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LoadGage User's Guide

Product 0-4519-P3

Cooperative Research Program

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LOADGAGE USER'S GUIDE

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CHAPTER I
INTRODUCTION

LoadGage is a computer program for checking flexible pavement designs that incorporates improvements to the modified triaxial design method currently implemented by the Texas Department of Transportation (TxDOT). These improvements are based on the findings from Project 0-4519, during which researchers verified the triaxial design method and characterized the variations of climatic and soil conditions between the different counties of the state. The research and development efforts conducted in that project are documented in two companion reports by Fernando, Oh, Estakhri, and Nazarian (2007) and by Fernando, Oh, Ryu, and Nazarian (2007). The interested reader is referred to these reports for details on the work conducted during the project to review and understand the original development of the load-thickness design curves, to verify these curves from laboratory and field test data, and to improve the existing design method based on the project findings. This document provides a user's guide to the *LoadGage* program. Among the enhancements implemented in *LoadGage* are:

- a stress-based analysis procedure that provides users with greater versatility in modeling flexible pavement systems compared to the limited range of approximate layered elastic solutions represented in the existing modified triaxial thickness design curves;
- more realistic modeling of pavement wheel loads, in lieu of the current practice of using a correction factor of 1.3, which was found to be overly conservative from the verification efforts conducted in Project 0-4519;
- an extensive database of soil properties covering each of the 254 Texas counties for evaluating the effects of moisture changes on soil strength properties; and
- a moisture correction procedure (to account for differences between wet and dry regions of the state) that provides users the option of adjusting strength properties determined from laboratory triaxial tests (such as TxDOT Test Method Tex-117E) to the expected in-service moisture conditions.

The moisture correction procedure considers the contribution of soil suction to the shear strength of unsaturated soils. As the soil dries, the soil suction component increases with an accompanying increase in shear strength. The relationship between soil moisture content and soil suction is given by the soil-water characteristic curve. The moisture correction procedure in *LoadGage* uses this relationship to adjust failure envelope parameters determined from triaxial tests performed on samples prepared at a particular moisture content to corresponding values representative of the expected in-service moisture conditions. This adjustment is performed using equations derived from relationships determined by Glover and Fernando (1995) who conducted triaxial tests on a range of base and subgrade soils, and developed relationships for predicting failure envelope parameters as a function of soil suction and other properties.

To implement the moisture correction procedure in *LoadGage*, researchers compiled a database of soil suction properties based on an extensive review of available data. This review covered county soil survey reports, available climatic data from weather stations in Texas, published data on soil suction parameters for different soils, and reports documenting the development of the enhanced integrated climatic model (EICM). EICM is a useful program for predicting moisture content, pavement temperature, frost and thaw depth, frost heave, and the elastic modulus of each pavement layer given the climatic and drainage conditions for a given pavement design. The model was originally developed by Lytton et al. (1990) in a research project funded by the Federal Highway Administration. Subsequently, Larson and Dempsey (1997) modified the program to provide a Windows-based graphical user interface in a project sponsored by the Minnesota Department of Transportation. More recently, EICM was incorporated into a computer program for mechanistic-empirical pavement design developed in National Cooperative Highway Research Program (NCHRP) Project 1-37A (Applied Research Associates, 2004).

For developing *LoadGage*, researchers used the EICM program to predict the expected in-service moisture contents for the range of climatic conditions and soil types found across Texas. The EICM analyses were conducted on flexible pavements representative of low-volume Farm-to-Market (FM) roads, where the pavement design is typically governed by the modified triaxial design method. Researchers used the results from these analyses to compile a database of expected in-service moisture contents covering each county in the state.

TxDOT engineers can use *LoadGage* to check the thickness design from the Department's flexible pavement system (FPS-19) program to verify whether adequate cover is provided to protect the subgrade against overstressing under a wheel load equal to the average of the ten heaviest wheel loads (ATHWLD) expected on the pavement. In current practice, the ATHWLD is usually the load carried by the dual tires at each end of the drive or trailer axles. However, it could also represent a single wheel load, such as the load on each tire of the steering axle, or the tire load on drive or trailer axles equipped with wide-base radials (not commonly observed on trucks in Texas). For the design check, the user inputs into *LoadGage* the layer moduli, Poisson's ratios, and thicknesses from the FPS-19 design program. When the FPS design is predicted to be inadequate, *LoadGage* estimates the base thickness required such that the predicted subgrade stresses for the specified ATHWLD are within the failure envelope of the material based on the Mohr-Coulomb strength criterion. Researchers note that this criterion also forms the basis for the existing Texas modified triaxial design procedure.

Conducting a triaxial design check using *LoadGage* will require the following information from the user:

- modulus, Poisson's ratio, and thickness of each pavement layer;
- average of the ten heaviest wheel loads; and
- data from Texas triaxial tests (Texas triaxial class of the subgrade or parameters of the subgrade failure envelope, and the moisture content at which laboratory triaxial tests were conducted).

The above data may be obtained from the flexible pavement design and represent the minimum that are required to run *LoadGage*. Note that running the program and getting good results are two different things. To do an adequate analysis, the engineer should know the properties of the materials to be placed and model the pavement realistically. Good engineering practice will require an effort to search published information, review past experience, and/or run tests to characterize the materials for a given problem.

CHAPTER II

USING THE LOADGAGE TRIAXIAL DESIGN CHECK PROGRAM

This chapter provides a user's guide to *LoadGage* version 1.0, a computer program for evaluating the structural adequacy of pavement designs based on the Mohr-Coulomb yield criterion. The program requires a microcomputer operating under the Windows 2000, NT, or XP environment. To install *LoadGage*, run the setup file *LoadGageSetup.exe* provided with the program disk and follow the on-screen instructions. After installation, double click the *LoadGage* program icon on your desktop to run the program. *LoadGage* brings up the opening screen shown in Figure 1, followed by the main menu in Figure 2. From this menu, the user can specify the parameters characterizing the pavement and load for a given analysis, or retrieve an existing input file. Before going further, here are two simple guidelines for navigating through the different menus of *LoadGage*:

- To select a particular option on the screen, move the pointer to the option, and then click with the left mouse button.
- To enter data for a particular variable, move the cursor to the field or cell, click with the left mouse button on the input field, and type in the required data.

The options in the main menu permit the user to open an existing input file; specify material parameters (i.e., resilient and strength properties); save input data; run a triaxial design check; and view/print program output. The succeeding sections describe these functions.

MAIN MENU

Figure 2 illustrates the main menu of the *LoadGage* program. On this menu, the user defines the pavement for a given analysis by first specifying the number of layers above the rigid bottom. This variable is restricted to three or four in the computer program. By default, *LoadGage* initially assumes three pavement layers, as indicated in Figure 2. To specify four layers, simply click on ***4 Layers*** at the top left portion of the menu to select it. The program will add another row in the menu for specifying the properties of the fourth pavement layer. While the minimum number of pavement layers is three, the user may

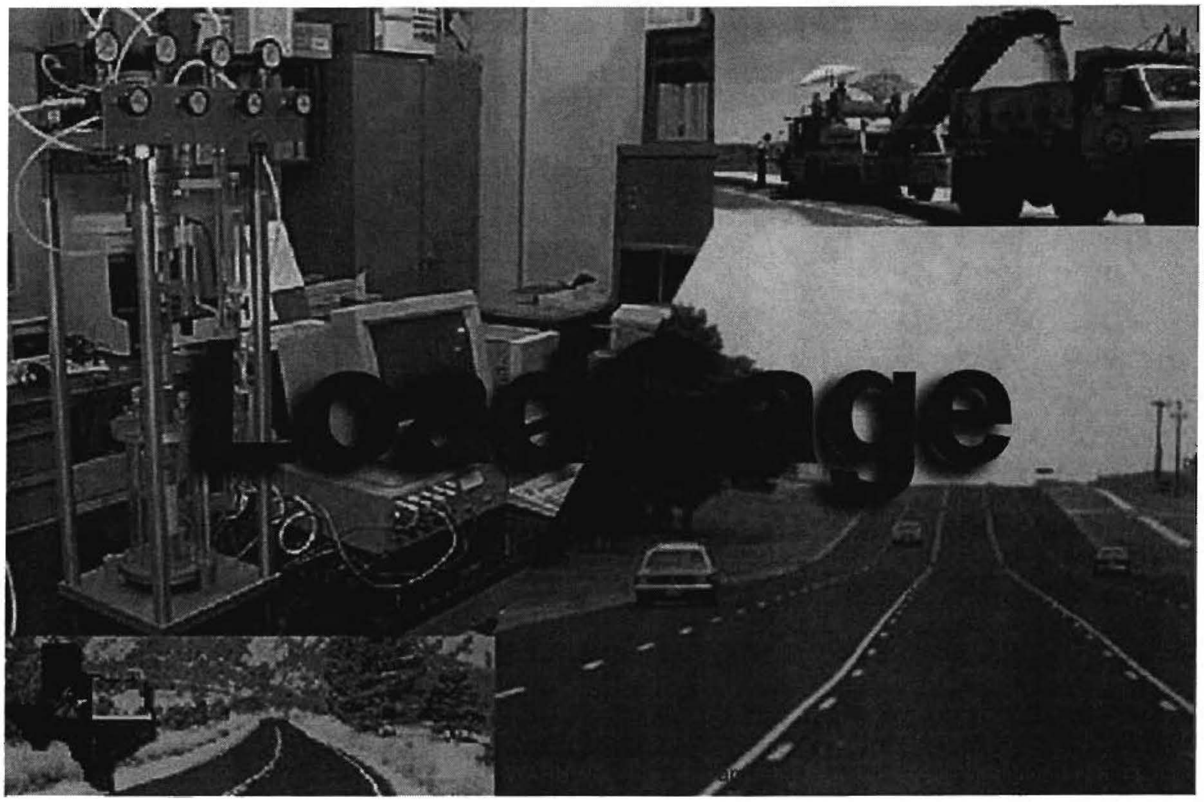


Figure 1. *LoadGage* Opening Screen.

evaluate a pavement consisting of a stabilized layer over subgrade by specifying three layers and entering the same properties for the first and second layers.

For each layer, enter its modulus, Poisson's ratio, and thickness. *LoadGage* uses English units, so enter the modulus in psi and the thickness in inches. The modulus, Poisson's ratio, and thickness for each layer should correspond to the pavement design determined from FPS-19, on which the triaxial design check is made. In addition, *LoadGage* requires the cohesion (in psi) and friction angle (in degrees) that define the Mohr-Coulomb failure envelope of the subgrade. The program uses these properties to determine whether the existing depth of subgrade cover is adequate or not. The user determines these properties by running triaxial tests on molded samples of the subgrade material found on a given project. Alternatively, the engineer can specify the Texas triaxial class (TTC) of the material, which is then used to estimate the failure envelope parameters. To specify the TTC, check the box for this option in the main menu and enter its value in the space provided. *LoadGage* automatically estimates the cohesion and friction angle for the specified TTC. If the failure envelope parameters and the Texas triaxial class are not known,

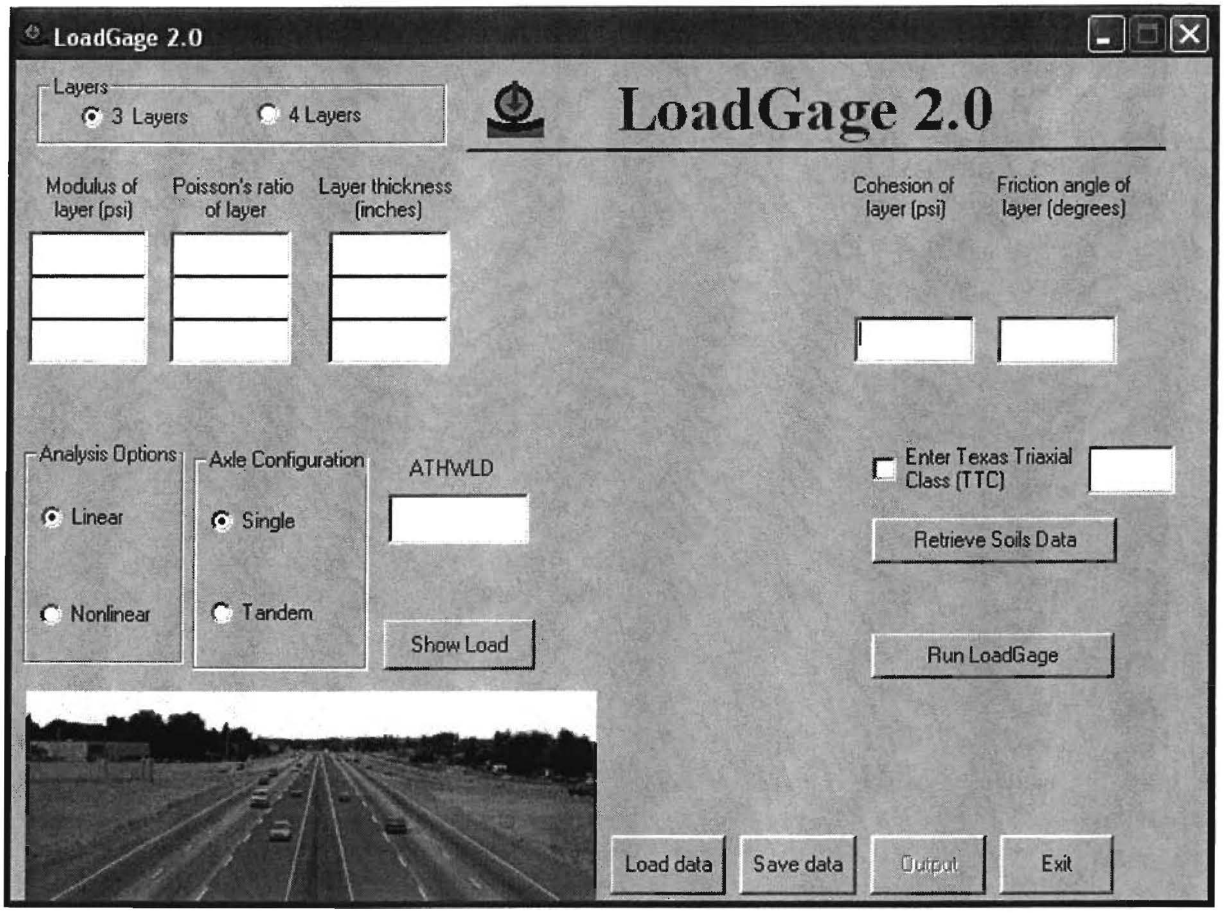


Figure 2. Main Menu of *LoadGage* Program.

LoadGage has a database of soil properties to evaluate subgrade strength properties for a given problem. This database is accessed by clicking the ***Retrieve Soils Data*** button of the main menu, which is described in the *Defining the Subgrade Failure Envelope* section.

LoadGage uses layered elastic theory to predict the stresses induced under load for the specified pavement. These stresses are then checked against the Mohr-Coulomb failure envelope to evaluate the potential for pavement damage resulting from one application of a heavy wheel load characterized by the average of the ten heaviest wheel loads used in pavement design. By default, the program runs a linear analysis to predict the stresses. However, for the advanced user, a nonlinear option is included to permit modeling of the stress-dependency. The nonlinear analysis option is described in "Nonlinear Analysis Option" later in this user's guide. To select an analysis option, simply click on ***Linear*** or ***Nonlinear*** in the main menu (Figure 2).

LoadGage also permits modeling of single and tandem axle loads. Researchers incorporated this capability as a modification to the present practice of applying a correction factor of 1.3 to the ATHWLD when the percent tandem axles is greater than 50. This correction factor was found to result in very conservative estimates of allowable wheel loads from the verification tests conducted during Project 0-4519. To analyze a tandem axle, click on ***Tandem*** in the main menu.

The user may load an existing data file by clicking on ***Load data*** in the main menu. This action brings up the dialog box shown in Figure 3 where one selects the particular file to load into the program. Simply highlight the file name in the dialog box. Then click on ***Open*** to read the data into *LoadGage*. The main menu displays the data as shown in Figure 4. To help users learn the program, two sample input files named *Example Data1.DAT* and *Example Data2.DAT* are copied into the *LoadGage* program directory during installation. Try loading *Example Data1.DAT* as an exercise on using the ***Load data*** function. The data in this file are displayed in Figure 4 where a three-layer pavement is characterized with the moduli, Poisson's ratios, and thicknesses shown. The subgrade failure envelope in this particular example is defined by a cohesion of 2 psi and a friction angle of 40.1°. Also note that a single axle load is specified. The load per wheel of the single axle is determined from the ATHWLD that is given as 12,000 lb in Figure 4. To show the load characteristics, click on ***Show Load*** in the main menu. The program then displays the wheel load, tire pressure, and tire spacing on the right side of the main menu as illustrated in Figure 5. Since the ATHWLD is transmitted to the pavement on dual tires, the wheel load is taken as half of the ATHWLD. Thus in Figure 5, the wheel load is displayed as 6000 lb (½ × 12,000) without the 1.3 correction factor. This wheel load is assumed for all tires of the axle or group of axles when tandems are selected. To close the window displaying the load characteristics, click on ***Hide Load*** in the main menu shown in Figure 5.

In addition to the tire load, the user also specifies the tire pressure and dual tire spacing to define the load geometry for single axle configurations. By default, *LoadGage* assumes 100 psi for the tire pressure and 14 inches for the dual tire spacing. For tandem axle assemblies, the axle spacing is also specified as illustrated in Figure 6. For this variable, a default value of 54 inches is used. The tire pressure specified in *LoadGage* represents the tire contact pressure. In current practice, this design variable is usually assumed equal to the tire inflation pressure. For most pavement designs where the program is expected to be used,

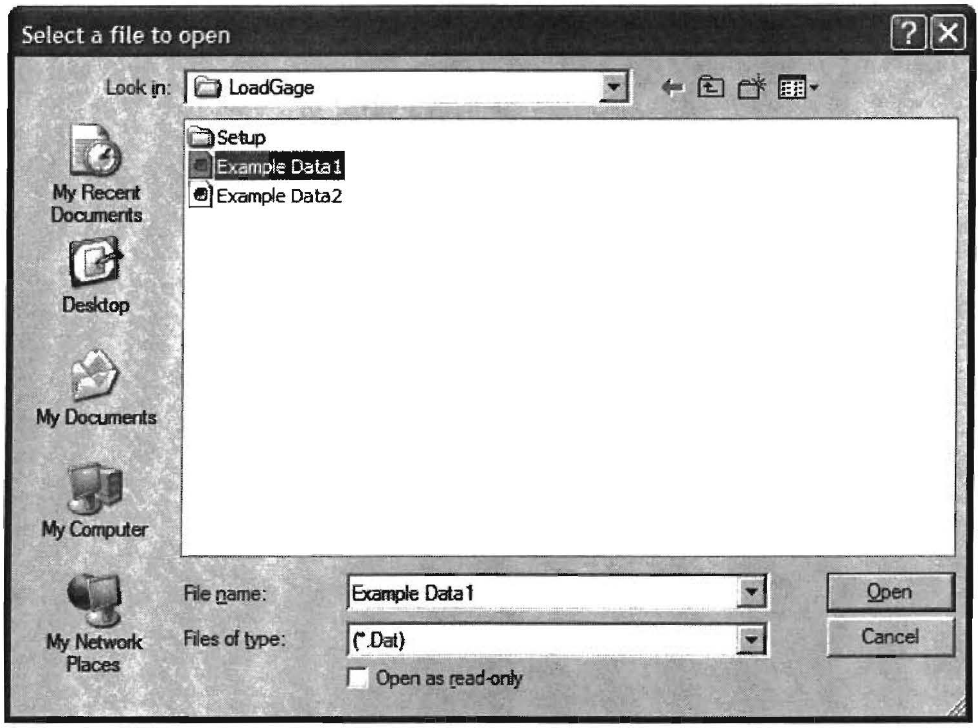


Figure 3. Dialog Box to Load an Input Data File into *LoadGage*.

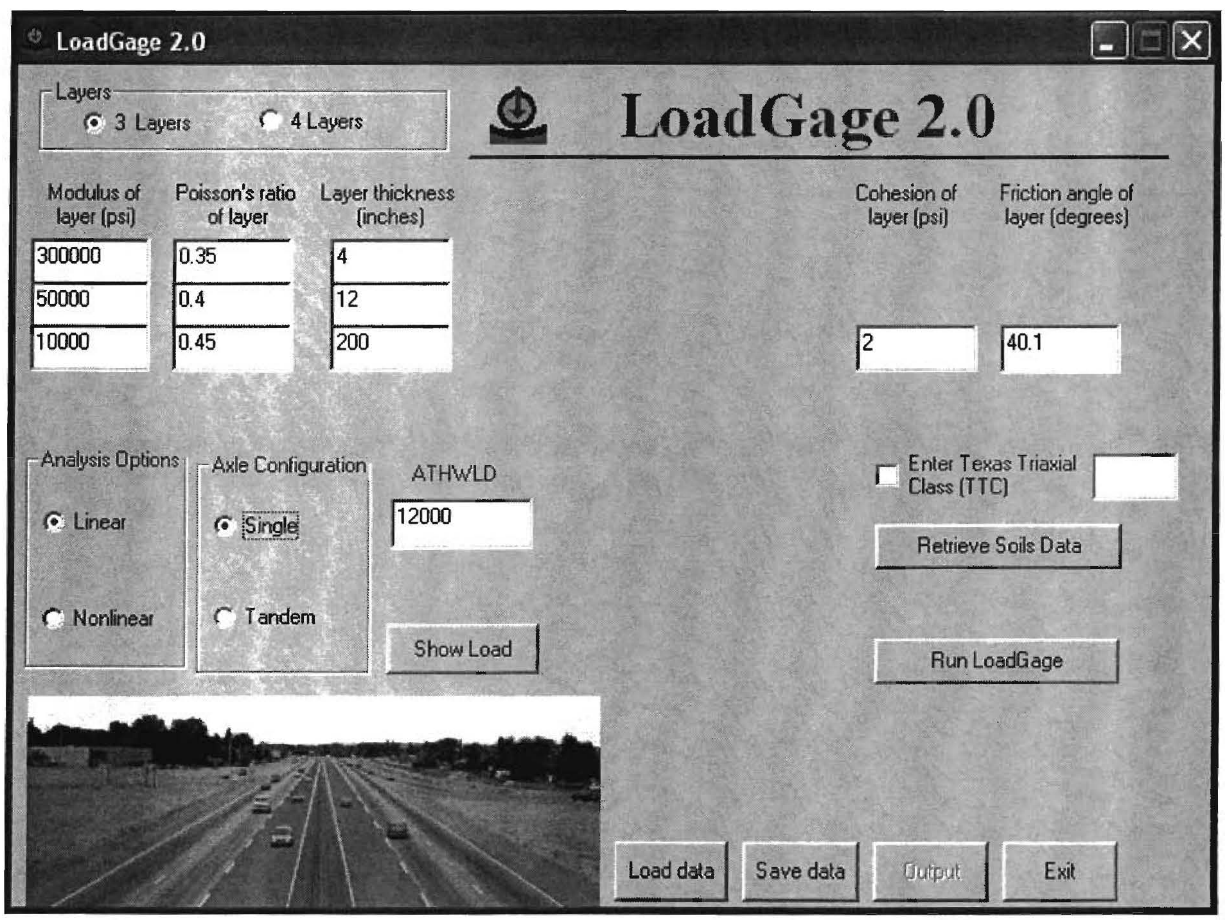


Figure 4. Main Menu Displaying Data Read from an Existing Input File.

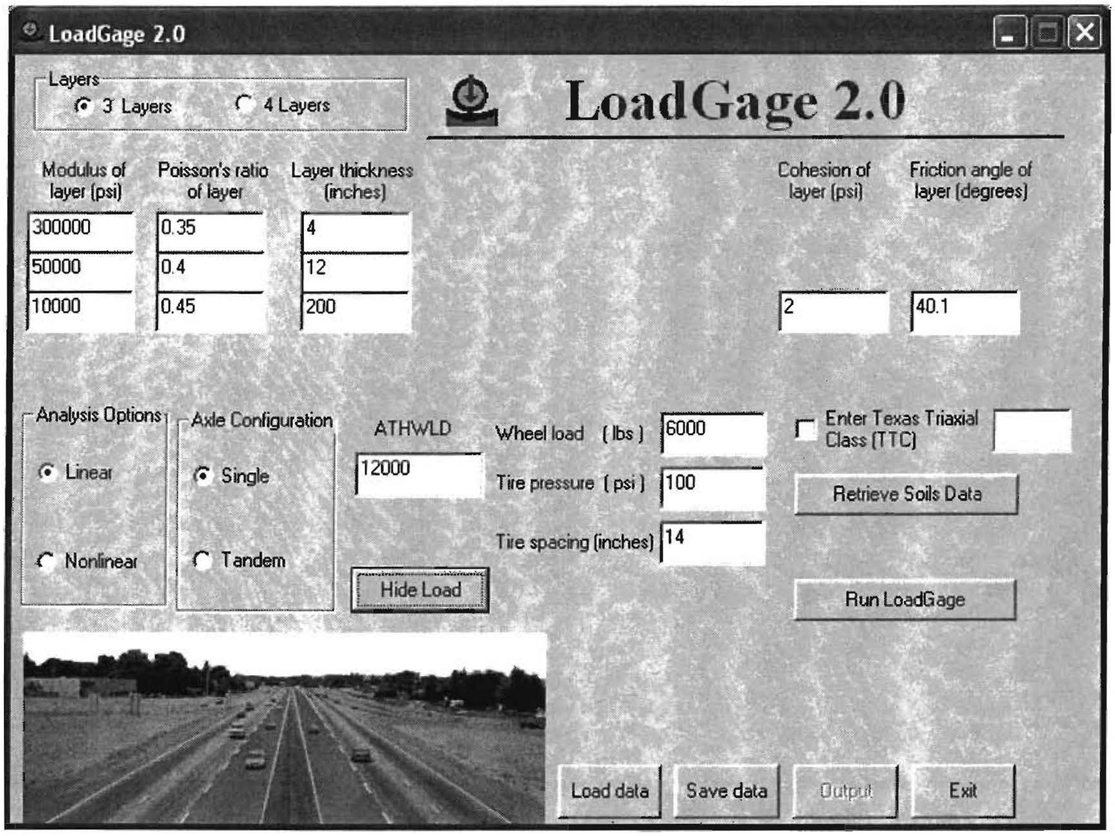


Figure 5. Display of Load Characteristics for a Single Axle Configuration.

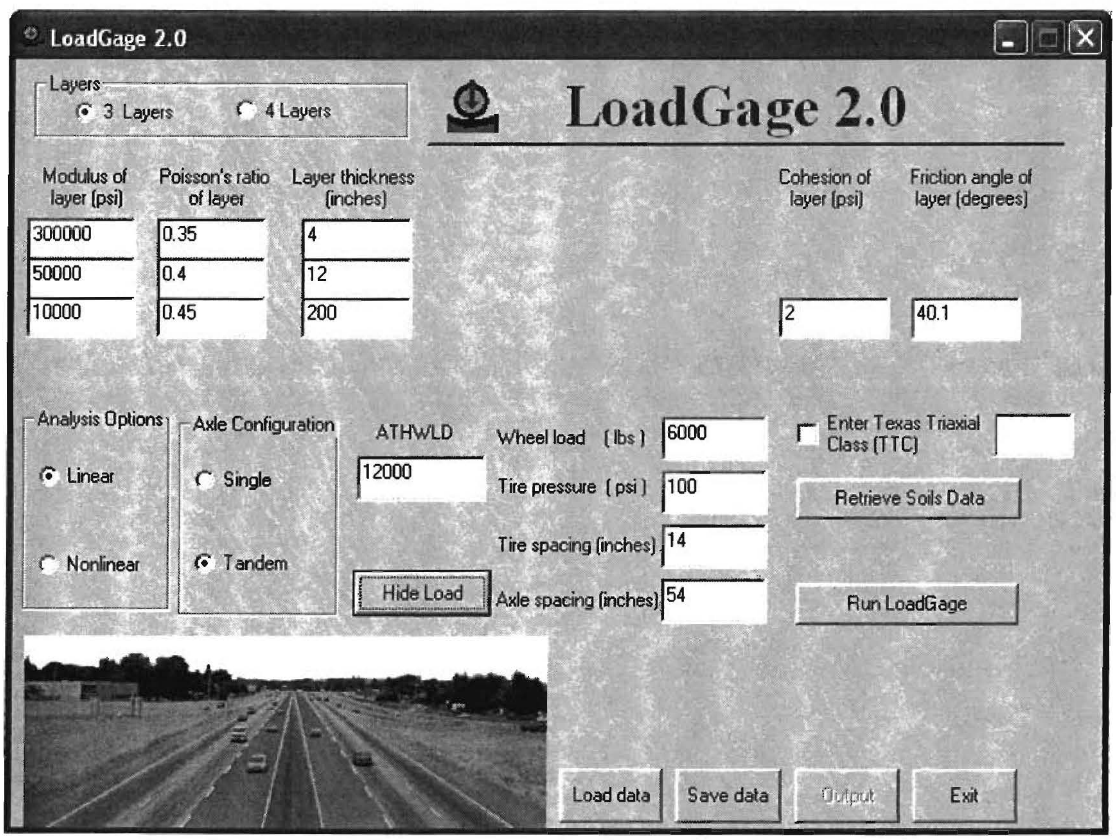


Figure 6. Display of Load Characteristics for a Tandem Axle Configuration.

the authors are of the opinion that the magnitude of the wheel load will have a much greater influence on the predicted subgrade stresses than the tire contact pressure distribution. This opinion is based on the findings from TxDOT Project 0-4361 (Fernando, Musani, Park, and Liu, 2006) as well as other studies that found tire contact pressures to significantly influence the predicted pavement response primarily near the pavement surface. Thus, for a given wheel load, tire pressure is not expected to be a critical factor in the *LoadGage* analysis, and the user may simply input the tire inflation pressure.

After specifying the data for a given evaluation, the user may choose to save the program inputs by clicking on ***Save data*** in the main menu. This action brings up the dialog box shown in Figure 7, where the user can specify the name of the file to write the data to. *LoadGage* writes the input data in the format shown in Table 1. The user may then run the program using the specified data by clicking on ***Run LoadGage*** in the main menu. This function is described in the next section.

RUNNING AN EVALUATION AND VIEWING OUTPUT

The run time screen shown in Figure 8 is displayed during the evaluation of a given pavement design. If this evaluation shows that no overstressing is predicted in the subgrade, *LoadGage* displays the message box shown in Figure 9, telling the user that the given pavement passes the Texas triaxial design check. If the pavement design is inadequate, the program will automatically search for the minimum base thickness required to prevent overstressing at the top of the subgrade for the given load. During this time, the run time screen will display each trial base thickness and the corresponding value of the Mohr-Coulomb yield function (Figure 10). An adequate base thickness is indicated when the value of the yield function becomes negative. At the end of the analysis, *LoadGage* will display a message box that shows the current design base thickness and the minimum value required to prevent overstressing the subgrade (corresponding to a predicted yield function just below zero). Figure 11 illustrates the message box that is displayed when the design base thickness is insufficient to prevent overstressing the subgrade.

The information that is displayed in the message box at the end of an analysis is typically the only output necessary for most design applications. However, the program has an output function that provides additional details of the analysis. Clicking on ***Output*** in the main menu of the *LoadGage* program brings up the screen illustrated in Figure 12. As

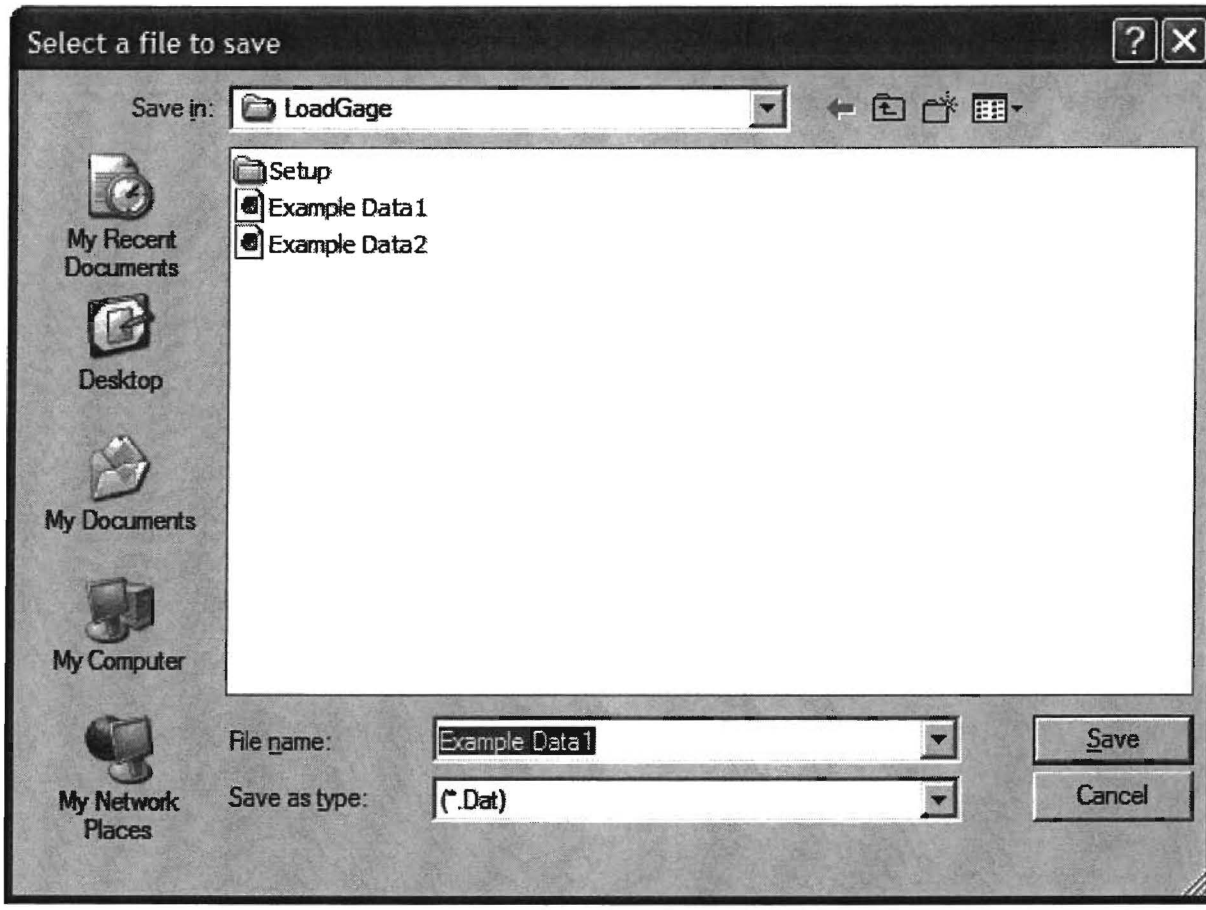


Figure 7. Saving the Input Data in *LoadGage*.

Table 1. Format of *LoadGage* Input File[1].

Record Number	Record Entries
1	Number of pavement layers, N (3 or 4)
	Analysis option (1 = linear/2 = nonlinear)
2 to N	Modulus (psi)
	Poisson's ratio
	Thickness (in)
	Parameters K_1, K_2, and K_3 of Eq. (8). For linear analysis, $K_2 = K_3 = 0$, and K_1 = Modulus/14.5 where 14.5 is the atmospheric pressure in psi.
$N + 1$	Subgrade modulus (psi)
	Subgrade Poisson's ratio
	Subgrade thickness (in)
	Parameters K_1, K_2, and K_3 of Eq. (8). For linear analysis, $K_2 = K_3 = 0$, and K_1 = Subgrade modulus/14.5 where 14.5 is the atmospheric pressure in psi.
	Cohesion (psi) and friction angle (°) of subgrade failure envelope
$N + 2$	Axle configuration (1 = single/2 = tandem)
$N + 3$	Wheel load (½ × ATHWLD, lb)
	Tire pressure (psi)
	Dual tire spacing (in)
	For tandem axle configuration, axle spacing (in)

[1]Entries in each record are read in free format (i.e., commas or spaces separate the data entries in a given record).

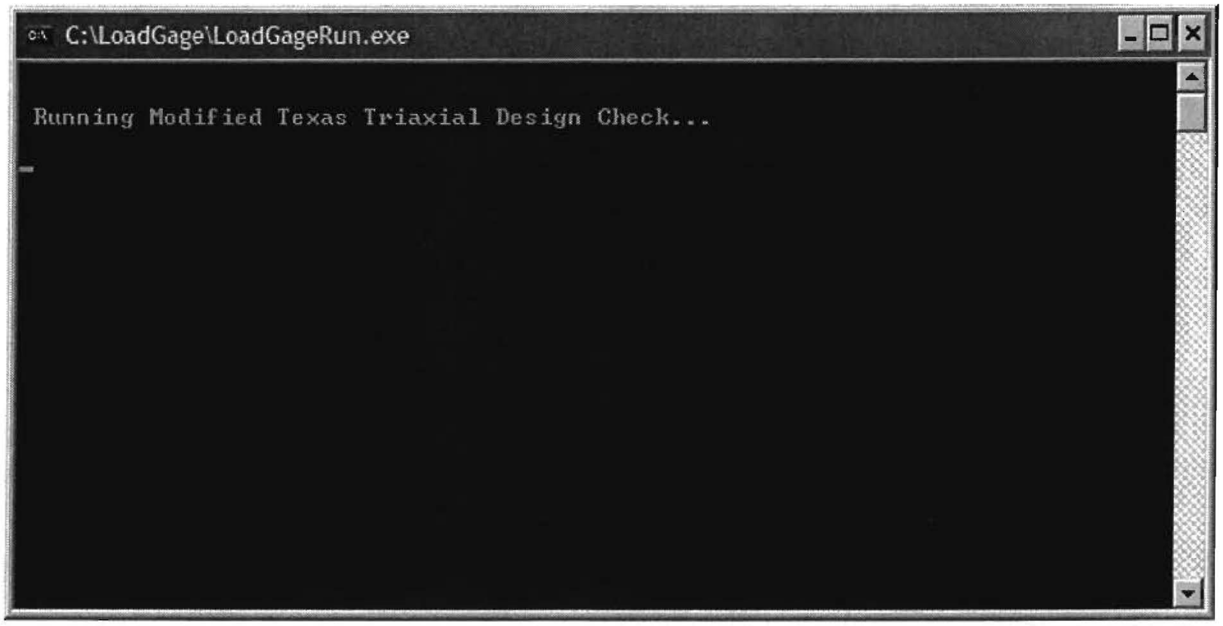


Figure 8. Run Time Screen Displayed during an Analysis.

Figure 9. Message Displayed when Pavement Design Passes Triaxial Design Check.

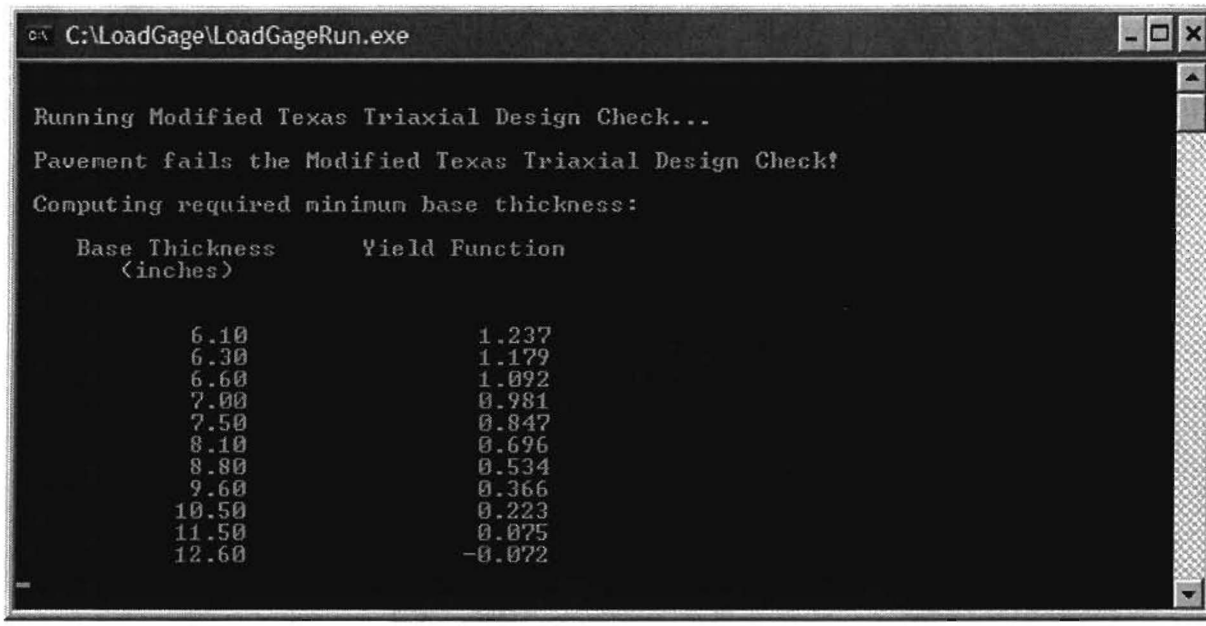


Figure 10. Run Time Screen during Search for Minimum Required Base Thickness.

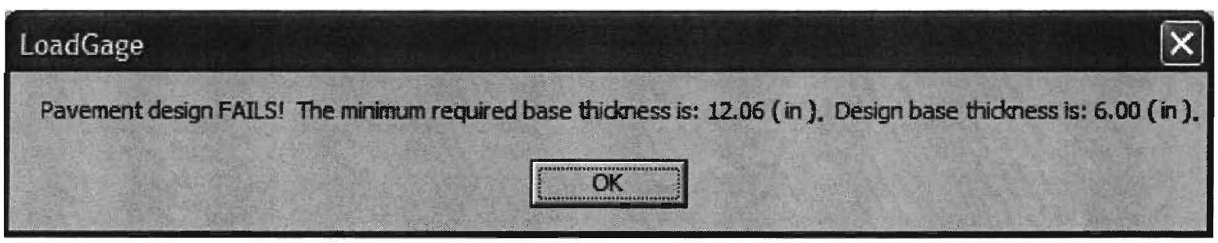


Figure 11. Message Displayed when Pavement Design Fails Triaxial Design Check.

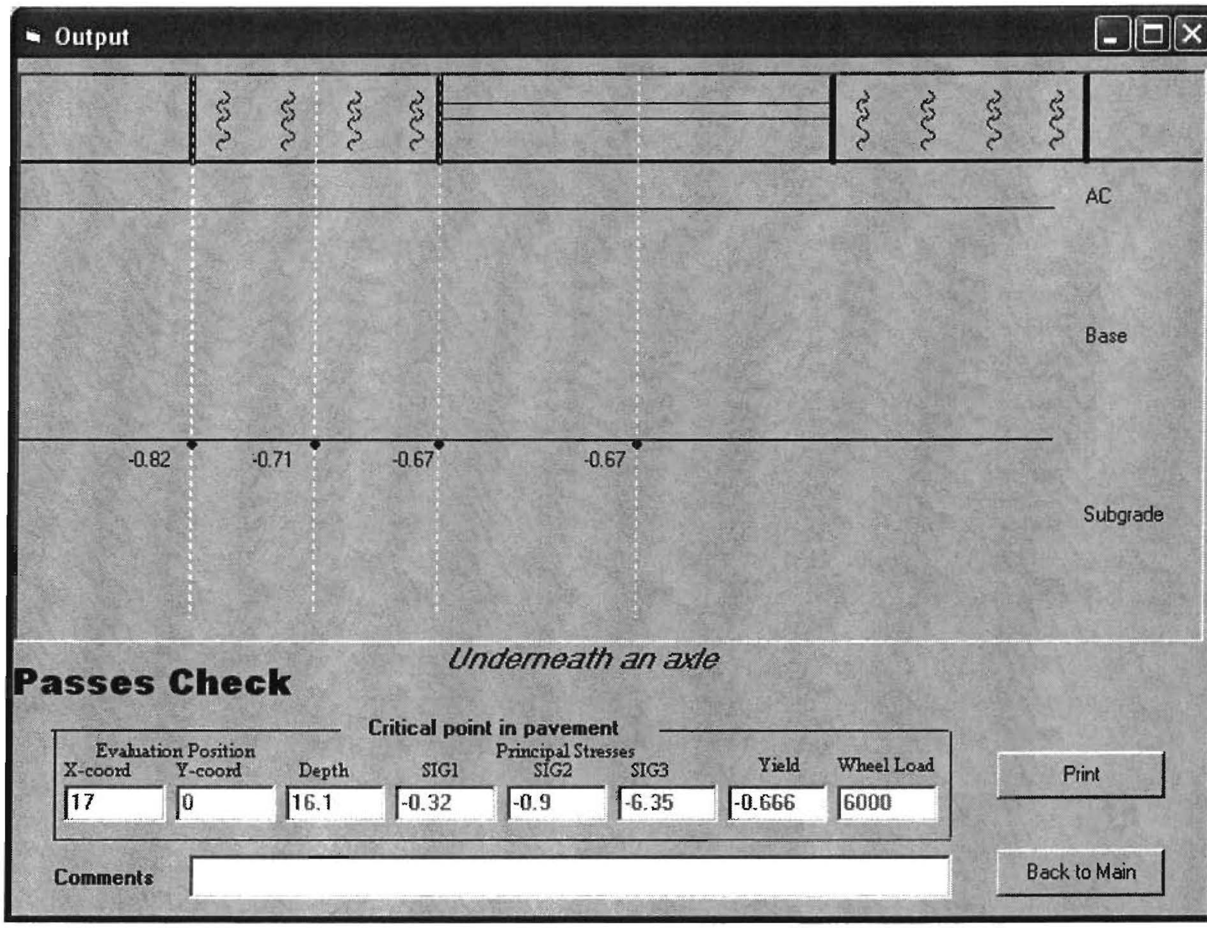


Figure 12. Output Screen of Computed Mohr-Coulomb Yield Function Values.

shown, the Mohr-Coulomb yield criterion is checked at a number of positions along the top of the subgrade corresponding to locations below the outside tire edge, middle of the tire, inside tire edge, and midway between tires. For tandem axle assemblies, the stresses at the same positions are evaluated midway between the axles, and the corresponding values of the Mohr-Coulomb yield function are displayed in another screen similar to Figure 12. The interested reader is referred to the Appendix for an explanation of the method used to calculate the Mohr-Coulomb yield function values. These values are used in *LoadGage* to determine whether the given pavement passes the triaxial design check or not. In the example given in Figure 12, the computed yield function values are −0.82, −0.71, −0.67, and −0.67. When the computed yield function values are all negative, such as illustrated in this figure, pavement damage from one application of the ATHWLD is deemed unlikely. However, when one or more points are predicted to be at yield, pavement damage may occur, so a thicker base is indicated.

The location of the critical point with the greatest value of the yield function is shown at the bottom of the output screen along with the principal stresses and yield function value computed at that point. Users may print the chart illustrated in Figure 12 by clicking on ***Print*** in the output screen. There is a field available to type in comments related to the analysis. Users, for example, may enter identifiers for the project just analyzed. Comments are also printed with the output.

Figure 13 shows an example printout of the results from an analysis. The printout shows the information displayed in the output screen (Figure 12), gives the date and time of the analysis, and specifies whether the pavement passes the modified triaxial design check. If the pavement fails the design check, the printout will also show the minimum required base thickness to prevent overstressing the subgrade for the given ATHWLD. After viewing the results, click on ***Back to Main*** in the output screen to return to the main menu.

DEFINING THE SUBGRADE FAILURE ENVELOPE

If the cohesion and friction angle for the subgrade are known, the user simply enters these parameters into the corresponding cells of the main menu shown in Figure 4 to specify the subgrade failure envelope. However, there may be instances when the failure envelope parameters and the Texas triaxial class of the subgrade are not readily available. For these instances, the engineer can use the soils database built into *LoadGage* to estimate failure envelope parameters for the given design problem. Included in the database are default triaxial class values for the different Texas counties, which researchers compiled from Texas triaxial data provided by TxDOT. Also included in the database are soil properties used in the program to adjust failure envelope parameters for moisture effects. To access the database, click on ***Retrieve Soils Data*** of the *LoadGage* main menu (Figure 4). The program displays the screen shown in Figure 14.

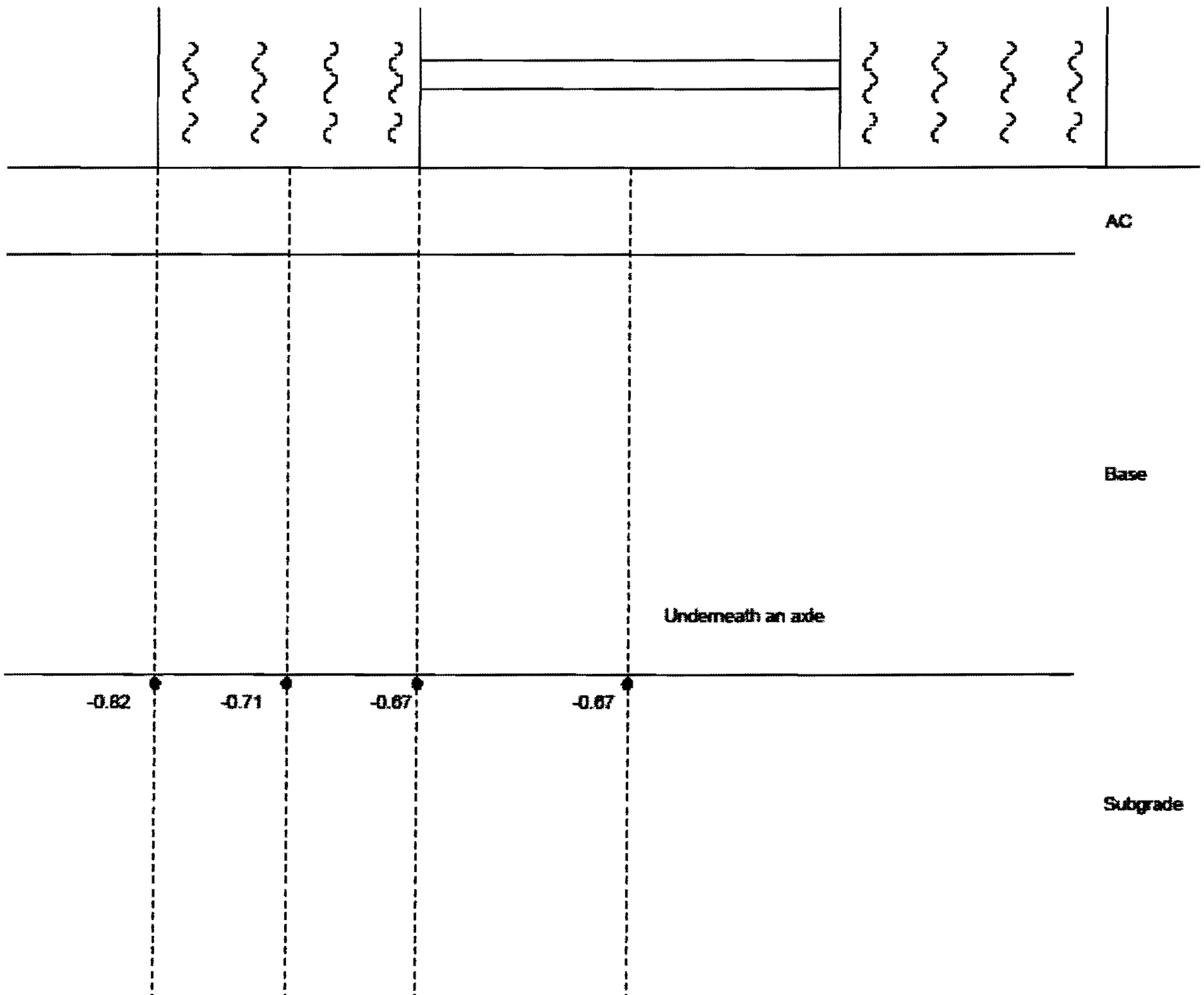
Soils data are organized by county. By clicking on the down arrow to the right of the county field shown in Figure 14, the user can view an alphabetical list of Texas counties, as illustrated in Figure 15. Scroll down this list to select the county for the given design problem, and click on the county name to view the available soils data for that county. For example, if the pavement design under consideration is in Anderson County (located in the Tyler District), click on Anderson in the list of counties shown in Figure 15.

Structural Adequacy Analysis Results

Comment : Output from LoadGage Analysis for Design Problem 1

Date : 10/25/2006 Time : 9:31:41 PM

Pavement design passes Modified Texas Triaxial design check.



Critical point in pavement

X coordinate	Y coordinate	Z coordinate	Sig1	Sig2	Sig3	Yield	Wheel load
17	0	16.1	-0.32	-0.9	-6.35	-0.666	6000

Figure 13. Example Printout of Analysis Results from *LoadGage*.

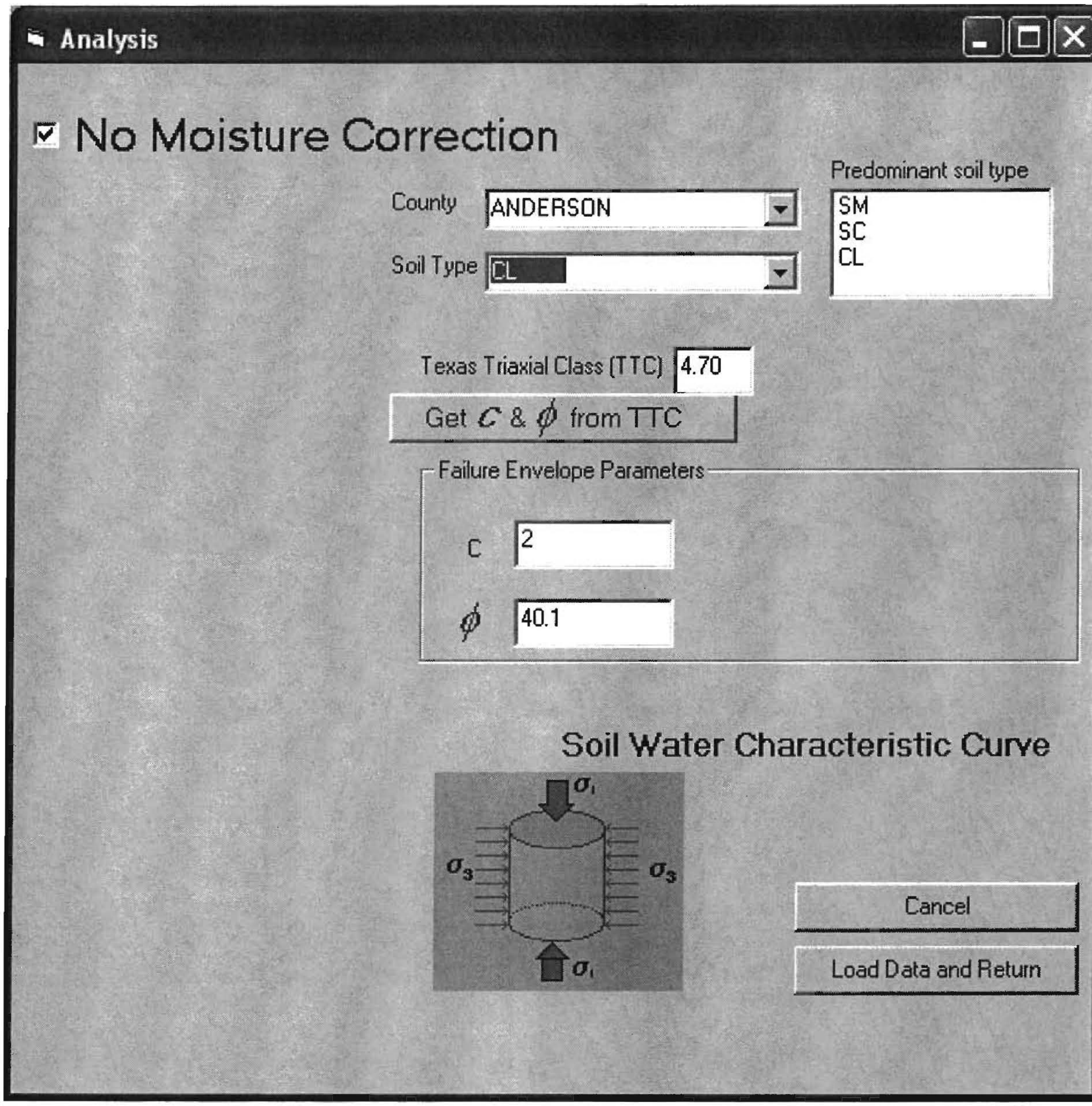


Figure 14. Screen for Viewing *LoadGage* Soils Database.

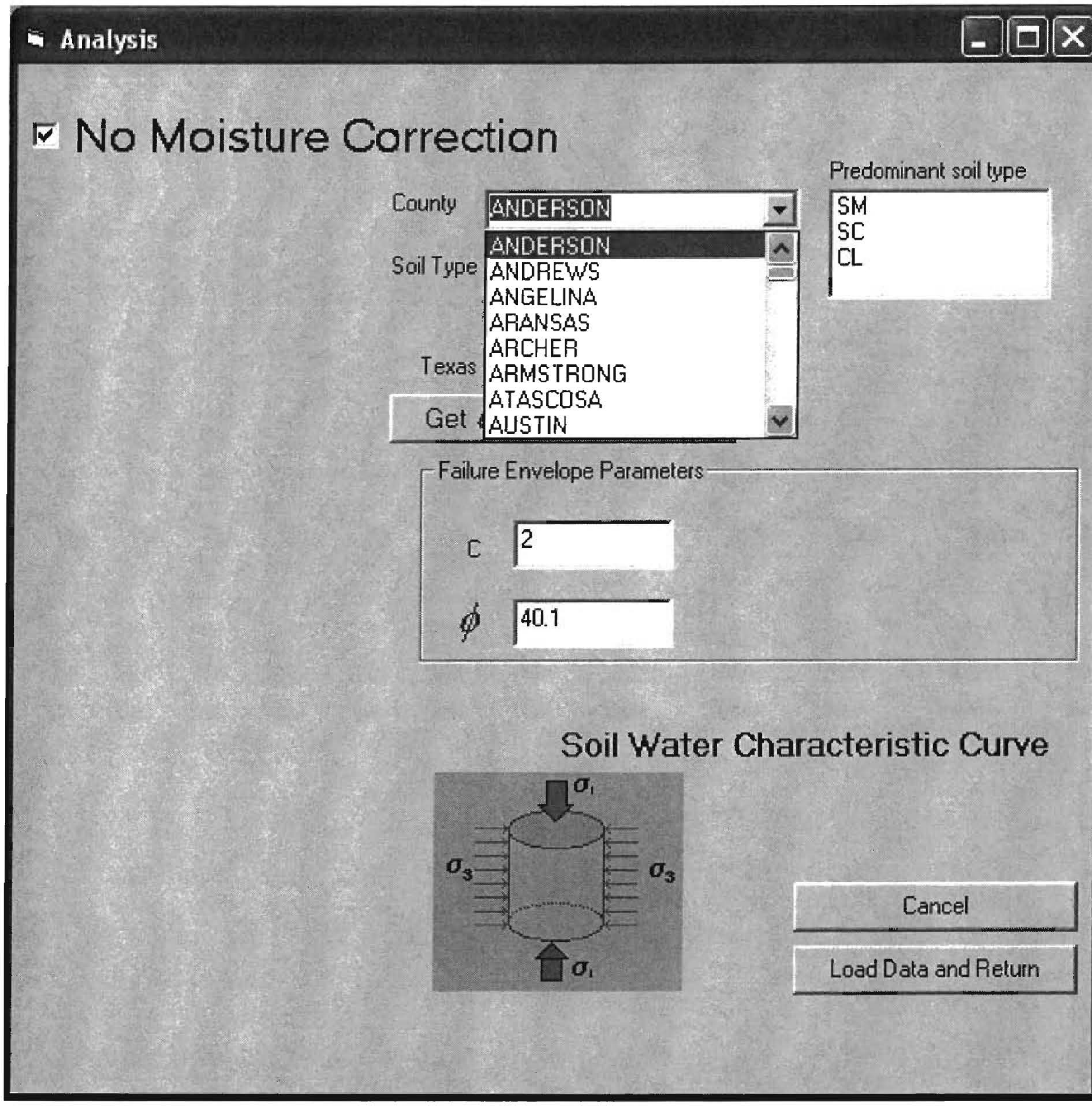


Figure 15. Viewing the County List in the Soils Database.

Given the selected county, *LoadGage* displays a list of the predominant soils found in that county. Figure 14, for example, identifies the predominant soils in Anderson County as comprising silty sands (SM), clayey sands (SC), and lean clays (CL), where the abbreviations follow the soil designations used in the Unified Soil Classification System. By clicking on the down arrow to the right of the soil type field of the menu shown in Figure 14, the user can view a list of the soils found for the given county (Figure 16). To specify the soil type for a particular analysis, click on its label. *LoadGage* then displays the default properties for the selected soil that are stored in its database (Figure 17). For the case where no moisture

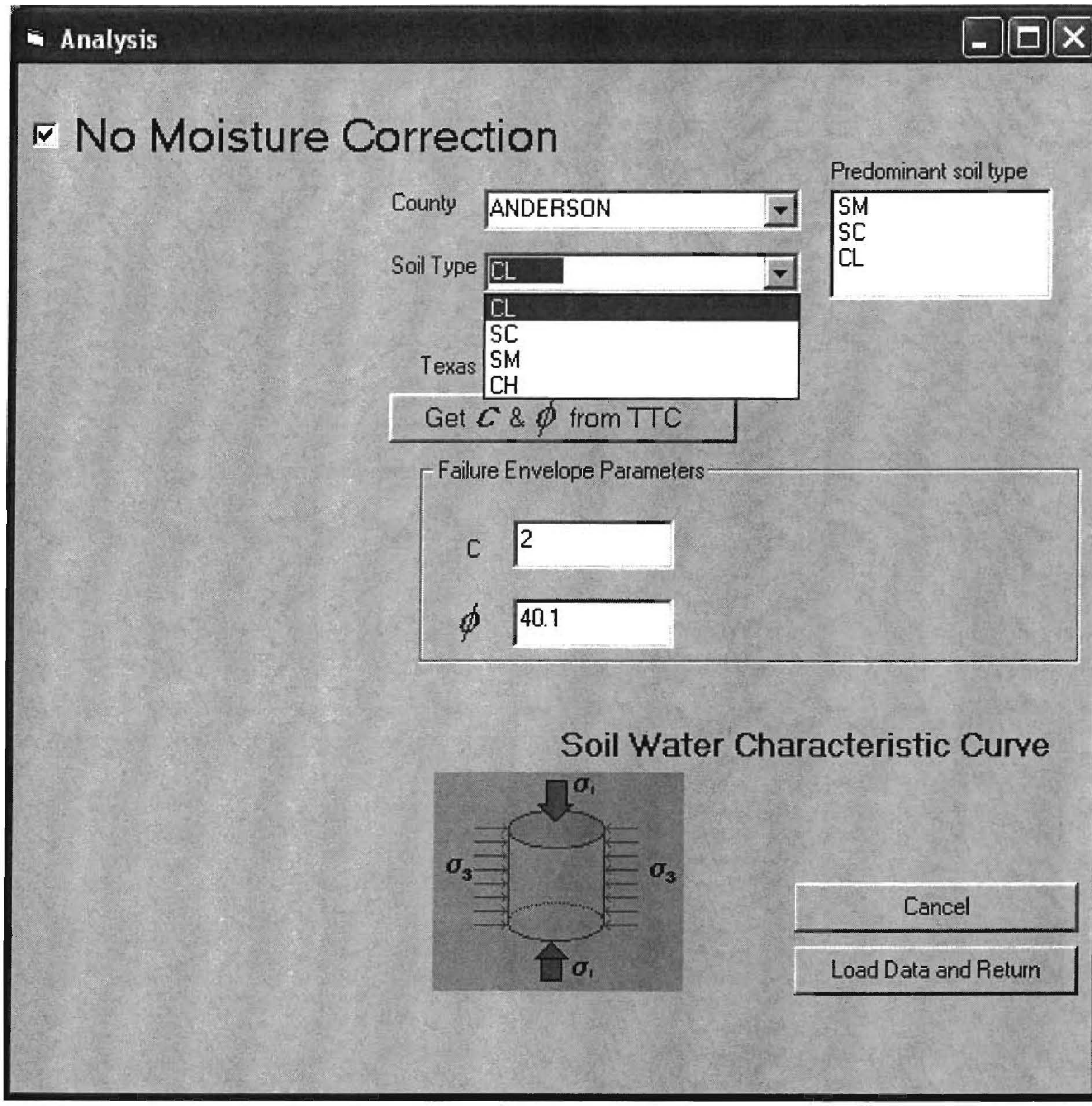


Figure 16. Viewing the List of Soil Types for a Given County.

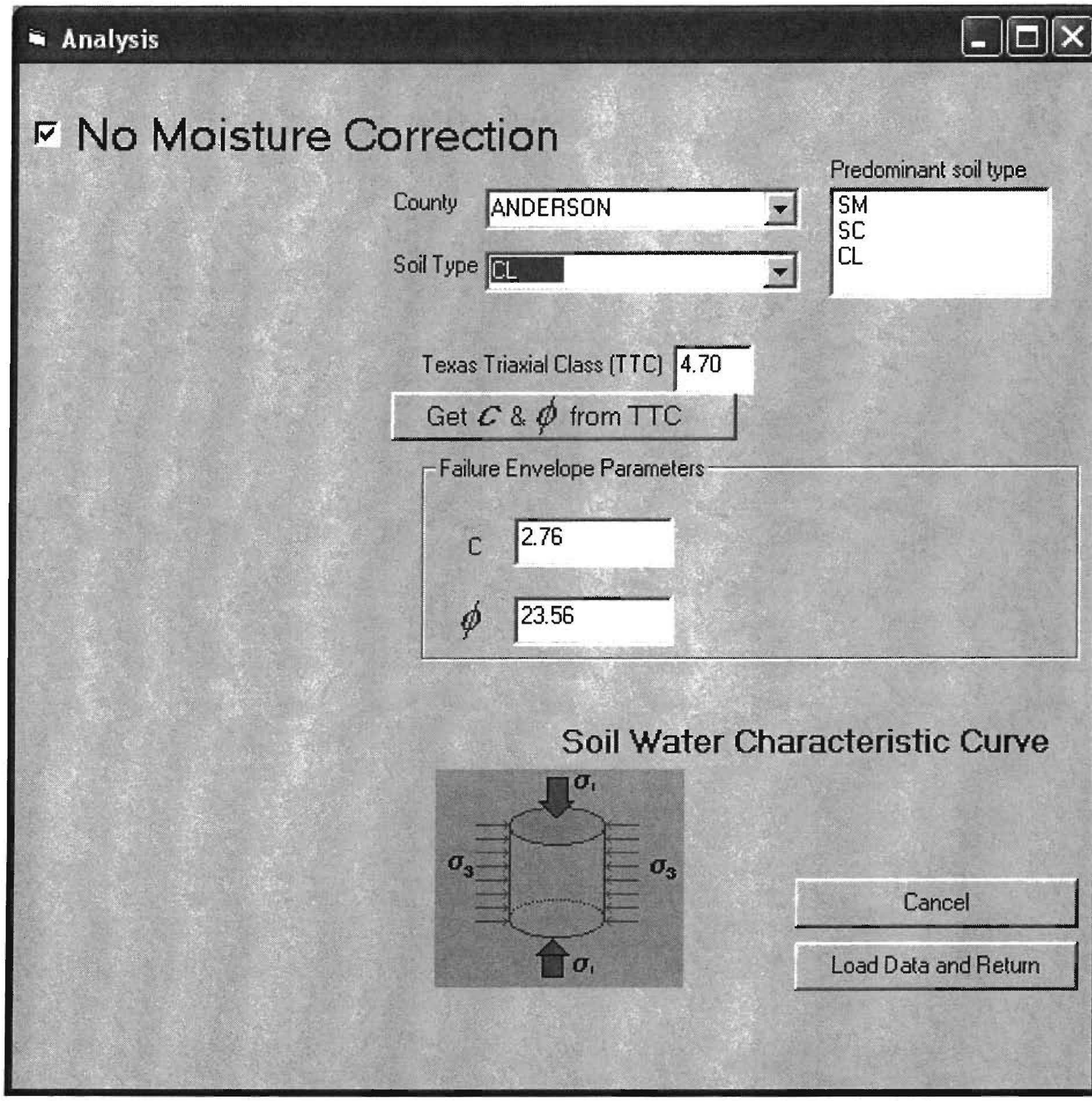


Figure 17. Default Material Properties Displayed for Selected Soil.

correction is specified (the default analysis option in *LoadGage*), the program displays the parameters defining the failure envelope for the selected soil and the corresponding Texas triaxial class. For example, Figure 17 shows 4.70 as the default Texas triaxial class for the lean clay in Anderson County. Likewise, the corresponding failure envelope parameters are displayed, specifically, the cohesion c (2.76 psi) and the friction angle ϕ (23.56 degrees). As appropriate, the user can override the default values that define the failure envelope by entering another TTC, or another set of c and ϕ values. If the user enters another TTC, the corresponding failure envelope parameters should be recalculated by clicking on ***Get c & ϕ***

from TTC in the screen shown in Figure 17. Failure envelope parameters are estimated from the specified TTC based on the linearized forms of the Texas triaxial class failure envelopes given in Figure 18. Linearized boundaries between soil classes were determined by fitting a line to each of the class boundaries in the standard Test Method Tex-117E classification chart.

LoadGage also has an option to adjust the given failure envelope parameters for moisture effects. Current TxDOT practice for characterizing the soil failure envelope is based on triaxial testing of capillary moisture conditioned specimens following Test Method Tex-117E. While the properties determined from this test might be applicable in wet areas of the state (such as east Texas), the test conditions are not necessarily representative of soil moisture contents in the drier areas of Texas, or in areas where the soils are not as moisture susceptible. For these cases, *LoadGage* provides the option to adjust soil strength properties determined from Test Method Tex-117E to values considered to be more representative of the in-service moisture conditions.

Note that by default, *LoadGage* does not apply moisture correction in the analysis. To use this option, uncheck the box for ***No Moisture Correction*** in the analysis screen illustrated in Figure 17. The program then displays additional parameters that are used to adjust the subgrade failure envelope for moisture effects. As illustrated in Figure 19, these parameters are the expected field moisture content and the corresponding parameters of the suction curve for the specified soil. In the example given in Figure 19, the expected field moisture content, ω (expected), for the specified soil (CL) is 15.20 percent. By default, the field moisture content, ω (field), for the given design problem is set equal to the expected field moisture content found in the database. The user may type in a different value, as appropriate. The initial moisture content, ω (initial), is the moisture content that corresponds to the specified soil failure envelope parameters. This variable may be the moisture content of capillary moisture conditioned specimens tested using Test Method Tex-117E, the optimum moisture content for soil specimens tested using other triaxial test methods, or the moisture content immediately after construction. In the example illustrated in Figure 19, the initial moisture content is 17 percent. The moisture contents specified in *LoadGage* are gravimetric moisture contents, which are the values typically reported from laboratory triaxial tests. To convert these values to the corresponding volumetric quantities used for

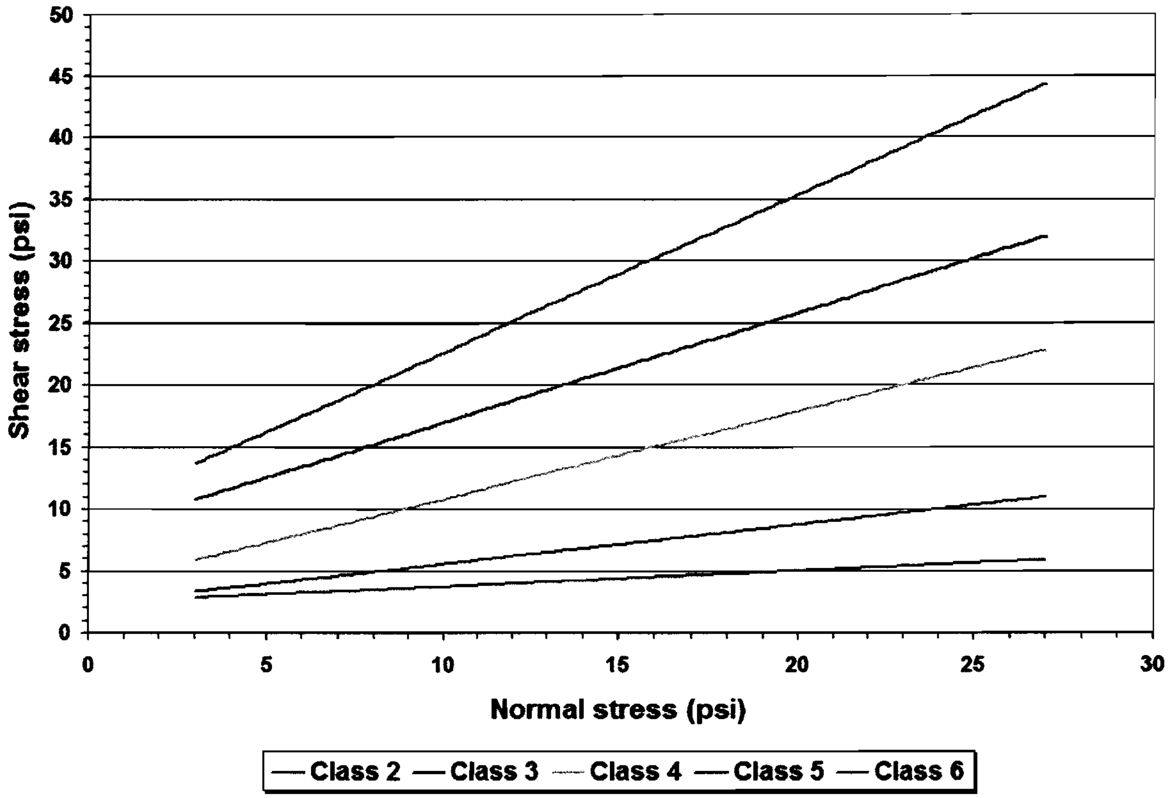


Figure 18. Linearized Texas Triaxial Class Failure Envelopes.

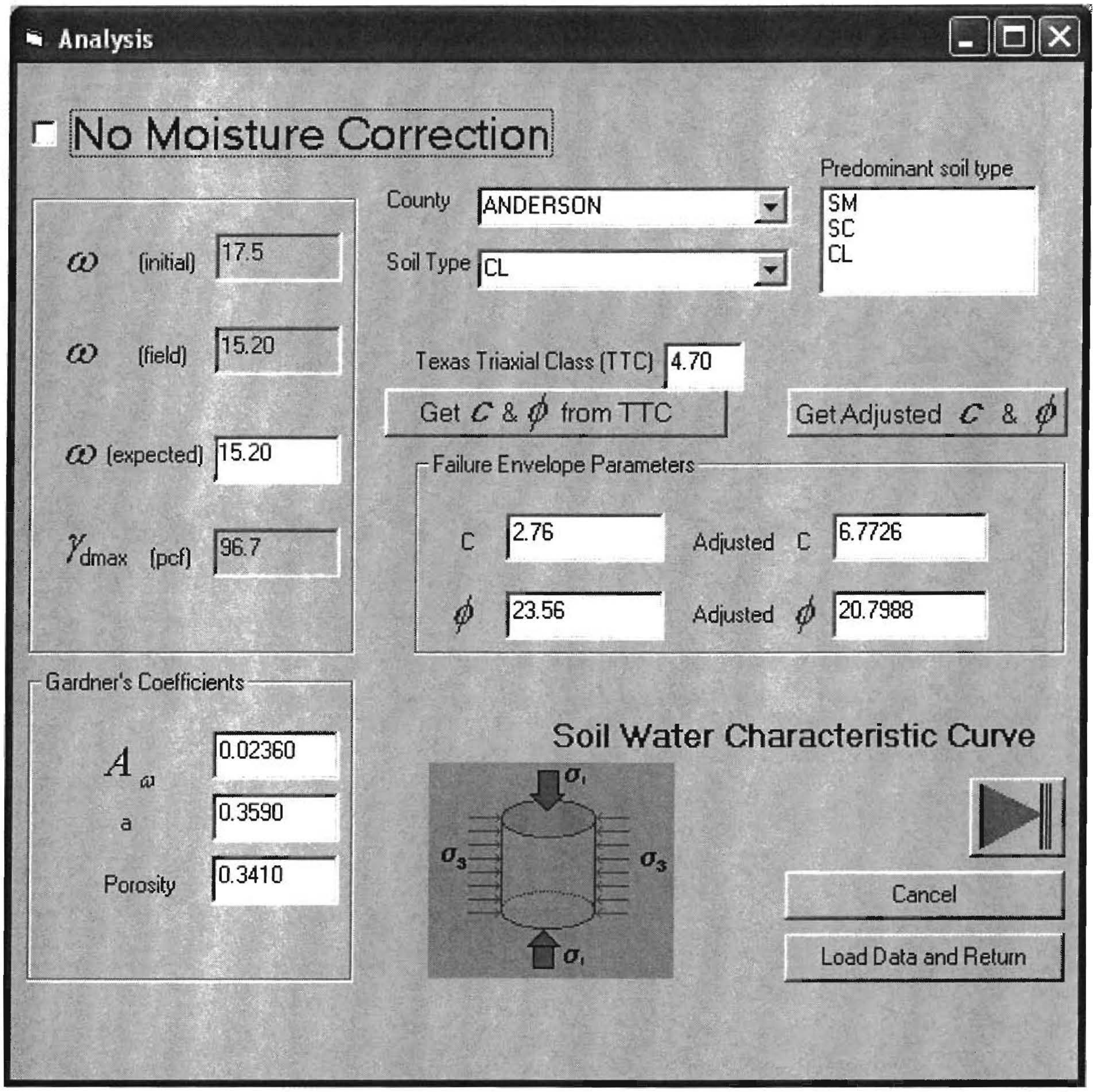


Figure 19. Example Illustration of Input Data with Moisture Correction Applied.

moisture correction, the user needs to specify the maximum dry density, γ_{dmax}, in lb per ft^3 (pcf) for the given soil.

As indicated previously, the moisture correction is based on the difference in soil suction values between the initial and field moisture contents specified by the user. In *LoadGage*, the soil suction at a given moisture content is determined from the soil water characteristic curve of the material. This curve is characterized by Gardner's equation, given by the model (Gardner, 1958):

$$\theta_u = \frac{n}{A_w \, |h|^a + 1} \tag{1}$$

where,

θ_u = unsaturated volumetric moisture content,

n = porosity,

A_w, a = model coefficients, and

h = soil suction in cm of water head.

The user needs to specify the parameters of Gardner's equation in the corresponding input fields of the screen illustrated in Figure 19. For each soil in the database, the program provides representative values of these coefficients. The user may accept the default coefficients that are displayed for the specified soil, or enter other values, as appropriate.

The soil water characteristic curve for the prescribed Gardner's coefficients may be viewed by clicking on the green right arrow of the menu shown in Figure 19. This action brings up the soil suction curve illustrated in Figure 20. Plotted on the chart are the soil suction values (in pF) corresponding to the specified initial and field moisture contents (after converting from gravimetric to volumetric units). Note that pF is equivalent to $\log_{10}|h|$. To close the chart window, click on the left green arrow of the menu illustrated in Figure 20.

For the prescribed inputs, click on ***Get Adjusted c & ϕ*** to perform the moisture correction. The program then corrects the soil failure envelope based on the change in soil suction from the initial to the field moisture content. From the soil suction curve illustrated in Figure 20, it is observed that the soil suction increases as the moisture content decreases. This positive change in soil suction generally results in a larger area under the failure envelope, and consequently higher allowable wheel load estimates. To do an analysis with no moisture correction, check the box with this label in the screen shown in Figure 19. For this case, *LoadGage* assumes that the field moisture content is the same as the moisture content at which the specified failure envelope parameters for the soil were determined. Thus, the failure envelope is not adjusted.

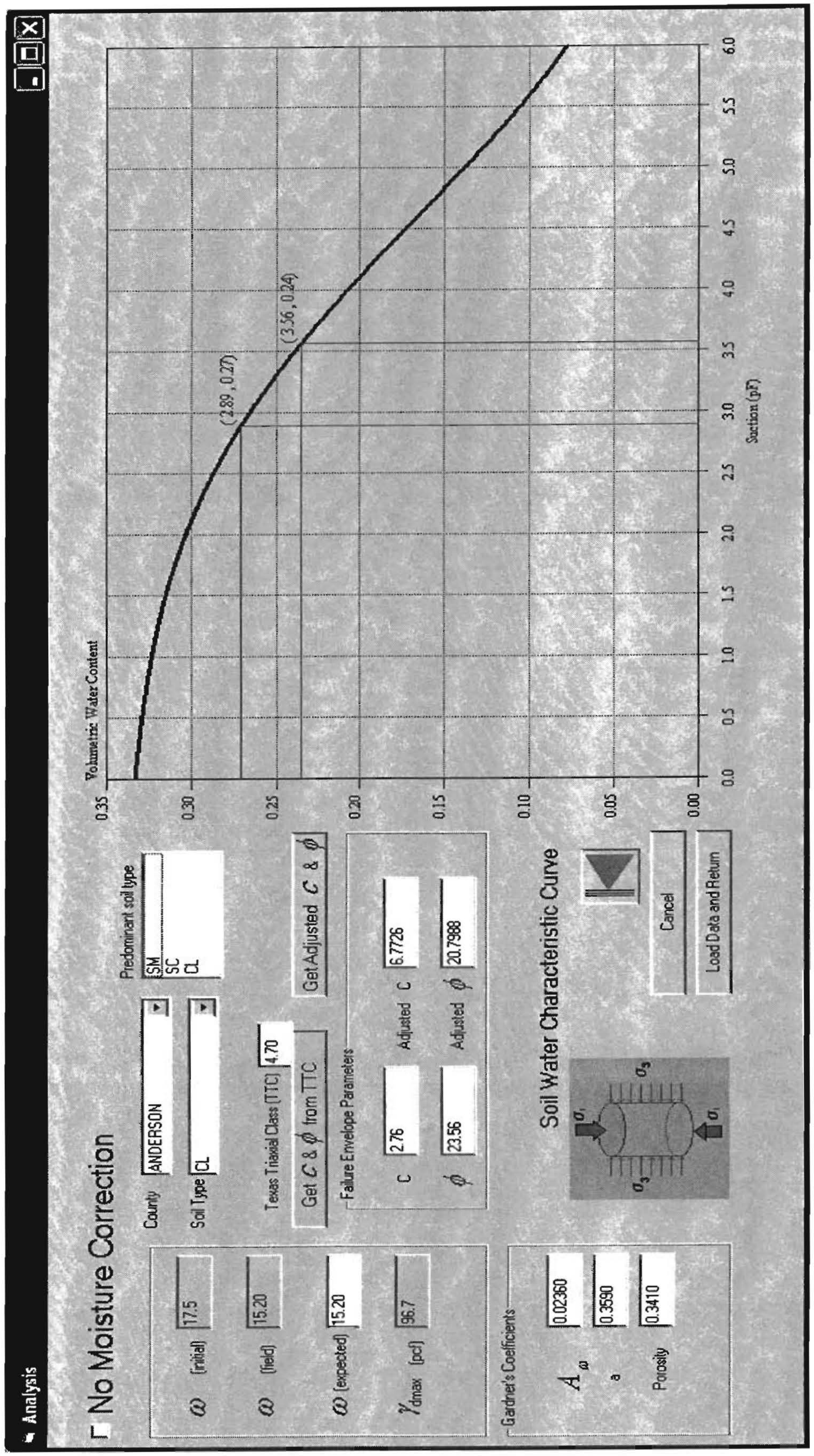


Figure 20. Viewing the Soil Suction Curve in *LoadGage*.

Once the subgrade failure envelope is defined, click on ***Load Data and Return*** to accept the current parameter values and return to the main menu illustrated in Figure 4. Alternatively, click on ***Cancel*** to return to the main menu without changing the failure envelope parameters previously entered into the program.

NONLINEAR ANALYSIS OPTION

As mentioned earlier, *LoadGage* provides the option of modeling the nonlinear behavior observed in most pavement materials. This capability becomes particularly important for thin pavements, which comprise a big portion of the highway network in Texas. For these pavements, a nonlinear analysis is expected to provide a more realistic prediction of the stresses induced under loading (Jooste and Fernando, 1995). *LoadGage* uses the following equation by Uzan (1985) to model the stress-dependency:

$$E = K_1\, pa \left(\frac{I_1}{pa}\right)^{K_2} \left(\frac{\tau_{oct}}{pa}\right)^{K_3} \qquad (2)$$

where,

E	=	layer modulus,
I_1	=	first stress invariant determined,
τ_{oct}	=	octahedral shear stress,
pa	=	atmospheric pressure (14.5 psi), and
K_1, K_2, K_3	=	material constants determined from resilient modulus testing.

The material constants of Eq. (2) may be characterized following AASHTO T-307 for untreated base, subbase, and subgrade materials, and ASTM D 3497 for asphalt-stabilized materials. K_2 is typically positive, indicating increased stiffness at higher confinement, while K_3 is typically negative, indicating a stiffness reduction with increased deviatoric stress. To use the nonlinear analysis option in *LoadGage*, these constants must be characterized. No approximate methods have been incorporated in this version of the analysis program, although Glover and Fernando (1995) present relationships for estimating these resilient properties based on Atterberg limits, gradation, and soil suction measurements made on unstabilized materials.

To use the nonlinear option for a particular design, click on ***Nonlinear*** in the main menu given in Figure 4. Cells for entering the K_1, K_2, and K_3 coefficients are then displayed in the menu as illustrated in Figure 21. By default, the K_2 and K_3 values are initially set to zero corresponding to linear behavior, i.e., the modulus is independent of stress as inferred from Eq. (2). In this case, K_1 is simply calculated by dividing the specified modulus of the material by the atmospheric pressure of 14.5 psi. The resulting value is displayed in the main menu as shown in Figure 21.

Enter the coefficients for the nonlinear pavement layer(s) in the main menu. To model a layer as linear, simply leave the initial values as they are, i.e., $K_2 = K_3 = 0$, and K_1 equal to the layer modulus divided by 14.5 psi. Continue entering other input data as described in this user's guide or run an analysis as appropriate.

EXAMPLE PROGRAM APPLICATION

To illustrate the application of *LoadGage*, assume that the pavement design given in Table 2 was determined using TxDOT's FPS-19 design program. Further, suppose that the ATHWLD and TTC are 12,000 lb and 4.7, respectively, for this problem. To perform a modified triaxial design check using *LoadGage*, input the pavement design parameters into the program as illustrated in Figure 22. For this problem, a three-layer system is specified. The steps to specify input data for this pavement design check are summarized as follows:

- Enter the modulus, Poisson's ratio, and thickness of each layer into the appropriate fields of the main menu as shown in Figure 22, and select the default ***Linear*** analysis option.
- Specify 12,000 for the ATHWLD and ***Single*** for the axle configuration.
- Check the option box for input of the Texas triaxial class and type in the design value of 4.7 for the subgrade material. Note that *LoadGage* automatically estimates the cohesion and friction angle corresponding to this TTC.

To perform the analysis with the specified input data, click on ***Run LoadGage*** of the main menu illustrated in Figure 22. When the analysis is done, *LoadGage* displays the result as shown in Figure 23. For this particular example, the analysis indicates that the pavement design given in Table 2 is inadequate, and that a thicker base of 13.5 inches is needed to protect the subgrade. The engineer may then decide to specify this base thickness in the design plans or to explore other alternatives of keeping the stress level in the subgrade to

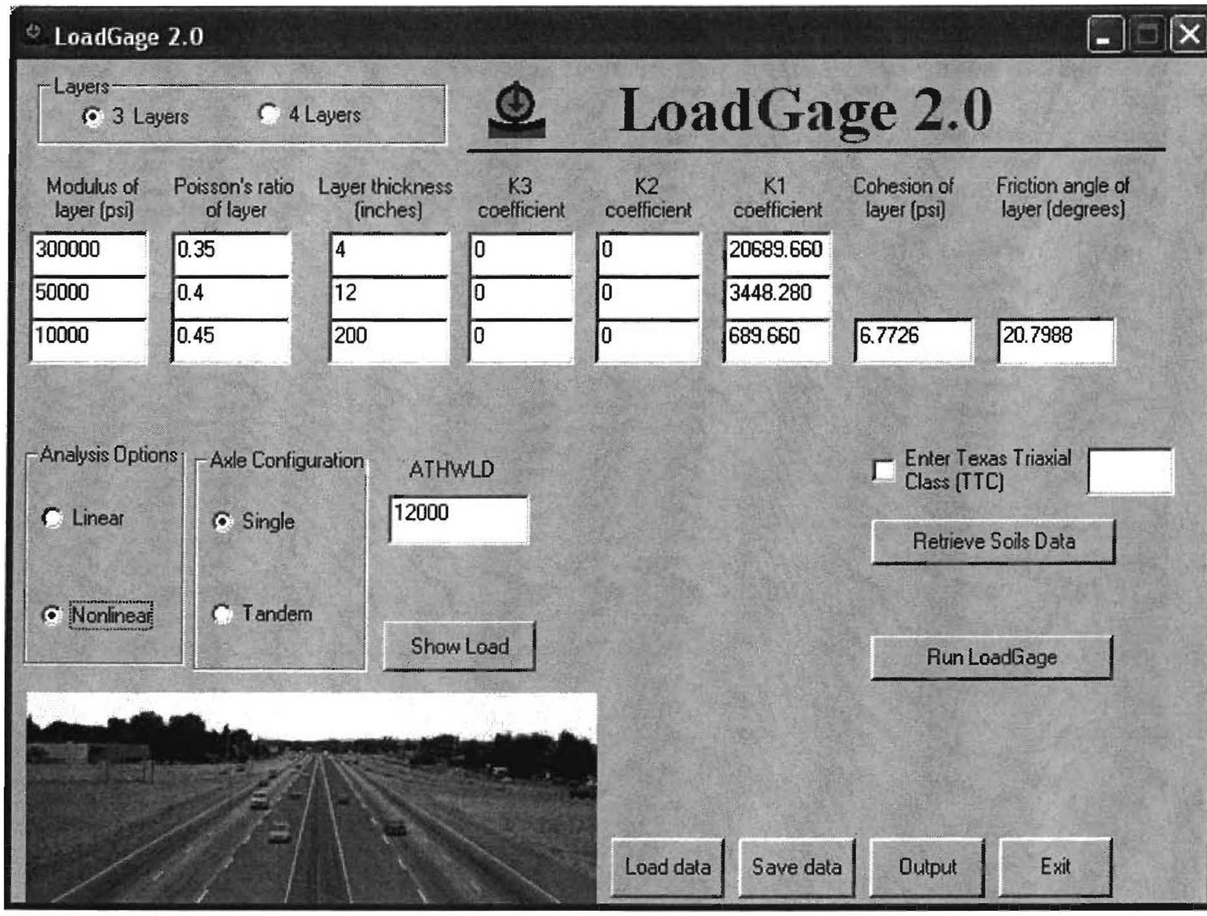


Figure 21. Specifying K_1, K_2, and K_3 Coefficients for Nonlinear Analysis in *LoadGage*.

Table 2. Pavement Structure for *LoadGage* Design Check Example.

Layer	Modulus (psi)	Poisson's ratio	Thickness (in)
Asphalt surface	350,000	0.35	2
Flexible base	40,000	0.35	12
Subgrade	10,000	0.40	200

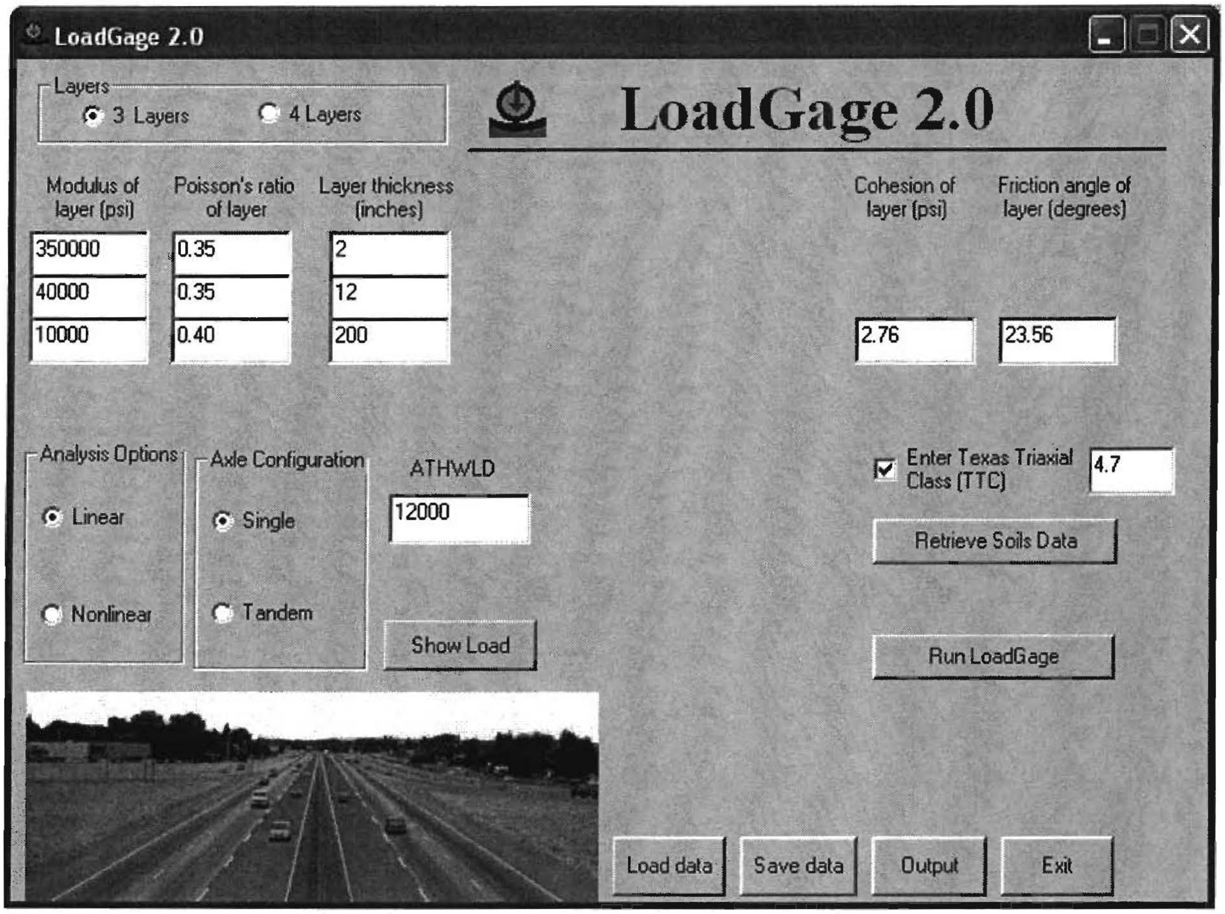


Figure 22. Input Data for Example Design Problem.

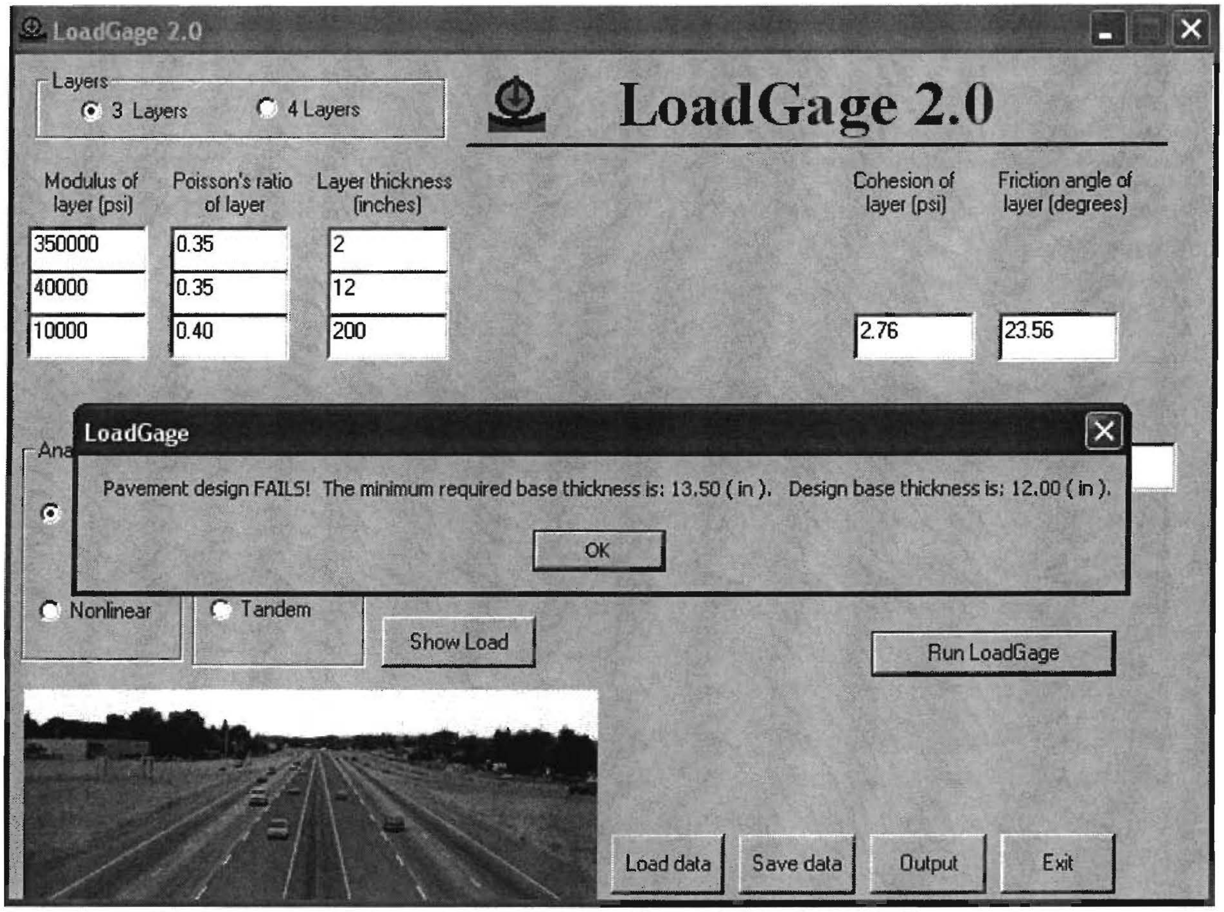


Figure 23. Analysis Result for Example Design Problem.

within its failure envelope. For this purpose, the engineer may use *LoadGage* to investigate other design alternatives, such as specifying a thicker hot-mix asphalt concrete layer, using a different base material with a higher modulus, or adding a subbase layer to reduce the stresses in the subgrade. For example, if the engineer runs the program with a 3-inch asphalt concrete layer instead of the 2-inch thickness specified previously, he/she would find that this change provides an acceptable pavement design (see Figure 24) where the subgrade stresses are predicted to be within the material's failure envelope. Alternatively, a pavement design with a stiffer base material may be analyzed. For example, if a different base material with a modulus of 55,000 psi is considered, an acceptable pavement design is also obtained (see Figure 25).

Table 3 summarizes the pavement design alternatives that are acceptable in terms of triaxial design criteria for this previous example. The important point to remember is that the program can assist the engineer in evaluating alternatives in case the original design from the

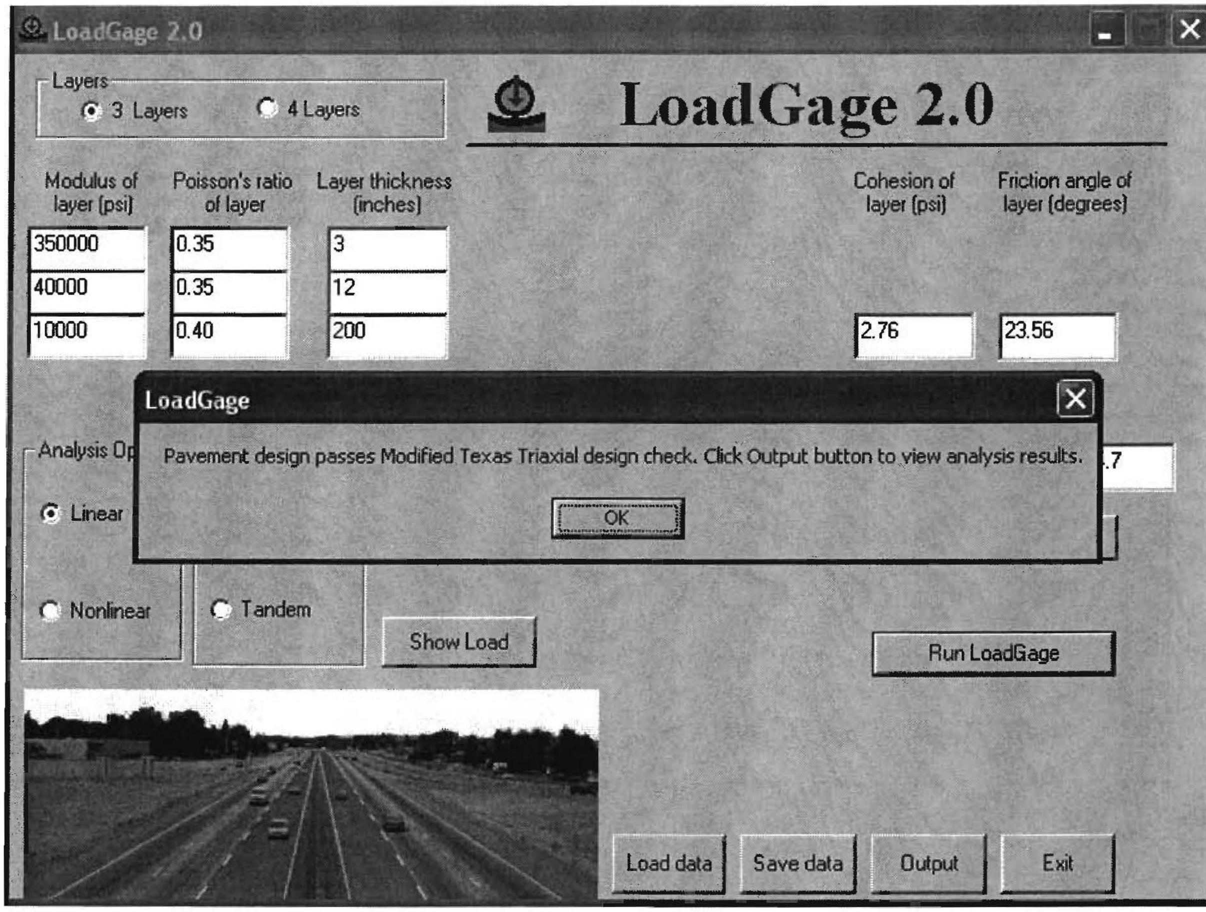


Figure 24. ***LoadGage*** **Result for Pavement Design with 3-inch Asphalt Surface Layer.**

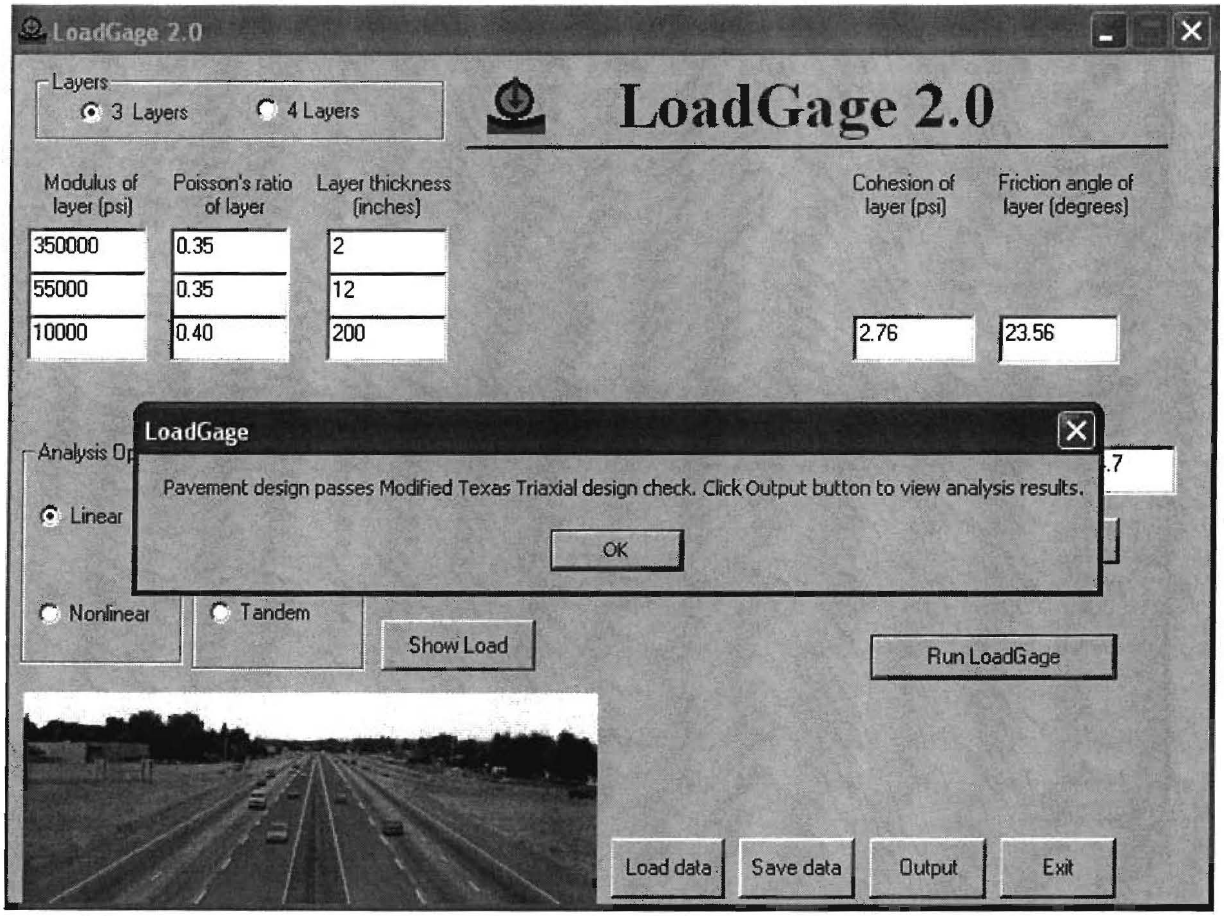


Figure 25. *LoadGage* Result for Pavement Design with Stiffer Base Material.

Table 3. Summary of Pavement Design Alternatives Evaluated in *LoadGage* Example.

Pavement Design	Layer	Modulus (psi)	Poisson's ratio	Thickness (in)	Result from Triaxial Design Check
Original	Asphalt surface	350,000	0.35	2	Fails
	Flexible base	40,000	0.35	12	
	Subgrade	10,000	0.40	200	
Alternative 1: thicker base layer	Asphalt surface	350,000	0.35	2	Passes
	Flexible base	40,000	0.35	**13.5***	
	Subgrade	10,000	0.40	200	
Alternative 2: thicker asphalt layer	Asphalt surface	350,000	0.35	**3***	Passes
	Flexible base	40,000	0.35	12	
	Subgrade	10,000	0.40	200	
Alternative 3: stiffer base material	Asphalt surface	350,000	0.35	2	Passes
	Flexible base	**55,000***	0.35	12	
	Subgrade	10,000	0.40	200	

* Numbers in bold and underlined show change between the original and alternative designs

FPS program fails the triaxial design check. The engineer would then have to decide which alternative is best for the particular problem considering cost, availability of materials, existing highway geometry, material specifications, and other factors.

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APPENDIX

CALCULATION OF MOHR-COULOMB YIELD FUNCTION

The *LoadGage* program calculates the Mohr-Coulomb yield function value at a number of positions along the top of the subgrade corresponding to locations below the outside tire edge, middle of the tire, inside tire edge, and midway between tires. For tandem axle assemblies, the stresses at the same positions are evaluated midway between the axles where the corresponding values of the Mohr-Coulomb yield function are also determined. At the evaluation positions, the stresses under load are predicted and used with the following equation from Chen and Baladi (1985) to calculate the values of the yield function:

$$f = \frac{I_1}{3}\sin(\phi) + \sqrt{J_2}\sin\left(\theta + \frac{\pi}{3}\right) + \frac{\sqrt{J_2}}{\sqrt{3}}\cos\left(\theta + \frac{\pi}{3}\right)\sin(\phi) - c\cos(\phi) \qquad \text{(A1)}$$

where,

I_1	=	first stress invariant,
J_2	=	second deviatoric stress invariant,
c	=	cohesion,
φ	=	friction angle, and
θ	=	Lode angle.

Physically, the first stress invariant is associated with volume change in a material under loading, while the second deviatoric stress invariant is associated with distortion of the material. The Lode angle is calculated from the equation:

$$\theta = \frac{1}{3}\cos^{-1}\left(\frac{3\sqrt{3}}{2}\frac{J_3}{J_2^{3/2}}\right) \qquad \text{(A2)}$$

where J_3 is the third deviatoric stress invariant. From mechanics, I_1, J_2, and J_3 are computed from the principal stresses, σ_1, σ_2, and σ_3 from the following equations:

$$I_1 = \sigma_1 + \sigma_2 + \sigma_3 \tag{A3}$$

$$J_2 = \frac{1}{6}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right] \tag{A4}$$

$$J_3 = \left(\sigma_1 - \frac{I_1}{3}\right)\left(\sigma_2 - \frac{I_1}{3}\right)\left(\sigma_3 - \frac{I_1}{3}\right) \tag{A5}$$

The onset of yield or inelastic deformation is predicted when the value of the yield function is zero, i.e., $f = 0$ in Eq. (A1). When this condition is plotted for the Mohr-Coulomb yield function, the surface illustrated in Figure A1 is obtained. Stress states falling inside the yield surface correspond to elastic behavior, i.e., below yield. Mathematically, this is equivalent to a computed yield function value less than zero, i.e., $f < 0$, for the given pavement and load. It is observed from Figure A1 that the cross-sectional area of the Mohr-Coulomb yield surface increases as the hydrostatic stress component, represented by the mean stress, $I_1/3$, in Eq. (A1) increases. Physically, this means that a material subjected to higher confinement will sustain a higher level of stress before reaching the yield condition.

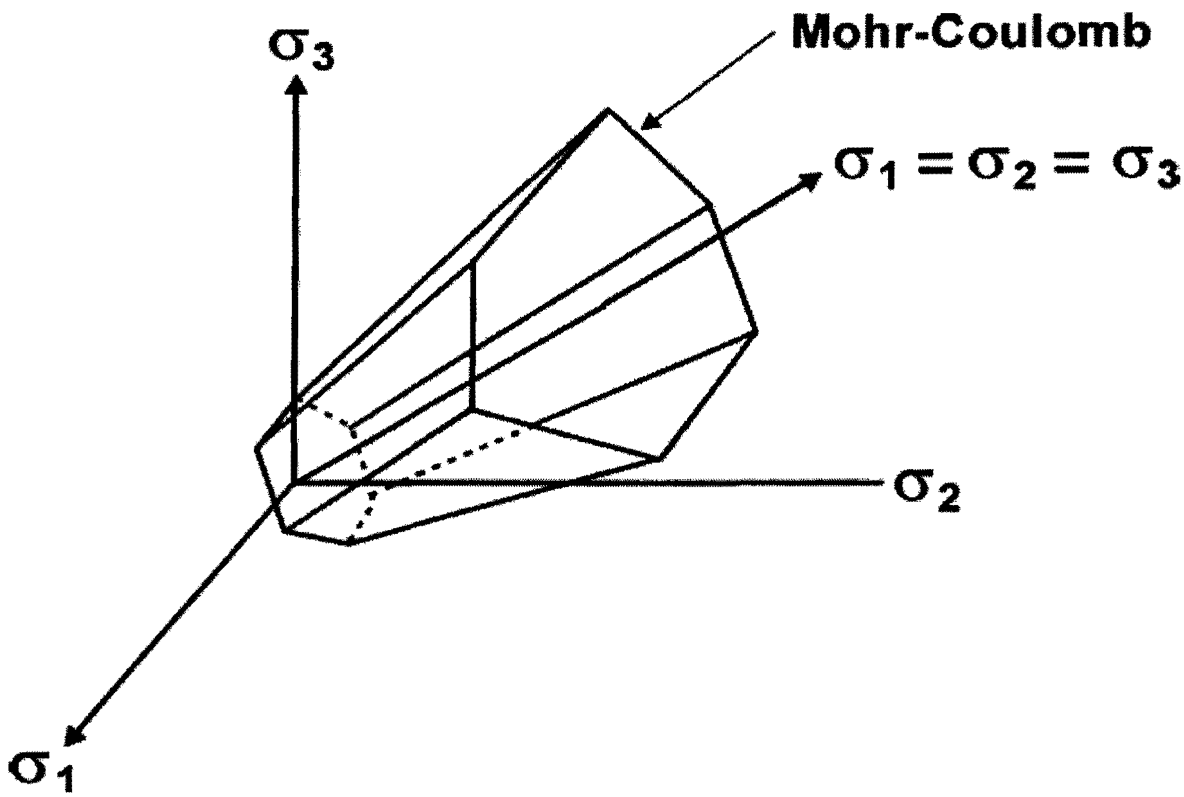

Figure A1. Graphical Illustration of Mohr-Coulomb Yield Criterion.

DESIGN DETAIL STANDARD SHEETS FOR CONCRETE PAVEMENT TRANSITION AREA

by

Youn su Jung
Graduate Assistant Research
Texas Transportation Institute

and

Dan G. Zollinger
Associate Research Engineer
Texas Transportation Institute

Product 0-5320-P2
Project 0-5320
Project Title: Best Design and Construction Practices for Concrete Pavement Transition Area

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

August 2006
Resubmitted: November 2006
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College Station, Texas 77843-3135

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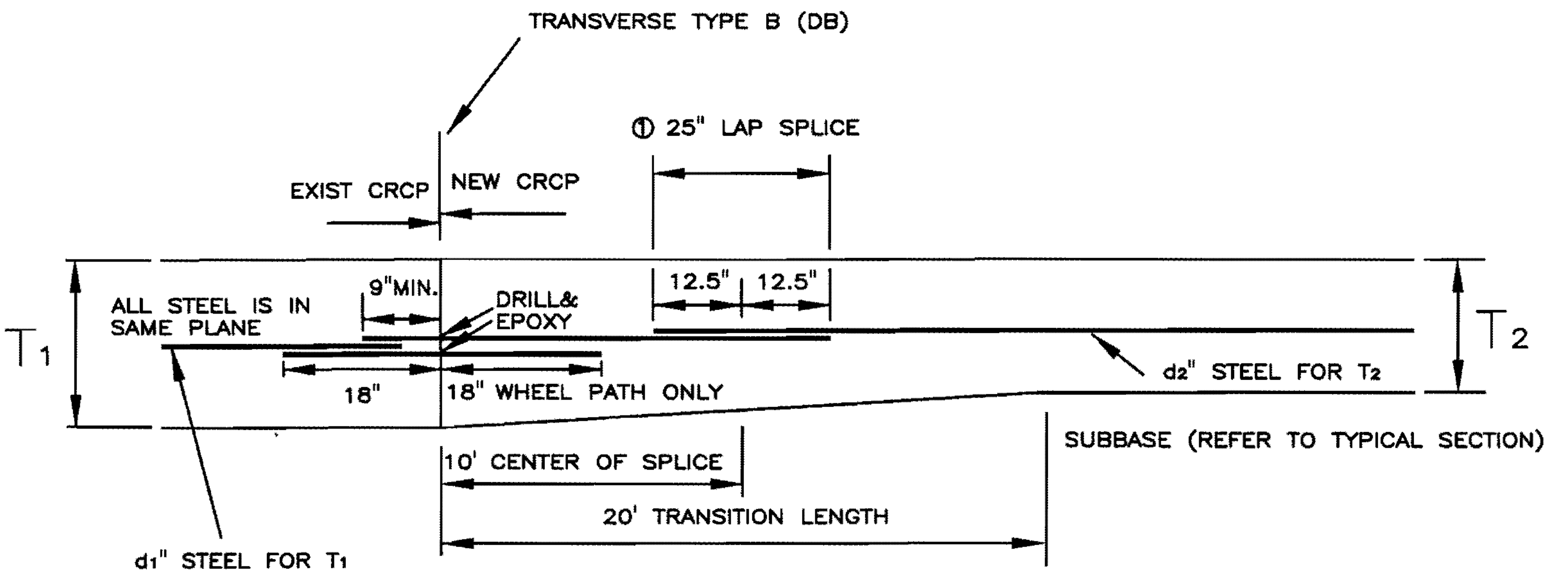


CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

THICKNESS T, IN.	BAR SIZE	SPACING
8	#6 (0.75")	9"
9	#6 (0.75")	8"
10	#6 (0.75")	7"
11	#6 (0.75")	6.5"
12	#6 (0.75")	6"
13	#6 (0.75")	5.5"
14	#6 (0.75")	9.5" DOUBLE
15	#6 (0.75")	8.5" DOUBLE

① BASED ON #6 BAR FOR OTHER BAR SIZES LAB SPLICE = 33d"

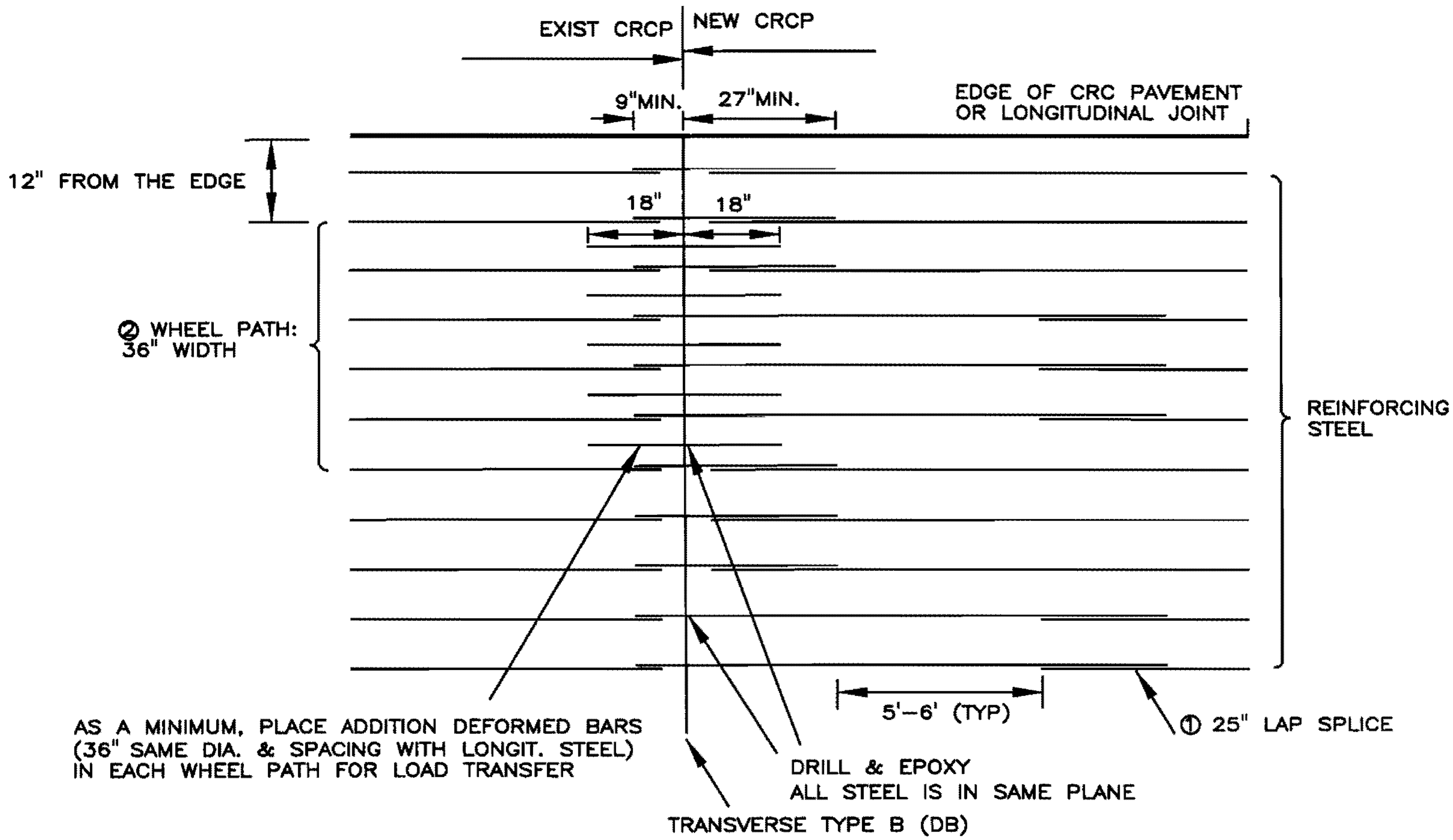
T_1 = THICKNESS OF EXISTING CRC PAVEMENT

T_2 = THICKNESS OF NEW CRC PAVEMENT

CRC PAVEMENT TO CRC PAVEMENT
(THICKNESS TRANSITION)

FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT / JOB	HIGHWAY

2



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THICKENED EDGE	TE
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SLEEPER SLAB	SS
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LONGITUDINAL STEEL SIZE AND SPACING

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12	#6 (0.75")	6"
13	#6 (0.75")	5.5"
14	#6 (0.75")	9.5" DOUBLE
15	#6 (0.75")	8.5" DOUBLE

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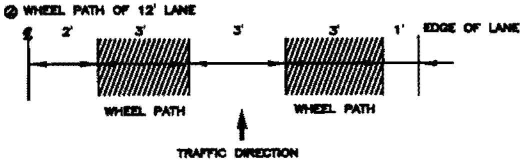
② WHEEL PATH OF 12' LANE



CRC PAVEMENT TO CRC PAVEMENT
(HEADER JOINT - OPTION 1)

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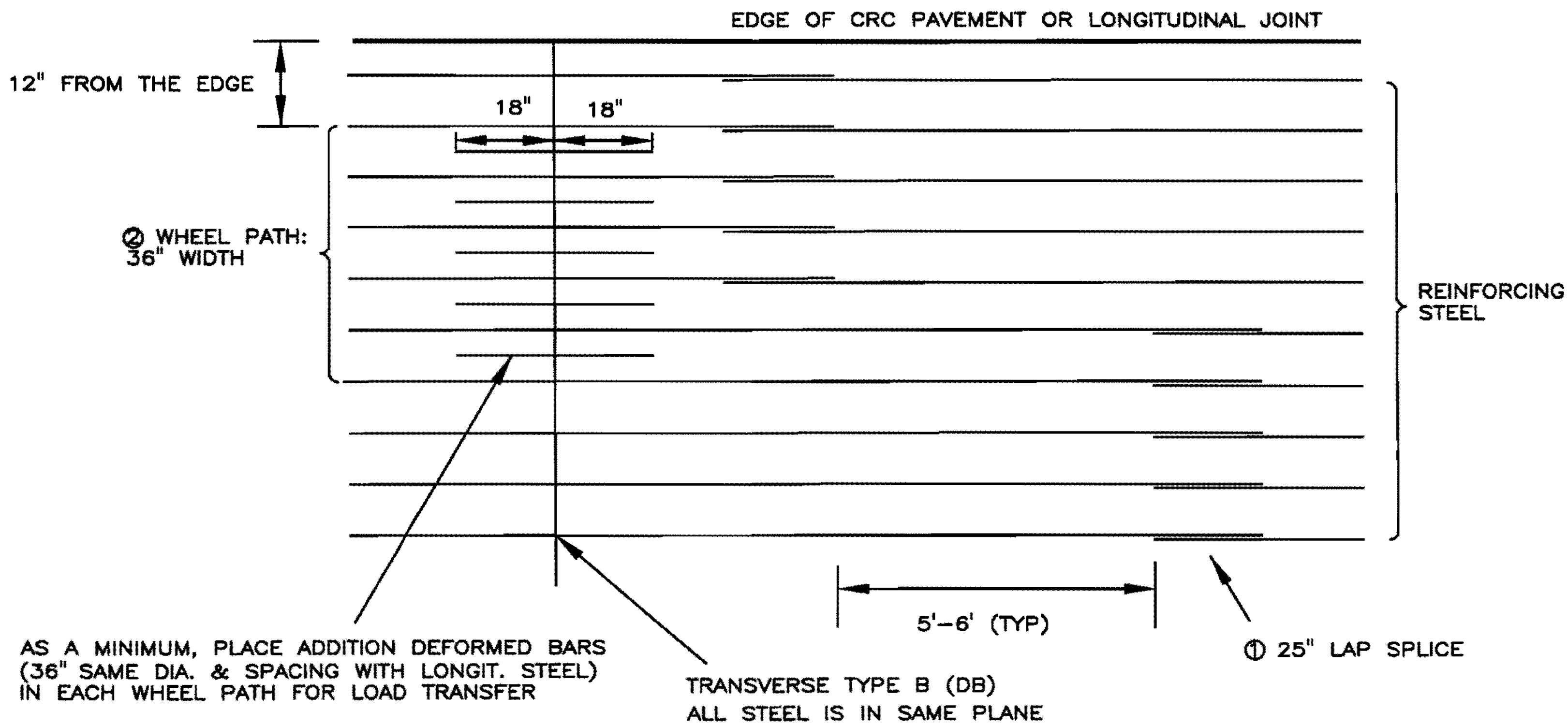
REVISIONS	COUNTY	CONTROL	SECT / JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

THICKNESS T, IN.	BAR SIZE	SPACING
8	#6 (0.75")	9"
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10	#6 (0.75")	7"
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12	#6 (0.75")	6"
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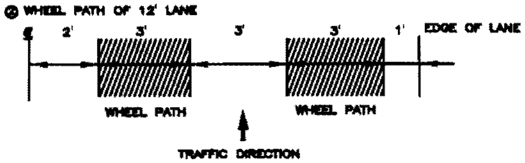
14	#6 (0.75")	9.5" DOUBLE
15	#6 (0.75")	8.5" DOUBLE

① BASED ON #6 BAR FOR OTHER BAR SIZES LAB SPLICE = 330"
② WHEEL PATH OF 12' LANE



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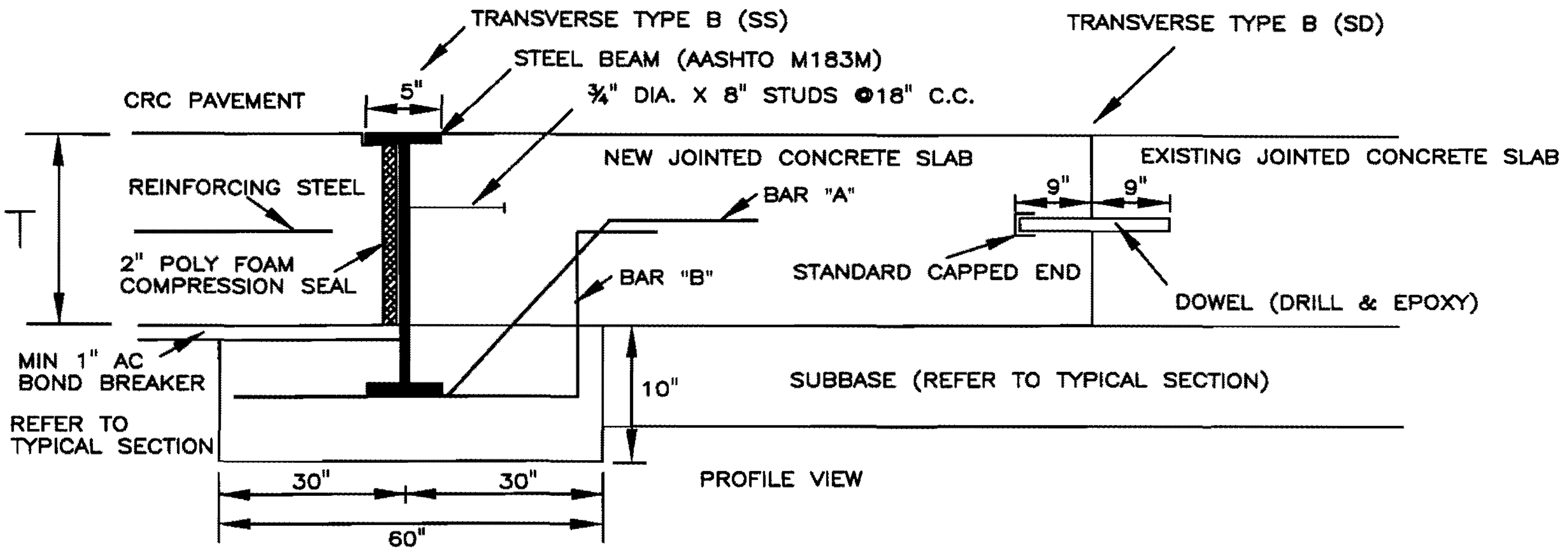
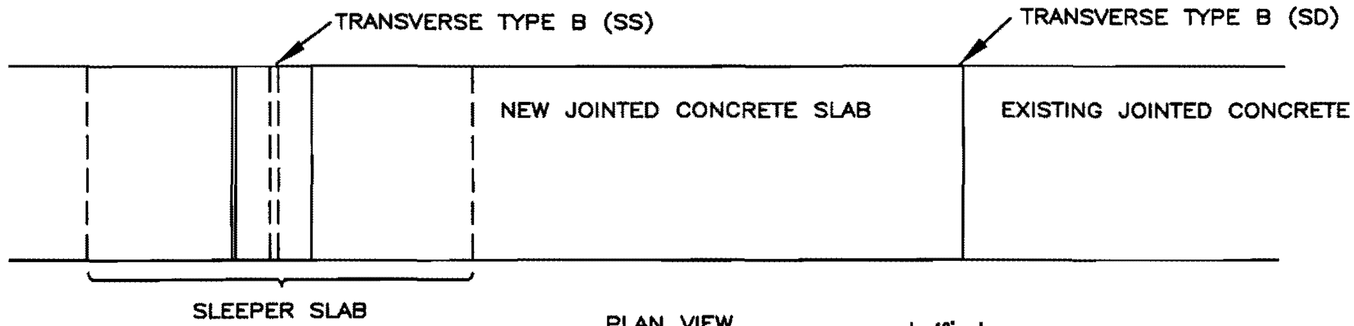


PROFILE VIEW



PLAN VIEW

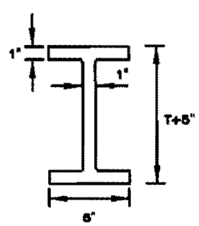
CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIREMENTS

THICKNESS T, IN.	DOWELS (SMOOTH BARS) SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 ⅛" X 18"	12"
10	1 ¼" X 18"	12"
11	1 ⅜" X 18"	12"
12	1 ½" X 18"	12"
13	1 ⅝" X 18"	12"
14	1 ¾" X 18"	12"
15	1 ⅞" X 18"	12"



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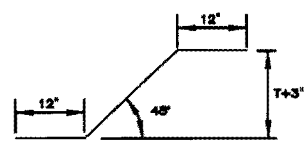
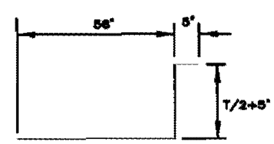


BAR "A" – #5 BAR AT 12" C.C



BAR "B" – #5 BAR AT 12" C.C

CRC PAVEMENT TO JOINTED
CONCRETE PAVEMENT (OPTION 1)

FILE:	DN:	CK:	DW:	CK:

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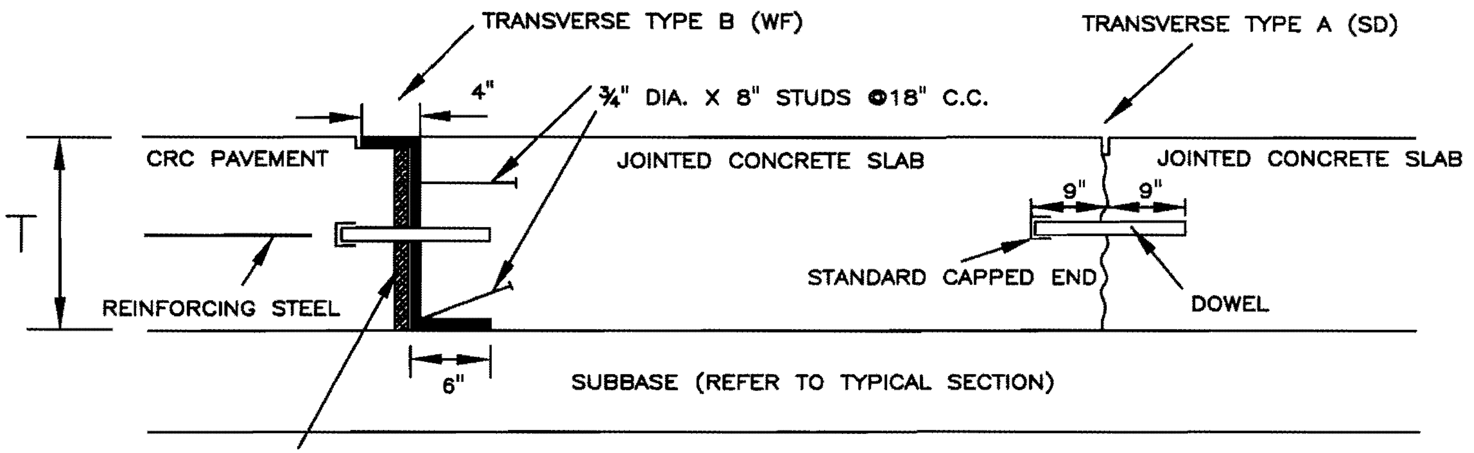
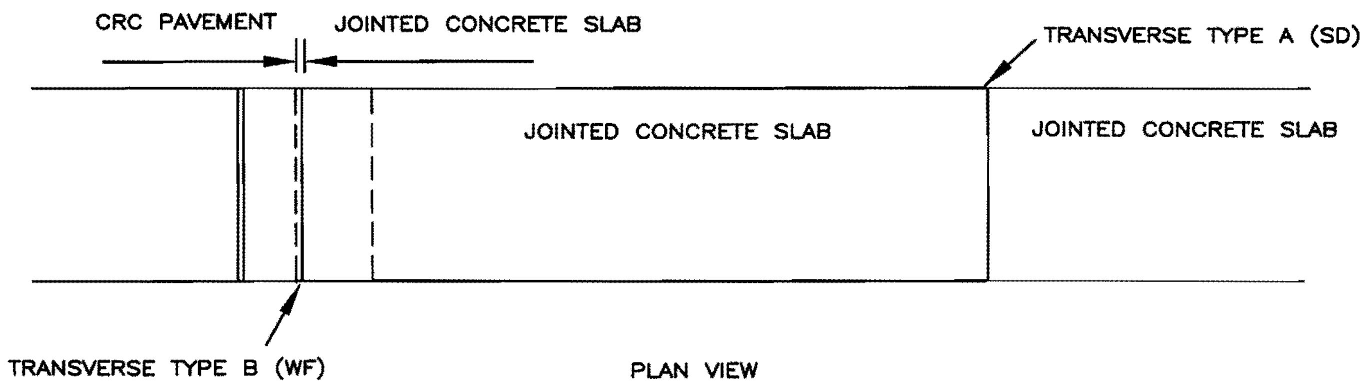
REVISIONS

DISTRICT	FEDERAL AID PROJECT	SHEET

COUNTY	CONTROL	SECT	JOB	HIGHWAY



PROFILE VIEW

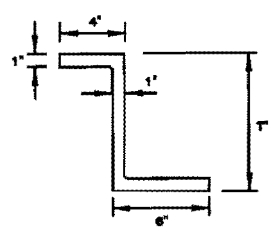


PLAN VIEW

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED



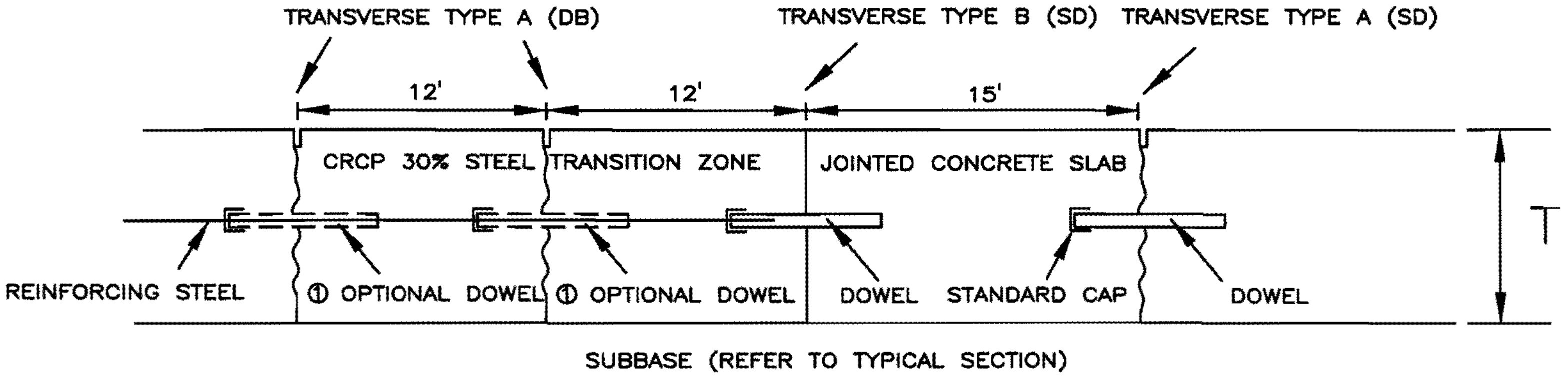
STEEL BEAM DETAIL

DOWELS REQUIRMENTS

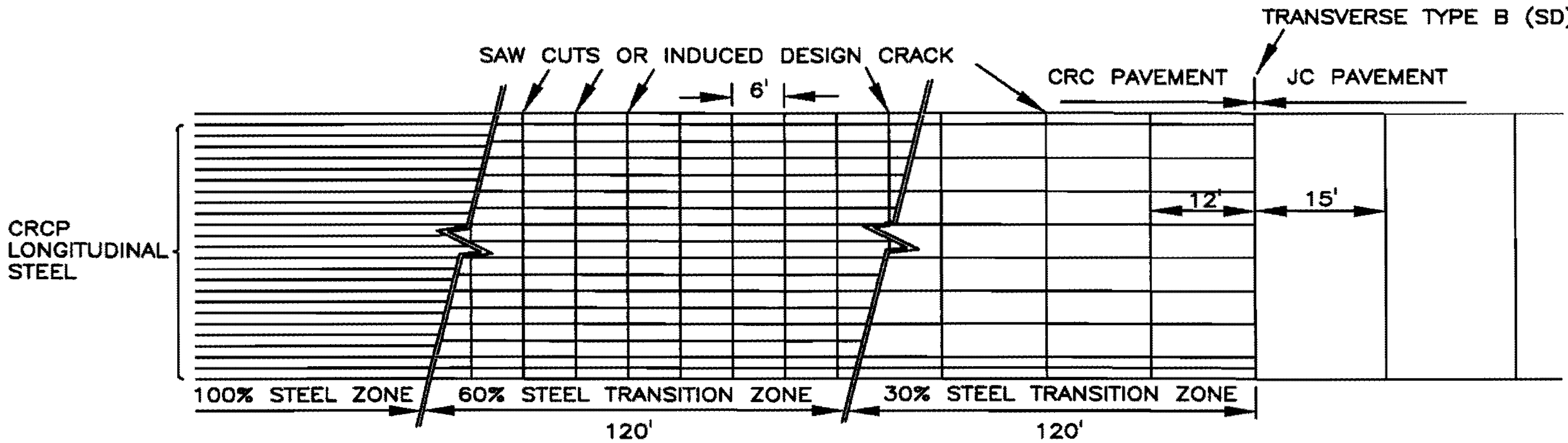
THICKNESS T IN.	DOWELS (SMOOTH BARS) SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 1/8" X 18"	12"
10	1 1/4" X 18"	12"
11	1 3/8" X 18"	12"
12	1 1/2" X 18"	12"
13	1 5/8" X 18"	12"
14	1 3/4" X 18"	12"
15	1 3/4" X 18"	12"

CRC PAVEMENT TO JOINTED CONCRETE PAVEMENT (OPTION 2)

FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT / JOB	HIGHWAY



PROFILE VIEW



PLAN VIEW

① PLACE OPTIONAL DOWEL THROUGH 30% STEEL TRANSITION ZONE IF LOAD TRANSFER BY AGGREGATE INTERLOCKING ONLY IS INSUFFICIENT BASED ON CURRENT DESIGN SLAB LENGTH AND THICKNESS

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

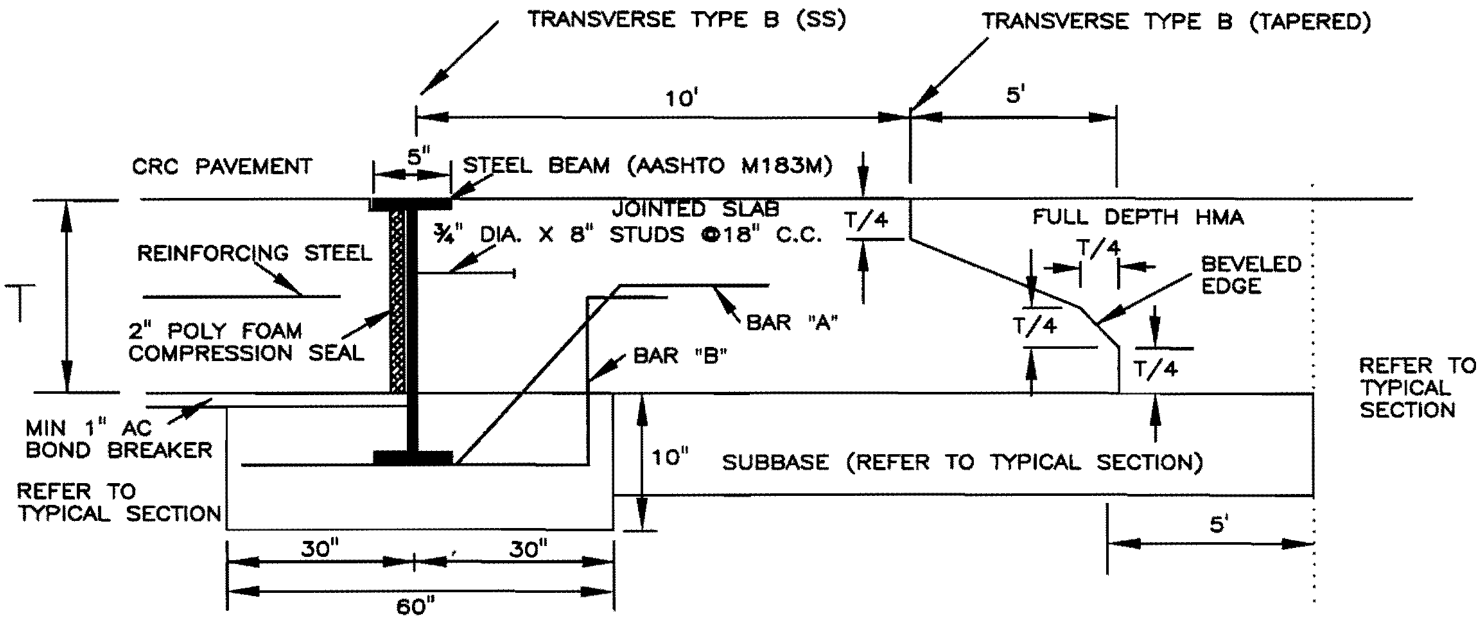
THICKNESS T, IN.	BAR SIZE	LONGITUDINAL STEEL SPACING		
		100% ZONE	60% ZONE	30% ZONE
8	#6 (0.75")	9"	13.5"	27"
9	#6 (0.75")	8"	12"	24"
10	#6 (0.75")	7"	10.5"	21"
11	#6 (0.75")	6.5"	9.5"	19"
12	#6 (0.75")	6"	9"	18"
13	#6 (0.75")	5.5"	8.5"	17"
14	#6 (0.75")	9.5" DOUBLE	14" DOUBLE	14"
15	#6 (0.75")	8.5" DOUBLE	13" DOUBLE	13"

DOWELS REQUIRMENTS

THICKNESS T, IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 [illegible]" X 18"	12"
10	1 [illegible]" X 18"	12"
11	1 [illegible]" X 18"	12"
12	1 [illegible]" X 18"	12"
13	1 [illegible]" X 18"	12"
14	1 [illegible]" X 18"	12"
15	1 [illegible]" X 18"	12"

CRC PAVEMENT TO JOINTED CONCRETE PAVEMENT (OPTION 3)

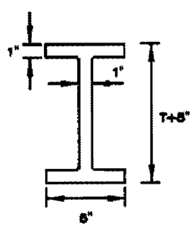
FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY



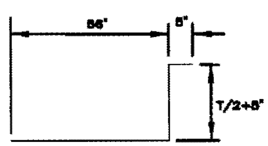
CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

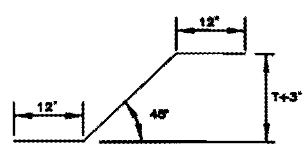
MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED



STEEL BEAM DETAIL



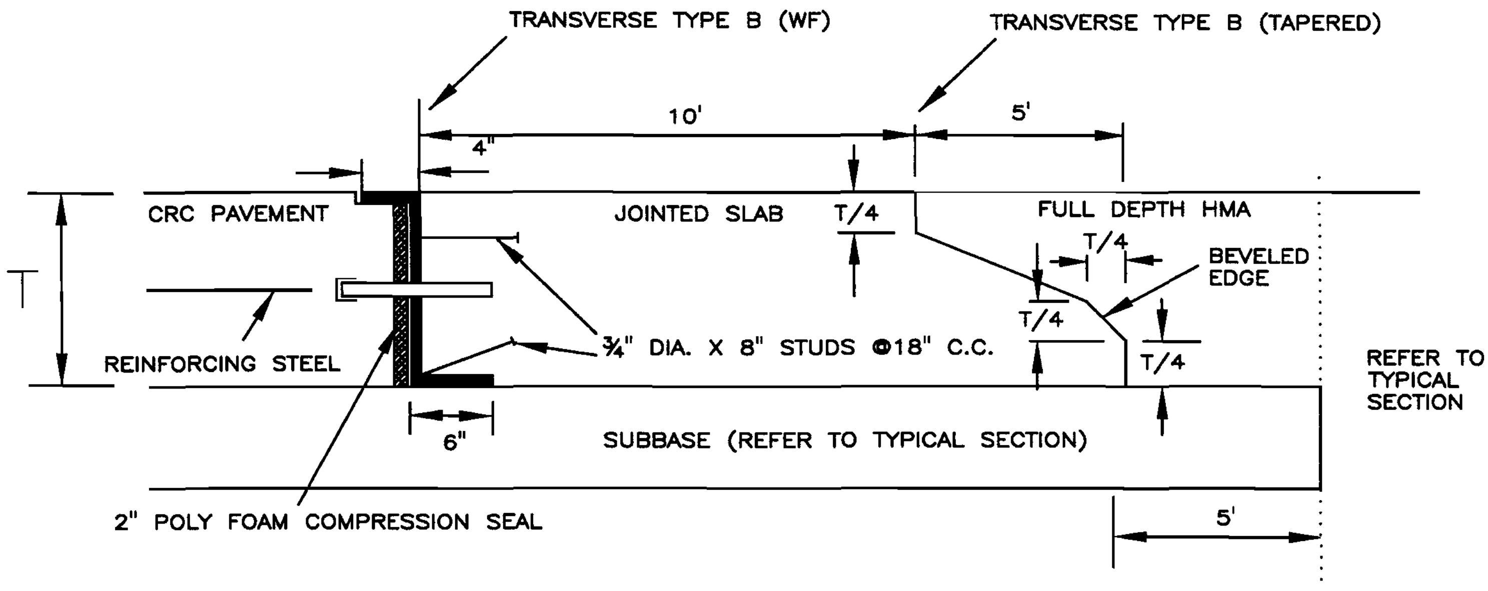
BAR "B" – #5 BAR AT 12" C.C



BAR 'A' – #5 BAR AT 12" C.C

CRC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 1 - SLEEPER SLAB)

FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS				
	COUNTY	CONTROL	SECT	JOB	HIGHWAY

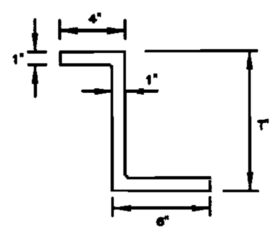


8

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED



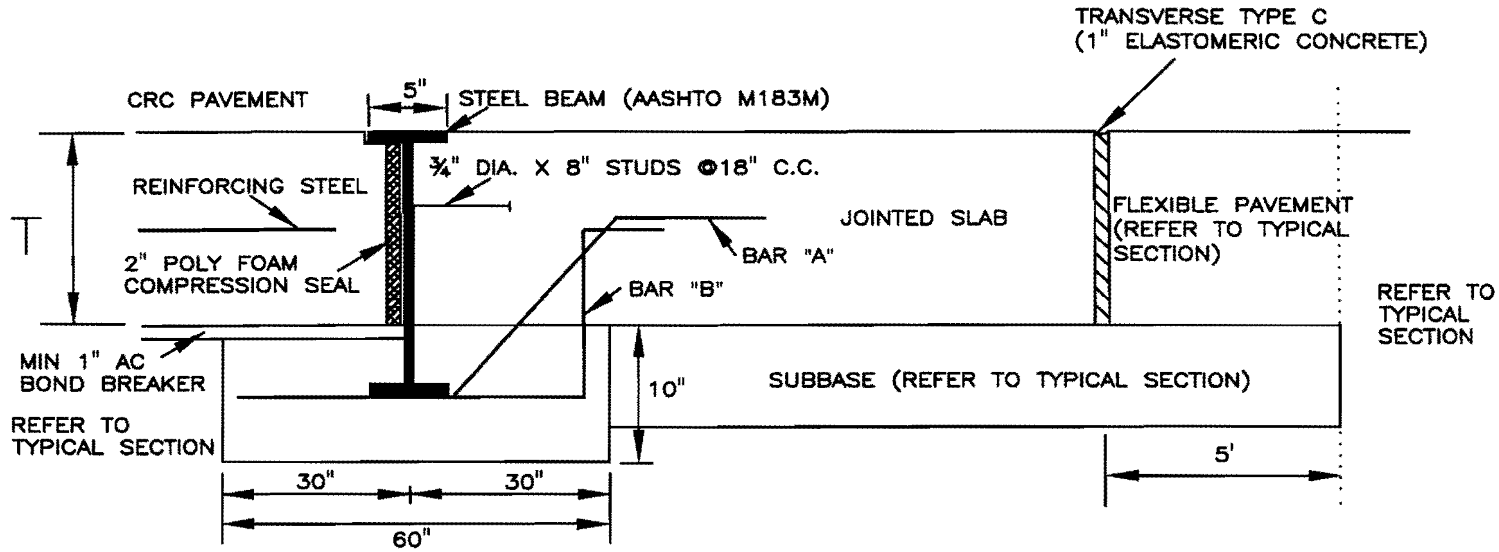
STEEL BEAM DETAIL

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS) SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 ⅛" X 18"	12"
10	1 ¼" X 18"	12"
11	1 ⅜" X 18"	12"
12	1 ½" X 18"	12"
13	1 ⅝" X 18"	12"
14	1 ¾" X 18"	12"
15	1 ⅞" X 18"	12"

CRC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 1 - WIDE FLANGE)

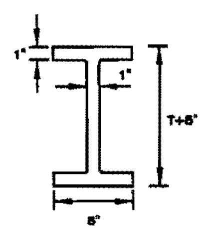
FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY



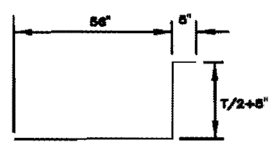
CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

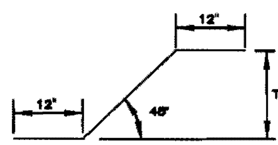
MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED



STEEL BEAM DETAIL



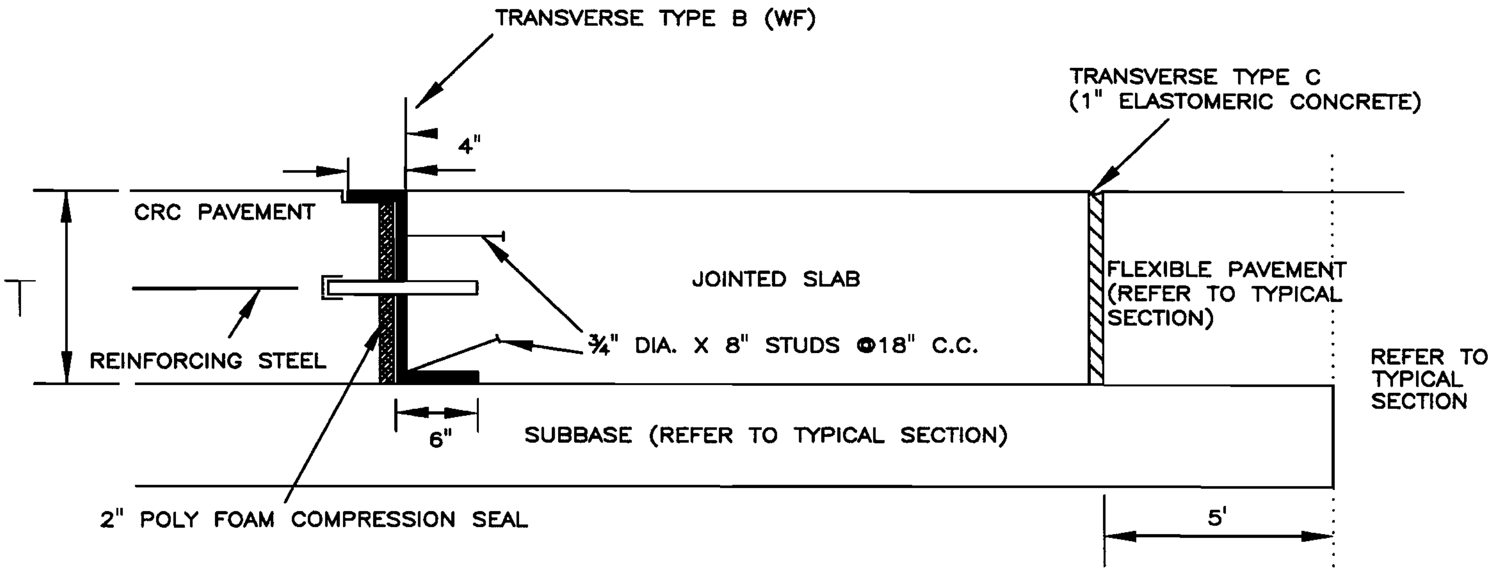
BAR "B" – #6 BAR AT 12" C.C



BAR "A" – #6 BAR AT 12" C.C

CRC PAVEMENT TO FLEXIBLE
PAVEMENT (OPTION 2 - SLEEPER SLAB)

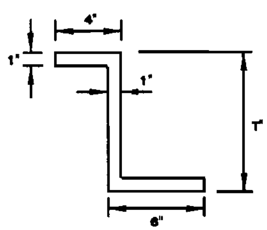
FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED



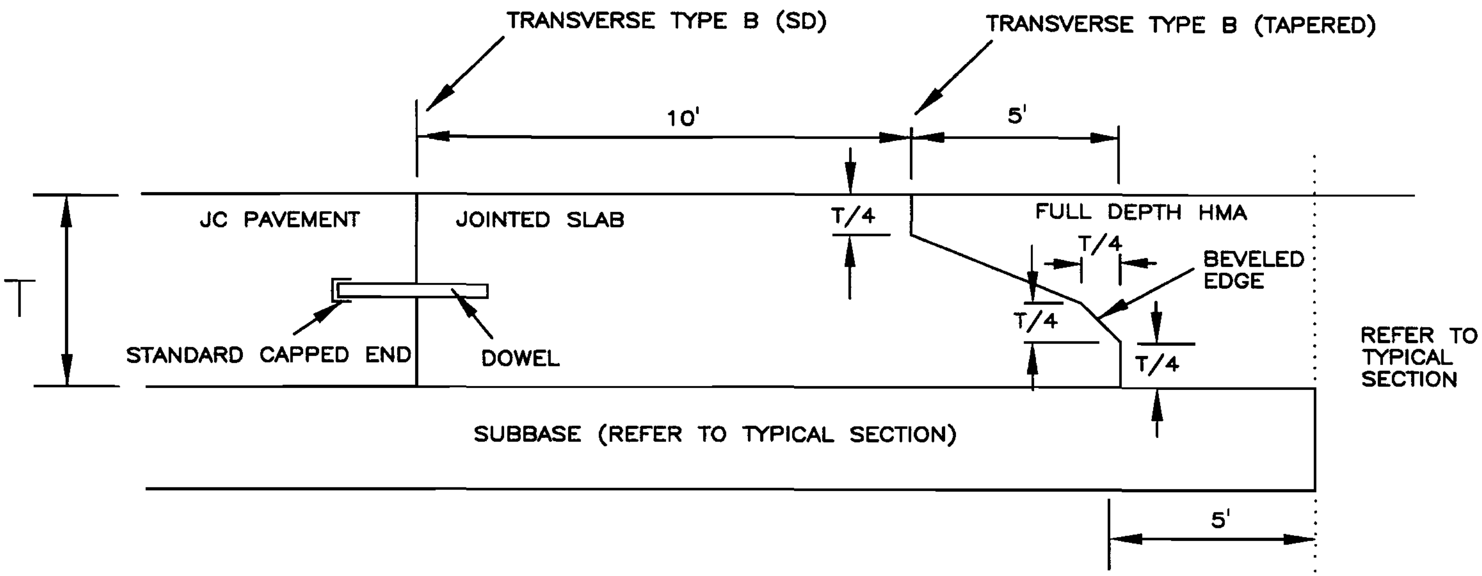
STEEL BEAM DETAIL

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 ⅛" X 18"	12"
10	1 ¼" X 18"	12"
11	1 ⅜" X 18"	12"
12	1 ½" X 18"	12"
13	1 ⅝" X 18"	12"
14	1 ¾" X 18"	12"
15	1 ⅞" X 18"	12"

CRC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 2 - WIDE FLANGE)

FILE:	DN:	CK:	DW:	CK:
REVISIONS	DISTRICT	FEDERAL AID PROJECT		SHEET
	COUNTY	CONTROL	SECT	JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

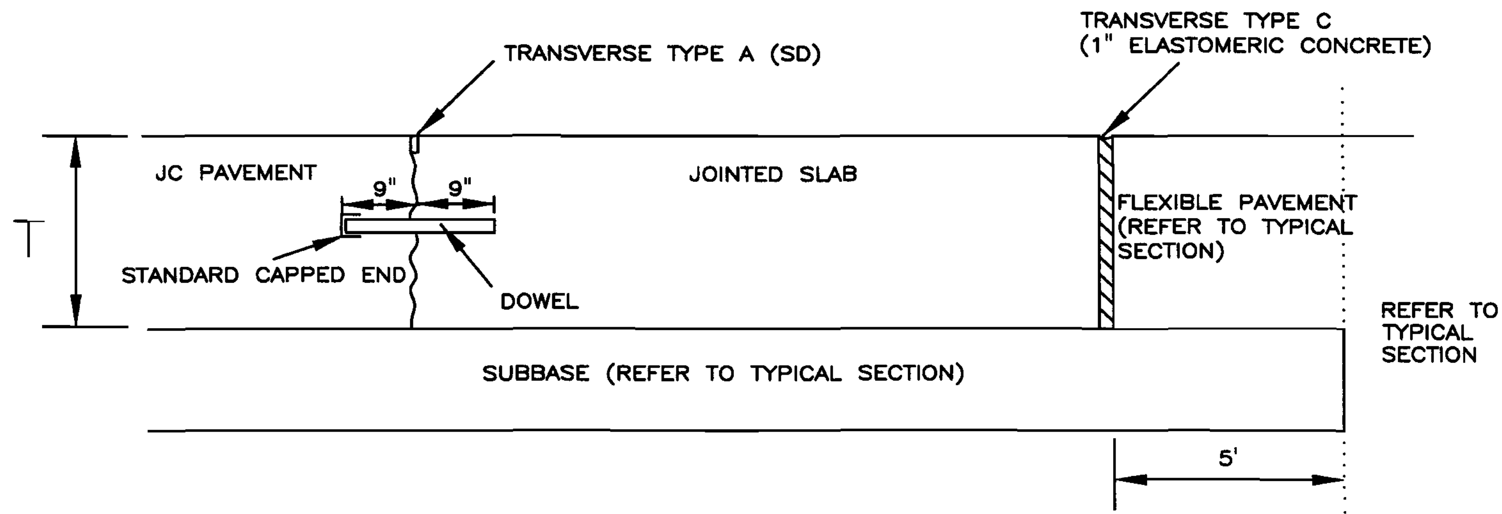
MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 [illegible]" X 18"	12"
10	1 [illegible]" X 18"	12"
11	1 [illegible]" X 18"	12"
12	1 [illegible]" X 18"	12"
13	1 [illegible]" X 18"	12"
14	1 [illegible]" X 18"	12"
15	1 [illegible]" X 18"	12"

JC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 1)

FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS				
	COUNTY	CONTROL	SECT / JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

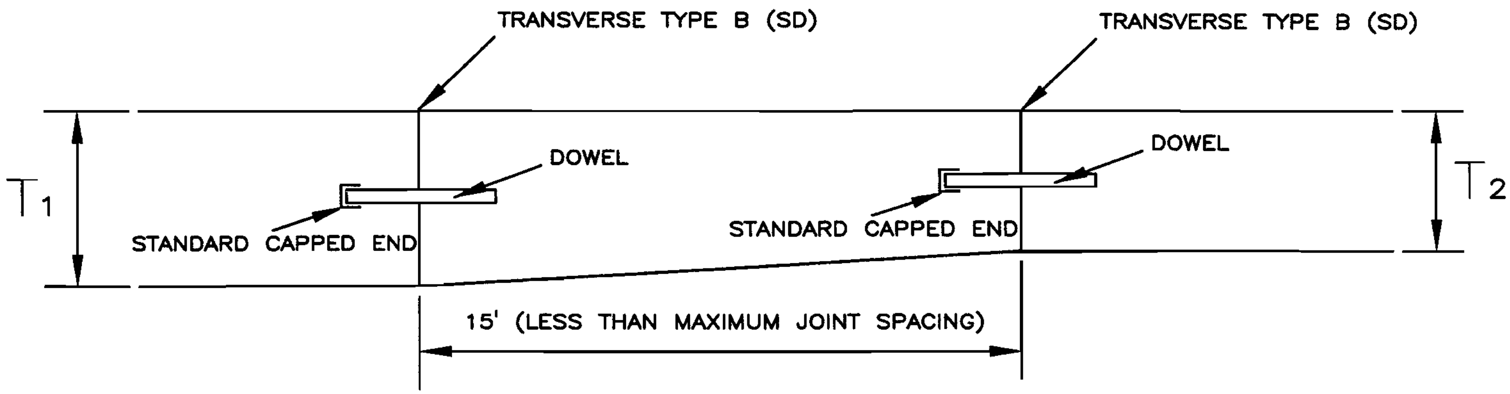
MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS) SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 1/8" X 18"	12"
10	1 1/4" X 18"	12"
11	1 3/8" X 18"	12"
12	1 1/2" X 18"	12"
13	1 5/8" X 18"	12"
14	1 3/4" X 18"	12"
15	1 7/8" X 18"	12"

JC PAVEMENT TO FLEXIBLE PAVEMENT (OPTION 2)

FILE:	DN:	CK:	DW:	CK:		
©	DISTRICT	FEDERAL AID PROJECT			SHEET	
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY	



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

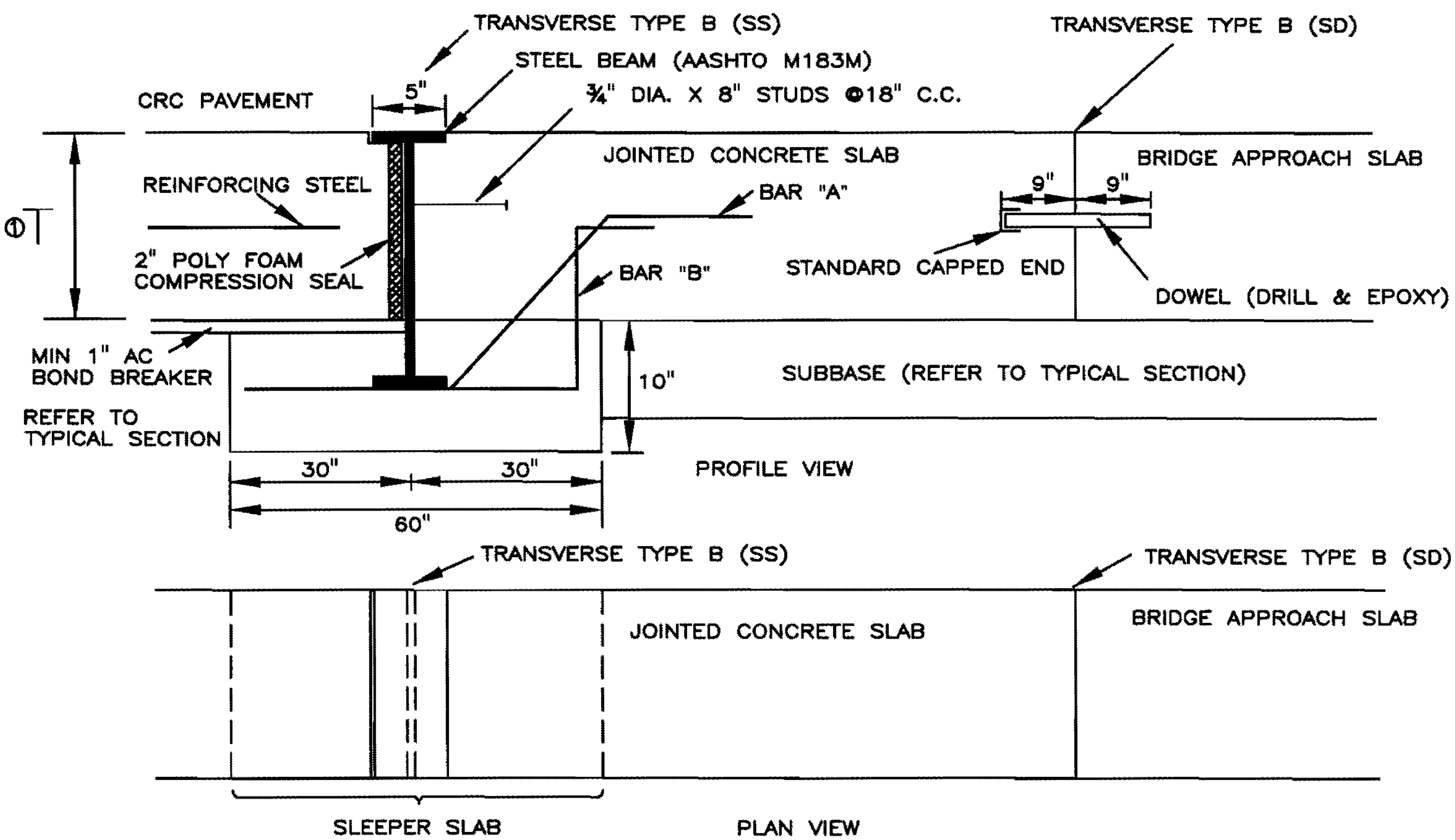
MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 1/8" X 18"	12"
10	1 1/4" X 18"	12"
11	1 3/8" X 18"	12"
12	1 1/2" X 18"	12"
13	1 5/8" X 18"	12"
14	1 3/4" X 18"	12"
15	1 7/8" X 18"	12"

JC PAVEMENT TO JC PAVEMENT
(THICKNESS TRANSITION)

FILE: | DN: | CK: | DW: | CK:
ID | DISTRICT | FEDERAL AID PROJECT | SHEET
REVISIONS
COUNTY | CONTROL | SECT | JOB | HIGHWAY



① IF PCC PAVEMENT THICKNESS IS DIFFERENT WITH BRIDGE APPROACH SLAB, EMPLOY PAVEMENT THICKNESS TRANSITION BEFORE THE TRANSITION TO BRIDGE APPROACH SLAB

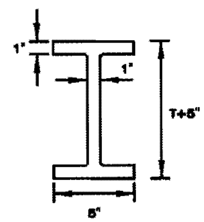
CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

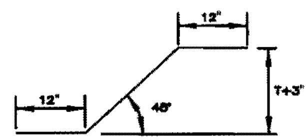
MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIREMENTS

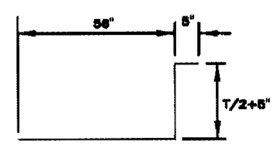
THICKNESS T, IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 ⅛" X 18"	12"
10	1 ¼" X 18"	12"
11	1 ⅜" X 18"	12"
12	1 ½" X 18"	12"
13	1 ¾" X 18"	12"
14	1 ¾" X 18"	12"
15	1 ¾" X 18"	12"



STEEL BEAM DETAIL



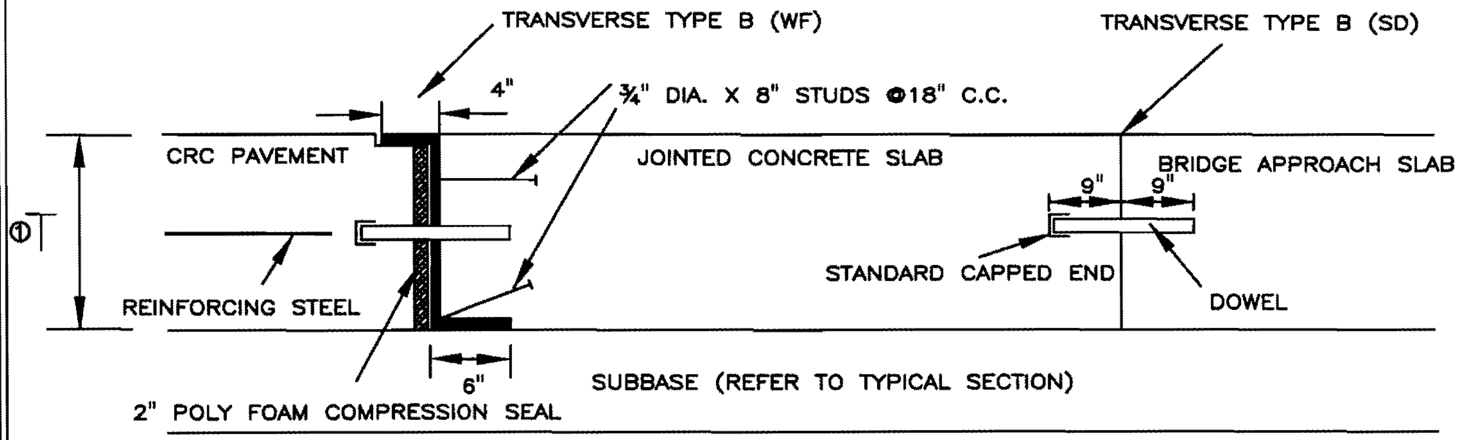
BAR "A" – #6 BAR AT 12" C.C



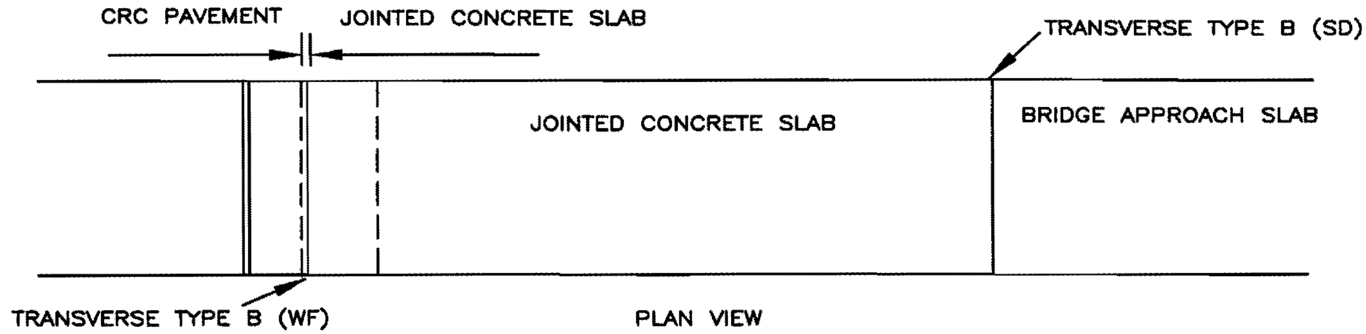
BAR "B" – #6 BAR AT 12" C.C

CRC PAVEMENT TO BRIDGE APPROACH SLAB (OPTION 1)

FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY



PROFILE VIEW



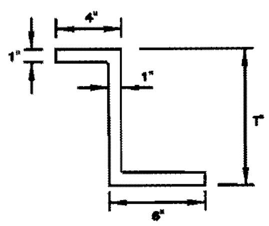
PLAN VIEW

① IF PCC PAVEMENT THICKNESS IS DIFFERENT WITH BRIDGE APPROACH SLAB, EMPLOY PAVEMENT THICKNESS TRANSITION BEFORE THE TRANSITION TO BRIDGE APPROACH SLAB

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED



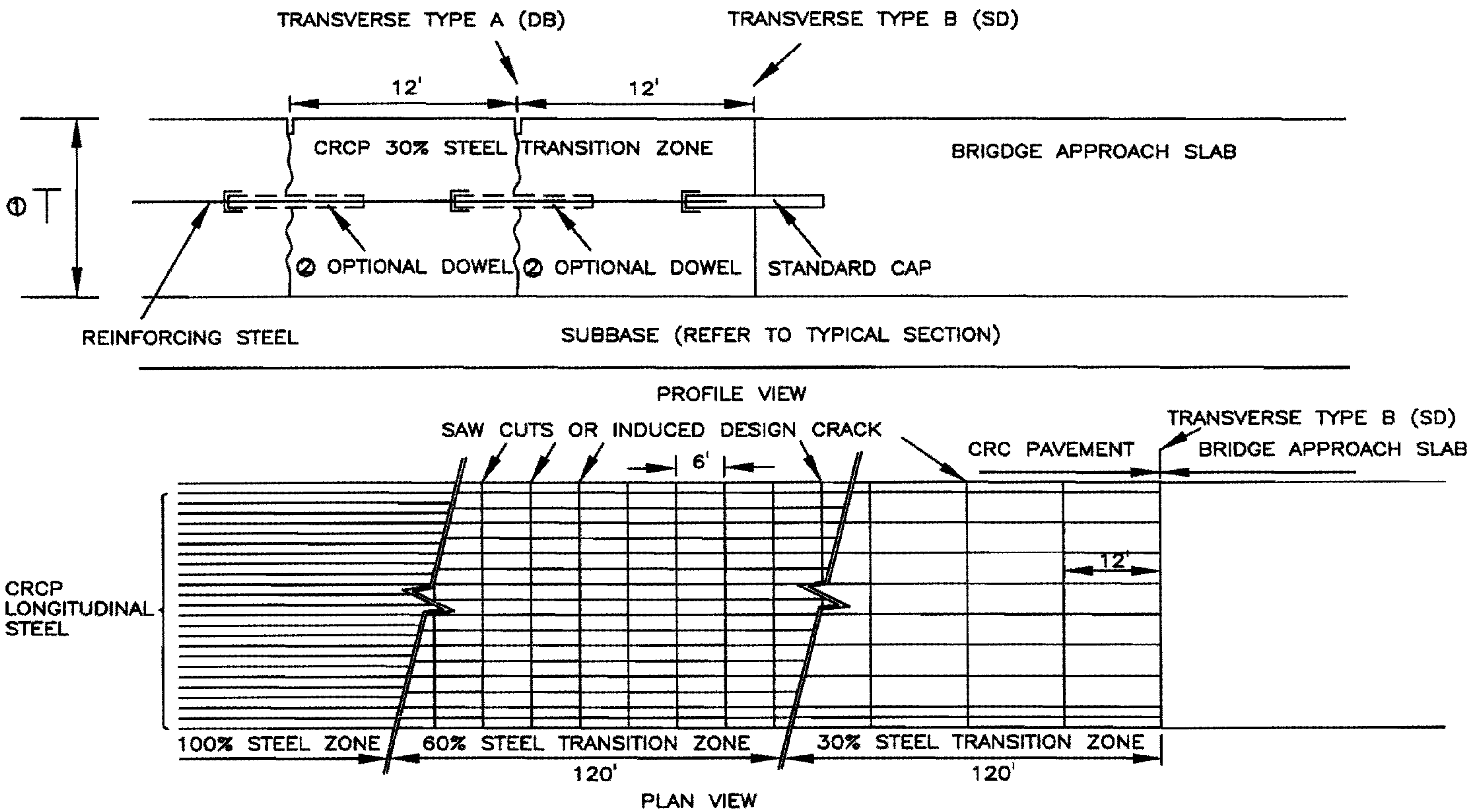
STEEL BEAM DETAIL

DOWELS REQUIRMENTS

THICKNESS T, IN.	DOWELS (SMOOTH BARS) SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 [illegible]" X 18"	12"
10	1 [illegible]" X 18"	12"
11	1 [illegible]" X 18"	12"
12	1 [illegible]" X 18"	12"
13	1 [illegible]" X 18"	12"
14	1 [illegible]" X 18"	12"
15	1 [illegible]" X 18"	12"

CRC PAVEMENT TO BRIDGE APPROACH SLAB (OPTION 2)

FILE:	DN:	CK:	DW:	CK:
©	DISTRICT	FEDERAL AID PROJECT		SHEET
REVISIONS	COUNTY	CONTROL	SECT / JOB	HIGHWAY



① IF PCC PAVEMENT THICKNESS IS DIFFERENT WITH BRIDGE APPROACH SLAB, EMPLOY PAVEMENT THICKNESS TRANSITION BEFORE THE TRANSITION TO BRIDGE APPROACH SLAB

② PLACE OPTIONAL DOWEL THROUGH 30% STEEL TRANSITION ZONE IF LOAD TRANSFER BY AGGREGATE INTERLOCKING ONLY IS INSUFFICIENT BASED ON CURRENT DESIGN SLAB LENGTH AND THICKNESS

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

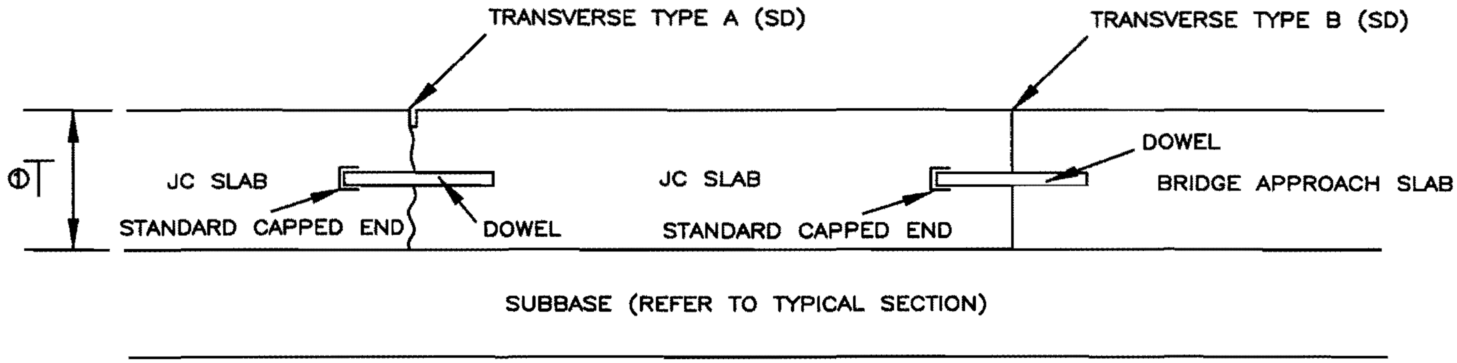
THICKNESS T, IN.	BAR SIZE	LONGITUDINAL STEEL SPACING		
		100% ZONE	60% ZONE	30% ZONE
8	#6 (0.75")	9"	13.5"	27"
9	#6 (0.75")	8"	12"	24"
10	#6 (0.75")	7"	10.5"	21"
11	#6 (0.75")	6.5"	9.5"	19"
12	#6 (0.75")	6"	9"	18"
13	#6 (0.75")	5.5"	8.5"	17"
14	#6 (0.75")	9.5" DOUBLE	14" DOUBLE	14"
15	#6 (0.75")	8.5" DOUBLE	13" DOUBLE	13"

DOWELS REQUIRMENTS

THICKNESS T, IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 [illegible]" X 18"	12"
10	1 [illegible]" X 18"	12"
11	1 [illegible]" X 18"	12"
12	1 [illegible]" X 18"	12"
13	1 [illegible]" X 18"	12"
14	1 [illegible]" X 18"	12"
15	1 [illegible]" X 18"	12"

CRC PAVEMENT TO BRIDGE APPROACH SLAB (OPTION 3)

FILE:	DN:	CK:	DW:	CK:	
©	DISTRICT	FEDERAL AID PROJECT			SHEET
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY



① IF PCC PAVEMENT THICKNESS IS DIFFERENT WITH BRIDGE APPROACH SLAB, EMPLOY PAVEMENT THICKNESS TRANSITION BEFORE THE TRANSITION TO BRIDGE APPROACH SLAB

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIRMENTS

THICKNESS T, IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 1/8" X 18"	12"
10	1 1/4" X 18"	12"
11	1 3/8" X 18"	12"
12	1 1/2" X 18"	12"
13	1 5/8" X 18"	12"
14	1 3/4" X 18"	12"
15	1 7/8" X 18"	12"

JC PAVEMENT TO BRIDGE APPROACH SLAB

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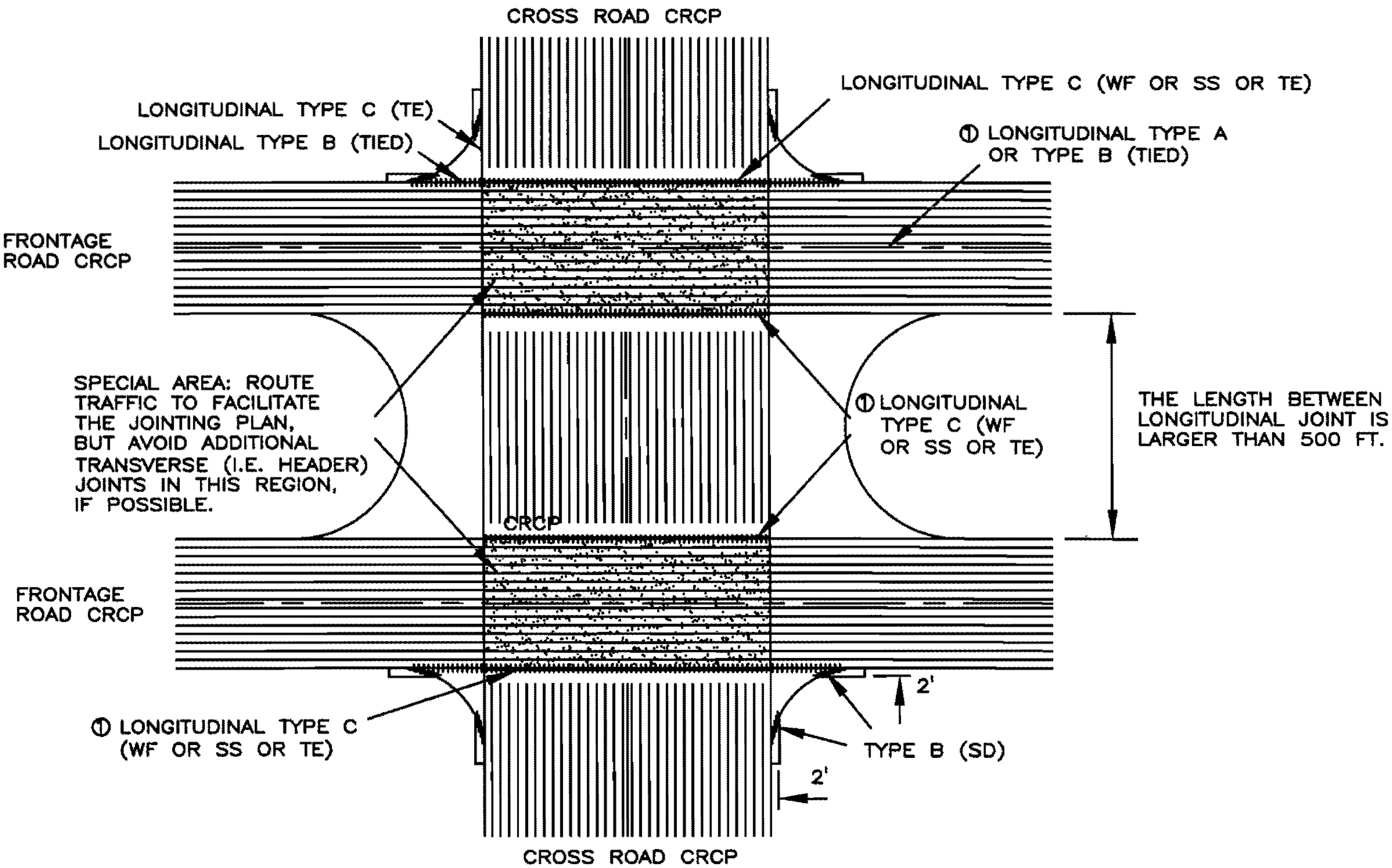

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIREMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 1/8" X 18"	12"
10	1 1/4" X 18"	12"
11	1 3/8" X 18"	12"
12	1 1/2" X 18"	12"
13	1 5/8" X 18"	12"
14	1 3/4" X 18"	12"
15	1 7/8" X 18"	12"

① EMPLOY LONGITUDINAL TYPE C (1" ELASTOMERIC CONCRETE) WHEN CROSS ROAD TYPE IS FLEXIBLE PAVEMENT

INTERSECTION (OPTION 1 - JOINT DISTANCE > 500 FT)

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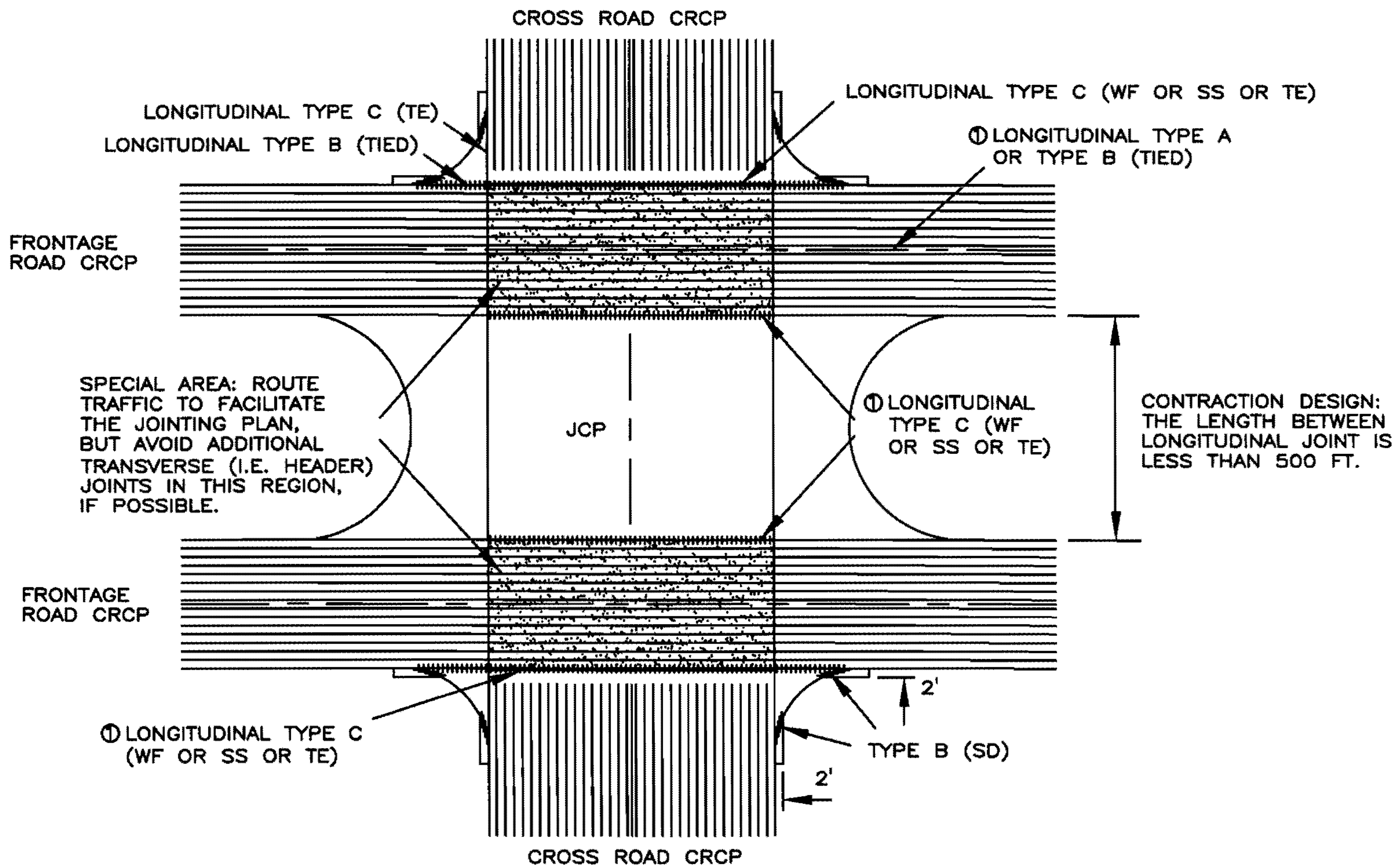

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 [illegible]" X 18"	12"
10	1 [illegible]" X 18"	12"
11	1 [illegible]" X 18"	12"
12	1 [illegible]" X 18"	12"
13	1 [illegible]" X 18"	12"
14	1 [illegible]" X 18"	12"
15	1 [illegible]" X 18"	12"

① EMPLOY LONGITUDINAL TYPE C (1" ELASTOMERIC CONCRETE) WHEN CROSS ROAD TYPE IS FLEXIBLE PAVEMENT

INTERSECTION (OPTION 2 - JOINT DISTANCE < 500 FT)

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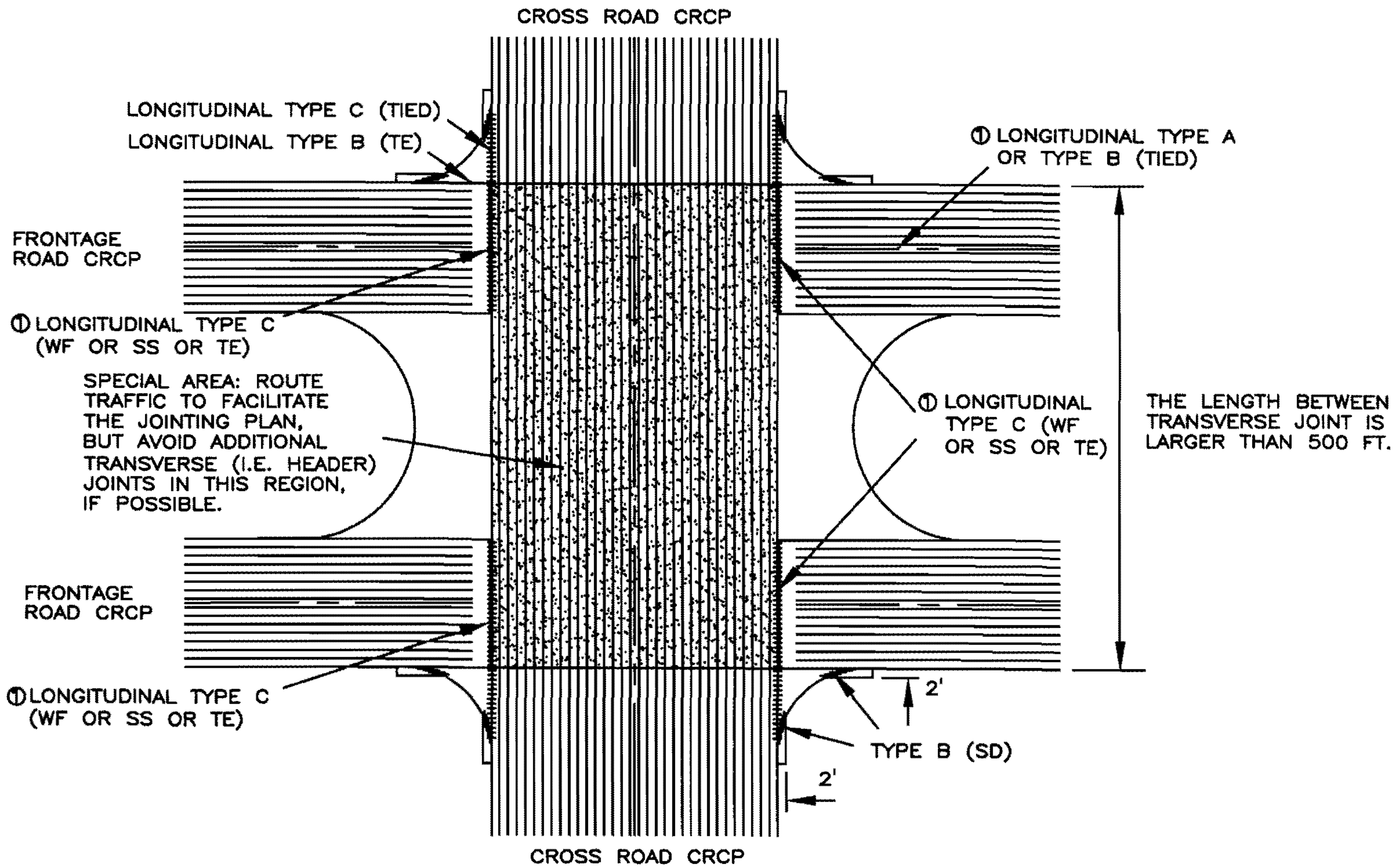

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIREMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS) SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 ⅛" X 18"	12"
10	1 ¼" X 18"	12"
11	1 ⅜" X 18"	12"
12	1 ½" X 18"	12"
13	1 ⅝" X 18"	12"
14	1 ¾" X 18"	12"
15	1 ⅞" X 18"	12"

① EMPLOY LONGITUDINAL TYPE C (1" ELASTOMERIC CONCRETE) WHEN FRONTAGE ROAD TYPE IS FLEXIBLE PAVEMENT

INTERSECTION (OPTION 3)

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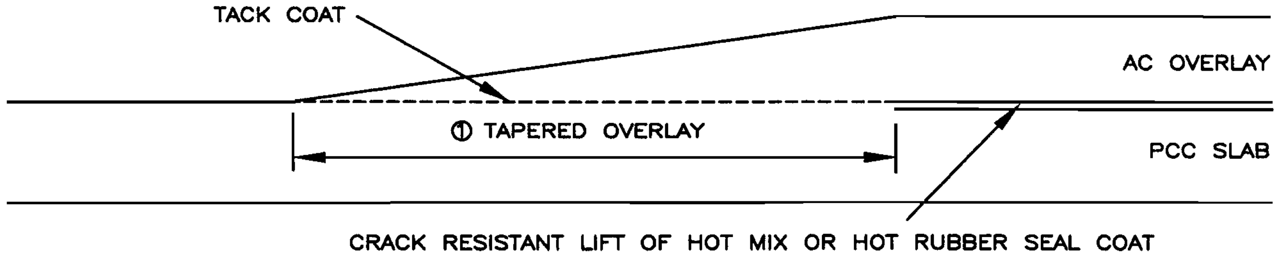
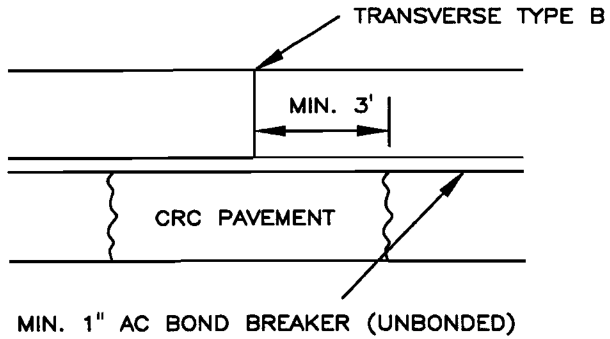
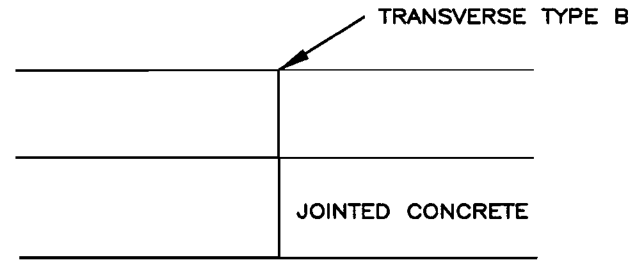


BONDED AC OVERLAY GRADE TRANSITION





THIS DETAIL ALSO APPLIES TO UNBONDED OVERLAYS

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

① TAPERED OVERLAY LENGTH

OVERLAY THICKNESS	TAPER MINIMUM LENGTH
1 "	50 '
2 "	100 '
3 "	150 '
4 "	200 '
5 "	250 '
6 "	300 '

OVERLAY - UNBONDED,
BONDED, AC OVERLAYS

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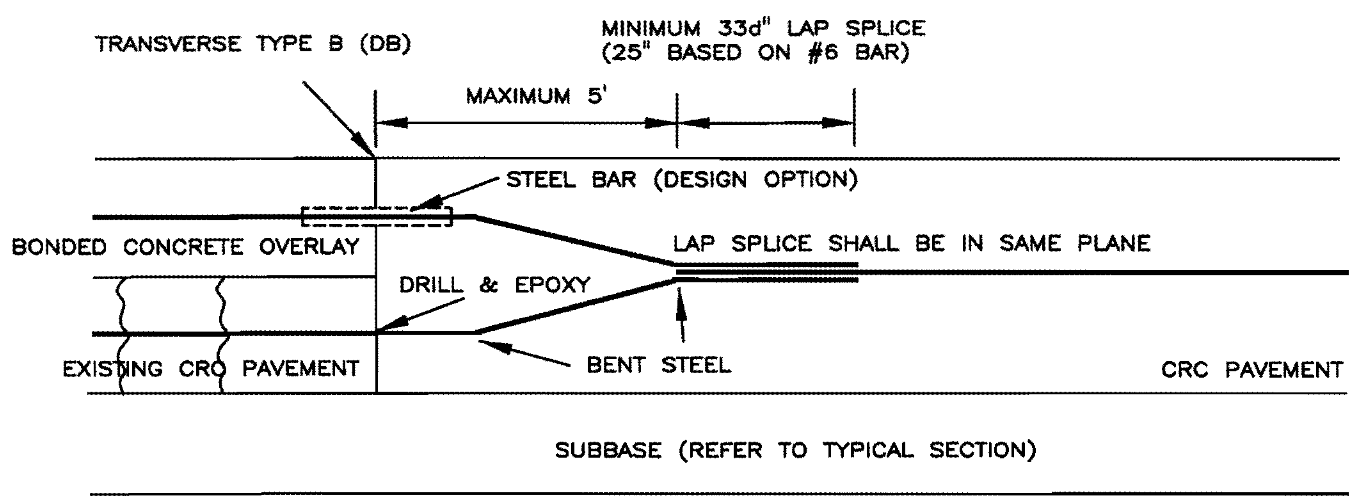
REVISIONS	COUNTY	CONTROL	SECT	JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

THICKNESS T IN.	BAR SIZE	SPACING
8	#6 (0.75")	9"
9	#6 (0.75")	8"
10	#6 (0.75")	7"
11	#6 (0.75")	6.5"
12	#6 (0.75")	6"
13	#6 (0.75")	5.5"
14	#6 (0.75")	9.5" DOUBLE
15	#6 (0.75")	8.5" DOUBLE

CRC BONDED OVERLAY TO SINGLE-LAYERED STEEL CRC PAVEMENT

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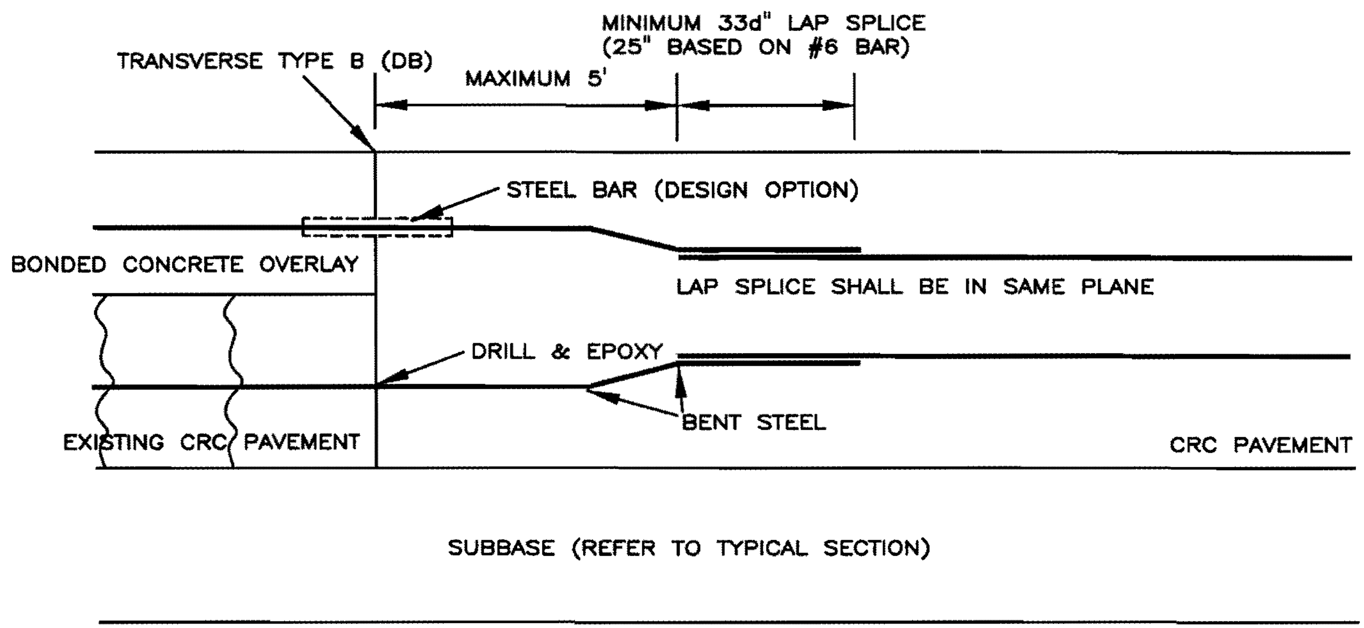
	COUNTY	CONTROL	SECT	JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

THICKNESS T, IN.	BAR SIZE	SPACING
8	#6 (0.75")	9"
9	#6 (0.75")	8"
10	#6 (0.75")	7"
11	#6 (0.75")	6.5"
12	#6 (0.75")	6"
13	#6 (0.75")	5.5"
14	#6 (0.75")	9.5" DOUBLE
15	#6 (0.75")	8.5" DOUBLE

CRC BONDED OVERLAY TO
DOUBLE-LAYERED STEEL CRC
PAVEMENT

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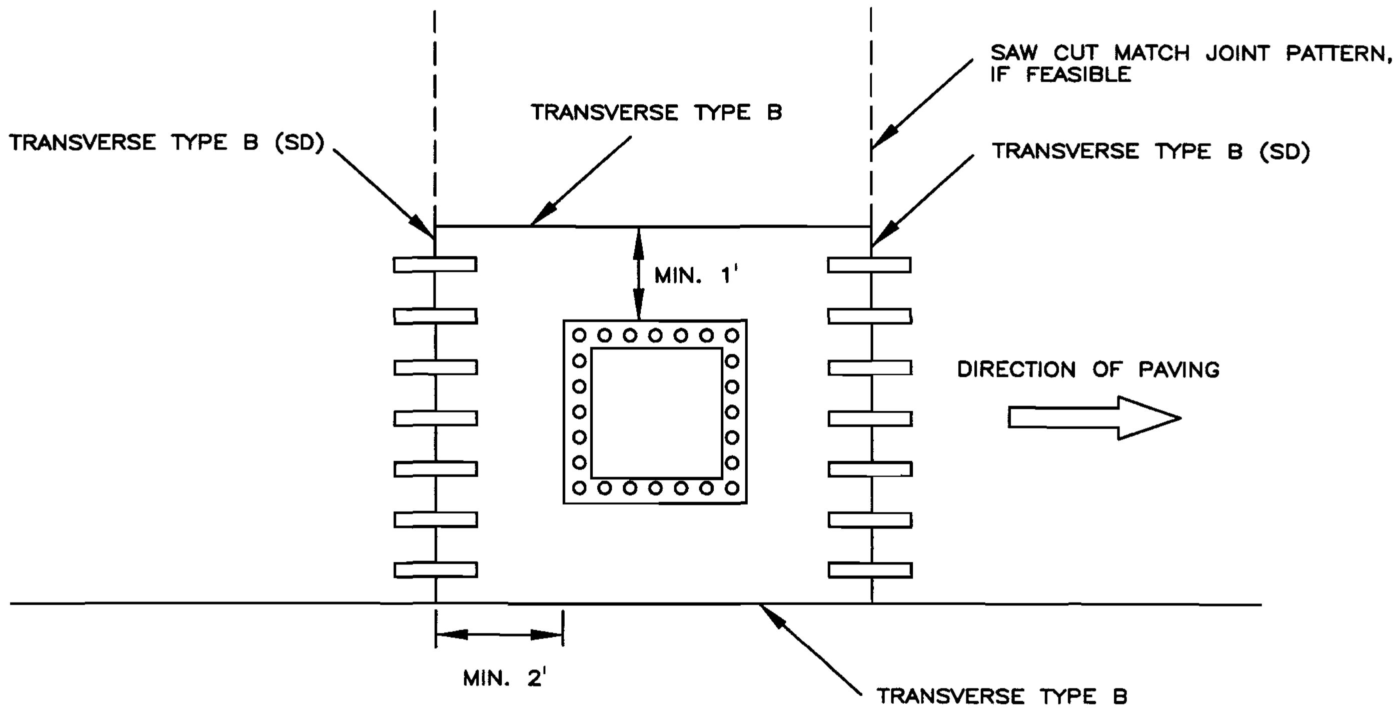
	COUNTY	CONTROL	SECT	JOB	HIGHWAY



CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DISCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

DOWELS REQUIRMENTS

THICKNESS T IN.	DOWELS (SMOOTH BARS)	
	SIZE & LENGTH	SPACING
8	1" X 18"	12"
9	1 1/8" X 18"	12"
10	1 1/4" X 18"	12"
11	1 3/8" X 18"	12"
12	1 1/2" X 18"	12"
13	1 5/8" X 18"	12"
14	1 3/4" X 18"	12"
15	1 7/8" X 18"	12"

DROP INLET/DRAINAGE BOX

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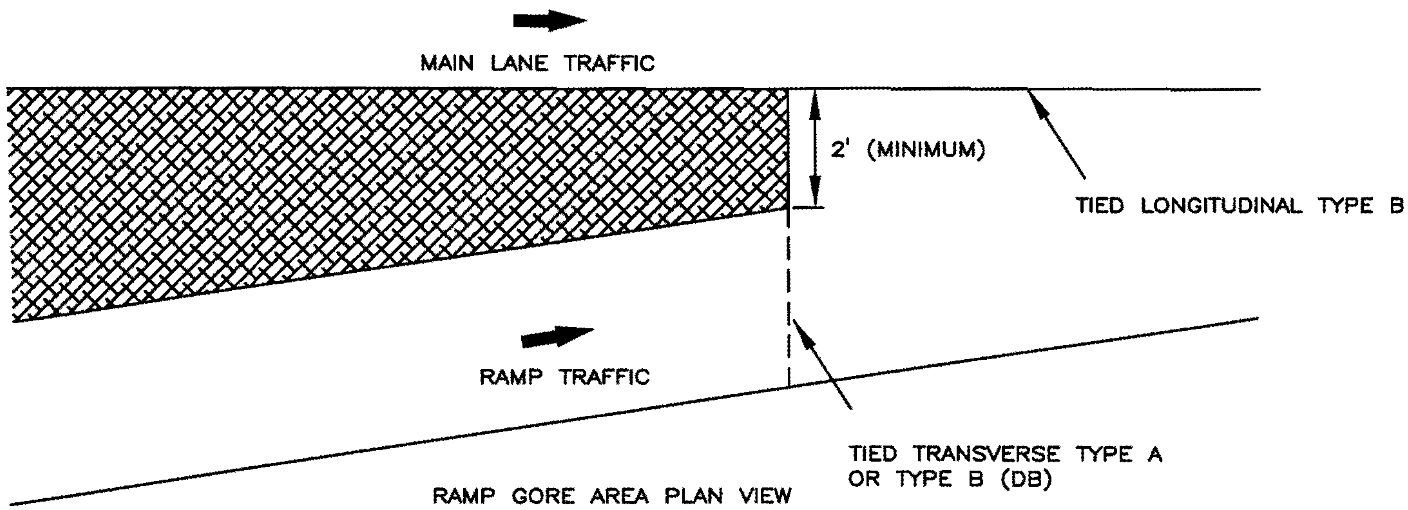
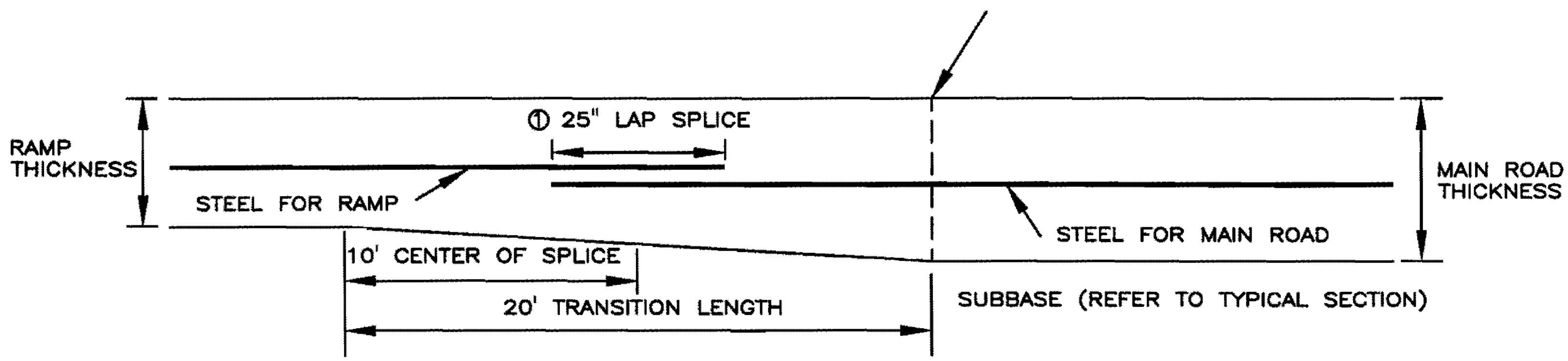


RAMP GORE AREA PLAN VIEW



RAMP PROFILE VIEW

CLASSIFICATION AND NOTATION OF JOINT

TYPE	JOINT DESCRIPTION
A	CONTRACTION JOINT
B	CONSTRUCTION JOINT
C	ISOLATION JOINT

MODIFIER	ABBREVIATION
WITH SMOOTH DOWEL	SD
WITH DEFORMED BAR	DB
TIED	TIED
THICKENED EDGE	TE
WIDE FLANGE	WF
SLEEPER SLAB	SS
TAPERED	TAPERED

LONGITUDINAL STEEL SIZE AND SPACING

THICKNESS T IN.	BAR SIZE	SPACING
8	#6 (0.75")	9"
9	#6 (0.75")	8"
10	#6 (0.75")	7"
11	#6 (0.75")	6.5"
12	#6 (0.75")	6"
13	#6 (0.75")	5.5"
14	#6 (0.75")	9.5" DOUBLE
15	#6 (0.75")	8.5" DOUBLE

① BASED ON #6 BAR FOR OTHER BAR SIZES LAB SPLICE = 33d"

RAMP/GORE AREA TRANSITION

FILE:	DN:	CK:	DW:	CK:
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