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16. Abstract

This study was undertaken to provide the LA DOTD with an implementation package to facilitate adoption of the new AASHTO Guide for Design of Pavement Structures. The study included evaluation of design parameters for rigid and flexible pavements, including several new parameters such as design reliability, resilient modulus, drainage, and use of tied concrete shoulders and widened lanes. Recommendations were made for design values which best represent Louisiana conditions, materials, and construction procedures. An automated procedure was developed to estimate roadbed resilient modulus by using soils engineering and classification data as an interim design measure. Traffic equivalence factors were updated using Weigh-in-Motion data for selected vehicle types. Layer structural coefficients were updated for flexible design to reflect new materials and construction procedures. A computer program was developed for DOTD use which is tailored to its design reporting format and which has storage capabilities for pavement management purposes. The program is designed to calculate layer thicknesses for a variety of available materials to satisfy the flexible design structural number while maintaining a uniform final pavement elevation. Recommendations are provided for a high stability wearing course layer which is designed to resist rutting and early surface failure, and for permeable asphalt base drainage for rigid and flexible pavement designs.

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IMPLEMENTATION OF THE

NEW AASHTO PAVEMENT DESIGN PROCEDURE

IN LOUISIANA

FINAL REPORT

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Research Report No. 218
Research Project No. 89-1DEM

Conducted by
LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
Louisiana Transportation Research Center
In Cooperation with
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ABSTRACT

This study was undertaken to provide the LA DOTD with an implementation package to facilitate adoption of the new AASHTO Guide for Design of Pavement Structures. The study included evaluation of design parameters for rigid and flexible pavements, including several new parameters such as design reliability, resilient modulus, drainage, and use of tied concrete shoulders and widened lanes. Recommendations were made for design values which best represent Louisiana conditions, materials, and construction procedures. An automated procedure was developed to estimate roadbed resilient modulus by using soils engineering and classification data as an interim design measure. Traffic equivalence factors were updated using Weigh-in-Motion data for selected vehicle types. Layer structural coefficients were updated for flexible design to reflect new materials and construction procedures. A computer program was developed for DOTD use which is tailored to its design reporting format and which has storage capabilities for pavement management purposes. The program is designed to calculate layer thicknesses for a variety of available materials to satisfy the flexible design structural number while maintaining a uniform final pavement elevation. Recommendations are provided for a high stability wearing course layer which is designed to resist rutting and early surface failure, and for permeable asphalt base drainage for rigid and flexible pavement designs.

IMPLEMENTATION STATEMENT

The new AASHTO Guide for Design of Pavement Structures will be implemented by Louisiana DOTD as a part of its Pavement Management Information System (PMIS). The computer software developed under this study (LA PAVE) has been designed to accomplish data storage of project design information for PMIS.

The portion of the new guide which will be implemented by this study is specific to section design of new pavements and does not include overlay, rehabilitation, staged construction, or calculation of life costs.

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INTRODUCTION

The design of pavements requires the prediction of the interrelation of several influencing factors. To help define these interrelationships, the AASHO Road Test was performed. In 1961 and 1962 the results of the AASHO Road Test were published in the Interim Design Guides.[1,2] Louisiana adopted the Interim Design Guides as its pavement design procedure in that same year and participated in subsequent revisions is 1972 [3] and again in 1981.[4]

In 1986, AASHTO released a new revision of the pavement design guide entitled <u>AASHTO Guide for Design of Pavement Structures, 1986</u>, henceforth referred to as the AASHTO Design Guide.[5] With this revision several new factors were considered and defined in terms of their influence on pavement thickness selection. Among these are:

> Reliability of the Pavement Structure
> Resilient Modulus for Soil Support
> Drainage
> Tied Concrete Shoulders or Widened Lanes

Each of these factors served to add to or modify a computational term in the flexible and/or rigid design equations. To facilitate implementation by DOTD, these new design factors were incorporated into computer software which was tailored to the needs of flexible and rigid pavement design in Louisiana. One of the goals in the software development was to include a subroutine which calculates several flexible section designs using alternate base course materials.

The report describes the factors used in both the rigid and flexible design equations with recommendations on which values or range of input variables best apply to design of pavements in this state. Several changes are recommended to improve the design and

performance of flexible pavements constructed with cement-treated bases. The flexible pavement structural design coefficients were updated to reflect new materials and constructions practices. These include the new, high-stability, high friction, asphaltic concrete surface mix, crushed portland cement concrete used as an aggregate layer, a synthetic aggregate, and plant mixing of materials stabilized with portland cement.

SCOPE

The study and software development are specific to the design of new pavements for a single design period, and therefore, do not address overlay, design of staged construction, determination of life cycle costing, or pavement rehabilitation. The study includes an update of design factors which reflect new materials and new construction practices. The study does not address new methods for estimating future traffic loading for design, but does include updated vehicle equivalency factors.

OBJECTIVES

The objectives of the study included:

1. Familiarization with the new AASHTO pavement design procedure and software.

2. Development of a modified computer program for DOTD which is tailored to its design reporting format, which has storage capabilities for pavement management purposes, and which incorporates internal policies governing materials and mix type useage.

3. Development of a subroutine which predicts soil resilient modulus from soil engineering classification using test data developed in Louisiana.

4. Updating the structural design coefficients used in flexible pavement design to reflect new materials and construction practices.

5. Recommendation of values for the new design input parameters which best represent Louisiana conditions, materials and construction procedures.

6. Updating vehicle equivalency factors where appropriate.

7. Providing recommendations regarding where internal drainage would most likely benefit flexible pavement performance in Louisiana.

INPUT VARIABLES USED IN THE PAVEMENT DESIGN EQUATIONS

In the chapters which follow, the discussion of input variables for pavement design has been divided into those variables which are to be used in both flexible and rigid pavement designs, and those which are unique to the design of one pavement type. These variables are listed as follows:

Variables Common to Flexible and Rigid Design

Change in Present Serviceability Index (PSI)
Traffic Loading (Cumulative 18-kip Equivalent Single Axles)
Design Reliability of the Pavement Structure

Variables Unique to Flexible Design

Roadbed Soil Resilient Modulus
Structural Design Coefficients

Variables Unique to Rigid Design

Modulus of Subgrade Reaction (Composite K-value)
Modulus of Concrete Rupture (Flexural Strength)
Concrete Elastic Modulus
Drainage Coefficient
Load Transfer Coefficient

DISCUSSION OF COMMON INPUT VARIABLES

Change in Present Serviceability Index

The serviceability of a pavement is defined as its ability to serve the automobiles and trucks which use the facility. The primary measure of serviceability is the Present Serviceability Index (PSI), which ranges from 0 (impassable road) to 5 (perfect road). The AASHTO design philosophy is based upon the performance concept, by which the designed pavement will carry the estimated traffic loading over the performance period while maintaining at least a minimum level of serviceability.

The constructed serviceability of a pavement decreases with time and traffic. To find change in PSI two values are needed, the initial serviceability index (P_i) and the terminal serviceability index (P_t).

P_i is an estimate of the value of PSI for the pavement structure immediately after construction. Typical values encountered in Louisiana on construction of major highways are 4.2 - 4.6 for flexible pavements and 4.0 - 4.3 for rigid pavements. These typical PSI values reflect surface tolerances specified and tested using the 10-foot rolling straightedge. Minimum acceptable values of 4.3 are being targeted for major highways as DOTD implements the rolling profilograph for construction control and acceptance. This level of PSI is attainable on jointed concrete pavements, although some degree of ride correction may be required. Recent evaluations of new asphaltic concrete construction indicate that this level of PSI should be routinely attainable, therefore 4.3 is viewed as the minimum level allowed for this type of construction before corrective action is required. Target values necessary to obtain a PSI of 4.3 have recently been determined by LTRC using a California style (Ames) profilograph (0.2-inch blanking band). The values to be specified are 5-inches per mile for jointed concrete paving and 2-inches per mile for asphaltic concrete paving.

P_t is defined as the value of PSI which is the lowest acceptable level before resurfacing or reconstruction becomes necessary. It is usually represented by values of 3.0 or 2.5 for major highways, and 2.0 for lower classed highways and 1.5 for relatively minor highways.

One of the changes in the AASHTO Design Guide is that the designer can now address change in PSI as design input. In the past, P_t was used in the design process based upon the functional classification of the highway (major, minor, etc.) and pavements were assumed to have high P_i values. The new guide allows for the input of a value for the change in PSI over the life of the pavement structure. This permits the designer to account for multiple factors affecting the change in PSI. Among the most influential factors affecting this change are the traffic and the environmental conditions.

In an effort to recognize the importance of route class, the change in PSI was evaluated on the basis of the class of highway under design such as interstate, primary, collectors, and local routes. This resulted in levels of design serviceability loss (ΔPSI) indicated in Table 1, based on the expected initial serviceability index and the minimum desirable terminal serviceability index for each route class.

TABLE 1

SERVICEABILITY INDEX -- DESIGN LOSS, INITIAL, AND TERMINAL

	ΔPSI	P_i	P_t
Interstate	1.5	4.3	2.8
Primary	1.8	4.3	2.5
Collectors	2.0	4.0	2.0
Local	2.0	3.5	1.5

Prediction of Total Traffic Loading

Pavement are designed, regardless of the type of materials, to withstand repeated applications of traffic load. This load is

expressed in terms of the total 18-kip equivalent single axle loads generated over the design life of the project.

The AASHO Road Test experiment produced equivalency factors which can be used to convert the relative damage associated with a single or tandem axle of known weight, to an equivalent unit of damage associated with an 18-kip single axle load. As a result, any vehicle of known axle loading can be converted to an equivalent single axle loading (ESAL, 18-kip). In an effort to best estimate total expected loading, pavement designers use a design factor (Vehicle Equivalency Factor) which is characteristic of a particular vehicle type. In the case of trucks, which are the most damaging to pavements, the factors take into consideration the fact that not all trucks in the traffic stream are always loaded. These design factors are produced by periodically conducting loadometer studies in which trucks are sampled for weighing without bias to a load or no-load condition. The information published for use in pavement design is entitled the "W-4" Table, which is specific to three criteria:

1.   Terminal PSI of the pavement structure.

2.   Initial assumption of thickness for rigid pavement or structural number for flexible pavement.

3.   Number of axles of the vehicle for which the 18-kip equivalence factor is desired.

The vehicle equivalency factors currently used in Louisiana are listed in Appendix A. Several of these factors were determined from Weigh-in-Motion studies[6] used to supplement data not collected in the most recent loadometer study data. The design software developed in this study includes a data file with these factors for rigid and flexible pavements so the designer need only enter the projected 24-hour vehicle classification (design lane) distribution for the median design year, and the length of the

design period in years. The program will then compute the total
design load and the average daily load for the median design year.

Reliability of the Pavement Structure

Although the flexible and rigid pavement design equations have
several unique computational terms representing the various
influencing factors, there is a term in the equations which is
shared by both. This term represents the design reliability of the
pavement structure.

According to the AASHTO Design Guide, the reliability level of a
pavement structure is defined as "the probability that a pavement
section designed using the process will perform satisfactorily
over the traffic and environmental conditions for the design
period." Naturally, all state agencies desire 100 percent
reliability in their pavement structures, as this would mean that
no future costs for maintenance and/or repair of the pavement
structure would be required during its design life. In the
theoretical world this is possible, but in reality the cost of
producing a 100 percent reliable pavement structure is not
economically feasible.

It can be demonstrated graphically that as reliability increases,
so does the initial cost of construction of the pavement
structure. This is shown in Figure 1 on page 13 . In addition,
there is a line on the graph that demonstrates how future costs
(projected back to present value) decrease with increased
reliability. The key to selecting an appropriate value of
pavement structure reliability is to look at the total of the
future and the initial cost curves. There will be a point in the
graph of total costs versus reliability where total costs will be
at a minimum. The corresponding reliability level will be the
desired level of pavement structure reliability.

The selection of a reliability levels for the current study was
based upon the functional classification of each pavement facility
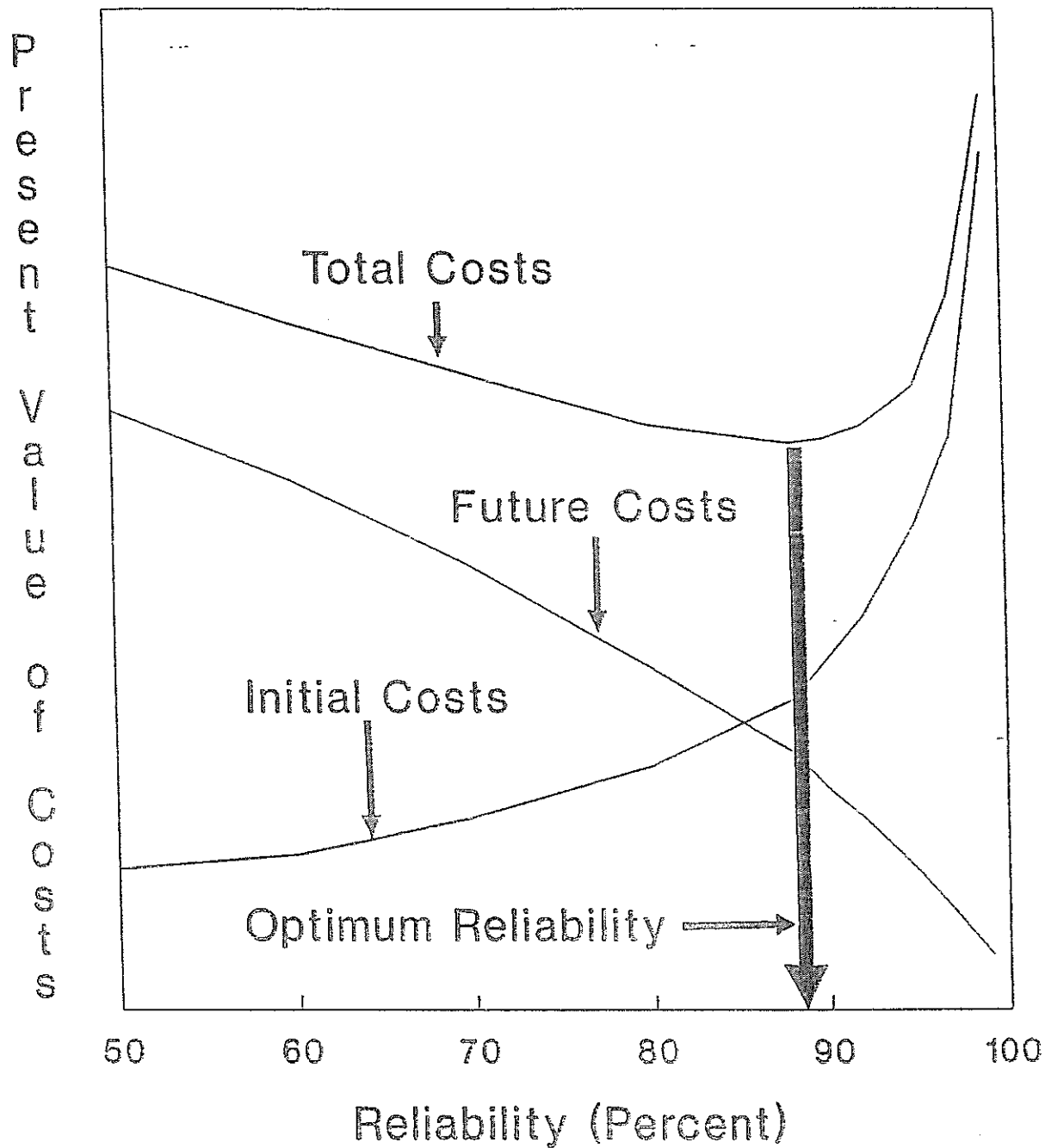
Figure 1

Present value of costs versus reliability
(from the AASHTO Design Guide, 1986)

and whether the facility is located in a urban or rural location. The suggested values included in the AASHTO Design Guide and the levels recommended for incorporation into the Louisiana Pavement Design System are included in Table 2 on page 14. The values recommended typically represent the upper range of AASHTO recommended values for interstate and primary routes and the median to upper range of recommended values for collector and local routes.

TABLE 2

AASHTO SUGGESTED RELIABILITY LEVELS

Location	Functional Class	AASHTO Suggested Reliability Levels	Louisiana Recommended Reliability Levels
Urban	Interstate	85 - 99.99	99
	Principal	80 - 99	97
	Collectors	80 - 95	90
	Local	50 - 80	75
Rural	Interstate	80 - 99.99	97
	Principal	75 - 95	95
	Collectors	75 - 95	85
	Local	50 - 80	70

These default values are automatically selected by the computer software after the user identifies the location and functional class of the pavement structure.

Higher levels of reliability are recommended for urban construction due to the increased difficulty in interrupting traffic for maintenance or rehabilitation in these areas. A sensitivity analysis of the effect of change in reliability level on pavement thickness is illustrated in Figures 2 and 3 on pages 15 and 16 for an example rigid and flexible pavement, respectively.

Concrete Thickness (Inches)

Rural – Interstate
Overall Standard Deviation – 0.37
Change in PSI – 1.5
Concrete Elastic Modulus – 4,200,000
Concrete Flexural Strength – 550
Asphalt Shoulder & 15 ft Truck Lane
Drainable Shoulder Layer
Traffic Factor – 3,000
Composite Subgrade Modulus – 350
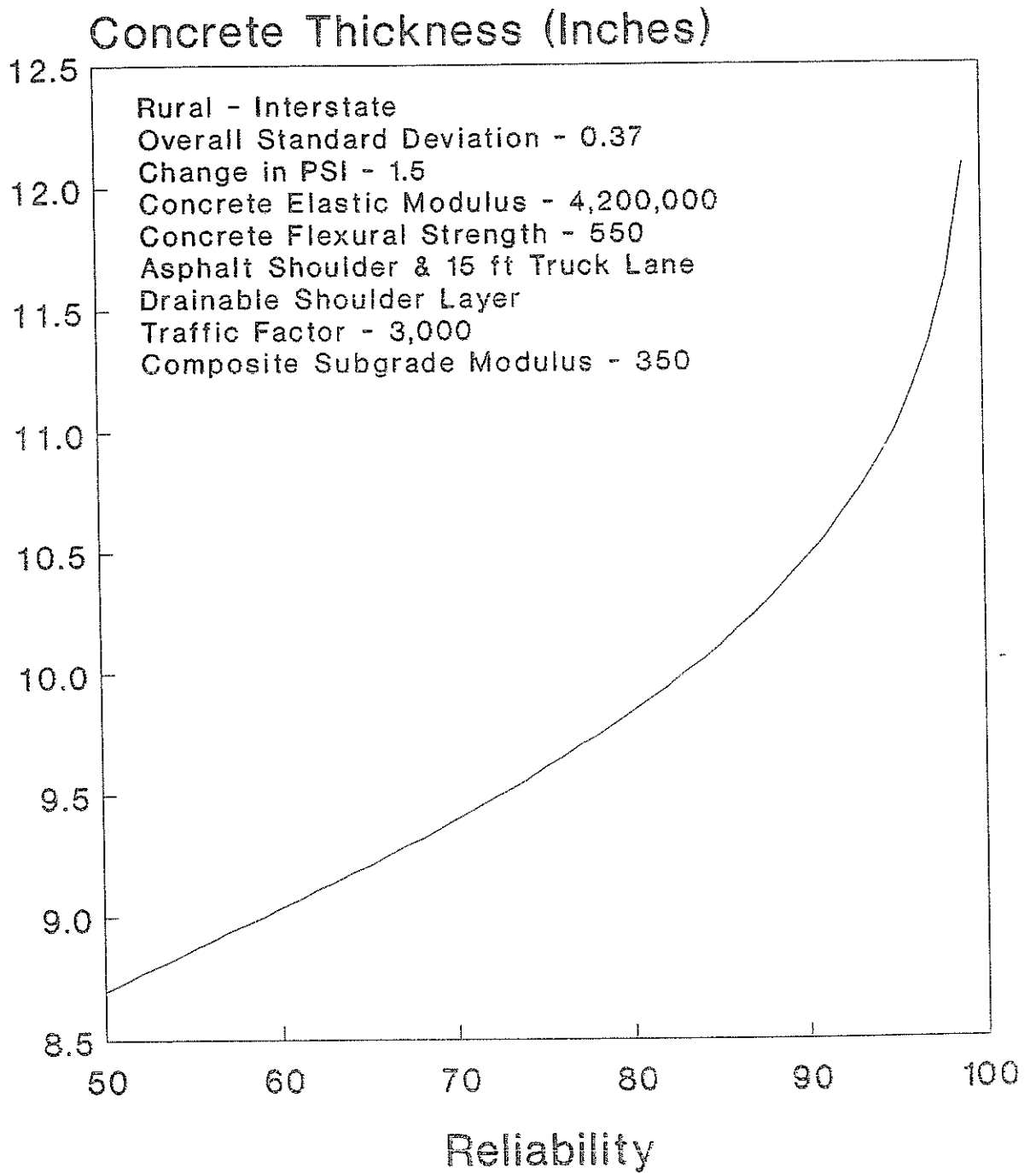
Reliability

Figure 2
Sensitivity analysis -- reliability, rigid design
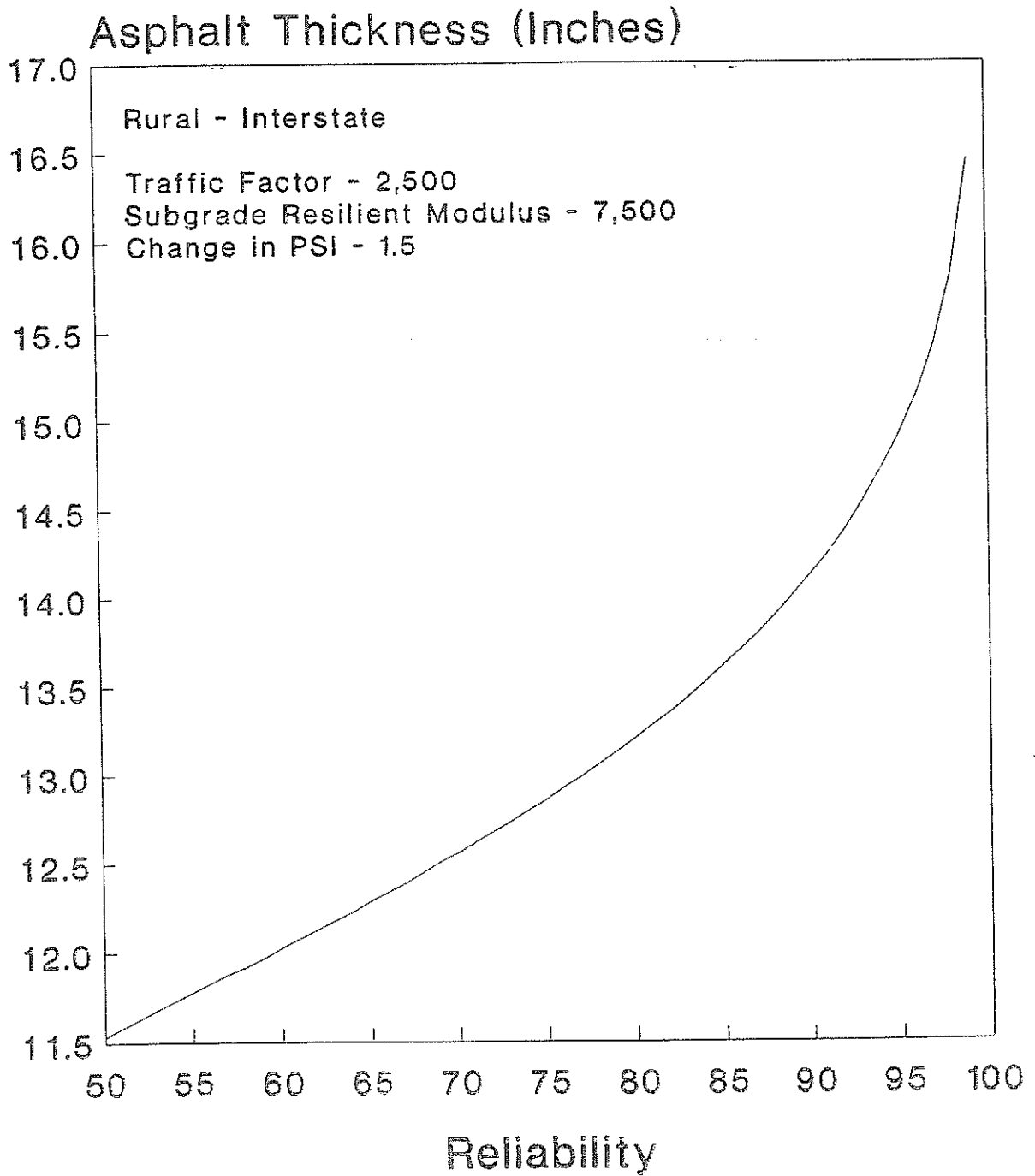
Figure 3

Sensitivity analysis -- reliability, flexible design

Reliability Design Factor

The reliability concept is intended to provide the designer with a mechanism for applying a factor of safety in design as a safeguard against incorrect traffic predictions and overloads, unfavorable environmental effects, and variations in material strengths which cannot be controlled by construction and specification requirements. The new AASHTO design procedure accomplishes this by calculating a reliability design factor using the selected reliability level (previously discussed) and the expected overall standard deviation associated with the type of pavement under design (described below). These two values are combined by the following equation.

$$\log R_f = -Z_r * S_o$$

where:

R_f = Reliability Design Factor

Z_r = Standard Normal Value Corresponding to the selected Reliability Level

S_o = Overall Standard Deviation of Pavement Structure

The Z_r term, standard normal value, corresponds statistically to the level of reliability selected in design. Refer to the new AASHTO Guide for Design of Pavement Structures for additional discussion.

The S_o term, the overall standard deviation, is included to account for expected variation in the prediction of pavement performance for a given traffic loading. Values for the overall standard deviation are selected by the type of pavement structure being designed. The AASHTO Design Guide recommends the following range of values:

0.33 - 0.39   for rigid pavements and
0.44 - 0.49   for flexible pavements

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The lower end of each range corresponds roughly to the estimated variances associated with the AASHO Road Test pavements. Since it is reasonable to expect that on any given construction project the variation in material components, density of asphaltic concrete, strength of portland cement concrete, etc. would typically exceed the variation expected in a controlled experiment like the Road Test, the midpoint values have been recommended for general design practice in Louisiana.

The values of S_O recommended are:

      0.37 for rigid pavements and

      0.47 for flexible pavements

A sensitivity analysis for a particular set of parameters was conducted to determine the effect of a change in S_O on pavement thickness, as illustrated in Figures 4 and 5, pages 19 and 20. The effect of S_O on design thickness is so slight that additional study of this variable would not appear to be cost effective.

Since the reliability design factor, R_f, is applied in the design process as a factor of safety on the predicted traffic load for each pavement type, the factors of safety previously used in pavement design are no longer necessary. This would include the factor of safety applied to concrete flexural strength and the regional factor used in flexible pavement design. It is, therefore, the intent of the design procedure that design input values reflect the normally expected or statistical mean level of material strengths.
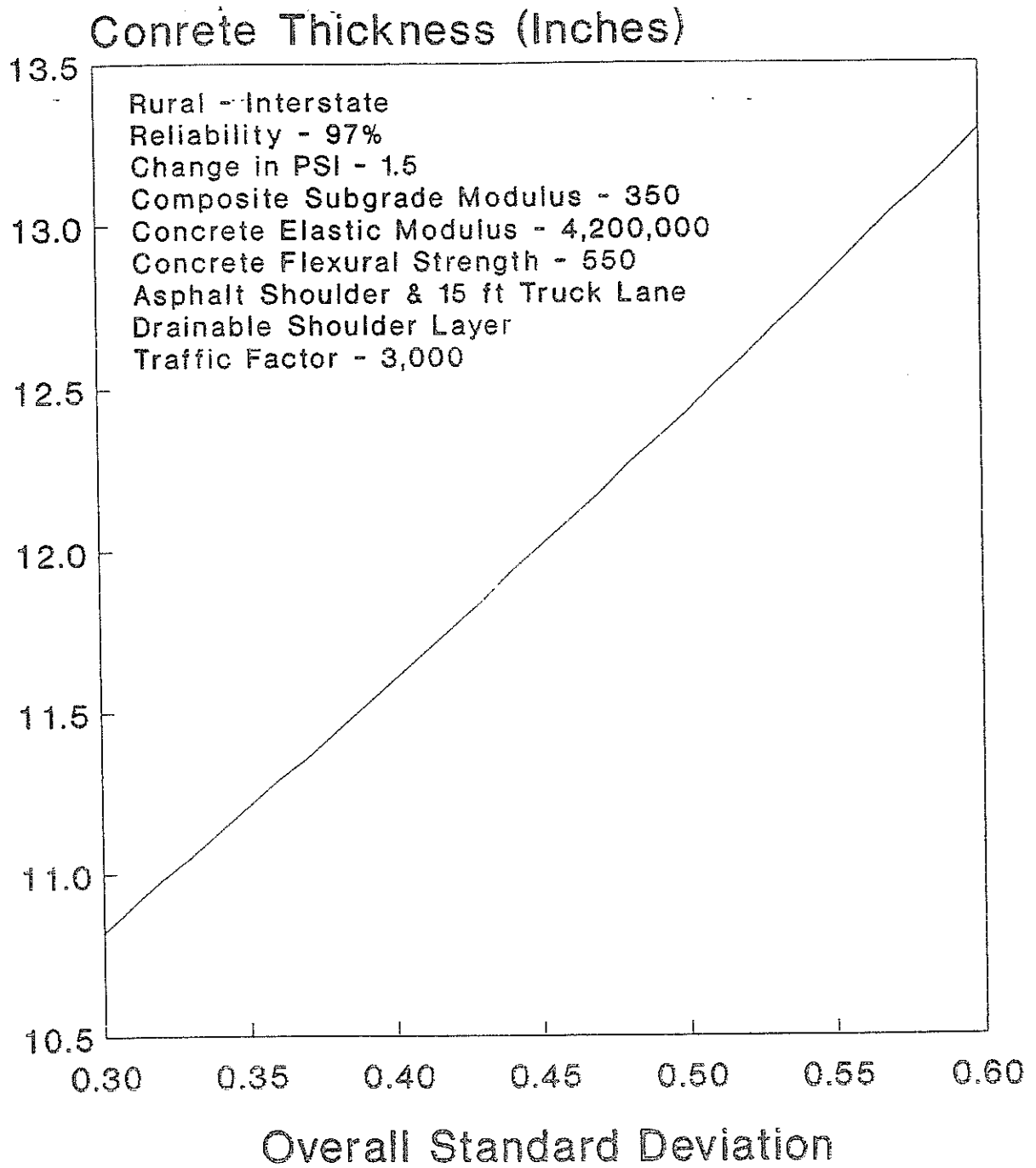
Figure 4

*Sensitivity analysis -- overall standard deviation,
rigid design*

Asphalt Thickness (Inches)

Rural - Interstate

Reliability - 97 %
Traffic Factor - 2,500
Subgrade Resilient Modulus - 7,500
Change in PSI - 1.5

Overall Standard Deviation
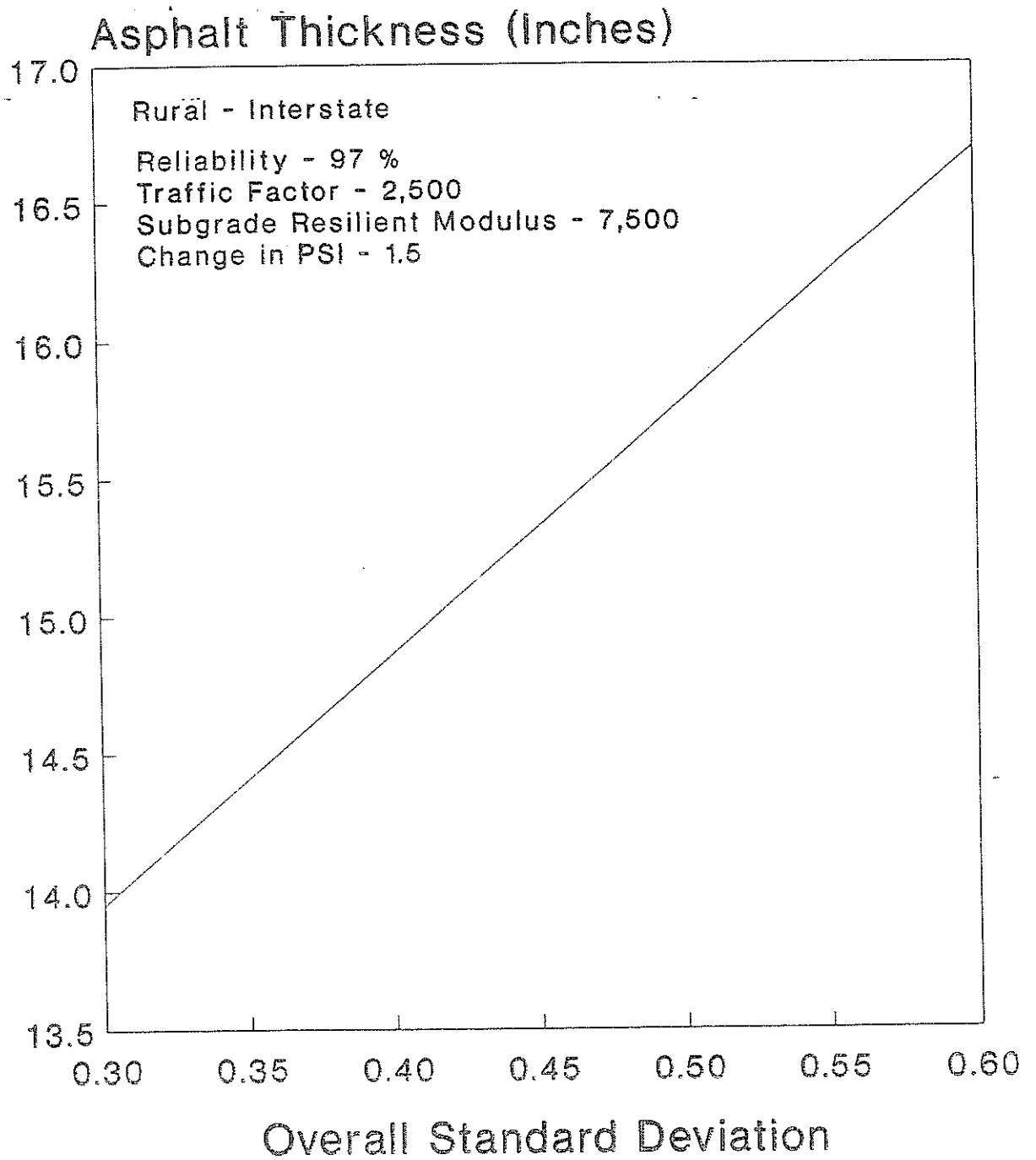
Figure 5

Sensitivity analysis -- overall standard deviation,
flexible design

DISCUSSION OF FLEXIBLE PAVEMENT DESIGN INPUT VARIABLES

As previously stated, the two input factors unique to flexible pavement design are the roadbed soil resilient modulus (M_r), which replaces the Soil Support Value, and the flexible pavement structural design coefficients, which have been updated for this study. Discussion is also provided on an automated layer thickness selection subroutine developed to facilitate design of alternate base materials.

Roadbed Soil Resilient Modulus

Resilient Modulus (M_r) is the definitive materials property used by the AASHTO Guide to characterize roadbed soils. It is a measure of the elastic property of soil which recognizes certain nonlinear characteristics.

In Louisiana, resilient modulus is neither a standard soils test, nor is the equipment for such testing currently owned by DOTD. Extensive soil modulus testing as a part of a recent research study "Louisiana Experimental Base Study"[7], LTRC, 1987, has provided the relationships necessary to generally verify the soil R-value -- M_r conversion relationships suggested in the AASHTO Design Guide for use by agencies as an interim procedure.

Louisiana currently uses a relationship (developed by the Research Section in 1963[8]) to estimate soil support values which converts soil class/engineering properties to R-values. This procedure has been used successfully for over 20 years in pavement design in the state. The referenced R-value -- M_r relationship will permit the designer to convert from soil class/engineering properties to M_r. These relationships are depicted in Figures 6 and 7 pages 22 and 23 for the following general soil types: sand, sandy loam, sandy-clay loam, silt, silty clay, and heavy clay. The procedure is believed to be adequate in defining the variation in support afforded by the various, indicated soil types and is therefore usable as an interim design tool.

1	Sand	A·2·4(0)
2	Sa/Lo	A·2·6(0)
3	Sa/Cl/Lo	A·2·6(2)
4	Silt	A·4·(8)
5	Si/Cl	A·6·(12)
6	Mv/Cl	A·7·6(20)

Mr
(ksi)

40

3

2

35

30

1

25

20

4

5

6

15

10

5

10 12 14 16 18 20 22 24 26 28

Moisture   Content   %
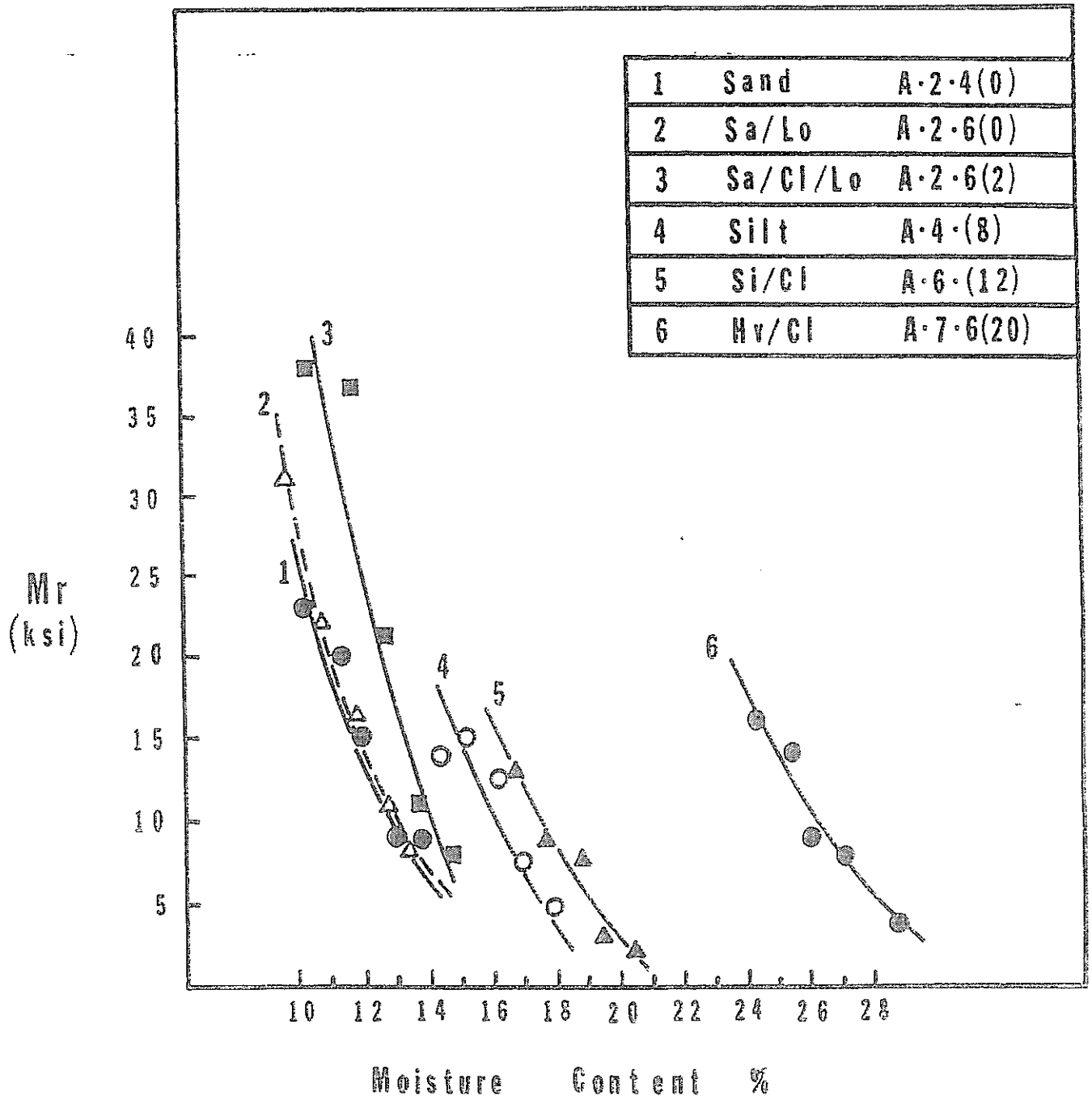
Figure 6

Soil resilient modulus for typical Louisiana soil types
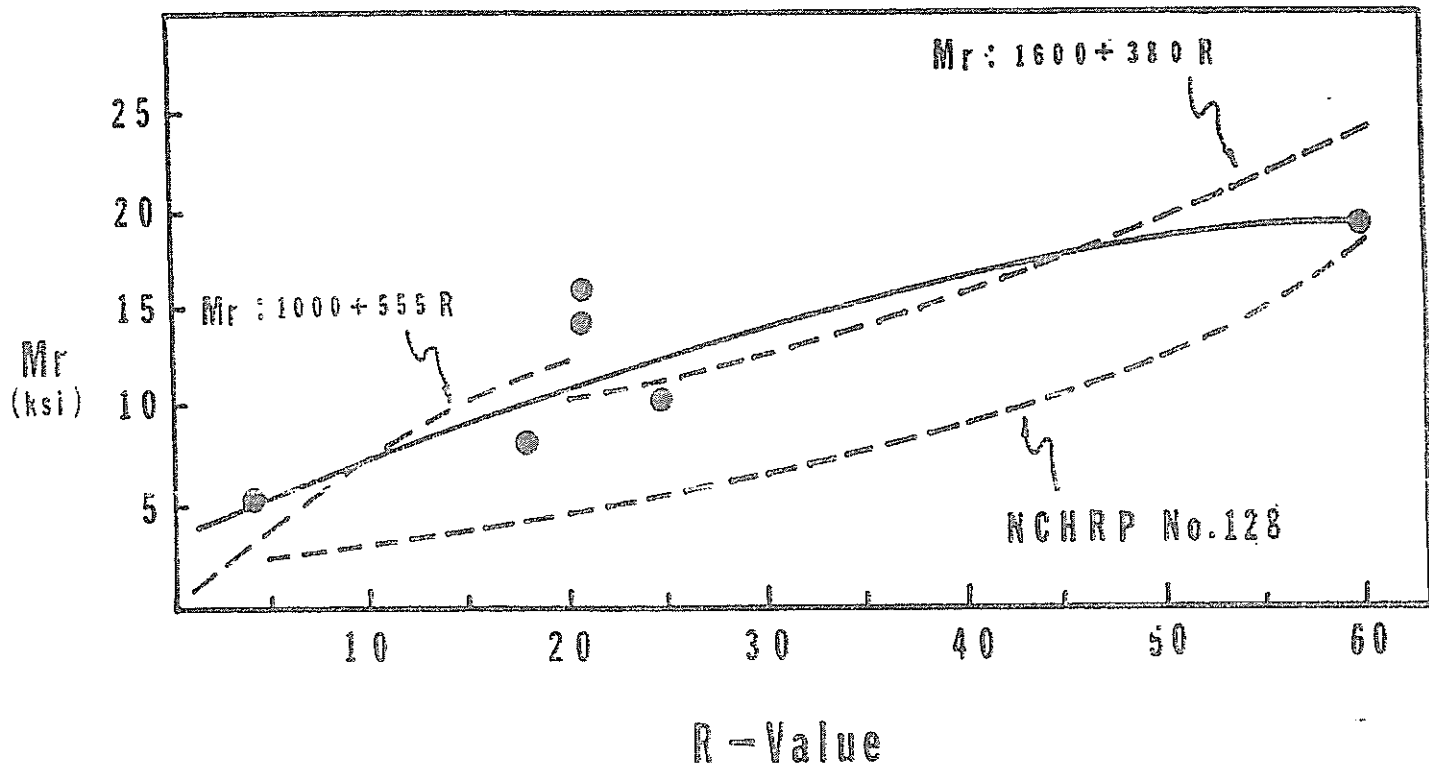
Figure 7

Soil resilient modulus -- R-value correlations

Values of measured roadbed resilient moduli (determined by the
Asphalt Institute) were generally confirmed in the referenced
"Experimental Base Study" using two independent methods: (1)
laboratory R-values with the indicated correlations and (2)
Dynaflect defection data, used in conjunction with a computer
program which estimates layer moduli using deflection basin
fitting techniques.[7]

A subroutine has been programmed for the design software which
will provide the designer with soil resilient modulus by inputing
the following soil characteristics:

1. Soil classification
2. Liquid, plastic limits
3. Percent retained on #4, 10, 40, 200 sieves
4. Percent silt, percent clay

In the future comparisons will be made of resilient modulus values
determined by this method and laboratory developed materials
properties.

Structural Design Coefficients

As a part of the updating of the Louisiana pavement design process
for flexible pavements, structural coefficients (listed in
Appendix B) used to determine layer thickness necessary to satisfy
the required structural number (SN) have been revised predicated
on the following:

1) Providing interim design values for new materials, for new
   combinations of existing materials, and for changes in
   materials strengths.

2) Providing for the use of central plant mixing of cement
   stabilized base course materials for higher traffic loadings
   (ADL $\geq$ 250). A higher structural coefficient has been
   provided for bases which are plant-mixed. These revised

values are reflective of the anticipated, improved stiffness and the anticipated improved performance of these bases.

3) Requiring design of total asphaltic concrete thickness which is greater than or equal to the thickness of the cement stabilized base, where ADL ≥ 250. This requirement is not generally implementable for lower traffic loadings since the thickness of base course might fall below a six-inch layer thickness.

Several research studies have indicated that improved construction practices are needed to improve the long term performance of asphaltic concrete pavements placed on cement treated bases in Louisiana.[7][9][10] Improved blending of cement and soil or aggregate is needed to provide uniform cement distribution and ultimately to improve the cracking characteristics and load carrying capabilities of the bases. The concept of plant mixing and of increasing the relative portion of the pavement section which consists of asphalt concrete were recently endorsed by the "Louisiana Asphaltic Concrete Forum", [11] a group comprised of paving contractors, consultants, and engineers from DOTD.

The high stability, high friction, "Type 8" wearing course mix is designed to have a minimum stability of 1700 pounds; however, test records indicate that the mix is typically providing a stability closer to 2100 pounds. This is a result of increased strength provided by the angular aggregate currently required to add skid resistance. Accordingly this mix has been assigned a design coefficient of 0.44 as indicated in Appendix B. The wearing course mix is currently required by DOTD where traffic volume (ADT) is equal to or greater than 3500. The software developed in this study will automatically select this wearing course mix at the appropriate levels of traffic volume.

The material strength values for asphaltic concrete in Appendix B reflect minimum specified Marshall stabilities and actual mean

values obtained for all mix placed from 1986-1988 in Louisiana.
The design coefficients listed reflect the mean material strengths
in accordance with the intent of the 1986 AASHTO Design Guide.
The layer moduli values listed were based on relationships
provided in the guide.

Automated Layer Thickness Selection

One of the primary benefits in computer aided pavement design is
the rapid calculation of alternative designs for layered pavement
systems. This is particularly helpful where several alternate
materials which vary in strength are to be allowed.

A subroutine has been included in the pavement design software to
accomplish this, and to generate a table of layer thickness for
inclusion in project plans. A sample of the programming logic
used for the flexible pavement design is contained in Appendix C.
The automated thickness selection procedure contains the following
features:

(1) Layer thicknesses are calculated considering a variety of
     available base course materials.

(2) All alternate flexible designs begin and end at the same
     roadway elevation. This is accomplished by calculating the
     thickest total pavement section and specifying the additional
     inches of subbase required in thinner sections to make final
     elevations equal.

(3) The thickness of all layers are automatically rounded off to
     values which are reasonable to construct with consideration
     given to each unique material type and layer thickness
     requirements.

(4) The designer has the option of deleting a base or subbase
     material due to considerations which affect availability of
     materials. If by chance the material deleted represented the

thickest design then the program will recalculate the
additional inches of subbase required for each alternate
based on the next thickest design.

(5)   The designer has the option of selecting an asphaltic
      concrete base for full-depth design or a non-asphaltic base
      as the principal load carrying base course.

(6)   The designer also has the choice of selecting a "subbase
      treatment" where the designed layer contributes to the SN, or
      of selecting a "subbase treatment" where the layer does not
      contribute to the SN. In the latter case the layer is
      considered a working table only. This decision is a
      consideration which reflects design policy, and may vary as
      policies change.

Minimum and/or maximum layer thickness have been included for the
wearing and binder course layers, as well as for the asphaltic
concrete, cement stabilized, and granular base layers. These
limiting values are necessary to develop the programming logic and
to provide realistic design thickness. The upper and lower limits
are listed in Table 3.

TABLE 3

PROGRAMMED LAYER THICKNESS LIMITS (inches)

LAYER	SN < 5	SN ≥ 5
Wearing Course	1.5	3.0
Binder Course	1.5 - 5.0	1.5 - 6.0
Asphaltic Concrete Base	3.0 min.	3.0 min.
Cement Treated Base		
Mixed in Place	8.5	8.5
Plant Mixed	6.0 - 8.5	6.0 - 8.5
Granular Base	8.5	8.5

The thickness of high stability wearing mix has been set at 1.5-
inches or 3.0-inches depending on the relative level of designed

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SN; whether below or above SN=5. This is intended to provide increased upper pavement strength (stability), specifically to resist rutting and to improve upper layer performance where repeated heavy loads and repeated high tire pressures are expected, such as on Interstate routes and other major facilities. It is not intended that special non-polishing aggregate be required in the lower 1.5-inches of a 3.0-inch wearing course; however, the mix stability should be in the 1800-2000 pound range. In this instance, the computer program will select the 2100-pound Marshall Stability "Type 8" wearing course mix for the top 1.5-inch and the 1800-pound Marshall Stability "Type 3" mix for the lower 1.5-inch layer for the condition SN $\geq$ 5

Drainage of Flexible Pavements

Drainage of flexible pavement sections is encouraged in the AASHTO design guide and a mechanism is included in the design to account for the effects of drainage. The design provides for layer thickness adjustment for a drainable layer by increasing the design coefficient of the material in that layer. This process effectively reduces the total required thickness of the flexible pavement. This procedure has not been included in the software developed for this study since DOTD does not currently utilize drainable layers within flexible pavement sections.

Based on observations of the performance of flexible pavements with cement-treated bases, it is believed that DOTD should consider adding through the shoulder drainage (such as a drainable asphaltic concrete layer) where the following conditions exist:

1) A cement-treated base is the principle load carrying component other than the pavement surfacing.

2) The roadbed soil $M_r \leq 12,000$ psi. This will provide for drainage in the flat, poorly drained areas of the state.

3) The pavement is subjected to repeated heavy loads, ADL $\geq$ 250.

Differential settlement of cracked bases under layers of asphaltic concrete is more prevalent in moderate to low soil support conditions. Once cracks in the base occur, the bases tend to exhibit characteristics similar to an overlaid concrete pavement, but with no mechanism for load transfer across the cracks. It is believed that a well-drained roadbed would reduce the rate of differential settlement of the cement-treated bases under repeated heavy loads and thereby reduce the rate of serviceability decline.

Louisiana DOTD is considering incorporating a permeable asphalt base course in construction of full-depth asphalt concrete pavements. Inclusion of a permeable base will remove the "bathtub" effect created by the use of full-depth asphaltic concrete shoulders on flexible pavements.

DISCUSSION OF RIGID PAVEMENT DESIGN INPUT VARIABLES

There are five data input variables unique to the design of rigid pavements. These variables include:

1. Modulus of Subgrade Reaction
2. Modulus of Concrete Rupture (Flexural Strength)
3. Modulus of Elasticity
4. Drainage Coefficient
5. Load Transfer Coefficient

Modulus of Subgrade Reaction

The modulus of subgrade reaction, K-value, has traditionally been defined as the vertical deflection (penetration) of a 30-inch diameter plate into a layer loaded to 10 psi according to the formula:

$$D = 1.5 \text{ pa} / E_S \text{ ; where}$$

D = deflection or penetration of plate into subgrade

p = 10 psi

a = radius of plate (15-inches)

E_S = subgrade modulus (M_r);

therefore the expression;

$$K = \frac{\text{pressure}}{\text{deflection}} = \frac{10 \text{ psi}}{D} = \frac{E_S}{22.5}$$

provides the relationship between K-value and subgrade (roadbed) resilient modulus, as indicated in Figure 8, page 32.

The chart for determination of the combined support of a subgrade and subbase layer (composite K-value) is the same as is currently used in Louisiana. The actual determination of the composite K-value was not included in the software package and therefore remains a manual procedure. In addition to simplifying the

SUBBASE TYPE	MODULUS (E_1)
Crushed Stone	30,000
Sand - Shell	30,000
Soil Cement	600,000
Asphaltic Concrete	320,000
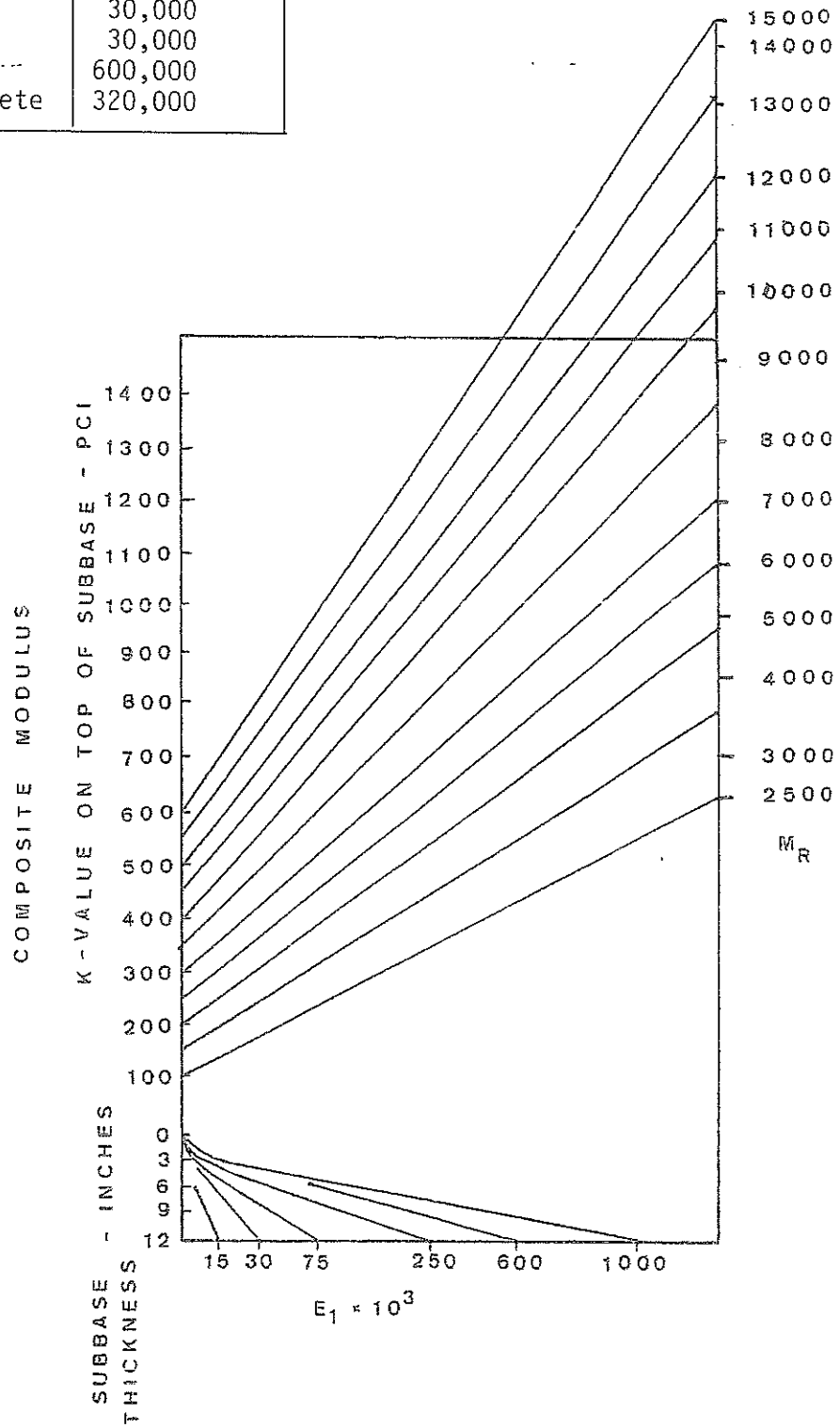
Figure 8

Composite K-value

program, this enables the designer to include or not included the contribution of a working table to the concrete slab support computations, as prescribed by design policy.

Modulus of Concrete Rupture

The modulus of concrete rupture or flexural strength of portland cement concrete is determined though the use of a mean value of third point loading failure (AASHTO T97, ASTM C78). AASHTO suggests that the normal construction specification for flexural strength not be used as the design input value. A more representative design input value is the mean value of the actual test results. The suggested value for Louisiana rigid pavement design is 550 psi. This value assumes the substitution of 20% fly ash for cement and the use of gravel aggregate, and is therefore conservative when alternative materials are used.

Concrete Elastic Modulus

The elastic modulus of concrete is determined through the procedure described in ASTM C459. The value recommended to represent Louisiana rigid pavement design is 4.2×10^6 psi.

Load Transfer Coefficient

The load transfer coefficient, J, is used to account for the ability of a rigid pavement to transfer load across joints and/or cracks in the pavement. The design procedure is programmed to require thicker concrete pavements where a lower level of load transfer is designed. Lower values of J indicate higher levels of load transfer. The addition of load transfer devices, tied concrete shoulders, and widened lanes all serve all serve to lower the J values selected thereby reducing the final concrete thickness.

Table 4 contains the AASHTO Design Guide recommended values of load transfer coefficient, J.

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TABLE 4

AASHTO RECOMMENDED LOAD TRANSFER COEFFICIENTS

	ASPHALT SHOULDERS		TIED PCC SHOULDERS	
	Load Transfer Device?		Load Transfer Device?	
	YES	NO	YES	NO
Jointed	3.2	3.8 - 4.4	2.5 - 3.1	3.6 - 4.2
CRC	2.9 - 3.2	N/A	2.3 - 2.9	N/A

Current policy for Louisiana DOTD rigid pavement design includes 20-foot transverse joint spacing with steel dowels placed on 12-inch centers. Interstate designs may contain tied concrete shoulders and an outside lane which is 15-feet wide, a combination which is not addressed in the AASHTO Design Guide. The recommended values for load transfer coefficient, J, follow the AASHTO recommended values and are as follows for jointed concrete pavement:

TABLE 5

LOAD TRANSFER COEFFICIENTS RECOMMENDED FOR LOUISIANA

Asphalt Shoulder and 12 ft. Truck Lane	3.2
Asphalt Shoulder and 15 ft. Truck Lane or Concrete Shoulder	2.5

Performance studies of jointed, doweled pavements in Louisiana have indicated that joint faulting is not a contributor to loss of serviceability. In fact, in many cases Interstate pavements of this type have carried more than their design loads without joint faulting exceeding 0.15 inch and this is without the benefit of tied concrete shoulders or widened lanes. (10) For this reason, it is felt that a value of J of 2.5 is appropriate.

A sensitivity analysis depicting change in concrete thickness with change in J is illustrated in Figure 9, page 35.

Concrete Thickness (Inches)

Rural - Interstate
Reliability - 97%
Overall Standard Deviation - 0.37
Composite Subgrade Modulus - 350
Drainable Shoulder Layer
Concrete Elastic Modulus - 4,200,000
Concrete Flexural Strength - 550
Change in PSI - 1.5
Traffic Factor - 3,000

Load Transfer Coefficient
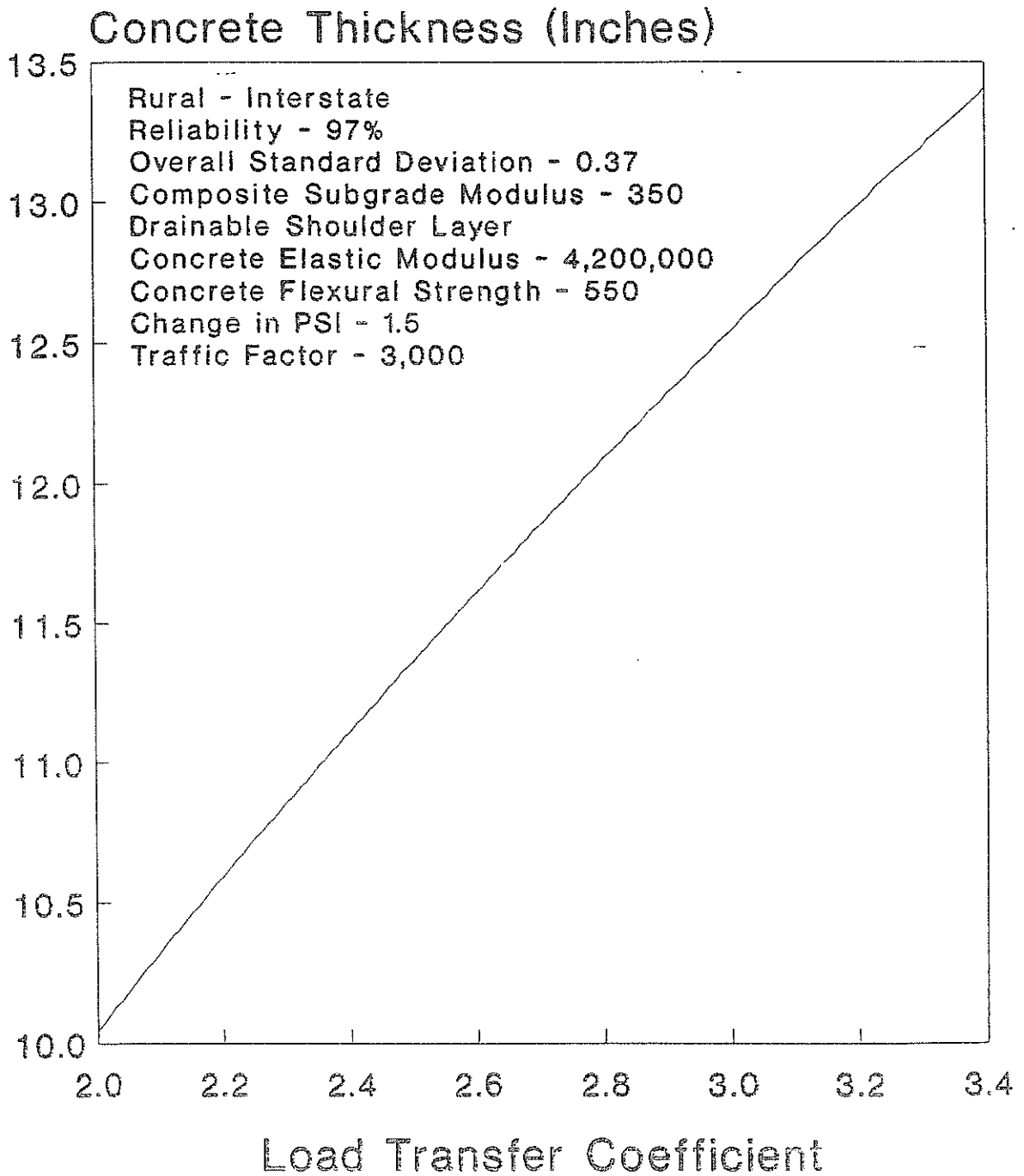
Figure 9

Sensitivity analysis -- load transfer coefficient,
rigid design

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Drainage Coefficient

The drainage coefficient (C_d) is used to account for the expected level of drainage a rigid pavement is to encounter over its life. Values of C_d are dependent upon the quality of drainage and the percent of time during the year the pavement structure is normally exposed to moisture levels approaching saturation. Descriptions of the quality of drainage and are listed in Table 6, and the AASHTO Design Guide recommended values for C_d are provided in Table 7 below.

TABLE 6

QUALITY OF DRAINAGE DESCRIPTIONS

Quality of Drainage	Water Removed Within
Excellent	2 Hours
Good	1 Day
Fair	1 Week
Poor	1 Month
Very Poor	No Drainage

TABLE 7

AASHTO RECOMMENDED VALUES FOR DRAINAGE COEFFICIENT

Quality of Drainage	Percent of Time Pavement Structure is Exposed to Moisture Levels Approaching Saturation			
	< 1%	1 - 5%	5 - 25%	25%
Excellent	1.25 - 1.20	1.20 - 1.15	1.15 - 1.10	1.10
Good	1.20 - 1.25	1.15 - 1.10	1.10 - 1.00	1.00
Fair	1.15 - 1.10	1.10 - 1.00	1.00 - 0.90	0.90
Poor	1.10 - 1.00	1.00 - 0.90	0.90 - 0.80	0.80
Very Poor	1.00 - 0.90	0.90 - 0.80	0.80 - 0.70	0.70

The effect of C_d on slab thickness is similar to that of the load transfer coefficient J; that is, better drainage will decrease the slab thickness required. A sensitivity analysis of how the change in C_d will affect the change in slab thickness is presented in Figure 10 on page 38.

The choice of drainage characteristics for rigid pavements in Louisiana is based on a presumption that greater than 25% of the time pavements will be exposed to moisture levels approaching saturation. The quality of drainage where a drainage layer is included in the shoulder section (through-the-shoulder-drainage) is considered excellent, since drainage is provided immediately adjacent to the outside lane. Accordingly, when through-the-shoulder-drainage features are designed, the value for C_d is recommended to be 1.10. Where longitudinal edge drains are added to drain a concrete shoulder (outside edge of shoulder), a C_d value of 1.05 is recommended. A lower value is recommended because although a drainage mechanism is provided, it is not immediately adjacent to the travel lane. A preferred drainage design would incorporate a permeable asphalt base for the full width of concrete pavements and shoulders, whether the shoulder section is asphaltic or portland cement concrete. In rigid pavement designs where no drainage features are incorporated, it is believed that a value of 0.90 for C_d should be selected. This value of C_d will effectively thicken a concrete slab to overcome the negative effects that not providing internal drainage has been observed to have on pavement performance. The pavement design software will automatically apply these values of C_d, depending on whether or not the designer indicates which drainage feature is planned or whether no drainage feature is planned.

Concrete Thickness (Inches)

Rural - Interstate
Reliability - 97%
Overall Standard Deviation - 0.37
Change in PSI - 1.5
Composite Subgrade Modulus - 350
Concrete Elastic Modulus - 4,200,000
Concrete Flexural Strength - 550
Asphalt Shoulder & 15 ft Truck Lane
Traffic Factor - 3,000

Drainage Coefficient
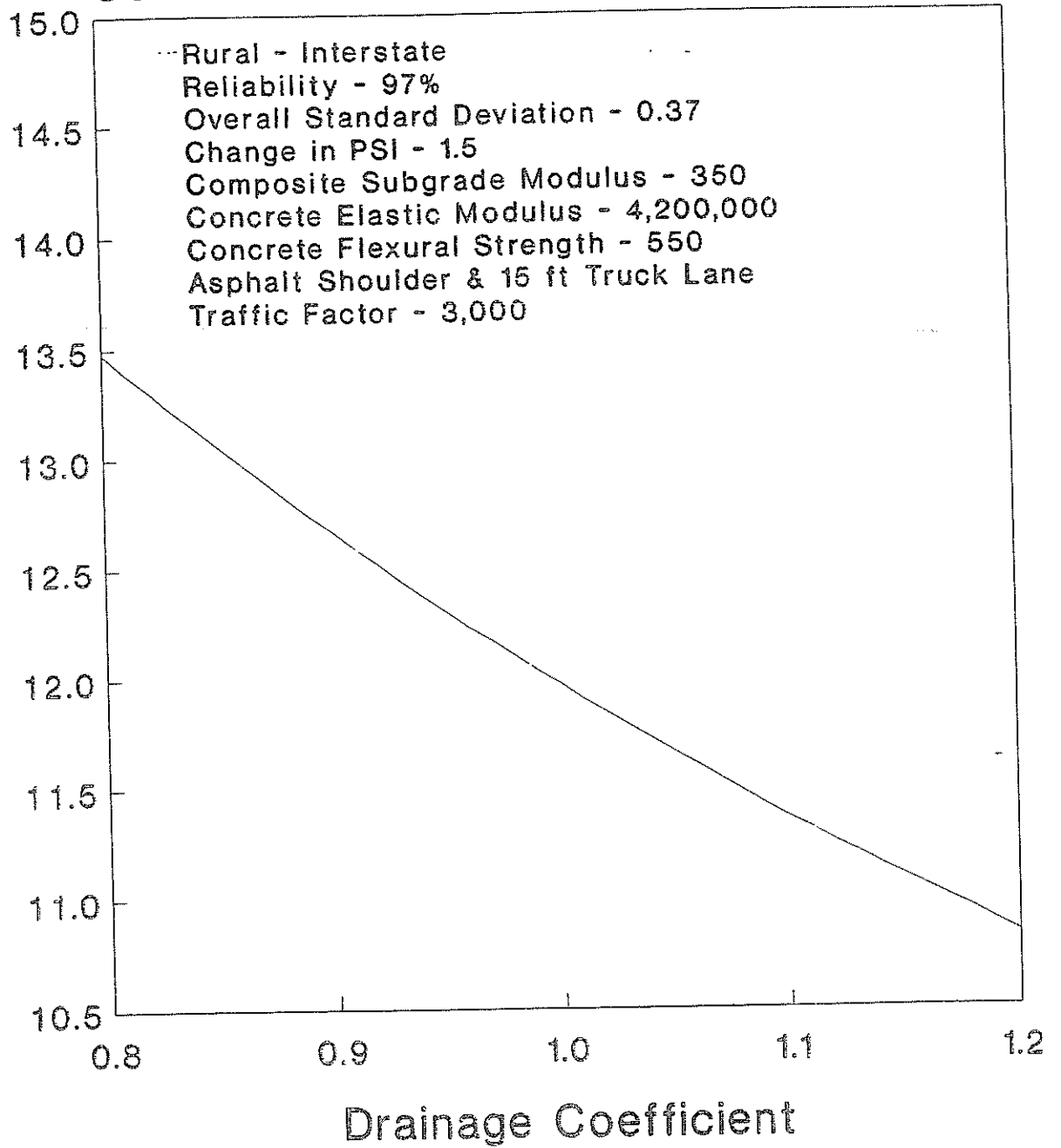
Figure 10

Sensitivity analysis -- drainage coefficient,
rigid design

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RECOMMENDATIONS

The following is a summary of the recommendations included in the report:

1. Design serviceability loss (ΔPSI) factors are recommended as follows:

Interstate	ΔPSI = 1.5
Primary	ΔPSI = 1.8
Secondary, Local	ΔPSI = 2.0

2. An expanded table of vehicle equivalency factors is recommended with updated factors determined from evaluation of Weigh-In-Motion data for the 3-S-3 and Double Trailer carriers.

3. Reliability Levels for urban and rural routes for Interstate, Primary, Collector, and Local roads are recommended as follows:

	URBAN	RURAL
Interstate	99	97
Primary	97	95
Collector	90	85
Local	75	70

4. Overall standard deviation, S_O, values by pavement types are recommended as follows:

	S_O
Rigid	0.37
Flexible	0.47

5. An automated procedure for estimating the road bed resilient from soils engineering and classification data was developed and is recommended.

6. A table of updated structural coefficients for flexible pavement design is recommended, which includes:

      (a) Interim design values for several new materials and revised values for asphaltic concrete which reflect mean field stabilities.

      (b) A provision for plant mixing of cement-treated base materials with an associated higher design value.

7. A design guideline for selecting the relative thickness of asphaltic concrete surfacing and cement - treated base has been automated in the design software and is recommended to improve the performance of this type of pavement.

8. Design values reflecting expected strengths of portland cement concrete are recommended as follows:

    Flexural Strength   =   550 psi
    Modulus of Elasticity   = 4.2×10^6 psi

9. Design Load Transfer coefficients, J, are recommended for the following situations in concrete paving:

	J
Asphalt Shoulder and 12 ft. Truck Lane	3.2
Asphalt Shoulder and 15 ft. Truck Lane or Concrete Shoulder	2.5

10. Design Drainage Coefficient, C_d, values are recommended for the following situations in concrete paving:

	C_d
Drainable Layer Through the Shoulder	1.10
Longitudinal Edge Drain Outside Shoulder	1.05
No Drainage Feature	0.90

A permeable asphalt base is recommended full width through the shoulder for both rigid and flexible pavement.

11. Drainage of flexible pavements which utilize cement treated bases constructed on roadbeds with $M_r < 12,000$ psi and with design average daily traffic values (ADL) greater than 250 ESAL should contain through-the-shoulder drainage. An asphaltic concrete drainage layer in the shoulder at a depth equal to the bottom of the pavement base is recommended.

REFERENCES

1. "AASHO Interim Guide for the Design of Flexible Pavement Structures," AASHO, October 1961.

2. "AASHO Interim Guide for the Design of Rigid Pavement Structures," AASHO, April 1962.

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4. "AASHTO Interim Guide for Design of Pavement Structures," AASHTO, 1981.

5. "AASHTO Guide for Design of Pavement Structures, 1986," AASHTO, 1986.

6. Broussard, David T., "Weigh-in-Motion for Planning Applications in Louisiana", Report No. FHWA/LA-87/196, Louisiana Transportation Research Center, April, 1988.

7. Temple, W. H., Shah, S. C., "Louisiana Experimental Base Project", Report No. FHWA/LA-87/192, Louisiana Transportation Research Center, December 1987.

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9. Shah, S. C., Melancon, J. L., "Soil Cement Study", Report No. FHWA/LA-73/72, Research and Development Section, Louisiana Department of Highways, 1973.

10. Temple, W. H., Cumbaa, Steven L., Boleware, Deborah, "Life Cycle, Cost and Loading Characteristics of AASHTO Designed Rigid and Flexible Pavements in Louisiana (1965 - 1989)", Report No. FHWA/LA-88/214, Louisiana Transportation Research Center, February, 1989.

APPENDIX A

Louisiana 18-kip Vehicle Equivalence Factors

	Terminal PSI = 2.0					
Vehicle Classification	Assumed Rigid Pavement Thickness					
	6	7	8	9	10	11
Passenger Cars	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Pickups & Panels	0.0028	0.0027	0.0027	0.0029	0.0029	0.0026
2-Axle, 4-Tire	0.0149	0.0145	0.0143	0.0190	0.0189	0.0141
2-Axle, 6-Tire	0.1716	0.1687	0.1676	0.2018	0.2016	0.1678
3-Axle	0.5809	0.5746	0.5761	0.5956	0.5991	0.5856
2-S-1	0.5192	0.5099	0.5034	0.5549	0.5527	0.4989
2-S-2, 3-S-1	0.9954	0.9843	0.9851	1.0331	1.0368	0.9967
3-S-2	1.7567	1.7456	1.7376	1.7738	1.8046	1.7918
3-S-3	2.8730	2.8730	2.8730	2.8730	2.8730	2.8730
Double Trailer	1.8400	1.8400	1.8400	1.8400	1.8400	1.8400

Terminal PSI = 2.5						
Vehicle Classification	Assumed Rigid Pavement Thickness					
	6	7	8	9	10	11
Passenger Cars	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Pickups & Panels	0.0031	0.0028	0.0027	0.0027	0.0026	0.0026
2-Axle, 4-Tire	0.0162	0.0150	0.0144	0.0143	0.0142	0.0141
2-Axle, 6-Tire	0.1779	0.1700	0.1672	0.1673	0.1680	0.1677
3-Axle	0.5745	0.5600	0.5623	0.5706	0.5781	0.5658
2-S-1	0.5490	0.5251	0.5105	0.5044	0.5018	0.4998
2-S-2, 3-S-1	0.9945	0.9684	0.9687	0.9794	0.9891	0.9939
3-S-2	1.7102	1.6862	1.7099	1.7485	1.7719	1.7855
3-S-3	2.8730	2.8730	2.8730	2.8730	2.8730	2.8730
Double Trailer	1.8400	1.8400	1.8400	1.8400	1.8400	1.8400

Terminal PSI = 2.0					
Vehicle Classification	Assumed Flexible Pavement Structural Number				
	2	3	4	5	6
Passenger Cars	0.0004	0.0004	0.0004	0.0004	0.0004
Pickups & Panels	0.0030	0.0029	0.0026	0.0024	0.0023
2-Axle, 4-Tire	0.0154	0.0152	0.0143	0.0135	0.0132
2-Axle, 6-Tire	0.1733	0.1737	0.1690	0.1654	0.1644
3-Axle	0.3856	0.3907	0.3833	0.3768	0.3738
2-S-1	0.5036	0.5192	0.5086	0.4928	0.4843
2-S-2, 3-S-1	0.8744	0.8641	0.8506	0.8423	0.9127
3-S-2	1.0456	1.0580	1.0458	1.0313	1.0224
3-S-3	1.4500	1.4500	1.4500	1.4500	1.4500
Double Trailer	1.8400	1.8400	1.8400	1.8400	1.8400

	Terminal PSI = 2.5				
Vehicle Classification	**Assumed Flexible Pavement Structural Number**				
	2	3	4	5	6
Passenger Cars	0.0007	0.0006	0.0004	0.0004	0.0004
Pickups & Panels	0.0045	0.0041	0.0036	0.0027	0.0024
2-Axle, 4-Tire	0.0198	0.0192	0.0227	0.0145	0.0137
2-Axle, 6-Tire	0.1853	0.1900	0.2216	0.1681	0.1648
3-Axle	0.4051	0.4215	0.4227	0.3842	0.3764
2-S-1	0.5469	0.5872	0.6274	0.5191	0.4969
2-S-2, 3-S-1	0.8999	0.9034	0.9101	0.8308	0.8315
3-S-2	1.0809	1.1271	1.1186	1.0543	1.0322
3-S-3	1.4500	1.4500	1.4500	1.4500	1.4500
Double Trailer	1.8400	1.8400	1.8400	1.8400	1.8400

APPENDIX B

Structural Coefficients for Flexible Section Design

STRUCTURAL COEFFICIENTS FOR FLEXIBLE SECTION DESIGN
(MAY 1989)

MATERIAL STRENGTH VALUES

		SPECIFIED MINIMUM	ACTUAL MEAN	LAYER MODULI PSIx10³ (MEAN)	DESIGN COEFFICIENT
SURFACE COURSE					
Asphaltic Concrete	Type 8	1700 MS	2100 MS	450	0.44
	Type 3 WC	1500 MS	1800 MS	400	0.42
	Type 3 BC	1400 MS	1600 MS	400	0.42
	Type 1, WC, BC	1200 MS	1600 MS	350	0.38
BASE COURSE					
Untreated	Sand Clay Gravel		3.5 TxTr	17	0.07
	Sand/Shell, Sand		2.2 TxTr	30	0.10
	Crushed Stone		2.0 TxTr	30	0.14
	Crushed PCC			30	0.14
Cement Treated (Mixed in Place)	Soil Cement			550	0.14
	Sand Clay Gravel			550	0.14
	Sand/Shell, Shell (4%)			600	0.15
	Sand/Shell, Shell (5%)			650	0.18
Cement Stabilized (Plant Mixed)	Soil Cement			650	0.18
	Sand Clay Gravel			650	0.18
	Sand/Shell, Shell (6%)			725	0.20
Asphalt	Hot Mix Base Course (5A)	1200 MS	1500 MS	320	0.28
SUBBASE COURSE					
	Lime Treated Sand Clay Gravel			20	0.14
	Crushed Stone			20	0.14
	Sand/Shell, Shell			20	0.14
	Sand Clay Gravel			15	0.11
	Sand			15	0.11
	Old Gravel, Shell Roadbed (8")			15	0.11
	Lime Treated Soil			10	0.07
	Suitable Material (Soil)			8	0.04

MS - Marshall Stability
TxTr - Texas Triaxial
Layer Moduli related from design coefficients unless otherwise indicated

APPENDIX C

Programming Logic for Flexible Section Design

```
                        ┌──────────────────────────┐
                        │  Select Type of Base     │
                        └──────────────────────────┘

┌──────────────┐                                          ┌──────────────┐
│  Bituminous  │                                          │    Other     │
└──────────────┘                                          └──────────────┘

                        ┌──────────────────────────┐
                        │ Select Type of Subbase   │
                        └──────────────────────────┘

┌──────────────────────┐                          ┌──────────────────────────┐
│   Working Table      │                          │       Subbase            │
│   (No Support)       │                          │  (Support Supplied)      │
└──────────────────────┘                          └──────────────────────────┘

              ┌──────────────────────────────────────────────┐
              │       Enter Thickness of Subbase             │
              │ (6" Default Thickness for Working Table)     │
              └──────────────────────────────────────────────┘

                  ┌──────────────────────────────────┐
                  │  Select Type of Wearing Course   │
                  └──────────────────────────────────┘

┌──────────────────────┐ ┌──────────────────────────┐ ┌──────────────────────┐
│   ADT ≤ 1,000        │ │  1,000 < ADT < 3,500     │ │   ADT ≥ 3,500        │
│     Type 1           │ │        Type 3            │ │     Type 8           │
└──────────────────────┘ └──────────────────────────┘ └──────────────────────┘

                  ┌──────────────────────────────────┐
                  │  Thickness of Wearing Course     │
                  └──────────────────────────────────┘

┌──────────────┐                                          ┌──────────────┐
│  SN < 5      │                                          │  SN ≥ 5      │
│   1.5"       │                                          │   3.0"       │
└──────────────┘                                          └──────────────┘

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                                      │
                    ┌─────────────────────────────────────┐
                    │        Bituminous Base ?            │
                    └─────────────────────────────────────┘
                                      │
        ┌─────────────────────────────┴────────────────────────────────────┐
   ┌────────┐                                                          ┌────────┐
   │  No    │                                                          │  Yes   │
   └────────┘                                                          └────────┘
        │                                                                   │
        │         ┌─────────────────────────────────────┐                  │
        │         │     Calculate Base Thickness        │                  │
        │         └─────────────────────────────────────┘                  │
        │                          │                                       │
```

$$\text{Inches of Base} = \frac{\text{SN Required} - \text{SN Produced by Previous Layers}}{\text{Base Structural Coefficient}}$$

```
        ┌───────────────────────────────────────────────────────┐
        │  Thickness of Base > Maximum Thickness of Base ?      │
        └───────────────────────────────────────────────────────┘
                │                                      │
   ┌──────────────────────────┐       ┌──────────────────────────┐
   │ Cement Treated Base      │       │ Non-Treated Base         │
   │ Maximum Thickness = 8.5" │       │ Maximum Thickness = 12.0"│
   └──────────────────────────┘       └──────────────────────────┘
                │                                      │
   ┌────────┐                                               ┌────────┐
   │  Yes   │                                               │  No    │
   └────────┘                                               └────────┘
        │                                                       │
        │    ┌─────────────────────────────────────┐           │
        │    │  Reduce Base Thickness to           │           │
        │    │  Maximum Base Thickness             │           │
        │    └─────────────────────────────────────┘           │
        │                     │                                 │
   ┌─────────────────────────────────────────────────────────────────┐
   │  SN Required < SN Generated by Previous Layers ?                │
   └─────────────────────────────────────────────────────────────────┘
        │                                                       │
   ┌────────┐                                               ┌────────┐
   │  Yes   │                                               │  No    │
   └────────┘                                               └────────┘
        │                                                       │
   ┌─────────────────┐                                          │
   │ Design          │                                          │
   │ Complete        │                                          │
   └─────────────────┘                                          │
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              ┌────────────────────────────────────────┐
              │  Calculate Binder Course Thickness     │
              └────────────────────────────────────────┘
                               │
   ┌────────────────────────────────────────────────────────────────────┐
   │ Inches       SN Required - SN Produced by Previous Layers          │
   │   of    =   ─────────────────────────────────────────────          │
   │ Binder          Binder Course Structural Coefficient               │
   │ Course                                                             │
   └────────────────────────────────────────────────────────────────────┘
                               │
          ┌───────────────────────────────────────────────────┐
          │  Check for Maximum Thickness of Binder Course     │
          └───────────────────────────────────────────────────┘
                               │
        ┌──────────────────────┴───────────────────────────┐
 ┌────────────────────────────┐       ┌────────────────────────────────┐
 │          SN < 5            │       │          SN ≥ 5                │
 │ Maximum Binder Thickness   │       │  Maximum Binder Thickness      │
 │          = 5.0"            │       │          = 6.0"                │
 └────────────────────────────┘       └────────────────────────────────┘
                               │
   ┌────────────────────────────────────────────────────────────────┐
   │ Thickness of Binder > Maximum Thickness of Binder ?            │
   └────────────────────────────────────────────────────────────────┘
       │                                                        │
 ┌─────────┐                                               ┌─────────┐
 │   Yes   │                                               │   No    │
 └─────────┘                                               └─────────┘
       │                                                        │
              ┌───────────────────────────────────┐
              │  Reduce Binder Thickness to       │
              │  Maximum Binder Thickness         │
              └───────────────────────────────────┘
                               │
   ┌────────────────────────────────────────────────────────────────┐
   │ SN Required < SN Generated by Previous Layers ?               │
   └────────────────────────────────────────────────────────────────┘
       │                                                        │
 ┌─────────┐                                               ┌─────────┐
 │   Yes   │                                               │   No    │
 └─────────┘                                               └─────────┘
       │                                                        │
     ┌──────────────┐
     │  Design      │
     │  Complete    │
     └──────────────┘
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                              │
                    ┌─────────────────────────────────────┐
                    │  Calculate Black Base Thickness      │
                    └─────────────────────────────────────┘
                              │
        ┌──────────────────────────────────────────────────────────────┐
        │  Inches        SN Required - SN Produced by Previous Layers   │
        │    of     =   ─────────────────────────────────────────────   │
        │  Black            Black Base Structural Coefficient           │
        │  Base                                                         │
        └──────────────────────────────────────────────────────────────┘
                              │
        ┌──────────────────────────────────────────────────────────────┐
        │  Thickness of Black Base < Minimum Thickness of Black Base ?  │
        └──────────────────────────────────────────────────────────────┘
                              │
    ┌───────┐                                                    ┌───────┐
    │  Yes  │                                                    │  No   │
    └───────┘                                                    └───────┘
                ┌──────────────────────────────────────┐
                │  Increase Thickness of Black Base to  │
                │  Minimum Thickness of Black Base      │
                └──────────────────────────────────────┘
                ┌──────────────────────────────────────┐
                │  Recalculate Thickness of Binder Course│
                └──────────────────────────────────────┘
                              │
                    ┌─────────────────────────┐
                    │  Cement Treated Base     │
                    └─────────────────────────┘
                              │
    ┌───────┐                                          ┌────────────┐   ┌───────┐
    │  Yes  │                                          │  Design    │   │  No   │
    └───────┘                                          │  Complete  │   └───────┘
                                                       └────────────┘
                              │
                    ┌─────────────────────────┐
                    │  ADL ≥ 250 ?             │
                    └─────────────────────────┘
                              │
    ┌───────┐                                          ┌────────────┐   ┌───────┐
    │  Yes  │                                          │  Design    │   │  No   │
    └───────┘                                          │  Complete  │   └───────┘
                                                       └────────────┘
                    ┌─────────────────────────┐
                    │  Go To Next Page         │
                    └─────────────────────────┘
```

```
                    ┌────────────────────────────────────┐
                    │  Continued From Previous Page       │
                    └────────────────────────────────────┘
                                     │
┌──────────────────────────────────────────────────────────────────────┐
│  Inches of Wearing, Binder and Black Base < Inches of Base ?           │
└──────────────────────────────────────────────────────────────────────┘
                                     │
       ┌─────────────┐                              ┌──────────────┐   ┌──────┐
       │  Yes        │                              │  Design      │   │  No  │
       └─────────────┘                              │  Complete    │   └──────┘
                                                    └──────────────┘

                    ┌────────────────────────────────────┐
                    │  Reduce Base Thickness by 1"        │
                    └────────────────────────────────────┘
                                     │
          ┌──────────────────────────────────────────────────┐
          │  Return to Calculate Binder Course Thickness      │
          └──────────────────────────────────────────────────┘
```
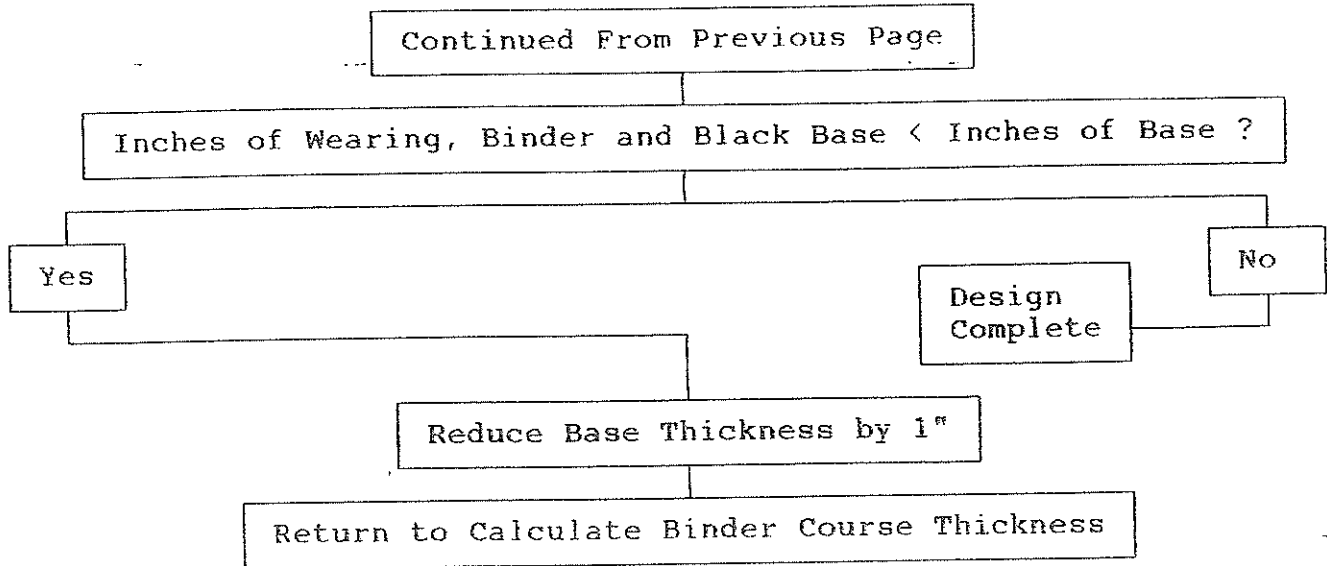
APPENDIX D

Louisiana Pavement Design Program - Input, Output Guide

USE OF THE LOUISIANA AASHTO PAVEMENT DESIGN PROGRAM

This section describes the input necessary for the use of the program and the output generated by its use. For the user without the availability of a personal computer the design nomographs for both flexible and rigid pavement design are shown in Appendix G.

Selection of Type of Design:

The designer must select whether the design is to be interactive design or a modification of a previous design from a stored design file. This design file is created upon completion of a design using the program. In Appendix F are the record layouts for both a flexible and rigid pavement design file.

If the design is to be from a previous design file, a list of available data files is displayed. From this list, the user must select the project to be modified. Upon selection of a project the traffic data is displayed and the design proceeds from that point.

Selection of the Type of Pavement to be Designed:

The designer must choose whether the design is to be for a flexible or a rigid pavement.

Selection of Roadway Location and Type:

The designed must choose whether the pavement to be designed is to be in an Urban or Rural location and whether the pavement is to be for an Interstate, Primary, Collector, or Local roadway. From this information, the program will load the appropriate default design parameters.

Selection of the Terminal PSI and Assumed Design Thickness (for a rigid design) or Assumed Structural Number (for a flexible design):

The designer will select from the displayed options and the appropriate 18-kip equivalent axle load factors will be loaded by the program.

Entry of the Traffic Classification Distribution Data:

The designer will enter the number of vehicles for each vehicle classification shown. From these entries a Traffic Factor will be calculated.

Entry of Subgrade Soil Survey Data:

The designer is given the option of entering the subgrade soil data, so that the soil support value and resilient modulus can be calculated for use in the design equations. If the values have been previously calculated, this procedure can be by-passed, but if used a data file will be created for future design use.

Selection of Type of Shoulder and Drainage (Rigid Only):

The designer must select the type of shoulder and drainage feature the roadway will have upon completion.

Entry of Design Parameters:

The designer has the option of using the default parameters listed or entering values deemed more applicable.

Entry of Projection Information:

The designer must enter a project number and all other information for the design data storage file.

Recommended Design Table (Flexible Only):

The designer selects whether the flexible pavement section is to be full-depth or layered. If full-depth is selected a response as to subbase support is requested. A recommended design table is generated based upon these responses. This table is created through limiting criteria set by ADL, ADT, M_r and SN. The recommended design table lists possible combinations of paving and base materials which will meet the criteria created by the traffic and subgrade soil characteristics. Upon completion of the recommended design table the designer can select to print the table if desired. In Appendix E is an example of the recommended design table created by the program.

Entry of the Recommended Section:

The Recommended Section allows the designer to record the recommended thickness and materials for the final design.

Commands Available for Recommended Section

Alt+i - Insert a blank line at the cursor

Alt+s - Save Recommended Section and End Design Process

The designer now has the option to print the design just finished. In Appendix E are examples of the hardcopy output created by print option of the program. The program will then return to the initial screen and the process restarted.

Some input screens have help screens available. These help screens can be activated by pressing "F1". If a "beep" is heard then no help screen is available.

Once a design is completed the traffic classification distribution data entered can be re-used without being entered a second time. This allows quick comparison of different design options.

Upon request a more detailed user's guide will be supplied. The user's guide contains more detailed information about the use and performance of the software.

APPENDIX E

Example of Hardcopy of Rigid and Flexible Designs

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

```
Project Number  : 001-00-00
FAP Number      :
Description     :                          (RIGID PAVEMENT)
Location        :
Route           :
Parish          :
Type of Roadway : URBAN - INTERSTATE
```

Pt = 2.5   t = 11 inches

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	18,041	0.0004	7.22
Pic-ups	0	0.0026	0.00
2-Axle, 4-Tire	0	0.0141	0.00
2-Axle, 6-Tire	0	0.1677	0.00
3-Axle	0	0.5658	0.00
2-S-1	0	0.4998	0.00
2-S-2	0	0.9939	0.00
3-S-1	0	0.9939	0.00
3-S-2	1,959	1.7855	3,497.79
3-S-3	0	2.8730	0.00
Double Trailer	0	1.8400	0.00

```
Projected DAILY 18-K Equivalent Load              3,505.01
Projected TOTAL 18-K Equivalent Load          25,586,580.00
```

```
Number of Lanes : 4
1990 ADT        :        0      Median Year ADT    :  50,000
2010 ADT        :        0      Critical Lane ADT  :  20,000
```

```
Change in PSI over life of surface            : 1.5
Concrete Elastic Modulus (x 1,000,000 psi)    : 4.2
Composite Modulus of Subgrade Reaction (pci)  : 270
Mean Concrete Modulus of Rupture (psi)        : 550
Concrete Shoulder                             : 2.50
Shoulder Edge Drains                          : 1.05
Traffic Factor                                : 3,505
Design Life in Years                          : 20
```

```
Inches of Concrete Required                   : 12.9
```

RECOMMENDED SECTION

Base: 2.0 in. Asphaltic Concrete

Pavement: 13.0 in. Portland Cement Concrete Pavement

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 001-00-01
FAP Number :
Description :   (RIGID PAVEMENT)
Location :
Route :
Parish :
Type of Roadway : URBAN - INTERSTATE

Pt = 2.5   t = 11 inches

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	18,041	0.0004	7.22
Pic-ups	0	0.0026	0.00
2-Axle, 4-Tire	0	0.0141	0.00
2-Axle, 6-Tire	0	0.1677	0.00
3-Axle	0	0.5658	0.00
2-S-1	0	0.4998	0.00
2-S-2	0	0.9939	0.00
3-S-1	0	0.9939	0.00
3-S-2	1,959	1.7855	3,497.79
3-S-3	0	2.8730	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   3,505.01
Projected TOTAL 18-K Equivalent Load   25,586,580.00

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   : 50,000
2010 ADT   :   0   Critical Lane ADT : 20,000

Change in PSI over life of surface   : 1.5
Concrete Elastic Modulus (x 1,000,000 psi)   : 4.2
Composite Modulus of Subgrade Reaction (pci)   : 270
Mean Concrete Modulus of Rupture (psi)   : 550
Asphalt Shoulder and 12 ft Truck Lane   : 3.20
Drainable Shoulder Layer   : 1.10
Traffic Factor   : 3,505
Design Life in Years   : 20

Inches of Concrete Required   : 14.3

RECOMMENDED SECTION

Base: 2.0 in. Asphaltic Concrete

Pavement: 14.5 in. Portland Cement Concrete Pavement

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 001-00-05
FAP Number :
Description :
Location :   (RIGID PAVEMENT)
Route :
Parish :
Type of Roadway : URBAN - PRIMARY

Pt = 2.5

t = 11 inches

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	4,302	0.0004	1.72
Pic-ups	0	0.0026	0.00
2-Axle, 4-Tire	0	0.0141	0.00
2-Axle, 6-Tire	0	0.1677	0.00
3-Axle	0	0.5658	0.00
2-S-1	0	0.4998	0.00
2-S-2	0	0.9939	0.00
3-S-1	0	0.9939	0.00
3-S-2	698	1.7855	1,246.28
3-S-3	0	2.8730	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   1,248.00
Projected TOTAL 18-K Equivalent Load   9,110,399.00

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   : 15,000
2010 ADT   :   0   Critical Lane ADT :   5,000

Change in PSI over life of surface   : 1.8
Concrete Elastic Modulus (x 1,000,000 psi)   : 4.2
Composite Modulus of Subgrade Reaction (pci)   : 270
Mean Concrete Modulus of Rupture (psi)   : 550
Asphalt Shoulder and 12 ft Truck Lane   : 3.20
Drainable Shoulder Layer   : 1.10
Traffic Factor   : 1,248
Design Life in Years   : 20

Inches of Concrete Required   : 11.2

RECOMMENDED SECTION

Base: 2.0 in. Asphaltic Concrete

Pavement: 11.5 in. Portland Cement Concrete Pavement

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number   : 001-00-07
FAP Number   :   (RIGID PAVEMENT)
Description   :
Location   :
Route   :
Parish   :
Type of Roadway : URBAN - SECONDARY

Pt = 2.5   t = 11 inches

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	2,221	0.0004	0.89
Pic-ups	0	0.0026	0.00
2-Axle, 4-Tire	0	0.0141	0.00
2-Axle, 6-Tire	0	0.1677	0.00
3-Axle	0	0.5658	0.00
2-S-1	0	0.4998	0.00
2-S-2	0	0.9939	0.00
3-S-1	0	0.9939	0.00
3-S-2	279	1.7855	498.15
3-S-3	0	2.8730	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   499.04
Projected TOTAL 18-K Equivalent Load   3,643,013.25

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   :   5,000
2010 ADT   :   0   Critical Lane ADT :   2,500

Change in PSI over life of surface   : 2.0
Concrete Elastic Modulus (x 1,000,000 psi)   : 4.2
Composite Modulus of Subgrade Reaction (pci)   : 270
Mean Concrete Modulus of Rupture (psi)   : 550
Asphalt Shoulder and 12 ft Truck Lane   : 3.20
Drainable Shoulder Layer   : 1.10
Traffic Factor   : 499
Design Life in Years   : 20

Inches of Concrete Required   :   8.7

RECOMMENDED SECTION

Base: 2.0 in. Asphaltic Concrete

Pavement: 9.0 in. Portland Cement Concrete Pavement

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

```
Project Number  : 001-00-09
FAP Number      :
Description     :                              (RIGID PAVEMENT)
Location        :
Route           :
Parish          :
Type of Roadway : URBAN - LOCAL
```

Pt = 2.0   t = 8 inches

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	363	0.0004	0.15
Pic-ups	0	0.0027	0.00
2-Axle, 4-Tire	0	0.0143	0.00
2-Axle, 6-Tire	0	0.1676	0.00
3-Axle	0	0.5761	0.00
2-S-1	0	0.5034	0.00
2-S-2	0	0.9851	0.00
3-S-1	0	0.9851	0.00
3-S-2	137	1.7376	238.05
3-S-3	0	2.8730	0.00
Double Trailer	0	1.8400	0.00

```
Projected DAILY 18-K Equivalent Load                    238.20
Projected TOTAL 18-K Equivalent Load              1,738,833.75
```

```
Number of Lanes : 4
1990 ADT        :        0        Median Year ADT   :   1,000
2010 ADT        :        0        Critical Lane ADT :     500
```

```
Change in PSI over life of surface          : 2.0
Concrete Elastic Modulus (x 1,000,000 psi)  : 4.2
Composite Modulus of Subgrade Reaction (pci): 270
Mean Concrete Modulus of Rupture (psi)      : 550
Asphalt Shoulder and 12 ft Truck Lane       : 3.20
Drainable Shoulder Layer                    : 1.10
Traffic Factor                              : 238
Design Life in Years                        : 20
```

Inches of Concrete Required   : 8.0

RECOMMENDED SECTION

Base: 2.0 in. Asphaltic Concrete

Pavement: 8.0 in. Portland Cement Concrete Pavement

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number   : 000-00-01
FAP Number   :   (FLEXIBLE PAVEMENT)
Description   :
Location   :
Route   :
Parish   :
Type of Roadway : RURAL - LOCAL

s = 2

Pt = 2.0

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	176	0.0004	0.07
Pic-ups	0	0.0030	0.00
2-Axle, 4-Tire	0	0.0154	0.00
2-Axle, 6-Tire	0	0.1733	0.00
3-Axle	0	0.3856	0.00
2-S-1	0	0.5036	0.00
2-S-2	0	0.8744	0.00
3-S-1	0	0.8744	0.00
3-S-2	24	1.0456	25.09
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   25.16
Projected TOTAL 18-K Equivalent Load   183,703.06

Number of Lanes : 2
1990 ADT   :   0   Median Year ADT   :   400
2010 ADT   :   0   Critical Lane ADT :   200

Change in PSI   : 2.0
Resilient Modulus (Soil Support Value) : 7,532 (3.2)
Traffic Factor   : 25
Design Life in Years   : 20

Structural Number Required   : 2.30

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-01
RURAL - LOCAL	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 200
Average Daily Load	: 25
Required Structural Number	: 2.30
Total Pavement Thickness	: 12.0 inches

A - Inches of Type 1 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	2.0		8.5	Sand/shell, Shell		2.26
1.5	1.5		8.5	Crushed Stone	0.5	2.39
1.5	1.5		8.5	Crushed PCC	0.5	2.39
1.5	1.5		8.5	Mixed in Place Soil (Cement)	0.5	2.39
1.5	1.5		8.5	Mixed in Place Sand Clay Gravel (Cement)	0.5	2.39
2.5			8.5	Mixed in Place Sand/Shell (Cement)	1.0	2.23

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number   : 000-00-02
FAP Number   :   (FLEXIBLE PAVEMENT)
Description   :
Location   :
Route   :
Parish   :
Type of Roadway : RURAL - SECONDARY

                                                              s = 3
Pt = 2.0

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	366	0.0004	0.15
Pic-ups	0	0.0029	0.00
2-Axle, 4-Tire	0	0.0152	0.00
2-Axle, 6-Tire	0	0.1737	0.00
3-Axle	0	0.3907	0.00
2-S-1	0	0.5192	0.00
2-S-2	0	0.8641	0.00
3-S-1	0	0.8641	0.00
3-S-2	84	1.0580	88.87
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   89.02
Projected TOTAL 18-K Equivalent Load   649,834.25

Number of Lanes : 2
1990 ADT   :   0   Median Year ADT   :   900
2010 ADT   :   0   Critical Lane ADT :   450

Change in PSI   : 2.0
Resilient Modulus (Soil Support Value)   : 7,532 (3.2)
Traffic Factor   : 89
Design Life in Years   : 20

Structural Number Required   : 3.06

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-02
RURAL - SECONDARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 450
Average Daily Load	: 89
Required Structural Number	: 3.06
Total Pavement Thickness	: 14.0 inches

A - Inches of Type 1 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	4.0		8.5	Sand/shell, Shell		3.10
1.5	3.0		8.5	Crushed Stone	1.0	3.02
1.5	3.0		8.5	Crushed PCC	1.0	3.02
1.5	3.0		8.5	Mixed in Place Soil (Cement)	1.0	3.02
1.5	3.0		8.5	Mixed in Place Sand Clay Gravel (Cement)	1.0	3.02
1.5	3.0		8.5	Mixed in Place Sand/Shell (Cement)	1.0	3.11

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 000-00-03
FAP Number :
Description :   (FLEXIBLE PAVEMENT)
Location :
Route :
Parish :
Type of Roadway : RURAL - SECONDARY

Pt = 2.0   s = 3

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	1,845	0.0004	0.74
Pic-ups	0	0.0029	0.00
2-Axle, 4-Tire	0	0.0152	0.00
2-Axle, 6-Tire	0	0.1737	0.00
3-Axle	0	0.3907	0.00
2-S-1	0	0.5192	0.00
2-S-2	0	0.8641	0.00
3-S-1	0	0.8641	0.00
3-S-2	155	1.0580	163.99
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   164.73
Projected TOTAL 18-K Equivalent Load   1,202,514.38

Number of Lanes : 2
1990 ADT :   0   Median Year ADT :   4,000
2010 ADT :   0   Critical Lane ADT :   2,000

Change in PSI   : 2.0
Resilient Modulus (Soil Support Value) : 7,532 (3.2)
Traffic Factor   : 165
Design Life in Years   : 20

Structural Number Required   : 3.36

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-03
RURAL - SECONDARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 2,000
Average Daily Load	: 165
Required Structural Number	: 3.36
Total Pavement Thickness	: 14.5 inches

A - Inches of Type 3 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	4.5		8.5	Sand/shell, Shell		3.37
1.5	3.5		8.5	Crushed Stone	1.0	3.29
1.5	3.5		8.5	Crushed PCC	1.0	3.29
1.5	3.5		8.5	Mixed in Place Soil (Cement)	1.0	3.29
1.5	3.5		8.5	Mixed in Place Sand Clay Gravel (Cement)	1.0	3.29
1.5	3.5		8.5	Mixed in Place Sand/Shell (Cement)	1.0	3.38

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 000-00-04
FAP Number   :
Description   :   ...   (FLEXIBLE PAVEMENT)
Location   :
Route   :
Parish   :
Type of Roadway : RURAL - SECONDARY

Pt = 2.0   s = 4

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	2,667	0.0004	1.07
Pic-ups	0	0.0026	0.00
2-Axle, 4-Tire	0	0.0143	0.00
2-Axle, 6-Tire	0	0.1690	0.00
3-Axle	0	0.3833	0.00
2-S-1	0	0.5086	0.00
2-S-2	0	0.8506	0.00
3-S-1	0	0.8506	0.00
3-S-2	233	1.0458	243.67
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   244.74
Projected TOTAL 18-K Equivalent Load   1,786,588.75

Number of Lanes : 2
1990 ADT   :   0   Median Year ADT   :   5,800
2010 ADT   :   0   Critical Lane ADT :   2,900

Change in PSI   : 2.0
Resilient Modulus (Soil Support Value)   : 7,532 (3.2)
Traffic Factor   : 245
Design Life in Years   : 20

Structural Number Required   : 3.58

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-04
RURAL - SECONDARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 2,900
Average Daily Load	: 245
Required Structural Number	: 3.58
Total Pavement Thickness	: 15.0 inches

A - Inches of Type 3 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	5.0		8.5	Sand/shell, Shell		3.58
1.5	4.0		8.5	Crushed Stone	1.0	3.50
1.5	4.0		8.5	Crushed PCC	1.0	3.50
1.5	4.0		8.5	Mixed in Place Soil (Cement)	1.0	3.50
1.5	4.0		8.5	Mixed in Place Sand Clay Gravel (Cement)	1.0	3.50
1.5	4.0		8.5	Mixed in Place Sand/Shell (Cement)	1.0	3.59

6.0 inches of Subbase (No Credit to SN)

Project Number : 000-00-05
FAP Number   : ...
Description   :
Location   :   (FLEXIBLE PAVEMENT)
Route   :
Parish   :
Type of Roadway : RURAL - PRIMARY

s = 5

Pt = 2.5

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	3,365	0.0004	1.35
Pic-ups	0	0.0027	0.00
2-Axle, 4-Tire	0	0.0145	0.00
2-Axle, 6-Tire	0	0.1681	0.00
3-Axle	0	0.3842	0.00
2-S-1	0	0.5191	0.00
2-S-2	0	0.8308	0.00
3-S-1	0	0.8308	0.00
3-S-2	235	1.0543	247.76
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   249.11
Projected TOTAL 18-K Equivalent Load   1,818,477.25

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   : 10,800
2010 ADT   :   0   Critical Lane ADT :   3,600

Change in PSI   : 1.8
Resilient Modulus (Soil Support Value) : 7,532 (3.2)
Traffic Factor   : 249
Design Life in Years   : 20

Structural Number Required   : 4.06

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-05
RURAL - PRIMARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 3,600
Average Daily Load	: 249
Required Structural Number	: 4.06
Total Pavement Thickness	: 17.0 inches

A - Inches of Type 8 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	4.0	3.0	8.5	Sand/shell, Shell		4.03
1.5	3.5	3.0	8.5	Crushed Stone	0.5	4.16
1.5	3.5	3.0	8.5	Crushed PCC	0.5	4.16
1.5	3.5	3.0	8.5	Mixed in Place Soil (Cement)	0.5	4.16
1.5	3.5	3.0	8.5	Mixed in Place Sand Clay Gravel (Cement)	0.5	4.16
1.5	5.0		8.5	Mixed in Place Sand/Shell (Cement)	2.0	4.03

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 000-00-06

FAP Number :   (FLEXIBLE PAVEMENT)

Description :

Location :

Route :

Parish :

Type of Roadway : RURAL - PRIMARY

s = 4

Pt = 2.5

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	3,287	0.0004	1.31
Pic-ups	0	0.0036	0.00
2-Axle, 4-Tire	0	0.0227	0.00
2-Axle, 6-Tire	0	0.2216	0.00
3-Axle	0	0.4227	0.00
2-S-1	0	0.6274	0.00
2-S-2	0	0.9101	0.00
3-S-1	0	0.9101	0.00
3-S-2	313	1.1186	350.12
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   351.44

Projected TOTAL 18-K Equivalent Load   2,565,487.00

Number of Lanes : 4   Median Year ADT : 10,800

1990 ADT   :   0   Critical Lane ADT :   3,600

2010 ADT   :   0

Change in PSI   : 1.8

Resilient Modulus (Soil Support Value) : 7,532 (3.2)

Traffic Factor   : 351

Design Life in Years   : 20

Structural Number Required   :   4.28

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-06
RURAL - PRIMARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 3,600
Average Daily Load	: 351
Required Structural Number	: 4.28
Total Pavement Thickness	: 17.5 inches

A - Inches of Type 8 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	4.5	3.0	8.5	Sand/shell, Shell		4.24
1.5	4.0	3.0	8.5	Crushed Stone	0.5	4.37
1.5	4.0	3.0	8.5	Crushed PCC	0.5	4.37
1.5	3.5	3.0	7.5	Plant Mixed Soil (Cement)	2.0	4.32
1.5	3.5	3.0	7.5	Plant Mixed Sand Clay Gravel (Cement)	2.0	4.32
1.5	3.5	3.0	7.0	Plant Mixed Sand/Shell (Cement)	2.5	4.37
1.5	3.5	3.0	7.0	Plant Mixed Crushed Stone (Cement)	2.5	4.37

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 000-00-07
FAP Number   :
Description   :   (FLEXIBLE PAVEMENT)
Location   :
Route   :
Parish   :
Type of Roadway : RURAL - PRIMARY

Pt = 2.5   s = 5

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	4,431	0.0004	1.77
Pic-ups	0	0.0027	0.00
2-Axle, 4-Tire	0	0.0145	0.00
2-Axle, 6-Tire	0	0.1681	0.00
3-Axle	0	0.3842	0.00
2-S-1	0	0.5191	0.00
2-S-2	0	0.8308	0.00
3-S-1	0	0.8308	0.00
3-S-2	569	1.0543	599.90
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   601.67
Projected TOTAL 18-K Equivalent Load   4,392,184.00

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   : 15,000
2010 ADT   :   0   Critical Lane ADT :   5,000

Change in PSI   : 1.8
Resilient Modulus (Soil Support Value)   : 7,532 (3.2)
Traffic Factor   : 602
Design Life in Years   : 20

Structural Number Required   :   4.62

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-07
RURAL - PRIMARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 5,000
Average Daily Load	: 602
Required Structural Number	: 4.62
Total Pavement Thickness	: 18.5 inches

A - Inches of Type 8 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	5.0	3.5	8.5	Sand/shell, Shell		4.59
1.5	4.5	3.0	8.5	Crushed Stone	1.0	4.58
1.5	4.5	3.0	8.5	Crushed PCC	1.0	4.58
1.5	4.0	3.0	8.5	Plant Mixed Soil (Cement)	1.5	4.71
1.5	4.0	3.0	8.5	Plant Mixed Sand Clay Gravel (Cement)	1.5	4.71
1.5	3.5	3.0	8.0	Plant Mixed Sand/Shell (Cement)	2.5	4.57
1.5	3.5	3.0	8.0	Plant Mixed Crushed Stone (Cement)	2.5	4.57

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 000-00-08
FAP Number :
Description :   (FLEXIBLE PAVEMENT)
Location :
Route :
Parish :
Type of Roadway : RURAL - PRIMARY

Pt = 2.5   s = 5

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	9,242	0.0004	3.70
Pic-ups	0	0.0027	0.00
2-Axle, 4-Tire	0	0.0145	0.00
2-Axle, 6-Tire	0	0.1681	0.00
3-Axle	0	0.3842	0.00
2-S-1	0	0.5191	0.00
2-S-2	0	0.8308	0.00
3-S-1	0	0.8308	0.00
3-S-2	758	1.0543	799.16
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   802.86
Projected TOTAL 18-K Equivalent Load   5,860,850.00

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   : 30,000
2010 ADT   :   0   Critical Lane ADT : 10,000

Change in PSI   : 1.8
Resilient Modulus (Soil Support Value)   : 7,532 (3.2)
Traffic Factor   : 803
Design Life in Years   : 20

Structural Number Required   : 4.82

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-08
RURAL - PRIMARY	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 10,000
Average Daily Load	: 803
Required Structural Number	: 4.82
Total Pavement Thickness	: 19.5 inches

A - Inches of Type 8 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
1.5	5.0	4.5	8.5	Sand/shell, Shell		4.87
1.5	5.0	3.0	8.5	Crushed Stone	1.5	4.79
1.5	5.0	3.0	8.5	Crushed PCC	1.5	4.79
1.5	4.5	3.0	8.5	Plant Mixed Soil (Cement)	2.0	4.92
1.5	4.5	3.0	8.5	Plant Mixed Sand Clay Gravel (Cement)	2.0	4.92
1.5	4.0	3.0	8.5	Plant Mixed Sand/Shell (Cement)	2.5	4.88
1.5	4.0	3.0	8.5	Plant Mixed Crushed Stone (Cement)	2.5	4.88

6.0 inches of Subbase (No Credit to SN)

Project Number : 000-00-09
FAP Number :
Description :   (FLEXIBLE PAVEMENT)
Location :
Route :
Parish :
Type of Roadway : RURAL - INTERSTATE

s = 6

Pt = 2.5

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	18,041	0.0004	7.22
Pic-ups	0	0.0023	0.00
2-Axle, 4-Tire	0	0.0137	0.00
2-Axle, 6-Tire	0	0.1648	0.00
3-Axle	0	0.3764	0.00
2-S-1	0	0.4969	0.00
2-S-2	0	0.8315	0.00
3-S-1	0	0.8315	0.00
3-S-2	1,959	1.0322	2,022.08
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   2,029.30
Projected TOTAL 18-K Equivalent Load   14,813,862.00

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   :   50,000
2010 ADT   :   0   Critical Lane ADT :   20,000

Change in PSI   : 1.5
Resilient Modulus (Soil Support Value)   : 7,532 (3.2)
Traffic Factor   : 2,029
Design Life in Years   : 20

Structural Number Required   : 6.00

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-09
RURAL - INTERSTATE	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 20,000
Average Daily Load	: 2,029
Required Structural Number	: 6.00
Total Pavement Thickness	: 22.5 inches

A - 1 1/2 Inches of Type 8 Wearing Course   1 1/2 Inches of Type 3 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
3.0	6.0	5.0	8.5	Sand/shell, Shell		6.06
3.0	6.0	3.5	8.5	Crushed Stone	1.5	5.98
3.0	6.0	3.5	8.5	Crushed PCC	1.5	5.98
3.0	5.5	3.0	8.5	Plant Mixed Soil (Cement)	2.5	5.97
3.0	5.5	3.0	8.5	Plant Mixed Sand Clay Gravel (Cement)	2.5	5.97
3.0	5.0	3.0	8.5	Plant Mixed Sand/Shell (Cement)	3.0	5.93
3.0	5.0	3.0	8.5	Plant Mixed Crushed Stone (Cement)	3.0	5.93

6.0 inches of Subbase (No Credit to SN)

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number   : 000-00-10
FAP Number   :   (FLEXIBLE PAVEMENT)
Description   :
Location   :
Route   :
Parish   :
Type of Roadway   : RURAL - INTERSTATE

| | | | s = 6 |
| Pt = 2.5 | | | |

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	18,041	0.0004	7.22
Pic-ups	0	0.0023	0.00
2-Axle, 4-Tire	0	0.0137	0.00
2-Axle, 6-Tire	0	0.1648	0.00
3-Axle	0	0.3764	0.00
2-S-1	0	0.4969	0.00
2-S-2	0	0.8315	0.00
3-S-1	0	0.8315	0.00
3-S-2	1,959	1.0322	2,022.08
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load	2,029.30
Projected TOTAL 18-K Equivalent Load	14,813,862.00

Number of Lanes : 4
1990 ADT   :   0   Median Year ADT   : 50,000
2010 ADT   :   0   Critical Lane ADT : 20,000

Change in PSI   : 1.5
Resilient Modulus (Soil Support Value) : 7,532 (3.2)
Traffic Factor   : 2,029
Design Life in Years   : 20

Structural Number Required   : 6.00

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-10
RURAL - INTERSTATE	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 20,000
Average Daily Load	: 2,029
Required Structural Number	: 6.00
Total Pavement Thickness	: 12.5 inches

A - 1 1/2 Inches of Type 8 Wearing Course   1 1/2 Inches of Type 3 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
3.0	6.0	3.5				5.98

8.5 inches of Crushed Stone for Subbase

STATE OF LOUISIANA
DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT

Project Number : 000-00-11
FAP Number :
Description :
Location :
Route :
Parish :
Type of Roadway : RURAL - INTERSTATE

(FLEXIBLE PAVEMENT)

s = 6

Pt = 2.5

Vehicle Type	Number of Vehicles	18-Kip Eq. Factor	Equivalent 18-Kip Axles
Passenger Cars	18,041	0.0004	7.22
Pic-ups	0	0.0023	0.00
2-Axle, 4-Tire	0	0.0137	0.00
2-Axle, 6-Tire	0	0.1648	0.00
3-Axle	0	0.3764	0.00
2-S-1	0	0.4969	0.00
2-S-2	0	0.8315	0.00
3-S-1	0	0.8315	0.00
3-S-2	1,959	1.0322	2,022.08
3-S-3	0	1.4500	0.00
Double Trailer	0	1.8400	0.00

Projected DAILY 18-K Equivalent Load   2,029.30
Projected TOTAL 18-K Equivalent Load   14,813,862.00

Number of Lanes : 4   Median Year ADT   : 50,000
1990 ADT   :   0   Critical Lane ADT : 20,000
2010 ADT   :   0

Change in PSI   : 1.5
Resilient Modulus (Soil Support Value)   : 7,532 (3.2)
Traffic Factor   : 2,029
Design Life in Years   : 20

Structural Number Required   : 6.00

RECOMMENDED SECTION

LOUISIANA DEPARTMENT OF TRANSPORTATION
RECOMMENDED PAVEMENT CROSS-SECTIONS

Project Number	: 000-00-11
RURAL - INTERSTATE	
Resilient Modulus	: 7,532 (3.2)
Average Daily Traffic	: 20,000
Average Daily Load	: 2,029
Required Structural Number	: 6.00
Total Pavement Thickness	: 11.0 inches

A - 1 1/2 Inches of Type 8 Wearing Course   1 1/2 Inches of Type 3 Wearing Course
B - Inches of Type 3 Binder Course
C - Inches of Type 5A Black Base (if used)
D - Inches of Base Material
E - Inches of Additional Subbase (if needed)

A	B	C	D	Type of Base Material	E	SN
3.0	5.0	3.0				5.91

12.0 inches of Crushed Stone for Subbase

APPENDIX F

Record Layout of Flexible and Rigid Data Storage Files

Storage of Designs

Upon completion of a design the user has the option of saving the design parameters in a data file. The data file created will contain all information necessary to duplicate the design when the file is retrieved. The data file is automatically named based upon the project number entered on Screen 11 shown on page 19. Additionally the file name includes either a F or R as the 8th character of the name. This will "tag" the file as either a flexible or rigid design. The extension give the file will be "PDF", this appropriately represents "Pavement Design File".

Examples of created data files are:

   4551413R.PDF - Rigid design for project 455-14-13

   1233212F.PDF - Flexible design for project 123-32-12

Record Layout of Pavement Design Data File

Type of design code - (1 - Rigid / 2 - Flexible)
Location and Class Code (1 - Urban Interstate ... 8 - Rural Local)
Date of Design
Project Number
FAP Number
Location
Route
Parish
Number of Lanes
Design Year ADT
End-of-Life ADT
Median Year ADT
Critical Lane ADT

— Designer Recommended Section
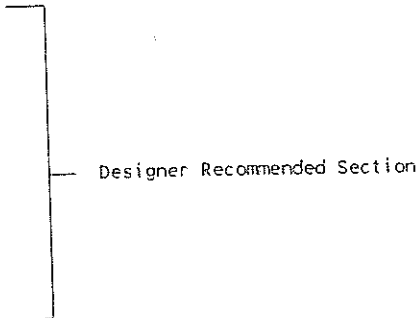
Initial PSI Code (1 - 2.0 / 2 - 2.5)
Initial Thickness or SN Code (1 - 6 in. or 2.0 SN, etc.)

— Traffic Factor Calculation Data
Number of Vehicles   Equivalence Factor   18-KIP ESAL
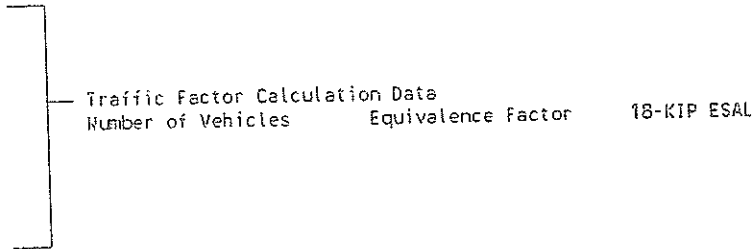
Standard Normal of Reliability Level
Overall Standard Deviation
Reliability Level
Design Life in Years
Traffic Factor
Change in PSI

Next Lines are unique to type of pavement design is for

Concrete Elastic Modulus (x 10^6)
Composite K value
Concrete Flexural Strength
Type of Shoulder Code   — Rigid Pavement Design Only
Load Transfer Coefficient
Type of Drainage Code
Drainage Coefficient
Inches of Concrete

Soil Support Value
Structural Number   — Flexible Pavement Design Only
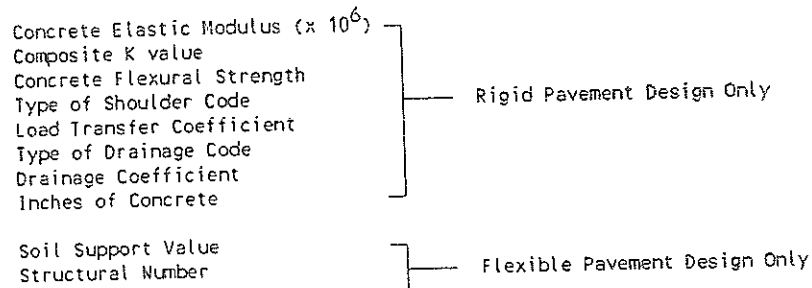
```
2
5
01-13-1989
450-18-47
IR-10-5(254)271
I-10 over Pearl Flood Plain
I-10
Saint Tammany
4
21,200
38,160
29,680
14,840
```

SN = (0.10 x 12.0) + (0.33 x 6.5) + (0.36 x 3.5) + (0.44 x 2.0)
   = 1.20   + 2.15   + 1.26   + 0.88
   = 5.49

Base: 12.0 in. Sand/Shell Base Course

Surfacing: 12.0 in. Asphaltic Concrete Pavement as follows:
             6.5 in. Asphaltic Concrete (Type 5A) Base Course
             3.5 in. Asphaltic Concrete (Type 3) Binder Course
             2.0 in. Asphaltic Concrete (Type 8) Wearing Course

```
4
4
 9587 0.0004    3.83
 2523 0.0027    6.81
   74 0.0145    1.07
  579 0.1681   97.33
  178 0.3842   68.39
   45 0.5191   23.36
  134 0.8308  111.33
   89 0.8308   73.94
 1618 1.0543 1705.86
   15 1.4500   21.75
    0 1.8400    0.00
-1.645
.47
95
20
2114
1.5
 3.5
5.44
```

Actual Rigid Pavement Design Data File

```
1
7
01-20-1988
826-44-15

Hickory Avenue (Harahan) (LA 48 - LA 3139)
LA 3154
Jefferson
4
30,226
45,370
37,798
18,899
Base:      9.0 in. Sand/Shell Base Course

Pavement:  9.5 in. Portland Cement Concrete Pavement




2
4
13682 0.0004      5.47
 3064 0.0027      8.27
   70 0.0143      1.00
 1266 0.1673    211.80
  266 0.5706    151.78
   60 0.5044     30.26
   13 0.9794     12.73
   13 0.9794     12.73
  465 1.7485    813.05
    0 2.8730      0.00
    0 1.8400      0.00
-1.037
.37
85
20
1247
2
4.2
300
575
1
3.2
2
1.1
  9.5
```

APPENDIX G

Original and Abbreviated Design Nomographs
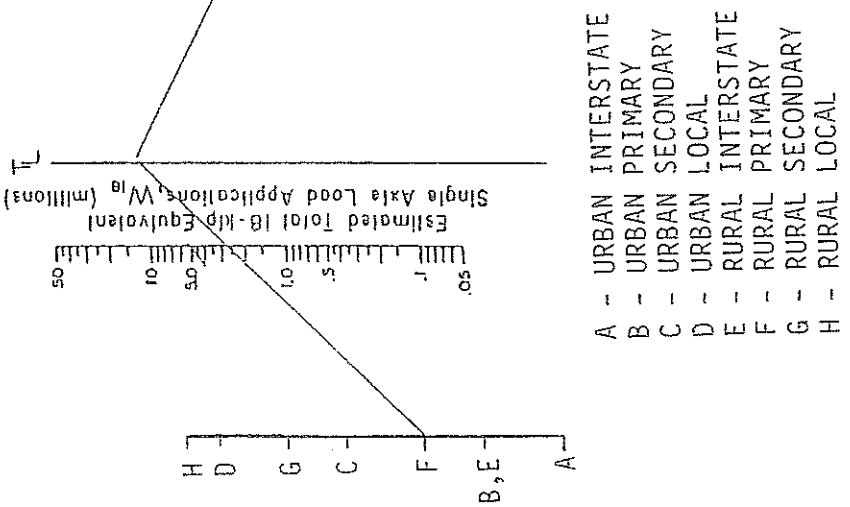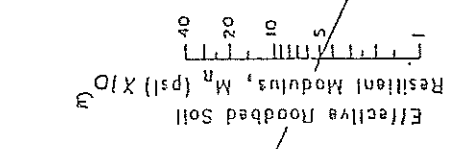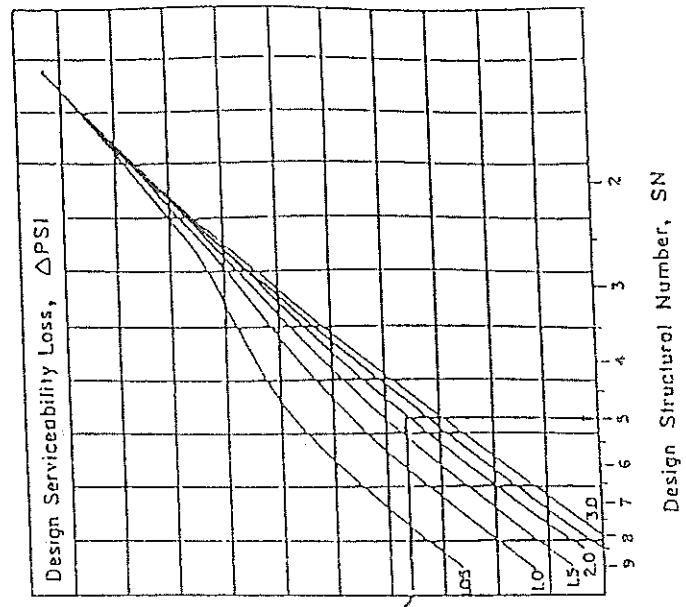
Abbreviated Flexible Design Nomograph
(LA DOTD Design Procedure)

A – URBAN INTERSTATE
B – URBAN PRIMARY
C – URBAN SECONDARY
D – URBAN LOCAL
E – RURAL INTERSTATE
F – RURAL PRIMARY
G – RURAL SECONDARY
H – RURAL LOCAL

Original Flexible Design Nomograph

(AASHTO Design Procedure)

NOMOGRAPH SOLVES:

$$\log_{10} W_{18} = Z_R \cdot S_o + 9.36 \cdot \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN+1)^{5.19}}} + 2.32 \cdot \log_{10} M_R - 8.07$$
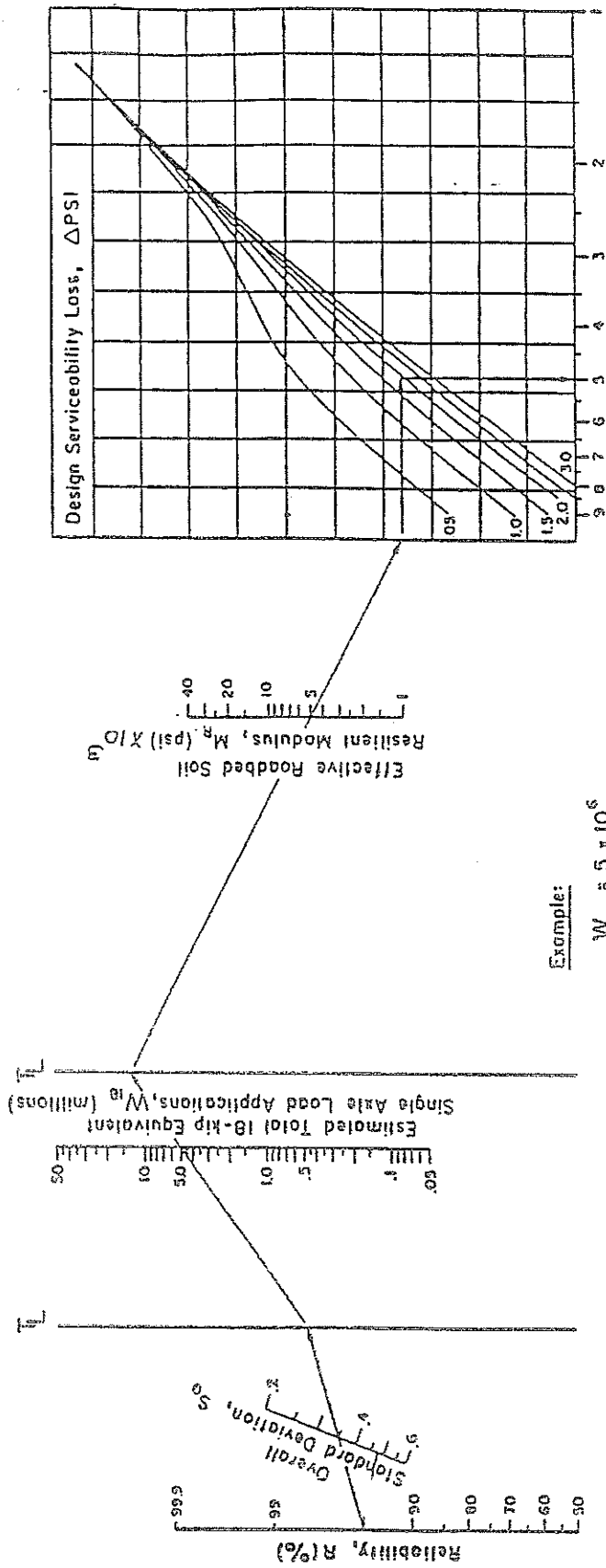
Example:

$W_{18} = 5 \times 10^6$

$R = 95\%$

$S_o = 0.35$

$M_R = 5000$ psi

$\Delta PSI = 1.9$

Solution: $SN = 5.0$

Design Serviceability Loss, ΔPSI

Design Structural Number, SN

Effective Roadbed Soil Resilient Modulus, M_R (psi) $X 10^3$

Estimated Total 18-kip Equivalent Single Axle Load Applications, W_{18} (millions)

Overall Standard Deviation, S_o

Reliability, R(%)

1 – Drainable Shoulder Layer
2 – Shoulder Edge Drains
3 – No Drainage Feature

Design Slab Thickness, D (inches)

Estimated Total 18-kip Equivalent Single Axle Load (ESAL) Applications, W_{18} (millions)

Location and Functional Class of Roadway

H D G C F B,E A

Design Serviceability Loss, ΔPSI

T_L

Type of Drainage Structure

1 2 3

Type of Shoulder

X Y

T_L

800
500

100
50
10

Effective Modulus of Subgrade Reaction, k

A – URBAN INTERSTATE
B – URBAN PRIMARY
C – URBAN SECONDARY
D – URBAN LOCAL
E – RURAL INTERSTATE
F – RURAL PRIMARY
G – RURAL SECONDARY
H – RURAL LOCAL

X – Asphalt Shoulder and 12 ft. Truck Lane
Y – Asphalt Shoulder and 15 ft. Truck Lane or Concrete Shoulder

EXAMPLE
k = 500
Asphalt Shoulder
   and 12 ft. Truck Lane
No Drainage Feature
Change in PSI = 2.0
W_{18} = 5,000,000
URBAN SECONDARY

Abbreviated Rigid Design Nomograph
(LA DOTD Design Procedure)

109
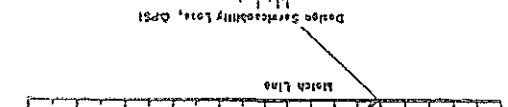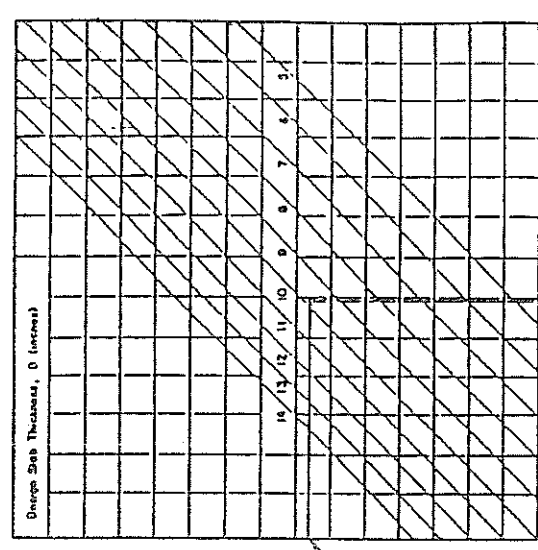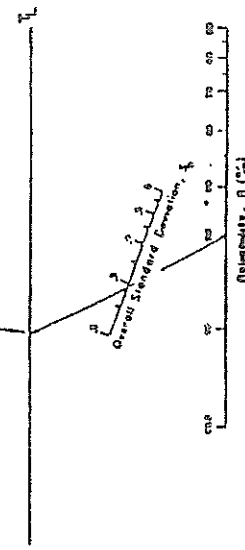
Original Rigid Design Nomograph

(AASHTO Design Procedure)