Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/AR-04-003		

4. Title and Subtitle TRC-0209 Improvements to the ROADHOG Overlay Design Program Final Report	5. Report Date May 2004 6. Performing Organization Code
7. Author(s) Stacy G. Williams Kevin D. Hall	8. Performing Organization Report No.
9. Performing Organization Name and Address University of Arkansas, Department of Civil Engineering 4190 Bell Engineering Center Fayetteville, AR 72701	10. Work Unit No. (TRAIS) 11. Contract or Grant No. TRC-0209
12. Sponsoring Agency Name and Address Arkansas State Highway and Transportation Department P.O. Box 2261 Little Rock, AR 72203-2261	13. Type of Report and Period covered Final Report 1 Jul 02 thru 31 Dec 03 14. Sponsoring Agency Code
15. Supplementary Notes Conducted in cooperation with U.S. Department of Transportation, Federal Highway Administration	

16. Abstract

The ROADHOG overlay design system and associated computer program has been used by the Arkansas State Highway and Transportation Department (AHTD) for the design of flexible pavement overlays. The program is based on the results of research conducted for AHTD and has been through two modifications since its original inception. While the technical aspects of the program continued to meet expectations, the program itself needed updating. AHTD acquired a new falling weight deflectometer (FWD) in the 1990s, which uses a file format that is not compatible with the original version of ROADHOG. In addition, the original ROADHOG software was written in a DOS-based computer language that would not run consistently on Windows-based personal computers. Finally, a revision could provide additional features to assist designers with overlay designs and provide researchers an opportunity to re-investigate some of the basic relationships underlying the computational algorithms contained in ROADHOG.

The two primary global objectives for the proposed research included completely upgrading the existing ROADHOG computer program into an Excel based, interactive system; the second involved incorporating identified improvements to the existing ROADHOG system. In general, all project objectives were met. The ROADHOG system was programmed into Microsoft™ EXCEL® for ease of use. A new, more streamlined equation was developed for estimating the effective structural number of an existing flexible pavement. The sensitivity of ROADHOG to the (required) input of existing pavement thickness was evaluated; it appears that a one-inch difference in input existing pavement thickness results in a difference in recommended overlay thickness ranging from 0.05 to 0.2 inches. Comparisons to the ELMOD system indicated that ROADHOG continues to provide reasonable overlay thicknesses comparable to those provided by the ELMOD "basin fit" procedure. A user's guide for ROADHOG was developed to aid designers in using the Excel based system.

17. Key Words	18. Distribution Statement
Pavement, Flexible Pavement Design, Overlay, Overlay Design	No Restrictions

19. Security Classif. (Of this report)	20. Security Classif. (Of this page)	21. No. of Pages	22. Price
(none)	(none)	33	

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

TRC-0209
Improvements to the ROADHOG Overlay Design Program

EXECUTIVE SUMMARY

The ROADHOG overlay design system and associated computer program has been used by the Arkansas State Highway and Transportation Department (AHTD) for the design of flexible pavement overlays. The program is based on the results of research conducted for AHTD and has been through two modifications since its original inception. While the technical aspects of the program continued to meet expectations, the program itself needed updating. AHTD acquired a new falling weight deflectometer (FWD) in the 1990s, which uses a file format that is not compatible with the original version of ROADHOG. In addition, the original ROADHOG software was written in a DOS-based computer language that would not run consistently on Windows-based personal computers. Finally, a revision could provide additional features to assist designers with overlay designs and provide researchers an opportunity to re-investigate some of the basic relationships underlying the computational algorithms contained in ROADHOG.

The two primary global objectives for the proposed research included completely upgrading the existing ROADHOG computer program into an Excel based, interactive system; the second involved incorporating identified improvements to the existing ROADHOG system. In general, all project objectives were met. The ROADHOG system was programmed into Microsoft™ EXCEL® for ease of use. A new, more streamlined equation was developed for estimating the effective structural number of an existing flexible pavement. The sensitivity of ROADHOG to the (required) input of existing pavement thickness was evaluated; it appears that a one-inch difference in input existing pavement thickness results in a difference in recommended overlay thickness ranging from 0.05 to 0.2 inches. Comparisons to the ELMOD system indicated that ROADHOG continues to provide reasonable overlay thicknesses comparable to those provided by the ELMOD "basin fit" procedure. A user's guide for ROADHOG was developed to aid designers in using the Excel based system.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

Problem Statement

The ROADHOG overlay design system and associated computer program is currently used by the Arkansas State Highway and Transportation Department (AHTD) for the design of flexible pavement overlays. The program is based on the results of research conducted for AHTD (TRC-8705, TRC-9403) and has been through two modifications since its original inception. While the technical aspects of the program continued to meet expectations, the program itself needed updating.

AHTD acquired a new falling weight deflectometer (FWD) in the 1990s, which uses a file format that is not compatible with the original version of ROADHOG. This incompatibility necessitated an update of the software so that it can read both the data file generated by the new FWD and the files previously collected by the "old" FWD. Also, the original software was written in a DOS-based computer language that would not run consistently on Windows-based personal computers. Finally, a revision could provide additional features to assist designers with overlay designs. In addition to updates of the software, Project TRC-0209 also provided researchers an opportunity to re-investigate some of the basic relationships underlying the computational algorithms contained in ROADHOG.

CHAPTER TWO

Project Objectives

There were two primary global objectives for the proposed research. One was to completely upgrade the existing ROADHOG computer program into an Excel based, interactive system. The second was to incorporate any improvements to the existing ROADHOG system, both from a user-defined "operational" perspective, and from a technical design perspective. Specific project objectives included:

- *Ensure specific algorithms used by ROADHOG represent current state-of-the-practice in overlay design.*
- *Incorporate desired features into the ROADHOG computer program.*
- *Completely reprogram the ROADHOG computer system.*
- *Provide user training and design aids to designers.*

In general, all project objectives were met. The ROADHOG system was programmed into Microsoft™ EXCEL® for ease of use. The computational algorithms contained in ROADHOG were examined to ensure they continued to provide consistent, reasonable values for required overlay thickness. After two meetings with AHTD personnel, additional features were incorporated into the ROADHOG spreadsheet. Finally, users were given a demonstration regarding the use of the system at a session held at AHTD headquarters.

CHAPTER THREE

Background

Structural pavement design concepts developed by the American Association of State Highway and Transportation Officials (AASHTO) are based primarily on analyses of data collected at the (then) AASHO road test conducted in Illinois from 1957 to 1961. These concepts were first published for routine use by designers in the 1972 *AASHO Interim Guide for the Design of Pavement Structures*. ***(1)*** The 1972 Guide, however, did not include information relating to the design of overlays (overlays were not included in the original AASHO road test).

A completely updated and revised AASHTO *Guide* was published in 1986. ***(2)*** The 1986 *Guide* did include some design information relating to structural overlays, but did not include specific procedures to be followed by designers. Recognizing this, the Arkansas State Highway and Transportation Department (AHTD) sponsored research project TRC-8705, "NDT Overlay Design", conducted by the Dept. of Civil Engineering at the University of Arkansas. ***(3)*** The goal of the research was to develop a comprehensive design procedure for flexible overlays of existing flexible pavements, based on surface deflection data generated by the falling weight deflectometer (FWD). The two major technical achievements of TRC-8705 were methods for estimating the effective structural number of an existing flexible pavement system (SN_{eff}) and for estimating the *in-situ* resilient modulus of the subgrade soil underlying the structure (M_R). These two methodologies developed by the researchers were actually departures from the analyses suggested in the 1986 *Guide*. Complete descriptions of the specific procedures used by ROADHOG are available elsewhere. ***(3,4)***

The final product of TRC-8705 was ROADHOG, a computer-based flexible pavement overlay design procedure incorporating all necessary analyses related to AASHTO structural pavement design. ***(4)*** The ROADHOG program was written in a compiled, executable database language to allow for the handling of large amounts of FWD deflection data. ***(5)*** After a period of comparative analyses with the then-existing overlay designs used by AHTD, ROADHOG was implemented by AHTD for routine use.

Amid advances in pavement design technology and the growing need for rehabilitation strategies for existing, deteriorating pavement structures, AASHTO published an updated version of its *Guide* in 1993. ***(6)*** The 1993 *Guide* included full procedures for the design of overlays of both flexible and rigid existing structures. To ensure ROADHOG provided overlay designs consistent to those provided by the procedures detailed in the 1993 *Guide*, AHTD sponsored research project TRC-9403, "Reliability and Design Procedure Revisions of ROADHOG". The analyses conducted under TRC-9403 confirmed that ROADHOG indeed provided overlay designs comparable to, and in many cases preferable to, those provided by the "new" AASHTO procedures in the 1993 *Guide*. Complete details of the comparisons are available elsewhere. ***(7,8)***

While TRC-9403 confirmed the efficacy of the ROADHOG procedure, the computer program itself was not updated to operate fully in a WINDOWS computing environment. At that time, the program performed its functions adequately, and a complete re-programming was felt to be beyond the scope of the research project in terms of time and available funds. Continued advances in computing have rendered the original ROADHOG system increasingly obsolete. Thus, a complete re-programming of ROADHOG is needed. During the re-programming process, algorithms contained in ROADHOG should be re-evaluated to ensure ROADHOG continues to provide reasonable, consistent recommendations for overlay thickness.

CHAPTER FOUR

Research Approach

Programming

The research team decided, in conjunction with AHTD, that the best approach to providing a user-friendly version of ROADHOG was to program the procedure into EXCEL® via embedded macros. This way, the user is free to manipulate required overlay thickness for each FWD result as needed in a spreadsheet environment. It was anticipated that AHTD personnel would develop relatively "standardized" reporting and data plotting formats for overlay data. Such an approach greatly reduced the complexity of the re-programming by taking out generic data reporting routines.

After experimenting with a variety of methods to "launch" ROADHOG from within a spreadsheet, it was decided to include the ROADHOG modules in a pull-down menu placed in the menu bar of EXCEL®. Figure 1 shows the pull-down menu containing ROADHOG.

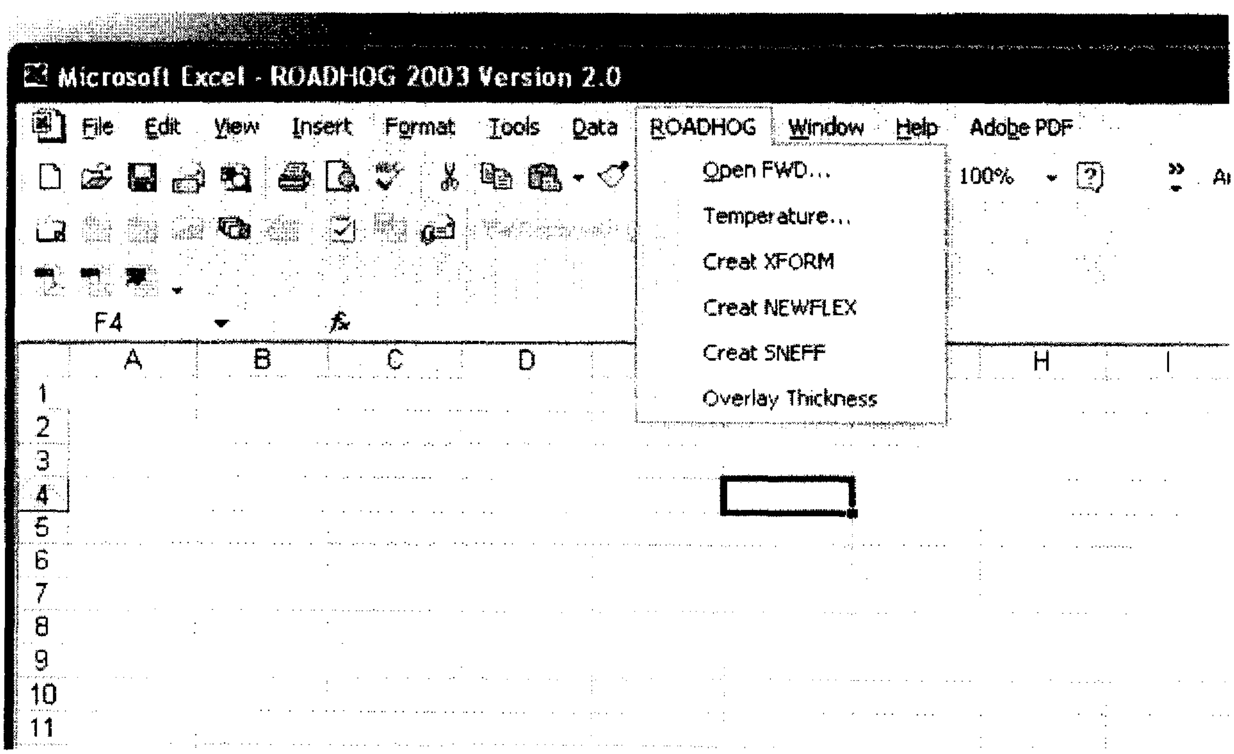


Figure 1. ROADHOG Pull-Down Menu

By using a pull-down menu approach, the ROADHOG program remains "modular" in format – that is, at any time a single module of the program can be updated with little to no effect on the operation as a whole. The user simply follows the menu options downward in order to complete a design. Specific procedures to be followed for each option on the main pull-down menu are contained in Appendix A, Implementation Report.

Procedure Upgrades

Specific algorithms contained in the original ROADHOG program source code were re-evaluated prior to programming within macros. In some cases, computational algorithms and procedures were improved (see Chapter 5). In all cases, dialog boxes containing user prompts were re-envisioned.

Literature relating to procedures followed in the overlay design process was scrutinized for new and/or improved design approaches. It is noted that a thorough evaluation of the ROADHOG system relative to procedures contained in the most current AASHTO pavement design guide (1993) was performed in TRC-9403. *(7,8)* AASHTO-based flexible pavement overlay procedures have not significantly changed since that evaluation. Most new approaches in overlay design are related to *mechanistic* design concepts – the modeling of stresses and strains in the pavement structure, and subsequently relating these stresses and strains to pavement performance. It was beyond the scope of this project to develop and/or include mechanistic design concepts in the ROADHOG system.

One area related to FWD deflection-based procedures scrutinized by the research team involved temperature corrections of field deflections. An extensive study carried out in North Carolina recommended guidelines for correcting FWD deflections based on pavement temperature. *(9)* However, the amount and type(s) of data required to accomplish the recommended corrections is not routinely measured by AHTD personnel during deflection surveys. The research team decided to continue with the temperature correction originally developed for ROADHOG by Kong in TRC-8705. *(3)*

CHAPTER FIVE

Design Algorithm Modifications and Investigations

In the process of reprogramming design algorithms used in the ROADHOG system into EXCEL® macros, equations were examined for accuracy and consistency. As a result, some adjustments to ROADHOG calculation procedures were made. The sections that follow detail these investigations and adjustments.

Deflection / Effective Structural Number Relationship

The centerpiece of the ROADHOG procedure -- the specific algorithm that is unique to ROADHOG – is the methodology used to estimate the effective structural number of the existing flexible pavement structure (SN_{eff}). The concept was originally developed by Kong. ***(10)*** The effective structural number of the existing pavement is related to *Delta-D*, the difference between the FWD surface deflection measured directly under the load (the maximum deflection, d_0) and the deflection measured at a distance from the applied load equal to the thickness of the pavement structure, t (d_t). Figure 2 illustrates the Delta-D concept.

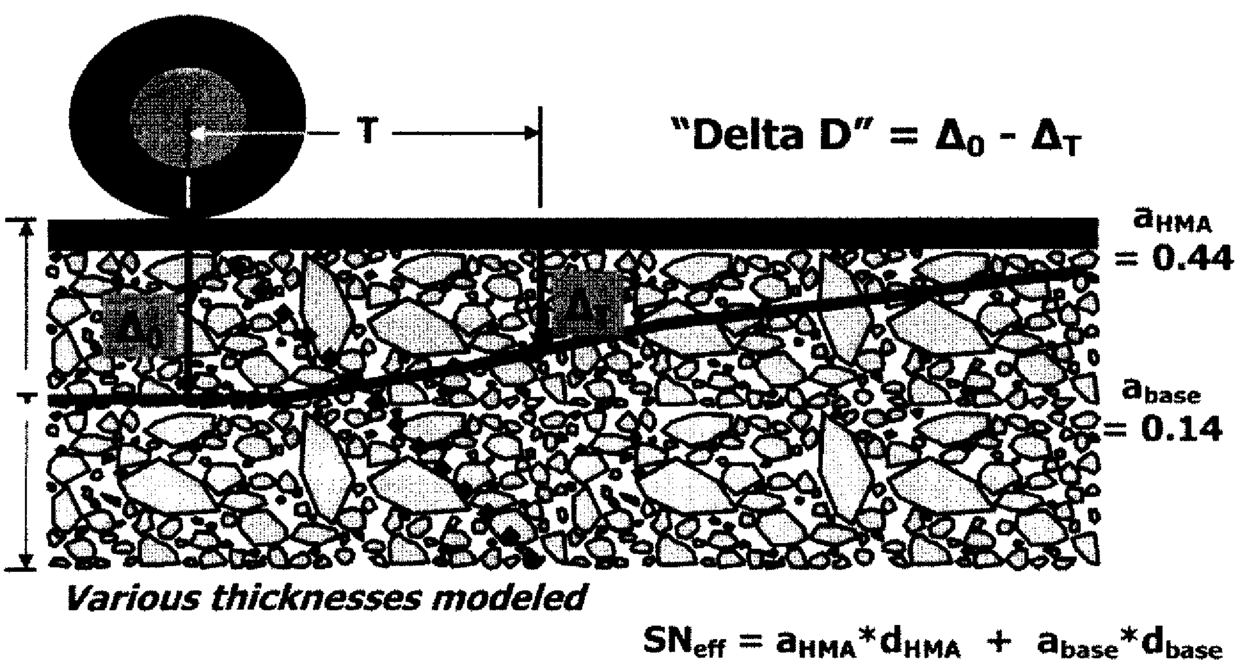


Figure 2. Effective Structural Number "Delta D" Concept

The SN_{eff} approach used in ROADHOG requires the existing pavement structure thickness to be known, or closely estimated. The SNEFF module contained in ROADHOG contains three equations relating SN_{eff} and Delta-D originally developed by Kong. *(10)* These three equations represent total existing pavement structure thicknesses of 8, 12, and 24 inches. Existing pavement structures with thicknesses different than these three require interpolation in the module. For example, a pavement structure of 10 inches requires the SN_{eff} to be determined for both the 8-inch and 12-inch relationship, and interpolated for the given 10-inch thickness.

Each of Kong's relationships was originally programmed into ROADHOG using 4^{th}-order polynomial equations, which gave the "best fit" to the data. *(4)* However, in testing the equations after being placed into macro-based modules for this project using field FWD files supplied by AHTD, it was noted that for certain FWD results a very erroneous SN_{eff} was obtained. Additional investigation revealed that, due to the nature of a polynomial equation, large values of Delta-D caused the equation to produce errors, as shown in Figure 3.

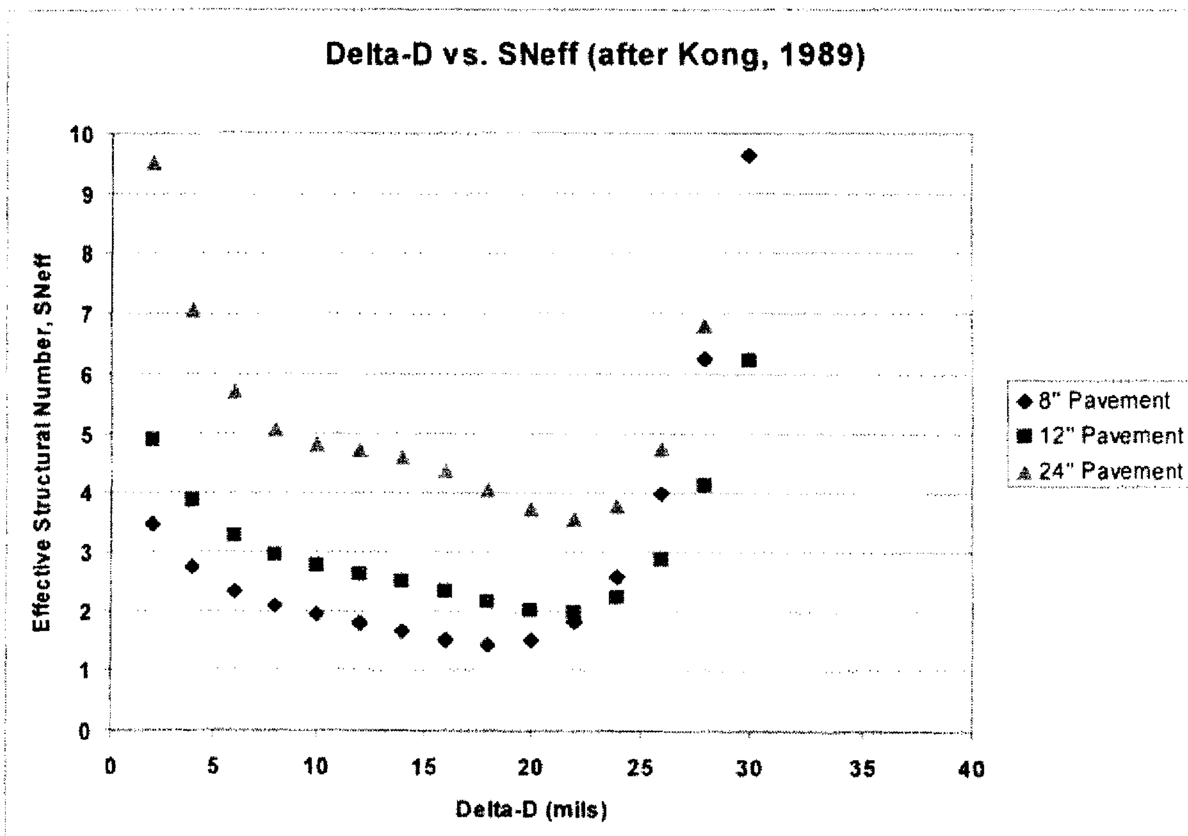


Figure 3. Delta-D / SN_{eff} Relationship (after Kong, 1989)

As shown in Figure 3, the equation used to represent Kong's Delta-D / SN_{eff} relationship contains an inflection point at Delta-D values between 20 and 25 mils (one mil is equal to 1/1000 inch). Therefore, large values of Delta-D result in erroneous SN_{eff} values.

To solve the issue illustrated in Figure 3, new equations were developed to represent Kong's original data. Figure 4 shows Delta-D / SN_{eff} curves generated using the new equations.

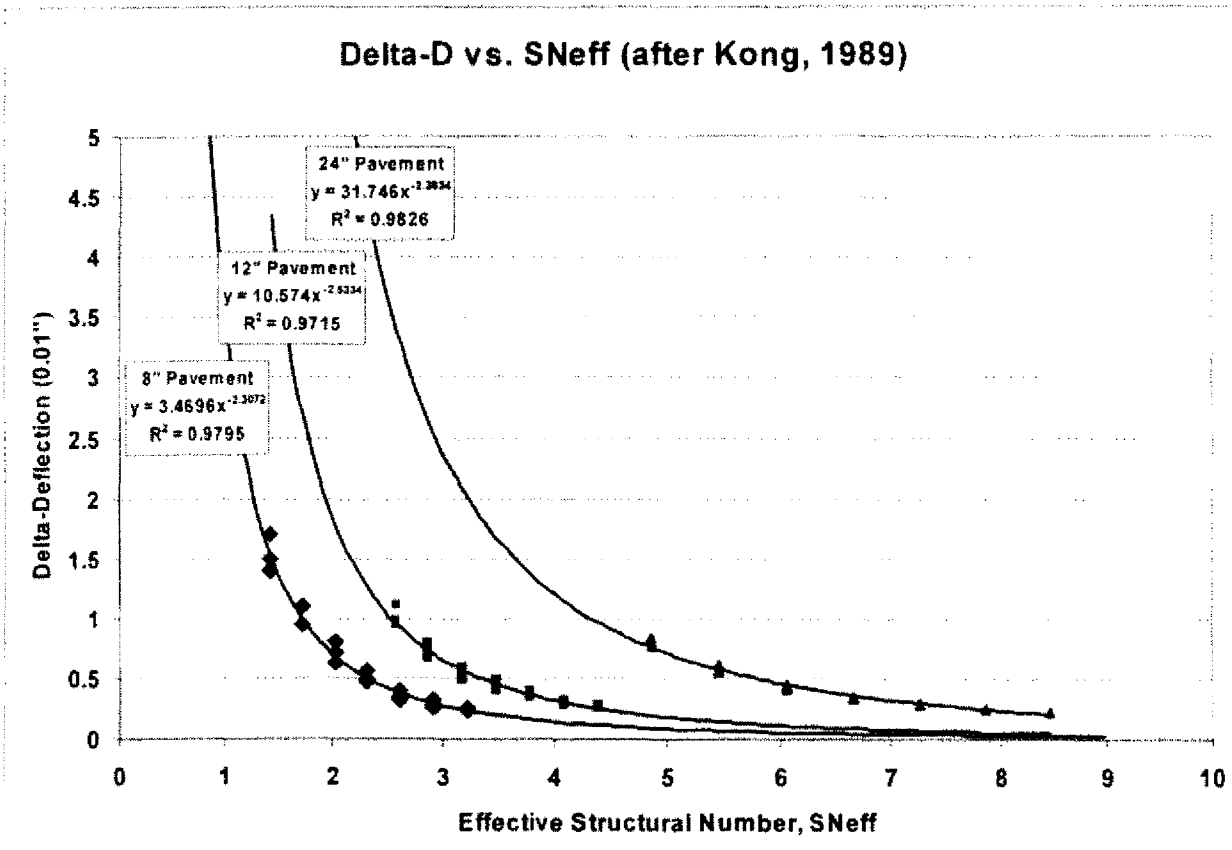


Figure 4. Improved Delta-D / SN_{eff} Relationships

It is noted that in Figure 4, the "x" and "y" axes have been reversed from those shown in Figure 3. The equations shown in Figure 4 were proven valid for any value of Delta-D. One problem remained, however. Implementation of the equations shown in Figure 4 would still require the interpolation of SN_{eff} for existing pavement thicknesses different than those shown – 8, 12, and 24 inches. The interpolation used in ROADHOG is linear; that is, it is assumed that the SN_{eff} value for existing pavement thicknesses between those shown in Figure 4 is linearly related to those values for which SN_{eff} is known. It is obvious from the curves shown in Figure 4 that an assumption of linearity is a simplification.

Additional analyses of Kong's original Delta-D / SN_{eff} data led to the development of a single equation that incorporates any given existing pavement thickness. Figure 5 shows the equation and resulting curves in relation to Kong's data. It is apparent from Figure 5 that the new equation is adequate to describe the Delta-D / SN_{eff} relationship. The equation shown in Figure 5 is reproduced as Equation 1, and is now included in ROADHOG.

$$SN_{eff} = 0.3206\,(Delta\ D)^{-0.42}\,(Pavement\ Thickness)^{0.8175} \qquad Eq.\ 1$$

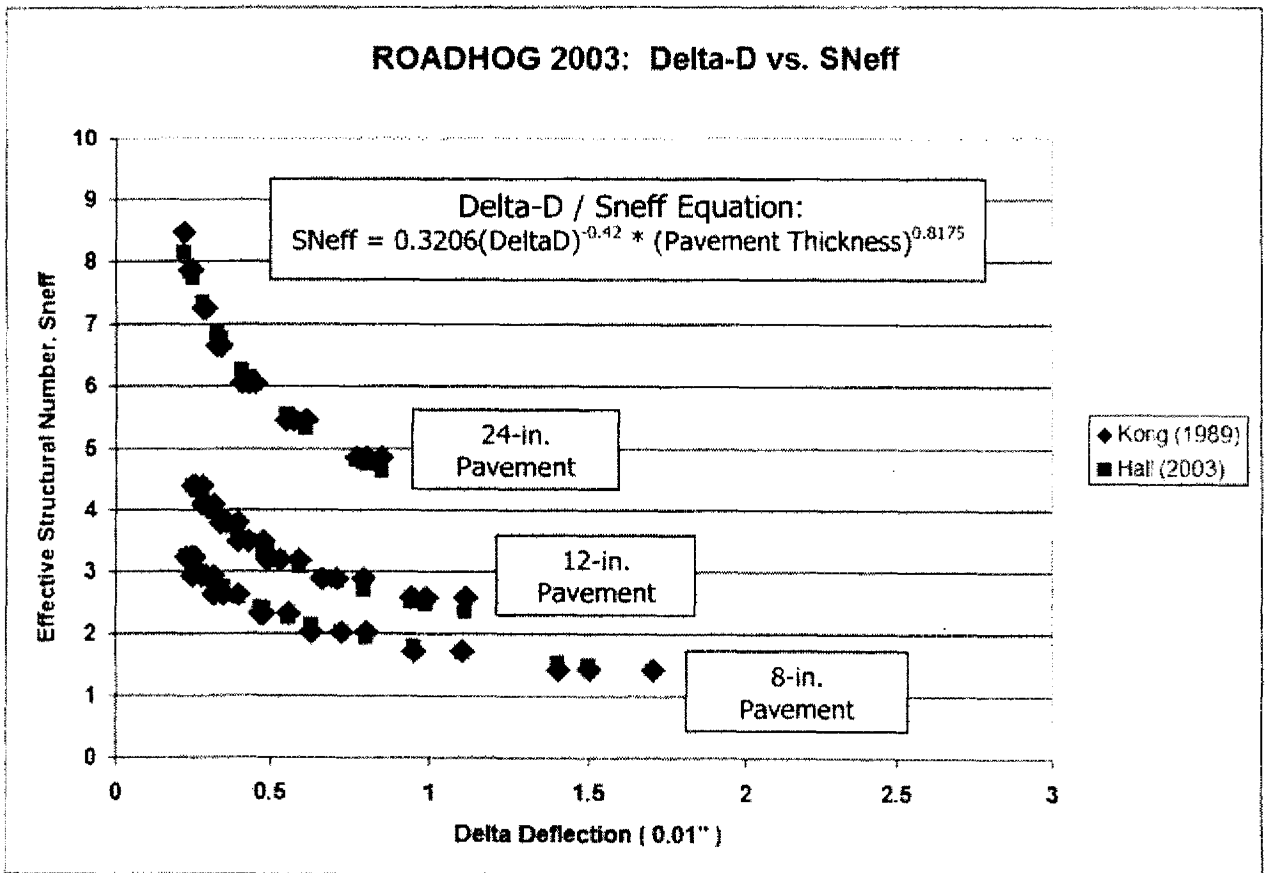


Figure 5. New ROADHOG Delta-D / SN_{eff} Relationship

ROADHOG Overlay Thickness Sensitivity

The ROADHOG overlay design procedure is primarily deflection based; that is, most inputs into the design procedure are calculated using pavement surface deflections obtained using the falling weight deflectometer (FWD). The NEWFLEX module does require the designer to input AASHTO new flexible pavement design variables: Traffic, Reliability, Standard Deviation, and Delta PSI (for in-depth discussions of these inputs refer to the AASHTO Guide ***(6)***). The Arkansas State Highway and Transportation Department (AHTD) provides guidance for selecting these inputs. ***(11)***

Additional designer inputs are required by the SNEFF module – total pavement structure thickness and total thickness of the hot-mix asphalt (ACHM) layers (surface, base, and binder courses). In many cases these values are known; in other cases pavement thickness is only estimated. AHTD provided a field FWD file for Job No. 110384, Route 49, Section 10, located in Phillips County. The nominal measured pavement thickness on site was determined to be approximately twelve inches, including approximately six inches of ACHM. A number of design "runs" were performed with ROADHOG 2003, using various pavement and ACHM thickness values within the SNEFF module. All other inputs were held constant. Figure 6 is a plot of required overlay thickness versus ACHM thickness for Job 110384.

Of primary interest in Figure 6 is the slope(s) of the lines shown that represent various total input pavement thickness values. These slopes range from 0.05 to 0.21; the slope relates to the relative sensitivity of the required overlay thickness to the input ACHM thickness. For this job, underestimating the ACHM thickness (in the SNEFF input) by one inch could result in underestimating the required overlay thickness by 0.05 to 0.2 inches. Thus, in order to ensure the required overlay thickness remains within about one-half inch of the "true" required overlay thickness (the overlay thickness which would result from using a precise, known measurement of pavement layer thicknesses) a designer would need to estimate total and ACHM thicknesses within about two inches.

The relative sensitivity of ROADHOG-generated overlay thickness values shown in Figure 6 are typical for most of the jobs provided by AHTD. In general, overestimating or underestimating ACHM thickness in the SNEFF module by one inch may result in over- or underestimating required overlay thickness by up to one-quarter inch.

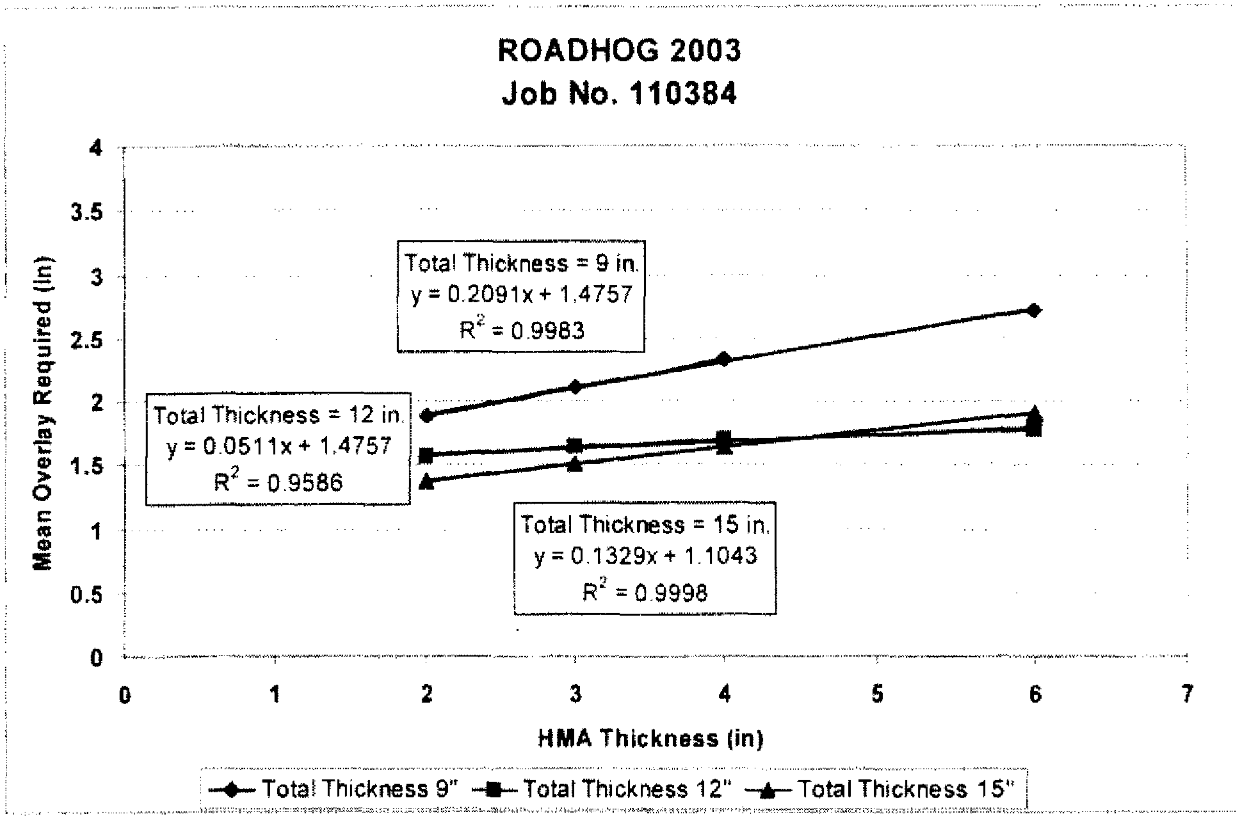


Figure 6. Sensitivity of Overlay Thickness to Pavement / ACHM Thickness (Job 110384)

ROADHOG versus ELMOD

Four overlay design projects were provided by AHTD to perform a comparison between the ROADHOG design procedure and the ELMOD (Elastic Layer Method Overlay Design) procedure. Routine use of ROADHOG was discontinued due to difficulties running the software on Windows-based computers, and deflection-based overlay design analyses have subsequently been performed using ELMOD. The comparison is based on overlay thickness values obtained from ELMOD when performed using the 'deflection basin fit' protocol. Traffic inputs and pavement layer thicknesses used in ROADHOG were taken from the ELMOD output files. Table 1 lists the projects used in the comparison. Figure 7 shows the comparison of overlay thickness values.

Job No.	Route	Section	County	Total Thickness (in)	ACHM Thickness (in)	No. of FWD Observations
050100	36	3	White	10	8	59
110384	49	10	Phillips	12	6	229
110337	64	17	Crittenden	13	7	108
R60032	70	8	Garland	15	7.5	66

Table 1. Projects Used for ROADHOG / ELMOD Comparison

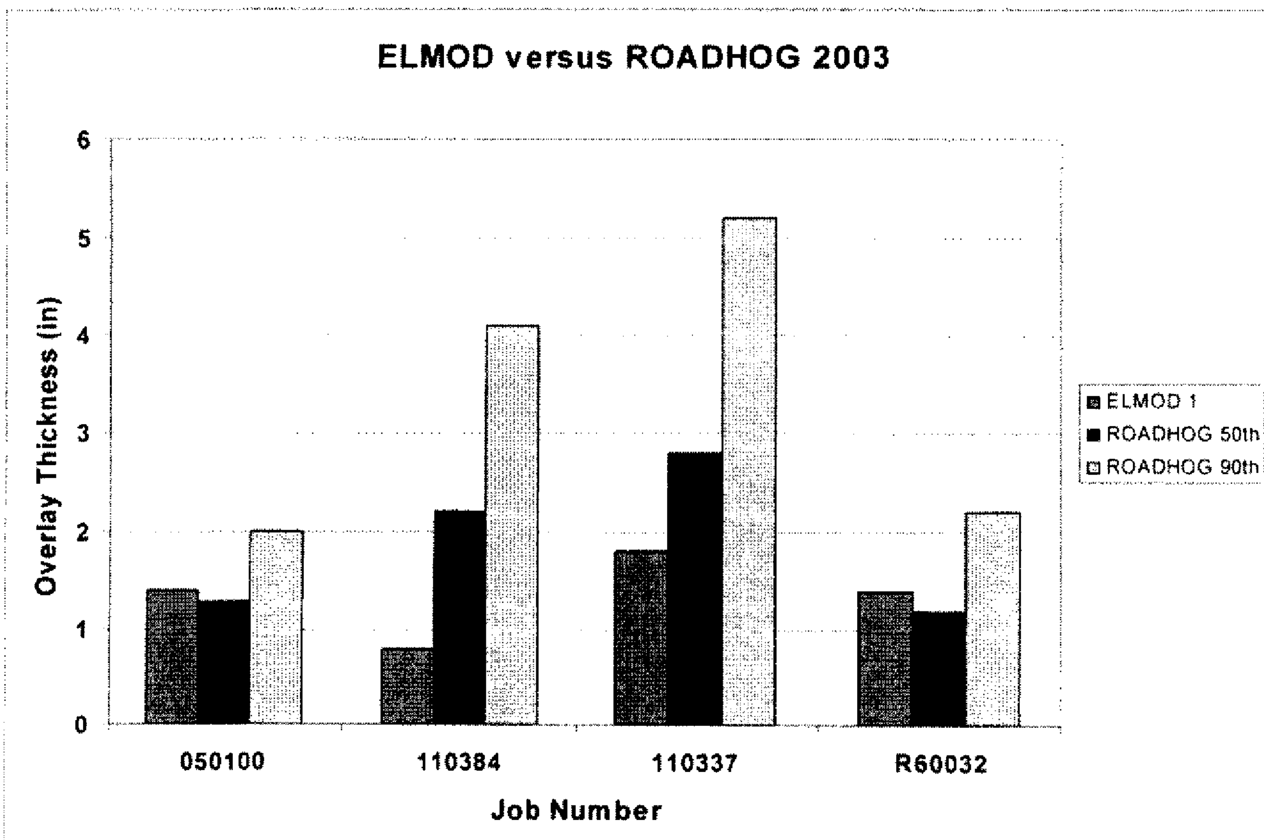


Figure 7. Overlay Thickness Comparison – ROADHOG versus ELMOD

Figure 7 shows a mixed-bag of results. A comparison of ELMOD results with the 50th Percentile (average) ROADHOG results suggests the two procedures provide similar recommendations regarding overlay thickness. However, the ELMOD results shown represent a 90th Percentile value. A comparison of ELMOD results with the 90th Percentile ROADHOG values indicates that ROADHOG recommends a higher overlay thickness for all jobs shown – yet it must be noted that the "average" (50th Percentile) ROADHOG result is typically used for design. Reiterating the first observation, it appears that ROADHOG provides a similar, if not only slightly more conservative, recommended overlay thickness than does ELMOD.

CHAPTER SIX

Conclusions and Recommendations

As stated earlier, all project objectives were generally met. Specific observations, conclusions, and recommendations related to the project are contained in the listing that follows.

- The ROADHOG overlay design system has been programmed into Microsoft™ EXCEL®.
- Design procedures contained in ROADHOG continue to reflect current AASHTO flexible pavement design and rehabilitation principles.
- Specific ROADHOG algorithms related to the estimation of the effective structural number (SN_{eff}) of the existing pavement were upgraded. A new equation was developed and incorporated which includes a direct input of existing pavement thickness – eliminating the need to interpolate results for thicknesses other than 8, 12, and 24 inches.
- The sensitivity of the ROADHOG procedure was evaluated in terms of the accuracy of the existing pavement thickness input. It appears that a change in the existing pavement structure thickness and/or ACHM thickness input of one inch results in an associated change in required overlay thickness ranging from 0.05 to 0.2 inches.
- A comparison of required overlay thickness generated by ROADHOG with thickness generated by ELMOD shows that ROADHOG provides overlay thickness comparable to the "basin fit" ELMOD model (90th percentile value).
- Overall, the ROADHOG procedure may be used with confidence to design ACHM overlays of existing flexible pavements.

An Implementation Report containing a user guide for the ROADHOG system is included in this report as Appendix A.

REFERENCES

1. *Interim Guide for the Design of Pavement Structures*, American Association of State Highway Officials, Washington, D.C., 1972.
2. *AASHTO Guide for the Design of Pavement Structures,* American Association of State Highway and Transportation Officials, Washington, D.C., 1986.
3. Elliott, R.P., Hall, K.D., Morrison, N.T., and Hong, K.S., "The Development of ROADHOG, A Flexible Pavement Overlay Design Procedure", *Final Report, TRC-8705 NDT Overlay Design*, Report No. FHWA/AR-91/003, Arkansas State Highway and Transportation Department, Little Rock, AR, Nov. 1990.
4. Hall, K.D., "Development of a Flexible Pavement Overlay Design Procedure Utilizing Nondestructive Testing Data", MS Thesis, University of Arkansas, Fayetteville, AR, August 1990.
5. Hall, K.D., and Elliott, R.P., "ROADHOG.exe User's Manual", Report No. UAF-ANTRC-90-001, University of Arkansas, Fayetteville, AR, May 1990.
6. *AASHTO Guide for the Design of Pavement Structures, 1993*, American Association of State Highway and Transportation Officials, Washington, D.C., 1993.
7. Hall, K.D., Elliott, R.P., and Watkins, Q.B., "Final Report – TRC 9403, Reliability and Design Procedure Revisions of ROADHOG", Arkansas State Highway and Transportation Department, Little Rock, AR, 1995.
8. Watkins, Q.B., "A Comparison of the AASHTO and ROADHOG Flexible Pavement Overlay Design Procedures", MS Thesis, University of Arkansas, Fayetteville, AR, May 1995.
9. Park, HM, Kim, YR, and Park, S., "Temperature Correction of Multiload-Level Falling Weight Deflectometer Deflections", Transportation Research Record No. 1806, TRB, National Academy of Sciences, Washington, DC, 2002.
10. Kong, S.H., "Determination of Effective Structural Number in Flexible Pavement Overlay Design", Master's Thesis, University of Arkansas, Fayetteville, Arkansas, 1987.
11. *Roadway Plan Development Guidelines*, Arkansas State Highway and Transportation Department, Little Rock, Arkansas, 1997.

APPENDIX A

IMPLEMENTATION REPORT
ROADHOG User's Manual

ROADHOG User's Manual

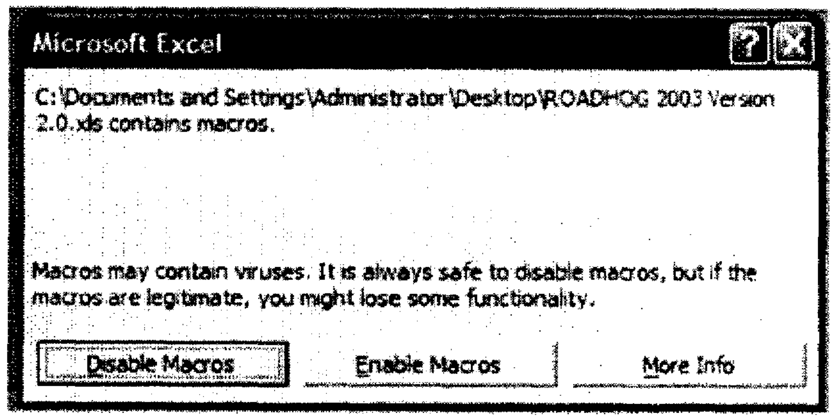
The ROADHOG design procedure is contained in macro programming within a Microsoft Excel spreadsheet. This document provides information related to running the ROADHOG program. It does not provide details concerning the theory and concepts behind AASHTO pavement design or specific ROADHOG algorithms. For design concepts, refer to the Project Final Reports for TRC-8705, TRC-9403, and TRC-0209.

This document does not contain detailed instructions regarding the normal file operations associated with the Windows operating environment, nor detailed instructions regarding normal operations associated with Microsoft Excel.

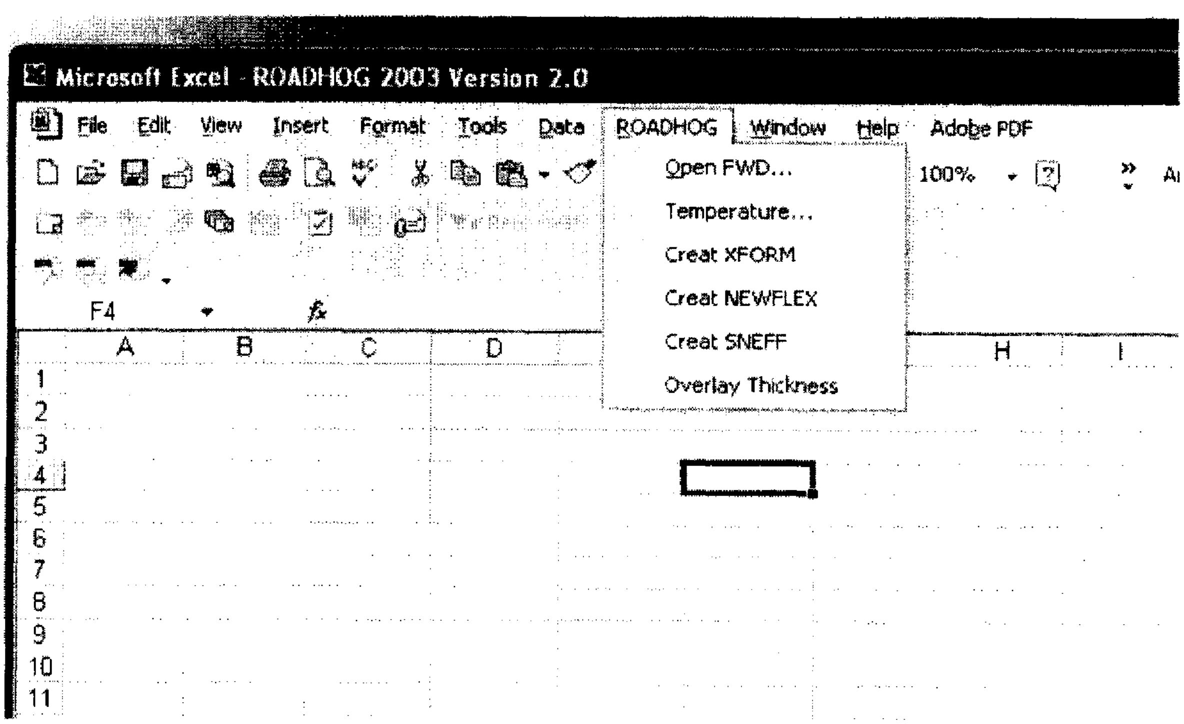
Opening ROADHOG

ROADHOG is started by double-clicking the ROADHOG 2003 Version 2.0 icon – this opens an Excel spreadsheet containing the ROADHOG macro. ROADHOG cannot be started from within the Excel program – it must be started "externally" using the icon.

Since ROADHOG is programmed as a macro within Excel, a macro-enable dialog box will appear when the spreadsheet opens. Click the "Enable Macros" button to ensure ROADHOG is available.

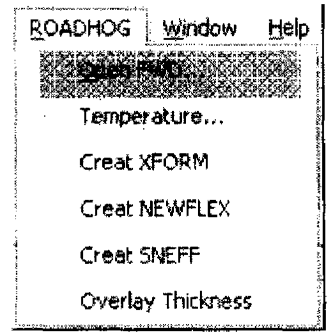


The ROADHOG macro program places a pulldown menu in the main menu bar of Excel. To initiate ROADHOG and access its modules, simply click on the ROADHOG entry in the menu bar. The modules contained in ROADHOG will appear. Clicking on any entry in the pull-down menu will launch that module.

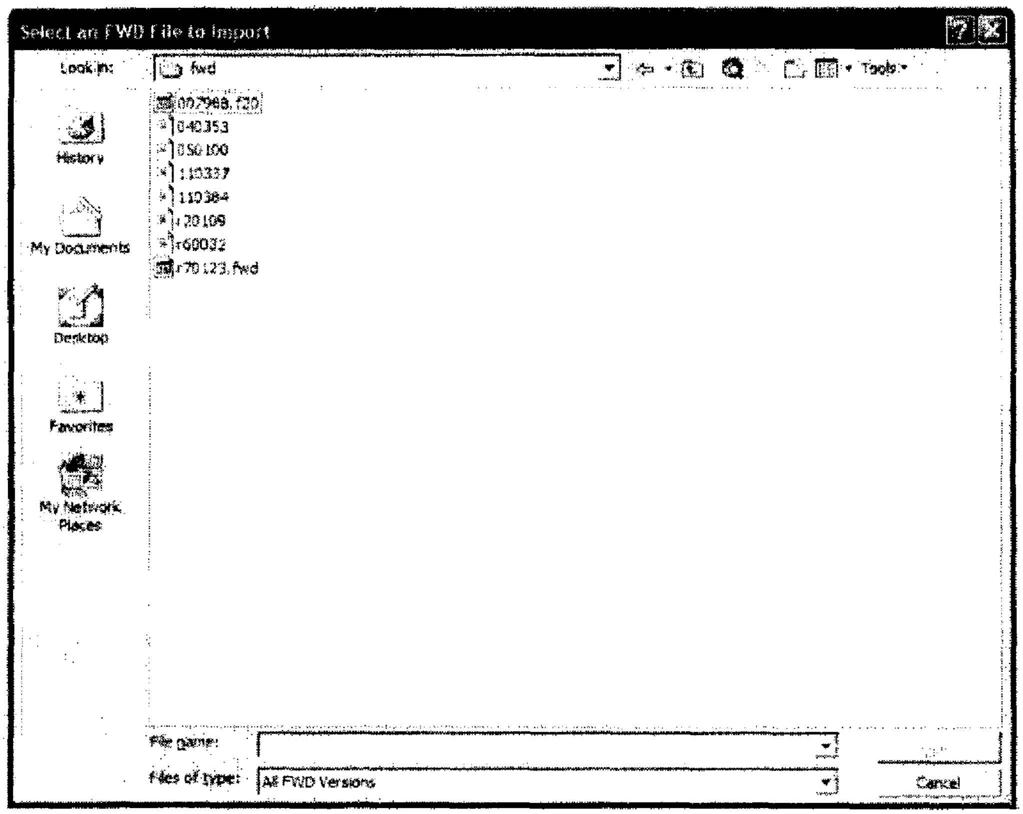


The sections that follow detail the use of each module in ROADHOG.

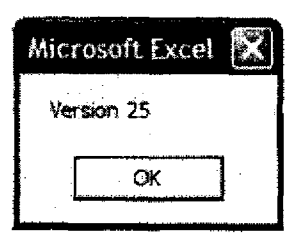
Importing an FWD File into ROADHOG



- Click on the ROADHOG entry in the Excel menu bar.
- Highlight and click the "Open FWD" entry in the ROADHOG pull-down menu.
- Select the desired FWD file within the file selection dialog box (this box operates identically to any Windows-based program).

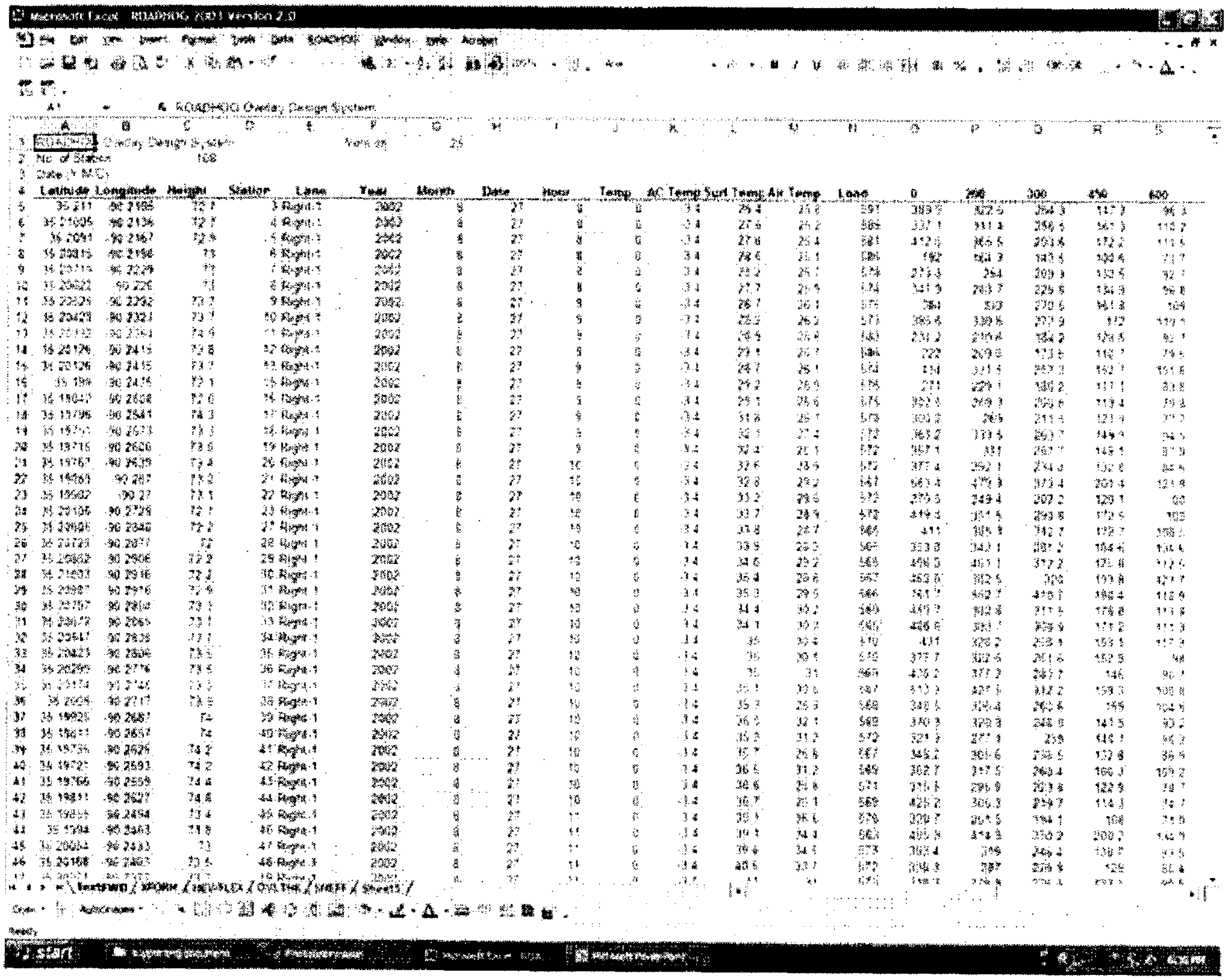


- Once a file has been selected, the user is informed of the FWD version number (15, 20, 25). Click the "OK" button to acknowledge the selection.



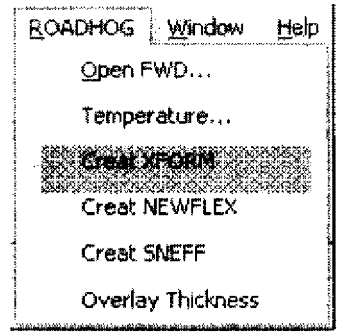
- ROADHOG reads the field FWD file into a spreadsheet. The worksheet TAB (the name of the worksheet, located at the bottom of the worksheet) will read "TextFWD".

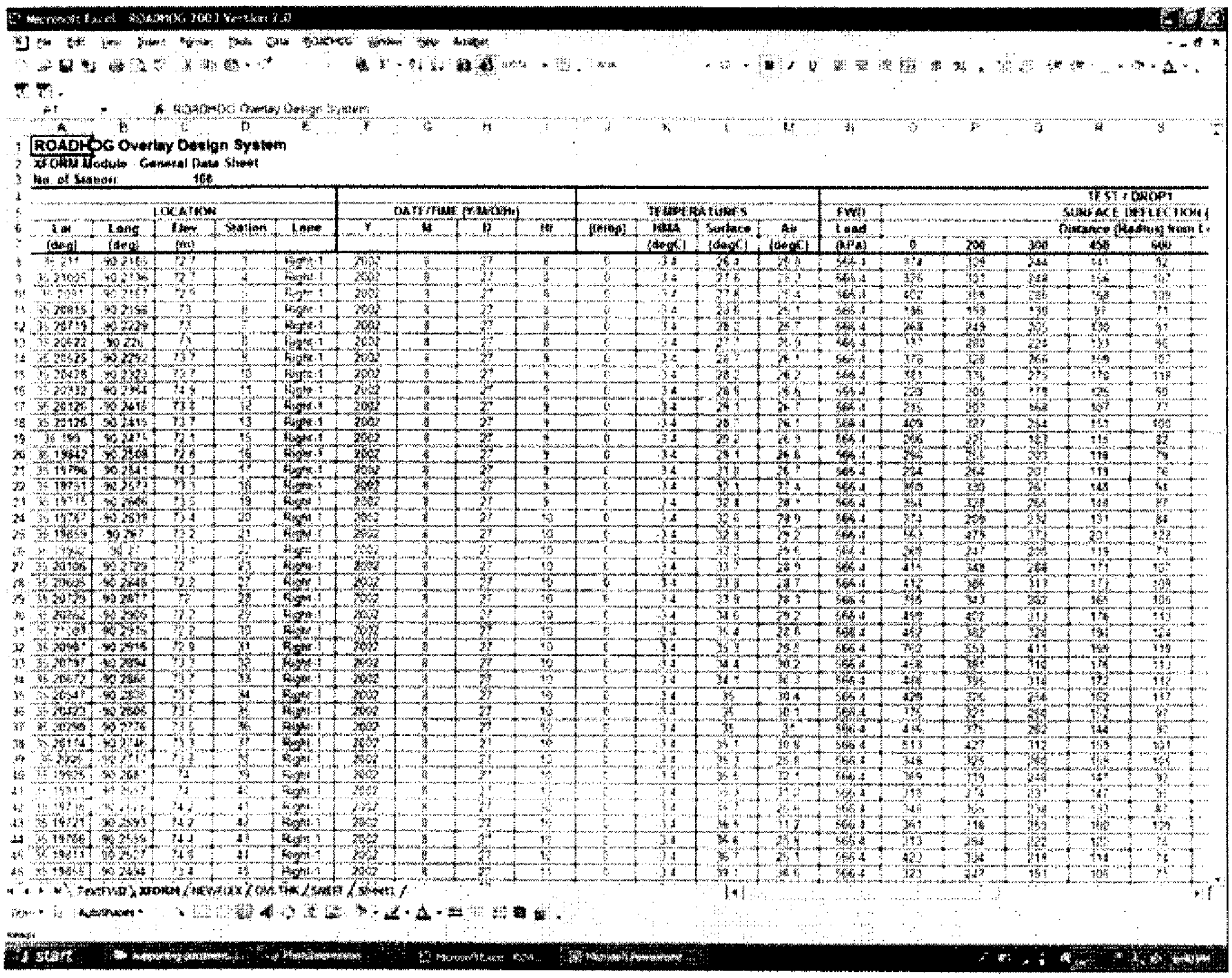
  This file is a delimited text file – it must be transformed into a ROADHOG data file before use.



Transforming a Field FWD File into a ROADHOG Data File

- Click on the ROADHOG entry in the Excel menu bar.
- Highlight and click the "Creat XFORM" entry in the ROADHOG pull-down menu.

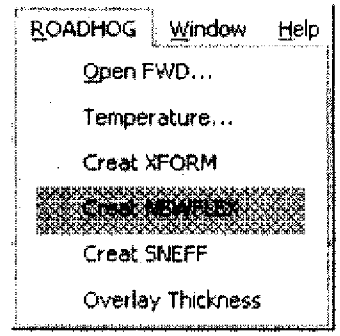




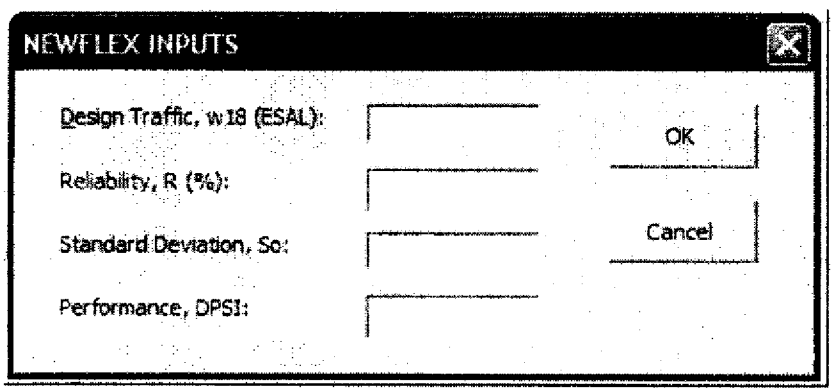
The XFORM process executes automatically – the TextFWD worksheet is used to create a new worksheet – XFORM – that is formatted for further use in ROADHOG. Note that multiple FWD drops are separated in the XFORM worksheet.

Determination of SN_{future} – New Pavement Design: NEWFLEX Module

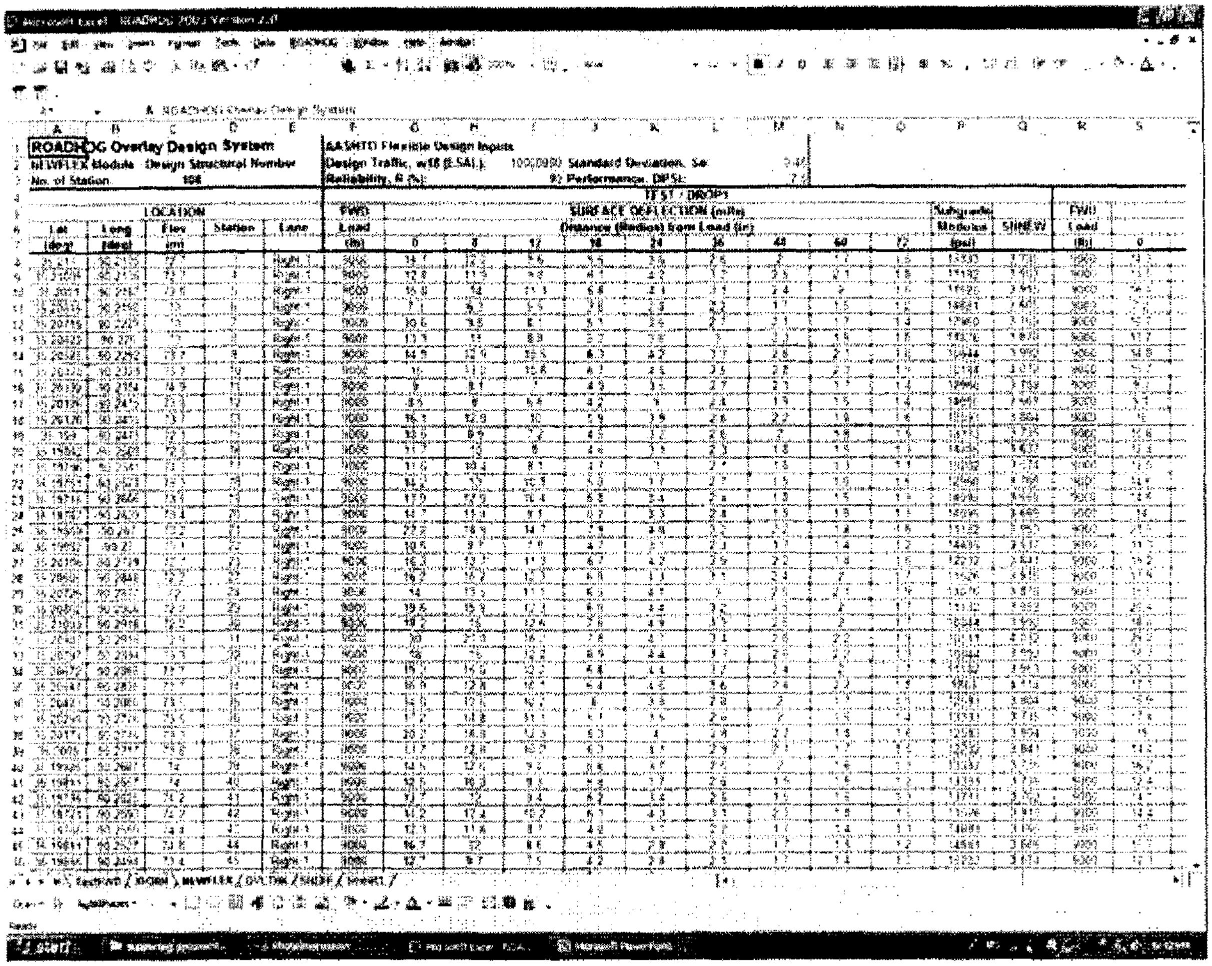
- Click on the ROADHOG entry in the Excel menu bar.
- Highlight and click the "Creat NEWFLEX" entry in the ROADHOG pull-down menu.



- Supply pavement design input values in the NEWFLEX dialog box (shown below). Click "OK" in the dialog box to complete the NEWFLEX module.



Values used for pavement design required by the NEWFLEX module are established by the AHTD Roadway Design section. AHTD policy for new pavement design may be found in the AHTD *Roadway Plan Development Guidelines*.



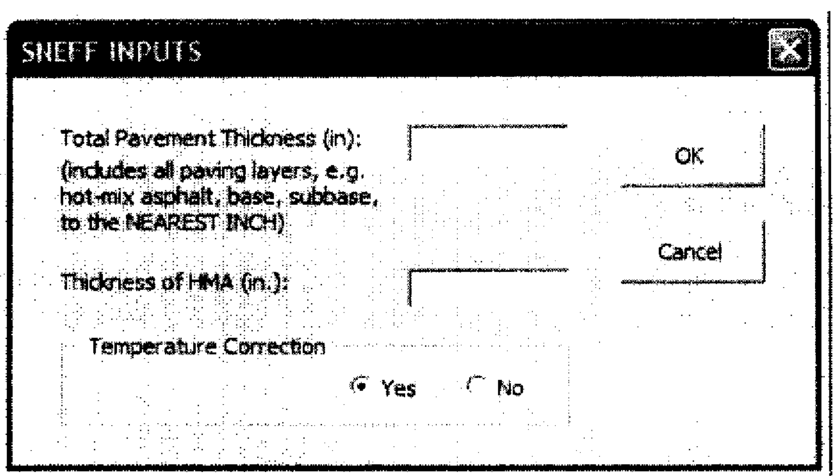
The NEWFLEX module creates a new worksheet – NEWFLEX. Within the NEWFLEX module, three calculations are executed; the results are shown on the NEWFLEX screen. The calculations include:

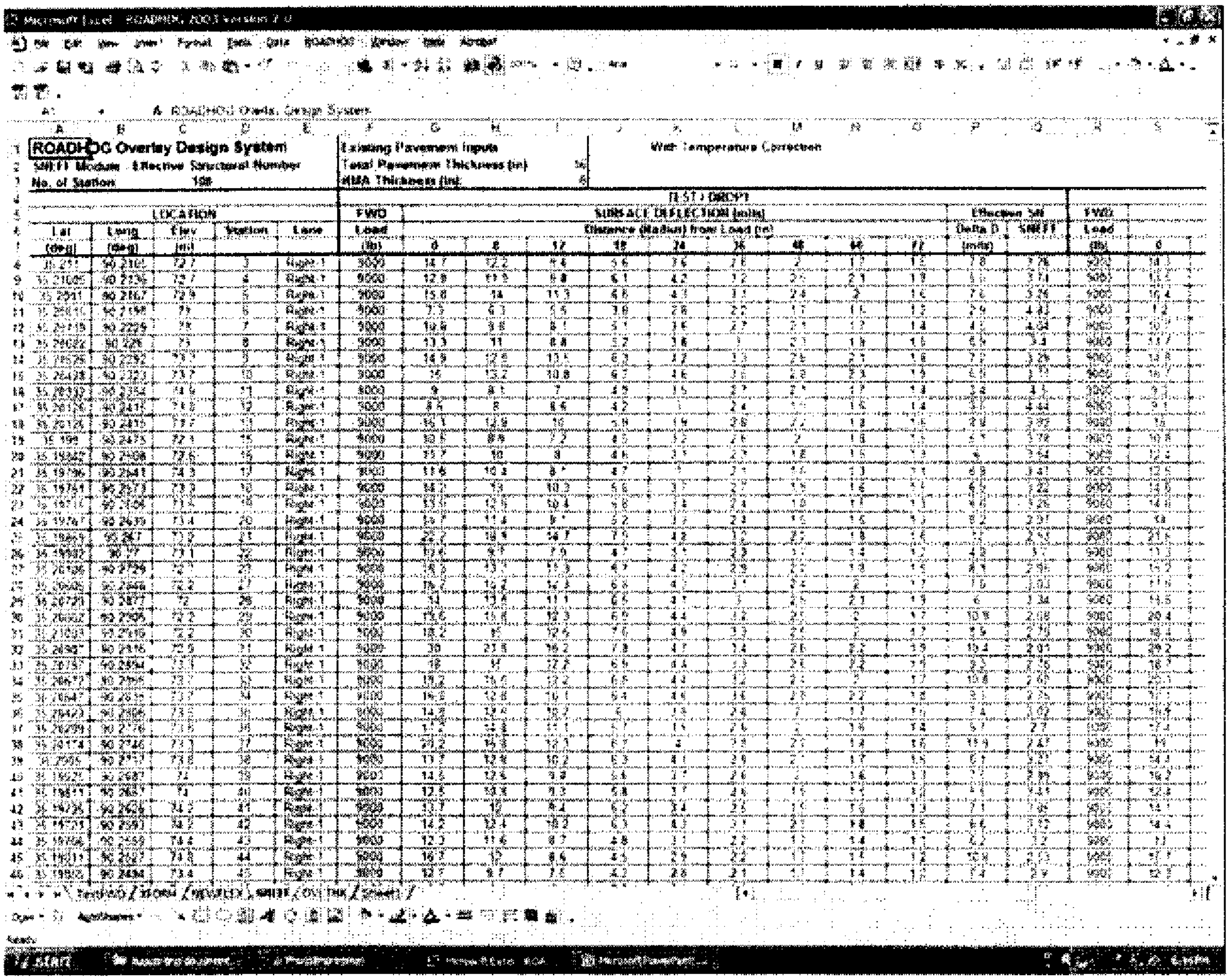
- The FWD load/force is normalized to 9000 pounds; resulting pavement deflections are adjusted to reflect this normalization.
- The subgrade resilient modulus is calculated from normalized FWD deflections.
- The AASHTO flexible design equation is solved, based on the input values provided in the NEWFLEX dialog box and the calculated subgrade resilient modulus.

Determination of $SN_{effective}$ – SNEFF Module

- Click on the ROADHOG entry in the Excel menu bar.
- Highlight and click the "Creat SNEFF" entry in the ROADHOG pull-down menu.

- Supply pavement layer thickness and hot-mix asphalt layer thickness values in the SNEFF dialog box (shown below).
- ROADHOG contains algorithms for adjusting deflections for measured pavement temperature. To enlist this procedure, click YES in the Temperature Correction area of the SNEFF dialog box. Designers should note that FWD results obtained during periods when pavement temperatures range beyond approximately 65 – 75 deg. F should be corrected for possible temperature effects.
- Click "OK" in the dialog box to complete the SNEFF module.

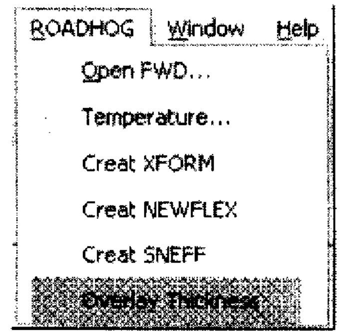




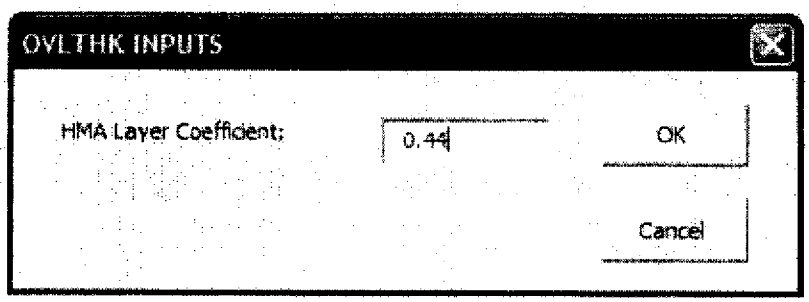
The SNEFF module creates a new worksheet – SNEFF. For each FWD drop, the worksheet shows the calculated "Delta D" (see TRC-0209 Final Report) and the associated effective structural number of the existing pavement structure (SN_{eff}). The worksheet also shows, in the header section, the input total pavement thickness, the input ACHM thickness, and whether temperature correction was chosen.

Determination of Overlay Thickness – OVLTHK Module

- Click on the ROADHOG entry in the Excel menu bar.
- Highlight and click the "Overlay Thickness" entry in the ROADHOG pull-down menu.



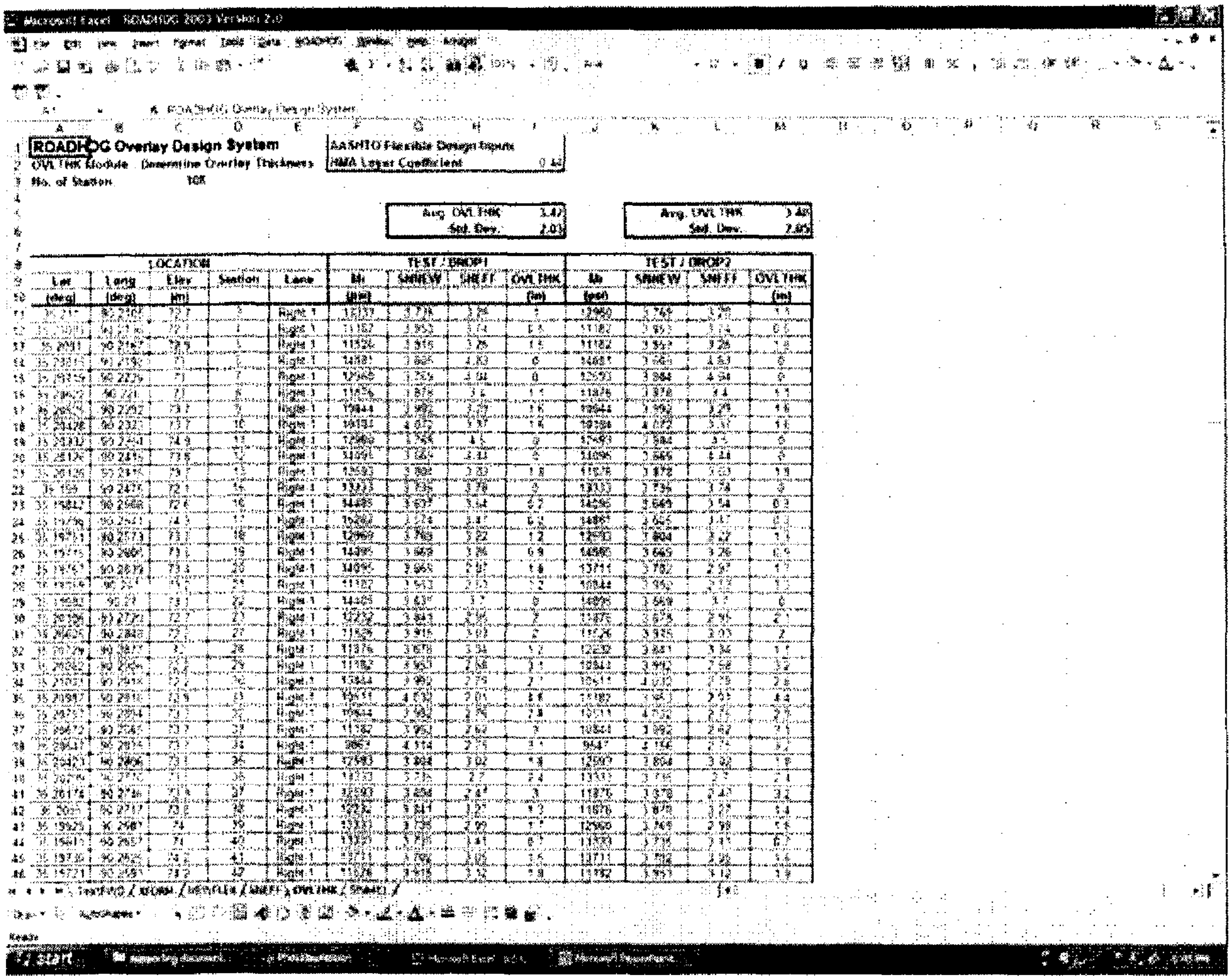
- Supply the AASHTO structural layer coefficient for hot-mix asphalt in the OVLTHK dialog box (shown below). For ease of use, a default value of 0.44 is supplied.
- Click "OK" in the dialog box to complete the OVLTHK module.



- AHTD uses the following 'a' values (layer coefficient) for hot-mix asphalt:

Surface (9.5 mm and 12.5 mm nominal maximum size):	0.44
Binder (25 mm nominal maximum size)	0.44
Base (37.5 mm nominal maximum size)	0.36

- The OVLTHK module does not contain a provision for using more than one structural layer coefficient 'a' value within a single overlay. In other words, a given recommended overlay thickness may be subdivided into surface and binder layers (since each uses an 'a' value of 0.44), but cannot include a base layer.



The OVLTHK module creates a new worksheet – OVLTHK. For each FWD drop, the worksheet includes the following information:

- Drop location / station
- Subgrade resilient modulus (M_R)
- Future required structural number (SN_{NEW})
- Effective structural number of existing pavement (SN_{EFF})
- Required overlay thickness

The OVLTHK worksheet also shows, for each drop series, the average recommended overlay thickness and the associated standard deviation. Designers may use this information to determine various "percentile" thickness requirements.

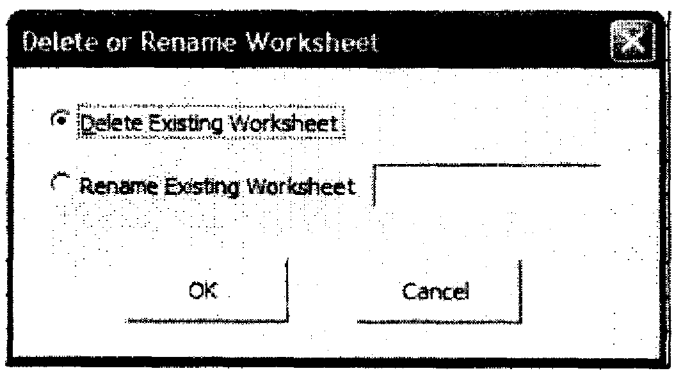
Performing Multiple Overlay Designs Using the Same FWD File

ROADHOG allows the designer to perform multiple design scenarios without restarting the design process 'from scratch'. Typically, multiple designs may be investigated by the following process:

- A new set of design values, i.e. Reliability, are used in the NEWFLEX module to create a new set of required (future) structural numbers.

- An associated new set of required overlay thicknesses are generated using the OVLTHK module.

When a new design run is desired, simply re-perform the NEWFLEX module. When a new module is started (after the module has been previously performed) the user is given a choice of deleting the previous design, or saving the previous design by saving the worksheet using a different name, as shown in the dialog box below:



The designer is cautioned that if an existing worksheet is deleted in order to create a new design, subsequent modules must still be performed – data is not updated automatically. For example, if a new NEWFLEX module is performed (and a new NEWFLEX worksheet is created) – a new OVLTHK worksheet is not automatically created, nor is the existing OVLTHK worksheet automatically updated. The OVLTHK module must be re-performed in order to use the newly created NEWFLEX module in design.

Saving a ROADHOG Design

Once a design has been completed, the entire Excel workbook file may be saved. **The designer is strongly cautioned to save the completed ROADHOG design file using the 'Save As' command in the File menu in order to avoid overwriting the original ROADHOG file.** The 'Save As' command is shown (below) in the File pull-down menu.