OVERVIEW OF FLEXIBLE PAVEMENT DESIGN

by

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Early Road Building

History tells us that road building dates back to about 3500 B.C. which was soon after the discovery of the wheel. The Romans are usually considered as the first "scientific road builders". They began construction of the "Appian Way" in 312 B.C., this roadway is still in use and is a major tourist attraction. The invention of the automobile at about the beginning of the twentieth century (1900 A.D.) marks what is usually considered as the beginning of paved highways as they are known today. John MacAdam (1736-1836) is credited with what is known as "macadam construction". The "macadam construction" evolved into the following basic types:

(1) Traffic - bound macadam
(2) Water - bound macadam
(3) Bituminous - bound macadam
(4) Cement - bound macadam

The "macadam construction" was still moderately popular in the 1940's according to a report by the Bureau of Public Roads. The water-bound macadam and the bituminous-bound macadam were the most predominent of the macadam types in usage early flexible roadway construction in the United States. It appears likely that the water-bound macadam was the forerunner of flexible bases as they are used today. The bituminous bound macaday was also referred to as a penetration macadam. The macadam construction originally involved the use of a aggregate which was predominately one size or gradation. As the bituminous-bound macadam construction evolved it became a multi-layer procedure with the upper layers being smaller aggregate. It appears reasonable to think that surface treatments, seal coats, open graded friction courses and asphaltic concrete pavement may have all evolved from the bituminous bound macadam construction procedure.

ROAD TESTS AND FLEXIBLE PAVEMENTS

Road tests are usually performed to determine the effects of loads and repetitions of loads on various types of pavements. Over the years there have been several road tests that relate to flexible pavement, they are:

(1) Bates Road Test
(2) WASHO Road Test
(3) AASHTO Road Test
(4) Individual States
(5) Corps of Engineers

Probably the best known of these and possibly the most significant was the American Association of State Highway Officials (AASHO) Road Test in Ottawa, Illinois in 1958-1961.

DEFINITION OF PAVEMENT TYPES

The topic of this paper is "Overview of Flexible Pavement Design" but it appears desirable to define several other pavement types along with the flexible pavement. The various pavement types and their definition are:

(1) Flexible Pavement: The flexible pavement has been classically defined as a pavement that has an asphaltic concrete surface. Another well used flexible pavement definition is those pavements that are not made of Portland cement concrete. The true flexible pavement is one which consists of one or more unbound or unstabilized base courses resting on a natural subgrade and surfaced with a asphaltic material. In the flexible pavement the unbound base courses transmit the load to the natural subgrade by aggregate interlock or the contact between aggregates.

(2) Semi-Rigid Pavement: The semi-rigid pavement has the asphaltic surfacing but may have one or more base or subbase layers which are bound or cemented with material such as asphaltic or Portland Cement. The bound layers are assumed to have the ability to withstand tensile stress and/or tensile strains. These layers transmit load by slab action to the underlying layers or subgrade.

(3) Rigid Pavement: The classical definition of rigid pavement is a pavement that is bound by the use of Portland Cement. The rigid pavement exibits a slab like distribution of load stresses to the subbase or natural subgrade.

(4) Composite Pavement: The composite pavement is a rigid pavement which has been overlaid with asphaltic concrete. Its behavior in distribution of the load stresses is essentially the same as the rigid pavement.

PAVEMENT DISTRESS TYPES

Generally distress in pavements can be divided into two categories, structural distress and functional distress.

Structural distress or load carrying capacity sometimes is referred to as the engineers distress. In the early stages of structural distress the effects may not be serious enough to effect the functional aspects of a pavement. Such things as minor cracking, excessive deflection.

Functional distress more nearly relates to the highway users preception of how the highway is serving their needs. A loss in ride comfort would likely be looked upon by the user as a functional distress or failure. Safety related items such as the skid resistance of the pavement would be considered as a function skid resistance of the pavement would be considered as a function distress if the skid resistance was causing a safety problem.

SERVICEABILITY CONCEPT

One of the major achievements of the AASHO Road Test was the development of the serviceability concept. The serviceability of a pavement is defined as the ability to serve high-speed, high-volume automobile and truck traffic. The rating scale which is known as the "Present Serviceability Index (PSI)" runs from 0 to 5.0. Quanlitative description of scale value versus pavement performance is as follows:

5.0 - 4.0	Very Good
4.0 - 3.0	Good
3.0 - 2.0	Fair
2.0 - 1.0	Poor
1.0 - 0.0	Very Poor

The Present Serviceability Index concept is based on being able to correlate user opinion to some measure of pavement roughness.

Present Serviceability Rating (PSR) is the "rating" value given to a pavement by a panel of raters such as the group used at the AASHO Road Test. The panel of raters should reflect the opinion of a pavements serviceability in terms of the user public. Since it is not possible for "the panel" to go to all projects it becomes necessary to adopt some electro-mechanical means of measuring pavement roughness or smoothness. There are several definitions which are important with respect to pavements and their performance or serviceability. These definitions as defined by AASHTO are as follows:

Serviceability - the ability at time of observation of a pavement to serve high-speed high volume automobile and truck traffic.

Present Serviceability Rating (PSR) - the mean value of the independent subjective ratings by members of a special Panel for the AASHO Road Test as to the serviceability of a section of highway.

Pavement Serviceability Index (PSI) - a number derived by formula for estimating the serviceability rating from measurements of certain physical features of the pavement.

Pavement Performance - the trend of serviceability with load applications.

There are a number of devices which are capable of measuring road roughness. Some of these devices are:

1. U.S. Bureau of Public Roads roughometer (BPR)
2. CHLOE profilometer
3. Rolling straightedge
4. Surface dynamics profilometer
5. Portland Cement Association (PCA) road meter
6. Mays Road Meter
7. Precision leveling
8. SIOMETER (Walker)

In order for these devices to be able to measure Pavement Serviceability Index (PSR) it is necessary to calibrate them with a group of pavements which have been "panel" rated to determine their Present Serviceability Rating (PSR).

Measurements of pavement roughness on the various pavement test sections of the AASHO Road Test were made with the BPR roughometer and compared to the measurements made with the CHLOE profilometer which was developed at the Road Test.

In February of 1967, during the course of Research Project 73, the Texas State Department of Highways and Pubic Transportation (TSDHPT) Then named Texas Highway Department (THD), took delivery of a new profilometer. This profilometer was called the Surface Dynamics (SD) Profilometer. Also in connection with Project 73 a panel rating was conducted on a group of pavements in and around the Austin, Texas area. Subsequently the new SD profilometer was used to profile the sections which previously been rated by the panel. Following these two steps, equations were developed which correlated the SD profilometer to the panel rating thus the SDHPT had a device available which could rapidly measure profile information which could then be reduced to a Pavement Serviceability Index (PSI) value.

In 1967 the Mays Ride Meter was designed by Ivan K. Mays and is fabricated and sold by the Rainhart Company. The Mays Road Meter has become the SDHPT's principal pavement roughness inventory tool. Calibration roadway sections are maintained in and around Austin, Texas. Periodically profile of each section is determined by use of the SD Profilometer. Subsequently these same sections are profiled by the Mays Road Meters which results in a calibraion of the Mays Road Meter.

In January, 1982 SDHPT purchased a new profilometer which is designated as the 690D Surface Dynamics Profilometer. The acquisition of the new profilometer and its calibration are a part of Research Project 251. As a part of Project 251 a new users panel was formed and sections of roadway were rated so that the new profilometer could be calibrated. The new raters panel rode in automobiles which reflect current production models. This should allow SDHPT to calibrate all profile measuring equipment to the current user opinions on roughness or smoothness of pavements.

ELEMENTS OF THICKNESS DESIGN

At mid-twentieth century when the author was in engineering college there were three elements of pavement thickness design which were in general usage. These elements are:

1. Magnitude and method of application of wheel loads
2. Function of pavement and base in transmitting the load to the subgrade
3. Measure of subgrade support

Terminology or pavement jargon change with time and new pavement experts enter the scene, but these three basic elements of pavement thickness design appear to still be applicable. If the pavement is to function or perform satisfactorily the wheel loads and repetitions thereof must be accommodated. Also the pavement surface base and subbase layers must be of sufficient thickness and quality to transmit the loads into the subgrade without causing either a catastrophic failure due to one large wheel load or the accumulated failure due to repeated loads of lesser magnitude.

In subsequent sections of this report these three elements of thickness design will be discussed. An understanding of the loads applied to a pavement, the resulting stresses and an understanding of flexible pavement design methodologies will allow the designer to select a flexible pavement design which will provide a pavement that has satisfactory functional and structural characteristics.

DESIGN WHEEL LOADS

Pavement structure design must consider two wheel load concepts, the static wheel load and repetitions of wheel load. The findings of the various road tests indicated that the effects of wheel loads are accumulative many small wheel loads can cause the same damage that fewer repetitions of a larger wheel load.

The need to consider the static wheel load in flexible pavement is based on the fact that pavements for city streets, farm roads and other light duty pavements will usually have a very small truck traffic component in their traffic mix, but some of these trucks may have very large wheel loads. It is possible for some light duty pavements to suffer extensive pavement damage due to the passage of only one very heavily loaded truck. Its this one very large wheel load that must be accounted for by use of a static wheel load pavement design concept. This will be further discussed under design methodologies.

Another of the very important results of the AASHTO Road Test was the development of a procedure for converting mixed traffic equivalent 18-kip single-axle loads. The use of 18-kip single-axle equivalents as a traffic variable has been widely accepted in both flexible and rigid pavement design. Basically the procedure allows the conversion traffic with various axle loads to an equivalent 18-kip single-axle load. It was possible to determine the equivalency factor for various axle loads based on the relative damage to the AASHO Road Test sections. The Road Test had test loops that contained various pavement design. For each loop the trucks were all loaded to a constant axle-load. Also some of the loops contained replicate pavement sections of other loops. With this information it was possible to determine the equivalency factors based on damage to the pavement.

The equivalent 18-kip single-axle load concept is used by a majority of the states in their pavement design processes. Additional discussion of 18-kip single-axle equivalents will be made in the section on design methodologies.

FUNCTION OF PAVEMENT (SURFACE) AND BASE IN TRANSMITTING THE LOAD TO THE SUBGRADE

Figure 1, Simple Flexible Pavement Section, and Figure 2, Complex Flexible Pavement Section, are an indication of the variation in flexible pavement designs. In the simple flexible pavement section the surfacing would likely be a surface treatment or a thin asphaltic concrete. The flexible base in this type of construction would typically be unbound. The flexible base would be placed directly on the natural subgrade. The basic function of the surfacing is to act as a wearing course or to protect the base course from the wearing action of the wheel loads. The surfacing also protects the base course from the intrusion of surface moisture which would tend to soften the base and reduce its load carrying or spreading capability. The function of the base course is to transfer the load into the subgrade without causing compressive or shear failures of the subgrade. The base course depends on aggregate interlock to spread the load and thereby reducing its unit pressure to an acceptable level before they are transferred to the subgrade.

Figure 3, Load Distribution In Flexible Pavements, is a somewhat crude concept of how loads were distributed in flexible pavements. This concept seemed to be in vogue in the early 1950's. The concept of spreading the load to the subgrade doesn't appear to be quite this simple, but it does illustrate the role that the surfacing and base material must play if the load magnitude is to be reduced to a level which will not fail the subgrade in compression. It was and is assumed that the wheel load (P) is distributed over a circular area as follows:

Tire Pressure = Wheel Load/Contact Area

By knowing the tire pressure and design wheel load and by assuming that the contact area was circular the contact area radius (a) could be computed. If some assumption or determination of the load spreading angle (O) could be made then stresses could be calculated at any depth in the pavement structure. If allowable compressive stresses to the subgrade were known then the thickness of base material could be calculated. From this it would appear that base materials with good load spreading capability would allow a lesser thickness then those of lesser load spreading ability. This good load spreading capability is a function of how well the base material is graded, how hard or abrasion resistant the aggregate is and how well the material retains these quantities when exposed to high mositure levels.

The pavement structure diagrammed in Figure 2, Complex Flexible Pavement Structure Section, cannot be explained in the simple terms of the true flexible pavement shown in Figure 1 and discussed above. The discussion of the pavement stucture shown in Figure 2 will be deferred to the section of this paper which discusses pavement design methodologies.

MEASURES OF SUBGRADE SUPPORT

The measurement of subgrade support is just one facet of the larger picture which is materials characterization in general. For determination of subgrade support for flexible pavements the following is a partial listing of methods:

1. Plate loading
2. Triaxial
3. California Bearing Ratio (CBR)
4. Resilient modulus

The above noted measures of subgrade support for flexible pavements are only a sample of the methods available. In Texas the SDHPT uses two basic methods of quanifying subgrade support for flexible pavements, they are:

1. Texas Triaxial (Tex-117-E)
2. Dynaflect stiffness coefficients

If the Texas SDHPT elects to use the flexible pavement design procedures proposed in the new AASHTO Guide for Design of Pavements (July 15 1985) then it will be necessary to quantify the resilient modulus of the subgrade because it is an input to the AASHTO procedure.

The quantification of subgrade support is one of the major factors in flexible pavement design. The subgrade must support the pavement structure and the pavement structure transmits the wheel loads to the subgrade. If the support value of the subgrade is not evaluated correctly the pavement layers thickness and strength will most likely be either under designed or over designed. If the pavement is under designed because the subgrade support was rated too high the end result will be a failure of both the pavement and the subgrade. On the opposite side of the picture, an under evaluation of the subgrade will lead to pavement thickness greater than needed which will be uneconomical.

STRESSES, STRAINS AND DEFLECTIONS IN FLEXIBLE PAVEMENTS

Layered elastic theory or a multilayered elastic system is a good analysis procedure which will allow an understanding of the stresses, strains, deflections (deformations) which occur in a multilayered pavement structure such as was pictured in Figure 2, Complex Pavement Stucture Section.

Figure 4, Generalized Multilayered Elastic System, illustrates the general concept of a multilayered elastic system. For each pavement layer the thickness, the elastic modulus and Poisson's Ratio must be input to the calculation procedure. For the subgrade layer the thickness is omitted because the procedure assume that it is infinite in thickness. Linear elastic thoery has been available since 1885 when Boussinesq presented his one layer elastic concept. In the 1940's Burmister expanded the theory to a two layer system. It took the advent of the high speed electronic computer to make layered elastic theory a practical design and analysis tool. The computer made it possible to economically solve for stresses, strains and deformations in a multilayerd elastic system.

Most computer programs for multilayered elastic systems allow multiple loads to be applied to the system. Usually the loads may be input as a "load and radius" combination or a "unit stress (tire pressure) and radius" combination. Figure 5, Coordinate System for Multilayered Elastic Systems" is one of the means by which some programs define the location of the loads and the points at which stress, strain or deflections are to be made.

DEFLECTIONS IN FLEXIBLE PAVEMENT STRUCTURES

Figure 6, Typical Flexible Pavement Deflection Basin, depicts the deflection basin or bowl that is expected to occur in a linear elastic flxible pavement structure as a result of a single applied load. As load is applied to a multilayered elastic pavement system each layer is compressed to a degree depending on its thickness, elastic modulus of the material and Poisson's Ratio. If a summation of vertical compressive strains for each layer was made at successive vertical planes normal to the "X" axis the deflective pavement surface shows in Figure 6 could be computed.

The deflections basin under a given load or loads can also be measured directly by general devices, three of which are:

1. Benkelman Beam
2. Dynaflect
3. Falling Weigh Deflectometer

The Dynaflect is a very popular device for measuring deflections in existing flexible pavements, Figrue 7, Dynaflect Loading and Measurement Layout, is a schematic of the loading and measurement procedure.

When measured deflections are available they can be used to characterize the elastic layer properties of existing pavement structures. The procedure requires that elastic moduli values be assumed for each of the pavement layers and then multilayered theory (computer program) is used to calculate a deflection basin. The calculated basis is compared with the measured basin and the process is iterated until there is good agreement between measured and calculated basins.

When deflections are taken on an existing pavement at some equal or known distance along the roadway the deflections themselves as well as computed moduli of the layers can be used to generate a profile that characterizes either pavement structure condition or subgrade condition along the project.

FLEXIBLE PAVEMENT DESIGN METHODS

There appear to be about as many flexible pavement methods as there are self-professed flexible pavement design experts. Some of the more widely recognized flexible pavement design methodologies are:

1. AASHTO Flexible-Pavement Design Procedure
2. Multilayer Elastic Analysis
3. The Asphalt Institute Design Procedure
4. Texas Flexible Pavement Design System (FPS)
5. Texas Triaxial Design (Tex-117-E).

The above is just a small sampling of the known methods of flexible pavement design.

The AASHTO Flexible Pavement Design Procedure was a development of the AASHO Road Test. As noted earlier, the AASHO road Test took place in 1958-1961. During the time since the end of the Road Test and the present time the AASHTO procedures for pavement design have been labeled as "interim". Webster's dictionary defines the adjective "interim" as temporary. This temporary procedure has been around for some 24-25 years. Over the last several years the AASHTO Joint Task Force on Pavements has been working with a consultant group under NCHRP Project 20-7/24 to revise the "interim" guide. One of the giant steps in this revision will be the removal of the word "interim". It is expected that the "AASHTO Guide for Design of Pavement Structures" will be published sometime in 1986.

Texas has not used the AASHTO Flexible Pavement Procedures, but has a related procedure known as the Flexible Pavement Design System (FPS) which will be discussed later.

The Multilayer elastic analysis procedure was discussed earlier in the report. The procedure is based on the theory of elasticity. The concept dates back many years, but the recent usage and acceptance of the procedure is made possible by the use of high speed electronic computers. For elastic theory to apply the material of each layer must conform to the following:

1. Material properties of each layer are homogeneous.
2. Each layer except for the bottom layer is of a finite thickness and all are infinite in the lateral direction.
3. Each layer is isotropic.
4. Full friction is developed between layers at each interface.
5. Surface shearing forces are not present at the surface.
6. Stress solutions are characterized by two material properties for each layer, the Poisson's ratio and the elastic modulus.

Some of the current day computer programs allow a varying friction at the interfaces and also allow the input of shear forces to the face of the pavement. One of the major difficulties with the use of mutilayer elastic analysis centers about the assumption that typical pavement materials act linearly due to the stress applications which large wheel loads apply. Tests indicate that cohesive soils are non-linear in their reaction to load. The standard traixial test at various confining pressures varifies the non-linearity of the cohesive soils. Multilayer elastic systems can be used for design and analysis, but basically the design is an iterative procedure, a structure is assumed (input) and calculations of stress and strain are made and compared to limiting values. When the assumed structure stresses/strains meet the limiting criteria it is assumed that that particular strategy is satisfactory.

The Asphalt Institute published their new thickness procedure in 1981. This procedure is titled "Thickness Designs - Asphalt Pavements For Highways and Streets", Manual Series No. 1 (MS-1), September 1981. The procedure is based on the use of elastic theory. The Asphalt Institute procedure can be done by use of the charts and tables published in MS-1 or by the use of the DAMA computer program. The manual presents a structural thickness design procedure for pavements utilizing asphalt cement or emulsified asphalt in all, or in part of the pavement structure.

Guidelines are offered for defining subgrade properties, materials properties, and traffic values. Also there are procedures for stage construction design and economic analysis.

The Texas Flexible Pavement Design System (FPS) is the principal flexible pavement design procedure used in the Texas SDHPT at this time. The FPS procedure is sponsored by the Highway Design Division of the Texas SDHPT. The FPS procedure will be presented in more detail in a later section of this report.

The Texas Triaxial Design procedure is defined in the File D-9 Manual of Testing Procedures and is Designated as Test Method-Tex-117-E, Triaxial Compression Tests For Disturbed Soils and Base Materials. Test Method Tex-117-E may be divided into two very general areas, a classification procedure for base and subgrade materials and a base thickness design procedure. The Texas Triaxial Design procedure is sponsored by the Materials and Test Division (File D-9) of the Texas SDHPT. As a design tool, this procedure is most useful for thickness design of flexible pavements which utilize the thin surfacing and unstabiized base concept. The Texas Triaxial Design procedure uses the design wheel load (static load) as its basic traffic data input. Because of this feature the procedure is most applicable for those projects such as farm-to-market roads or light urban streets where the number of 18-KSA equivalents is low, but a few excessively heavy loads exist in the traffic mix.

THE TEXAS FLEXIBLE PAVEMENT DESIGN SYSTEM (FPS)

As previously noted, the Highway Design Division, of the Texas SDHPT sponsors the Texas Flexible Pavement Design System (FPS). The official User's Manual for FPS is titled as follows:

> "Texas State Department of Highways and Public Transportation, Part I, Flexible Pavement Designers' Manual, Highway Design Division, 1972 (Revised through May 1983)".

FPS consists of three computer programs:

1. FPS-11 (Principal program)
2. Stiffness Coefficient Program
3. Profile Analysis Program

The purpose of the FPS system is to provide, from available materials, a pavement that can be maintained above a specified level of serviceability, over a specified period of time, with a specified reliability, at a minimum overall total cost.

The FPS-11 Program has the capability of designing a new flexible pavement (or rehabilitation of an existing pavement structure) or an Asphalt Concrete Pavement overlay for an existing flexible pavement.

The FPS system objective of providing a pavement design "at a minimum overall total cost" is the backbone of the program. The optimization procedure is an optimization of total cost for a given analysis period. Items considered in the total cost optimization are:

1. Initial construction cost,
2. Overlay construction,
3. User cost (delay),
4. Routine maintenance cost, and
5. Salvage value.

Sixty-six inputs to the system are provided by the FPS-11 program. These inputs are in ten categories listed below. The parenthetical numbers indicate the inputs on each card or category.

Card No.	Category
1	Project Identification (8)
2	Project Comments (1)
3	Basic Design Criteria (6)
4	Program Controls and Constraints (5)
5	Traffic Data (8)
6	Environmental and Subgrade (5)
7	Construction and Maintenance Data (9)
8	Detour Design for Overlays (7)
9	Existing Pavement and Proposed ACP (8)
10	Paving Materials Information (9)

A very important feature in training a flexible-pavement designer in the use of the FPS system is the understanding or recognition of the major inputs to FPS. Stated in another way, What are the most sensitive inputs? If pavement design performance is the major objective, then the input items contained in the FPS performance equation should be examined. The performance equation input items are:

1. Serviceability Index
    a. Initial serviceability

   b. Serviceability after ACP overlay
   c. Terminal serviceability

2. Materials Stiffness Coefficients (or Surface Curvature Index)

3. Traffic (18-KSA applications)

4. Temperature Constant

5. Swelling Clay Properties

FPS DESIGN PROGRESS

The FPS design process can be divided into the following basic steps:

1. Develop Input Data

   (a) Measure Field Data
   (b) Select Materials Properties
   (c) Secure Traffic Data

2. Compute with the FPS Program

3. Select best pavement design strategy.

Field data for use in FPS consists of Dynaflect deflections of existing pavements. From the Dynaflect deflections stiffness coefficients for the composite pavement structure and the subgrade can be calculated. In the "new" pavement design mode, the strength of the subgrade and the proposed pavement layers are input in terms of stiffness coefficients. The FPS program uses the stiffness coefficients and layer thicknesses to determine the anticipated Dynaflect deflection basin for the design strategy in qeustion. The shape of this basin is used by the program to compute a Surface Curvature Index (SCI) value. The SCI value represents the bending strength for the design in question. The SCI value is one of the prime inputs to the FPS performance equation. When the FPS program is to be operated in the ACP Overlay mode the input to FPS which represents the strength of the existing pavement structure is the measured SCI value and a corresponding standard deviation of SCI.

The stiffness coefficient computer program is used to process the Dynaflect data and compute properties such as the composite pavement stiffness coefficient (AP2), subgrade stiffness coefficient (AS2), Dynaflect basin deflections and Surface Curvature Index (SCI) which is part of the "select materials properties" phase of the data development phase.

Another very important part of the data development process is the securing of traffic projections for input to FPS. Traffic data is secured from the Transportation Planning Division, D-10. If possible the request should be made to D-10 in writing as far in advance of the need as possible. D-10 should be advised of any unusual circumstances expected on the project within the design period such as new developments, proposed highway re-routings, materials hauls, an any other items which might affect traffic projections. When requesting traffic for use in FPS it should be based on a 20 year projection period. If the design analysis period is to be shorter or longer than 20 years the FPS program will make the necessary traffic adjustments. The beginning of the 20 year projection period should be based on the pavement designers' best judgement as to when the project will be completed and opened to traffic.

Computing with FPS consists of coding the FPS data sheets, keying in the data and submitting the job for execution. Appendix A, Coding of Example Design Problem, is a typical example problem for the new pavement design mode. After coding the input data the designer must either key the inputs to "ROSCOE" or have this done by automation personnel, subsequently the coded data is submitted for execution.

Appendix B, Computer Output for Example Design Problem, is the end result of the FPS design process, all that remains is the selection of a design strategy.

When the FPS printout is returned to the designer, their first step should be a careful proofreading of the first two pages. The first two pages of output are an echo print of the input data. This check must be made to assure that the intent of the designer has been achieved.

Reviewing the FPS output will reveal that FPS will use the building block principal to design the pavement. FPS will increment through the first layer plus subgrade in an attempt to find designs meeting design criteria. Next FPS will increment through the first two layers plus subgrade looking for designs. This step process will follow until all layers are included in the design process. The designer will note that FPS prints out the optimum (lowest total cost) design in each group. Finally FPS will provide a summary listing of designs by layer code in order of least total cost.

The design selection process will involve reviewing the FPS output and selecting the design strategy which best meets the designers criteria. This final selection may not always be the least cost design. The designer is encouraged to document his reasons for selecting a given strategy.

The use of the ACP Overlay feature of FPS-11 differs from the new pavement mode in one major respect. In the new pavement mode the designer submits information on the cost, stiffness coefficient, and allowable thickness range for each material layer proposed for the design. With the ACP Overlay procedure there is an existing pavement structure in place which is to receive the overlay. The strength of the existing structure is input to FPS as the average Surface Curvature Index (SCI) value for the design section and the standard deviation of the SCI. All other coding is essentially the same for both design modes.

PAVEMENT DESIGN ASSISTANCE

The Pavement Design Section of the Highway Design Division (File D-8) offers both pavement design training and consultative assistance in the area of pavement design and performance.

SUMMARY

It is hoped that the very brief look at flexible pavement design will give the pavement designer and the potential pavement designers a brief idea on what a flexible pavement consists of and the design procedures which can be used to successfully design a flexible pavement. To fully appreciate the area of pavement design a person needs to be aware that the Texas SDHPT spends approximately fifty percent of its construction funds for the items which are typically noted as pavement items. Since such a large percentage of our funds are spent on pavement items it is apparent that the Department should be making a design effort which is in keeping with the funds spent if the taxpayer is expected to get his "money's worth".

To get full worth for the money spent it is obvious that pavement designs must be optimized against performance. All will agree with the optimization concept, but it is seldom achieved or practiced. The timeliness of a pavement design has a lot to do with optimization. If the proper or optimum pavement design is not available to the engineer responsible for programs when program funds are set for a project it appears that the likelihood of programming the proper amount of funds will not occur. Most likely there will be an inadequate amount of funding available to the project and the actual design at some future date will be short of optimum. An overprogramming of funds on the other hand will give a satisfactory pavement design, but the over usage of funds will be reflected in other projects.

It must be concluded that pavement design is a very important area of highway design. With the importance of pavement design established it becomes evident that both administrative and design personnel must be willing to increase material and personnel allocations to achieve the overall objective of better performing highways at lesser unit costs.

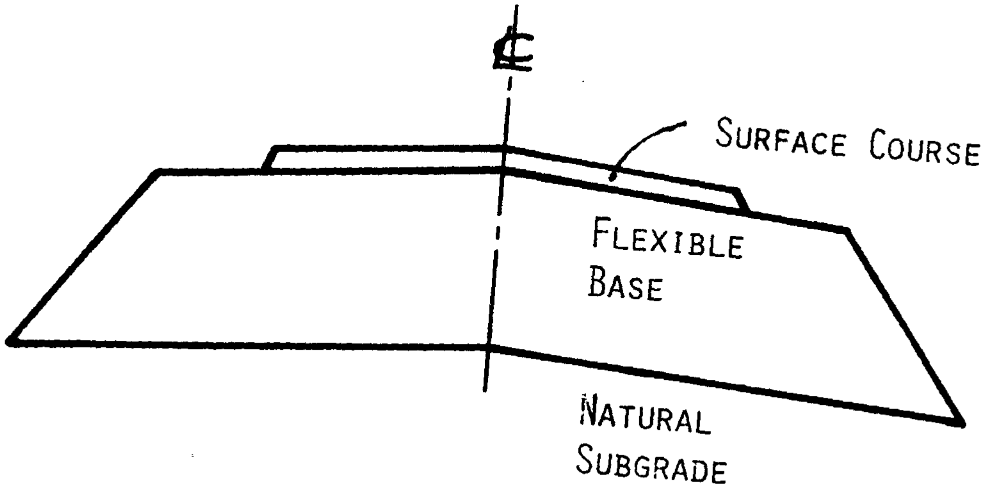


FIGURE 1
Simple Flexible Pavement Structure Section

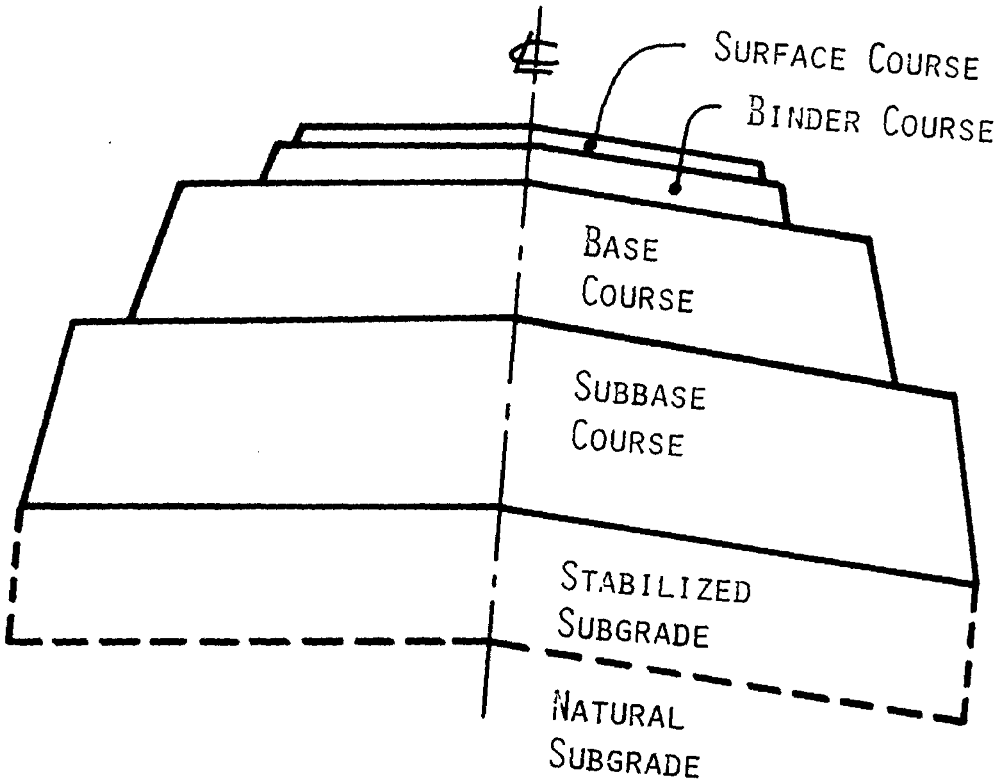


FIGURE 2
Complex Flexible Pavement Structure Section

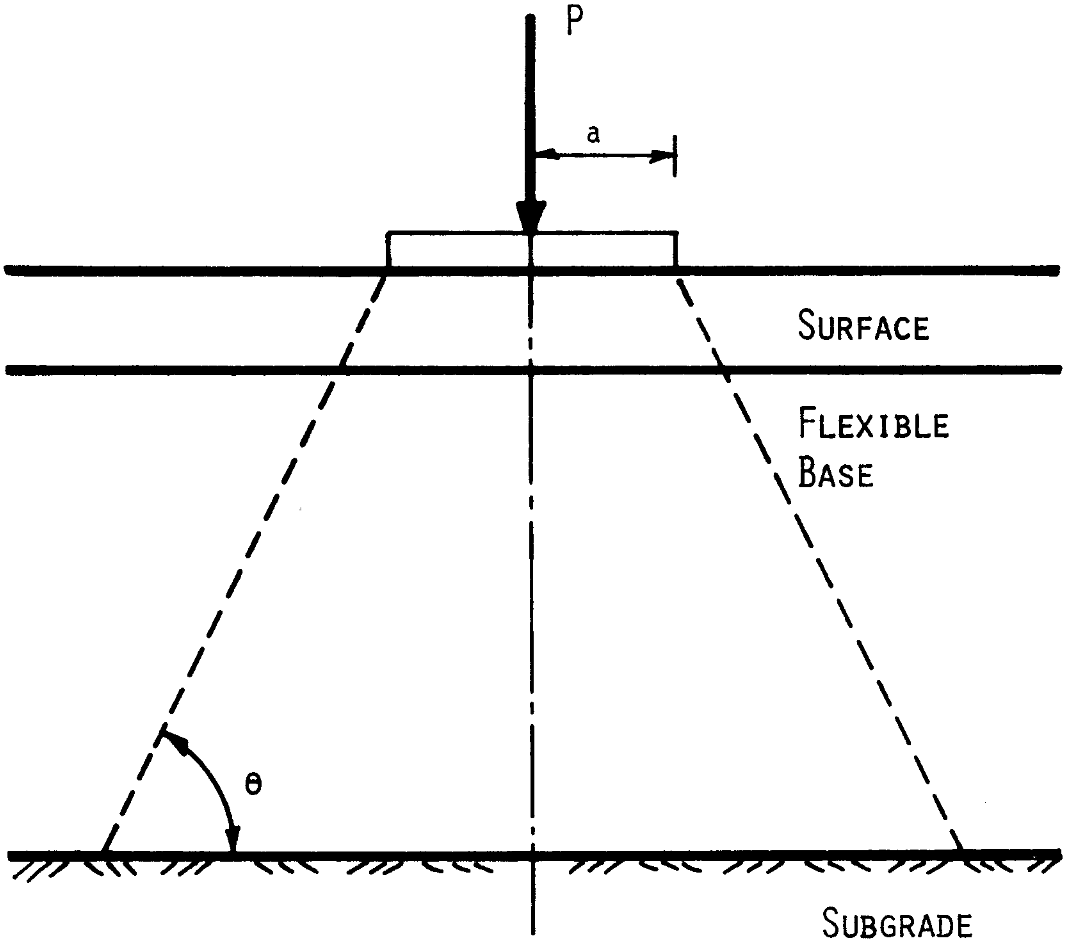


FIGURE 3

LOAD DISTRIBUTION

IN FLEXIBLE PAVEMENTS

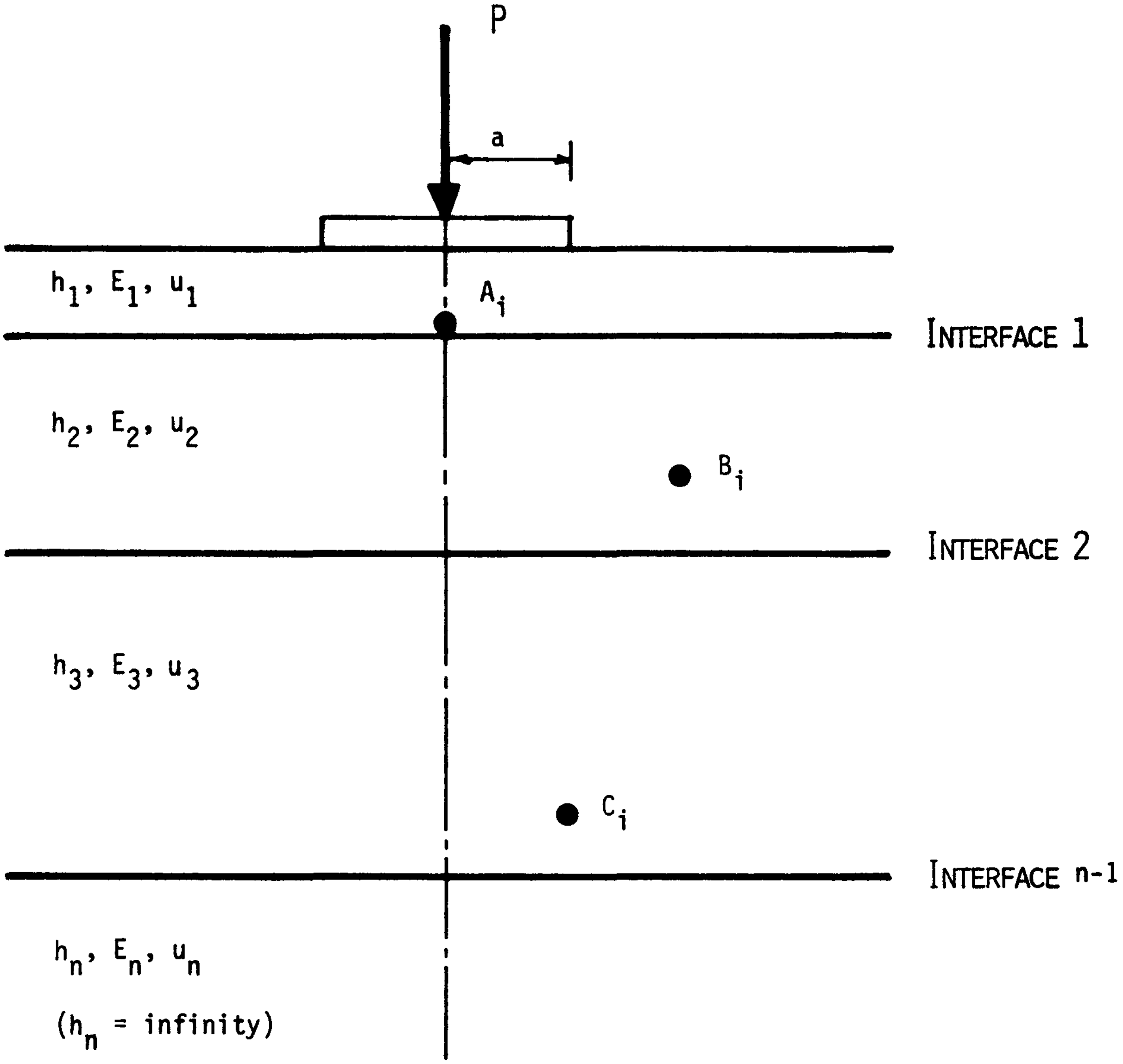


FIGURE 4

GENERALIZED MULTILAYERED ELASTIC SYSTEM

h = LAYER THICKNESS
E = ELASTIC MODULUS OF MATERIAL
u = POISSON'S RATIO
A_i, etc = CALCULATION LOCATIONS

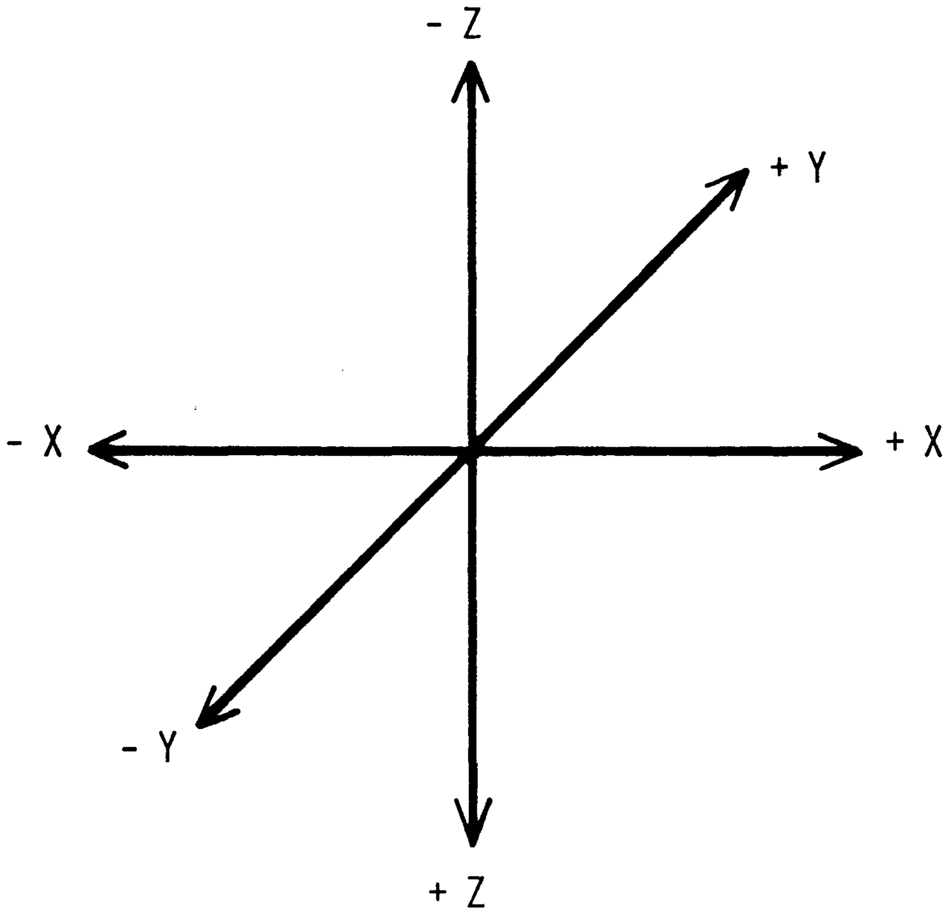


FIGURE 5

Coordinate System For
Multilayer Elastic Systems

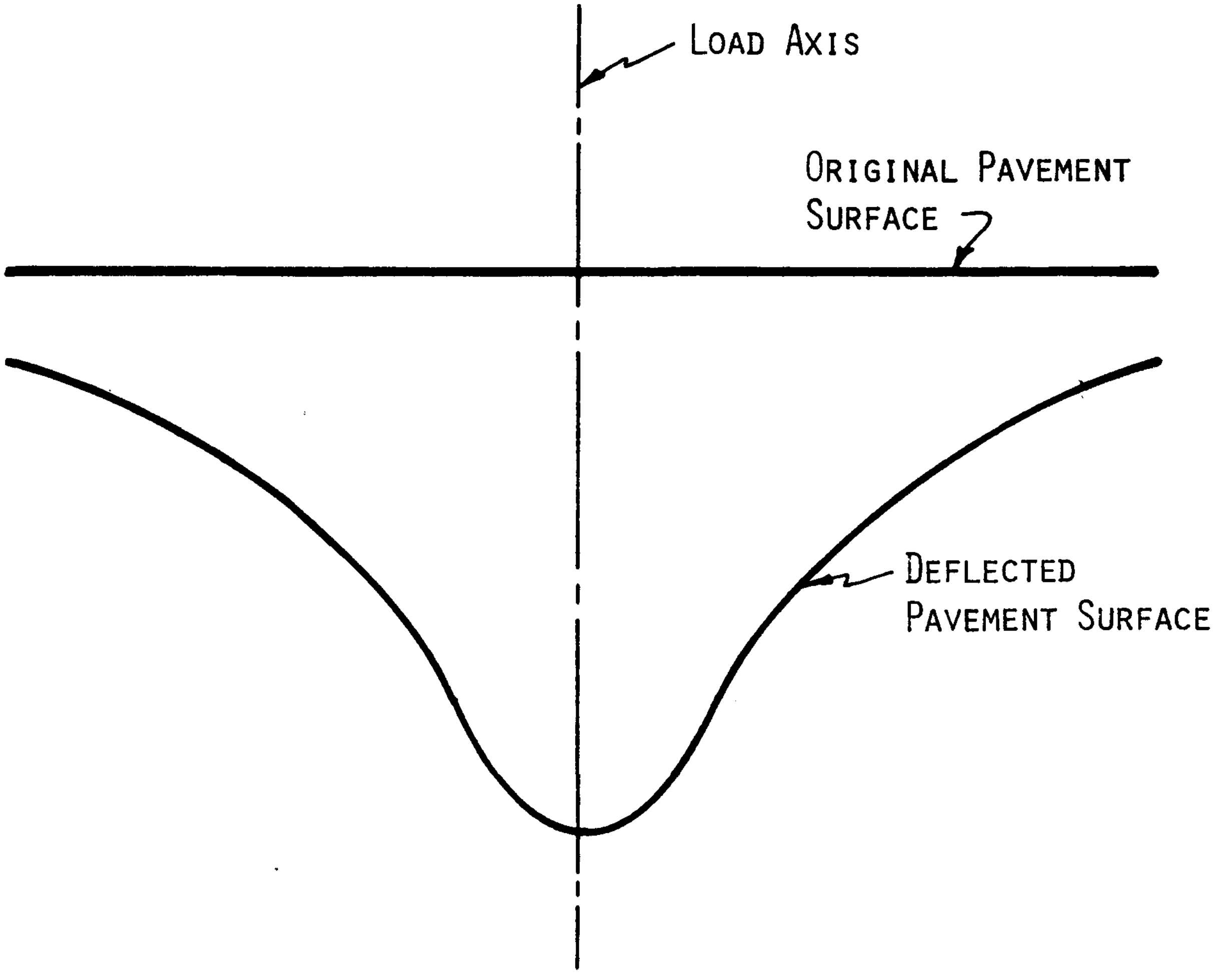


FIGURE 6

TYPICAL FLEXIBLE PAVEMENT
DEFLECTION BASIN

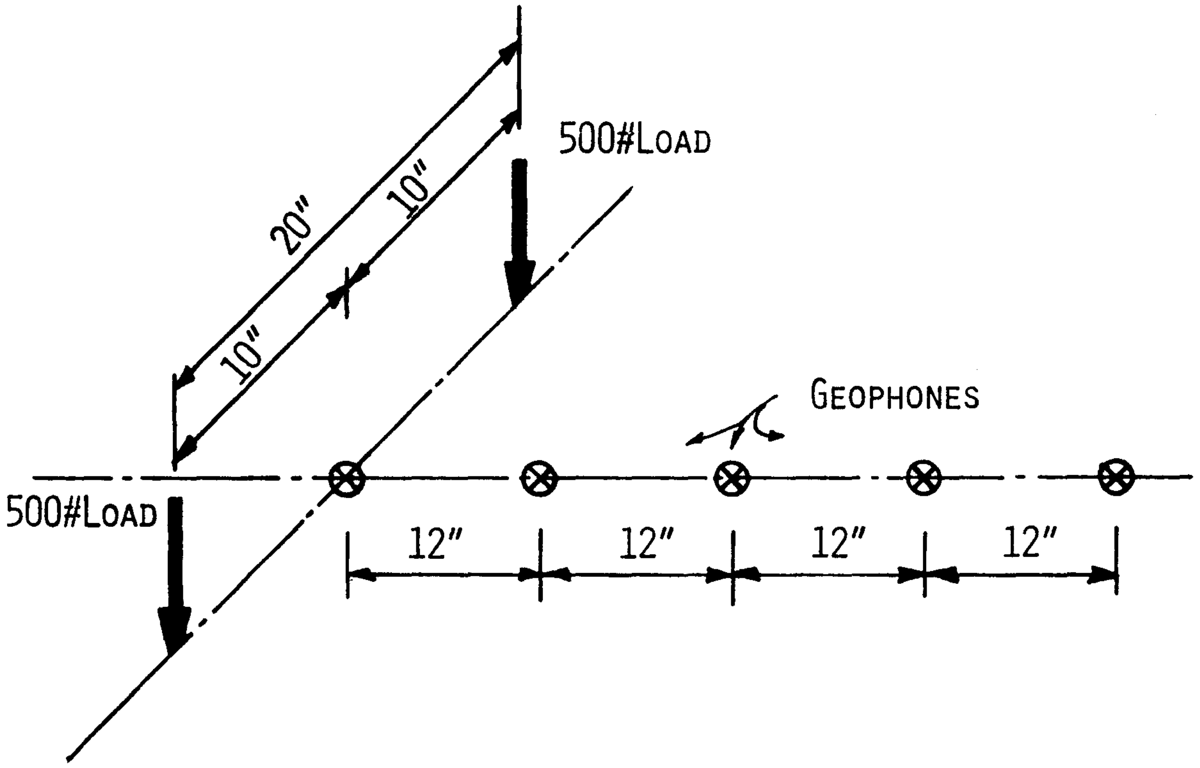


FIGURE 7

Dynaflect Loading and Measurement Layout

APPENDIX A

Coding of Example Design Problem

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PROJECT IDENTIFICATION

1.0 Card type ______ 01
1 2

1.1 Problem number ______ X-1
3 4 5

1.2 District ______ 48
6 7

1.3 County ______ SOFTNWET
8 9 10 11 12 13 14 15 16 17 18 19 20 21

1.4 Control ______ 0080
22 23 24 25

1.5 Section ______ 07
26 27

1.6 Highway ______ BUMPY 1
28 29 30 31 32 33 34 35 36 37

1.7 Date ______ 09-13-85
38 39 40 41 42 43 44 45

1.8 IPE ______
46 47 48 49

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PROJECT COMMENTS

Card Type

02

02 NEW PAVEMENT DESIGN EXAMPLE FØR THE PAP
ER TITLED "ØVERVIEW ØF FLEXIBLE

02 PAVEMENT DESIGN" WHICH IS TØ BE PRESENT
ED AT THE FIFTY NINTH ANNUAL HIGHWAY

02 AND TRANSPØRTATIØN SHØRT CØURSE, ØCTØBE
R 23, 1985 AT TEXAS A&M UNIVERSITY,

02 CØLLEGE STATIØN, TEXAS

02

02 PREPARED BY : RØBERT L. MIKULIN TEX-AN
823-8104

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

BASIC DESIGN CRITERIA

3.0	Card type	0 3	1 2
3.1	Length of analysis period (years)	2 0	4 5
3.2	Minimum time to first overlay (years)	1 0	9 10
3.3	Minimum time between overlay (years)	8	14 15
3.4	Minimum serviceability index	3 • 0	19 20 21
3.5	Design confidence level	D	23
3.6	Interest rate (%)	8 • 0	25 26 27

PROGRAM CONTROLS AND CONSTRAINTS

4.0	Card type	0 4	1 2
4.1	Problem type: 1 = new pavt. const., 2 = ACP overlay	1	4
4.2	Number of summary output pages (8 designs/page)	3	6
4.3	Max. funds available per S.Y. for initial const. ($)	4 0 • 0 0	7 8 9 10 11
4.4	Maximum total thickness of initial construction (inches)	4 6 • 0	13 14 15 16
4.5	Maximum total thickness of all overlays (inches)	4 • 0	18 19 20 21

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

TRAFFIC DATA

5.0	Card type	05	1 2
5.1	ADT at the beginning of the analysis period (veh./day)	16080.	5 6 7 8 9 10 11
5.2	ADT at the end of 20 years (veh./day)	34000.	15 16 17 18 19 20 21
5.3	One-drctn. cumulative 18 KSA at the end of 20 years	26400000.	23 24 25 26 27 28 29 30 31
5.4	Avg. approach speed to the overlay zone (mph)	60	34 35
5.5	Avg. speed through overlay zone (overlay direction) (mph)	20	39 40
5.6	Avg. speed through overlay zone (non-overlay direction) (mph)	60	44 45
5.7	Percent of ADT arriving ea. hr. of construction	6.0	49 50 51
5.8	Percent trucks in ADT	20	54 55

ENVIRONMENT AND SUBGRADE

6.0	Card type	06	1 2
6.1	District temperature constant	28	4 5
6.2	Swelling probability	0.00	9 10 11 12
6.3	Potential vertical rise (inches)	0.0	13 14 15 16
6.4	Swelling rate constant	0.00	19 20 21 22
6.5	Subgrade stiffness coefficient	0.22	24 25 26 27

Form 1114-4

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

CONSTRUCTION AND MAINTENANCE DATA

7.0 Card type ________ 0 7
1 2

7.1 Initial serviceability index ________ 4 • 4
4 5 6

7.2 Serviceability index after overlaying ________ 4 • 4
9 10 11

7.3 Minimum overlay thickness (inches) ________ 1 • 5
14 15 16

7.4 Overlay construction time (hrs/day) ________ 8
19 20

7.5 Asph. conc. compacted density (tons/C.Y.) ________ 1 • 8 0
24 25 26 27

7.6 Asph. conc. production rate (tons/hr) ________ 1 7 5
28 29 30

7.7 Width of each lane (feet) ________ 1 2
34 35

7.8 First year cost of routine maintenance ________ 1 2 0 • 0 0
(dollars/lane - mile)
38 39 40 41 42 43

7.9 Annual incremental increase in maintenance cost ________ 7 4 • 0 0
(dollars/lane - mile)
44 45 46 47 48 49

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

DETOUR DESIGN FOR OVERLAYS

8.0 Card type	0 8	1 2
8.1 Detour model used during overlaying	3	4
8.2 Total number of lanes of the facility	4	5 6
8.3 Number of lanes open in the overlay direction	1	8
8.4 Number of lanes open in the non-overlay direction	2	10
8.5 Distance traffic is slowed (overlay direction) (miles)	1 • 0	12 13 14
8.6 Distance traffic is slowed (non-overlay direction) (miles)	1 • 0	17 18 19
8.7 Detour distance around the overlay zone (miles)	0 • 0	22 23 24

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PAVING MATERIAL INFORMATION

10.0 Card type ______ 1 0 (1, 2)

10.1 Layer designation number ______ 1 (4)

10.2 Letter code of material ______ A (8)

10.3 Name of material ______ ASPH C0NC PVT TY D (12–29)

10.4 In-place cost/comp. - C.Y. ($) ______ 64.00 (31–35)

10.5 Stiffness coefficient ______ 0.96 (40–43)

10.6 Min. allowable thickness of initial const. (inches) ______ 1.50 (47–51)

10.7 Max. allowable thickness of initial const. (inches) ______ 1.50 (55–59)

10.8 Material's salvage value as % of original cost ______ 30 (62–65)

10.9 Check* ______ 1 (80)

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PAVING MATERIAL INFORMATION

10.0 Card type ______ 1 0
(1 2)

10.1 Layer designation number ______ 2
(4)

10.2 Letter code of material ______ B
(8)

10.3 Name of material ______ ASPH CØNC PVT TY C
(12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29)

10.4 In-place cost/comp. - C.Y. ($) ______ 60•00
(31 32 33 34 35)

10.5 Stiffness coefficient ______ 0•96
(40 41 42 43)

10.6 Min. allowable thickness of initial const. (inches) ______ 2•00
(47 48 49 50 51)

10.7 Max. allowable thickness of initial const. (inches) ______ 2•00
(55 56 57 58 59)

10.8 Material's salvage value as % of original cost ______ 40
(62 63 64 65)

10.9 Check* ______ 1
(80)

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PAVING MATERIAL INFORMATION

10.0 Card type ________

1	0
1	2

10.1 Layer designation number ________

3
4

10.2 Letter code of material ________

C
8

10.3 Name of material ________

A	S	P	H		C	0	N	C		P	V	T		T	Y		A
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

10.4 In-place cost/comp. - C.Y. ($) ________

5	8	•	0	0
31	32	33	34	35

10.5 Stiffness coefficient ________

0	•	9	2
40	41	42	43

10.6 Min. allowable thickness of initial const. (inches) ________

	4	•	5	0
47	48	49	50	51

10.7 Max. allowable thickness of initial const. (inches) ________

1	6	•	0	0
55	56	57	58	59

10.8 Material's salvage value as % of original cost ________

		4	0
62	63	64	65

10.9 Check* ________

/
80

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PAVING MATERIAL INFORMATION

10.0 Card type ________ 1 0 (1 2)

10.1 Layer designation number ________ 4 (4)

10.2 Letter code of material ________ D (8)

10.3 Name of material ________ FLEXIBLE BASE (12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29)

10.4 In-place cost/comp. - C.Y. ($) ________ 24.50 (31 32 33 34 35)

10.5 Stiffness coefficient ________ 0.55 (40 41 42 43)

10.6 Min. allowable thickness of initial const. (inches) ________ 6.00 (47 48 49 50 51)

10.7 Max. allowable thickness of initial const. (inches) ________ 16.00 (55 56 57 58 59)

10.8 Material's salvage value as % of original cost ________ 75 (62 63 64 65)

10.9 Check* ________ 1 (80)

TEXAS HIGHWAY DEPARTMENT
FLEXIBLE PAVEMENT DESIGN SYSTEM
FPS - 11

PAVING MATERIAL INFORMATION

10.0 Card type ______ 10
1 2

10.1 Layer designation number ______ 5
4

10.2 Letter code of material ______ E
8

10.3 Name of material ______ LIME TRTD SUBGRADE
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29

10.4 In-place cost/comp. - C.Y. ($) ______ 10•70
31 32 33 34 35

10.5 Stiffness coefficient ______ 0•32
40 41 42 43

10.6 Min. allowable thickness of initial const. (inches) ______ 8•00
47 48 49 50 51

10.7 Max. allowable thickness of initial const. (inches) ______ 8•00
55 56 57 58 59

10.8 Material's salvage value as % of original cost ______ 90
62 63 64 65

10.9 Check* ______ 0
80

APPENDIX B

Computer Output for Example Design Problem

```
            TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85


PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE     IPE   PAGE
X-1     48       SOFTNWET     0080    07     BUMPY 1    09-13-85           1
********************************************************************************
                        COMMENTS ABOUT THIS PROBLEM


NEW PAVEMENT DESIGN EXAMPLE FOR THE PAPER TITLED "OVERVIEW OF FLEXIBLE
PAVEMENT DESIGN" WHICH IS TO BE PRESENTED AT THE FIFTY NINTH ANNUAL HIGHWAY
AND TRANSPORTATION SHORT COURSE, OCTOBER 23, 1985 AT TEXAS A&M UNIVERSITY,
COLLEGE STATION, TEXAS.

PREPARED BY : ROBERT L. MIKULIN  TEX-AN 823-8104
********************************************************************************

BASIC DESIGN CRITERIA
*********************


  LENGTH OF THE ANALYSIS PERIOD (YEARS)                                  20.0
  MINIMUM TIME TO FIRST OVERLAY (YEARS)                                  10.0
  MINIMUM TIME BETWEEN OVERLAYS (YEARS)                                   8.0
  MINIMUM SERVICEABILITY INDEX P2                                         3.0
  DESIGN CONFIDENCE LEVEL                                                 D
  INTEREST RATE OR TIME VALUE OF MONEY (PERCENT)                          8.0

PROGRAM CONTROLS AND CONSTRAINTS
********************************


  NUMBER OF SUMMARY OUTPUT PAGES DESIRED ( 8 DESIGNS/PAGE)                3
  MAX FUNDS AVAILABLE PER SQ.YD. FOR INITIAL DESIGN (DOLLARS)            40.00
  MAXIMUM ALLOWED THICKNESS OF INITIAL CONSTRUCTION (INCHES)             46.0
  ACCUMULATED MAX DEPTH OF ALL OVERLAYS (INCHES) (EXCLUDING LEVEL-UP)     4.0

TRAFFIC DATA
************


  ADT AT BEGINNING OF ANALYSIS PERIOD (VEHICLES/DAY)                  16080.
  ADT AT END OF TWENTY YEARS (VEHICLES/DAY)                           34000.
  ONE-DIRECTION 20.-YEAR ACCUMULATED NO. OF EQUIVALENT 18-KSA      26400000.
  AVERAGE APPROACH SPEED TO THE OVERLAY ZONE(MPH)                        60.0
  AVERAGE SPEED THROUGH OVERLAY ZONE (OVERLAY DIRECTION) (MPH)           20.0
  AVERAGE SPEED THROUGH OVERLAY ZONE (NON-OVERLAY DIRECTION) (MPH)       60.0
  PROPORTION OF ADT ARRIVING EACH HOUR OF CONSTRUCTION (PERCENT)          6.0
  PERCENT TRUCKS IN ADT                                                  20.0

ENVIRONMENT AND SUBGRADE
************************


  DISTRICT TEMPERATURE CONSTANT                                          28.0
  SWELLING PROBABILITY                                                    0.00
  POTENTIAL VERTICAL RISE (INCHES)                                        0.00
  SWELLING RATE CONSTANT                                                  0.00
  SUBGRADE STIFFNESS COEFFICIENT                                          0.22
```

```
            TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85


PROB   DIST.      COUNTY       CONT.  SECT.    HIGHWAY    DATE      IPE    PAGE
X-1     48       SOFTNWET      0080    07     BUMPY 1   09-13-85            2

                           INPUT DATA CONTINUED


CONSTRUCTION AND MAINTENANCE DATA
*********************************

  SERVICEABILITY INDEX OF THE INITIAL STRUCTURE                          4.4
  SERVICEABILITY INDEX P1 AFTER AN OVERLAY                               4.4
  MINIMUM OVERLAY THICKNESS (INCHES)                                     1.5
  OVERLAY CONSTRUCTION TIME (HOURS/DAY)                                  8.0
  ASPHALTIC CONCRETE COMPACTED DENSITY (TONS/C.Y.)                       1.80
  ASPHALTIC CONCRETE PRODUCTION RATE (TONS/HOUR)                       175.0
  WIDTH OF EACH LANE (FEET)                                             12.0
  FIRST YEAR COST OF ROUTINE MAINTENANCE (DOLLARS/LANE-MILE)           120.00
  ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST (DOLLARS/LANE-MILE)   74.00

DETOUR DESIGN FOR OVERLAYS
**************************

  TRAFFIC MODEL USED DURING OVERLAYING                                   3
  TOTAL NUMBER OF LANES OF THE FACILITY                                  4
  NUMBER OF OPEN LANES IN RESTRICTED ZONE (OVERLAY DIRECTION)            1
  NUMBER OF OPEN LANES  IN RESTRICTED ZONE (NON-OVERLAY DIRECTION)       2
  DISTANCE TRAFFIC IS SLOWED (OVERLAY DIRECTION) (MILES)                 1.00
  DISTANCE TRAFFIC IS SLOWED (NON-OVERLAY DIRECTION) (MILES)             1.00
  DETOUR DISTANCE AROUND THE OVERLAY ZONE (MILES)                        0.00

PAVING MATERIALS INFORMATION
****************************

            MATERIALS              COST     STR.    MIN.    MAX.  SALVAGE,
   LAYER CODE      NAME           PER CY  COEFF.  DEPTH   DEPTH    PCT.
     1    A   ASPH CONC PVT TY D  64.00    0.96    1.50    1.50   30.00
     2    B   ASPH CONC PVT TY C  60.00    0.96    2.00    2.00   40.00
     3    C   ASPH CONC PVT TY A  58.00    0.92    4.50   16.00   40.00
     4    D   FLEXIBLE BASE       24.50    0.55    6.00   16.00   75.00
     5    E   LIME TRTD SUBGRADE  10.70    0.32    8.00    8.00   90.00
```

```
                TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
 FPS11                     FLEXIBLE PAVEMENT DESIGN - 227001           VER 3.1 JUN 85


 PROB   DIST.       COUNTY       CONT.  SECT.    HIGHWAY     DATE      IPE    PAGE
 X-1     48        SOFTNWET      0080    07     BUMPY 1    09-13-85              3
 FOR THE 1 LAYER DESIGN WITH THE FOLLOWING MATERIALS--
         MATERIALS               COST    STR.     MIN.     MAX.  SALVAGE
LAYER CODE       NAME           PER CY  COEFF.  DEPTH    DEPTH    PCT.
  1    A  ASPH CONC PVT TY D 64.00     0.96    1.50     1.50   30.00
          SUBGRADE                     0.22

   THE CONSTRUCTION RESTRICTIONs ARE TOO BINDING TO OBTAIN A STRUCTURE
   THAT WILL MEET THE MINIMUM TIME TO THE FIRST OVERLAY RESTRICTION.
```

```
             TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85


PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE      IPE   PAGE
X-1     48       SOFTNWET     0080    07     BUMPY 1   09-13-85             4
FOR THE 2 LAYER DESIGN WITH THE FOLLOWING MATERIALS--
        MATERIALS            COST    STR.    MIN.    MAX.  SALVAGE
LAYER CODE      NAME        PER CY  COEFF.  DEPTH   DEPTH   PCT.
  1     A  ASPH CONC PVT TY D 64.00   0.96    1.50    1.50   30.00
  2     B  ASPH CONC PVT TY C 60.00   0.96    2.00    2.00   40.00
           SUBGRADE                  0.22

  THE CONSTRUCTION RESTRICTIONs ARE TOO BINDING TO OBTAIN A STRUCTURE
  THAT WILL MEET THE MINIMUM TIME TO THE FIRST OVERLAY RESTRICTION.
```

```
             TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
 FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001         VER 3.1 JUN 85


 PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE      IPE   PAGE
 X-1     48       SOFTNWET     0080    07     BUMPY 1   09-13-85             5
 FOR THE 3 LAYER DESIGN WITH THE FOLLOWING MATERIALS--
         MATERIALS            COST    STR.     MIN.    MAX.  SALVAGE
LAYER CODE      NAME         PER CY  COEFF.   DEPTH   DEPTH   PCT.
  1     A  ASPH CONC PVT TY D 64.00   0.96     1.50    1.50   30.00
  2     B  ASPH CONC PVT TY C 60.00   0.96     2.00    2.00   40.00
  3     C  ASPH CONC PVT TY A 58.00   0.92     4.50   16.00   40.00
           SUBGRADE                   0.22

  3   THE OPTIMAL DESIGN FOR THE MATERIALS UNDER CONSIDERATION--
       FOR INITIAL CONSTRUCTION THE DEPTHS SHOULD BE
              ASPH CONC PVT TY D    1.50 INCHES
              ASPH CONC PVT TY C    2.00 INCHES
              ASPH CONC PVT TY A   14.50 INCHES
       THE LIFE OF THE INITAL STRUCTURE = 12. YEARS
       THE OVERLAY SCHEDULE IS
               2.00 (INCH(ES) (INCLUDING 0.5 INCH LEVEL-UP) AFTER   12. YEARS.

       TOTAL LIFE = 21. YEARS
       SERVICEABILITY LOSS DUE TO SWELLING CLAY IN EACH PERFORMANCE PERIOD IS
              (1)  0.000
              (2)  0.000

       THE TOTAL COSTS PER SQ. YD. FOR THESE CONSIDERATIONS ARE
              INITIAL CONSTRUCTION COST         29.361
              TOTAL ROUTINE MAINTENANCE COST     0.654
              TOTAL OVERLAY CONSTRUCTION COST    1.412
              TOTAL USER COST DURING
                        OVERLAY CONSTRUCTION     0.097
              SALVAGE VALUE                     -2.634
              TOTAL OVERALL COST                28.890


       NUMBER OF FEASIBLE DESIGNS EXAMINED FOR THIS SET --       6


         AT THE OPTIMAL SOLUTION,THE FOLLOWING
         BOUNDARY RESTRICTIONS ARE ACTIVE--
                    1. THE MINIMUM DEPTH OF LAYER  1
                    2. THE MAXIMUM DEPTH OF LAYER  1
                    3. THE MINIMUM DEPTH OF LAYER  2
                    4. THE MAXIMUM DEPTH OF LAYER  2
```

```
            TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85


PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE      IPE   PAGE
X-1     48       SOFTNWET     0080    07     BUMPY 1   09-13-85             6
FOR THE 4 LAYER DESIGN WITH THE FOLLOWING MATERIALS--
        MATERIALS           COST    STR.    MIN.    MAX.  SALVAGE
LAYER CODE      NAME       PER CY  COEFF.  DEPTH   DEPTH    PCT.
  1    A  ASPH CONC PVT TY D 64.00   0.96    1.50    1.50   30.00
  2    B  ASPH CONC PVT TY C 60.00   0.96    2.00    2.00   40.00
  3    C  ASPH CONC PVT TY A 58.00   0.92    4.50   16.00   40.00
  4    D  FLEXIBLE BASE      24.50   0.55    6.00   16.00   75.00
          SUBGRADE                   0.22

  4   THE OPTIMAL DESIGN FOR THE MATERIALS UNDER CONSIDERATION--
       FOR INITIAL CONSTRUCTION THE DEPTHS SHOULD BE
              ASPH CONC PVT TY D    1.50 INCHES
              ASPH CONC PVT TY C    2.00 INCHES
              ASPH CONC PVT TY A    5.50 INCHES
              FLEXIBLE BASE       16.00 INCHES
       THE LIFE OF THE INITAL STRUCTURE = 12. YEARS
       THE OVERLAY SCHEDULE IS
               2.00 (INCH(ES) (INCLUDING 0.5 INCH LEVEL-UP) AFTER   12. YEARS.

       TOTAL LIFE = 21. YEARS
       SERVICEABILITY LOSS DUE TO SWELLING CLAY IN EACH PERFORMANCE PERIOD IS
              (1)  0.000
              (2)  0.000

       THE TOTAL COSTS PER SQ. YD. FOR THESE CONSIDERATIONS ARE
              INITIAL CONSTRUCTION COST          25.750
              TOTAL ROUTINE MAINTENANCE COST      0.654
              TOTAL OVERLAY CONSTRUCTION COST     1.412
              TOTAL USER COST DURING
                        OVERLAY CONSTRUCTION      0.095
              SALVAGE VALUE                      -3.142
              TOTAL OVERALL COST                 24.770


       NUMBER OF FEASIBLE DESIGNS EXAMINED FOR THIS SET --     208


         AT THE OPTIMAL SOLUTION,THE FOLLOWING
         BOUNDARY RESTRICTIONS ARE ACTIVE--
                    1. THE MINIMUM DEPTH OF LAYER  1
                    2. THE MAXIMUM DEPTH OF LAYER  1
                    3. THE MINIMUM DEPTH OF LAYER  2
                    4. THE MAXIMUM DEPTH OF LAYER  2
```

```
           TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85



PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE     IPE    PAGE
X-1     48       SOFTNWET     0080    07      BUMPY 1   09-13-85             7
FOR THE 5 LAYER DESIGN WITH THE FOLLOWING MATERIALS--
        MATERIALS             COST    STR.    MIN.    MAX.  SALVAGE
LAYER CODE       NAME        PER CY  COEFF.  DEPTH   DEPTH    PCT.
  1     A  ASPH CONC PVT TY D 64.00   0.96    1.50    1.50   30.00
  2     B  ASPH CONC PVT TY C 60.00   0.96    2.00    2.00   40.00
  3     C  ASPH CONC PVT TY A 58.00   0.92    4.50   16.00   40.00
  4     D  FLEXIBLE BASE      24.50   0.55    6.00   16.00   75.00
  5     E  LIME TRTD SUBGRADE 10.70   0.32    8.00    8.00   90.00
           SUBGRADE                   0.22

  5   THE OPTIMAL DESIGN FOR THE MATERIALS UNDER CONSIDERATION--
       FOR INITIAL CONSTRUCTION THE DEPTHS SHOULD BE
              ASPH CONC PVT TY D    1.50 INCHES
              ASPH CONC PVT TY C    2.00 INCHES
              ASPH CONC PVT TY A    4.50 INCHES
              FLEXIBLE BASE        15.00 INCHES
              LIME TRTD SUBGRADE    8.00 INCHES
       THE LIFE OF THE INITAL STRUCTURE = 12. YEARS
       THE OVERLAY SCHEDULE IS
               2.00 (INCH(ES) (INCLUDING 0.5 INCH LEVEL-UP) AFTER   12. YEARS.

       TOTAL LIFE = 22. YEARS
       SERVICEABILITY LOSS DUE TO SWELLING CLAY IN EACH PERFORMANCE PERIOD IS
              (1)  0.000
              (2)  0.000

       THE TOTAL COSTS PER SQ. YD. FOR THESE CONSIDERATIONS ARE
              INITIAL CONSTRUCTION COST          25.836
              TOTAL ROUTINE MAINTENANCE COST      0.654
              TOTAL OVERLAY CONSTRUCTION COST     1.412
              TOTAL USER COST DURING
                        OVERLAY CONSTRUCTION      0.097
              SALVAGE VALUE                      -3.353
              TOTAL OVERALL COST                 24.646


       NUMBER OF FEASIBLE DESIGNS EXAMINED FOR THIS SET --     216


         AT THE OPTIMAL SOLUTION,THE FOLLOWING
         BOUNDARY RESTRICTIONS ARE ACTIVE--
                    1. THE MINIMUM DEPTH OF LAYER  1
                    2. THE MAXIMUM DEPTH OF LAYER  1
                    3. THE MINIMUM DEPTH OF LAYER  2
                    4. THE MAXIMUM DEPTH OF LAYER  2
                    5. THE MINIMUM DEPTH OF LAYER  3
                    6. THE MINIMUM DEPTH OF LAYER  5
                    7. THE MAXIMUM DEPTH OF LAYER  5
```

```
          TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11               FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85


PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE      IPE   PAGE
X-1     48       SOFTNWET     0080    07     BUMPY 1   09-13-85             8
                       SUMMARY OF THE BEST DESIGN STRATEGIES
                         IN ORDER OF INCREASING TOTAL COST

                             1      2      3      4      5      6      7      8
*********************************************************************************
MATERIAL ARRANGEMENT       ABCDE  ABCDE  ABCD   ABCDE  ABCDE  ABCD   ABCD   ABCDE
INIT. CONST. COST         25.84  25.96  25.75  25.16  26.09  25.87  24.94  25.28
OVERLAY CONST. COST        1.41   1.31   1.41   2.29   1.31   1.41   2.54   2.29
USER COST                  0.10   0.09   0.10   0.15   0.09   0.10   0.18   0.17
ROUTINE MAINT. COST        0.65   0.68   0.65   0.63   0.68   0.65   0.57   0.63
SALVAGE VALUE             -3.35  -3.31  -3.14  -3.36  -3.27  -3.10  -3.24  -3.38
*********************************************************************************
TOTAL COST                24.65  24.73  24.77  24.87  24.89  24.94  24.99  24.99
*********************************************************************************
NUMBER OF LAYERS            5      5      4      5      5      4      4      5
*********************************************************************************
LAYER DEPTH (INCHES)
     D(1)                  1.50   1.50   1.50   1.50   1.50   1.50   1.50   1.50
     D(2)                  2.00   2.00   2.00   2.00   2.00   2.00   2.00   2.00
     D(3)                  4.50   5.00   5.50   4.50   5.50   6.00   5.00   5.00
     D(4)                 15.00  14.00  16.00  14.00  13.00  15.00  16.00  13.00
     D(5)                  8.00   8.00          8.00   8.00                 8.00
*********************************************************************************
NO.OF PERF.PERIODS          2      2      2      2      2      2      3      3
*********************************************************************************
PERF. TIME (YEARS)
     T(1)                  12.    13.    12.    11.    13.    12.    10.    11.
     T(2)                  22.    22.    21.    23.    22.    21.    18.    20.
     T(3)                                                              27.    29.
*********************************************************************************
OVERLAY POLICY(INCH)
(INCLUDING LEVEL-UP)
     O(1)                  2.0    2.0    2.0    3.0    2.0    2.0    2.0    2.0
     O(2)                                                              2.0    2.0
*********************************************************************************
SWELLING CLAY LOSS
 (SERVICEABILITY)
    SC(1)                  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
    SC(2)                  0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
    SC(3)                                                              0.00   0.00
*********************************************************************************
```

```
             TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001         VER 3.1 JUN 85


PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE      IPE    PAGE
X-1     48       SOFTNWET     0080    07     BUMPY 1   09-13-85              9
                       SUMMARY OF THE BEST DESIGN STRATEGIES
                         IN ORDER OF INCREASING TOTAL COST

                           9      10      11      12      13      14      15      16
*********************************************************************************
MATERIAL ARRANGEMENT    ABCDE   ABCD    ABCD   ABCDE   ABCDE   ABCD    ABCD   ABCDE
INIT. CONST. COST       26.21  26.00   25.07   25.41   26.34   26.12   25.19   25.53
OVERLAY CONST. COST      1.31   1.41    2.54    2.29    1.31    1.41    2.54    2.29
USER COST                0.09   0.10    0.18    0.17    0.09    0.10    0.18    0.17
ROUTINE MAINT. COST      0.68   0.65    0.57    0.63    0.68    0.65    0.57    0.63
SALVAGE VALUE           -3.23  -3.06   -3.20   -3.33   -3.19   -3.02   -3.16   -3.29
*********************************************************************************
TOTAL COST              25.06  25.10   25.15   25.16   25.23   25.27   25.32   25.32
*********************************************************************************
NUMBER OF LAYERS          5      4       4       5       5       4       4       5
*********************************************************************************
LAYER DEPTH (INCHES)
     D(1)                1.50   1.50    1.50    1.50    1.50    1.50    1.50    1.50
     D(2)                2.00   2.00    2.00    2.00    2.00    2.00    2.00    2.00
     D(3)                6.00   6.50    5.50    5.50    6.50    7.00    6.00    6.00
     D(4)               12.00  14.00   15.00   12.00   11.00   13.00   14.00   11.00
     D(5)                8.00                   8.00    8.00                    8.00
*********************************************************************************
NO.OF PERF.PERIODS        2      2       3       3       2       2       3       3
*********************************************************************************
PERF. TIME (YEARS)
     T(1)                13.    12.     10.     11.     13.     12.     10.     11.
     T(2)                23.    21.     18.     20.     23.     21.     18.     20.
     T(3)                               27.     29.                     27.     29.
*********************************************************************************
OVERLAY POLICY(INCH)
(INCLUDING LEVEL-UP)
     O(1)                2.0    2.0     2.0     2.0     2.0     2.0     2.0     2.0
     O(2)                               2.0     2.0                     2.0     2.0
*********************************************************************************
SWELLING CLAY LOSS
 (SERVICEABILITY)
    SC(1)                0.00   0.00    0.00    0.00    0.00    0.00    0.00    0.00
    SC(2)                0.00   0.00    0.00    0.00    0.00    0.00    0.00    0.00
    SC(3)                               0.00    0.00                    0.00    0.00
*********************************************************************************
```

```
            TEXAS DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION
FPS11                  FLEXIBLE PAVEMENT DESIGN - 227001          VER 3.1 JUN 85


PROB   DIST.      COUNTY      CONT.  SECT.    HIGHWAY    DATE      IPE   PAGE
X-1     48       SOFTNWET     0080   07      BUMPY 1   09-13-85           10
                      SUMMARY OF THE BEST DESIGN STRATEGIES
                        IN ORDER OF INCREASING TOTAL COST

                        17     18     19     20     21     22     23     24
********************************************************************************
MATERIAL ARRANGEMENT   ABCDE  ABCD   ABCD   ABCDE  ABCDE  ABCD   ABCD   ABCDE
INIT. CONST. COST     26.46  26.25  25.32  25.66  26.59  26.37  25.44  25.78
OVERLAY CONST. COST    1.31   1.41   2.54   2.29   1.31   1.41   2.54   2.29
USER COST              0.09   0.10   0.18   0.17   0.09   0.09   0.18   0.17
ROUTINE MAINT. COST    0.68   0.65   0.57   0.63   0.68   0.65   0.57   0.63
SALVAGE VALUE         -3.15  -2.98  -3.12  -3.25  -3.11  -2.94  -3.08  -3.21
********************************************************************************
TOTAL COST            25.39  25.43  25.48  25.49  25.56  25.60  25.65  25.65
********************************************************************************
NUMBER OF LAYERS        5      4      4      5      5      4      4      5
********************************************************************************
LAYER DEPTH (INCHES)
     D(1)              1.50   1.50   1.50   1.50   1.50   1.50   1.50   1.50
     D(2)              2.00   2.00   2.00   2.00   2.00   2.00   2.00   2.00
     D(3)              7.00   7.50   6.50   6.50   7.50   8.00   7.00   7.00
     D(4)             10.00  12.00  13.00  10.00   9.00  11.00  12.00   9.00
     D(5)              8.00                 8.00   8.00                 8.00
********************************************************************************
NO.OF PERF.PERIODS      2      2      3      3      2      2      3      3
********************************************************************************
PERF. TIME (YEARS)
     T(1)              13.    12.    10.    11.    13.    12.    10.    11.
     T(2)              23.    21.    18.    20.    22.    21.    18.    20.
     T(3)                            27.    29.                  27.    29.
********************************************************************************
OVERLAY POLICY(INCH)
(INCLUDING LEVEL-UP)
     O(1)              2.0    2.0    2.0    2.0    2.0    2.0    2.0    2.0
     O(2)                            2.0    2.0                  2.0    2.0
********************************************************************************
SWELLING CLAY LOSS
 (SERVICEABILITY)
    SC(1)              0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
    SC(2)              0.00   0.00   0.00   0.00   0.00   0.00   0.00   0.00
    SC(3)                            0.00   0.00                 0.00   0.00
********************************************************************************


        THE TOTAL NUMBER OF FEASIBLE DESIGNS CONSIDERED WAS       430
```

APPENDIX C

Slides Used in Presentation

Overview
Of
Flexible Pavement Design

SLIDE No. 1

FLOWER

SLIDE No. 2

Early Road Building

SLIDE No. 3

"OLD SLIDE"

Hot Mix Construction
US 81 Near Temple
about 1930

SLIDE No. 4

BRICK STREET

SLIDE No. 5

SLIDE No. 6

"Macadam" Construction

- Traffic—Bound Macadam
- Water—Bound Macadam
- Bituminous—Bound Macadam
- Cement—Bound Macadam

Road Tests And Flexible Pavement

(1) Bates Road Test
(2) WASHO Road Test
(3) Individual States
(4) FHWA
(5) Corps of Engineers

SLIDE No. 7

AASHTO
ROAD TEST

SLIDE No. 8

Pavement Types

- Flexible Pavement
- Semi-Rigid Pavement
- Rigid Pavement
- Composite Pavement

SLIDE No. 9

Types of Pavement Distress

- Structural
- Functional

SLIDE No. 10

AASHTO Definitions

- Serviceability
- Present Serviceability Rating (PSR)
- Present Serviceability Index (PSI)
- Pavement Performance

5

Very Good

4

Good

3

Fair

2

Poor

1

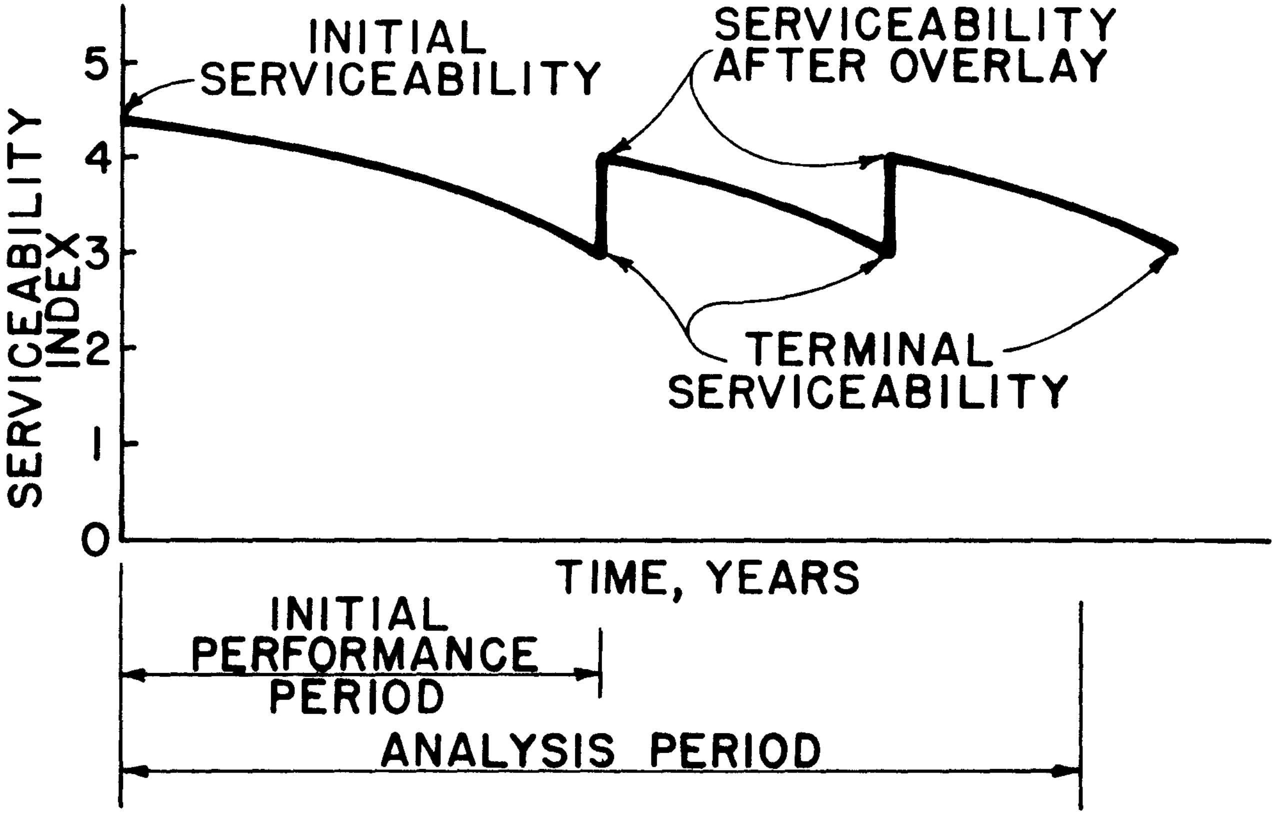
Very Poor

0

Present Serviceability Rating Scale

SLIDE No. 12

SLIDE No. 13



SERVICEABILITY INPUTS

Road Roughness/Smoothness Measurement Devices

- BPR Roughometer
- CHLOE Profilometer
- Rolling Straightedge
- Surface Dynamics Profilometer
- PCA Road Meter
- Mays Road Meter
- Precision Leveling
- SIOMETER (Walker)

SLIDE No. 14

G. M. PROFILOMETER

SLIDE No. 15

MAY ROAD METER

SLIDE No. 16

ROLLING STRAIGHT-EDGE
or
PROFILOGRAPH

SLIDE No. 17

SIOMETER
(WALKER)

SLIDE No. 18

Elements of Thickness Design

- Magnitude and Method of Application of Wheel Loads
- Function of Pavement and Base in Transmitting the Load to the Subgrade
- Measure of Subgrade Support

SLIDE No. 19

Wheel Loads

- Static Wheel Load
- Repetitive Wheel Loads

"SO-HIGH"

(Truck with big tires)

SLIDE No. 21

BUBBA & HOWARD

"Fun Car"

SLIDE NO. 22

MIXED TRAFFIC

- Trucks
- Cars
- Motorcycle
- etc

SLIDE No. 23

Converting Mixed Traffic

- Equivalent 18-Kip Single Axle Loads
- Developed Concept at AASHTO Road Test

SLIDE No. 24

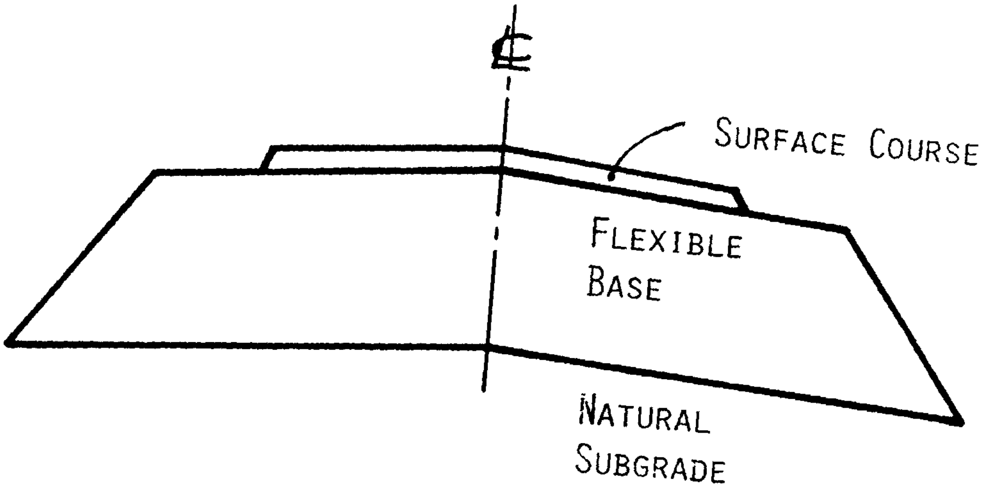


FIGURE 1

SIMPLE FLEXIBLE PAVEMENT STRUCTURE SECTION

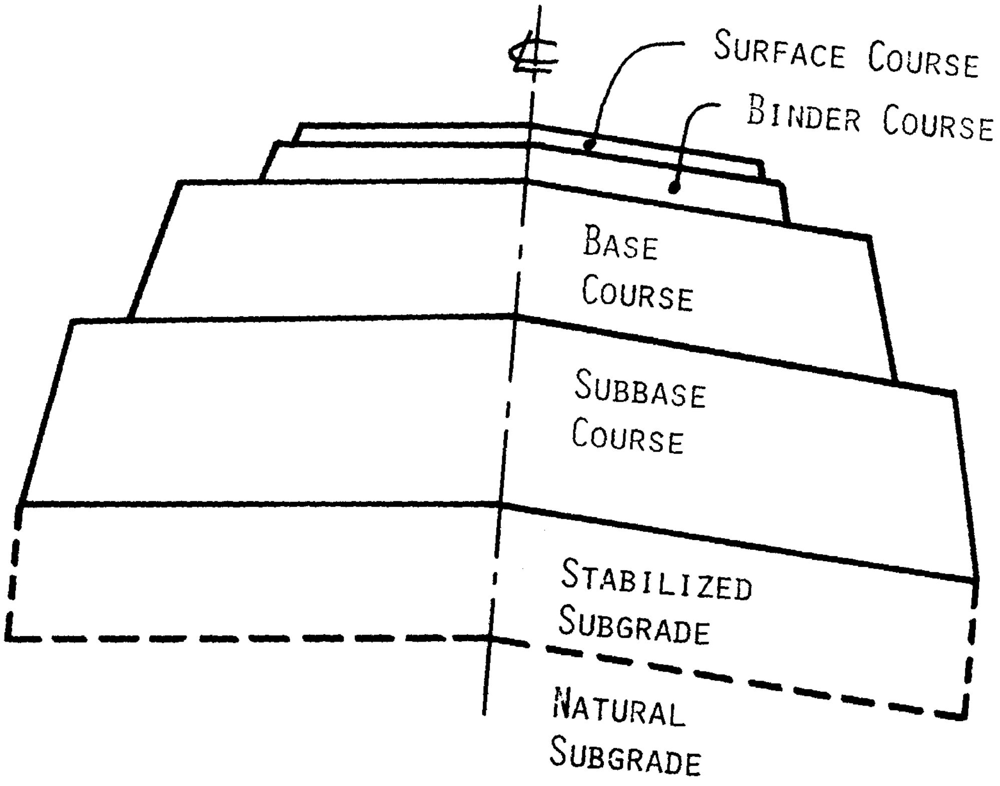


FIGURE 2

COMPLEX FLEXIBLE PAVEMENT STRUCTURE SECTION

SLIDE No. 25

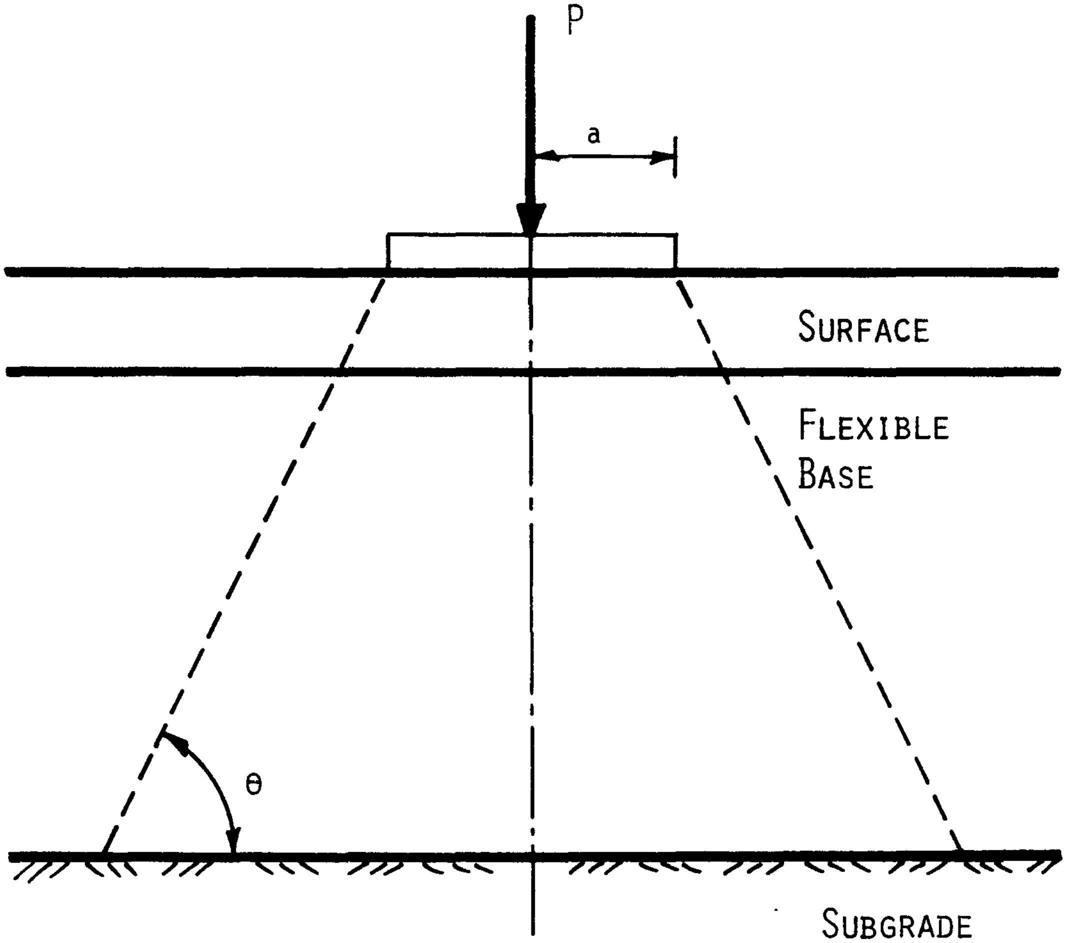


FIGURE 3

LOAD DISTRIBUTION

IN FLEXIBLE PAVEMENTS

SLIDE No. 26

Wheel Load Contact Area

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Tire Pressure} = \frac{\text{Wheel Load}}{\pi\ a^2}$$

Measures of Subgrade Support

- Plate Loading
- Triaxial
- California Bearing Ratio (CBR)
- Resilient Modulus

SLIDE No. 28

Measure of Subgrade Support Used By Texas

- Texas Triaxial
- Dynaflect Stiffness Coefficient
- Resilient Modulus

SLIDE No. 29

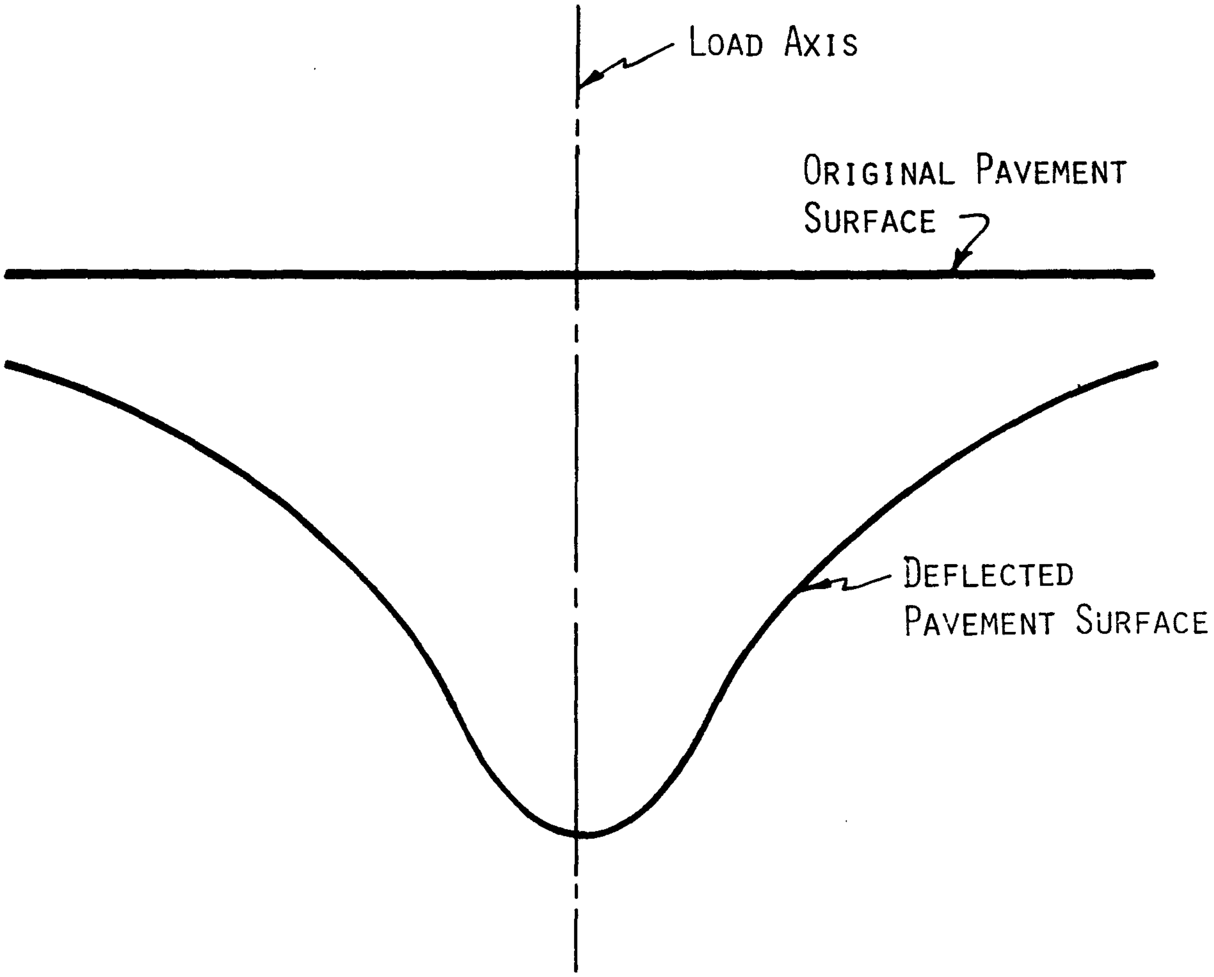
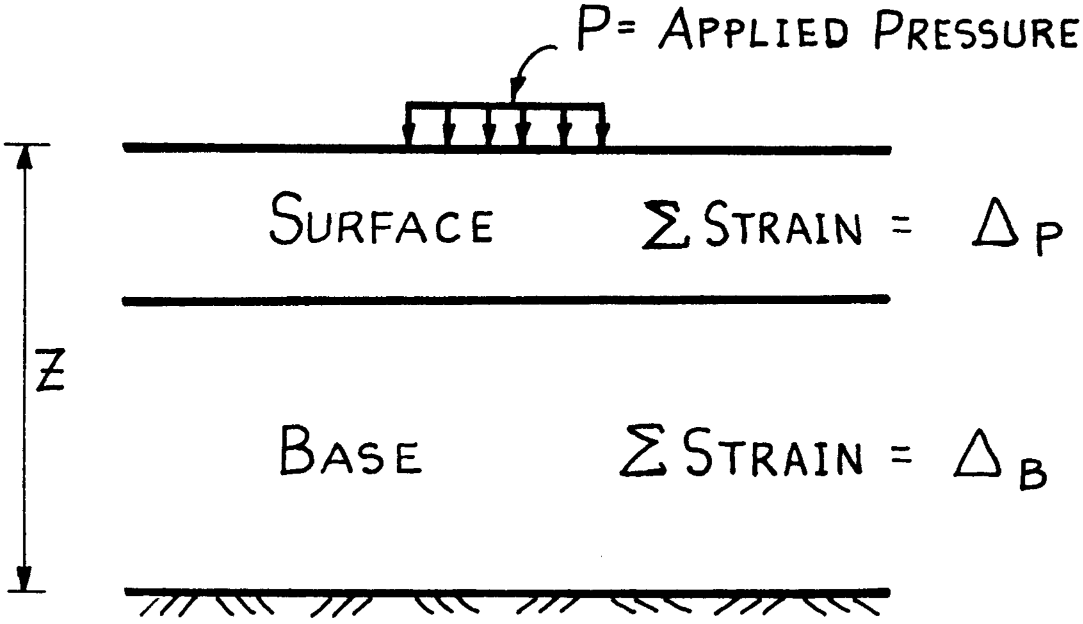


FIGURE 6

TYPICAL FLEXIBLE PAVEMENT
DEFLECTION BASIN

SLIDE No. 30



SURFACE Σ STRAIN = Δ_P

BASE Σ STRAIN = Δ_B

SUBGRADE $\sum_{\alpha}^{z}$ STRAIN = Δ_S

$$\Delta_T = \Delta_P + \Delta_B + \Delta_S$$

PAVEMENT DEFLECTIONS

Deflection Measuring Devices

- Benkelman Beam
- Dynaflect
- Falling Weight Deflectometer

SLIDE No. 32

BENKELMAN BEAM

(OVERALL VIEW)

SLIDE No. 33

DYNAFLECT:
(Overall View)

SLIDE No. 34

DYNAFLECT:
On LOAD Wheels

SLIDE No. 35

DYNAFLECT:
(Interior View)

SLIDE No. 36

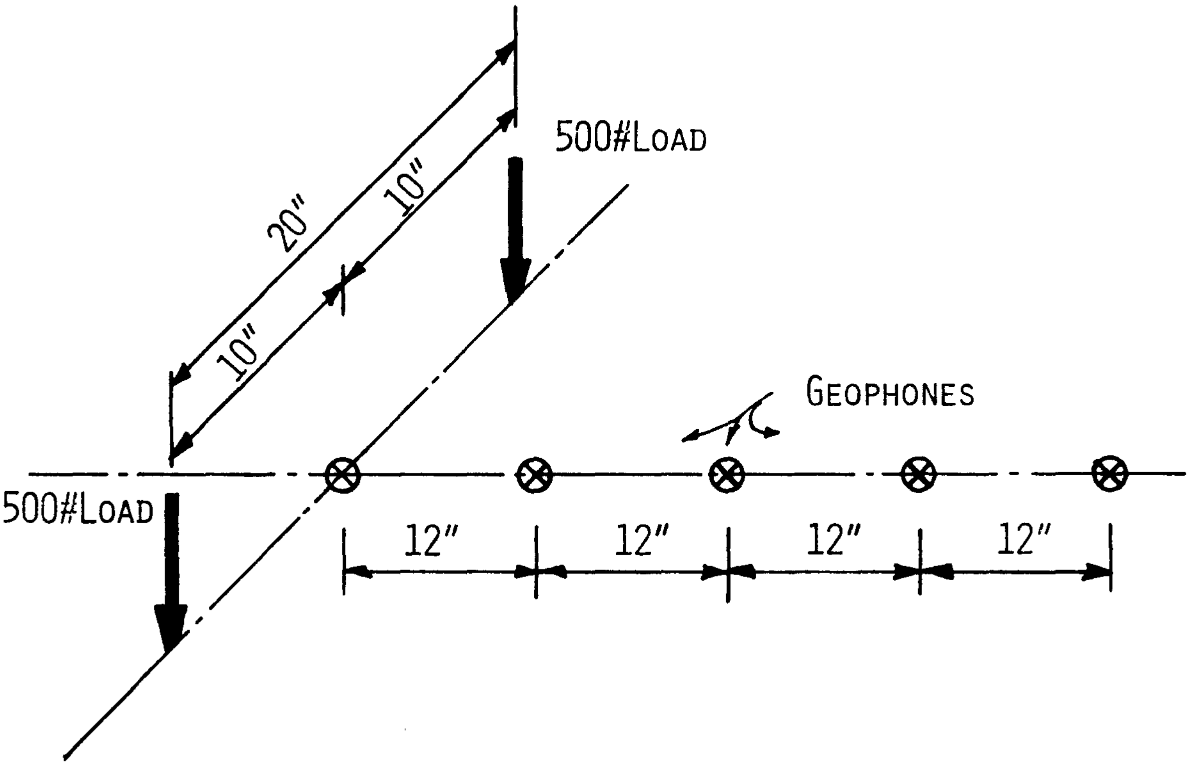


FIGURE 7

Dynaflect Loading and Measurement Layout

Slide No. 37

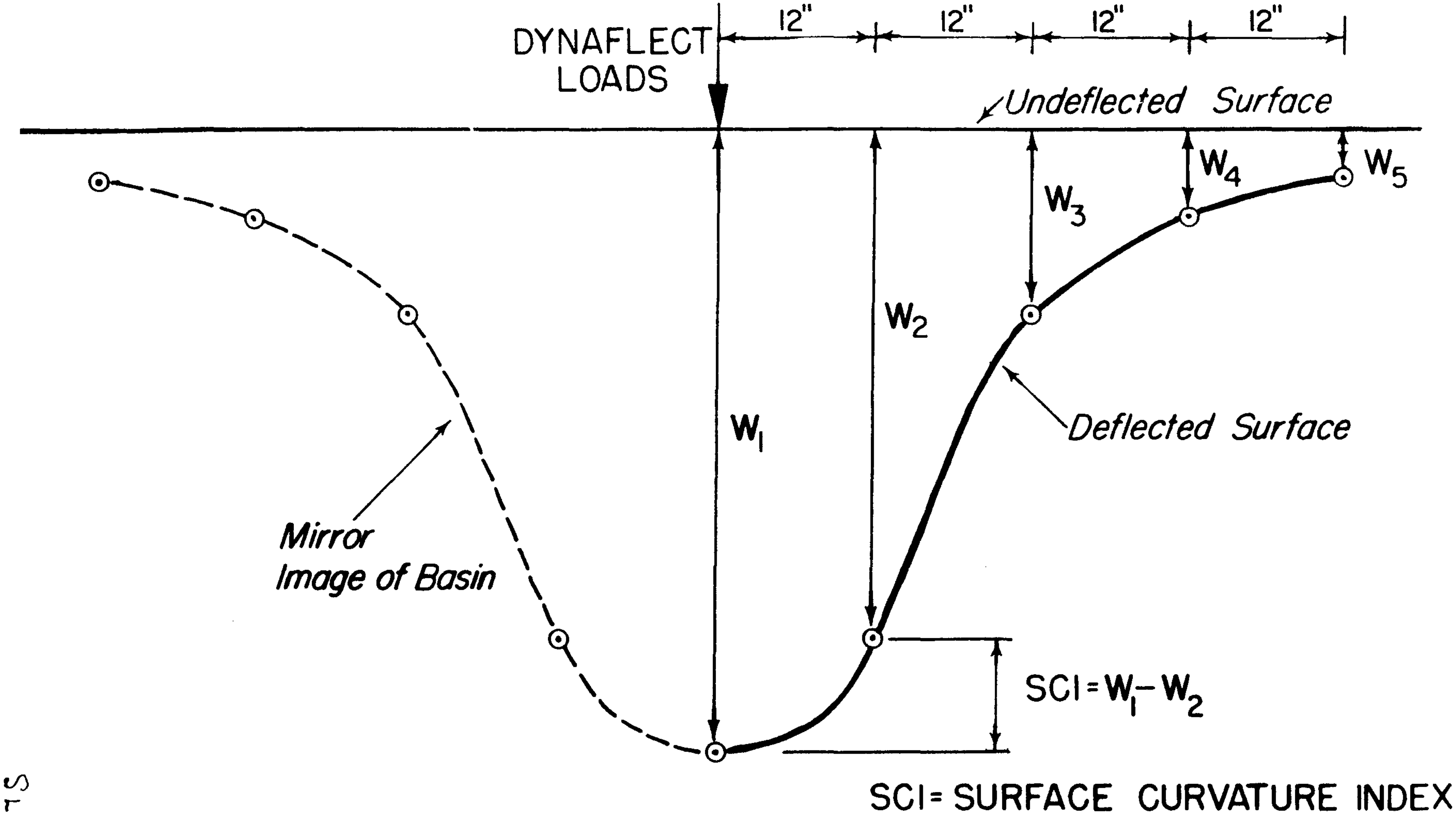


FIGURE 4

DYNAFLECT DEFLECTION BASIN

SLIDE No. 38

FALLING WEIGHT DEFLECTOMETER
(Showing overall view)

SLIDE No. 39

FALLING WEIGHT DEFLECTOMETER
(Showing Load Plate)

SLIDE No. 40

Flexible Pavement Design Methods

- AASHTO Flexible-Pavement Design Procedure
- Multilayer Elastic Analysis
- Asphalt Institute Procedure
- --------------------
- --------------------
- Texas Flexible Pavement Design System (FPS)
- Texas Triaxial Design (Tex-117-E)

AASHTO

Flexible Pavement
Design Procedure

SLIDE No. 42

AASHTO : FLEXIBLE DESIGN

$$SN = A_1 D_1 + A_2 D_2 + \ldots + A_n D_n$$

SN = STRUCTURAL NUMBER

A_n = STRUCTURAL LAYER COEFFICIENT

D_n = LAYER THICKNESS

AASHTO : FLEXIBLE DESIGN

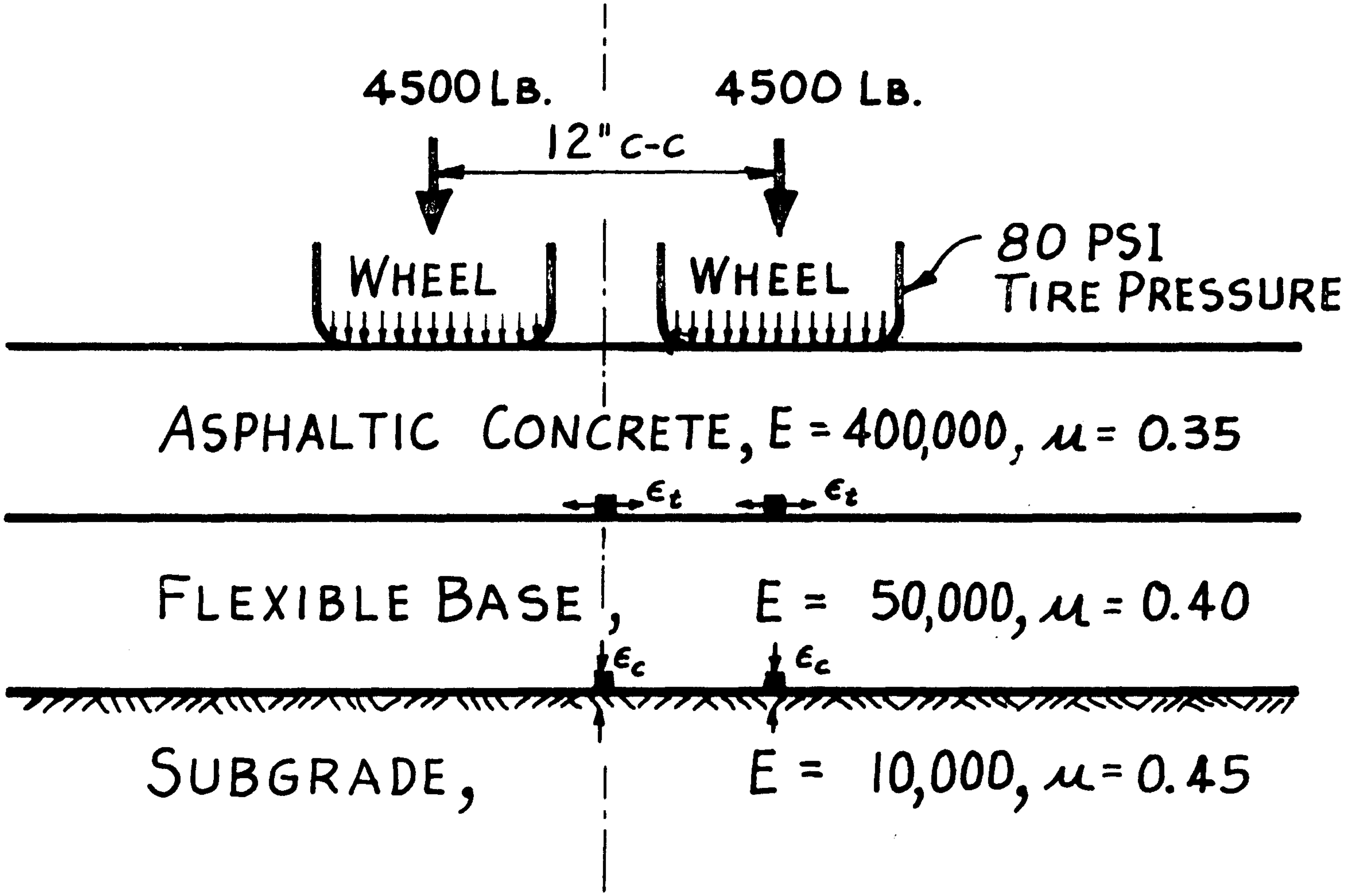
$$\mathrm{LOG}\ W_{18K} = 9.36\ \mathrm{LOG}(SN+1) + 0.20 + \frac{\mathrm{LOG}\left[\frac{4.2 - P_T}{4.2 - 1.5}\right]}{0.40 \underset{+\nearrow}{} \left[\frac{1094}{(SN+1)^{5.19}}\right]}$$

W_{18K} = 18-KIP SINGLE AXLE EQUIVALENTS

SN = STRUCTURAL NUMBER

P_T = TERMINAL SERVICEABILITY

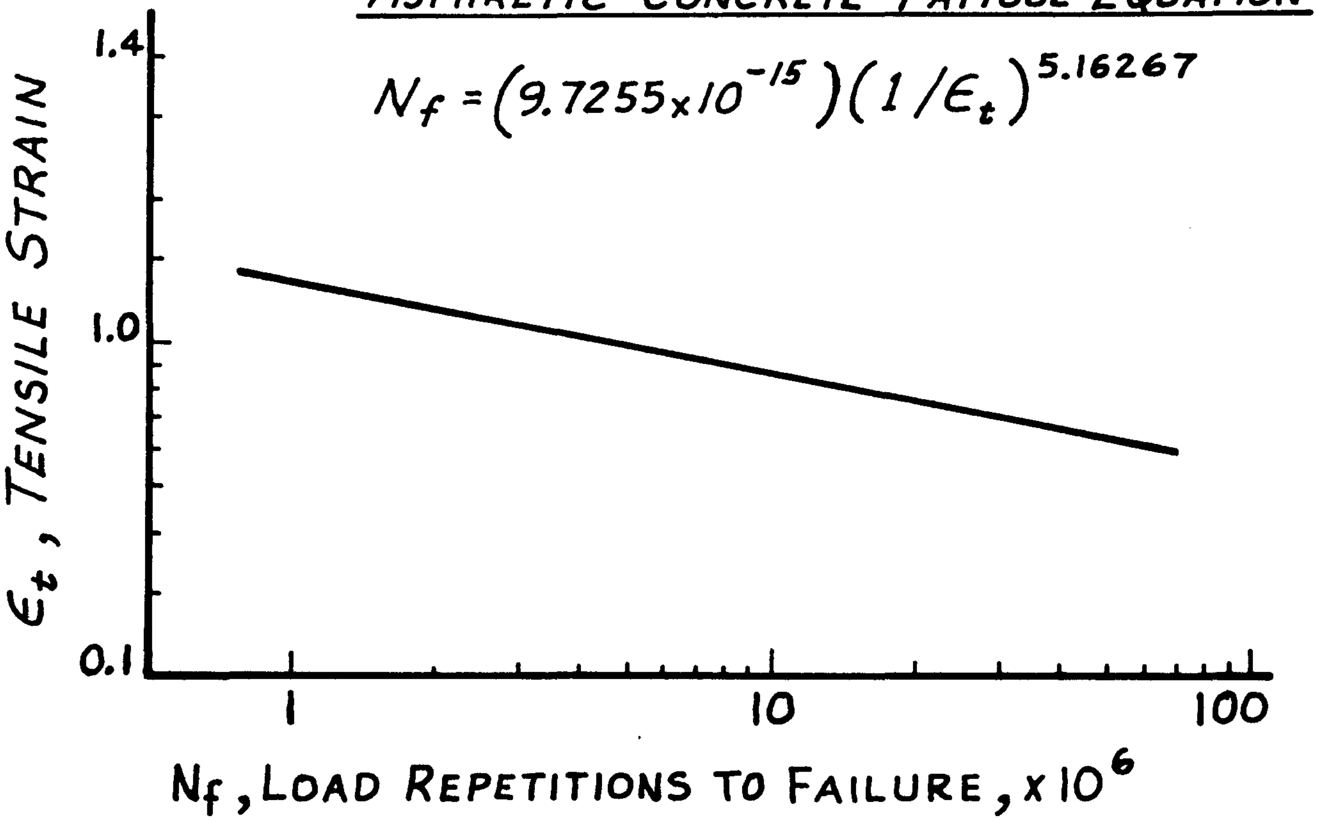
Multilayer Elastic Analysis


4500 LB.
4500 LB.
12" c-c
WHEEL
WHEEL
80 PSI TIRE PRESSURE
ASPHALTIC CONCRETE, E = 400,000, μ = 0.35
ϵ_t
ϵ_t
FLEXIBLE BASE, E = 50,000, μ = 0.40
ϵ_c
ϵ_c
SUBGRADE, E = 10,000, μ = 0.45

SLIDE No. 46

ASPHALTIC CONCRETE FATIGUE EQUATION

$$N_f = (9.7255 \times 10^{-15})(1/\epsilon_t)^{5.16267}$$



FROM REPORT NO. FHWA-RD-75-75

Asphalt Institute Procedure

SLIDE No. 48

THE ASPHALT INSTITUTE

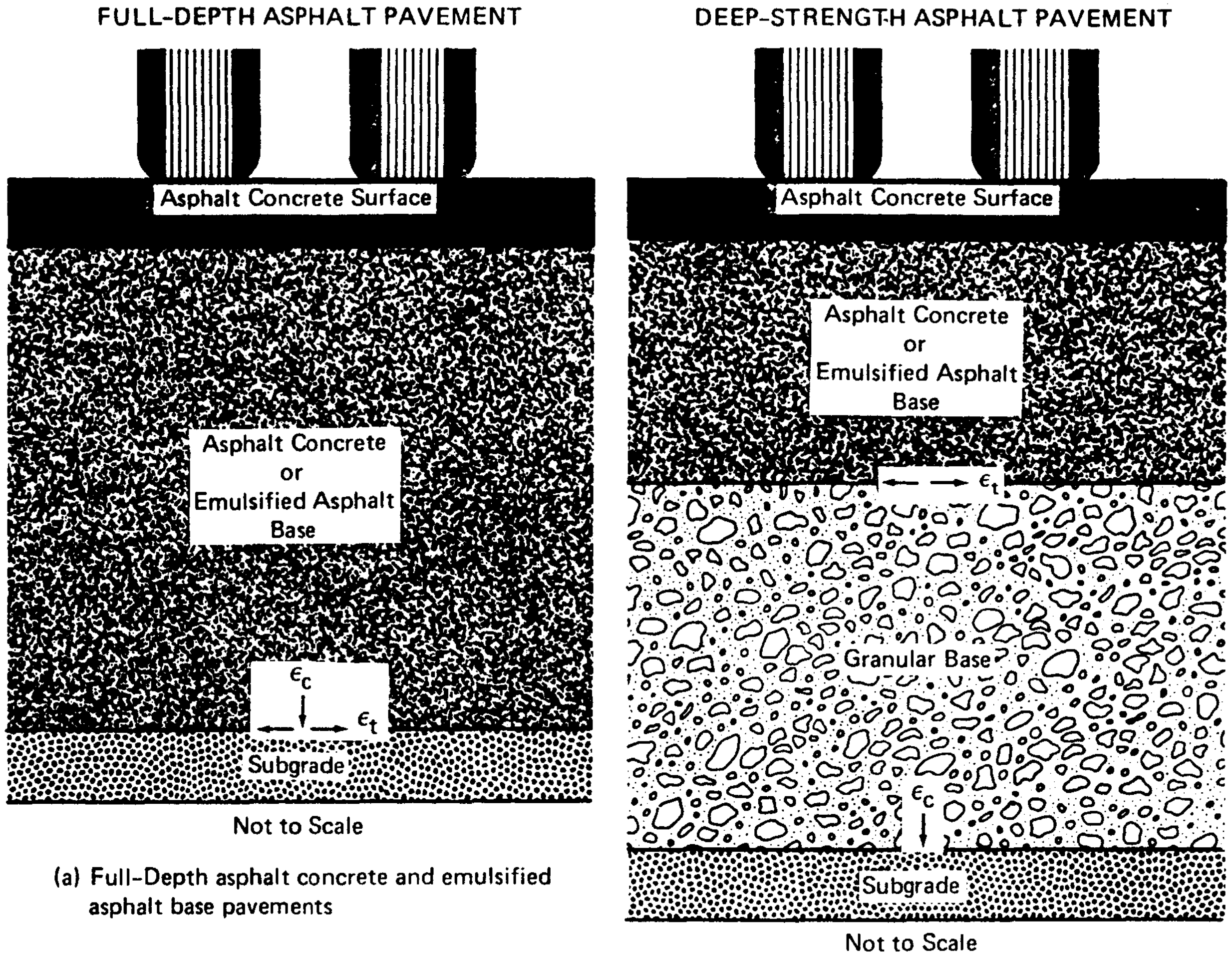
- ELASTIC THEORY (MECHANISTIC)
- RESULTS OF RESEARCH

SLIDE No. 49

THE ASPHALT INSTITUTE

- DESIGN METHODS
  - CHARTS IN MANUAL
  - COMPUTER PROGRAM DAMA
    (NOT AVAILABLE TO SDHPT)

SLIDE NO. 50



(a) Full-Depth asphalt concrete and emulsified asphalt base pavements

(b) Pavements with granular base

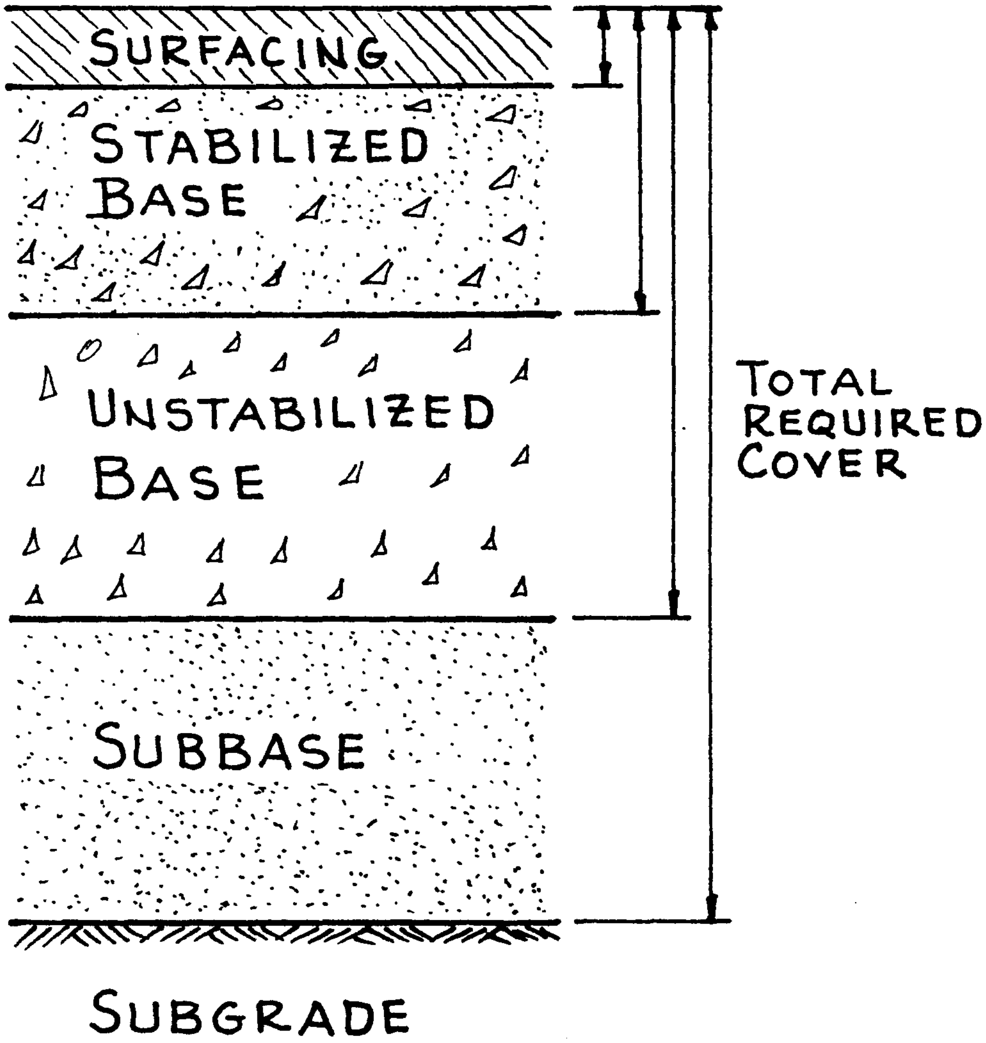
Locations of strains considered in design procedure.

SLIDE No. 51

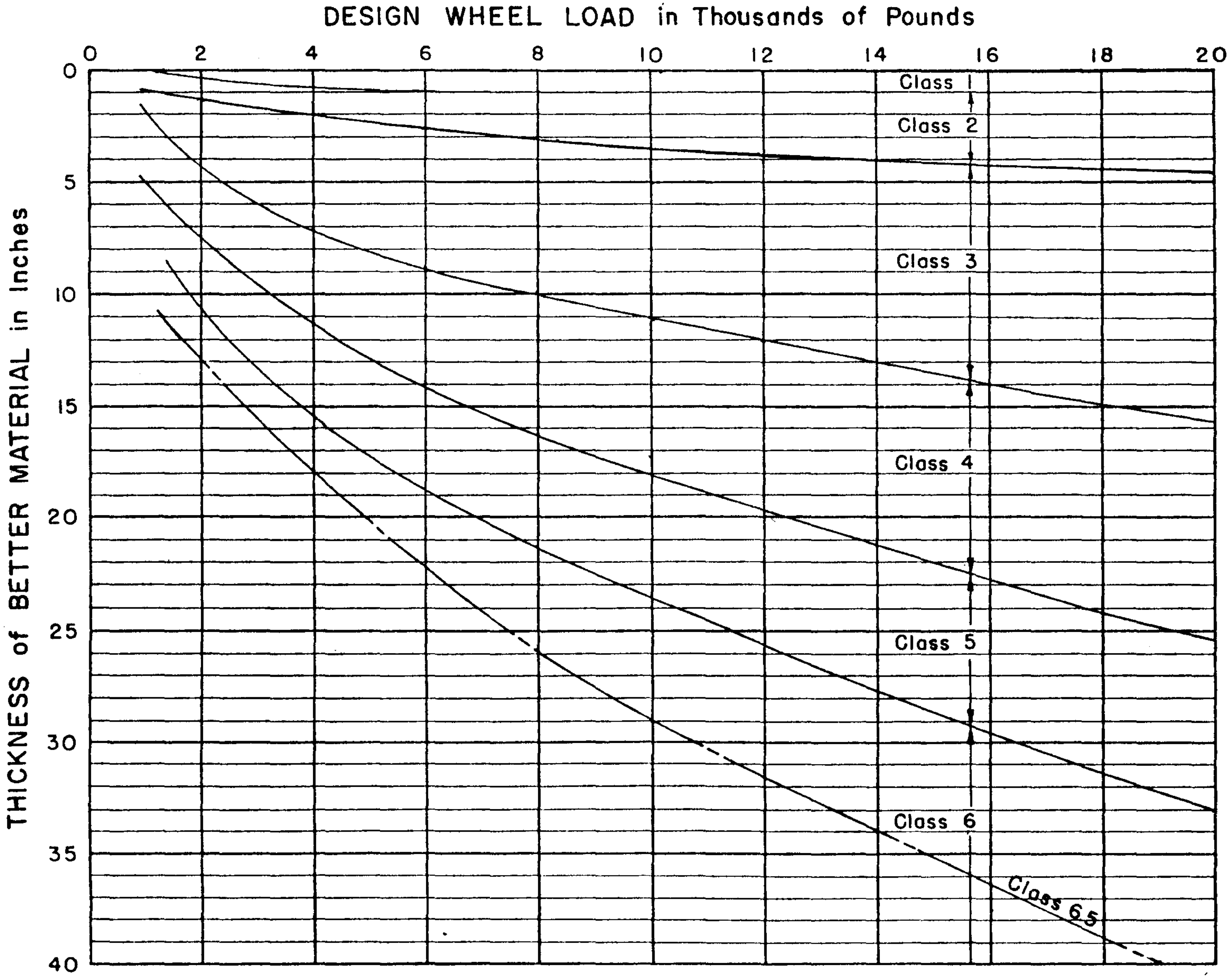
Texas Triaxial Design Procedure (TEX-117-E)

STANDARD

TEXAS TRIAXIAL DESIGN



SLIDE NO. 53



FLEXIBLE BASE DESIGN CHART

Figure 16

Slide No. 54

FLOWER

SLIDE No. 55

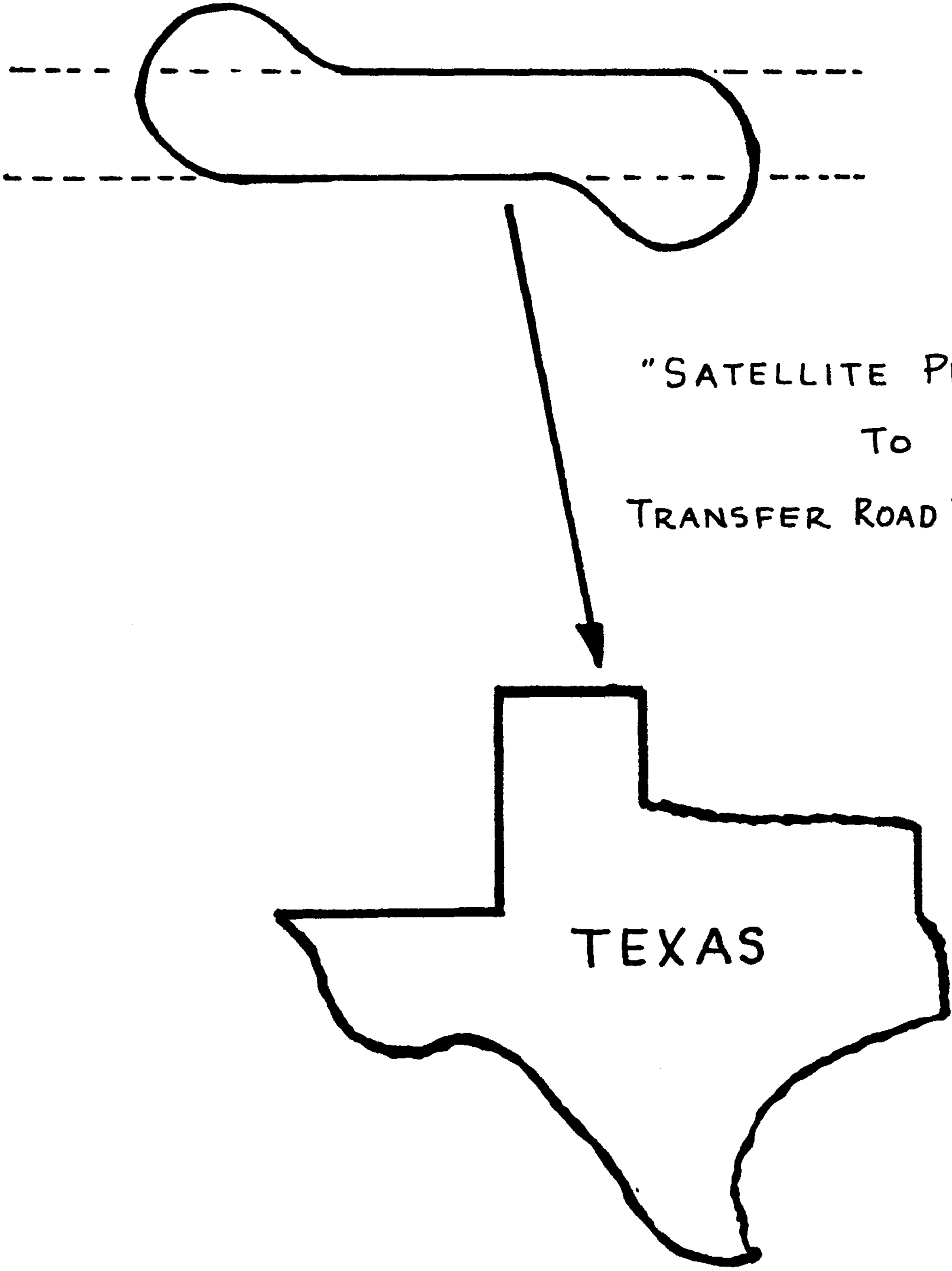
Texas Flexible Pavement Design System (FPS)

SLIDE No. 56

AASHO ROAD TEST

OTTAWA, ILL.

LATE 1950's AND EARLY 1960's



"SATELLITE PROJECTS"

TO

TRANSFER ROAD TEST FINDINGS

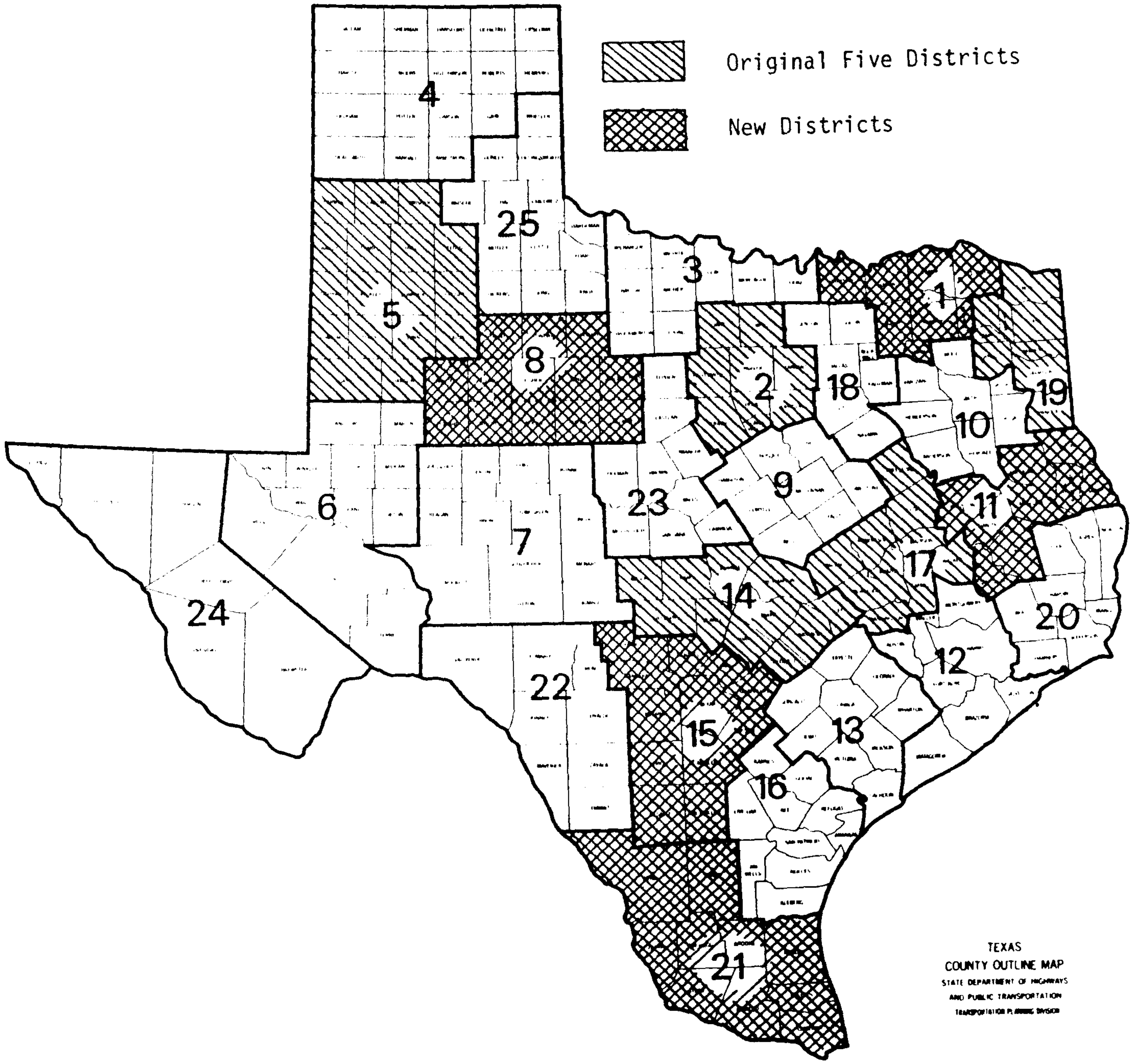


Figure 1
The Ten Participating Districts

SLIDE No. 58

Purpose of FPS System:

To provide, from available materials, a pavement that can be maintained above a specified level of serviceability, over a specified period of time, with a specified reliability, at a minimum overall total cost.

FPS Computer Programs

(1) FPS-11 (Principal Program)

(2) Stiffness Coefficient Program

(3) Profile Analysis Program

SLIDE No. 60

OPTIMIZATION

- STATE LEVEL
- DISTRICT LEVEL
- PROJECT LEVEL

SLIDE No. 61

FPS System Optimization

- Total Cost for Analysis Period

1. Initial Construction Cost,
2. Overlay Construction Cost,
3. User Cost (Delay),
4. Routine Maintenance Cost, and
5. Salvage Value.

SLIDE No. 62

66 Inputs to FPS

Card No.	Category
1	Project Identification (8)
2	Project Comments (1)
3	Basic Design Criteria (6)
4	Program Controls and Constraints (5)
5	Traffic Data (8)
6	Environment and Subgrade (5)
7	Construction and Maintenance Data (9)
8	Detour Designs for Overlays (7)
9	Existing Pavement and Proposed ACP (8)
10	Paving Materials Information (9)

SLIDE No. 63

Performance Equation Inputs

1. Serviceability Index
   a. Initial Serviceability
   b. Serviceability After ACP Overlay
   c. Terminal Serviceability
2. Materials Stiffness Coefficients (or Surface Curvature Index)
3. Traffic (18-KSA Applications)
4. Temperature Constant
5. Swelling Clay Properties

SLIDE No. 64

FPS Design Process

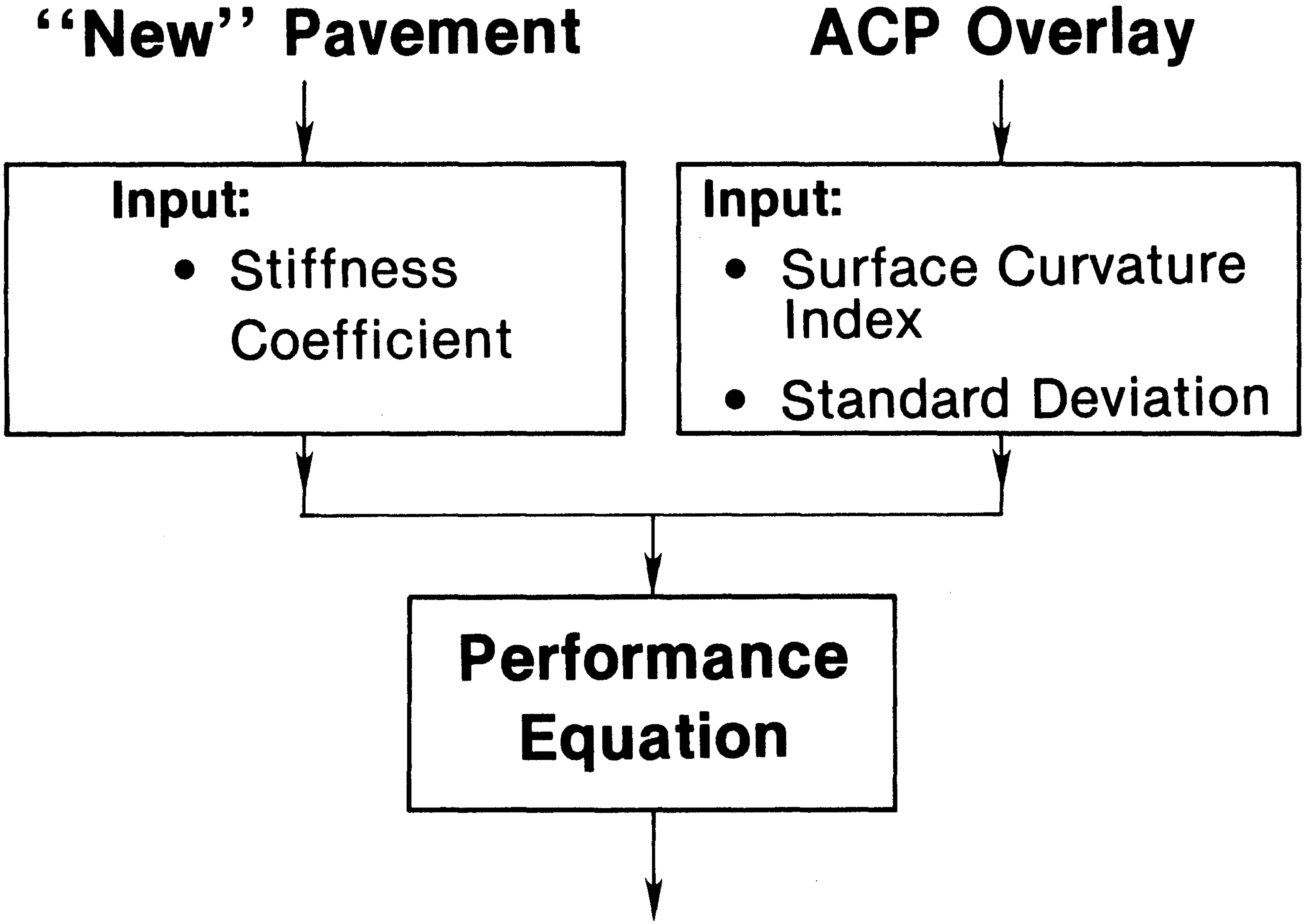
- Develop Input Data
  - —Measure Field Data
  - —Select Materials Properties
  - —Secure Traffic Data
- Compute with FPS Program
- Select Best Pavement Design Strategy

SLIDE No. 65

COLLECTION OF DATA:

- DYNAFLECT DATA
- TRAFFIC DATA
- EXISTING PAVEMENT
- SOILS SURVEY
- VISUAL CONDITION SURVEY

SLIDE NO. 66



"New" Pavement

Input:
- Stiffness Coefficient

ACP Overlay

Input:
- Surface Curvature Index
- Standard Deviation

Performance Equation

SLIDE No. 67

Traffic Data

- File D-10
  - —20 Year Data for FPS
  - —Historical Traffic
  - —Local Knowledge

SLIDE No. 68

SLIDE No. 69

Confidence Level

- Highway Capacity Within Analysis Period
  - —Greater Than 50% Of Capacity
  - —Less Than 50% Of Capacity

Confidence Level

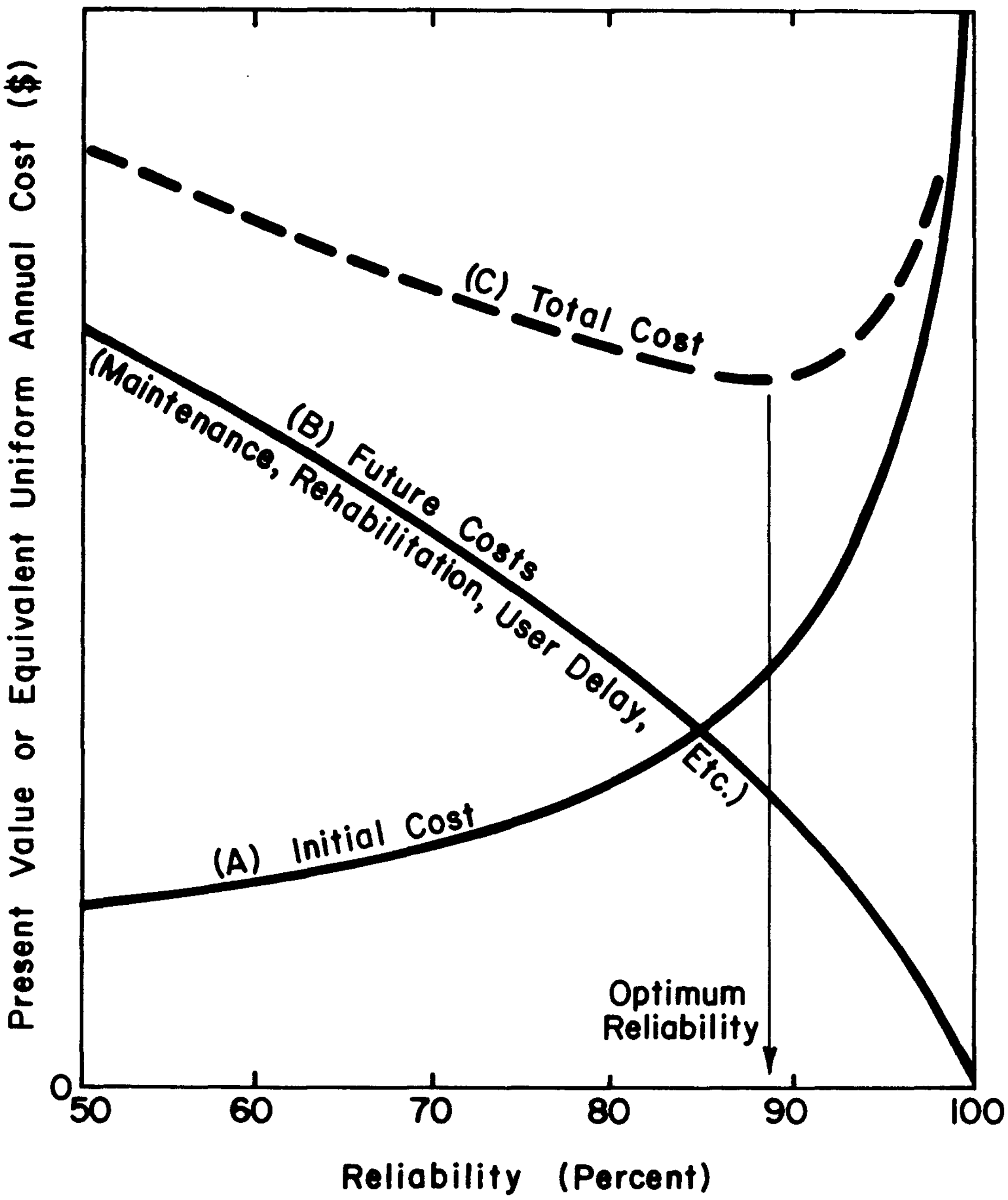
- Highway Status During Analysis Period
  - —Will Remain Rural
  - —Is Or Will Become Urban

TABLE 3.1

GUIDELINES FOR SELECTING THE DESIGN CONFIDENCE LEVEL

	THE HIGHWAY WILL REMAIN RURAL THROUGHOUT THE ANALYSIS PERIOD	THE HIGHWAY IS OR WILL BECOME URBAN BEFORE THE END OF THE ANALYSIS PERIOD
THE HIGHWAY WILL BE OPERATING AT GREATER THAN 50% OF CAPACITY SOMETIME WITHIN THE ANALYSIS PERIOD	C OR D	E
THE HIGHWAY WILL BE OPERATING AT LESS THAN 50% OF CAPACITY THROUGHOUT THE ANALYSIS PERIOD	C	D OR E

SLIDE No. 71



IDENTIFYING THE OPTIMUM RELIABILITY LEVEL FOR A GIVEN FACILITY

SLIDE NO. 72

FLOWER

PAVEMENT DESIGN ASSISTANCE

SLIDE NO. 74

THE END

SLIDE NO. 75