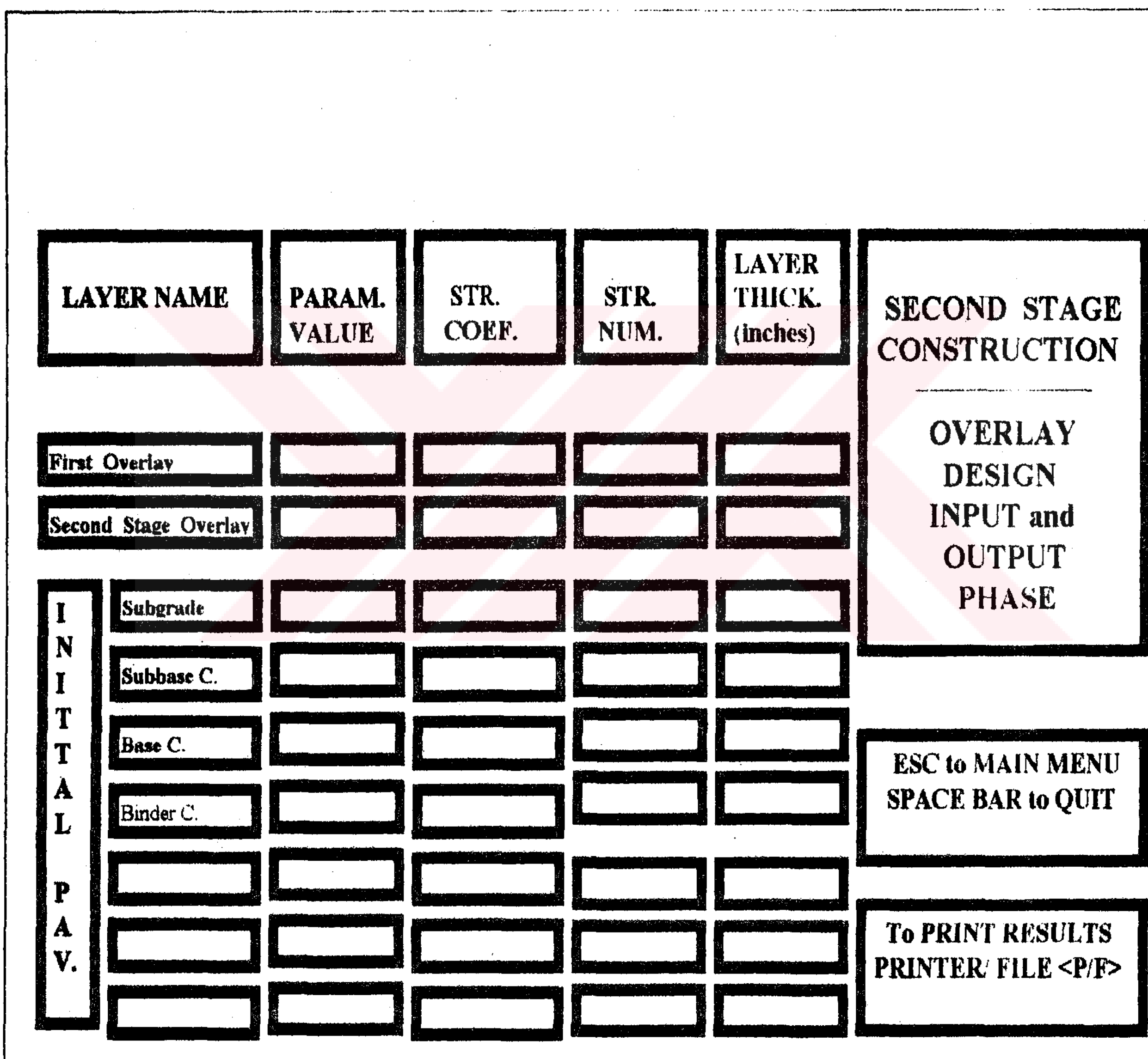
F5



Screen F-5 Material characteristics data input screen



Screen F-6 Initial pavement design, output screen.



Screen F-7 Overlay design, data input and output screen.

APPENDIX G

UNITS AND VARIABLES USED IN THE STUDY

a_i : Structural Coefficient
C_x : Pavement Condition Factor
D : Layer Thickness (inches)
D_D : Directional Distribution Factor (%)
D_L : Lane Distribution Factor (%)
F_R : Reliability Factor
F_{RL} : Remaining Life Factor
g : Growth Rate (%)
m_i : Layer Drainage Coefficient
M_R : Roadbed Resilient Modulus (psi)
P_0 : Initial Service
PSI : Present Serviceability Index
P_t : Terminal Serviceability Index
P_{t1} : Serviceability At Time Of Overlay
R : Reliability
RL_x : Remaining Life Of Existing Pavement (%)
RL_y : Remaining Life Of Overlaid Pavement (%)
SN : Structural Number
S_0 : Overall Standard Deviation (%)
W_{18} : Traffic
w_{18} : The Cumulative Two-directional 18-kip ESAL
Z_R : Standard Normal Deviate
ΔPSI : Design Serviceability Loss
$\Delta PSI_{sw,fh}$: Serviceability Loss Due To Swelling and Frost Heave
ΔPSI_{TR}: Serviceability Loss Due To Traffic

NOTE : 1 *feet* = 12 inches = 30.48 cm
1 *inches* = 2.54 cm
1 *psi* = 0.070307 kg/cm^2
1 *lb(pound)* = 0.454 kg^2

APPENDIX H

CONTENT OF THE PROGRAM PIECES

In this appendix, content of all files is listed.

```
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*              MAIN PROGRAM ORGANIZING ALL UNIT PROGRAMS               *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$A+,B-,D+,G+,I+,L+,R-,S+,V+,X-}{$M 16384,0,655360}{$O+,F+,E+,N+}
PROGRAM MAINPROGRAM;
USES OVERLAY,DOS,GRAPH,CRT,SCREENS,HELPS,WARNINGS,INPUTS,DATASTOR,
        OUTPUTS,COMPUTE;

{O SCREENS}{O HELPS}{O WARNINGS}{O INPUTS}{O DATASTOR}{O OUTPUTS}{O COMPUTE}

LABEL  SON,NEWFILE,PRINTSCREEN,PRINTPRINTER,GIVEUP,SWELLFROST,MATERIALCHAR,
       MATERIALCHAR1,STARTNEW, OVERLAYDESIGN,TEK,TEK1,TEK2,TEK3,TEK4,TEK5,
       TEK6,TEK7,TEK8,TEK9,TEK10,TEK11,TEK12,TEK13,TEK14,TEK15,TEK16,TEK17,
       TEK18,TEK19,TEK20,TEK21;

VAR    DEVAM                                      :^CHAR;
       DEVAM1                                     :BOOLEAN;
       DEVAM2,YESNO1                              :CHAR;
       VIEWPORT                                   :VIEWPORTTYPE;
       AAA,BBB,CCC,ESALTime,Timerel               :REAL;
       III,JJJ,KKK,FILELENGTH                     :INTEGER;
       PRFILE                                     :STRING;

CONST  Triangle : array[1..10] of PointType =
       ((x:  160; y: 414),(x: 180; y: 412), (x: 187; y: 395),(x: 190; y: 410),
       (x: 215; y: 397),(x: 197; y: 422),(x: 203; y: 445),(x: 185; y: 439),
       (x: 158; y: 455),(x: 169; y: 430));

FUNCTION IntToStrReal(i: REAL): string;VAR  s: string[5];
BEGIN  Str(i, s);IntToStrReal:= s; END;
FUNCTION IntToStr(i: longINT): string;VAR  s: string[7];
BEGIN  Str(i, s);IntToStr:= s; END;
BEGIN    OVRINIT('AASHTO.PAS');

RFNEW:=0.0;
GRC;  TITLE1;        NEW(DEVAM);   DEVAM^:=Readkey;
                     I:=467;J:=420;K:=164;L:=50;OFF;delay(500);
                     IF DEVAM^=CHR(27) THEN BEGIN CLOSEGRAPH;EXIT;END;
                     DISPOSE(DEVAM);

TEK:
STARTNEW:
```

```
IF DEVAM2=CHR(27) THEN begin I:=469;J:=420;K:=160;L:=50;OFF;delay(500);GOTO SON;end;

IF DEVAM2=CHR(72) THEN BEGIN  I:= 469;J:=360;K:=160;L:=50;OFF;delay(500);
                              SESVER2;HELPMAINMENU; GOTO STARTNEW; END;

Wwr;  SETFILLSTYLE(1,3);
FillPoly(SizeOf(Triangle) div SizeOf(PointType), Triangle);
Settextstyle(0,Horizdir,2);
SETCOLOR(8);        OuttextXY(187,430,DEVAM2);
YWR;                OuttextXY(183,427,DEVAM2);


CASE DEVAM2 OF

CHR(49): begin I:= 30;J:=150;K:=30;L:=20;OFF;DELAY(250);
               GOTO NEWFILE;end;

CHR(50): BEGIN  I:= 30;J:=180;K:=30;L:=20;OFF;DELAY(250);
                CONSFH:=#78;CHANGEEXISTINGINPUTS;COMPUTED;SCREEN4;GOTO PRINTSCREEN;END;

CHR(51): BEGIN  I:= 30;J:=210;K:=30;L:=20;OFF;DELAY(250);
                IF RFNEW=0 THEN BEGIN IKAZ8;GOTO STARTNEW;END
                ELSE BEGIN
                IF SSNEW=1 THEN BEGIN IKAZ12;GOTO STARTNEW;END
                ELSE GOTO OVERLAYDESIGN;END;END;

CHR(52): BEGIN  I:= 30;J:=250;K:=30;L:=20;OFF;DELAY(250);
                PREPARESFHDATA;MAINMENU;GOTO STARTNEW;END;

CHR(53): BEGIN  I:= 30;J:=280;K:=30;L:=20;OFF;DELAY(250);
                PREPARERRMDATA;MAINMENU;GOTO STARTNEW;END;

CHR(54): BEGIN  I:= 30;J:=320;K:=30;L:=20;OFF;DELAY(250);
                IF RFNEW=0 THEN BEGIN IKAZ8;GOTO STARTNEW;END
                ELSE BEGIN SCREEN4;GOTO PRINTSCREEN;
                END;END;

CHR(55): BEGIN I:= 30;J:=350;K:=30;L:=20;OFF;DELAY(250);
               IF RFNEW=0 THEN BEGIN IKAZ8;GOTO STARTNEW;END
                          ELSE BEGIN
                                TEK2: {$I-} FILEOUTPUT(PRFILE);IKAZ9;PROUTPUT;
                                {$I+} IF IORESULT<>0 THEN
                                                BEGIN IKAZ10;END;
                                                GOTO STARTNEW;
                                END;END;
END; { of case }


NEWFILE:(*------------ BLOCK OPEN NEW FILE ----------------*)

SCREEN1;

 MSNEW:=0;  RSFNEW:=0; PINEW:=0; MCNEW:=' '; LTNEW:=0;  SPNEW:=0;
 FHRNEW:=0.0;  DFPNEW:=0.0;      DQNEW:=' ';    FHPNEW:=0;

Settextstyle(0,HORIZDIR,1);
Settextjustify(LEFTTEXT,CENTERTEXT);

RWR;        OuttextXY(20,40,'<Any Key to Continue>');
```

```
                    SESVER2;HELPNEWFILE;END;


{-----------------------------------------------------------------------}
           SCREEN1;I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
           Setviewport(0,0,639,118,CLIPON);
           GENERALINPUTS;
           SESVER2;

YWR;Clearviewport;
                Setviewport(470,422,628,468,CLIPON);Clearviewport;
                Setviewport(0,0,639,479,CLIPON);
                I:=469;J:=420;K:=160;L:=50;ON;
                Settextjustify(CENTERTEXT,CENTERTEXT);
YWR;            OuttextXY(545,436,'Press');
                OuttextXY(545,452,'ESC to Re-Input');

                Setviewport(0,0,639,118,CLIPON);Clearviewport;
                Settextjustify(LEFTTEXT,CENTERTEXT);
REPEAT YWR; OuttextXY(20,40,'Consider Swelling and/or Frost Heave (Yes/No) <Yes>');

CONSFH:=Readkey;CONSFH:=UPCASE(CONSFH);
IF CONSFH IN [CHR(13),CHR(89),CHR(78),CHR(27)] THEN CONSFH:=CONSFH
                                  ELSE IKAZ1;
IF CONSFH=CHR(13) THEN CONSFH:=CHR(89);
UNTIL CONSFH IN [CHR(13),CHR(89),CHR(78),CHR(27)];
Setviewport(0,0,639,479,CLIPON);
IF CONSFH=CHR(27) THEN BEGIN I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
                        SESVER2;GOTO NEWFILE;END;
IF CONSFH=CHR(78) THEN BEGIN IF APNEW=MPPNEW THEN BEGIN
                        IF SSNEW>1 THEN BEGIN IKAZ15;SSNEW:=1;END;END;
                        GOTO MATERIALCHAR;END;

{---------------- SWELLING AND FROST HEAVE PHASE --------------------------}
SCREEN2;

RWR;       OuttextXY(20,40,'<Any Key to Continue>');

DEVAM2:=Readkey;DEVAM2:=UPCASE(DEVAM2);
IF DEVAM2=#72 THEN BEGIN I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
                   SESVER2;HELPSWELLFROST;END;

MATERIALCHAR1:  SCREEN3;
                I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
                Setviewport(0,0,639,118,CLIPON);
                MATERIALCHARINPUTS;SESVER2;

YWR;            Setviewport(470,422,628,468,CLIPON);Clearviewport;
                Setviewport(0,0,639,479,CLIPON);
                Settextjustify(CENTERTEXT,CENTERTEXT);
                I:=469;J:=420;K:=160;L:=50;ON;
YWR;            OuttextXY(545,436,'Press');
                OuttextXY(545,452,'ESC to Re-Input');

                Setviewport(0,0,639,118,CLIPON);Clearviewport;
                Settextjustify(LEFTTEXT,CENTERTEXT);
RWR;            OuttextXY(20,40,'<Any Key to Start Computing>');

YESNO1:=Readkey;YESNO1:=UPCASE(YESNO1);
Setviewport(0,0,639,479,CLIPON);
```

```
{-------------- PHASE COMPUTING & WRITING RESULTS ON SCREEN ----------------}
IKAZ16; COMPUTED;SCREEN4;

PRINTSCREEN: SESVER2;
SETVIEWPORT(0,0,639,118,CLIPON);CLEARVIEWPORT;
SETVIEWPORT(0,0,639,479,CLIPON);

OVERLAYDESIGN: (*------------- BLOCK OVERLAY DESIGN  ---------------------*)

IF SSNEW=3 THEN BEGIN OVERLAYSCREEN; COMPUTEOVERLAYTH2;OVERLAYSCREEN; END
         ELSE BEGIN OVERLAYSCREEN; COMPUTEOVERLAYTH1;OVERLAYSCREEN;  END;

TEK21: Settextstyle(0,HORIZDIR,1);SESVER2;

JJJ:=310;WWR;SETTEXTJUSTIFY(0,1);
FOR III:=1 TO LNUM+3 DO BEGIN
OuttextXY(45,JJJ,LAYERNAME[III]);
INC(JJJ,25);            END;

JJJ:=310;SETTEXTJUSTIFY(1,1);

FOR III:=1 TO LNUM+3 DO BEGIN

OuttextXY(162,JJJ,IntTOStr(MR[III]));

IF A[III]<0.01 THEN BEGIN IF A[III]=0.0 THEN BEGIN
        OuttextXY(237,JJJ,IntTOStrREAL(A[III])+' E+00');GOTO TEK10;END
                                     ELSE BEGIN
        OuttextXY(237,JJJ,IntTOStrREAL(A[III])+' E-03');GOTO TEK10;END;END;
IF A[III]<0.1  THEN   OuttextXY(237,JJJ,IntTOStrREAL(A[III])+' E-02');
              ELSE  OuttextXY(237,JJJ,IntTOStrREAL(A[III])+' E-01');

TEK10:
IF SN[III]<0.1  THEN BEGIN
                    OuttextXY(325,JJJ,IntTOStrReal(SN[III])+' E-02');
                    GOTO TEK8;END;
IF SN[III]<1.0  THEN BEGIN
                    OuttextXY(325,JJJ,IntTOStrReal(SN[III])+' E-01');
                    GOTO TEK8;END;
IF SN[III]<10.0 THEN OuttextXY(325,JJJ,IntTOStrReal(SN[III])+' E+00')
                ELSE OuttextXY(325,JJJ,IntTOStrReal(SN[III])+' E+01');
TEK8:
IF D[III]=0.0  THEN BEGIN
                   OuttextXY(415,JJJ,IntTOStrReal(D[III])+' E+00');
                   GOTO TEK9;END;
IF D[III]<0.1  THEN BEGIN
                   OuttextXY(415,JJJ,IntTOStrReal(D[III])+' E-02');
                   GOTO TEK9;END;
IF D[III]<1.0  THEN BEGIN
                   OuttextXY(415,JJJ,IntTOStrReal(D[III])+' E-01');
                   GOTO TEK9;END;
IF D[III]<10.0 THEN OuttextXY(415,JJJ,IntTOStrReal(D[III])+' E+00')
               ELSE OuttextXY(415,JJJ,IntTOStrReal(D[III])+' E+01');
TEK9:

INC(JJJ,25);            END; {of FOR}

IF AOverlay1<0.01 THEN BEGIN IF AOverlay1=0.0 THEN BEGIN
          OuttextXY(237,285,IntTOStrREAL(AOverlay1)+' E+00');GOTO TEK12;END
                                ELSE BEGIN
```

```
IF AOverlay1<0.1  THEN  OuttextXY(237,285,IntTOStrREAL(AOverlay1)+' E-02')
                 ELSE  OuttextXY(237,285,IntTOStrREAL(AOverlay1)+' E-01');

TEK12:
IF AOverlay2<0.01 THEN BEGIN IF AOverlay2=0.0 THEN BEGIN
          OuttextXY(237,260,IntTOStrREAL(AOverlay2)+' E+00');GOTO TEK17;END
                                 ELSE BEGIN
          OuttextXY(237,260,IntTOStrREAL(AOverlay2)+' E-03');GOTO TEK17;END;END;

IF AOverlay2<0.1  THEN  OuttextXY(237,260,IntTOStrREAL(AOverlay2)+' E-02')
                  ELSE  OuttextXY(237,260,IntTOStrREAL(AOverlay2)+' E-01');
TEK17:
IF SNOverlay1=0.0  THEN BEGIN
                     OuttextXY(325,285,IntTOStrReal(SNOverlay1)+' E+00');
                     GOTO TEK13;END;
IF SNOverlay1<0.1  THEN BEGIN
                     OuttextXY(325,285,IntTOStrReal(SNOverlay1)+' E-02');
                     GOTO TEK13;END;

IF SNOverlay1<1.0  THEN BEGIN
                     OuttextXY(325,285,IntTOStrReal(SNOverlay1)+' E-01');
                     GOTO TEK13;END;
IF SNOverlay1<10.0 THEN OuttextXY(325,285,IntTOStrReal(SNOverlay1)+' E+00')
                  ELSE OuttextXY(325,285,IntTOStrReal(SNOverlay1)+' E+01');
TEK13:
IF SNOverlay2=0.0  THEN BEGIN
                     OuttextXY(325,260,IntTOStrReal(SNOverlay2)+' E+00');
                     GOTO TEK18;END;
IF SNOverlay2<0.1  THEN BEGIN
                     OuttextXY(325,260,IntTOStrReal(SNOverlay2)+' E-02');
                     GOTO TEK18;END;
IF SNOverlay2<1.0  THEN BEGIN
                     OuttextXY(325,260,IntTOStrReal(SNOverlay2)+' E-01');
                     GOTO TEK18;END;
IF SNOverlay2<10.0 THEN OuttextXY(325,260,IntTOStrReal(SNOverlay2)+' E+00')
                  ELSE OuttextXY(325,260,IntTOStrReal(SNOverlay2)+' E+01');
TEK18:
IF DOverlay1=0.0  THEN BEGIN
                    OuttextXY(415,285,IntTOStrReal(DOverlay1)+' E+00');
                    GOTO TEK14;END;
IF DOverlay1<0.1  THEN BEGIN
                    OuttextXY(415,285,IntTOStrReal(DOverlay1)+' E-02');
                    GOTO TEK14;END;
IF DOverlay1<1.0  THEN BEGIN
                    OuttextXY(415,285,IntTOStrReal(DOverlay1)+' E-01');
                    GOTO TEK14;END;
IF DOverlay1<10.0 THEN OuttextXY(415,285,IntTOStrReal(DOverlay1)+' E+00')
                 ELSE OuttextXY(415,285,IntTOStrReal(DOverlay1)+' E+01');
TEK14:
IF DOverlay2=0.0  THEN BEGIN
                    OuttextXY(415,260,IntTOStrReal(DOverlay2)+' E+00');
                    GOTO TEK19;END;
IF DOverlay2<0.1  THEN BEGIN
                    OuttextXY(415,260,IntTOStrReal(DOverlay2)+' E-02');
                    GOTO TEK19;END;
IF DOverlay2<1.0  THEN BEGIN
                    OuttextXY(415,260,IntTOStrReal(DOverlay2)+' E-01');
                    GOTO TEK19;END;
IF DOverlay2<10.0 THEN OuttextXY(415,260,IntTOStrReal(DOverlay2)+' E+00')
                 ELSE OuttextXY(415,260,IntTOStrReal(DOverlay2)+' E+01');
```

```
OuttextXY(162,260,IntTOStr(MROverlay2));

CROSSSECTIONOVERLAY;
    CASE BASETYPE OF #66: BEGIN OuttextXY(115,113,'Bituminous');END;
                     #67: BEGIN OuttextXY(115,113,'Cement Treated');END;
                     #71: BEGIN OuttextXY(115,113,'Granular');END;END;
                                OuttextXY(115,123,'Base Course');
IF SSNEW=2 THEN BEGIN
                    Setfillstyle(9,15);BAR(60,70,340,80);
WWR;                RECTANGLE(60,70,340,80);
                    LINE(100,67,140,67);     LINE(100,67,105,64);
                    LINE(260,67,300,67);     LINE(300,67,295,65);
                    LINE(345,75,390,75);     LINE(345,75,350,73);
                    LINE(345,75,350,77);
                    SETLINESTYLE(3,0,3);   LINE(200,20,200,205);
                    SETLINESTYLE(0,0,1);
                    Setfillstyle(1,6);
YWR;TIMEREL:=APNEW-TIME;
IF TIMEREL>=10 THEN
OUTTEXTXY(505,75,' OVERLAY for '+INTTOSTRREAL(TIMEREL)+' E+01 Years')
               ELSE
OUTTEXTXY(505,75,' OVERLAY for '+INTTOSTRREAL(TIMEREL)+' E+00 Years');
GOTO TEK4;END;

IF SSNEW=3 THEN BEGIN
Setfillstyle(9,15);BAR(60,70,340,80);Setfillstyle(11,15);BAR(60,55,340,65);
WWR;                RECTANGLE(60,70,340,80);RECTANGLE(60,55,340,65);
         LINE(100,52,140,52);LINE(100,52,105,49);LINE(260,52,300,52);
         LINE(300,52,295,50);LINE(345,75,390,75);LINE(345,75,350,73);
         LINE(345,75,350,77);LINE(345,60,390,60);LINE(345,60,350,58);
         LINE(345,60,350,62);
         SETLINESTYLE(3,0,3);   LINE(200,20,200,205);
                    SETLINESTYLE(0,0,1);Setfillstyle(1,6);
YWR;
IF FOLT1>=10 THEN
OUTTEXTXY(505,75,' OVERLAY for '+INTTOSTRREAL(FOLT1)+' E+01 Years')
               ELSE
OUTTEXTXY(505,75,' OVERLAY for '+INTTOSTRREAL(FOLT1)+' E+00 Years');
YWR; TIMEREL:=APNEW-(TIME+FOLT1);
IF TIMEREL>=10 THEN
OUTTEXTXY(505,60,' OVERLAY for '+INTTOSTRREAL(TIMEREL)+' E+01 Years')
               ELSE
OUTTEXTXY(505,60,' OVERLAY for '+INTTOSTRREAL(TIMEREL)+' E+00 Years');

                 END;

TEK4: YESNO1:=READKEY;YESNO1:=UPCASE(YESNO1);
IF YESNO1=#27 THEN begin I:=469;J:=360;K:=160;L:=50;OFF;delay(500);GOTO STARTNEW;end;
IF YESNO1=#80 THEN BEGIN  SETVIEWPORT(468,418,632,472,CLIPON);CLEARVIEWPORT;
                          SETVIEWPORT(0,0,639,479,CLIPON);
                          I:=469;J:=420;K:=160;L:=50;ON;
WWR;  OuttextXY(549,436,'Press Any Key');
      OuttextXY(549,452,'If Printer Ready');I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
                          devam2:=readkey;
SETVIEWPORT(468,418,632,472,CLIPON);CLEARVIEWPORT;
                          SETVIEWPORT(0,0,639,479,CLIPON);
                          I:=469;J:=420;K:=160;L:=50;ON;
WWR;  OuttextXY(549,436,'Please Wait,');
      OuttextXY(549,452,'Printing ...');
                                {$I-}I:=469;J:=360;K:=160;L:=50;OFF;
                                PROUTPUT;
```

```
                    SETVIEWPORT(0,0,639,479,CLIPON);
                    I:=469;J:=420;K:=160;L:=50;ON;I:=469;J:=360;K:=160;L:=50;ON;
YWR; OuttextXY(549,436,'To Print Results');
     OuttextXY(549,452,'PRINTER/FILE <P/F>');
     OuttextXY(545,376,'ESC to MAIN MENU');
     OuttextXY(545,392,'SPACE BAR to quit');

                          GOTO TEK4;END;

IF YESNO1=#70 THEN BEGIN I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
                         FILEOUTPUT(PRFILE);I:=469;J:=420;K:=160;L:=50;ON;
                    YWR; OuttextXY(549,436,'To Print Results');
                         OuttextXY(549,452,'PRINTER/FILE <P/F>');
                         GOTO TEK4;END
  ELSE begin I:=469;J:=360;K:=160;L:=50;OFF;delay(500);GOTO SON;end;


SON:  ENDINGSCREEN; CLOSEGRAPH;  EXIT;  END.



END.{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*                 UNIT PROGRAM CONSISTING HELP SCREENS                   *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$O+,F+}      UNIT HELPS;      INTERFACE      USES GRAPH,CRT,SCREENS;
VAR OKU1:CHAR;
PROCEDURE HELPMAINMENU;
  PROCEDURE HELPNEWFILE;
    PROCEDURE HELPSWELLFROST;
  PROCEDURE HELPMATERIALCHAR;
PROCEDURE HELPOVERLAY;        IMPLEMENTATION
PROCEDURE HELPMAINMENU;BEGIN {-------------------------------------------}
Clearviewport;Settextjustify(1,1);Setfillstyle(10,15); Bar(11,11,458,49);
        I:=10;J:=60;K:=449;L:=409;CER;
        I:=469;J:=419;K:=160;L:=50;ONBAR;
        I:=10;J:=10;K:=449;L:=40;CER;
setcolor(14);    OuttextXY(549,444,'ESC to Quit');
        OuttextXY(230,30,'About MAIN MENU ITEMS');

Settextstyle(0,Horizdir,1);Settextjustify(0,1);
setcolor(14); OuttextXY(20,90, '1:');     OuttextXY(20,125,'2:');
     OuttextXY(20,180,'3:');     OuttextXY(20,235,'4:');
     OuttextXY(20,270,'5:');     OuttextXY(20,305,'6:');
     OuttextXY(20,340,'7:');     OuttextXY(20,385,'Note:');
setcolor(15);
OuttextXY(45,90,  'Select this  item  if  you  want to  compute a new');
```

```
OuttextXY(45,100, 'project, putting new data in.');
OuttextXY(45,125, 'Select  this  item  if  you  computed any pavement');
OuttextXY(45,135, 'project  before  and want to change a few input(s)');
OuttextXY(45,145, 'of this project now.  Note  that it is possible to');
OuttextXY(45,155, 'change all data of this project.');
OuttextXY(45,180, 'Select this  item if you computed a project before');
OuttextXY(45,190, 'and want to  compute  overlay  thickness  to  last');
OuttextXY(45,200, 'Analysis  Period');
OuttextXY(45,235, 'Select this item for preparing  swelling and frost');
OuttextXY(45,245, 'heave  data  to use for a new project computation.');
OuttextXY(45,270, 'Select this item for preparing   Roadbed Resilient');
OuttextXY(45,280, 'Modulus data to use for a new project computation.');
OuttextXY(45,305, 'Select  this  item  if  you  want  to  see  again');
OuttextXY(45,315, 'the project which you computed just before.');
OuttextXY(45,340, 'Select this item if you  want to  print results of');
OuttextXY(45,350, 'the project which you  computed just  before. This');
OuttextXY(45,360, 'item  prints  results  to both a file and printer.');
OuttextXY(65,385, 'To function items 3,6 and 7, 1 must be run first.');

REPEAT OKU1:=READKEY; UNTIL OKU1 IN [CHR(27)];
I:=469;J:=419;K:=160;L:=50;OFF;delay(500);
Settextjustify(1,1);END;

PROCEDURE HELPNEWFILE; {-----------------------------------------------}
LABEL SON1,SAYFA1,SAYFA2,SAYFA3;       BEGIN
Setviewport(0,0,639,479,CLIPON);
SAYFA1: Clearviewport;Settextjustify(1,1);Setfillstyle(10,15);
       Bar(11,11,458,49);
       I:=10;J:=60;K:=449;L:=409;CER;  I:=469;J:=419;K:=160;L:=50;ONBAR;
       I:=469;J:=349;K:=160;L:=50;ONBAR; I:=10;J:=10;K:=449;L:=40;CER,
setcolor(14);  OuttextXY(549,444,'ESC to Quit'); OuttextXY(549,374,'Page DOWN');
       OuttextXY(230,30,'About INITIAL PAVEMENT GENERAL DATA INPUTS ');

Settextstyle(0,Horizdir,1);Settextjustify(0,1);

        OuttextXY(45,80, 'NOTE:');
        OuttextXY(20,105, '1:');     OuttextXY(20,175,'2:');
        OuttextXY(20,370,'3:');     OuttextXY(20,425,'4:');
setcolor(15);
OuttextXY(90,80, 'Program will warn you prompting slides.');
OuttextXY(45,105,'Enter  file  name  in  which file input and output');
OuttextXY(45,120,'data will be saved, properly  8  letters  or less.');
OuttextXY(45,135,'If it is left blank program appoints name as first');
OuttextXY(45,150,'6 letters `aashto`, last two randomized.');
OuttextXY(45,175,'This is controlled through the use of  reliability').
OuttextXY(45,190,'factor (Fr)  that  is  multiplied times the design');
OuttextXY(45,205,'period traffic  prediction (W18).  Consider  table');
OuttextXY(45,220,'below to decide.');
OuttextXY(45,240,'    Functional    Recommended Level of Reliability ');
OuttextXY(45,255,' Classification       Urban          Rural'),
OuttextXY(45,270,' Interstate &');
OuttextXY(45,285,' Other freeways      85-99.9       80-99.9');
OuttextXY(45,300,' Principal');
OuttextXY(45,315,' Arterials            80-99         75-95');
OuttextXY(45,330,' Collectors           80-95         75-95'),
OuttextXY(45,345,' Local                50-80         50-80');

setcolor(14); LINE(45,230,445,230); LINE(445,230,445,350); LINE(445,350,45,350);
     LINE(45,350,45,230);  LINE(45,263,445,263);  LINE(175,230,175,350);
     LINE(300,250,300,350);
setcolor(15);
OuttextXY(45,370,'This refers to the period of time  for  which  the');
OuttextXY(45,385,'analysis is to be conducted.  Consider  table  on'),
OuttextXY(45,400,'next page when (      .');
```

```
OuttextXY(45,425,'This is the shortest amount of time  a given stage');
OuttextXY(45,440,'should last.  It  must  be integer and lower value');
OuttextXY(45,455,'than Analysis Period.');

REPEAT OKU1:=READKEY; UNTIL OKU1 IN [CHR(27),CHR(73)];
IF OKU1=CHR(73) then begin I:=469;J:=349;K:=160;L:=50;OFF;delay(500);GOTO SAYFA2;end;

SON1: I:=469;J:=419;K:=160;L:=50;OFF;delay(500);END;

PROCEDURE HELPSWELLFROST;       LABEL SON2,SAYFA3,SAYFA4;   BEGIN

Setviewport(0,0,639,479,CLIPON);

SAYFA3: Clearviewport;Settextjustify(1,1);Setfillstyle(10,15);
        Bar(11,11,458,49);
        I:=10;J:=60;K:=449;L:=409;CER;  I:=469;J:=419;K:=160;L:=50;ONBAR;
        I:=469;J:=349;K:=160;L:=50;ONBAR; I:=10;J:=10;K:=449;L:=40;CER;

setcolor(14); OuttextXY(549,444,'ESC to Quit'); OuttextXY(549,374,'Page DOWN');
    OuttextXY(230,30,'About SWELLING & FROST HEAVE DATA INPUTS');
Settextjustify(0,1);
         OuttextXY(20,90, '1:');    OuttextXY(20,175,'2:');
         OuttextXY(20,230,'3:');    OuttextXY(20,285,'4:');
         OuttextXY(20,430,'5:');
setcolor(15);
OuttextXY(45,90, 'This  factor  depends  on  rainfall  and  drainage');
OuttextXY(45,105,'quality. It is expressed as percent.  Low moisture');
OuttextXY(45,120,'supply  means  low  rainfall, good drainage,  high');
OuttextXY(45,135,'moisture means high rainfall,poor drainage.  Enter');
OuttextXY(45,150,'percent of moisture supply, predicting.');
OuttextXY(45,175,'This  is  based  on  soil fabric. Enter percent of');
OuttextXY(45,190,'Roadbed Soil Fabric. 100% means fractured, 0 means');
OuttextXY(45,205,'tight fabric.');
OuttextXY(45,230,'This  is  plasticity  index  of  Roadbed soil at a');
OuttextXY(45,245,'particular  location.  It  varies  from  20 to 80.');
OuttextXY(45,285,'This is a subjective decision based on an estimate');
OuttextXY(45,300,'of  how  close the soil moisture conditions during');
OuttextXY(45,315,'construction   are   to   the   in situ  moisture');
OuttextXY(45,330,'conditions of later date.');
OuttextXY(45,345,'Minimum  Natural  Dry  conditions mean no moisture');
OuttextXY(45,360,'control,  Average Conditions  mean  normal  field,');
OuttextXY(45,375,'control field and density, Optimum Conditions mean');
OuttextXY(45,390,'closely controlled moisture and density throughout');
OuttextXY(45,405,'life of facility.');
OuttextXY(45,430,'Enter overall thickness of layer in feet, among (2');
OuttextXY(45,445,'5,10,15,20,25,>30). A higher value than 30 will be');
OuttextXY(45,460,'put in as 30.');

REPEAT OKU1:=READKEY; UNTIL OKU1 IN [CHR(27),CHR(73)];
IF OKU1=CHR(73) THEN begin I:=469;J:=349;K:=160;L:=50;OFF;delay(500);GOTO SAYFA3;end;
SON2: I:=469;J:=419;K:=160;L:=50;OFF;delay(500);END;

PROCEDURE HELPMATERIALCHAR;{---------------------------------------------}
LABEL SON2,SAYFA3,SAYFA4;                    BEGIN

Setviewport(0,0,639,479,CLIPON);

SAYFA3: Clearviewport;Settextjustify(1,1);Setfillstyle(10,15);
      Bar(11,11,458,49);
      I:=10;J:=60;K:=449;L:=409;CER;  I:=469;J:=419;K:=160;L:=50;ONBAR;
      I:=469;J:=349;K:=160;L:=50;ONBAR; I:=10;J:=10;K:=449;L:=40;CER;

setcolor(14);  OuttextXY(549,444,'ESC to Quit');  OuttextXY(549,374,'Page DOWN');
      OuttextXY(230,30,'About MATERIAL CHARACTERISTICS DATA INPUTS');
```

```
Settextjustify(0,1);
setcolor(15);
OuttextXY(45,90, 'You must here follow prompts.');
OuttextXY(45,115,'Firstly, you must decide  how many layers you will');
OuttextXY(45,130,'build over  Base Course  (up to 4 layers),  giving');
OuttextXY(45,145,'response to prompt beginning `Number of Layers ..`');
OuttextXY(45,160,'After entering number,   you must give names these');
OuttextXY(45,175,'layers. Note  that  if  first  two names over base');
OuttextXY(45,190,'course  are  left  blank, program  appoints  names');
OuttextXY(45,205,'`Binder Course` for first one and `Surface Course`');
OuttextXY(45,220,'for second one  promting a warning  but others are');
OuttextXY(45,235,'asked you to give their names if necessary.');
OuttextXY(45,260,'Second, You must enter letters in quotes symbolize');
OuttextXY(45,275,'strengt parameters you decided to use, such as CBR,');
OuttextXY(45,290,'R or Elasticity of Modulus. In this stage,  follow');
OuttextXY(45,305,'promts carefully. After entering these parameters,');
OuttextXY(45,320,'you must enter their magnitude, such as 60 for CBR,');
OuttextXY(45,335,'12 for R, 70000 for Elasticity of Modulus.');
OuttextXY(45,360,'And  then  you  will have prompt  asking  drainage');
OuttextXY(45,375,'coefficients of subbase course,  base course   and');
OuttextXY(45,390,'one more layer. Program assumes  drainage coef. of');
OuttextXY(45,405,'other layers as 1.0 except for first 3 layers.');
OuttextXY(45,420,'You can use the table on next page for need.');

REPEAT OKU1:=READKEY; UNTIL OKU1 IN [CHR(27),CHR(81)];
IF OKU1=CHR(27) THEN begin I:=469;J:=419;K:=160;L:=50;OFF;delay(500);GOTO SON2;end;
I:=469;J:=349;K:=160;L:=50;OFF;delay(500);  end;

PROCEDURE HELPOVERLAY; {-----------------------------------------------}
LABEL SON2,SAYFA3,SAYFA4;        BEGIN

Setviewport(0,0,639,479,CLIPON);

SAYFA3: Clearviewport;Settextjustify(1,1);Setfillstyle(10,15);
       Bar(11,11,458,49);
       I:=10;J:=60;K:=449;L:=409;CER;I:=10;J:=10;K:=449;L:=40;CER;
       I:=469;J:=419;K:=160;L:=50;ONBAR;I:=469;J:=349;K:=160;L:=50;ONBAR;
setcolor(14);
    OuttextXY(549,444,'ESC to Quit'); OuttextXY(549,374,'Page DOWN');
    OuttextXY(230,30,'About OVERLAY DESIGN DATA INPUTS');
Settextjustify(0,1);
setcolor(15);
OuttextXY(45,120, '    At this stage,  you will have  prompts asking');
OuttextXY(45,135, 'overlay material elasticity modulus and  lifetime');
OuttextXY(45,150, 'of this overlay.');
OuttextXY(45,170, '    There are two situations, one is  if only one');
OuttextXY(45,185, 'overlay  is   constructed  depending  upon  stage');
OuttextXY(45,200, 'strategy number, that in  this situation only one');
OuttextXY(45,215, 'question prompt appears asking elasticity modulus');
OuttextXY(45,230, 'of  this  overlay,  and  two  is two overlays are');
OuttextXY(45,245, 'constructed over initial layers  selecting  stage');
OuttextXY(45,260, 'strategy as 3, that  in this situation  3 prompts');
OuttextXY(45,275, 'appear asking both elasticity modulus of overlays');
OuttextXY(45,290, 'and lifetime of first overlay.');
OuttextXY(45,310, 'Elasticity modulus is limited as max. 500000.');
OuttextXY(45,330, 'Lifetime of first layer is entered as such:');
OuttextXY(45,345, '    If one overlay is  required  selecting  stage');
OuttextXY(45,360, 'strategy   as   2   lifetime  of  this  layer  is');
OuttextXY(45,375, 'determined  automatically as  difference time  of');
OuttextXY(45,390, 'analysis period and new computed max. performance');
OuttextXY(45,405, 'period depending  upon  swelling  and frost heave');
OuttextXY(45,420, 'consideration.');
OuttextXY(45,435, '    If two overlay is required  that  this  shows');
```

```
OuttextXY(45,450, 'stage strategy was selected as  3,  the  lifetime');

REPEAT OKU1:=READKEY; UNTIL OKU1 IN [CHR(27),CHR(73)];
IF OKU1=CHR(73) THEN begin I:=469;J:=349;K:=160;L:=50;OFF;delay(500);GOTO SAYFA3;end;
SON2: I:=469;J:=419;K:=160;L:=50;OFF;delay(500);  END;

END.




{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*              UNIT PROGRAM ALL DATA ARE GIVEN                          *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$A+,B-,D+,E+,F-,G+,I+,L+,N+,R-,S+,V+,X-}   {$M 16384,0,655360}
UNIT INPUTS;  INTERFACE   USES   HELPS,DOS,CRT,GRAPH,WARNINGS,SCREENS;
VAR
   SFB,MCNEW,DQNEW,BASETYPE,CONSFH                        :CHAR;
   MSNEW,RSFNEW,PINEW,LTNEW,SPNEW,FHPNEW,LNUM,MM          :INTEGER;
   MPPNEW,APNEW,SSNEW,LDFNEW,DDFNEW                       :INTEGER;
   RFNEW,FHRNEW,DFPNEW,ISNEW,TSNEW,OSDNEW,ESALNEW,EGRNEW  :REAL;
   FILENAME                                               :STRING[8];
   LAYERNAME                          :ARRAY[1..7] OF STRING[10];
   CBRMOD                             :ARRAY[1..7] OF CHAR;
   LVAL                               :ARRAY[1..7] OF LONGINT;
   M                                  :ARRAY[1..7] OF REAL;
   GI:ARRAY[1..11] OF STRING[30];SFI:ARRAY[1..10] OF STRING[30];
   LNI:ARRAY[1..7] OF STRING[15];SPI:ARRAY[1..7] OF STRING[33];
   MRI,DCI:ARRAY[1..7] OF STRING[13];

CONST
   MS:INTEGER=20;   FHP:INTEGER=20;  RSF:INTEGER=20;   SP:INTEGER=20;
   PI:INTEGER=40;   LT:INTEGER=2;    MPP:INTEGER=15;   AP:INTEGER=20;
   SS:INTEGER=2;    LDF:INTEGER=50;  DDF:INTEGER=50;
   IS:REAL=4.5;     TS:REAL=2.5;     OSD:REAL=(0.45);  ESAL:REAL=(1E+6);
   EGR:REAL=0.0001; FHR:REAL=2.0;    DFP:REAL=2.0;     RF:REAL=90.0;

PROCEDURE  GENERALINPUTS;     PROCEDURE  SWELLFROSTINPUTS;
PROCEDURE  MATERIALCHARINPUTS;  IMPLEMENTATION
PROCEDURE GENERALINPUTS;  { -------------------------------------}

LABEL  TEK1,TEK2,TEK3,TEK4,TEK5,TEK6,TEK7,TEK8,TEK9,TEK10,TEK11,TEK12,
       TEK13,TEK14;
VAR R:INTEGER;Z:STRING;
FUNCTION IntToStr(i: INTEGER): string;
VAR  s: string[17];BEGIN  Str(i, s);IntToStr := s; END;
FUNCTION IntToStrReal(i: REAL): string;
VAR  s: string[12];BEGIN  Str(i, s);IntToStrReal:= s; END;
FUNCTION IntToStrReal4(i: REAL): string;
VAR  s: string[4];BEGIN  Str(i, s);IntToStrReal4:= s; END;
BEGIN
Setviewport(0,0,639,118,CLIPON);Clearviewport;
YWR;   OuttextXY(20,40,'File Name to Open (Without Extension):');
       GOTOXY(42,3);FILENAME:='EXAMPLE';
       GWR; READLN(FILENAME);
Setviewport(0,0,639,479,CLIPON);
WWR;   OuttextXY(315,132,FILENAME+'.OUT');
I:=10;J:=120;K:=285;L:=20;bas;I:=305;K:=144;bas;
Setviewport(0,0,639,118,CLIPON);
TEK2: {-----------------------------------------------------------------}
YWR;Clearviewport;
      OuttextXY(20,40,'Reliability Factor (50..99.99) (90):');
```

```
            GOTOXY(41,3);GWR;
            {$I-} READLN(Z);
            VAL(Z,RFNEW,R);{$I+}
 IF Z='' THEN RFNEW:=RF;
 IF RFNEW<50.0  THEN BEGIN IKAZ7;GOTO TEK2; END;
 IF RFNEW>99.99 THEN BEGIN IKAZ7;GOTO TEK2; END;
 Setviewport(0,0,639,479,CLIPON);
 WWR;   OuttextXY(310,162,CONCAT(IntTOStrReal(RFNEW)+' E+01'));
 I:=10;   J:=150;   K:=285;  L:=20;   bas;I:=305;K:=144;bas;
 Setviewport(0,0,639,118,CLIPON);
 TEK8:  {-----------------------------------------------------------------}
 REPEAT   YWR;Clearviewport;
        OuttextXY(20,40,'Analysis Period (3..60 year)  <20>:');
          GOTOXY(40,3);GWR;
          {$I-} READLN(Z);VAL(Z,APNEW,R);{$I+}
          IF Z='' THEN APNEW:=AP;
          IF APNEW<3 THEN IKAZ6; IF APNEW>60 THEN IKAZ6;
 UNTIL APNEW IN [3..60];
 Setviewport(0,0,639,479,CLIPON);
 WWR;   OuttextXY(315,192,IntTOStr(APNEW));
 I:=10;   J:=180;   K:=285;  L:=20;   bas;I:=305;K:=144;bas;
 Setviewport(0,0,639,118,CLIPON);
 TEK7: {-----------------------------------------------------------------}
 REPEAT      YWR;Clearviewport;
 OuttextXY(20,40,'Maximum Possible Performance Period (1..'+IntTOStr(APNEW)+' year)  <15>:');
            GOTOXY(59,3);GWR;
            {$I-} READLN(Z);VAL(Z,MPPNEW,R);{$I+}
            IF Z='' THEN MPPNEW:=MPP;
            IF MPPNEW<1 THEN IKAZ6;  IF MPPNEW>APNEW THEN IKAZ6;
 UNTIL MPPNEW IN [1..APNEW];
 Setviewport(0,0,639,479,CLIPON);
 WWR;   OuttextXY(315,222,IntTOStr(MPPNEW));
 I:=10;   J:=210;   K:=285;  L:=20;   bas;I:=305;K:=144;bas;
 Setviewport(0,0,639,118,CLIPON);
 TEK9:  {-----------------------------------------------------------------}
 REPEAT   YWR;Clearviewport;
          OuttextXY(20,40,'Stage Strategy (1..3) <2>:');
          GOTOXY(31,3);GWR;
          {$I-} READLN(Z);VAL(Z,SSNEW,R);{$I+}
          IF Z='' THEN SSNEW:=SS;
          IF SSNEW<1 THEN IKAZ6; IF SSNEW>3 THEN IKAZ6;
 UNTIL SSNEW IN [1..3];
 Setviewport(0,0,639,479,CLIPON);
 WWR;     OuttextXY(315,252,IntTOStr(SSNEW));
 I:=10;   J:=240;   K:=285;  L:=20;   bas;I:=305;K:=144;bas;
 Setviewport(0,0,639,118,CLIPON);
 TEK3: {-----------------------------------------------------------------}
          YWR;Clearviewport;
          OuttextXY(20,40,'Initial Serviceability (2..5) <4.5>:');
          GOTOXY(41,3);GWR;
          {$I-} READLN(Z);VAL(Z,ISNEW,R);{$I+}
          IF Z='' THEN ISNEW:=IS;
 IF ISNEW>5.0   THEN BEGIN IKAZ7;GOTO TEK3; END;
 IF ISNEW<2.0   THEN BEGIN IKAZ7;GOTO TEK3; END;
 Setviewport(0,0,639,479,CLIPON);
 WWR;     OuttextXY(308,282,IntToStrReal(ISNEW));
 I:=10;   J:=270;   K:=285;  L:=20;   bas;I:=305;K:=144;bas;
 Setviewport(0,0,639,118,CLIPON);
 TEK4: {-----------------------------------------------------------------}
          YWR;Clearviewport;
 OuttextXY(20,40,'Terminal Serviceability (1 ..'+IntToStrReal4(ISNEW)+') <2.5>:');
          GOTOXY(45,3);GWR;
          {$I-} READLN(Z);VAL(Z,TSNEW,R);{$I+}
```

```
IF Z='' THEN TSNEW:=TS;
IF TSNEW>=ISNEW THEN BEGIN IKAZ11;GOTO TEK4; END;
IF TSNEW<1.0 THEN BEGIN IKAZ7;GOTO TEK4; END;
Setviewport(0,0,639,479,CLIPON);
WWR;      OuttextXY(308,312,IntToStrReal(TSNEW));
I:=10;   J:=300;   K:=285;  L:=20;  bas;I:=305;K:=144;bas;
Setviewport(0,0,639,118,CLIPON);
TEK5: {----------------------------------------------------------------
        YWR;Clearviewport;
         OuttextXY(20,40,'Overall Standard Deviation (0..0.5) .45 :');
        GOTOXY(47,3);GWR;
        {$I-} READLN(Z);VAL(Z,OSDNEW,R);{$I+}
        IF Z='' THEN OSDNEW:=OSD;
IF OSDNEW>(0.5) THEN BEGIN IKAZ7;GOTO TEK5; END;
IF OSDNEW<(0.0) THEN BEGIN IKAZ7;GOTO TEK5; END;
Setviewport(0,0,639,479,CLIPON);
WWR;      OuttextXY(308,342,CONCAT(IntToStrReal(OSDNEW)+' E-01'));
I:=10;J:=330;K:=285;L:=20;bas;I:=305;K:=144;BAS;
Setviewport(0,0,639,118,CLIPON);
TEK6: {----------------------------------------------------------------}
        YWR;Clearviewport;
        OuttextXY(20,40,'Estimated 18-kip ESAL (100..10E+7) 1E-6 :');
        GOTOXY(47,3);GWR;
        {$I-} READLN(Z);VAL(Z,ESALNEW,R);{$I+}
        IF Z='' THEN ESALNEW:=ESAL;
IF ESALNEW>1E+8 THEN BEGIN IKAZ7;GOTO TEK6; END;
IF ESALNEW<100.0 THEN BEGIN IKAZ7;GOTO TEK6; END;
Setviewport(0,0,639,479,CLIPON);        WWR;
TEK13:
I:=10;   J:=360;   K:=285;  L:=20;  bas;I:=305;K:=144;bas;
Setviewport(0,0,639,118,CLIPON);
TEK10: {---------------------------------------------------------------}
        REPEAT YWR;Clearviewport;
        OuttextXY(20,40,'Directional Dis. Factor (10..100) 50 :');
        GOTOXY(44,3);GWR;
        {$I-} READLN(Z);VAL(Z,DDFNEW,R);{$I+}
        IF Z='' THEN DDFNEW:=DDF;
        IF DDFNEW<10 THEN IKAZ6;
        IF DDFNEW>100 THEN IKAZ6;
UNTIL DDFNEW IN [10..100];
Setviewport(0,0,639,479,CLIPON);
WWR;     OuttextXY(313,402,IntToStr(DDFNEW));
I:=10;   J:=390;   K:=285;  L:=20;  bas;I:=305;K:=144;bas;
Setviewport(0,0,639,118,CLIPON);
TEK11:  {--------------------------------------------------------------}
REPEAT   YWR;Clearviewport;
       OuttextXY(20,40,'Lane Dist. Factor (50..100) 50 :');
        GOTOXY(37,3);GWR;
        {$I-} READLN(Z);VAL(Z,LDFNEW,R);{$I+}
        IF Z='' THEN LDFNEW:=LDF;
        IF LDFNEW<50 THEN IKAZ6; IF LDFNEW>100 THEN IKAZ6;
UNTIL LDFNEW IN [50..100];      Setviewport(0,0,639,479,CLIPON);
WWR;     OuttextXY(315,432,IntTOStr(LDFNEW));
I:=10;   J:=420;   K:=285;  L:=20;  bas;I:=305;K:=144;bas;
Setviewport(0,0,639,118,CLIPON);
TEK12: {---------------------------------------------------------------}
        YWR;Clearviewport;
        OuttextXY(20,40,'Exponential Growth Rate (-20..20%) 0.001 :');
        GOTOXY(49,3);GWR;
        {$I-} READLN(Z);VAL(Z,EGRNEW,R);{$I+}
IF Z='' THEN EGRNEW:=EGR;
IF EGRNEW>20.0 THEN BEGIN IKAZ7;GOTO TEK12; END;
IF EGRNEW<-20.0  THEN BEGIN IKAZ7;GOTO TEK12; END;
```

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Setviewport(0,0,639,479,CLIPON);        WWR;
TEK14:
Setviewport(0,0,639,118,CLIPON);
END;{--------------------------------------------------------------------}

PROCEDURE SWELLFROSTINPUTS;
LABEL  TEK13,TEK14,TEK15,TEK16,TEK17,TEK18,TEK19,TEK20,TEK21,SWELLING,FROST,
       TEK22,TEK23,TEK24,TEK25;
VAR R:INTEGER;Z:STRING;
FUNCTION IntToStr(i: INTEGER): string;
VAR  s: string[5];BEGIN  Str(i, s);IntToStr := s; END;
FUNCTION IntToStrReal(i: REAL): string;
VAR  s: string[5];BEGIN  Str(i, s);IntToStrReal:= s; END;
BEGIN  Setviewport(0,0,639,165,CLIPON);
REPEAT      YWR;Clearviewport;
OuttextXY(20,40,'Consider Only Swelling,Only Frost H. or Both (S/F/B) (Both):');
            GWR;SFB:=READKEY;SFB:=UPCASE(SFB);
            IF SFB IN [CHR(83),CHR(70),CHR(66),CHR(13)] THEN SFB:=SFB
                    ELSE IKAZ3;
UNTIL SFB IN [CHR(83),CHR(70),CHR(66),CHR(13)];
                     SWELLING:
                     REPEAT   YWR;Clearviewport;
       OuttextXY(20,40,'Moisture Supply (0..100%) (20):');
            GOTOXY(35,3);GWR;
            {$I-} READLN(Z);VAL(Z,MSNEW,R);{$I+}
            IF Z='' THEN MSNEW:=MS;
            IF MSNEW<0 THEN IKAZ6;
            IF MSNEW>100 THEN IKAZ6;
                     UNTIL MSNEW IN [0..100];
Setviewport(0,0,639,479,CLIPON);
WWR;   OuttextXY(335,180,IntTOStr(MSNEW));
I:=140;J:=170;K:=180;L:=20;bas;I:=330;K:=130;bas;
Setviewport(0,0,639,165,CLIPON);
                     TEK13:
                     REPEAT   YWR;Clearviewport;
       OuttextXY(20,40,'Roadbed Soil Fabric (0..100%) (20):');
            GOTOXY(39,3);GWR;
            {$I-} READLN(Z);VAL(Z,RSFNEW,R);{$I+}
            IF Z='' THEN RSFNEW:=RSF;
            IF RSFNEW<0 THEN IKAZ6; IF RSFNEW>100 THEN IKAZ6;
                     UNTIL RSFNEW IN [0..100];
Setviewport(0,0,639,479,CLIPON);
WWR;   OuttextXY(335,210,IntTOStr(RSFNEW));
I:=140;J:=200;K:=180;L:=20;bas;I:=330;K:=130;bas;
I:=50;J:=170;K:=80;L:=50;bas;
Setviewport(0,0,639,165,CLIPON);
                     TEK15: REPEAT YWR;Clearviewport;
       OuttextXY(20,40,'Moisture Condition (M/A/O) (Average):');
            GWR;MCNEW:=READKEY;MCNEW:=UPCASE(MCNEW);
            IF MCNEW=#13 THEN MCNEW:=CHR(65);
            IF MCNEW IN [CHR(77),CHR(65),CHR(79)] THEN MCNEW:=MCNEW
                                                ELSE IKAZ3;
            UNTIL MCNEW IN [CHR(77),CHR(65),CHR(79)];
Setviewport(0,0,639,479,CLIPON);
WWR;CASE MCNEW OF #77: OuttextXY(335,240,'Minimum');
                  #65: OuttextXY(335,240,'Average');
                  #79: OuttextXY(335,240,'Optimum');END;
I:=140;J:=230;K:=180;L:=20;bas;I:=330;K:=130;bas;
Setviewport(0,0,639,165,CLIPON);
Setviewport(0,0,639,479,CLIPON);
WWR;   OuttextXY(335,270,IntTOStr(PINEW));
I:=140;J:=260;K:=180;L:=20;bas;I:=330;K:=130;bas;
Setviewport(0,0,639,165,CLIPON);
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                  TEK16: REPEAT   YWR;Clearviewport;
          OuttextXY(20,40,'Layer Thickness (2/5/10/15/20/25/30/31..100ft) (20):');
          GOTOXY(56,3);GWR;
          {$I-} READLN(Z);VAL(Z,LTNEW,R);{$I+}
          IF Z='' THEN LTNEW:=LT;
          IF LTNEW IN [2,5,10,15,20,25,30,31..100]
                   THEN LTNEW:=LTNEW ELSE IKAZ5;
                 UNTIL LTNEW IN [2,5,10,15,20,25,30,31..100];
Setviewport(0,0,639,479,CLIPON);
WWR;  OuttextXY(335,300,IntTOStr(LTNEW));
I:=140;J:=290;K:=180;L:=20;bas;I:=330;K:=130;bas;
I:=50;J:=230;K:=80;L:=80;bas;
Setviewport(0,0,639,165,CLIPON);
                 TEK17: REPEAT   YWR;Clearviewport;
      OuttextXY(20,40,'Swell Probability (0..100%) (20):');
          GOTOXY(39,3);GWR;
          {$I-} READLN(Z);VAL(Z,SPNEW,R);{$I+}
          IF Z='' THEN SPNEW:=SP;
          IF SPNEW<0 THEN IKAZ6; IF SPNEW>100 THEN IKAZ6;
          UNTIL SPNEW IN [0..100];
Setviewport(0,0,639,479,CLIPON);
WWR;  OuttextXY(335,330,IntTOStr(SPNEW));
I:=50;J:=320;K:=270;L:=20;bas;I:=330;K:=130;bas;
I:=10;J:=170;K:=30;L:=170;bas;
Setviewport(0,0,639,165,CLIPON);
                 TEK18: YWR;Clearviewport;
          OuttextXY(20,40,'Frost Heave Rate (0..30mm/day) (2):');
          GOTOXY(42,3);GWR;
          {$I-} READLN(Z);VAL(Z,FHRNEW,R);{$I+}
IF Z=''  THEN FHRNEW:=FHR;
IF FHRNEW>30.0 THEN BEGIN IKAZ7;GOTO TEK18; END;
IF FHRNEW<0.0  THEN BEGIN IKAZ7;GOTO TEK18; END;
Setviewport(0,0,639,479,CLIPON);
WWR;
TEK21: I:=50;J:=360;K:=270;L:=20;bas;I:=330;K:=130;bas;
Setviewport(0,0,639,165,CLIPON);
                 TEK19: YWR;Clearviewport;
       OuttextXY(20,40,'Depth of Frost Penetration (1..10ft) (2):');
          GOTOXY(46,3);GWR;
{$I-} READLN(Z);VAL(Z,DFPNEW,R);{$I+}
IF Z='' THEN DFPNEW:=DFP;
IF DFPNEW<1.0 THEN BEGIN IKAZ7;GOTO TEK19; END;
IF DFPNEW>10.0 THEN BEGIN IKAZ7;GOTO TEK19; END;
Setviewport(0,0,639,479,CLIPON);
WWR;  IF DFPNEW=10.0 THEN  OuttextXY(332,400,IntTOStrReal(DFPNEW)+' E+01');
I:=140;J:=390;K:=180;L:=20;bas;I:=330;K:=130;bas;
Setviewport(0,0,639,165,CLIPON);
                  REPEAT YWR;Clearviewport;
          OuttextXY(20,40,'Drainage Quality (Vp/P/F/G/E) (Poor):');
          GWR;DQNEW:=READKEY;DQNEW:=UPCASE(DQNEW);
          IF DQNEW=CHR(13) THEN DQNEW:=CHR(80);
          IF DQNEW IN [CHR(86),CHR(80),CHR(70),CHR(71),CHR(69)]
             THEN DQNEW:=DQNEW ELSE IKAZ3;
          UNTIL DQNEW IN [CHR(86),CHR(80),CHR(70),CHR(71),CHR(69)];
Setviewport(0,0,639,479,CLIPON);
WWR;CASE DQNEW OF #86: OuttextXY(335,430,'Very Poor');
                  #80: OuttextXY(335,430,'Poor');
                  #70: OuttextXY(335,430,'Fair');
                  #71: OuttextXY(335,430,'Good');
                  #69: OuttextXY(335,430,'Excellent');END;
I:=140;J:=420;K:=180;L:=20;bas;I:=330;K:=130;bas;
I:=50;J:=390;K:=80;L:=50;bas;
Setviewport(0,0,639,165,CLIPON);
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                 TEK20: REPEAT   YWR;Clearviewport;
          OuttextXY(20,40,'Frost Heave Probability (0..100%) (20):');
          GOTOXY(43,3);GWR;
          {$I-} READLN(Z);VAL(Z,FHPNEW,R);{$I+}
          IF Z='' THEN FHPNEW:=FHP;
          IF FHPNEW<0 THEN IKAZ6; IF FHPNEW>100 THEN IKAZ6;
                 UNTIL FHPNEW IN [0..100];
Setviewport(0,0,639,479,CLIPON);
WWR;OuttextXY(335,460,IntTOStr(FHPNEW));
I:=50;J:=450;K:=270;L:=20;bas;I:=330;K:=130;bas;
I:=10;J:=360;K:=30;L:=110;bas;
Setviewport(0,0,639,165,CLIPON);
                END;
END;    END;
PROCEDURE MATERIALCHARINPUTS;   LABEL TEK,TEK1,TEK2,TEK3,TEK4,TEK5;
VAR II,JJ,KK,LL,R     :INTEGER;    DEVAM             :BOOLEAN;
   AAA                :REAL;       Z                 :STRING;
FUNCTION IntToStr(i: INTEGER): string;
VAR  s: string[1];BEGIN  Str(i, s);IntToStr := s; END;
FUNCTION IntToStrReal(i: REAL): string;
VAR  s: string[17];BEGIN  Str(i, s);IntToStrReal:= s; END;
FUNCTION IntToStrRealM(i: REAL): string;
VAR  s: string[5];BEGIN  Str(i, s);IntToStrRealM:= s; END;
FUNCTION LongIntToStr(i: LONGINT): string;
VAR  s: string[7];BEGIN  Str(i, s);LongIntToStr := s; END;
BEGIN
WWR;        LAYERNAME[1]:='Subgrade';  LAYERNAME[2]:='Subbase C.';
            LAYERNAME[3]:='Base C.';   Setviewport(0,0,639,118,CLIPON);
                 TEK: REPEAT   YWR;Clearviewport;
    OuttextXY(20,40,'Number of Layers  Over Base Course (0..4) (2):');
            GOTOXY(51,3);GWR;
            {$I-} READLN(Z);VAL(Z,LNUM,R);{$I+} IF Z='' THEN LNUM:=2;
             IF LNUM<0 THEN IKAZ6; IF LNUM>4 THEN IKAZ6;
             UNTIL LNUM IN [0..4];
JJ:=270;        FOR II:=4 TO LNUM+3 DO BEGIN
TEK1: YWR; Setviewport(0,0,639,118,CLIPON);Clearviewport;
      OuttextXY(20,40,IntTOStr(II));
      OuttextXY(25,40,'. Layer Name :');GOTOXY(20,3);
GWR;READLN(LAYERNAME[II]);
IF II=4 THEN BEGIN IF LAYERNAME[II]='' THEN BEGIN IKAZ13;
                                   LAYERNAME[II]:='Binder C.';END;END;
IF II=5 THEN BEGIN IF LAYERNAME[II]='' THEN BEGIN IKAZ13;
                                   LAYERNAME[II]:='Surface C.';END;END;
Setviewport(0,0,639,479,CLIPON);
WWR;  OuttextXY(15,JJ,LAYERNAME[II]);
Setviewport(0,0,639,118,CLIPON);
      IF LAYERNAME[II]='' THEN BEGIN IKAZ14;
      GOTO TEK1;END;INC(JJ,30);
                 END;
FOR II:=LNUM+4 TO 7 DO BEGIN LAYERNAME[II]:=' ';Setviewport(0,0,639,479,CLIPON);
         Setviewport(0,0,639,118,CLIPON);END;END;END;
DEVAM:=FALSE;          REPEAT
YWR; Clearviewport;
OuttextXY(20,20,'Subgrade Strength Parameter :');
OuttextXY(20,40,'CBR,R (if > 20) or Elasticity of Modulus (C,R,E)  (E)');
     GWR;               CBRMOD[1]:=READKEY;CBRMOD[1]:=UPCASE(CBRMOD[1]);
                        IF CBRMOD[1]=#13 THEN CBRMOD[1]:=#69;
                        IF CBRMOD[1] IN [#67,#82,#69] THEN DEVAM:=TRUE;
                        IF DEVAM=FALSE THEN IKAZ3;
UNTIL CBRMOD[1] IN [#67,#82,#69];DEVAM:=FALSE;
Setviewport(0,0,639,479,CLIPON);
WWR; CASE CBRMOD[1] OF #67: OuttextXY(117,180,'CBR (California B. R.)');
                       #82: OuttextXY(117,180,'R-Value');
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                    #69: OuttextXY(117,180,'Elasticity of Modulus');end;
I:=10; J:=120;K:=90;L:=40;  BAS;I:=110; K:=190;L:=20; J:=170;BAS;
Setviewport(0,0,639,118,CLIPON);Clearviewport;
REPEAT YWR; Clearviewport;
      OuttextXY(20,20,'Subbase Strength Parameter :');
      OuttextXY(20,40,'CBR,R or Elasticity of Modulus (C.R/E) .E:');
      GWR;                CBRMOD[2]:=READKEY;CBRMOD[2]:=UPCASE(CBRMOD[2]);
                          IF CBRMOD[2]=#13 THEN CBRMOD[2]:=#69;
                          IF CBRMOD[2] IN [#67,#82,#69] THEN DEVAM:=TRUE;
                          IF DEVAM=FALSE THEN IKAZ3;
UNTIL CBRMOD[2] IN [#67,#82,#69];DEVAM:=FALSE;
Setviewport(0,0,639,479,CLIPON);
WWR; case CBRMOD[2] OF #67: OuttextXY(117,210,'CBR (California B. R.)');
                    #82: OuttextXY(117,210,'R-Value');
                    #69: OuttextXY(117,210,'Elasticity of Modulus');END;
I:=110; K:=190;L:=20; J:=200;BAS;
Setviewport(0,0,639,118,CLIPON);Clearviewport;
DEVAM:=FALSE;
REPEAT YWR; DEVAM:=FALSE; Clearviewport;
      OuttextXY(20,20,'Application Type of Base Course ');
      OuttextXY(20,40,'(Cement Treated,Bituminous Treated,Granular) (C-B/G) (G):');
        BASETYPE:=READKEY;BASETYPE:=UPCASE(BASETYPE);
        IF BASETYPE=#13 THEN BASETYPE:=#71;
        IF BASETYPE IN [#67,#66,#71] THEN DEVAM:=TRUE;
        IF DEVAM=FALSE THEN IKAZ3;
        UNTIL BASETYPE IN [#67,#66,#71];

Setviewport(0,0,639,118,CLIPON);

CASE BASETYPE OF #66: BEGIN

REPEAT DEVAM:=FALSE; YWR; Clearviewport;
     OuttextXY(20,20,'Base Strength Parameter :');
     OuttextXY(20,40,'Marshall Stability or Modulus (S/M) .M ');
GWR;                      CBRMOD[3]:=READKEY;CBRMOD[3]:=UPCASE(CBRMOD[3]);
                          IF CBRMOD[3]=#13 THEN CBRMOD[3]:=#77;
                          IF CBRMOD[3] IN [#83,#77] THEN DEVAM:=TRUE;
                          IF DEVAM=FALSE THEN IKAZ3;
UNTIL CBRMOD[3] IN [#83,#77];DEVAM:=FALSE;
Setviewport(0,0,639,479,CLIPON);

WWR;CASE CBRMOD[3] OF #83: OuttextXY(115,240,'Marshall Stability');
                   #77: OuttextXY(115,240,'Modulus (Bituminous)');END;
I:=110; K:=190;L:=20; J:=230;BAS;
Setviewport(0,0,639,118,CLIPON);Clearviewport;END;

              #67: BEGIN
REPEAT  DEVAM:=FALSE;
YWR; Clearviewport;
      OuttextXY(20,20,'Base Strength Parameter :');
      OuttextXY(20,40,'Unconfined Compressive Strength or Modulus (U/C) .C ');
GWR;             CBRMOD[3]:=READKEY;CBRMOD[3]:=UPCASE(CBRMOD[3]);
                          IF CBRMOD[3]=#13 THEN CBRMOD[3]:=#79;
                          IF CBRMOD[3] IN [#85,#79] THEN DEVAM:=TRUE;
                          IF DEVAM=FALSE THEN IKAZ3;
UNTIL CBRMOD[3] IN [#85,#79];DEVAM:=FALSE;
Setviewport(0,0,639,479,CLIPON);

WWR;CASE CBRMOD[3] OF #85: OuttextXY(115,240,'Unconfined Comp. Str.');
                   #79: OuttextXY(115,240,'Modulus (Cemented)');END;
I:=110; K:=190;L:=20; J:=230;BAS;
Setviewport(0,0,639,118,CLIPON);Clearviewport;END;
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                   #71: BEGIN
REPEAT  DEVAM:=FALSE;
YWR; Clearviewport;
      OuttextXY(20,20,'Base Strength Parameter :');
      OuttextXY(20,40,'CBR, R or Elasticity of Modulus (C.R.E.  E');
      GWR;             CBRMOD[3]:=READKEY;CBRMOD[3]:=UPCASE(CBRMOD[3]);
                       IF CBRMOD[3]=#13 THEN CBRMOD[3]:=#69;
                       IF CBRMOD[3] IN [#67,#69,#82] THEN DEVAM:=TRUE;
                       IF DEVAM=FALSE THEN IKAZ3;
UNTIL CBRMOD[3] IN [#67,#69,#82]; DEVAM:=FALSE;
Setviewport(0,0,639,479,CLIPON);

WWR; case CBRMOD[3] OF #67: OuttextXY(115,240,'CBR (California B. R.)');
                       #82: OuttextXY(115,240,'R-Value');
                       #69: OuttextXY(115,240,'Modulus (Granular)');END;
I:=110; K:=190;L:=20; J:=230;BAS;
Setviewport(0,0,639,118,CLIPON);Clearviewport;END;
END;

JJ:=270;J:=230; FOR II:=4 TO LNUM+3 DO BEGIN    Setviewport(0,0,639,479,CLIPON);

CBRMOD[II]:=#69;
WWR;   OuttextXY(115,JJ,'Elasticity of Modulus');
          INC(JJ,30);I:=110; K:=190;L:=20; J:=J+30;BAS;END;

FOR II:=LNUM+4 TO 7 DO BEGIN CBRMOD[II]:=#0;
Setviewport(0,0,639,118,CLIPON);

YWR; Clearviewport;     OuttextXY(20,20,'Their Magnitude:');
JJ:=180;J:=140;         FOR II:=1 TO LNUM+3 DO BEGIN
TEK2: YWR;OuttextXY(20,40,IntTOStr(II));
        IF II=1 THEN  OuttextXY(25,40,'.    Subgrade  :')
              ELSE
        OuttextXY(25,40,'.  Layer Value :');
        GOTOXY(21,3);
        {$I-} READLN(Z);VAL(Z,LVAL[II],R);{$I+}
IF Z='' THEN BEGIN
        IF LVAL[II]=0 THEN BEGIN IKAZ6;GOTO TEK2;END;
END;END;
IF II>=4 THEN BEGIN  IF LVAL[II]<100000 THEN LVAL[II]:=100000;
                     IF LVAL[II]>500000 THEN LVAL[II]:=500000;END;

Setviewport(0,0,639,479,CLIPON);
WWR;      OuttextXY(325,JJ,LongIntTOStr(LVAL[II]));
I:=310; K:=150;L:=20;J:=J+30;BAS;
Setviewport(0,0,639,118,CLIPON);Clearviewport;
      INC(JJ,30);          END;

FOR II:=LNUM+4 TO 7 DO BEGIN LVAL[II]:=0;Setviewport(0,0,639,479,CLIPON);
TEK5:
YWR; Clearviewport;
OuttextXY(20,20,'Drainage Coefficients of Layers Over Subgrade (0.6..1.4)  1.0 :');
JJ:=400;

M[1]:=1.0;IF LNUM+4>4 THEN LL:=5 ELSE LL:=4;    FOR II:=LL TO 7 DO  BEGIN M[II]:=1.0; END;

KK:=LNUM+3;IF KK>4 THEN KK:=4;  FOR II:=2 TO KK DO BEGIN TEK4:
YWR; OuttextXY(25,40,CONCAT(LAYERNAME[II]+' Drainage Coefficient :'));
            GOTOXY(38,3);
      GWR;{$I-} READLN(Z);VAL(Z,M[II],R);{$I+}
          IF Z=''THEN M[II]:=1.0;
          IF M[II]>1.4 THEN BEGIN IKAZ7;GOTO TEK4;END;
          IF M[II]<0.6 THEN BEGIN IKAZ7;GOTO TEK4;END;
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Setviewport(0,0,639,479,CLIPON);
WWR;     OuttextXY(135,JJ,CONCAT(LAYERNAME[II]+' Drainage Coef.'));

IF M[II]<1.0 THEN OuttextXY(375,JJ,CONCAT(IntTOStrRealM(M[II])+' E-01'),
              ELSE OuttextXY(375,JJ,IntTOStrRealM(M[II])+' E+00');
Setviewport(0,0,639,118,CLIPON);Clearviewport;
        INC(JJ,30);        END;
END;    END.
```

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{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*  *  *  *  *  *  *  *  *  *  *  *  *)
{(*              UNIT PROGRAM COMPUTING MR,A,SN,D,OVERLAY                       *)
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*  *  *  *  *  *  *  *  *  *  *  *  *)
{$A+,O+,B-,D+,E+,F-,G+,I+,L+,N+,R+,S+,V+,X-}  {$M 16384,0,655360}
UNIT COMPUTE;       INTERFACE

USES   OVERLAY,CRT,INPUTS,DATASTOR,GRAPH,SCREENS,WARNINGS,HELPS;
VAR    MR                          :ARRAY[1..7] OF LONGINT;
       D,A,SN                      :ARRAY[1..7] OF REAL;
       PSIMAX,ZR,TIME,SYI,W82TIME,SRCONS,PVRISE :REAL;
       PSISwFr,GetTime                          :REAL;
       MROverlay1,MROverlay2                    :LONGINT;
       SNOverlay1,DOverlay1,AOverlay1           :REAL;
       SNOverlay2,DOverlay2,AOverlay2,FOLT1     :REAL;

PROCEDURE COMPUTED;     PROCEDURE COMPUTEOverlayTH1;
IMPLEMENTATION

PROCEDURE COMPUTED;{---------------------------------------------}

LABEL SNCOMPUTE,DCOMPUTE,BASLA,HESAP;
VAR III,C                   :INTEGER;
    SNDAM,DMIN              :ARRAY[1..7] OF REAL;
    RREAL                   :REAL;

FUNCTION IntToStra(i: INTEGER): string;
VAR  s: string[1];BEGIN  Str(i, s);IntToStra := s; END;

BEGIN

{----------------LAYER THICKNESSES COMPUTATION PHASE -------------}
C:=0;
FOR III:=1 TO 7 DO BEGIN
IF CBRMOD[III]=#0 THEN INC(C);END;LNUM:=7-C-3;

CASE DQNEW OF #86: PSIMAX:=(DFPNEW/2.0);
              #80: PSIMAX:=(0.4*DFPNEW);
              #70: PSIMAX:=(3.0*DFPNEW/10.0);
              #71: PSIMAX:=(DFPNEW/5.0);
              #69: PSIMAX:=(DFPNEW/10.0);END;

CASE CBRMOD[1] OF #67: MR[1]:=1500*LVAL[1];
                  #69: MR[1]:=LVAL[1];
                  #82: MR[1]:=1000+555*LVAL[1];END;
                       A[1]:=0.0;

CASE CBRMOD[2] OF #67: MR[2]:=GetA3(LVAL[2]);
                  #69: MR[2]:=LVAL[2];
                  #82: MR[2]:=GetA3R(LVAL[2]);END;
                  A[2]:=abs((0.227*(LN(MR[2])/LN(10.0)))-0.839);

CASE CBRMOD[3] OF #67: BEGIN MR[3]:=GetA2(LVAL[3]);
                       A[3]:=abs((0.249*(LN(MR[3])/LN(10.0)))-0.977);END;
                  #69: BEGIN MR[3]:=LVAL[3];
                       A[3]:=abs((0.249*(LN(MR[3])/LN(10.0)))-0.977);END;
                  #83: BEGIN MR[3]:=GetA2MARSHALLMR(LVAL[3]);
                       A[3]:=GetA2MARSHALL(LVAL[3]);END;
                  #77: BEGIN MR[3]:=LVAL[3];
                       A[3]:=GetA2MODUL(MR[3]);END;
                  #85: BEGIN MR[3]:=GetA2UNCONFINEDMR(LVAL[3]);
                       A[3]:=GetA2UNCONFINED(LVAL[3]);END;
                  #79: BEGIN MR[3]:=LVAL[3];
                       A[3]:=GetA2MODULCEMENT(MR[3]);END;
```

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                  #82: BEGIN MR[3]:=GetA2MR(LVAL[3]);
                       A[3]:=GetA2R(LVAL[3]);END;
END;

FOR III:=4 TO LNUM+3 DO BEGIN
IF LVAL[III]>0 THEN BEGIN MR[III]:=LVAL[III];
                          IF MR[III]>500000 THEN MR[III]:=500000;
                     END;

IF LVAL[III]=0 THEN  MR[III]:=0;

A[III]:=abs(EXP(LN(0.017439252)+(0.530711351*LN(MR[III]/1000.0))));
                          END;

FOR III:=LNUM+4 TO 7 DO BEGIN A[III]:=0.0; LVAL[III]:=0; MR[III]:=0;
                          END;

RREAL:=100.0*(EXP(LN(RFNEW/100.0)/SSNEW));
ZR:=GetZR(RREAL);

SYI:=ISNEW-TSNEW;

IF CONSFH=#78 THEN GOTO SNCOMPUTE;

TIME:=MPPNEW;
W82TIME:=GetW82(DDFNEW,LDFNEW,ESALNEW,TIME,EGRNEW);
SN[1]:=GetSN(ZR,OSDNEW,W82TIME,SYI,MR[1]);

TIME:=TIME-(0.1);
BASLA:
IF SFB IN [#83,#13,#66] then BEGIN
    PVRISE:=POTVERRISE(PINEW,LTNEW,MCNEW);
    SRCONS:=SwellRATECONS(MSNEW,RSFNEW);end;
CASE SFB OF  #83: PSISWFR:=GetPSISwell(PVRISE,SRCONS,TIME,SPNEW);
             #70: PSISWFR:=GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW);
             #66: PSISWFR:=GetPSISwell(PVRISE,SRCONS,TIME,SPNEW)+GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW);
             #13: PSISWFR:=GetPSISwell(PVRISE,SRCONS,TIME,SPNEW)+GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW);   END;
SYI:=ISNEW-TSNEW-PSISWFR;
W82TIME:=GetW82FROMSN(SN[1],ZR,OSDNEW,SYI,MR[1]);
GetTIME:=GetTIMEFROMW82(DDFNEW,LDFNEW,ESALNEW,W82TIME,EGRNEW);
IF ABS(TIME-GETTIME)<0.1 THEN GOTO HESAP
                           ELSE BEGIN TIME:=(TIME+GETTIME)/2.0;GOTO BASLA;END;
HESAP:
TIME:=GetTIME;
IF SFB IN [#83,#13,#66] then BEGIN
    PVRISE:=POTVERRISE(PINEW,LTNEW,MCNEW);
    SRCONS:=SwellRATECONS(MSNEW,RSFNEW);end;
CASE SFB OF  #83: PSISWFR:=GetPSISwell(PVRISE,SRCONS,TIME,SPNEW);
             #70: PSISWFR:=GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW);
             #66: PSISWFR:=GetPSISwell(PVRISE,SRCONS,TIME,SPNEW)+GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW);
             #13: PSISWFR:=GetPSISwell(PVRISE,SRCONS,TIME,SPNEW)+GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW);   END;
SYI:=ISNEW-TSNEW-PSISWFR;
W82TIME:=GetW82(DDFNEW,LDFNEW,ESALNEW,TIME,EGRNEW);

FOR III:=2 TO LNUM+3 DO BEGIN
                          SN[III]:=GetSN(ZR,OSDNEW,W82TIME,SYI,MR[III]);
                          END;
FOR III:=LNUM+4 TO 7 DO BEGIN
                          SN[III]:=0.0;
                          END;

GOTO DCOMPUTE;
```

```
SNCOMPUTE:
TIME:=MPPNEW;
W82TIME:=GetW82(DDFNEW,LDFNEW,ESALNEW,TIME,EGRNEW);

FOR III:=1 TO LNUM+3 DO BEGIN
                        SN[III]:=GetSN(ZR,OSDNEW,W82TIME,SYI,MR[III]);
                        END;

FOR III:=LNUM+4 TO 7 DO BEGIN
                        SN[III]:=0.0;
                        END;

DCOMPUTE:  {---------------- MINIMUM THICKNESSES -----------------------}
IF ESALNEW<=50000.0 THEN BEGIN
                         DMIN[4]:=1.0;DMIN[5]:=1.0;DMIN[6]:=1.0;DMIN[7]:=1.0;
                         IF BASETYPE=#71 THEN DMIN[3]:=4.0
                                        ELSE DMIN[3]:=0.0;END;
IF ESALNEW>=50001.0 THEN BEGIN
                         IF ESALNEW<=150000.0 THEN
                         BEGIN
                         DMIN[4]:=2.0;DMIN[5]:=2.0;DMIN[6]:=2.0;DMIN[7]:=2.0;
                         IF BASETYPE=#71 THEN DMIN[3]:=4.0
                                        ELSE DMIN[3]:=0.0;END;END;
IF ESALNEW>=150001.0 THEN BEGIN
                          IF ESALNEW<=500000.0 THEN BEGIN
                          DMIN[4]:=2.5;DMIN[5]:=2.5;DMIN[6]:=2.5;DMIN[7]:=2.5;
                          IF BASETYPE=#71 THEN DMIN[3]:=4.0
                                         ELSE DMIN[3]:=0.0;END;END;
IF ESALNEW>=500001.0 THEN BEGIN
                          IF ESALNEW<=2000000.0 THEN BEGIN
                          DMIN[4]:=3.0;DMIN[5]:=3.0;DMIN[6]:=3.0;DMIN[7]:=3.0;
                          IF BASETYPE=#71 THEN DMIN[3]:=6.0
                                         ELSE DMIN[3]:=0.0;END;END;
IF ESALNEW>=2000001.0 THEN BEGIN
                           IF ESALNEW<=7000000.0 THEN BEGIN
                           DMIN[4]:=3.5;DMIN[5]:=3.5;DMIN[6]:=3.5;DMIN[7]:=3.5;
                           IF BASETYPE=#71 THEN DMIN[3]:=6.0
                           ELSE DMIN[3]:=0.0;END;END;

IF ESALNEW>=7000001.0 THEN BEGIN
                           DMIN[4]:=4.0;DMIN[5]:=4.0;DMIN[6]:=4.0;DMIN[7]:=4.0;
                           IF BASETYPE=#71 THEN DMIN[3]:=6.0
                                          ELSE DMIN[3]:=0.0;END;
DMIN[1]:=0.0;DMIN[2]:=0.0;

{---------------------- THICKNESS COMPUTATIONS ----------------------------}

{---- 7. LAYER -------------------------------------------------------------}
SNDAM[7]:=0.0;
SNDAM[6]:=0.0;
IF A[7]>0.0 THEN BEGIN
                 D[7]:=abs(SN[6]/(A[7]*M[7]));
       IF DMIN[7]>0.0 THEN BEGIN IF D[7]<DMIN[7] THEN D[7]:=DMIN[7];END;
                 SNDAM[6]:=abs(D[7]*A[7]*M[7]);END
                 ELSE D[7]:=0.0;

{---- 6. LAYER ------------------------------------------------------------
SNDAM[5]:=0.0;
IF A[6]>0.0 THEN BEGIN
                 D[6]:=abs((SN[5]-(SNDAM[6]))/(A[6]*M[6]));
       IF DMIN[6]>0.0 THEN BEGIN IF D[6]<DMIN[6] THEN D[6]:=DMIN[6];END;
                 SNDAM[5]:=abs(D[6]*A[6]*M[6]);END
                 ELSE D[6]:=0.0;
```

```
{---- 5. LAYER ---------------------------------------------------------------}
SNDAM[4]:=0.0;
IF A[5]>0.0 THEN BEGIN
                D[5]:=abs((SN[4]-(SNDAM[5]+SNDAM[6]))/(A[5]*M[5]));
       IF DMIN[5]>0.0 THEN BEGIN IF D[5]<DMIN[5] THEN D[5]:=DMIN[5];END;
                SNDAM[4]:=abs(D[5]*A[5]*M[5]);END
                ELSE D[5]:=0.0;

{---- 4. LAYER ---------------------------------------------------------------}
SNDAM[3]:=0.0;
IF A[4]>0.0 THEN BEGIN
                D[4]:=abs((SN[3]-(SNDAM[4]+SNDAM[5]+SNDAM[6]))/(A[4]*M[4]));
       IF DMIN[4]>0.0 THEN BEGIN IF D[4]<DMIN[4] THEN D[4]:=DMIN[4];END;
                SNDAM[3]:=abs(D[4]*A[4]*M[4]);END
                ELSE D[4]:=0.0;

{---- 3. LAYER ---------------------------------------------------------------}
SNDAM[2]:=0.0;
IF A[3]>0.0 THEN BEGIN
                D[3]:=abs((SN[2]-(SNDAM[3]+SNDAM[4]+SNDAM[5]+SNDAM[6]))/(A[3]*M[3]));
       IF DMIN[3]>0.0 THEN BEGIN IF D[3]<DMIN[3] THEN D[3]:=DMIN[3];END;
                SNDAM[2]:=abs(D[3]*A[3]*M[3]);END
                ELSE D[3]:=0.0;

{---- 2. LAYER ---------------------------------------------------------------}
SNDAM[1]:=0.0;
IF A[2]>0.0 THEN BEGIN
                D[2]:=abs((SN[1]-(SNDAM[2]+SNDAM[3]+SNDAM[4]+SNDAM[5]+SNDAM[6]))/(A[2]*M[2]));
       IF DMIN[2]>0.0 THEN BEGIN IF D[2]<DMIN[2] THEN D[2]:=DMIN[2];END;
                SNDAM[1]:=abs(D[2]*A[2]*M[2]);END
                ELSE D[2]:=0.0;

{---- 1. LAYER ---------------------------------------------------------------}
A[1]:=0.0;D[1]:=0.0;    END;

PROCEDURE COMPUTEOverlayTH1;{------- OVERLAY THICKNESS COMPUTATION ------}

VAR A                                          :CHAR;
    RLx,RLy,R                                  :INTEGER;
    SYIOverlayWITHSF,SYIOverlayWITHSwell,SYIOverlayWITHFrost:REAL;
    SYIOverlayWITHOUTSF,SYIOverlay,MAXOTIME,W32Overlay       :REAL;
    SNy,SNeffective,Cx,AA,BB                                 :REAL;
    SYIOverlayUltimate,W32Ultimate,FR1         :REAL;
    LVALOverlayNEW                             :LONGINT;
    Z                                          :STRING;
LABEL TEK,TEK1,TEK2,TEK3,TEK4;

FUNCTION IntToStrReal0(i: REAL): string;  VAR  s: string[4];
BEGIN  Str(i, s);IntToStrReal0:= s; END;

BEGIN

FOLT1:=0.0;

A:=READKEY;A:=UPCASE(A);
IF A=#72 THEN BEGIN I:=469;J:=420;K:=160;L:=50;OFF;delay(500);
                HELPOVERLAY; OVERLAYSCREEN; END;

I:=469;J:=420;K:=160;L:=50;OFF;

TEK:  Setviewport(0,0,639,80,CLIPON);CLEARVIEWPORT;
Settextjustify(0,1);
YWR;    OuttextXY(20,40,'Elas. Mod. of Ist Overlay Material (50000..500000 psi) (400000):');
```

```
        GOTOXY(68,3);GWR;
        {$I-} READLN(Z);VAL(Z,LVALOverlayNEW,R);{$I+}
        IF Z='' THEN LVALOverlayNEW:=400000;
        IF LVALOverlayNEW<50000 THEN BEGIN IKAZ6;GOTO TEK;END;
        IF LVALOverlayNEW>500000 THEN BEGIN IKAZ6;GOTO TEK;END;

        MROverlay1:=LVALOverlayNEW;
        AOverlay1:=ABS(EXP(LN(0.017439252)+(0.530711351*LN(MROverlay1 [illegible]

TEK3:
IKAZ16;

MAXOTIME:=APNEW;
AA:=GetW82(DDFNEW,LDFNEW,ESALNEW,TIME,EGRNEW);
BB:=GetW82(DDFNEW,LDFNEW,ESALNEW,MAXOTIME,EGRNEW);

W82Overlay:=BB-AA;

SYIOverlayWITHOUTSF:=ISNEW-TSNEW;

IF CONSFH=#78 THEN BEGIN SYIOverlayWITHSF:=0.0; GOTO TEK2; END;

CASE SFB OF  #83: BEGIN SYIOverlayWITHSF:=GetPSISwell(PVRISE,SRCONS,MAXOTIME,SPNEW)-GetPSISwell(PVRISE,SRCONS,TIME,SPNEW
                        SYIOverlayWITHFrost:=0.0;END;
             #70: BEGIN SYIOverlayWITHSF:=GetPSIFrost(FHRNEW,PSIMAX,MAXOTIME,FHPNEW)-GetPSIFrost(FHRNEW,PSIMAX,TIME,FHP
                        SYIOverlayWITHSwell:=0.0;END;
             #66: BEGIN GOTO TEK1;END;
             #13: TEK1: BEGIN
SYIOverlayWITHSF:=(GetPSISwell(PVRISE,SRCONS,MAXOTIME,SPNEW)-GetPSISwell(PVRISE,SRCONS,TIME,SPNEW))+
(GetPSIFrost(FHRNEW,PSIMAX,MAXOTIME,FHPNEW)-GetPSIFrost(FHRNEW,PSIMAX,TIME,FHPNEW));   END;
     END;

TEK2: SYIOverlay:=SYIOverlayWITHOUTSF-SYIOverlayWITHSF;
SNy:=GetSN(ZR,OSDNEW,W82Overlay,SYIOverlay,MR[1]);
RLx:=GetOverlayRLx(TSNEW,SN[1]);
SYIOverlayUltimate:=ISNEW-(2.0)-SYIOverlayWITHSF;
W82Ultimate:=GetW82FromSN(SNy,ZR,OSDNEW,SYIOverlayUltimate,MR[1]);
RLy:=ROUND(((W82Ultimate-W82Overlay)/W82Ultimate)*100);
FR1:=GetOverlayFr1(RLx,RLy);
Cx:=GetOverlayCx(RLx);
SNeffective:=SN[1]*Cx;
SNOverlay1:=SNy-(FR1*SNeffective);
DOverlay1:=SNOverlay1/AOverlay1;
```

```
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*                    UNIT PROGRAM ALL DATA ARE IN                 *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$A+,B-,D+,E+,F-,G+,I+,L+,N+,R+,S+,V+,X-}
{$M 16384,0,655360}    UNIT DATASTOR;     INTERFACE
USES CRT,INPUTS;

     FUNCTION SWELLRATECONS(MSNEW,RSFNEW:INTEGER):REAL;
   FUNCTION POTVERRISE(PINEW,LTNEW:INTEGER;MCNEW:CHAR):REAL;
 FUNCTION GetA3R(LVAL:LONGINT):INTEGER;
   FUNCTION GetA2(LVAL:LONGINT):INTEGER;
     FUNCTION GetA2MARSHALL(LVAL:LONGINT):REAL;
       FUNCTION GetA2MARSHALLMR(LVAL:LONGINT):LONGINT;
         FUNCTION GetA2MR(LVAL:LONGINT):LONGINT;
           FUNCTION GetA2MODULCEMENT(LVAL:LONGINT):REAL;
         FUNCTION GetPSISWELL(PVRISE,SRCONS,TIME:REAL;SPNEW:INTEGER):REAL;
       FUNCTION GetPSIFROST(FHRNEW,PSIMAX,TIME:REAL;FHPNEW:INTEGER):REAL;
     FUNCTION GetSN(ZR,OSDNEW,W82TIME,SYI:REAL;MR:LONGINT):REAL;
   FUNCTION GetW82(DDFNEW,LDFNEW:INTEGER;ESALNEW,TIME,EGRNEW:REAL):REAL;
 FUNCTION GetW82FromSN(SN,ZR,OSDNEW,SYI:REAL;MR:LONGINT):REAL;
   FUNCTION GetTIMEFromW82(DDFNEW,LDFNEW:INTEGER;ESALNEW,W82TIME,EGRNEW:REAL):REAL;
     FUNCTION GetOVERLAYRLx(Pt1,SN:REAL):INTEGER;
                                                IMPLEMENTATION
{-----------------------------------------------------------------------------}
FUNCTION SWELLRATECONS;
VAR SRC:ARRAY[0..10,0..10] OF REAL;A,B:INTEGER;     BEGIN

SRC[0,0]:=0.04;   SRC[0,1]:=0.04;   SRC[0,2]:=0.04;    SRC[0,3]:=0.04;
 SRC[0,4]:=0.04;   SRC[0,5]:=0.04;   SRC[0,6]:=0.04;   SRC[0,7]:=0.04;
  SRC[0,8]:=0.04;   SRC[0,9]:=0.04;   SRC[0,10]:=0.04;
   SRC[1,0]:=0.055;  SRC[1,1]:=0.057;  SRC[1,2]:=0.059;  SRC[1,3]:=0.06;
    SRC[1,4]:=0.062;  SRC[1,5]:=0.066;  SRC[1,6]:=0.07;   SRC[1,7]:=0.08;
     SRC[1,8]:=0.0905; SRC[1,9]:=0.117;  SRC[1,10]:=0.2;
    SRC[2,0]:=0.06;    SRC[2,1]:=0.069;   SRC[2,2]:=0.072;  SRC[2,3]:=0.0755;
   SRC[2,4]:=0.0795;  SRC[2,5]:=0.085;   SRC[2,6]:=0.092;  SRC[2,7]:=0.103;
  SRC[2,8]:=0.119;   SRC[2,9]:=0.145;   SRC[2,10]:=0.2;
 SRC[3,0]:=0.078;   SRC[3,1]:=0.08;  SRC[3,2]:=0.0845;  SRC[3,3]:=0.0885;
SRC[3,4]:=0.094;   SRC[3,5]:=0.1;   SRC[3,6]:=0.108,   SRC[3,7]:=0.119;
 SRC[3,8]:=0.136;   SRC[3,9]:=0.158; SRC[3,10]:=0.2;
  SRC[4,0]:=0.086;   SRC[4,1]:=0.0895; SRC[4,2]:=0.094;  SRC[4,3]:=0.098;
   SRC[4,4]:=0.104;   SRC[4,5]:=0.11;   SRC[4,6]:=0.1195; SRC[4,7]:=0.132;
    SRC[4,8]:=0.146;   SRC[4,9]:=0.167;  SRC[4,10]:=0.2;
     SRC[5,0]:=0.094;   SRC[5,1]:=0.098;   SRC[5,2]:=0.103; . SRC[5,3]:=0.107;
    SRC[5,4]:=0.1125;  SRC[5,5]:=0.1195;  SRC[5,6]:=0.1305; SRC[5,7]:=0.1405;
   SRC[5,8]:=0.154;   SRC[5,9]:=0.172;   SRC[5,10]:=0.2;
  SRC[6,0]:=0.1;      SRC[6,1]:=0.105;  SRC[6,2]:=0.108;  SRC[6,3]:=0.113;
 SRC[6,4]:=0.1195;  SRC[6,5]:=0.1285; SRC[6,6]:=0.1375; SRC[6,7]:=0.147;
SRC[6,8]:=0.1595;  SRC[6,9]:=0.176;  SRC[6,10]:=0.2;
 SRC[7,0]:=0.1055;  SRC[7,1]:=0.1095; SRC[7,2]:=0.1145;  SRC[7,3]:=0.1195;
  SRC[7,4]:=0.128;   SRC[7,5]:=0.1345; SRC[7,6]:=0.143;   SRC[7,7]:=0.1515;
   SRC[7,8]:=0.163;   SRC[7,9]:=0.179;  SRC[7,10]:=0.2;
    SRC[8,0]:=0.1105;  SRC[8,1]:=0.115;  SRC[8,2]:=0.12;    SRC[8,3]:=0.126;
     SRC[8,4]:=0.1335; SRC[8,5]:=0.139;  SRC[8,6]:=0.1475; SRC[8,7]:=0.156;
    SRC[8,8]:=0.167;  SRC[8,9]:=0.1805; SRC[8,10]:=0.2;
   SRC[9,0]:=0.115;  SRC[9,1]:=0.12;    SRC[9,2]:=0.125;    SRC[9,3]:=0.1315;
  SRC[9,4]:=0.1375; SRC[9,5]:=0.144;  SRC[9,6]:=0.1505;  SRC[9,7]:=0.1595;
 SRC[9,8]:=0.17;    SRC[9,9]:=0.184;  SRC[9,10]:=0.2;
SRC[10,0]:=0.12;     SRC[10,1]:=0.126; SRC[10,2]:=0.131;  SRC[10,3]:=0.136;
 SRC[10,4]:=0.1415;  SRC[10,5]:=0.148; SRC[10,6]:=0.155,  SRC[10,7]:=0.163;
  SRC[10,8]:=0.1725;  SRC[10,9]:=0.186; SRC[10,10]:=0.2;

 B:=ROUND(MSNEW/10.0);A:=ROUND(RSFNEW/10.0);SWELLRATECONS:=SRC[A,B];END;
```

```
{----------------------------------------------------------------------}
FUNCTION POTVERRISE;
VAR J,II,API,BPI,LTB,BBB         :INTEGER;
    VR                           :ARRAY[1..13,0..7] OF REAL;
    AAA                          :REAL;
BEGIN  II:=1;  REPEAT  J:=II*5;  INC(II);
UNTIL PINEW<J;API:=ABS(ROUND(J/5.0)-3); BPI:=ABS(ROUND((J-5.0)/5.0)-3);

CASE MCNEW OF #77: {Minimum Condition}
                   BEGIN IF PINEW>50 THEN BEGIN PINEW:=50 ;API:=7;BPI:=7; END;
                   LTB:=ROUND(LTNEW/5.0); IF LTNEW>30 THEN LTB:=7;

               VR[1,0]:=0.8;   VR[1,1]:=1.0;   VR[1,2]:=1.4;   VR[1,3]:=1.4;
              VR[1,4]:=1.4;   VR[1,5]:=1.4;   VR[1,6]:=1.4;   VR[1,7]:=1.4;
             VR[2,0]:=1.4;   VR[2,1]:=2.8;   VR[2,2]:=4.6;   VR[2,3]:=5.4;
            VR[2,4]:=5.4;   VR[2,5]:=5.4;   VR[2,6]:=5.4;   VR[2,7]:=5.4;
           VR[3,0]:=2.0;   VR[3,1]:=5.0;   VR[3,2]:=8.3;   VR[3,3]:=8.8;
          VR[3,4]:=10.2;  VR[3,5]:=10.2;  VR[3,6]:=10.2;  VR[3,7]:=10.2;
         VR[4,0]:=3.0;   VR[4,1]:=6.8;   VR[4,2]:=12.0;  VR[4,3]:=13.9;
        VR[4,4]:=15.0;  VR[4,5]:=15.0;  VR[4,6]:=15.0;  VR[4,7]:=15.0;
       VR[5,0]:=4.0;   VR[5,1]:=8.3;   VR[5,2]:=15.9;  VR[5,3]:=18.5;
VR[5,4]:=20.5;  VR[5,5]:=21.0;  VR[5,6]:=21.0;  VR[5,7]:=21.0;
VR[6,0]:=5.0;   VR[6,1]:=10.0;  VR[6,2]:=19.5;  VR[6,3]:=24.0;
VR[6,4]:=25.8;  VR[6,5]:=26.9;  VR[6,6]:=27.5;  VR[6,7]:=27.5;
VR[7,0]:=6.0;   VR[7,1]:=11.6;  VR[7,2]:=24.6;  VR[7,3]:=29.6;
VR[7,4]:=32.6;  VR[7,5]:=35.0;  VR[7,6]:=36.5;  VR[7,7]:=36.9;
VR[8,0]:=0.0;   VR[8,1]:=0.0;   VR[8,2]:=0.0;   VR[8,3]:=0.0;
VR[8,4]:=0.0;   VR[8,5]:=0.0;   VR[8,6]:=0.0;   VR[8,7]:=0.0;
VR[9,0]:=0.0;   VR[9,1]:=0.0;   VR[9,2]:=0.0;   VR[9,3]:=0.0;
       VR[9,4]:=0.0;   VR[9,5]:=0.0;   VR[9,6]:=0.0;   VR[9,7]:=0.0;
        VR[10,0]:=0.0;  VR[10,1]:=0.0;  VR[10,2]:=0.0;  VR[10,3]:=0.0;
         VR[10,4]:=0.0;  VR[10,5]:=0.0;  VR[10,6]:=0.0;  VR[10,7]:=0.0;
          VR[11,0]:=0.0;  VR[11,1]:=0.0;  VR[11,2]:=0.0;  VR[11,3]:=0.0;
           VR[11,4]:=0.0;  VR[11,5]:=0.0;  VR[11,6]:=0.0;  VR[11,7]:=0.0;
            VR[12,0]:=0.0;  VR[12,1]:=0.0;  VR[12,2]:=0.0;  VR[12,3]:=0.0;
             VR[12,4]:=0.0;  VR[12,5]:=0.0;  VR[12,6]:=0.0;  VR[12,7]:=0.0;
              VR[13,0]:=0.0;  VR[13,1]:=0.0;  VR[13,2]:=0.0;  VR[13,3]:=0.0;
               VR[13,4]:=0.0;  VR[13,5]:=0.0;  VR[13,6]:=0.0;  VR[13,7]:=0.0;
END;
             #65:  BEGIN {Average Condition}
                   IF PINEW>65 THEN BEGIN PINEW:=65;API:=10;BPI:=10; END;
                   IF PINEW<25 THEN BEGIN PINEW:=25;API:=2;BPI:=2;END;
                   LTB:=ROUND(LTNEW/5.0); IF LTNEW>30 THEN LTB:=7;

VR[1,0]:=0.0;   VR[1,1]:=0.0;   VR[1,2]:=0.0;   VR[1,3]:=0.0;
 VR[1,4]:=0.0;   VR[1,5]:=0.0;   VR[1,6]:=0.0;   VR[1,7]:=0.0;
  VR[2,0]:=0.5;   VR[2,1]:=0.6;   VR[2,2]:=1.0;   VR[2,3]:=1.0;
   VR[2,4]:=1.0;   VR[2,5]:=1.0;   VR[2,6]:=1.0;   VR[2,7]:=1.0;
    VR[3,0]:=1.0;   VR[3,1]:=2.0;   VR[3,2]:=3.0;   VR[3,3]:=3.5;
     VR[3,4]:=3.5;   VR[3,5]:=3.5;   VR[3,6]:=3.5;   VR[3,7]:=3.5;
      VR[4,0]:=1.5;   VR[4,1]:=3.8;   VR[4,2]:=6.0;   VR[4,3]:=7.0;
       VR[4,4]:=7.0;   VR[4,5]:=7.0;   VR[4,6]:=7.0;   VR[4,7]:=7.0;
        VR[5,0]:=2.1;   VR[5,1]:=5.5;   VR[5,2]:=9.0;   VR[5,3]:=10.5;
         VR[5,4]:=11.1;  VR[5,5]:=11.1;  VR[5,6]:=11.1;  VR[5,7]:=11.1;
          VR[6,0]:=3.0;   VR[6,1]:=7.0;   VR[6,2]:=12.0;  VR[6,3]:=14.0;
              VR[6,4]:=15.9;  VR[6,5]:=15.3;  VR[6,6]:=15.3;  VR[6,7]:=15.3;
              VR[7,0]:=4.0;   VR[7,1]:=8.3;   VR[7,2]:=16.0;  VR[7,3]:=19.0;
              VR[7,4]:=20.5;  VR[7,5]:=21.0;  VR[7,6]:=21.0;  VR[7,7]:=21.0;
              VR[8,0]:=4.8;   VR[8,1]:=10.0;  VR[8,2]:=19.0;  VR[8,3]:=23.0;
          VR[8,4]:=25.0;  VR[8,5]:=25.8;  VR[8,6]:=26.4;  VR[8,7]:=26.4;
         VR[9,0]:=5.4;   VR[9,1]:=11.0;  VR[9,2]:=22.0;  VR[9,3]:=26.8;
        VR[9,4]:=29.0;  VR[9,5]:=30.5;  VR[9,6]:=31.5;  VR[9,7]:=31.5;
       VR[10,0]:=6.2;  VR[10,1]:=12.0; VR[10,2]:=25.0; VR[10,3]:=30.0;
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VR[10,4]:=33.4; VR[10,5]:=36.0; VR[10,6]:=36.8; VR[10,7]:=37.3;
VR[11,0]:=0.0;  VR[11,1]:=0.0;  VR[11,2]:=0.0;  VR[11,3]:=0.0;
VR[11,4]:=0.0;  VR[11,5]:=0.0;  VR[11,6]:=0.0;  VR[11,7]:=0.0;
VR[12,0]:=0.0;  VR[12,1]:=0.0;  VR[12,2]:=0.0;  VR[12,3]:=0.0;
VR[12,4]:=0.0;  VR[12,5]:=0.0;  VR[12,6]:=0.0;  VR[12,7]:=0.0;
VR[13,0]:=0.0;  VR[13,1]:=0.0;  VR[13,2]:=0.0;  VR[13,3]:=0.0;
VR[13,4]:=0.0;  VR[13,5]:=0.0;  VR[13,6]:=0.0;  VR[13,7]:=0.0;
                END;

      #79:  BEGIN  {Optimum Condition}
            IF PINEW<35 THEN BEGIN  PINEW:=35;API:=4;BPI:=4;END;
            LTB:=ROUND(LTNEW/5.0);  IF LTNEW>30 THEN LTB:=7;

VR[1,0]:=0.0;   VR[1,1]:=0.0;   VR[1,2]:=0.0;   VR[1,3]:=0.0;
VR[1,4]:=0.0;   VR[1,5]:=0.0;   VR[1,6]:=0.0;   VR[1,7]:=0.0;
VR[2,0]:=0.0;   VR[2,1]:=0.0;   VR[2,2]:=0.0;   VR[2,3]:=0.0;
VR[2,4]:=0.0;   VR[2,5]:=0.0;   VR[2,6]:=0.0;   VR[2,7]:=0.0;
VR[3,0]:=0.0;   VR[3,1]:=0.0;   VR[3,2]:=0.0;   VR[3,3]:=0.0;
VR[3,4]:=0.0;   VR[3,5]:=0.0;   VR[3,6]:=0.0;   VR[3,7]:=0.0;
VR[4,0]:=0.6;   VR[4,1]:=1.0;   VR[4,2]:=1.4;   VR[4,3]:=1.4;
VR[4,4]:=1.4;   VR[4,5]:=1.4;   VR[4,6]:=1.4;   VR[4,7]:=1.4;
VR[5,0]:=1.0;   VR[5,1]:=2.0;   VR[5,2]:=3.0;   VR[5,3]:=3.4;
VR[5,4]:=3.4;   VR[5,5]:=3.4;   VR[5,6]:=3.4;   VR[5,7]:=3.4;
VR[6,0]:=1.5;   VR[6,1]:=3.2;   VR[6,2]:=5.3;   VR[6,3]:=6.0;
VR[6,4]:=6.0;   VR[6,5]:=6.0;   VR[6,6]:=6.0;   VR[6,7]:=6.0;
VR[7,0]:=2.0;   VR[7,1]:=4.8;   VR[7,2]:=8.0;   VR[7,3]:=9.0;
VR[7,4]:=9.5;   VR[7,5]:=9.5;   VR[7,6]:=9.5;   VR[7,7]:=9.5;
VR[8,0]:=2.6;   VR[8,1]:=6.0;   VR[8,2]:=10.2;  VR[8,3]:=12.0;
VR[8,4]:=12.8;  VR[8,5]:=12.8;  VR[8,6]:=12.8;  VR[8,7]:=12.8;
VR[9,0]:=3.0;   VR[9,1]:=7.0;   VR[9,2]:=12.5;  VR[9,3]:=15.0;
VR[9,4]:=16.5;  VR[9,5]:=16.5;  VR[9,6]:=16.5;  VR[9,7]:=16.5;
VR[10,0]:=4.0;  VR[10,1]:=8.3;  VR[10,2]:=15.6; VR[10,3]:=18.6;
VR[10,4]:=20.0; VR[10,5]:=20.8; VR[10,6]:=20.8; VR[10,7]:=20.8;
VR[11,0]:=4.8;  VR[11,1]:=9.7;  VR[11,2]:=18.0; VR[11,3]:=22.0;
VR[11,4]:=24.0; VR[11,5]:=24.8; VR[11,6]:=25.0; VR[11,7]:=25.0;
VR[12,0]:=5.0;  VR[12,1]:=10.5; VR[12,2]:=21.0; VR[12,3]:=25.6;
VR[12,4]:=27.7; VR[12,5]:=29.0; VR[12,6]:=30.0; VR[12,7]:=30.0;
VR[13,0]:=6.0;  VR[13,1]:=11.5; VR[13,2]:=24.0; VR[13,3]:=29.0;
VR[13,4]:=32.0; VR[13,5]:=34.0; VR[13,6]:=35.0; VR[13,7]:=35.4;
          END;
END;

AAA:=VR[API,LTB]-VR[BPI,LTB];BBB:=PINEW-(J-5);
POTVERRISE:=ABS(((AAA*BBB/5.0)+VR[BPI,LTB])/10.0);
END;
{-----------------------------------------------------------------}
FUNCTION GetPSISWELL;      VAR AA,BB,CC:REAL;  BEGIN

AA:=(-1.0)*(SRCONS)*TIME; BB:=1.0-EXP(AA);   CC:=0.00335*PVRISE*SPNEW;
GetPSISWELL:=CC*BB;                          END;
{-----------------------------------------------------------------}
FUNCTION GetPSIFROST;     VAR AA,BB,CC:REAL;   BEGIN

AA:=0.01*FHPNEW*PSIMAX;   BB:=0.02*FHRNEW*TIME;  CC:=1.0-EXP(-1.0*(BB));
     GetPSIFROST:=ABS(AA*CC);
                                             END;
{--------------------------------------------------------------------}
FUNCTION GetA2MODUL;  VAR A2:REAL;   BEGIN

LVAL:=ROUND(LVAL/10000);    IF LVAL>40 THEN LVAL:=40;

IF LVAL=0 THEN A2:=0.0;    IF LVAL=1 THEN A2:=1.24;
 IF LVAL=2 THEN A2:=2.48;   IF LVAL=3 THEN A2:=3.3750;
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  IF LVAL=4 THEN A2:=4.96;   IF LVAL=5 THEN A2:=6.20;
   IF LVAL=6 THEN A2:=7.51;   IF LVAL=7 THEN A2:=8.82;
    IF LVAL=8 THEN A2:=10.13;  IF LVAL=9 THEN A2:=11.44;
IF LVAL=10 THEN A2:=12.75; IF LVAL=11 THEN A2:=13.96;
 IF LVAL=12 THEN A2:=15.17; IF LVAL=13 THEN A2:=16.38;
  IF LVAL=14 THEN A2:=17.59; IF LVAL=15 THEN A2:=18.8;
   IF LVAL=16 THEN A2:=19.52; IF LVAL=17 THEN A2:=20.24;
    IF LVAL=18 THEN A2:=20.96; IF LVAL=19 THEN A2:=21.68;
IF LVAL=20 THEN A2:=22.4;  IF LVAL=21 THEN A2:=23.0;
 IF LVAL=22 THEN A2:=23.6;  IF LVAL=23 THEN A2:=24.2;
  IF LVAL=24 THEN A2:=24.8;  IF LVAL=25 THEN A2:=25.4;
   IF LVAL=26 THEN A2:=25.82; IF LVAL=27 THEN A2:=26.24;
    IF LVAL=28 THEN A2:=26.66; IF LVAL=29 THEN A2:=27.08;
IF LVAL=30 THEN A2:=27.5;  IF LVAL=31 THEN A2:=28.0;
 IF LVAL=32 THEN A2:=28.5;  IF LVAL=33 THEN A2:=29.0;
  IF LVAL=34 THEN A2:=29.75; IF LVAL=35 THEN A2:=30.0;
   IF LVAL=36 THEN A2:=30.48; IF LVAL=37 THEN A2:=30.96;
    IF LVAL=38 THEN A2:=31.44; IF LVAL=39 THEN A2:=31.92;
     IF LVAL=40 THEN A2:=31.4;

GetA2MODUL:=A2/100.0; END;
{-------------------------------------------------------------------}
FUNCTION GetA2MARSHALL;   VAR A2:REAL;    BEGIN

LVAL:=ROUND(LVAL/50)*50;   IF LVAL>1900 THEN LVAL:=1900;

IF LVAL=0    THEN A2:=7.0;    IF LVAL=50   THEN A2:=8.25;
 IF LVAL=100  THEN A2:=9.5;    IF LVAL=150  THEN A2:=11.125;
  IF LVAL=200  THEN A2:=12.75;  IF LVAL=250  THEN A2:=13.575,
   IF LVAL=300  THEN A2:=14.4;   IF LVAL=350  THEN A2:=15.2;
    IF LVAL=400  THEN A2:=16.0;   IF LVAL=450  THEN A2:=16.4;
     IF LVAL=500  THEN A2:=16.8;   IF LVAL=550  THEN A2:=17.3;
      IF LVAL=600  THEN A2:=17.8;   IF LVAL=650  THEN A2:=18.5;
IF LVAL=700  THEN A2:=19.2;   IF LVAL=750  THEN A2:=19.85;
 IF LVAL=800  THEN A2:=20.5;   IF LVAL=850  THEN A2:=21.25,
  IF LVAL=900  THEN A2:=22.0;   IF LVAL=950  THEN A2:=22.6;
   IF LVAL=1000 THEN A2:=23.2;   IF LVAL=1050 THEN A2:=23.7,
    IF LVAL=1100 THEN A2:=24.2;   IF LVAL=1150 THEN A2:=24.65;
     IF LVAL=1200 THEN A2:=25.1;   IF LVAL=1250 THEN A2:=25.65;
IF LVAL=1300 THEN A2:=26.2;   IF LVAL=1350 THEN A2:=26.85;
 IF LVAL=1400 THEN A2:=27.5;   IF LVAL=1450 THEN A2:=27.95;
  IF LVAL=1500 THEN A2:=28.4;   IF LVAL=1550 THEN A2:=29.05;
   IF LVAL=1600 THEN A2:=29.7;   IF LVAL=1650 THEN A2:=30.35;
    IF LVAL=1700 THEN A2:=31.0;   IF LVAL=1750 THEN A2:=31.4;
     IF LVAL=1800 THEN A2:=31.8;   IF LVAL=1850 THEN A2:=32.4;
      IF LVAL=1900 THEN A2:=33.0;

GetA2MARSHALL:=A2/100.0;   END;
{-------------------------------------------------------------------}
FUNCTION GetA2MARSHALLMR; VAR MR:LONGINT;   BEGIN

LVAL:=ROUND(LVAL/50)*50;   IF LVAL>1900 THEN LVAL:=1900;

IF LVAL=0    THEN MR:=50000;    IF LVAL=50   THEN MR:=62500;
 IF LVAL=100  THEN MR:=75000;    IF LVAL=150  THEN MR:=87500;
  IF LVAL=200  THEN MR:=100000;   IF LVAL=250  THEN MR:=110000;
   IF LVAL=300  THEN MR:=120000;   IF LVAL=350  THEN MR:=125000;
    IF LVAL=400  THEN MR:=130000;   IF LVAL=450  THEN MR:=132500;
     IF LVAL=500  THEN MR:=135000;   IF LVAL=550  THEN MR:=137500;
      IF LVAL=600  THEN MR:=140000;   IF LVAL=650  THEN MR:=145000;
IF LVAL=700  THEN MR:=150000;   IF LVAL=750  THEN MR:=162500;
 IF LVAL=800  THEN MR:=175000;   IF LVAL=850  THEN MR:=182500;
  IF LVAL=900  THEN MR:=190000;   IF LVAL=950  THEN MR:=205000;
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   IF LVAL=1000 THEN MR:=220000;   IF LVAL=1050 THEN MR:=225000;
    IF LVAL=1100 THEN MR:=230000;   IF LVAL=1150 THEN MR:=233750;
     IF LVAL=1200 THEN MR:=237500;   IF LVAL=1250 THEN MR:=256250;
      IF LVAL=1300 THEN MR:=275000;   IF LVAL=1350 THEN MR:=287500;
IF LVAL=1400 THEN MR:=300000;   IF LVAL=1450 THEN MR:=315000;
 IF LVAL=1500 THEN MR:=330000;   IF LVAL=1550 THEN MR:=340000;
  IF LVAL=1600 THEN MR:=350000;   IF LVAL=1650 THEN MR:=360000;
   IF LVAL=1700 THEN MR:=370000;   IF LVAL=1750 THEN MR:=380000;
    IF LVAL=1800 THEN MR:=390000;   IF LVAL=1850 THEN MR:=405000;
     IF LVAL=1900 THEN MR:=420000;

GetA2MARSHALLMR:=MR;   END;
{-------------------------------------------------------------------
FUNCTION GetA2MODULCEMENT;   VAR A2:REAL;    BEGIN

LVAL:=ROUND(LVAL/25000)*25000;  IF LVAL>1100000 THEN LVAL:=1100000;

IF LVAL=0       THEN A2:=0.0;   IF LVAL=25000   THEN A2:=0.52;
 IF LVAL=50000   THEN A2:=1.04;  IF LVAL=75000   THEN A2:=1.56;
  IF LVAL=100000  THEN A2:=2.08;  IF LVAL=125000  THEN A2:=2.6;
   IF LVAL=150000  THEN A2:=3.28;  IF LVAL=175000  THEN A2:=3.96;
    IF LVAL=200000  THEN A2:=4.64;  IF LVAL=225000  THEN A2:=5.53;
     IF LVAL=250000  THEN A2:=6.0;   IF LVAL=275000  THEN A2:=6.55;
IF LVAL=300000  THEN A2:=7.1;   IF LVAL=325000  THEN A2:=7.65;
 IF LVAL=350000  THEN A2:=8.2;   IF LVAL=375000  THEN A2:=8.75;
  IF LVAL=400000  THEN A2:=9.32;  IF LVAL=425000  THEN A2:=9.89;
   IF LVAL=450000  THEN A2:=10.46; IF LVAL=475000  THEN A2:=11.03;
    IF LVAL=500000  THEN A2:=11.6;  IF LVAL=525000  THEN A2:=12.6;
     IF LVAL=550000  THEN A2:=13.7;  IF LVAL=575000  THEN A2:=14.6;
IF LVAL=600000  THEN A2:=15.4;   IF LVAL=625000  THEN A2:=16.3;
 IF LVAL=650000  THEN A2:=17.25;  IF LVAL=675000  THEN A2:=18.0;
  IF LVAL=700000  THEN A2:=19.0;   IF LVAL=725000  THEN A2:=19.7;
   IF LVAL=750000  THEN A2:=20.5;   IF LVAL=775000  THEN A2:=21.2;
    IF LVAL=800000  THEN A2:=21.5;   IF LVAL=825000  THEN A2:=22.2;
     IF LVAL=850000  THEN A2:=22.7;   IF LVAL=875000  THEN A2:=23.5;
IF LVAL=900000  THEN A2:=24.0;  IF LVAL=925000  THEN A2:=24.5;
 IF LVAL=950000  THEN A2:=25.3;  IF LVAL=975000  THEN A2:=25.8;
  IF LVAL=1000000 THEN A2:=26.4;  IF LVAL=1025000 THEN A2:=[illegible];
   IF LVAL=1050000 THEN A2:=27.6;  IF LVAL=1075000 THEN A2:=28.5;
    IF LVAL=1100000 THEN A2:=29.5;

GetA2MODULCEMENT:=A2/100.0;  END;
{----------------------------------------------------------------}
FUNCTION GetSN;   VAR AA,BB,CC,DD,EE,FF,GG,HH,SN:REAL;   BEGIN

SN:=0.01;   REPEAT
AA:=ZR*OSDNEW;                BB:=(9.36)*LN(SN+1.0)/LN(10.0);
CC:=(2.32*LN(MR)/LN(10.0))-(8.07)-(0.20);
DD:=LN(SYI/(2.7))/LN(10.0);  EE:=EXP((5.19)*LN(SN+1.0));
FF:=(0.40)+(1094.0/EE);       GG:=AA+BB+CC+(DD/FF);
HH:=LN(W82TIME)/LN(10.0);     SN:=SN+0.01;
           UNTIL ABS(HH-GG)<0.01;
GetSN:=SN;                           END;
{---------------------------------------------------------------}
FUNCTION GetW82;   VAR AA,BB:REAL;      BEGIN

AA:=(DDFNEW/100.0)*(LDFNEW/100.0)*ESALNEW;
BB:=EXP(TIME*LN(1.0+(EGRNEW/100.0)))-1.0;
GetW82:=ABS(AA*(BB/(EGRNEW/100.0)));
                                       END;
{--------------------------------------------------------------}
FUNCTION GetW82FROMSN;   VAR AA,BB,CC,DD,EE,FF:REAL;   BEGIN
```

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AA:=LN(SYI/2.7)/LN(10.0);          BB:=EXP(5.19*LN(SN+1.0));
CC:=(ZR*OSDNEW)+(9.36*LN(SN+1.0)/LN(10.0));
DD:=(2.32*LN(MR)/LN(10.0))-8.27;  EE:=0.40+(1094.0/BB);
FF:=CC+DD+(AA/EE);
GetW82FROMSN:=EXP(FF*LN(10.0));                             END;
{--------------------------------------------------------------}
FUNCTION GetTIMEFromW82;  VAR AA,BB:REAL;                   BEGIN
AA:=(DDFNEW/100.0)*(LDFNEW/100.0)*ESALNEW;
BB:=((W82TIME/AA)*(EGRNEW/100.0))+1.0;
GetTIMEFromW82:=ABS((LN(BB)/LN(1.0+(EGRNEW/100.0))));    END;
{-------------------------------------------------------------}
FUNCTION GetOVERLAYRLx;   VAR AA,BB:INTEGER;
                          RLx:ARRAY[0..25,0..8] OF INTEGER;
BEGIN
  IF Pt1>4.5 THEN PT1:=4.5;   IF Pt1<2.0 THEN PT1:=2.0;
  IF SN>6.5 THEN SN:=6.5;     IF SN<2.5 THEN SN:=2.5;

AA:=ABS(ROUND(ROUND(TRUNC(Pt1*100.0)-200.0)/10.0));
BB:=ABS(ROUND(ROUND(TRUNC(SN*10.0)-25)/5));

RLx[0,0]:=1;   RLx[0,1]:=2;   RLx[0,2]:=3;   RLx[0,3]:=4;
RLx[0,4]:=5;   RLx[0,5]:=6;   RLx[0,6]:=7;   RLx[0,7]:=7;
RLx[0,8]:=8;   RLx[1,0]:=2;   RLx[1,1]:=5;   RLx[1,2]:=7;
  RLx[1,3]:=8;   RLx[1,4]:=12;  RLx[1,5]:=13;  RLx[1,6]:=15;
  RLx[1,7]:=15;  RLx[1,8]:=17;  RLx[2,0]:=4;   RLx[2,1]:=8;
    RLx[2,2]:=12;  RLx[2,3]:=15;  RLx[2,4]:=18;  RLx[2,5]:=20;
    RLx[2,6]:=22;  RLx[2,7]:=24;  RLx[2,8]:=25;  RLx[3,0]:=5;
      RLx[3,1]:=13;  RLx[3,2]:=16;  RLx[3,3]:=20;  RLx[3,4]:=24;
      RLx[3,5]:=26;  RLx[3,6]:=30;  RLx[3,7]:=32;  RLx[3,8]:=33;
RLx[4,0]:=8;   RLx[4,1]:=17;  RLx[4,2]:=22;  RLx[4,3]:=27;
RLx[4,4]:=30;  RLx[4,5]:=35;  RLx[4,6]:=37;  RLx[4,7]:=39;
RLx[4,8]:=41;  RLx[5,0]:=10;  RLx[5,1]:=22;  RLx[5,2]:=28;
  RLx[5,3]:=34;  RLx[5,4]:=38;  RLx[5,5]:=42;  RLx[5,6]:=45;
  RLx[5,7]:=47;  RLx[5,8]:=49;  RLx[6,0]:=13;  RLx[6,1]:=25;
    RLx[6,2]:=33;  RLx[6,3]:=40;  RLx[6,4]:=44;  RLx[6,5]:=49;
    RLx[6,6]:=51;  RLx[6,7]:=53;  RLx[6,8]:=55;  RLx[7,0]:=15;
      RLx[7,1]:=30;  RLx[7,2]:=38;  RLx[7,3]:=45;  RLx[7,4]:=49;
      RLx[7,5]:=55;  RLx[7,6]:=57;  RLx[7,7]:=58;  RLx[7,8]:=62;
RLx[8,0]:=17;  RLx[8,1]:=34;  RLx[8,2]:=43;  RLx[8,3]:=50;
RLx[8,4]:=55;  RLx[8,5]:=61;  RLx[8,6]:=63;  RLx[8,7]:=65;
RLx[8,8]:=66;  RLx[9,0]:=19;  RLx[9,1]:=37;  RLx[9,2]:=47;
  RLx[9,3]:=56;  RLx[9,4]:=60;  RLx[9,5]:=66;  RLx[9,6]:=68;
  RLx[9,7]:=70;  RLx[9,8]:=72;  RLx[10,0]:=22; RLx[10,1]:=42;
    RLx[10,2]:=53; RLx[10,3]:=62; RLx[10,4]:=65; RLx[10,5]:=72;
    RLx[10,6]:=73; RLx[10,7]:=75; RLx[10,8]:=76; RLx[11,0]:=25;
      RLx[11,1]:=45; RLx[11,2]:=57; RLx[11,3]:=67; RLx[11,4]:=71;
      RLx[11,5]:=76; RLx[11,6]:=78; RLx[11,7]:=79; RLx[11,8]:=81;
RLx[12,0]:=29; RLx[12,1]:=50; RLx[12,2]:=62; RLx[12,3]:=71;
RLx[12,4]:=76; RLx[12,5]:=80; RLx[12,6]:=82; RLx[12,7]:=83;
RLx[12,8]:=84; RLx[13,0]:=33; RLx[13,1]:=54; RLx[13,2]:=66;
  RLx[13,3]:=75; RLx[13,4]:=80; RLx[13,5]:=84; RLx[13,6]:=85;
  RLx[13,7]:=87; RLx[13,8]:=88; RLx[14,0]:=36; RLx[14,1]:=58;
    RLx[14,2]:=70; RLx[14,3]:=80; RLx[14,4]:=84; RLx[14,5]:=88;
    RLx[14,6]:=88; RLx[14,7]:=89; RLx[14,8]:=91; RLx[15,0]:=40;
      RLx[15,1]:=63; RLx[15,2]:=74; RLx[15,3]:=83; RLx[15,4]:=88;
      RLx[15,5]:=90; RLx[15,6]:=91; RLx[15,7]:=93; RLx[15,8]:=94;
RLx[16,0]:=44; RLx[16,1]:=68; RLx[16,2]:=78; RLx[16,3]:=87;
RLx[16,4]:=90; RLx[16,5]:=93; RLx[16,6]:=94; RLx[16,7]:=95;
RLx[16,8]:=96; RLx[17,0]:=50; RLx[17,1]:=72; RLx[17,2]:=82;
  RLx[17,3]:=90; RLx[17,4]:=93; RLx[17,5]:=95; RLx[17,6]:=96;
  RLx[17,7]:=97; RLx[17,8]:=98; RLx[18,0]:=56; RLx[18,1]:=77;
    RLx[18,2]:=86; RLx[18,3]:=93; RLx[18,4]:=95; RLx[18,5]:=97;
    RLx[18,6]:=98; RLx[18,7]:=98; RLx[18,8]:=99; RLx[19,0]:=63;
```

```
     RLx[19,1]:=82; RLx[19,2]:=90; RLx[19,3]:=95; RLx[19,4]:=98;
     RLx[19,5]:=99; RLx[19,6]:=99; RLx[19,7]:=100;RLx[19,8]:=100;
RLx[20,0]:=73; RLx[20,1]:=88; RLx[20,2]:=94; RLx[20,3]:=98;
RLx[20,4]:=99; RLx[20,5]:=100;RLx[20,6]:=100;RLx[20,7]:=100;
RLx[20,8]:=100;RLx[21,0]:=85; RLx[21,1]:=96; RLx[21,2]:=98;
  RLx[21,3]:=100;RLx[21,4]:=100;RLx[21,5]:=100;RLx[21,6]:=100;
  RLx[21,7]:=100;RLx[21,8]:=100;RLx[22,0]:=100;RLx[22,1]:=100;
    RLx[22,2]:=100;RLx[22,3]:=100;RLx[22,4]:=100;RLx[22,5]:=100;
    RLx[22,6]:=100;RLx[22,7]:=100;RLx[22,8]:=100;RLx[23,0]:=100;
      RLx[23,1]:=100;RLx[23,2]:=100;RLx[23,3]:=100;RLx[23,4]:=100;
      RLx[23,5]:=100;RLx[23,6]:=100;RLx[23,7]:=100;RLx[23,8]:=100;
RLx[24,0]:=100;RLx[24,1]:=100;RLx[24,2]:=100;RLx[24,3]:=100;
RLx[24,4]:=100;RLx[24,5]:=100;RLx[24,6]:=100;RLx[24,7]:=100;
RLx[24,8]:=100;RLx[25,0]:=100;RLx[25,1]:=100;RLx[25,2]:=100;
  RLx[25,3]:=100;RLx[25,4]:=100;RLx[25,5]:=100;RLx[25,6]:=100;
  RLx[25,7]:=100;RLx[25,8]:=100;

GetOVERLAYRLx:=RLx[AA,BB];   END;
{-------------------------------------------------------------}

END.
```

```
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*           UNIT PROGRAM PRINTING OUTPUTS to FILE/PRINTER         *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$O+,F+,N+,E+}  UNIT OUTPUTS;   INTERFACE
USES DOS,CRT,INPUTS,SCREENS,PRINTER,COMPUTE;
VAR     II,JJ                       :INTEGER;
        NEWMPP,OVERAGE,TIMES        :REAL;
        FILELENGTH                  :INTEGER;
PROCEDURE FILEOUTPUT(VAR PRFILE:STRING);        IMPLEMENTATION
PROCEDURE FILEOUTPUT; LABEL ATLA,ATLA1,ATLA2;   var   F:TEXT;
FUNCTION IntToStr(i: Longint): string;
VAR  s: string[17];BEGIN  Str(i, s);IntToStr := s; END;
begin  Assign(F,PRFILE);  ReWrite(F);
  WriteLN(F,'╔══════════════════════════════════════════════════════╗');
  Write(F,'║♦       FLEXIBLE HIGHWAY PAVEMENT DESIGN PROGRAM       ♦║');
  GetDate(YEAR,MONTH,DAY,DAYOFWEEK);
  DATE:=CONCAT(' ',MONTHS[MONTH],' ',IntToStr(DAY),'/',IntTOStr(YEAR),' ');
  FILELENGTH:=LENGTH(DATE);
  IF FILELENGTH<18 THEN BEGIN  FOR II:=1 TO 18-FILELENGTH DO BEGIN
  Write(F,DATE);WriteLN(F,#179);
WriteLN(F,'╠══════════════════════════════════════════════════════╣');
  Write(F,'║♦ INITIAL PAVEMENT STRUCTURE GENERAL DATA BLOCK  ♦║');
  Write(F,'   [Filename]:');Write(F,FILENAME); WriteLN(F,'      ║');
WriteLN(F,'╠══════════════════════════════════════════════════════╣');
WriteLN(F,'│NOTE                                │                 │');
Write(F,'│Maximum Possible Performance Period (year)        :│');
Write(F,MPPNEW:27);WriteLN(F,#179);
Write(F,'│Analysis Period  (year)                           :│');
Write(F,APNEW:27);WriteLN(F,#179);
Write(F,'│Initial Serviceability                            :│');
Write(F,ISNEW:27);WriteLN(F,#179);
Write(F,'│Terminal Serviceability                           :│');
Write(F,TSNEW:27);WriteLN(F,#179);
Write(F,'│Stage Strategy Number                             :│');
Write(F,SSNEW:27);WriteLN(F,#179);
Write(F,'│Overall Standard Deviation                        :│');
Write(F,OSDNEW:27);WriteLN(F,#179);
Write(F,'│Estimated 18 kip Single Axle Load                 :│');
```

```
Write(F,ESALNEW:27);WriteLN(F,#179);
Write(F,'|Directional Distribution Factor (%)            ');
Write(F,DDFNEW:27);WriteLN(F,#179);
Write(F,'|Lane Distribution Factor  (%)                  ');
Write(F,LDFNEW:27);WriteLN(F,#179);
Write(F,'|Exponential Growth Rate   (%)                  ');
Write(F,EGRNEW:27);WriteLN(F,#179);
Write(F,'|Reliability Factor   (%)                       ');
Write(F,RFNEW:27);WriteLN(F,#179);
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
  Write(F,'|♦        SWELLING & FROST HEAVE DATA BLOCK       ♦|');
case SFB of #83: BEGIN WriteLN(F,'  Only SWELLING Considered  |');GOTO ATLA;END;
           #70: BEGIN WriteLN(F,'  Only FROST H. Considered  |');GOTO ATLA;END;
           #13: BEGIN WriteLN(F,'     Both Considered        |');GOTO ATLA;END;END;
                      WriteLN(F,'     Not Considered         |');
ATLA:
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
Write(F,'|Moisture  Supply  (%)                          ');
Write(F,MSNEW:27);WriteLN(F,#179);
Write(F,'|Roadbed Soil Fabric (%)                        ');
Write(F,RSFNEW:27);WriteLN(F,#179);
Write(F,'|Plasticity Index                               ');
Write(F,PINEW:27);WriteLN(F,#179);
Write(F,'|Moisture Condition                             ');
CASE MCNEW OF #65: BEGIN WriteLN(F,'                   Average |');GOTO ATLA1;END;
              #77: BEGIN WriteLN(F,'                   Minimum |');GOTO ATLA1;END;
              #79: BEGIN WriteLN(F,'                   Optimum |');GOTO ATLA1;END;END;
ATLA1:
Write(F,'|Layer Thickness (inc)                          ');
Write(F,LTNEW:27);WriteLN(F,#179);
Write(F,'|Swell Probability  (%)                         ');
Write(F,SPNEW:27);WriteLN(F,#179);
Write(F,'|Frost Heave Rate  (mm/day)                     ');
Write(F,FHRNEW:27);WriteLN(F,#179);
Write(F,'|Depth of Frost Penetration  (feet)             ');
Write(F,DFPNEW:27);WriteLN(F,#179);
Write(F,'|Drainage Quality                               ');
CASE DQNEW OF #86: BEGIN WriteLN(F,'                 Very Poor |');GOTO ATLA2;END;
              #80: BEGIN WriteLN(F,'                      Poor |');GOTO ATLA2;END;
              #70: BEGIN WriteLN(F,'                      Fair |');GOTO ATLA2;END;
              #71: BEGIN WriteLN(F,'                      Good |');GOTO ATLA2;END;
              #69: BEGIN WriteLN(F,'                 Excellent |');GOTO ATLA2;END;END;
                         WriteLN(F,'                           |');
ATLA2:
Write(F,'|Frost Heave Probability  (%)                   ');
Write(F,FHPNEW:27);WriteLN(F,#179);
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
WriteLN(F,'|♦            PAVEMENT CONSTRUCTION MATERIAL PROPERTIES DATA BLOCK      ♦|');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
Write(F,'|  LAYER NAMES  |');Write(F,'        STRENGTH PARAMETER        |');
Write(F,'  MAGNITUDE  |');  WriteLN(F,' DRAINAGE C. |');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
FOR II:=1 TO 7 DO BEGIN Write(F,#179);  Write(F,LAYERNAME[II]:15);
CASE CBRMOD[II] OF #67: Write(F,'| CBR  (California Bearing Ratio)   |');
                   #82: Write(F,'| R-Value                           |');
                   #69: Write(F,'| Elasticity of Modulus             |');
                   #83: Write(F,'| Marshall Stability                |');
                   #77: Write(F,'| Modulus    (Bituminous Treated)   |');
                   #79: Write(F,'| Modulus     (Cemented Treated)    |');
                   #85: Write(F,'| Unconfined Compressive Strength   |');
Write(F,LVAL[II]:13);   Write(F,#179);Write(F,M[II]:13);
WriteLN(F,#179);END;
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
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WriteLN(F,'|♦                    INITIAL PAVEMENT OUTPUT BLOCK                    ♦|');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
Write(F,'| STRUCTURAL Coef. |');     Write(F,'  STRUCTURAL No.  |');
Write(F,'  LAYER THICK.   |');       WriteLN(F,'  CONVERTED  VALUE   |');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
FOR II:=1 TO 7 DO BEGIN
Write(F,#179); Write(F,A[II]:18);Write(F,#179); Write(F,SN[II]:18);Write(F,#179);
          Write(F,D[II]:18);Write(F,#179); Write(F,MR[II]:21);WriteLN(F,#179);END;
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
Write(F,'| ***   New  Max. Performance Period ');        Write(F,TIME:11);
WriteLN(F,' Computed.  After This Time An |');            OVERAGE:=abs(APNEW-TIME);
Write(F,'| Overlay Necessary For  ');Write(F,OVERAGE:11);
WriteLN(F,' Years.                              |');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
Write(F,'|♦  2. STAGE OVERLAY STRUCTURE DATA BLOCK  ♦|');
IF AOVERLAY1=0.0 THEN
        WriteLN(F,'             Not Required         |')
     ELSE WriteLN(F,'             Required             |');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
Write(F,'|LAYER NAME|');  Write(F,'MR (psi)|');Write(F,'  STRUCTURAL Coef. |');
Write(F,'  STRUCTURAL NUM.  |');             WriteLN(F,'   LAYER THICK.   |');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
         Write(F,'|OVERLAY 1 |');
WriteLN(F,'╞══════════════════════════════════════════════════════════════════════╡');
IF AOVERLAY1>0.0 THEN BEGIN
Write(F,#179);Write(F,' *** First Overlay is Necessary After '); Write(F,TIME:9);
         Write(F,' Years  Over  Initial Layers. ');WriteLN(F,#179);
IF SSNEW=3 THEN BEGIN
Write(F,#179);Write(F,' *** Second Overlay is Necessary After ');
         TIMES:=TIME+FOLT1; Write(F,TIMES:9);
         Write(F,' Years  Over First Overlay.  ');WriteLN(F,#179);END
       ELSE BEGIN
Write(F,#179);FOR II:=1 TO 78 DO BEGIN Write(F,' ');END;WriteLN(F,#179);
         END;END ELSE BEGIN
Write(F,#179);FOR II:=1 TO 78 DO BEGIN Write(F,' ');END;WriteLN(F,#179);
Write(F,#179);FOR II:=1 TO 78 DO BEGIN Write(F,' ');END;WriteLN(F,#179);END;
WriteLN(F,'╘══════════════════════════════════════════════════════════════════════╛');
CLOSE(F);
WriteLN(LST,' ╒═══╡ NOTE ╞═══════════════════════════════════════════════════════╕');
WriteLN(LST,'| *1 is the block where all main data were listed.                  |');
WriteLN(LST,'| *2 is the name of this file which is given in the program by the user.|');
WriteLN(LST,'| *3 is the block where SWELLING and FROST HEAVE data were listed (with |');
WriteLN(LST,'|    positive numbers if considered).                                |');
WriteLN(LST,'| *4 shows whether Swelling or/and Frost Heave is considered or not, or |');
WriteLN(LST,'|    which one is considered.                                        |');
WriteLN(LST,'| *5 is the block where all main material properties data were listed. |');
WriteLN(LST,'| *6 is the block where all layer names were listed.                 |');
WriteLN(LST,'| *7 is the block where the strength parameter of each layer is given. |');
WriteLN(LST,'|    These are the parameters  the user uses to find layer coefficients |');
WriteLN(LST,'|    at the charts.                                                  |');
WriteLN(LST,'| *8 shows strength parameter magnitude of each layer.  For example, if |');
WriteLN(LST,'|    R-Value for subbase is shown in Block *?,  this  value may vary 1 |');
WriteLN(LST,'|    to 85 or 90 limited in the layer coefficient charts.            |');
WriteLN(LST,'| *9 is the block  where  drainage  coefficient of each layer is listed |');
WriteLN(LST,'|    varying 0.6 to 1.4.                                             |');
WriteLN(LST,'| *10 is the block presenting results after program running.         |');
WriteLN(LST,'| *11 is the block where structural coefficient of each layer is listed.|');
WriteLN(LST,'| *12 is the block where structural number of each layer is listed.  |');
WriteLN(LST,'| *13 is the block where layer thicknesses are listed in inches.     |');
WriteLN(LST,'| *14 is the block where strength parameter of each layer is converted |');
WriteLN(LST,'|     in modulus to use in computation. For example, if CBR is given as |');
WriteLN(LST,'|     the strength parameter of subbase,  a 24 CBR magnitude, shown, is |');
WriteLN(LST,'|     used in computation as 13500 psi modulus being converted.      |');
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WriteLN(LST,'| *15 is the block presenting  max. performance period after computing. |');
WriteLN(LST,'|     The number will be less than the max. possible performance period |');
WriteLN(LST,'|     if Swelling or/and Frost Heave is considered.                     |');
WriteLN(LST,'| *16 is the block presenting overlay thicknesses and propreties        |');
WriteLN(LST,'| *17 shows if overlay computation is required or not.                  |');
WriteLN(LST,'| *18 shows the layer name of each overlay, standard as Overlay 1 and 2 |');
WriteLN(LST,'| *19 shows the elasticity  modulus of each  overlay.  Note that  if  1 |');
WriteLN(LST,'|     overlay is required, values of second overlay will be zero.       |');
WriteLN(LST,'| *20 shows the structural coefficient of each overlay.                 |');
WriteLN(LST,'| *21 shows the structural number of each overlay.                      |');
WriteLN(LST,'| *22 shows the layer thickness of each overlay in inches.              |');
WriteLN(LST,'| *23 shows the year which first overlay must be constructed.           |');
WriteLN(LST,'| *24 shows  the  year  which  second  overlay  must be constructed (if |');
WriteLN(LST,'|     required).                                                        |');
WriteLN(LST,'========================================================================');
END;    END.


{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*      UNIT PROGRAM CONSISTING ALL SCREENS Except for HELP SCREENS      *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$A+,B-,D+,E+,G+,F+,I+,L+,N+,O-,R-,S+,V+,X-} {$M 16384,0,655360}
UNIT SCREENS;    INTERFACE     USES CRT,DOS,GRAPH;
VAR      GraphDriver, GraphMode                            :Integer;
         I,J,K,L                                           :INTEGER;
         YEAR,MONTH,DAY,DAYOFWEEK,hour,minute,second,hund:Word;
         DATE                                              :STRING[18];
         PALETTE                                           :PALETTETYPE;
         PATHNAMENEW                                       :STRING;
CONST
   DAYS:Array [0..6] of String[9]=('Sunday','Monday','Tuesday','Wednesday',
                                   'Thursday','Friday','Saturday');
   MONTHS:ARRAY [1..12] OF STRING[9]=('JANUARY','FEBRUARY','MARCH','APRIL',
                                   'MAY','JUNE','JULY','AUGUST','SEPTEMBER',
                                   'OCTOBER','NOVEMBER','DECEMBER');
   ERENPAT:FILLPATTERNTYPE=(0, $11, $28, $55, $28, $11, 0, 1);

 PROCEDURE GRC;            PROCEDURE CER;              PROCEDURE SESVER1;
  PROCEDURE ywr;            PROCEDURE WWR;             PROCEDURE IKAZ1;
   PROCEDURE rwr;            PROCEDURE GWR;            PROCEDURE IKAZ2;
    PROCEDURE MAINMENU;       PROCEDURE TITLE1;        PROCEDURE SAAT;
     PROCEDURE SCREEN1;        PROCEDURE SCREEN2;      PROCEDURE SCREEN3;
    PROCEDURE SCREEN4;        PROCEDURE CROSSSECTION;  PROCEDURE SESVER;
   PROCEDURE PREPARERRMDATA; PROCEDURE OVERLAYSCREEN;  PROCEDURE SCREENE1;
  PROCEDURE IKAZ;           PROCEDURE PREPARESFHDATA;  PROCEDURE SCREENE2;
 PROCEDURE ENDINGSCREEN;   PROCEDURE CROSSSECTIONOVERLAY;PROCEDURE SCREENE3;
PROCEDURE ON;             PROCEDURE ONBAR;             PROCEDURE OFF;
PROCEDURE BAS;
IMPLEMENTATION

FUNCTION IntToStr(i: Longint): string;  VAR  s: string[11];
BEGIN  Str(i, s);IntToStr := s; END;

FUNCTION IntToStrRRM(i: INTEGER): string; VAR  s: string[6];
BEGIN  Str(i, s);IntToStrRRM:= s; END;

PROCEDURE SAAT; VAR SA:STRING[10];
function WordToStr(w : Word) : String;var  s : String;
begin Str(w:0,s);if Length(s)=1 then s:='0'+s;WordToStr:=s;end;

BEGIN   GetTime(hour,minute,second,hund);
```

```
SETCOLOR(15);OUTTEXTXY(545,338,SA);     delay(500);     end;

PROCEDURE ON;BEGIN  SETCOLOR(15);LINE(I,J,I+K,J);LINE(I,J,I,J+L);
                    SETCOLOR(15);LINE(I+1,J+1,I+K-1,J+1);LINE(I+1,J+1,I+1,J+L-1);
                                 LINE(I+2,J+2,I+K-2,J+2);LINE(I+2,J+2,I+2,J+L-2);
                                 LINE(I+3,J+3,I+K-3,J+3);LINE(I+3,J+3,I+3,J+L-3);
                     SETCOLOR(8);LINE(I,J+L,I+K,J+L);LINE(I+K,J,I+K,J+L);
                                 LINE(I+1,J+L-1,I+K-1,J+L-1);LINE(I+K-1,J+1,I+K-1,J+L-1);
                                 LINE(I+2,J+L-2,I+K-2,J+L-2);LINE(I+K-2,J+2,I+K-2,J+L-2);
                                 LINE(I+3,J+L-3,I+K-3,J+L-3);LINE(I+K-3,J+3,I+K-3,J+L-3);
                                 LINE(I+4,J+4,I+K-4,J+4);LINE(I+4,J+4,I+4,J+L-4);
                     SETCOLOR(15);LINE(I+4,J+L-4,I+K-4,J+L-4);LINE(I+K-4,J+4,I+K-4,J+L-4);
                     SETFILLSTYLE(10,15);BAR(I+5,J+5,I+K-5,J+L-5);
                          END;
PROCEDURE ONBAR; BEGIN   SETCOLOR(15);LINE(I,J,I+K,J);LINE(I,J,I,J+L);
                         SETCOLOR(15);LINE(I+1,J+1,I+K-1,J+1);LINE(I+1,J+1,I+1,J+L-1);
                                 LINE(I+2,J+2,I+K-2,J+2);LINE(I+2,J+2,I+2,J+L-2);
                                 LINE(I+3,J+3,I+K-3,J+3);LINE(I+3,J+3,I+3,J+L-3);
                     SETCOLOR(8);LINE(I,J+L,I+K,J+L);LINE(I+K,J,I+K,J+L);
                                 LINE(I+1,J+L-1,I+K-1,J+L-1);LINE(I+K-1,J+1,I+K-1,J+L-1);
                                 LINE(I+2,J+L-2,I+K-2,J+L-2);LINE(I+K-2,J+2,I+K-2,J+L-2);
                                 LINE(I+3,J+L-3,I+K-3,J+L-3);LINE(I+K-3,J+3,I+K-3,J+L-3);
                                 LINE(I+4,J+4,I+K-4,J+4);LINE(I+4,J+4,I+4,J+L-4);
                     SETCOLOR(15);LINE(I+4,J+L-4,I+K-4,J+L-4);LINE(I+K-4,J+4,I+K-4,J+L-4);
                     SETFILLSTYLE(9,8);BAR(I+5,J+5,I+K-5,J+L-5);
                          END;

PROCEDURE OFF;BEGIN  SETCOLOR(7); LINE(I+1,J+1,I+K-1,J+1);LINE(I+1,J+1,I+1,J+L-1);
                                  LINE(I+2,J+2,I+K-2,J+2);LINE(I+2,J+2,I+2,J+L-2);
                                  LINE(I+1,J+L-1,I+K-1,J+L-1);LINE(I+K-1,J+1,I+K-1,J+L-1);
                                  LINE(I+2,J+L-2,I+K-2,J+L-2);LINE(I+K-2,J+2,I+K-2,J+L-2);
              END;

PROCEDURE CER;BEGIN SETCOLOR(15);LINE(I,J,I+K,J);LINE(I,J,I,J+L);
          SETCOLOR(8);LINE(I+1,J+L,I+K,J+L);LINE(I+K,J+1,I+K,J+L);END;
PROCEDURE bas;BEGIN SETCOLOR(8);LINE(I,J,I+K,J);LINE(I,J,I,J+L);
          SETCOLOR(15);LINE(I+1,J+L,I+K,J+L);LINE(I+K,J+1,I+K,J+L);END;
PROCEDURE ywr;BEGIN SETCOLOR(14); END;
PROCEDURE WWR;BEGIN SETCOLOR(15); END;
PROCEDURE rwr;BEGIN SETCOLOR(6);  END;
PROCEDURE GWR;BEGIN SETCOLOR(10);TEXTCOLOR(10); END;

PROCEDURE GRC;begin
CLRSCR; TEXTCOLOR(7);TEXTBACKGROUND(0);
for I:=1 TO 25 DO BEGIN
WRITE(#176);WRITE(#176);WRITE(#176);WRITE(#177);WRITE(#177);WRITE(#177);
WRITE(#178);WRITE(#178);WRITE(#178);WRITE(#219);WRITE(#219);WRITE(#219);
FOR J:=1 TO 56 DO BEGIN textcolor(15);WRITE(#219);END;
textcolor(7);WRITE(#219);WRITE(#219);WRITE(#219);WRITE(#178);WRITE(#178);WRITE(#178);
WRITE(#177);WRITE(#177);WRITE(#177);WRITE(#176);WRITE(#176);WRITE(#176);
END;

textcolor(15);gotoxy(16,19);WRITEln('╔══════════════════════════════════════════════════╗');
              gotoxy(16,21);WRITEln('╚══════════════════════════════════════════════════╝');
              gotoxy(16,20);WRITEln('║                                                  ║');
textcolor(14);gotoxy(21,20);

WRITE('F');delay(50);WRITE('L');delay(50);WRITE('E');delay(50);
WRITE('X');delay(50);WRITE('I');delay(50);WRITE('B');delay(50);
WRITE('L');delay(50);WRITE('E');delay(50);WRITE(' ');delay(50);

WRITE('H');delay(50);WRITE('I');delay(50);WRITE('G');delay(50);
WRITE('H');delay(50);WRITE('W');delay(50);WRITE('A');delay(50);
WRITE('Y');delay(50);WRITE(' ');delay(50);
```

```
WRITE('P');delay(50);WRITE('A');delay(50);WRITE('V');delay(50);
WRITE('E');delay(50);WRITE('M');delay(50);WRITE('E');delay(50);
WRITE('N');delay(50);WRITE('T');delay(50);WRITE(' ');delay(50);

WRITE('D');delay(50);WRITE('E');delay(50);WRITE('S');delay(50);
WRITE('I');delay(50);WRITE('G');delay(50);WRITE('N');delay(50);
WRITE(' ');delay(50);

WRITE('P');delay(50);WRITE('r');delay(50);WRITE('o');delay(50);
WRITE('g');delay(50);WRITE('r');delay(50);WRITE('a');delay(50);
WRITE('m');delay(50);

textcolor(15+blink);gotoxy(31,15);write(' — Running ... — ');

DELAY(1500);
textcolor(15);gotoxy(31,15);for i:=1 to 19 do write(#219);
textcolor(0);gotoxy(21,20);
for i:=1 to 43 do begin write(' ');delay(30);end;
gotoxy(40,5);TEXTCOLOR(15);PATHNAMENEW:=paramstr(0);

delete(pathnamenew,(length(PATHNAMENEW)-10),11);
DETECTGraph(GraphDriver, GraphMode);
InitGraph(GraphDriver, GraphMode, pathnamenew);
IF GraphResult <> grOk then  BEGIN

GotoXY(14,11);TEXTCOLOR(15);
WRITE('╔══════════════╡');
TEXTCOLOR(14+BLINK);WRITE(' ERROR ');
TEXTCOLOR(15);WRITE('╞══════════════╗');TEXTCOLOR(15);  GotoXY(14,12);
WRITE('║ YOUR PC GRAPHICS CARD IMPROPER FOR THIS PROGRAM or  ║');
GotoXY(14,13);
WRITE('║ egavga.bgi FILE IS  ABSENT or NOT IN the DIRECTORY  ║');
GotoXY(14,14);
WRITE('║   THAT YOU ARE WORKING. PROGRAM WAS DESIGNED FOR    ║');
GotoXY(14,15);
WRITE('║         VGA 640x480 RESOLUTION GRAPHICS CARDS       ║');
TEXTCOLOR(10+BLINK);
GotoXY(14,16);
WRITE('║         PLEASE CONTROL THEM and START AGAIN.        ║');
TEXTCOLOR(15);
GotoXY(14,17);
WRITE('╚═════════════════════════════════════════════════════╝');
GotoXY(14,19); WRITE('┌══════════════════════════════════════════════┐');
TEXTCOLOR(15);
GotoXY(14,20); WRITE('│         < Press Any Key To Quit Process        │');
TEXTCOLOR(15);
GotoXY(14,21); WRITE('└══════════════════════════════════════════════┘');
GotoXY(40,5);sesver;sesver;sesver;
repeat until keypressed;CLRSCR;HALT(1); END; END;

PROCEDURE TITLE1;{------------ AASHTO TITLE ---------------------}
VAR A:INTEGER;P: pointer;Size: Word;E:CHAR;
BEGIN
Clearviewport;GetPalette(Palette);Setbkcolor(7);
SETTEXTJUSTIFY(1,1);
                    I:=10;J:=10;K:=449;L:=460;CER;

SETCOLOR(8);
FOR A:=1 TO 100 DO LINE(75+A,479,275+A,0);
setcolor(15);SETLINESTYLE(0,0,3);

Settextstyle(0,HORIZDIR,2);SETFILLSTYLE(1,1);
```

```
BAR(10,170,145,205);I:=10;J:=170;K:=135;L:=36;CER;
SETCOLOR(7);   OuttextXY(90,190,'AASHTO ');
SETCOLOR(15);  OuttextXY(85,185,'AASHTO ');

  Size := ImageSize(10,170,142,206);  GetMem(P, Size);
  GetImage(10,170,142,206,P^);

  SETVIEWPORT(11,170,145,210,CLIPON);CLEARVIEWPORT;
  SETVIEWPORT(0,0,639,479,CLIPON);
  FOR A:=11 TO 175 DO BEGIN PutImage(A, 170, P^, NOTPut);END;

SETLINESTYLE(0,0,1);
Settextstyle(0,HORIZDIR,1);
I:=467;J:=10;K:=164;L:=400;ONBAR;
setcolor(15);
       OuttextXY(549,70,'FLEXIBLE HIGHWAY');
       OuttextXY(549,90,'PAVEMENT DESIGN');
       OuttextXY(549,110,'PROGRAM');
       OuttextXY(549,150,'By');
       OuttextXY(549,190,'AASHTO');
       OuttextXY(549,210,'(AMERICAN');
       OuttextXY(549,230,'ASSOCIATION Of');
       OuttextXY(549,250,'STATE HIGHWAY And');
       OuttextXY(549,270,'TRANSPORTATION');
       OuttextXY(549,290,'OFFICIALS)');
       OuttextXY(549,310,'Method');
       OuttextXY(549,380,'ReViewed In 1986');
ywr;  OuttextXY(230,60, 'THIS STUDY WAS PRESENTED As A MASTER THESIS');
      OuttextXY(230,80, 'To GRADUATE SCHOOL Of NATURAL  And  APPLIED');
      OuttextXY(230,100,'SCIENCES Of DOKUZ EYLUL UNIVERSITY.        ');
      OuttextXY(230,140,'IT COMPUTES THICKNESSES OF HIGHWAY PAVEMENT');
      OuttextXY(230,160,'LAYERS By                                  ');
      OuttextXY(230,225,'                                    Method,');
      OuttextXY(230,245,'DEVELOPED  TILL  and  NEW  EDITED  in 1986,');
      OuttextXY(230,265,'USING HIGHLY NEW DATA.                     ');
      OuttextXY(230,305,'USE  COMPUTER  PROGRAM  USAGE MANUAL, SIXTH');
      OuttextXY(230,325,'CHAPTER OF THESIS, FOR GUIDENCE.           ');
      OuttextXY(230,450,'1994/IZMIR');
           I:=467;J:=420;K:=164;L:=50;ON;
           SESVER1;

I:=487;J:=447;K:=20;L:=9;BAS;
repeat
setfillstyle(1,3);bar(488,448,506,455);delay(650);
setfillstyle(10,15);bar(488,448,506,455);delay(350);
until keypressed;
END;

PROCEDURE MAINMENU;BEGIN {------------- MAINMENU SCREEN -------------------}
  Clearviewport;  Settextstyle(0,Horizdir,2);
  I:=469;K:=160;L:=50;J:=360;ON;J:=420;ON;
  I:= 70;    J:=90;   K:=385; L:=30;  CER;
  I:= 72;    J:=92;   K:=381; L:=26;  CER;

  I:= 30;J:=150;K:=30;L:=20;ON;J:=180;ON;J:=210;ON;J:=250;ON;J:=280;ON;J:=320;ON;J:=350;ON;
  I:= 70;J:=150;K:=385;L:=20;CER;J:=180;CER;J:=210;CER;J:=250;CER;J:=280;CER;J:=320;CER;J:=350;CER;

           LINE(45,380,35,415);LINE(45,405,55,415);
SETCOLOR(15);LINE(35,415,45,405);LINE(55,415,46,382);

  I:= 30;  J:=420;  K:=120;  L:=20;  CER;
I:=469;J:=90;K:=160;L:=200;ONBAR;J:=300;L:=50;ONBAR;
```

```
SETTEXTJUSTIFY(1,1);
SETCOLOR(8);  OuttextXY(260,105,'MAIN MENU');
setcolor(15); OuttextXY(262,107,'MAIN MENU');
setcolor(7);  OuttextXY(261,106,'MAIN MENU');Settextstyle(0,Horizdir,1);

     GetDate(YEAR,MONTH,DAY,DAYOFWEEK);
     DATE:=CONCAT(MONTHS[MONTH],' ',IntToStr(DAY),'/',IntTOStr(YEAR));

setcolor(15);     OuttextXY(545,150,'FLEXIBLE HIGHWAY');
                  OuttextXY(545,165,'PAVEMENT');
                  OuttextXY(545,180,'DESIGN');
                  OuttextXY(545,195,'PROGRAM');
                  OuttextXY(545,215,'By');
                  OuttextXY(545,230,'AASHTO Method');
                  OuttextXY(545,260,'Release 1.0');
setcolor(14);
     OuttextXY(547,445,'Press ESC to quit');
     OuttextXY(545,385,'Press H to help');
     OuttextXY(46,161,'1');     OuttextXY(46,191,'2');
     OuttextXY(46,221,'3');     OuttextXY(46,261,'4');
     OuttextXY(46,291,'5');     OuttextXY(46,331,'6');
     OuttextXY(46,361,'7');

setcolor(15); Settextjustify(0,1);
     OuttextXY(75,162,'Thickness Determination For Initial Pavement');
     OuttextXY(75,192,'Changing Data And Thickness ReDetermination');
     OuttextXY(75,222,'Thickness Determination For Overlay');
     OuttextXY(75,262,'Preparing Swelling And Frost Heave Data');
     OuttextXY(75,292,'Preparing Roadbed Resilient Modulus Data');
     OuttextXY(75,332,'Printing Again Last Results on Screen');
     OuttextXY(75,362,'Printing Last Results From Printer And To File');
setcolor(14); OuttextXY(40,430,'Your Choice  :'); Settextjustify(1,1);
END;
PROCEDURE SCREEN1;BEGIN {------------ NEW FILE 1. SCREEN -------------------}

           Setviewport(0,0,639,479,CLIPON);Clearviewport;
 I:=469;J:=420;K:=160;L:=50;ON;I:=469;J:=120;K:=160;L:=290;ONBAR;

 I:=10;  K:=285; L:=20; J:=120;    WHILE J<451 DO BEGIN CER;J:=J+30;END;
 I:=305; K:=144; L:=20; J:=120;    WHILE J<451 DO BEGIN CER;J:=J+30;END;

Settextjustify(1,1);Settextstyle(0,Horizdir,1);
setcolor(14);
       OuttextXY(550,225,'INITIAL PAVEMENT');
       OuttextXY(550,245,'STRUCTURE DESIGN');
       line(525,265,575,265);
       OuttextXY(550,285,'GENERAL DATA');
       OuttextXY(550,305,'INPUT PHASE');
       OuttextXY(545,445,'Press H to help');
Settextjustify(0,1);
       OuttextXY(20,132,'1)  File Name To Be Opened       :');
       OuttextXY(20,162,'2)  Reliability Factor (%)       :');
       OuttextXY(20,192,'3)  Analysis Period (years)      :');
       OuttextXY(20,222,'4)  Maximum Possible Per. Period :');
       OuttextXY(20,252,'5)  Stage Strategy Number        :');
       OuttextXY(20,282,'6)  Initial Serviceability       :');
       OuttextXY(20,312,'7)  Terminal Serviceability      :');
       OuttextXY(20,342,'8)  Overall Standard Deviation   :');
       OuttextXY(20,372,'9)  Estimated Single Axle Load   :');
       OuttextXY(20,402,'10) Directional Dist. Factor (%) :');
       OuttextXY(20,432,'11) Lane Distribution Factor (%) :');
       OuttextXY(20,462,'12) Exponential Growth Rate (%)  :');
  END;
```

```
PROCEDURE SCREEN2;BEGIN {---------- SWELLING / FROST HEAVE SCREEN ----------}

    Setviewport(0,0,639,479,CLIPON);Clearviewport;

    I:=469;J:=420;K:=160;L:=50;ON;      I:=469;J:=170;K:=160;L:=240;ONBAR;
    I:=10;J:=170;K:=30;L:=170;CER;      I:=10;J:=360;K:=30;L:=110;CER;
    I:=50;J:=170;K:=80;L:=50;CER;       I:=50;J:=230;K:=80;L:=80;CER;
    I:=50;J:=320;K:=270;L:=20;CER;      I:=50;J:=360;K:=270;L:=20;CER;
    I:=50;J:=390;K:=80;L:=50;CER;       I:=50;J:=450;K:=270;L:=20;CER;
    I:=140;J:=170;K:=180;L:=20;CER;     I:=140;J:=200;K:=180;L:=20;CER;
    I:=140;J:=230;K:=180;L:=20;CER;     I:=140;J:=260;K:=180;L:=20;CER;
    I:=140;J:=290;K:=180;L:=20;CER;     I:=140;J:=390;K:=180;L:=20;CER;
    I:=140;J:=420;K:=180;L:=20;CER;
    I:=330;J:=170;K:=130;L:=20;CER;     I:=330;J:=320;K:=130;L:=20;CER;
    I:=330;J:=200;K:=130;L:=20;CER;     I:=330;J:=360;K:=130;L:=20;CER;
    I:=330;J:=230;K:=130;L:=20;CER;     I:=330;J:=390;K:=130;L:=20;CER;
    I:=330;J:=260;K:=130;L:=20;CER;     I:=330;J:=420;K:=130;L:=20;CER,
    I:=330;J:=290;K:=130;L:=20;CER;     I:=330;J:=450;K:=130;L:=20;CER;
Settextjustify(1,1);    setcolor(14);
         OuttextXY(550,250,'INITIAL PAVEMENT');
         OuttextXY(550,270,'STRUCRURE DESIGN');line(525,290,575,290);
         OuttextXY(550,310,'SWELLING & FROST');
         OuttextXY(550,330,'HEAVE DATA INPUT');
         OuttextXY(550,350,'PHASE');
         OuttextXY(545,445,'Press H to help');
Settextstyle(0,VERTdir,1);
         OuttextXY(25,255,'SWELLING');       OuttextXY(25,415,'FROST HEAVE');
         Settextstyle(0,HORIZDIR,1);         OuttextXY(90,180,'Swell');
         OuttextXY(90,195,'Rate');           OuttextXY(90,210,'Constant');
         OuttextXY(90,255,'Potential');      OuttextXY(90,270,'Vertical');
         OuttextXY(90,285,'Rise');           OuttextXY(90,400,'Maximum');
         OuttextXY(90,410,'Service-');       OuttextXY(90,420,'ability');
         OuttextXY(90,430,'Loss');           Settextjustify(0,1);
setcolor(15);       OuttextXY(145,180,'1> Moisture Supply   :');
         OuttextXY(145,210,'2> Roadbed S. Fabric :');
         OuttextXY(145,240,'3> Moisture Condition:');
         OuttextXY(145,270,'4> Plasticity Index  :');
         OuttextXY(145,300,'5> Layer Thickness   :');
         OuttextXY(55,330,'6>  Swell Probability           :',
         OuttextXY(55,370,'7>  Frost Heave Rate            :';
         OuttextXY(145,400,'8> Depth of Frost P. :');
         OuttextXY(145,430,'9> Drainage Quality  :',
         OuttextXY(55,460,'10> Frost H. Probability        :';
END;
PROCEDURE SCREEN3; {---- MATERIAL CHARACTERISTICS INPUT SCREEN ------------}
BEGIN
                Setviewport(0,0,639,479,CLIPON);Clearviewport;
                Settextjustify(1,1);
  I:=469;J:=420;K:=160;L:=50;ON;  I:=469;J:=120;K:=160;L:=290;ONBAR;
 I:=10; J:=120;K:=90;L:=40;  CER;
 I:=110;J:=120;K:=190;L:=40; CER; I:=310;J:=120;K:=150;L:=40; CER;
 I:=10;  K:=90; L:=20; J:=170;BAS;I:=10;  K:=90; L:=20; J:=200;BAS;
 I:=10;  K:=90; L:=20; J:=230;BAS;
 I:=10;  K:=90; L:=20; J:=260;    WHILE J<351 DO BEGIN CER;J:=J+30;END,
 I:=110; K:=190;L:=20; J:=170;    WHILE J<351 DO BEGIN CER;J:=J+30;END;
 I:=310; K:=150;L:=20; J:=170;    WHILE J<351 DO BEGIN CER;J:=J+30;END;
 I:=10;   J:=390;K:=110;L:=80; CER;    I:=130;  J:=390;K:=230;L:=20;CER,
 I:=130;  J:=420;K:=230;L:=20; CER;    I:=130; J:=450; K:=230;L:=20;  CER;
 I:=370;  J:=390;K:=90;L:=20;  CER; I:=370; J:=420; K:=90; L:=20;   CER;
 I:=370;  J:=450;K:=90;L:=20;  CER;
setcolor(14);
       OuttextXY(550,225,'INITIAL PAVEMENT');
       OuttextXY(550,245,'STRUCTURE DESIGN');line(525,265,575,265);
```

```
        OuttextXY(550,285,'MATERIAL');
        OuttextXY(550,305,'PROPERTIES');
        OuttextXY(550,325,'DATA INPUT PHASE');
        OuttextXY(545,445,'Press H to help');
        OuttextXY(55,140,'LAYER NAME');
        OuttextXY(205,140,'STRENGTH Parameter');
        OuttextXY(65,415,'DRAINAGE');
        OuttextXY(65,435,'COEFFICIENT');
        OuttextXY(385,140,'VALUE of Parameter');
 Settextjustify(0,1);

setcolor(15); OuttextXY(15,180,'Subgrade');
     OuttextXY(15,210,'Subbase C.');
     OuttextXY(15,240,'Base C.');

END;
PROCEDURE SCREEN4; {------------------ RESULTS SCREEN --------------------}
BEGIN
 Setviewport(0,0,639,479,CLIPON);Clearviewport;Settextjustify(1,1);

 I:=469;J:=420;K:=160;L:=50;ON;  I:=469;J:=120;K:=160;L:=230;ONBAR;
 I:=469;J:=360;K:=160;L:=50;ON;

 I:=10; J:=200;K:=100;L:=40;  CER; I:=115;J:=200;K:=80;L:=40; CER;
 I:=200;J:=200;K:=80; L:=40;  CER; I:=285;J:=200;K:=85;L:=40; CER;
 I:=375;J:=200;K:=85; L:=40;  CER;

 I:=10;J:=425;K:=315; L:=20;  CER;I:=330;J:=425;K:=130; L:=20;  CER;
 I:=10;J:=450;K:=315; L:=20;  CER;I:=330;J:=450;K:=130; L:=20;  CER;

 I:=10;  K:=100; L:=20; J:=250;    WHILE J<411 DO BEGIN CER;J:=J+25;END;
 I:=115; K:=80;  L:=20; J:=250;    WHILE J<411 DO BEGIN CER;J:=J+25;END;
 I:=200; K:=80;  L:=20; J:=250;    WHILE J<411 DO BEGIN CER;J:=J+25;END;
 I:=285; K:=85;  L:=20; J:=250;    WHILE J<411 DO BEGIN CER;J:=J+25;END;
 I:=375; K:=85;  L:=20; J:=250;    WHILE J<411 DO BEGIN CER;J:=J+25;END;

         Settextstyle(0,HORIZDIR,1);
setcolor(14);
        OuttextXY(550,215,'INITIAL PAVEMENT');
        OuttextXY(550,235,'STRUCTURE DESIGN');line(525,255,575,255);
        OuttextXY(550,275,'OUTPUT PHASE');
OuttextXY(549,436,'To Print Results');  OuttextXY(549,452,'PRINTER/FILE  P/F.');
OuttextXY(545,376,'ESC to MAIN MENU');  OuttextXY(545,392,'SPACE BAR to quit');
OuttextXY(155,212,'STRUCTURAL');        OuttextXY(155,227,'LAYER Co.');
OuttextXY(240,212,'STRUCTURAL');        OuttextXY(240,227,'NUMBER');
OuttextXY(330,210,'LAYER');             OuttextXY(330,222,'THICKNESS');
OuttextXY(330,233,'(inches)');          OuttextXY(418,210,'CONVERTED');
OuttextXY(418,222,'STRENGTH');          OuttextXY(418,233,'Par. Value');
OuttextXY(170,435,'New Computed Max. Performance Period :');
OuttextXY(140,460,'A New Overlay Neccessary For ');
Settextstyle(0,HORIZDIR,1);
END;

PROCEDURE CROSSSECTIONOVERLAY;{------ OVERLAYED CROSSSECTION -------------}
BEGIN   Setviewport(0,0,639,80,CLIPON);Clearviewport;
   Setviewport(0,0,639,479,CLIPON);
   Settextstyle(0,HORIZDIR,1);   RECTANGLE(60,100,340,90);
   RECTANGLE(50,130,350,100);RECTANGLE(40,180,360,130);
   LINE(60,95,20,100);LINE(340,95,380,100);
   Setfillstyle(10,3);BAR(61,91,339,99);
   Setfillstyle(11,3);BAR(51,101,349,129);
   Setfillstyle(9,3);BAR(41,131,359,189);
Setfillstyle(4,8);BAR(30,181,60,197);BAR(90,181,120,197);
```

```
                 BAR(150,181,180,197);BAR(210,181,240,197);
                 BAR(270,181,300,197);BAR(330,181,370,197);
Setfillstyle(5,8);BAR(60,181,90,195);   BAR(120,181,150,195);
                 BAR(180,181,210,195); BAR(240,181,270,195);
                 BAR(300,181,330,195);
    LINE(190,25,210,45);     LINE(210,25,190,45);
    LINE(190,25,185,30);     LINE(210,25,215,30);
    LINE(185,30,194,30);     LINE(215,30,206,30);

setcolor(14); LINE(405,85,405,195);   LINE(405,85,380,85);   LINE(405,195,380,195);
    LINE(380,85,385,83);     LINE(380,195,385,197);

SETLINESTYLE(3,0,3);
setcolor(15);  LINE(20,182,200,181);  LINE(200,181,375,182);
SETLINESTYLE(2,0,1);
      LINE(30,85,370,85);
SETLINESTYLE(0,0,1);

Settextstyle(0,VERTDIR,1);
setcolor(14);   OuttextXY(417,140,'Initial LAYERS');
Settextstyle(0,HORIZDIR,1);

       OuttextXY(105,190,'Compacted Subgrade');
       OuttextXY(115,145,'Granular Subbase');
       OuttextXY(115,155,'Course');

       Setviewport(469,420,630,470,CLIPON);Clearviewport;
       Setviewport(0,0,639,479,CLIPON);

       I:=469;J:=360;K:=160;L:=50;ON;
       I:=469;J:=420;K:=160;L:=50;ON;

setcolor(14); . OuttextXY(549,436,'To Print Results');
       OuttextXY(549,452,'PRINTER/FILE (P/F)');
       OuttextXY(545,376,'ESC to MAIN MENU');
       OuttextXY(545,392,'SPACE BAR to quit');



Settextjustify(1,1);   END;   END.{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{(*             UNIT PROGRAM CONSISTING ALL WARNING PROMPTS             *)}
{(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)(*)}
{$O+,F+,N+,E+} UNIT WARNINGS;  INTERFACE     USES CRT,GRAPH,SCREENS;
VAR SSIS,LSIS:CHAR;
PROCEDURE SESVER2;   PROCEDURE IKAZ1;
  PROCEDURE IKAZ2;      PROCEDURE IKAZ3;      PROCEDURE IKAZ5;
    PROCEDURE IKAZ6;      PROCEDURE IKAZ7;      PROCEDURE IKAZ8;
      PROCEDURE IKAZ9;      PROCEDURE IKAZ10;     PROCEDURE IKAZ11;
        PROCEDURE IKAZ12;     PROCEDURE IKAZ13;     PROCEDURE IKAZ14;
          PROCEDURE IKAZ15;     PROCEDURE IKAZ16;     PROCEDURE IKAZ17; IMPLEMENTATION

PROCEDURE SESVER2;                    BEGIN
SOUND(4500);DELAY(100);NOSOUND;SOUND(5000);DELAY(100);NOSOUND;END;
PROCEDURE IKAZ1;                      BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* REQUESTED FROM GROUP *)');
DELAY(2000);Clearviewport;            END;
PROCEDURE IKAZ2;                      BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* MUST BE NUMERIC VALUE *)');
```

```
DELAY(2000);Clearviewport;                END;
PROCEDURE IKAZ3;                          BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* REQUESTED FROM GROUP *)');
DELAY(2000);Clearviewport;                END;
PROCEDURE IKAZ5;                          BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* FROM GROUP, NUMERIC and INTEGER VALUE REQUESTED * ');
DELAY(2000);Clearviewport;                END;
PROCEDURE IKAZ6;                          BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* IN LIMITS, NUMERIC and INTEGER VALUE REQUESTED * ');
DELAY(2000);Clearviewport;                END;
PROCEDURE IKAZ7;                          BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* IN LIMITS, NUMERIC and REAL VALUE REQUESTED *)');
DELAY(2000);Clearviewport;                END;
PROCEDURE IKAZ8;  var gg,ff,hh,a:integer;
gg:=25;ff:=25;
for hh:=2 to 11 do begin a:=hh*hh-4;gg:=gg+21;ff:=ff+21;
Setfillstyle(1,8);SETCOLOR(7);FILLELLIPSE(ff,gg,a,a);
Setfillstyle(1,3);SETCOLOR(15);FILLELLIPSE(ff-5,gg-5,a,a); end; SESVER2;
setcolor(8);Setfillstyle(1,14);FILLELLIPSE(230,190,25,25);
Settextstyle(0,HORIZDIR,2);
Setfillstyle(1,8);bar(226,177,234,192);FILLELLIPSE(230,202,4,4);
SETCOLOR(15);OuttextXY(230,240,'NO NEW DATA');OuttextXY(230,260,'HAVE BEEN');
           OuttextXY(230,280,'GIVEN To');   OuttextXY(230,300,'PROCESS');
           OuttextXY(230,320,'YET');
DELAY(3000);                              END;
PROCEDURE IKAZ9;                          BEGIN
SESVER2;Setfillstyle(1,8);SETCOLOR(7);FILLELLIPSE(235,240,125,125);
Settextstyle(0,HORIZDIR,2);
WWR;      OuttextXY(230,240,'PRESS ANY');
          OuttextXY(230,260,'KEY WHEN');
          OuttextXY(230,280,'PRINTER IS');
          OuttextXY(230,300,'READY');
Settextstyle(0,HORIZDIR,1);     REPEAT UNTIL KEYPRESSED; END;
PROCEDURE IKAZ10;                          BEGIN
SESVER2;Setfillstyle(1,8);SETCOLOR(7);FILLELLIPSE(235,240,125,125);
Settextstyle(0,HORIZDIR,2);
WWR;      OuttextXY(230,240,'Input/Output');
          OuttextXY(230,260,'ERROR');
          OuttextXY(230,280,'IS PRINTER');
          OuttextXY(230,300,'READY ?');
Settextstyle(0,HORIZDIR,1);
DELAY(3000);                              END;

PROCEDURE IKAZ11;                           BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* MUST BE LESS THAN INITIAL SERVICEABILITY * ');
DELAY(2000);Clearviewport;                  END;
PROCEDURE IKAZ12;
var gg,ff,hh,a:integer;                     BEGIN
gg:=25;ff:=25;
for hh:=2 to 11 do begin a:=hh*hh-4;gg:=gg+21;ff:=ff+21;
Setfillstyle(1,3);SETCOLOR(15);FILLELLIPSE(ff-5,gg-5,a,a); end,
WWR;      OuttextXY(230,230,'YOU REQUIRED ONLY');
          OuttextXY(230,245,'ONE STAGE CONSTRUCTION');
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        OuttextXY(230,260,'GIVING STAGE STRATEGY');
        OuttextXY(230,275,'NUMBER AS 1. YOU MUST');
        OuttextXY(230,290,'SELECT 2 or 3 and');
        OuttextXY(230,305,'COMPUTE AGAIN');
DELAY(6000);                              END;
PROCEDURE IKAZ13;                         BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(50,40,'(* NAME WILL BE APPOINTED by PROGRAM * ');
DELAY(2000);Clearviewport;                END;
PROCEDURE IKAZ14;                         BEGIN
SESVER2;SETVIEWPORT(0,0,639,110,CLIPON);Clearviewport;SETCOLOR(1);
OuttextXY(50,40,'(* NAME REQUESTED *)');
DELAY(2000);Clearviewport;SETVIEWPORT(0,0,639,479,CLIPON);END;
PROCEDURE IKAZ15; VAR A:CHAR;             BEGIN
SESVER2;Clearviewport;SETCOLOR(1);Settextstyle(0,HORIZDIR,2);
OuttextXY(20,25,#15);Settextstyle(0,HORIZDIR,1);SETCOLOR(1);
OuttextXY(50,25,'  (*   ! NOTE THAT stage  strategy number will be changed as 1    *)');
OuttextXY(50,35,'  (*   due to NOT CONSIDERING Swell & Frost Heave and SELECTING   *)');
OuttextXY(50,45,'  (* Analysis Period And Max. Possible Performance Period equally. *)');
OuttextXY(50,55,'  (*   Overlay design cannot be required in this situation.       *)');
RWR;OuttextXY(50,75,'                  Press Any Key To Continue          ');
A:=READKEY; Clearviewport;                END;
PROCEDURE IKAZ16;     var gg,ff,hh,a:integer;     BEGIN
SETVIEWPORT(0,0,639,110,CLIPON);CLEARVIEWPORT;
SETVIEWPORT(0,0,639,479,CLIPON);Settextjustify(1,1);
gg:=25;ff:=25;  for hh:=2 to 11 do begin a:=hh*hh-4;gg:=gg+21;ff:=ff+21;
Setfillstyle(1,8);SETCOLOR(7);FILLELLIPSE(ff,gg,a,a);
Setfillstyle(1,3);SETCOLOR(15);FILLELLIPSE(ff-5,gg-5,a,a); end;
setcolor(8);Setfillstyle(1,14);FILLELLIPSE(230,160,40,40);
Settextstyle(0,HORIZDIR,2);
SESVER2;SETCOLOR(15);OuttextXY(230,255,'PLEASE WAIT !');
OuttextXY(230,285,'COMPUTING');
  FOR I:=218 TO 242 DO LINE(230,170,I,180);
SetLineStyle(0,0,1);
LINE(208,147,252,175);LINE(252,147,208,175);delay(2500);  END;
PROCEDURE IKAZ17;                         BEGIN
SESVER2;SETVIEWPORT(0,0,639,110,CLIPON);Clearviewport;SETCOLOR(1);
Settextstyle(0,HORIZDIR,2);
OuttextXY(20,40,#15);Settextstyle(0,HORIZDIR,1);
OuttextXY(50,40,'(* FILE IS NOT IN THE  DIRECTORY  OR IS ABSENT. PROGRAM * ');
OuttextXY(50,50,'(* WILL OPEN `AASHTO.DEF` DEFAULT FILE NOT TO BE HALTED * ');
DELAY(4000);Clearviewport;SETVIEWPORT(0,0,639,479,CLIPON);END;
```