SHRP-P-633

Analysis of Section Homogeneity, Non-Representative Test Pit and Section Data, and Structural Capacity

FWDCHECK Version 2.00

Volume I—Technical Report

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Volume I—Technical Report

P-001B Technical Advisory Staff
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Program Manager: *Neil Hawks*
Project Manager: *Cheryl Richter*
Production Editor: *Carina S. Hreib*

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Strategic Highway Research Program
National Academy of Sciences
2101 Constitution Avenue N.W.
Washington, DC 20418

(202) 334-3774

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ABSTRACT

Nondestructive deflection testing using falling weight deflectometers is one element of the monitoring effort currently underway by the Strategic Highway Research Program (SHRP) for the Long Term Pavement Performance (LTPP) study. Because accurate data is key to the success of the LTPP study, SHRP has implemented a number of measures to ensure the quality of deflection data. They include equipment comparison and calibration, standardized field testing procedures and field data checks, and quality assurance software.

Equipment calibration and field data checks built into the FWD data acquisition software are the first line of defense against invalid deflection data. The second line of defense is a computer program, called FWDSCAN, which verifies the integrity, completeness, and compliance with the established test pattern of the field data after it is delivered to the SHRP regional office. For the final stage in the quality assurance process, a computer program called FWDCHECK has been developed to analyze deflection data for test section homogeneity, the degree to which test pit data is representative of the section, the presence of data outliers within the section, and overall reasonableness from a structural capacity viewpoint.

This report focuses on the FWDCHECK program. The report is provided in three separate volumes: Technical Documentation, User's Guide, and Program Listing. The technical documentation gives a detailed description of the program including the analyses and algorithms used. A detailed description of the program usage is provided in the User's Guide. Finally, a complete printout of the computer source code is included in the third volume, Program Listing.

PURPOSE

The purpose of this report is to describe the second FWD Quality Assurance computer program and its usage. The first program, **FWDSCAN**, has been developed to check FWD data for completeness and readability. Program **FWDCHECK** is intended to check FWD data files for:

- Section homogeneity,
- Non-representative test pit and section data, and
- General reasonableness of structural capacity.

An output file summarizing the results of the checking process is generated by the program.

The report is provided in three separate volumes as follows:

- Volume I - Technical Documentation
- Volume II - User's Guide
- Volume III - Program Listing

In this volume - Volume I: Technical Documentation - a detailed description of the program is provided including the analyses and algorithms used.

BACKGROUND

One of the most important data items that will be collected during the monitoring phase of the SHRP LTPP study is the deflection response of GPS and SPS pavement test sections under an applied load. In order to measure this response, SHRP is utilizing a non-destructive testing device called the Falling Weight Deflectometer (FWD). Each SHRP Regional Coordination Office (RCO) contractor is responsible for storing, maintaining and operating one FWD unit and the towing vehicle supplied by SHRP for the FWD deflection data collection.

In order to provide a uniform and standardized field deflection measurement procedure for SHRP-FWD units within each of the four operating SHRP RCO's, a SHRP publication titled "SHRP-LTPP Manual for FWD Testing and Operational Field Guidelines" was released for use in January 1989. Part of the field data collection scheme is a computer software system for test set-up and data collection and storage.

While the main purpose of the SHRP FWD program is the automated data collection process, there are five separate computerized data checks within the system to alert the FWD operator of potential data errors or problems. They are:

- *Roll-Off* - an electrical check of the sensor to verify that the signal attenuates with time.

- *Decreasing Deflections* - a check to verify that deflections are lower at greater distances from the load.

- *Out of Range* - a check to verify that deflections are less than the maximum deflection that the sensor is capable of recording accurately.

- *Load Variation* - a check that the load for a particular drop is within a specified tolerance of the average load for that drop height at that location.

- *Deflection Variation* - a check that the normalized deflection for a given sensor for a particular drop is within a specified tolerance of the average normalized deflection for that sensor for that drop height at that location.

After completion of each test section and before leaving the site, backup copies (diskettes) of the FWD deflection data are made in order to safeguard the information collected in the field. One of these copies, along with the printed hard copy produced by the data collection software, is mailed to the SHRP RCO where the data must first be reconstituted into files as they originally existed in the field and then verified.

All data received by the SHRP RCO is then checked to insure that it has been restored to its original form and that all data is present, complete and in a readable form. To accomplish this, an FWD Quality Assurance computer program called **FWDSCAN** was developed by the P-001 Technical Advisory Staff. This program automatically checks the data for completeness and readability, and generates an output file summarizing the results of the checking process. Additionally, this program creates a deflection file containing only peak data (i.e., no deflection- and load-time histories) which is required by the second FWD Quality Assurance program (**FWDCHECK**).

Finally, before any FWD data can be forwarded to the National Pavement Data Base, it must be checked to assess whether or not (1) the section tested is homogeneous, (2) the test pit data is representative of the section, (3) data outliers are present within the section, and (4) the data is reasonable from a structural capacity viewpoint. The objective of these checks is <u>not</u> to eliminate data but rather to <u>flag</u> potential errors or problems and correct them if possible before the information is processed further. In addition, remarks generated from the foregoing analysis regarding anomalies of section or test pit response will be of significant benefit to research users of the data base.

This last set of checks is accomplished automatically by means of a microcomputer program called **FWDCHECK**, developed by the P-001B Technical Advisory Staff. A detailed description of the **FWDCHECK** program is presented in the remainder of this document.

PROGRAM DESCRIPTION

Program **FWDCHECK** has been developed for use by SHRP to check FWD data files for section homogeneity, non-representative test pit and section data, and reasonableness of structural capacity estimates. An output file summarizing the results of the checking process is generated by the program.

The program is primarily intended for the analysis of test pits and mid-slab deflection basin test data for rigid pavements (test locations 0 and 1) and test pits and outer wheel path deflection basin test data for flexible pavements (test locations 0 and 3). The program is not intended to analyze joint/crack or edge deflection test data for rigid pavements (i.e., test locations 2 to 5) nor mid-lane deflection data for flexible pavements (i.e., test location 1).

Before running the program, the user must ensure that a deflection file containing only peak data (i.e., no load- and deflection-time histories) has been created for the pavement section in question. This file is automatically generated by the first FWD Quality Assurance program called **FWDSCAN**. The user is referred to the SHRP document titled "Data Readability and Completeness, FWDSCAN, Version 1.30, September 1990" for the description and usage of this program.

For purposes of describing the **FWDCHECK** program, this section has been subdivided into four subsections: Preliminary Data Analysis, Section Homogeneity Analysis, Non-Representative Data Analysis, and Structural Capacity Analysis. The order in which these subsections are presented corresponds with the **FWDCHECK** analysis sequence.

Preliminary Data Analysis

Before any of the major **FWDCHECK** quality assurance checks are performed, the deflection data in question is first normalized in order to provide a uniform set of data for comparison purposes. This initial set of computations is performed on all possible combinations of geophone, drop height and station. Additionally, for asphaltic concrete surfaced pavements, the computations include both uncorrected and temperature corrected deflection data.

Uncorrected normalized deflections for any of the above referenced combinations are calculated in the program by means of the following relation:

$$\hat{\delta}_u = \frac{\sum_{i=1}^{n}\left(\frac{\delta_{mi}}{P_i}\right)}{n}$$

where $\hat{\delta}_u$ = uncorrected normalized deflection, in mils/pound; i = repeat drop in question; n = number of repeat drops used; δ_{mi} = measured deflection for i^{th} repeat drop; and P_i = applied load, in pounds.

Temperature corrected normalized deflections are also computed in the manner described above except that the measured deflections are first corrected to a standard temperature of 68°F. The temperature correction procedure used in **FWDCHECK** is summarized in Table 1. This procedure, derived by the P-001B Technical Assistance Staff, is only used to correct maximum (i.e., Geophone No. 1) deflections associated with asphaltic concrete surfaced pavements for use in the structural capacity reasonableness portion of the program. The field temperatures from which the corrections are made are the measured temperature gradients in the drilled holes.

Finally, various uncorrected normalized deflection statistics (mean, standard deviation, and coefficient of variation for each geophone number and drop height combination) are calculated for the pavement section in question. These statistics do not incorporate test pit data.

Section Homogeneity Analysis

It is normal for the non-destructive evaluation of any pavement test section to yield variable deflection data. This variability is intrinsic to the pavement and should not be a concern as long as the data is statistically "homogeneous". Therefore, once the data has been reviewed for readability and completeness, the next step in the FWD Quality Assurance program is to verify the homogeneity of the test section; i.e., determine whether or not one or more pavement subsections are present.

This particular FWD data check is somewhat subjective in that the user selects, based upon a visual assessment of the deflection profile, the station, if any, for each pavement subsection. For statistical convenience, each subsection <u>must</u> contain at least four (4) test points. To aid the user in the definition of these boundaries, the following output to the screen is generated by **FWDCHECK**: (1) tabular summary of the uncorrected normalized deflection statistics for the section, (2) tabular summary of the temperature corrected normalized deflection statistics for the section/subsections (different from Item 1 for asphaltic concrete surfaced pavements only), (3) plots of the uncorrected normalized deflection versus station for all seven geophones and (4) plots of temperature corrected (to 68°F) normalized deflections versus station for geophones 1 and 7, only. Examples of these tabular summaries and plots are given in Tables 2 and 3 and Figures 1 and 2, respectively.

If two or more subsections are identified by the user, the program automatically computes the temperature corrected mean normalized deflection and standard deviation of geophone 1 for each subsection. The section uniformity analysis is based only on the analysis of the *9,000 lb load deflections.* **FWDCHECK** then performs a statistical comparison of the means for each pair of adjacent subsections to determine whether or not they are indeed unique

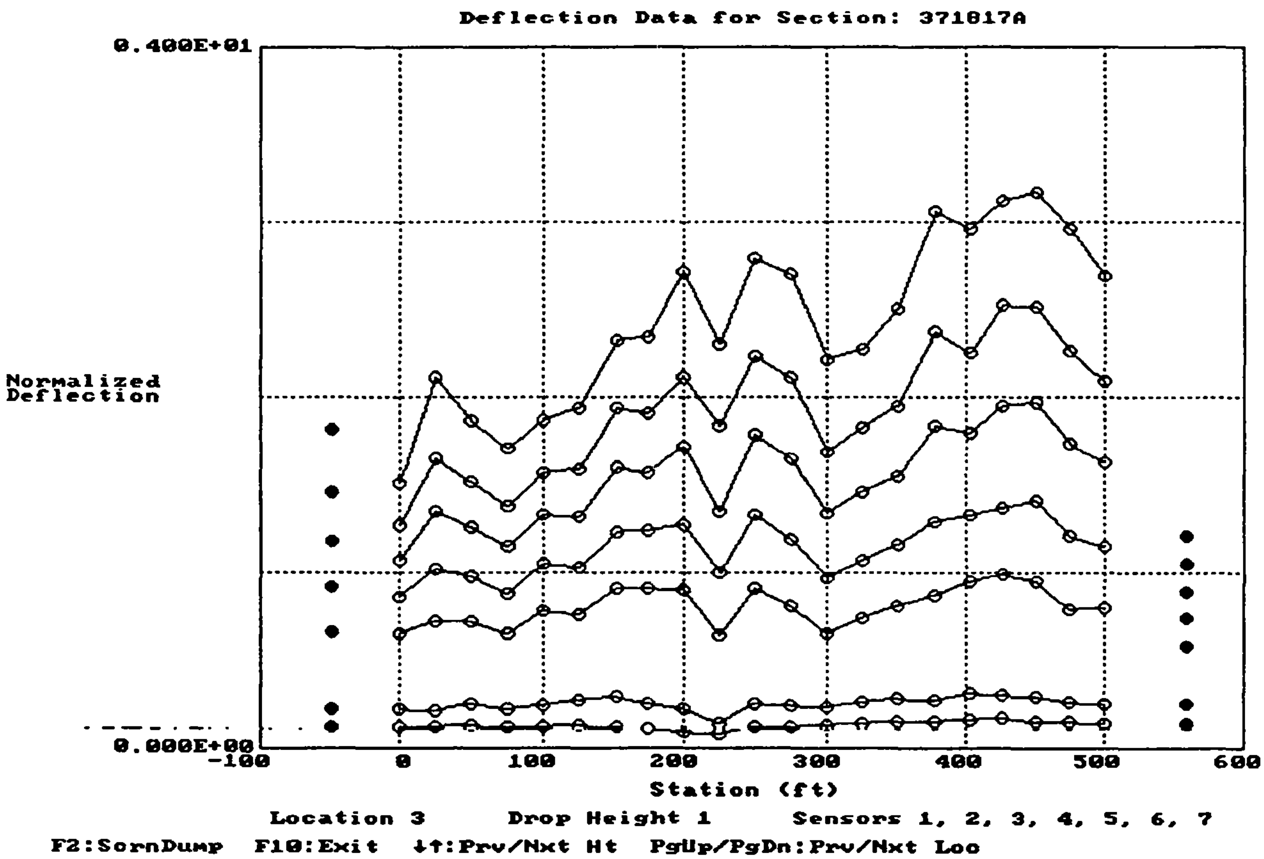

Figure 1 - Uncorrected Normalized Deflection Versus Station Plot

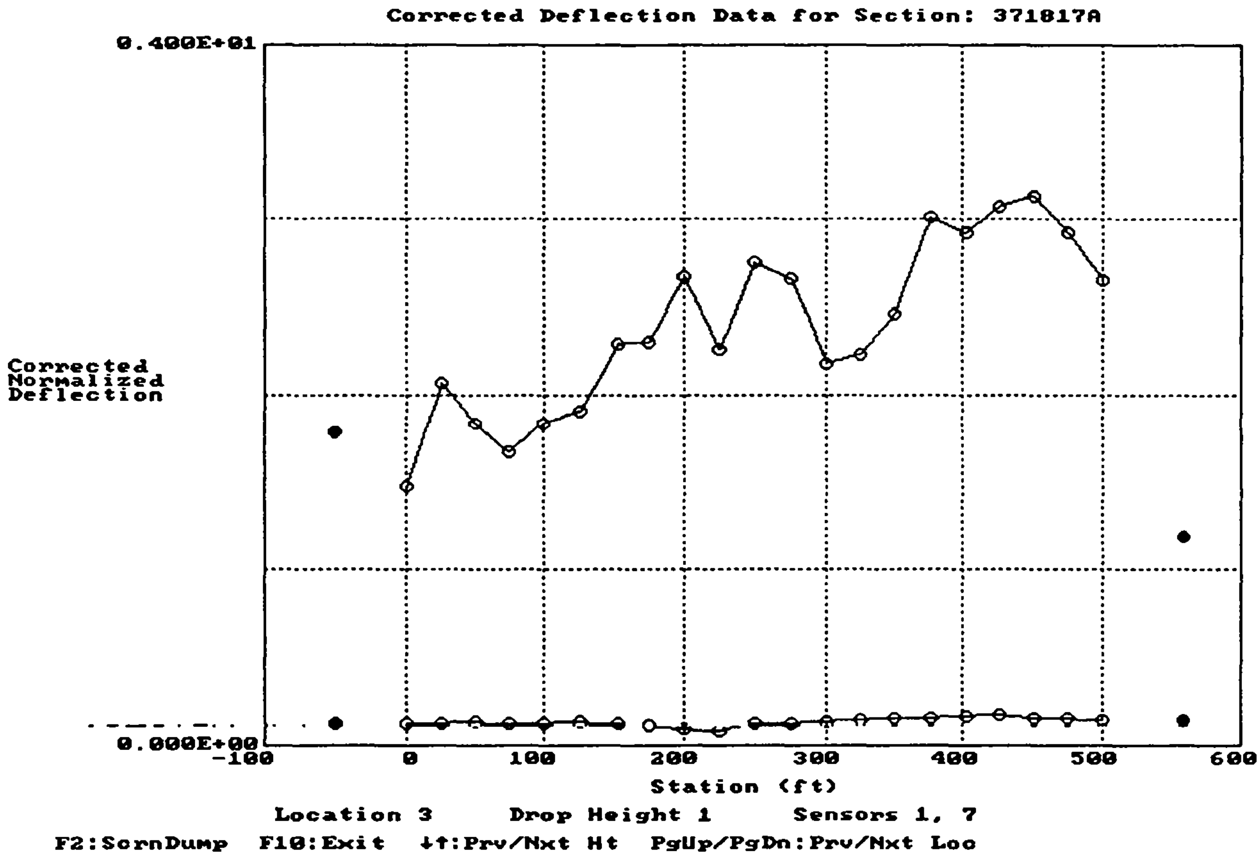

Figure 2 - Temperature Corrected Normalized Deflection Versus Station Plot

Table 1
Temperature Correction Procedure for Deflections

$$\delta_s = D_r * \delta_j$$

where: δ_s = maximum deflection adjusted to standard temperature (T_s = 68°F)
D_r = deflection adjustment factor
δ_j = maximum deflection measured at temperature (T_j) in the field.

$$D_r = \frac{\delta_s}{\delta_j} = \frac{\frac{1}{E_{1s}} + (1 - F_{b1B}) + \sum_{i=2}^{n-1} \frac{1}{E_i}(F_{biT} - F_{biB}) + \frac{1}{E_n} F_{bnT}}{\frac{1}{E_{1f}} + (1 - F_{b1B}) + \sum_{i=2}^{n-1} \frac{1}{E_i}(F_{biT} - F_{biB}) + \frac{1}{E_n} F_{bnT}}$$

where: E_{1S} = elastic modulus of AC surface layer at standard temperature (68°F)
E_{1F} = elastic modulus of AC surface layer at time of testing (field temperature)
E_n = elastic modulus of subgrade layer
F_b = Boussinesq's one-layer deflection factor

$$F_b = \left[\sqrt{1 + \left(\frac{h_i'}{a_c}\right)^2} - \left(\frac{h_i'}{a_c}\right)\right]\left[1 + \frac{\frac{h_i'}{a_c}}{2(1-u)\sqrt{1 + \left(\frac{h_i'}{a_c}\right)^2}}\right]$$

where:

$$h_i' = \sum_{j=1}^{i+1} \alpha_j\, h_j \sqrt[3]{\frac{E_j}{E_i}}$$

$$\alpha_j = 1 - \frac{\log\left(\frac{E_j}{E_i}\right)}{7.5 h_j^{0.2}}$$

h_i = transformed thickness of layers j=1 to i+1
h_j = actual thickness of layer j
E_j = elastic modulus of layer j
E_i = elastic modulus of layer i
α_j = thickness adjustment factor

NOTES:
1. F_{biT} = Boussinesq's one-layer deflection factor at top of layer i
2. F_{biB} = Boussinesq's one-layer deflection factor at bottom of layer i
3. n = number of pavement layers including subgrade

Table 2

Statistical Summary of Uncorrected Normalized Deflection Data

373 807

UNCORRECTED Deflection Statistics

Data for section 373807A

Mean Values (mils/kip)

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	0.3076	0.2947	0.2754	0.2619	0.2414	0.1730	0.1279
	2	0.3325	0.3142	0.2964	0.2820	0.2596	0.1850	0.1379
	4	0.3652	0.3466	0.3267	0.3115	0.2887	0.2088	0.1505
1	1	0.2865	0.2745	0.2555	0.2396	0.2271	0.1634	0.1096
	2	0.3025	0.2878	0.2754	0.2641	0.2391	0.1705	0.1183
	4	0.3402	0.3236	0.3072	0.2941	0.2736	0.1975	0.1327

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	0.0236	0.0190	0.0110	0.0061	0.0076	0.0022	0.0166
	2	0.0227	0.0163	0.0140	0.0101	0.0046	0.0063	0.0173
	4	0.0116	0.0042	0.0021	0.0004	0.0027	0.0080	0.0160
1	1	0.0364	0.0353	0.0328	0.0286	0.0272	0.0155	0.0102
	2	0.0394	0.0380	0.0363	0.0340	0.0283	0.0161	0.0104
	4	0.0473	0.0450	0.0423	0.0394	0.0350	0.0212	0.0135

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	7.68%	6.44%	3.99%	2.31%	3.17%	1.27%	12.97%
	2	6.83%	5.20%	4.74%	3.57%	1.76%	3.38%	12.53%
	4	3.18%	1.22%	0.64%	0.11%	0.93%	3.82%	10.62%
1	1	12.69%	12.85%	12.85%	11.94%	11.96%	9.51%	9.34%
	2	13.02%	13.21%	13.17%	12.87%	11.85%	9.45%	8.80%
	4	13.91%	13.89%	13.78%	13.41%	12.78%	10.75%	10.17%

PgDn

Table 3

Statistical Summary of Temperature Corrected Normalized Deflection Data

371 817

CORRECTED Deflection Statistics - Subsection 1

Data for section 371817A Mean Values (mils/kip)

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	2.4400	1.5612	1.2971	1.0073	0.7411	0.2426	0.1221
	2	2.6471	1.7067	1.4305	1.1267	0.8348	0.2726	0.1289
	3	2.8095	1.8302	1.5445	1.2323	0.9254	0.3075	0.1406
	4	2.8155	1.8421	1.5609	1.2521	0.9472	0.3199	0.1440

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	0.3266	0.2120	0.1692	0.1252	0.0884	0.0294	0.0062
	2	0.3695	0.2457	0.1997	0.1509	0.1052	0.0310	0.0061
	3	0.4058	0.2766	0.2283	0.1771	0.1250	0.0351	0.0083
	4	0.4040	0.2792	0.2319	0.1841	0.1293	0.0365	0.0095

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	13.38%	13.58%	13.05%	12.43%	11.93%	12.13%	5.07%
	2	13.96%	14.40%	13.96%	13.40%	12.60%	11.37%	4.74%
	3	14.44%	15.11%	14.78%	14.37%	13.50%	11.43%	5.90%
	4	14.35%	15.16%	14.86%	14.70%	13.66%	11.40%	6.62%

Note: Only sensor 1 deflections are corrected.

PgDn Ctrl-PgDn

pavement units. The acceptance criteria used in this comparison are given in Table 4. As shown, the statistical test assumes that the normalized deflections for each subsection follow a Student's "t" distribution and that the true standard deviations are unknown and unequal. The statistical hypothesis test for equal means utilizes a 95% level of probability (two-tailed). In addition to the means test, **FWDCHECK** also performs an F-test for the statistical comparison of the variances for each pair of adjacent subsections.

In order to provide assistance to users of this program performing this subsection delineation, Figures 3 and 4 are examples of SHRP GPS sections where subsections may exist. Figure 3 (section 371817A) shows a subsection boundaries at approximately stations 130 and 360. These boundaries separate the section into three areas of increasing deflection. The hypothesis testing indicates that these subsections <u>are</u> statistically different for means, but not for variances. Figure 4 (section 041007A) shows a section divided into three subsections at stations 130 and 290. Subsection 1 (station 0 to 130) has a relatively low maximum deflection. Subsection 2 (station 130 to 290) has much higher deflections than subsection 1, with its overall average about 50% higher than subsection 1. Subsection 3 (station 290 to 500) has a more uniform maximum deflection than subsection 2, with its overall average similar to subsection 1. The hypothesis tests for these subsections also shows that the means are statistically different, but that the variances are not statistically different for the current criteria.

Regardless of whether or not the mean normalized deflections for the user-specified subsections are found to be unequal, each subsection is treated as a unique pavement unit over the remainder of the program unless they are redefined by the user. Depending on the outcome of the analysis, one or more messages are sent to screen and the program output file. Table 5, an excerpt from one of these output files, contains (1) a warning message indicating that the first two adjacent subsections have equal means, (2) a message indicating that the last two subsections have unequal means, and (3) a partial summary of the deflection statistics for the first subsection. If two or more subsections are found to be equal by both means and variances, the user <u>should</u> redefine the subsection boundaries accordingly before proceeding with the program.

It should be noted that the user can look at any other combination(s) of boundaries, if desired. However, the information sent to the output file and the ensuing program analyses are <u>always</u> based on the results generated for the <u>last</u> set of boundaries investigated.

Non-Representative Data Analysis

Deflection data obtained from the test pit locations should be examined to assess whether or not it is representative of the SHRP pavement test section. Additionally, deflection data obtained from within the section should be analyzed to determine whether or not non-representative data or data outliers are present.

Table 4

Hypothesis Test of Means

Acceptance Criteria for Given Hypothesis (H: $u_x = u_y$; σ is unknown and unequal)

$$-t_{\frac{\alpha}{2},\nu_2} \leq t_1 \leq t_{\frac{\alpha}{2},\nu_2}$$

$$\nu_2 = \frac{\left[\left(\frac{S_x^2}{n_x}\right) + \left(\frac{S_y^2}{n_y}\right)\right]^2}{\left[\frac{\left(\frac{S_x^2}{n_x}\right)^2}{(n_x - 1)}\right] + \left[\frac{\left(\frac{S_y^2}{n_y}\right)}{(n_y - 1)}\right]}$$

$$t_1 = \frac{\bar{x} - \bar{y}}{\sqrt{\left[\left(\frac{S_x^2}{n_x}\right) + \left(\frac{S_y^2}{n_y}\right)\right]}}$$

where:

x, y	=	mean of population x and y
S_x, S_y	=	standard deviation associated with population x and y
n_x, n_y	=	number of units in population x and y
ν_2	=	degrees of freedom (associated with hypothesis criteria)
t_1	=	test statistic (t distribution)
$1 - \alpha$	=	probability level

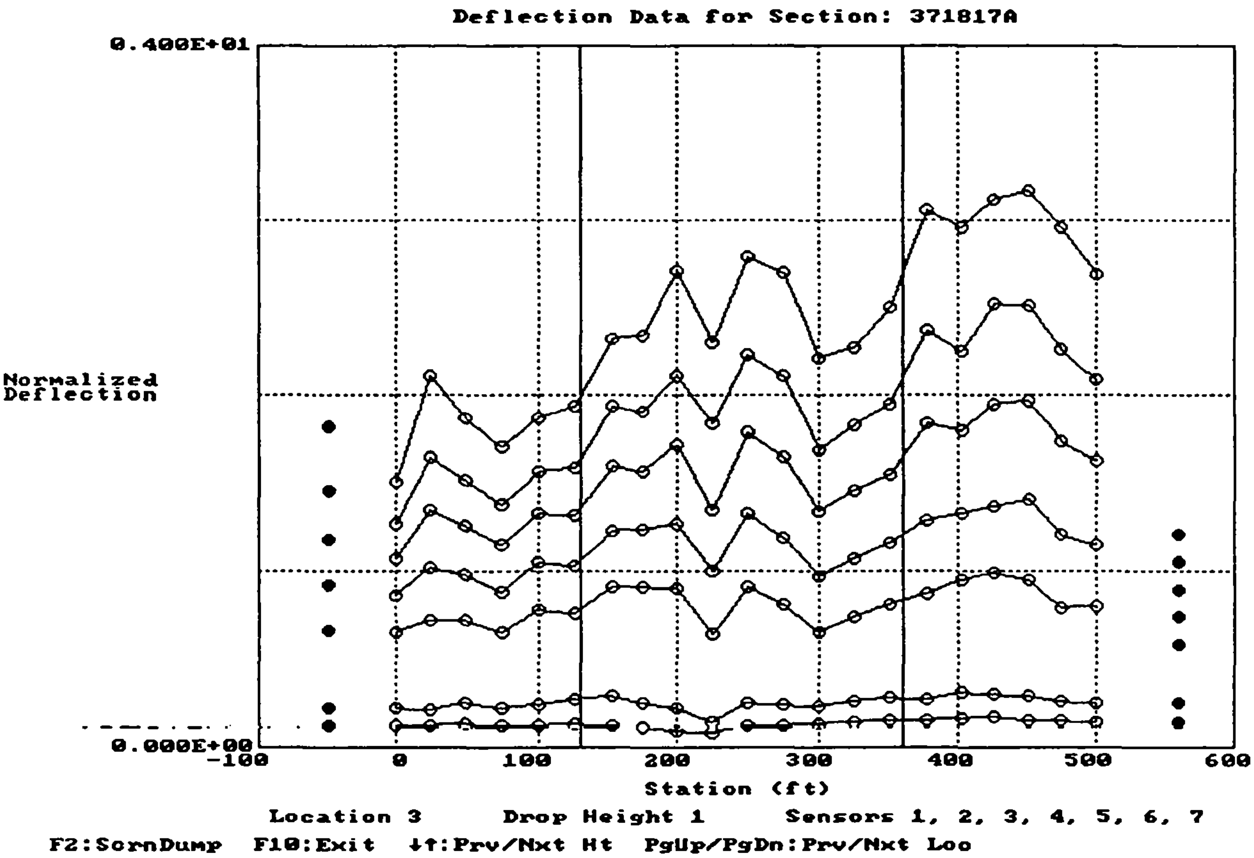

Figure 3 - Sample Subsection Delineation: Section 371817A

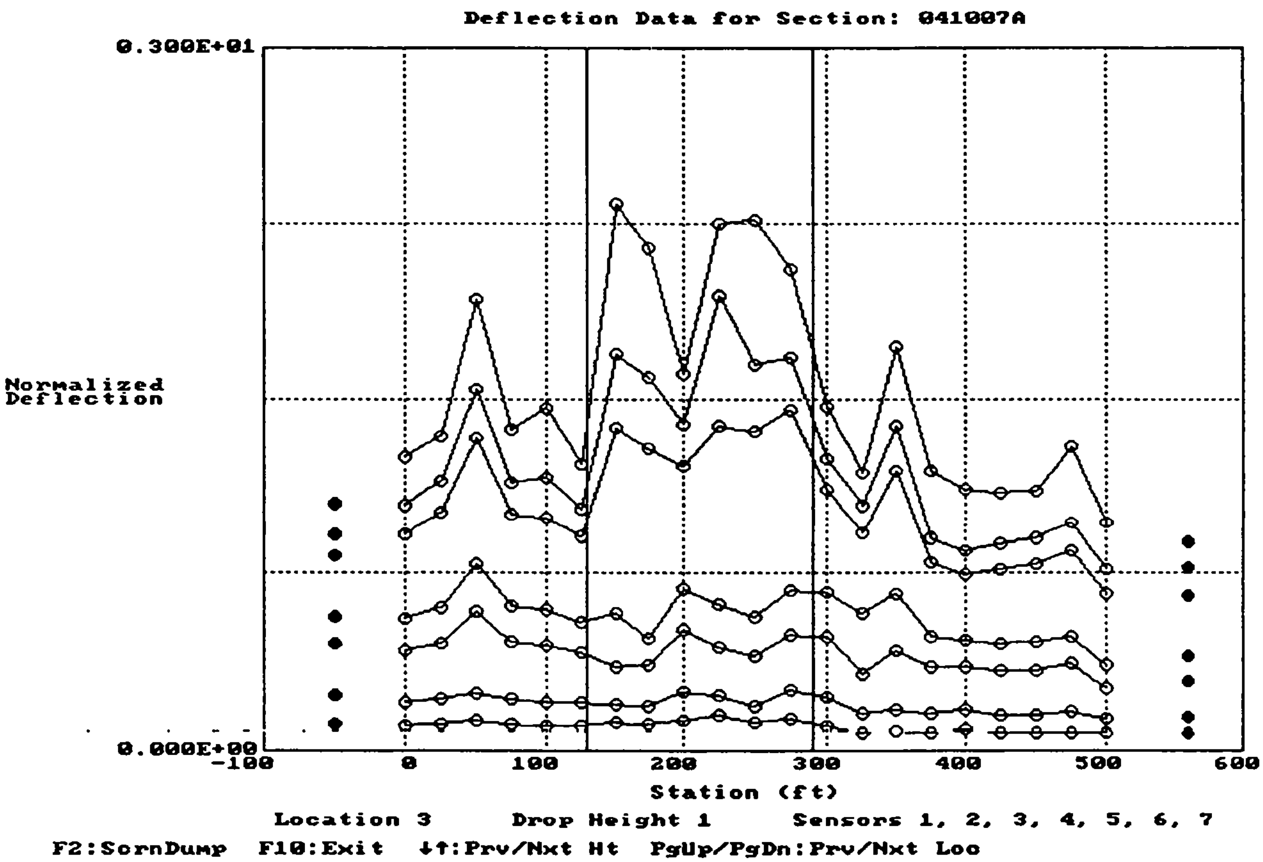

Figure 4 - Sample Subsection Delineation: Section 041007A

Table 5

Excerpt of FWDCHECK Output File - Section Homogeneity

Section uniformity:
Subsections were identified within the section.
Subsection 1 boundaries occur at 0 ft. and 100 ft.
Subsection 2 boundaries occur at 100 ft. and 200 ft.
Subsection 3 boundaries occur at 200 ft. and 300 ft.
Subsection 4 boundaries occur at 300 ft. and 400 ft.
Subsection 5 boundaries occur at 400 ft. and 500 ft.

Comparing subsections:
Subsections 1 and 2: UNEQUAL means and EQUAL variances.
Subsections 2 and 3: UNEQUAL means and EQUAL variances.
Subsections 3 and 4: EQUAL means and EQUAL variances.
Subsections 4 and 5: UNEQUAL means and EQUAL variances.

Flexible Pavement Deflection Statistics - 371817A
Subsection 1
Subsection begins at station 0
Subsection ends at station 100

Mean Values (mils/kip)

CORRECTED

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	1.7695	1.4567	1.2075	0.9339	0.6847	0.2248	0.1210
	2	1.9160	1.5848	1.3256	1.0407	0.7696	0.2537	0.1282
	3	2.0295	1.6894	1.4237	1.1330	0.8495	0.2865	0.1379
	4	2.0323	1.6983	1.4380	1.1496	0.8696	0.2981	0.1405

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	0.2480	0.1643	0.1225	0.0793	0.0384	0.0154	0.0050
	2	0.2648	0.1774	0.1365	0.0911	0.0468	0.0156	0.0055
	3	0.2691	0.1845	0.1465	0.1016	0.0565	0.0170	0.0065
	4	0.2473	0.1734	0.1396	0.0998	0.0564	0.0167	0.0065

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	14.02%	11.28%	10.14%	8.49%	5.61%	6.86%	4.12%
	2	13.82%	11.19%	10.30%	8.76%	6.09%	6.13%	4.31%
	3	13.26%	10.92%	10.29%	8.97%	6.65%	5.95%	4.71%
	4	12.17%	10.21%	9.71%	8.68%	6.49%	5.60%	4.65%

Both of these data checks are accomplished in **FWDCHECK** through the comparison of normalized deflection statistics at all geophone and drop height combinations. More specifically, the normalized deflection data at each test pit location is first compared to the corresponding mean of the section. In those cases where two or more subsections have been identified (see Section Homogeneity Analysis), the test pit data is compared to the mean of the adjacent subsection. In either case, warnings are automatically generated by the program when the test pit data exceeds the section or subsection mean by more than two (2) standard deviations.

Like the test pit analysis, the check for data outliers within a section also entails the comparison of the normalized deflections for each geophone and drop height combination at each station to the section or corresponding subsection mean. Also, warning messages are generated by the program whenever the section or subsection mean is exceeded by more than two (2) standard deviations.

Table 6 shows an excerpt of the **FWDCHECK** output file, which contains warning messages for both non-representative test pit data as well as data outliers within the section. As shown, the output consists of a tabular summary of non-representative data and includes, for each data point, the station, drop height, geophone number and number of standard deviations away from the section or subsection mean. If all the FWD data is representative, a message stating that there are no outliers is sent to the output file.

In addition to the automatic checks, the program is capable of generating, to the screen, normalized deflection versus station plots for each combination of geophone and drop height. An example of these plots is given in Figure 5. As shown, a series of lines indicating the mean, mean $\pm$ 1 standard deviation, mean $\pm$ 2 standard deviations, etc. are superimposed on these plots. This capability allows one to graphically look at the non-representative data analysis results and, if desired, include additional warning messages in the output file in the form of running comments.

Structural Capacity Analysis

The last set of **FWDCHECK** data checks deal with the reasonableness of the FWD data collected. Unlike previous checks which only look at the magnitude of the deflections, the data checks in this section are based upon a structural analysis of the FWD data. More specifically, they involve the computation of pavement structural capacity and the comparison of the results to what one would expect from the known layer thicknesses and material types. These checks are <u>only</u> applicable to deflection basin data and consider each drop height and station combination separately.

In general, two procedures for evaluating the structural capacity of pavements from deflection data are presently available. One approach utilizes the entire measured deflection basin to assess the effective in-situ pavement layer moduli. The other approach is based upon theoretical deflection equations that allow for the prediction of the effective structural

Table 6

Excerpt of FWDCHECK Output File - Non-Representative Data

Outlier Statistics - 373807A

Subsection 1

Station	Height	Sensor	Number of Std. Dev.
15	2	1	-2.02
15	4	1	-2.27
15	4	2	-2.20
15	4	3	-2.14
15	4	4	-2.13
15	4	5	-2.11
43	1	4	-2.06
62	2	7	2.08
62	4	7	2.00
208	1	1	2.03
208	1	2	2.11
208	1	5	2.14
208	2	4	2.14
244	4	7	-2.03

Subsection 2

Station	Height	Sensor	Number of Std. Dev.
No deflection data for this subsection is more than 2.0 standard deviations from the subsection mean.			

Subsection 3

Station	Height	Sensor	Number of Std. Dev.
566 (TP)	1	7	4.59
566 (TP)	2	5	2.39
566 (TP)	2	6	3.89
566 (TP)	2	7	8.21

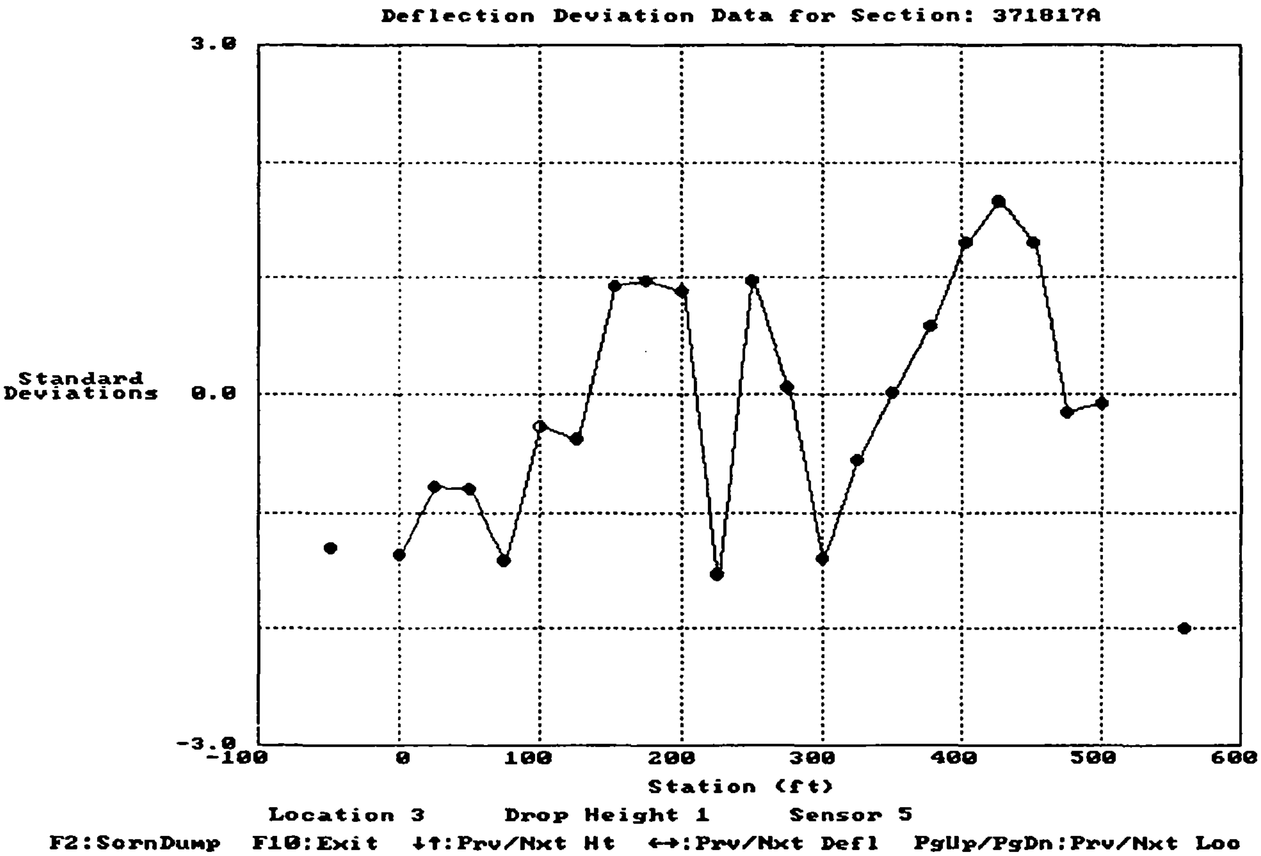

Figure 5 - Deflection Deviation Versus Station Plot for Non-Representative Data Analysis

capacity directly from the maximum NDT deflection and knowledge of the subgrade modulus as interpreted from the outer geophone deflection measurements.

The layer moduli approach is a slower solution but gives more detailed information as to the load bearing capacity of each layer as well as the total pavement capacity. Alternatively, the direct structural capacity approach is a much faster and simpler computational solution but does not calculate individual layer strengths, only the overall pavement structural capacity.

Because the main objective of the this last set of data checks is to insure the general reasonableness of the data from a structural viewpoint, the direct structural capacity approach was selected for implementation in **FWDCHECK**. The particular procedure used is dependent upon the pavement type; a modified Westergaard solution is used for rigid pavements and the AASHTO direct structural number analysis for flexible and composite pavements.

Both procedures are consistent with the current AASHTO design and analysis methodology. For rigid pavements, the analysis procedure is based upon the use of an effective slab thickness and composite modulus of subgrade reaction. The flexible pavement analysis procedure is based upon the use of a pavement structural number and subgrade elastic modulus.

A more detailed description of these procedures and their implementation in the **FWDCHECK** program is presented next. Note that in order to conduct the structural capacity data checks the user <u>must</u> specify the number of layers in the pavement as well as the material type and thickness of each layer.

Rigid Pavement Analysis

Structural capacity estimates for rigid pavements are derived based on a modified Westergaard solution for interior deflections. The specific model used in this analysis is given in Table 7. As shown, the maximum deflection is a function of the applied load, radius of loaded area, composite modulus of subgrade reaction, elastic modulus and Poisson's ratio of the Portland cement concrete, slab thickness, and various constants.

Assuming an elastic modulus of $E = 5{,}000{,}000$ psi and a Poisson's ratio of $\mu = 0.15$ for Portland cement concrete, Westergaards' solution is used in an iterative mode to calculate the effective thickness (h) of the slab at the time of testing. Because the maximum deflection, applied load and radius of loaded area are all known, the only unknown parameter is the composite modulus of subgrade reaction or K.

The K value is determined from the applied load and the volume of the deflection basin. This approach assumes that the slab is incompressible and, as a consequence, the volume of soil and/or other materials displaced by the load is equal to the volume of the deflection basin. Accordingly, the K value can be calculated as follows:

Table 7

Structural Capacity Analysis of Rigid Pavements

$$\delta = \frac{P}{8K\ell^2}\left[1 + \left(\frac{1}{2\pi}\right)\left(\log_e\left(\frac{a}{2\ell}\right) + \gamma - 1.25\right)\left(\frac{a}{\ell}\right)^2\right]$$

where: δ	=	maximum deflection (i.e., under load center)
a	=	radius of loaded area
P	=	total applied load
K	=	composite modulus of subgrade reaction
E	=	elastic modulus of Portland cement concrete
h	=	slab thickness
μ	=	Poisson's ratio of Portland cement concrete
γ	=	0.57721566490; Euler's constant
ℓ	=	radius of relative stiffness

$$= \sqrt[4]{\frac{Eh^3}{(12(1 - \mu^2)k)}}$$

$$K = \frac{P}{V}$$

where P = applied load and V = effective volume of deflection basin. In this version of **FWDCHECK**, the effective volume of the deflection basin is limited to approximately the dimension of half of the lane width (78 inches) and is determined by rotating the deflection basin area through 360 degrees.

Composite modulus of subgrade reaction and effective slab thickness values are determined for all possible location (test pit or within section), station and drop height combinations. The resulting thickness data is then compared to the expected range of thickness in order to assess the reasonableness of the deflection data from a structural viewpoint. The expected range is defined as 0.65 (to allow for deterioration of the slab) to 1.15 (to allow for hardening of the concrete) times the slab thickness.

When analyzing a pavement section that has a second PCC layer, both PCC layers and any other intervening layers are analyzed for a single slab with the same equivalent stiffness. Each PCC layer is assumed to have an elastic modulus of 5,000,000 psi and all intervening asphalt layers are assumed to have an elastic modulus of 450,000 psi (both are the standard moduli used in all calculations in the program). The stiffness of each layer (Eh^3) is summed, and the thickness of the equivalent single slab is computed. The range of expected values is then calculated based on the description above.

Warnings are automatically generated by the program and sent to the output file when the estimated effective thickness falls outside the expected range. Table 8 shows an excerpt of the **FWDCHECK** output file for this portion of the program. As shown, it contains (1) the predicted K and effective thickness values for each location, drop height, and station combination, (2) the K and effective thickness statistics for the entire section <u>or</u> each individual subsection (see Section Homogeneity Analysis) as a function of location and drop height, and (3) if required, a tabular summary of warning messages for each data point outside the expected range, including drop height, station, expected thickness range and predicted effective thickness.

In addition to the automatic checks, the program user can also generate, to the screen, the following information: (1) plot of equivalent thickness versus station (with the expected thickness range superimposed) for each drop height; (2) plot of composite modulus of subgrade reaction versus station for each drop height; (3) plots of composite modulus (i.e., single value representation of the overall pavement stiffness) versus radial distance (i.e., geophone location) for all drop heights at any given station; and (4) tabular summaries of K and thickness values as well as corresponding statistics at each drop height for either the entire pavement section <u>or</u> subsections. Examples of these plots and tabular summary are given in Figures 6 through 8 and Table 9. These capabilities allow one to look at the structural capacity analysis results and, if desired, include additional warning messages in the output file in the form of running comments.

Table 8

Excerpt of FWDCHECK Output File - Structural Analysis of Rigid Pavements

Pavement Construction Information - 373807A

Material Code	Material Name	Layer Thickness
730	Portland Cement Concrete	9.5
332	Econocrete	4.0

RIGID Pavement Thickness Data - 373807A
(comparison of each calculation to the expected value)

Minimum expected thickness: 6.17
Maximum expected thickness: 10.92

Height	Station	Effective Thickness
1	15	12.50
2	15	12.50
4	15	12.50
1	43	12.50
1	185	11.00
2	389	12.50
4	389	11.75
1	412	11.00
1	426	11.00
1	566 (TP)	11.00

RIGID Pavement Thickness Statistics - 373807A

Drop height 1

Subsection	Station	Volumetric k	Effective Thickness
(TP)	-50	327	10.25
1	15	354	12.50
	43	361	12.50
	62	306	10.25
	77	325	10.63
	98	329	10.63
	124	373	10.25
	144	346	10.63

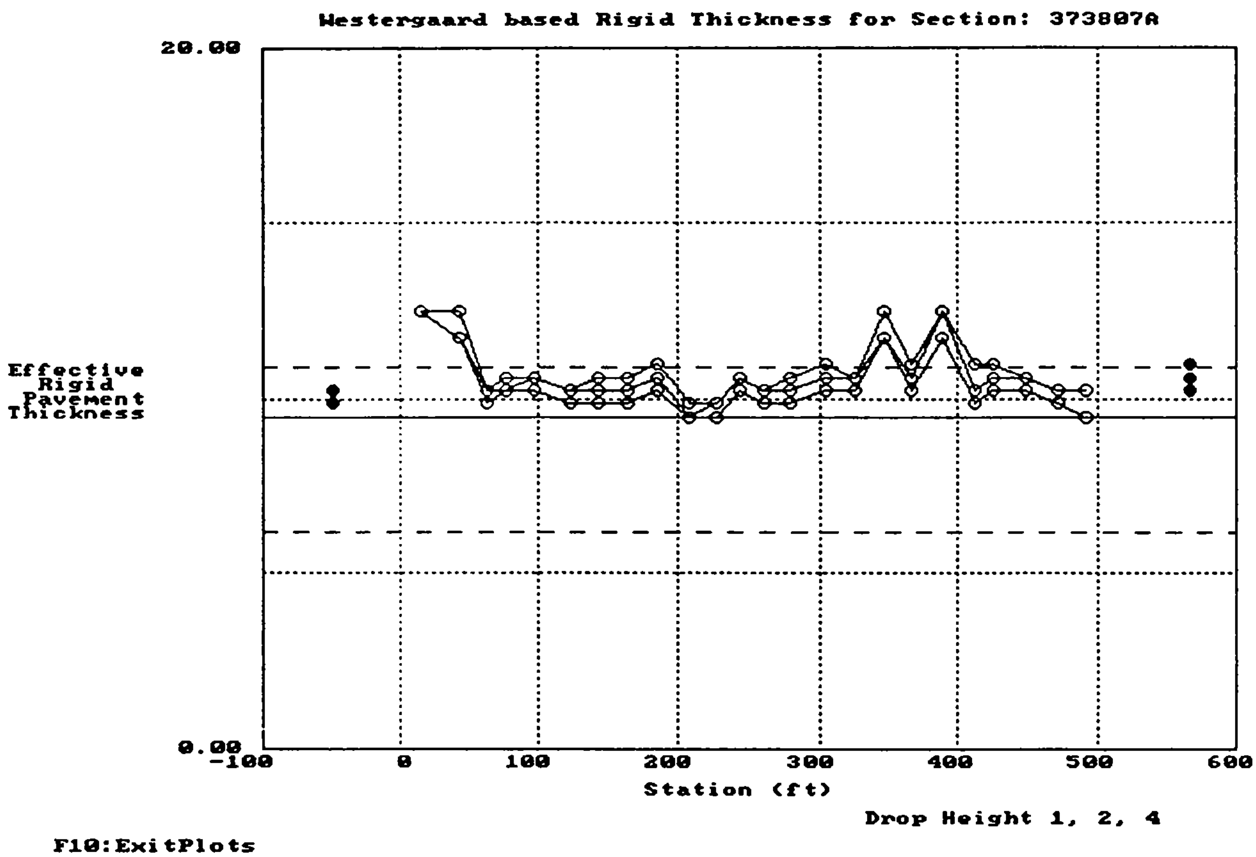

Figure 6 - Equivalent Thickness Versus Station Plot

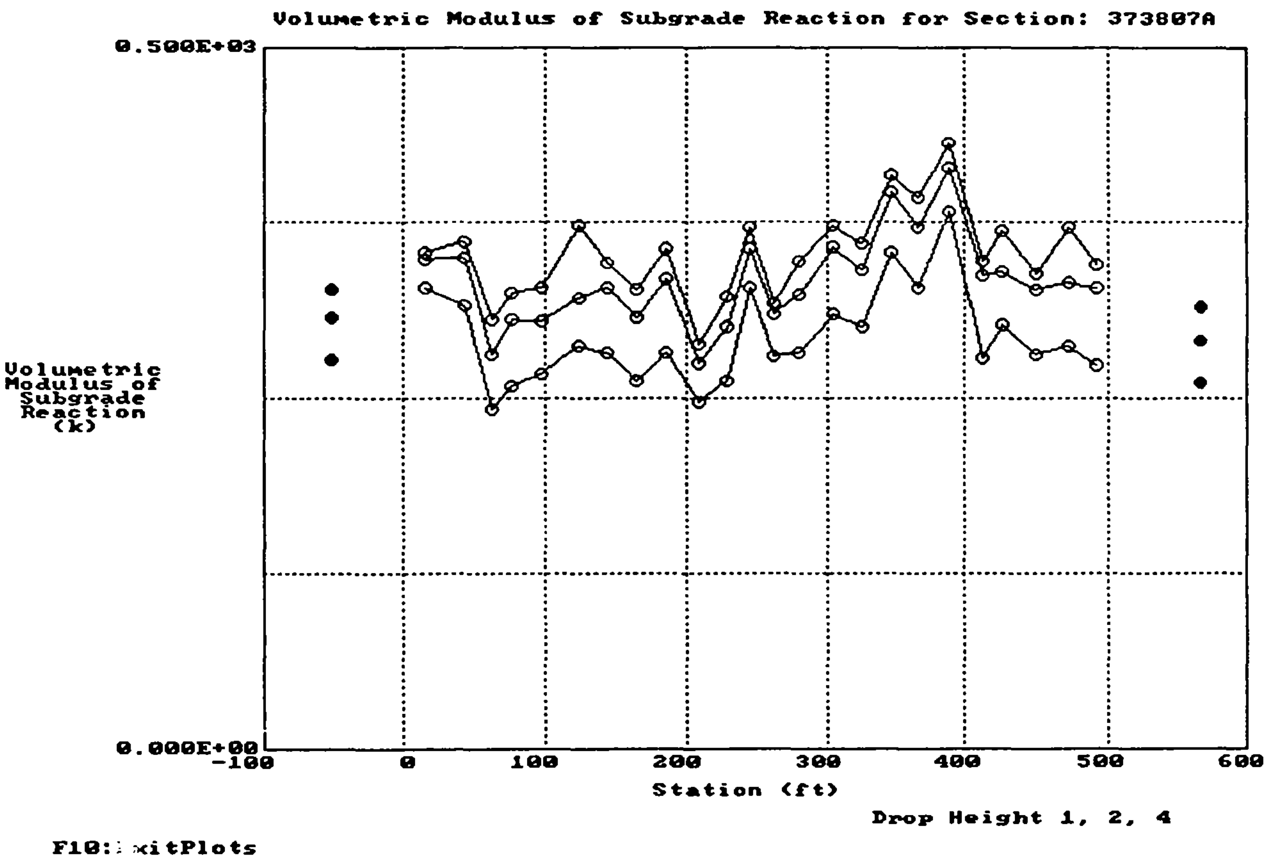

Figure 7 - Composite Modulus of Subgrade Reaction Versus Station Plot

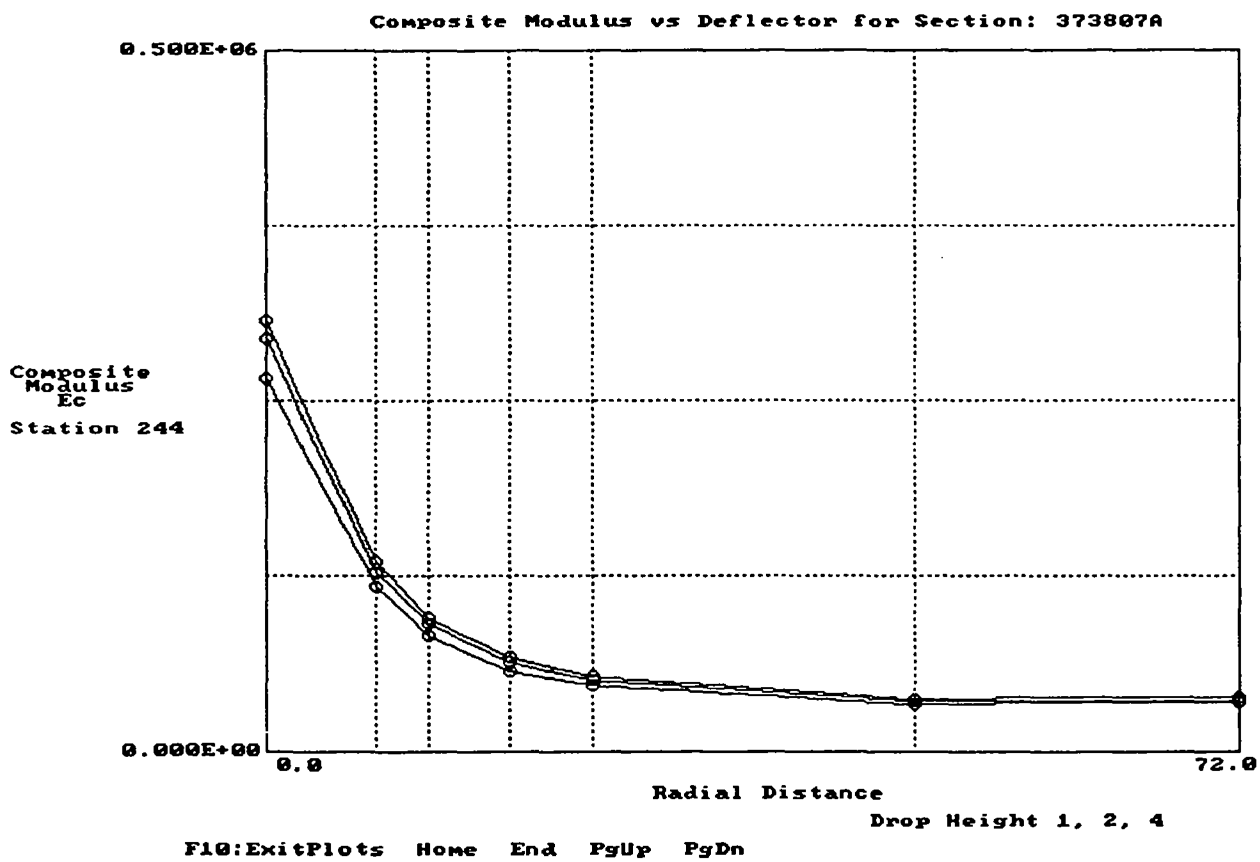

Figure 8 - Composite Modulus Versus Radial Distance
Plot - Rigid Pavements

Table 9

Tabular Summary of Volumetric K and Effective Thickness Values

373 807

RIGID Pavement Thickness Statistics

Data for section 373807A
Subsection 1
Drop height 1

Station	Volumetric k	Effective Thickness
15	354	12.50
43	361	12.50
62	306	10.25
77	325	10.63
98	329	10.63
124	373	10.25
144	346	10.63
164	327	10.63
185	356	11.00
208	288	9.88
228	323	9.88
244	371	10.63
261	317	10.25
280	348	10.63
305	373	11.00
Overall Mean:	340	10.75
Standard Deviation:	26	0.78
Coeff Of Variation:	7.59%	7.30%

PgUp PgDn

Flexible and Composite Pavement Analysis

The structural capacity analysis of flexible and composite pavements follows the AASHTO direct structural number procedure. This approach is based on the premise that the overall pavement structural capacity is the result of the combined stiffness influence of each layer. Accordingly, the maximum NDT deflection may be viewed as being comprised of two separate components: (1) pavement structural capacity and (2) subgrade support. Using these concepts, a computerized solution was developed and implemented in **FWDCHECK**. The procedure uses outer deflection basin data to estimate the subgrade modulus and then uses this parameter, along with the maximum NDT deflection, to directly estimate the effective structural number (SN) of the pavement system.

The fundamental concept used in **FWDCHECK** to establish the subgrade modulus is best illustrated by reference to Figure 9, which shows a pavement structure being deflected under a dynamic NDT load. As the test is conducted, the load applied to the surface is distributed through the depth of the pavement system. The distribution of stresses, represented in this figure by the "Zone of Stress", is obviously dependent upon the stiffness or modulus of the material within each layer. As the stiffness of the material increases, the stress is spread over a much larger area.

More importantly, Figure 9 shows a radial distance ($r = a_{3e}$) in which the stress zone intersects the interface of the subbase and subgrade layers. When the deflection basin is measured, any surface deflection obtained at or beyond the a_{3e} value are due only to stresses, and hence deformations, within the subgrade itself. Thus, the outer readings of the deflection basin primarily reflect the in-situ modulus of the subgrade soil.

Using this concept, the in-situ subgrade modulus is determined in **FWDCHECK** from the composite moduli predicted for radial distances greater than the effective radius, a_{3e}, of the stress bulb at the pavement-subgrade interface; as indicated by the horizontal dashed line in Figure 10 for linearly elastic subgrades or by the upward trend for non-linear (stress dependent) subgrades.

The specific evaluation technique used by the program to establish the subgrade modulus at each location, drop height and station combination involves three major steps as follows:

1. <u>Compute Radius of Influence, a_{3e}</u> - For each of the above combinations, an estimate of the radius of influence is made based on the composite modulus at each geophone location. Composite moduli are calculated in the program as follows:

$$E_c = \frac{2*(1 - \mu_{sg}^2)*p_c*a_c}{\delta}; \quad if\ r \le 0.25a_c$$

or

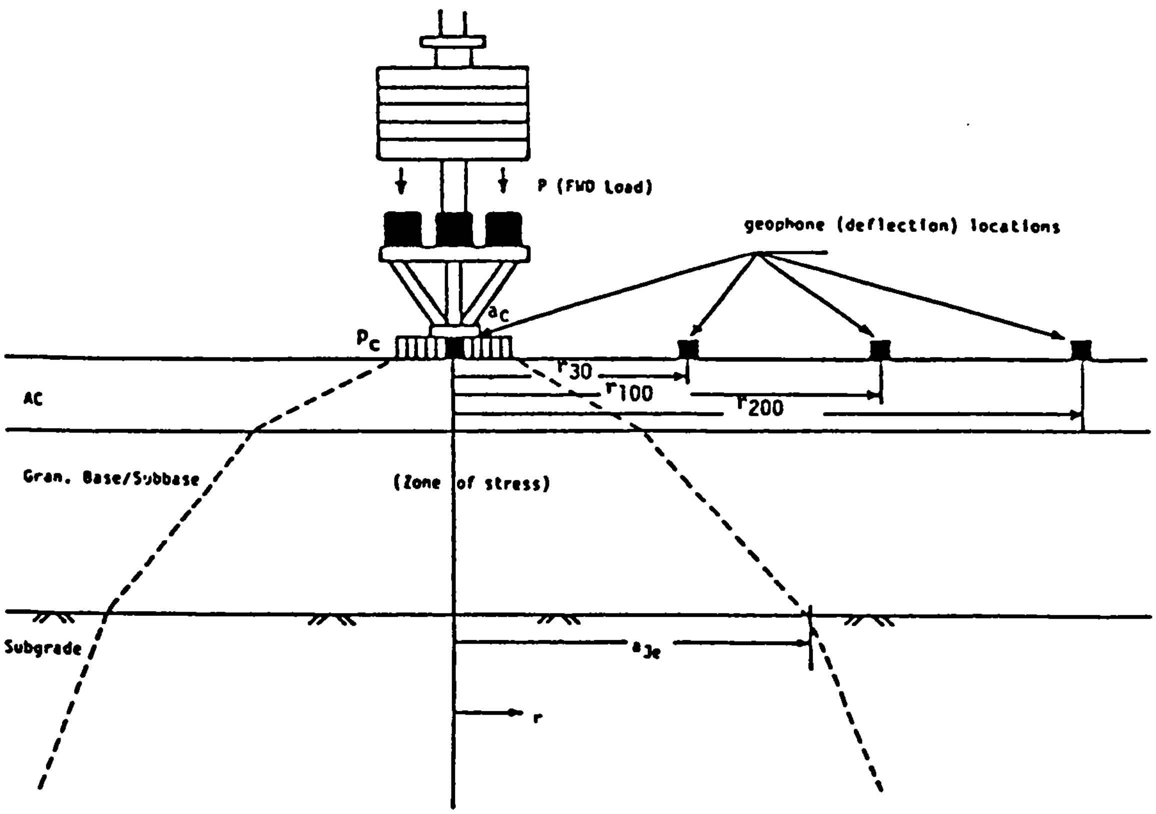

Figure 9 - Schematic of Stress Zone Within Pavement Structure Under the FWD Load (from AASHTO Guide)

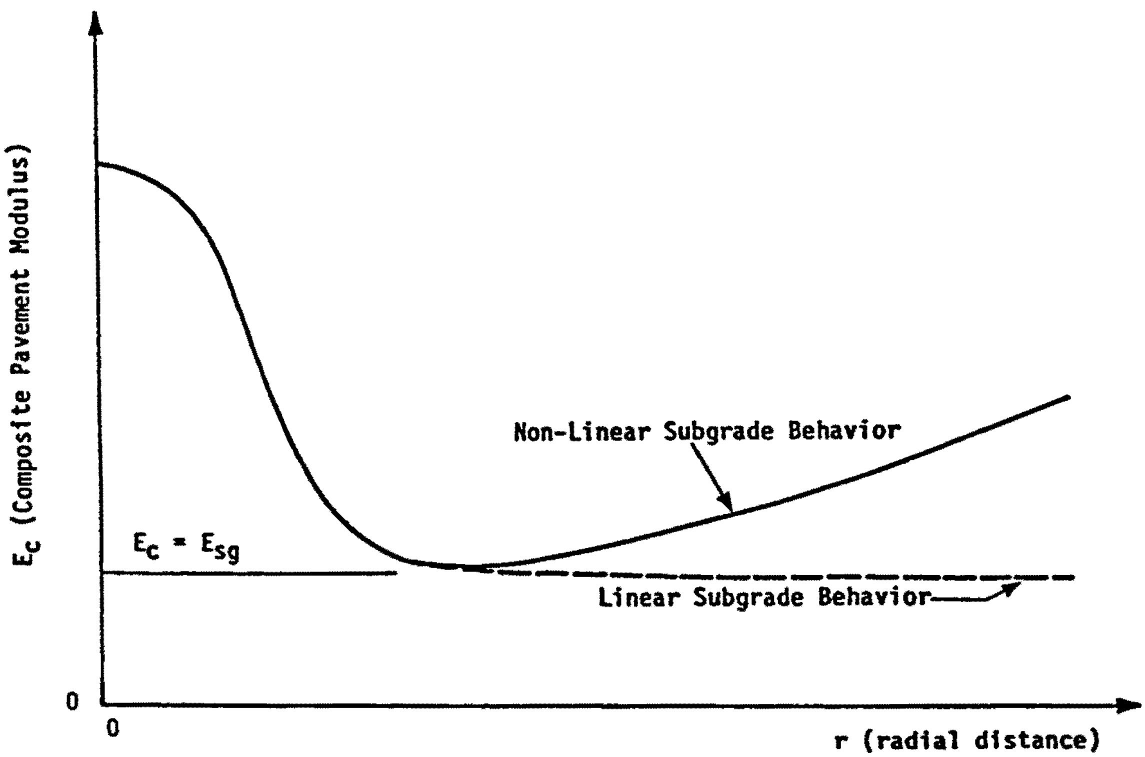

Figure 10 - Composite Modulus Versus Radial Distance Plot

$$E_c = \frac{(1 - \mu_{sg}^2)*p_c*a_c^2}{\delta * r}*C; \quad if\ r > 0.25a_c$$

where E_c = composite modulus; r = radial distance; p_c = contact pressure applied by NDT device; a_c = radius of contact of NDT device; μ_{sg} = Poisson's Ratio of the subgrade; δ = measured deflection at given radial distance; and C = "1.1*log(r/a_c) + 1.15" or "0.5*μ_{sg} + 0.875" (lowest of the two values).

2. Stiff Layer Analysis - If a stiff layer is present beneath the pavement-subgrade structure, it will have a major influence on the measured deflections and hence structural capacity analysis. To overcome this influence, the following approach is incorporated in **FWDCHECK**:

- Assume that the deflections measured at distances beyond the radius of influence (a_{3c}) are solely a function of the subgrade and stiff layers.

- Assume that the stiff layer has an elastic modulus of E = 1,000,000 psi and a Poisson's Ratio of μ = 0.35. User must specify depth to stiff layer; if unknown, a depth of 100 feet below the pavement surface is assumed.

- For each layer in the pavement structure (exclusive of subgrade), assume a typical modulus value and Poisson's ratio based on the material type. The values used in **FWDCHECK** are summarized in Table 10.

- Use the above pavement/stiff layer moduli and Poisson's ratios, along with the known layer thicknesses (user input), as input into CHEVRON N-Layer code to predict surface deflections at all geophone locations beyond the radius of influence for subgrade modulus values of 5,000, 15,000 and 30,000 psi.

- Based on the above results, develop a log-log regression equation of surface deflection versus subgrade modulus for each geophone location beyond a_{3c}.

- Using the appropriate surface deflection versus subgrade modulus correlation, determine the subgrade modulus that yields a surface

Table 10

Typical Modulus, Poisson's Ratio and Layer Coefficient Values Used in FWDCHECK

Material Type	Material Code	Elastic Modulus (ksi)	Poisson's Ratio	Layer Coefficient	
				Minimum	Maximum
Uncrushed Gravel	302	20.0	0.40	0.07	0.17
Crushed Stone	303	45.0	0.40	0.11	0.21
Crushed Gravel	304	30.0	0.40	0.09	0.18
Crushed Slag	305	50.0	0.40	0.12	0.22
Sand	306	10.0	0.40	0.05	0.15
Fine Soil-Agg. Mixture	307	15.0	0.40	0.06	0.16
Coarse Soil-Agg. Mixture	308	20.0	0.40	0.07	0.17
Sand Asphalt	320	200.0	0.40	0.10	0.30
Asphalt Treated Mixture	321	300.0	0.35	0.15	0.35
Cement Aggregate mixture	331	750.0	0.30	0.25	0.45
Econocrete	332	1,500.0	0.25	0.40	0.60
Cement Treated Soil	333	100.0	0.35	0.10	0.25
Lean Concrete	334	1,500.0	0.25	0.40	0.60
Sand-Shell Mixture	336	75.0	0.40	0.15	0.25
Limerock, Caliche	337	200.0	0.35	0.15	0.30
Lime Treated Soil	338	75.0	0.35	0.10	0.25
Soil Cement	339	200.0	0.35	0.15	0.30
Pozzolanic-Agg. Mixture	340	500.0	0.35	0.20	0.40
Cracked & Seated PCC	341	1,000.0	0.25	0.35	0.45
Asphaltic Concrete	700	450.0	0.35	0.35	0.45
Portland Cement Concrete	730	5,000.0	0.15	0.60	0.80

deflection equal to that measured in the field for each geophone location beyond a_{3e}.

While only an estimate, the resulting values represent the actual subgrade moduli at each geophone location, independent of the stiff layer.

Non-Linearity Analysis - If the subgrade soil is perfectly elastic, the subgrade moduli derived in Step 2 - "Stiff Layer Analysis" for distances beyond the radius of influence will all be the same. If non-linear, however, there will be some degree of stress softening; i.e., as the stresses increase, the subgrade modulus decreases. Because the structural analysis for flexible and composite pavements is based on the AASHTO structural number as calculated from the maximum measured deflection and the subgrade modulus, it is critical that the best possible estimate of the subgrade modulus underneath the load center be made. Accordingly, the following procedure is used in **FWDCHECK**:

- For each layer in the pavement structure (exclusive of subgrade), assume a typical modulus value and Poisson's ratio based on the material type. The values used in **FWDCHECK** are summarized in Table 10.

- Use the above layer moduli and Poisson's ratios, along with the known layer thicknesses (user input) and subgrade moduli predicted in Step No. 2 - "Stiff Layer Analysis", as input into CHEVRON N-Layer code to predict deviator stresses at the pavement-subgrade interface at all geophone locations beyond a_{3e} and directly under the load center (i.e., radial distance of zero).

- Using the deviator stresses predicted for distances beyond a_{3e} and the subgrade moduli computed in the stiff layer analysis, develop a log-log regression equation of subgrade modulus versus deviator stress.

- Using the predicted deviator stress at a radial distance of zero as input the subgrade modulus versus deviator stress correlation, determine the subgrade modulus directly under the load center.

The resulting value represents the actual subgrade modulus used in the SN derivation.

Once the subgrade modulus under the load center has been established, the effective structural number of the pavement is determined in the program through an iterative process. Assuming that the pavement structure can be represented by a one layer system resting on the subgrade and that crushed stone ($a_s = 0.14$, $E_s = 30{,}000$ psi and $\mu_s = 0.35$) is the standard material, the equivalent modulus of the one-layer system (for a given SN value) and the theoretical maximum deflection of the one-layer system can be easily derived using the equations given in Table 11.

Therefore, by iterating on the SN value, the structural number that results in a predicted maximum deflection equal to the measured value is determined in **FWDCHECK**. It is important to note that the maximum measured NDT deflection used in this comparison is first adjusted to a standard temperature of 68° F before the effective structural number, SN, is calculated (see Preliminary Data Analysis).

Subgrade modulus and structural number values are determined for all possible location (test pit or within section), station and drop height combinations. The resulting structural number data is then compared to the expected range in order to assess the reasonableness of the deflection data from a structural viewpoint. The expected SN range is defined for each pavement section based on the combination of material types and layer thicknesses as follows:

$$SN = \sum_{i=1}^{n} (a_i * h_i)$$

where SN = structural number of the pavement; n = number of layers in the pavement (exclusive of subgrade); i = pavement layer in question; a_i = structural layer coefficient of the i^{th} layer; and h_i = thickness of the i^{th} layer. Minimum and maximum material layer coefficients used in **FWDCHECK** to generate the expected range of SN values are summarized in Table 10.

As with the rigid pavement structural analysis, warnings are automatically generated by the program and sent to the output file when the predicted structural number falls outside the expected range. Table 12 shows an excerpt of the **FWDCHECK** output file for this portion of the program. As shown, it contains (1) the predicted subgrade modulus and SN values for each drop height and station combination, (2) subgrade modulus and SN statistics for the entire section <u>or</u> each individual subsection (see Section Homogeneity Analysis) as a function of drop height, and (3) if required, a tabular summary of warning messages for each data point outside the expected range, including drop height, station, expected SN range and predicted SN.

Additionally, the program user can also generate, to the screen, the following information: (1) plot of structural number versus station (with the expected SN range superimposed) for each drop height; (2) plot of subgrade modulus (under the load plate) versus station for each drop height; (3) plots of composite modulus versus radial distance (i.e., geophone location) for all drop heights at any given station; and (4) tabular summaries of subgrade modulus and SN values as well as corresponding statistics at each

Table 11

Structural Capacity Analysis of Flexible and Composite Pavements

$$E_e = \left(\frac{SN}{0.0043h_T}\right)^3 \left(1 - \mu_e^2\right)$$

where:	E_e	=	elasticity modulus of equivalent one-layer system
	SN	=	pavement structural number
	μ_o	=	Poisson's ratio of equivalent one-layer system
	h_T	=	total pavement thickness

$$\delta_o = \frac{2p_c a_c (1 - \mu_{sg}^2) F_w}{E_{sg}}$$

where:	δ_o	=	maximum measured deflection
	p_c	=	contact pressure
	a_c	=	radius of loaded area
	μ_{sg}	=	Poisson's ratio of subgrade
	E_{sg}	=	elastic modulus of subgrade
	F_w	=	Burmeister's two-layer deflection factor

$$F_w = \frac{E_{sg}(1 - \mu_e^2)}{E_e(1 - \mu_{sg}^2)} + F_b\left[1 - \left(\frac{E_{sg}}{E_e}\right)\right]$$

where:	F_b	=	Boussinesq's one-layer deflection factor

$$F_b = \left[\sqrt{\left(1 + \left(\frac{h_e}{a_c}\right)^2\right)} - \frac{h_e}{a_c}\right]\left[1 + \frac{\dfrac{h_e}{a_c}}{2(1 - \mu_{sg})\sqrt{\left(1 + \left(\dfrac{h_e}{a_c}\right)^2\right)}}\right]$$

where:	h_e	=	transformed thickness of pavement in terms of the subgrade modulus

$$h_e = 0.9h_T \sqrt[3]{\frac{E_e(1 - \mu_{sg}^2)}{E_{sg}(1 - \mu_e^2)}}$$

Table 12

Excerpt of FWDCHECK Output File - Structural Analysis of Flexible and Composite Pavements

FLEXIBLE Pavement Thickness Data - 371817A
(comparison of each calculation to the expected value)

Minimum expected SN value: 2.41
Maximum expected SN value: 4.07

Height	Station	Effective SN
1	0	4.10
1	560 (TP)	4.45
2	560 (TP)	4.45
3	560 (TP)	4.35
4	560 (TP)	4.30

FLEXIBLE Pavement Thickness Statistics - 371817A

Drop height 1

Subsection	Station	Subgrade Modulus	Effective SN
(TP)	-50	15708	3.70
1	0	15853	4.10
	25	14077	3.45
	50	14190	3.75
	75	16275	3.80
2	100	12409	3.85
	125	13040	3.75
	152	9714	3.60
	175	9547	3.65
3	200	9428	3.30
	225	15372	3.25
	250	9938	3.20
	275	11732	3.15

drop height for either the entire pavement section or subsections. Examples of these plots and tabular summary are given in Figures 11 through 13 and Table 13. These capabilities allow one to look at the structural capacity analysis results and, if desired, include additional warning messages in the output file in the form of running comments.

SUMMARY

This volume has provided a complete overview of the methods used internally by the program to perform its intended functions; to check FWD data and to flag potential errors or problems and correct them if possible before the information is processed further. Volume II of this report provides a detailed discussion of the programs' user interface, complete with excerpts and examples.

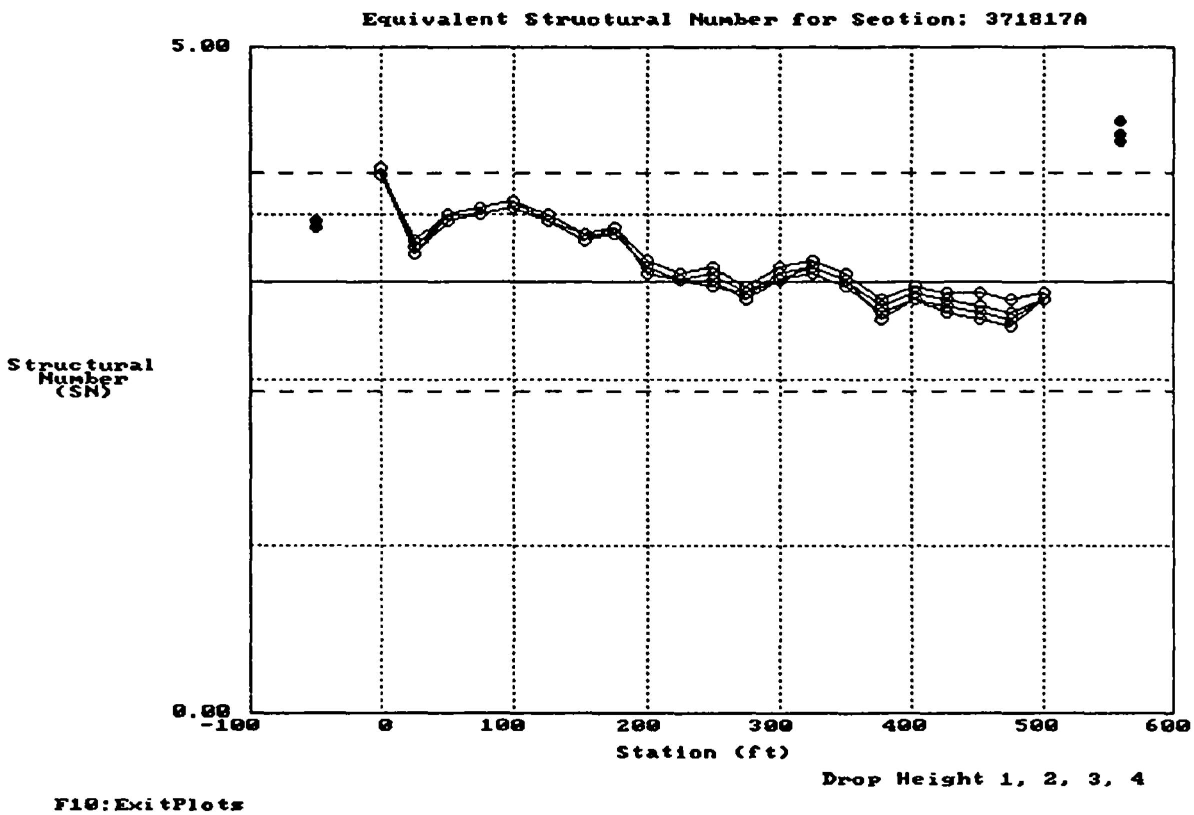

Figure 11 - Structural Number Versus Station Plot

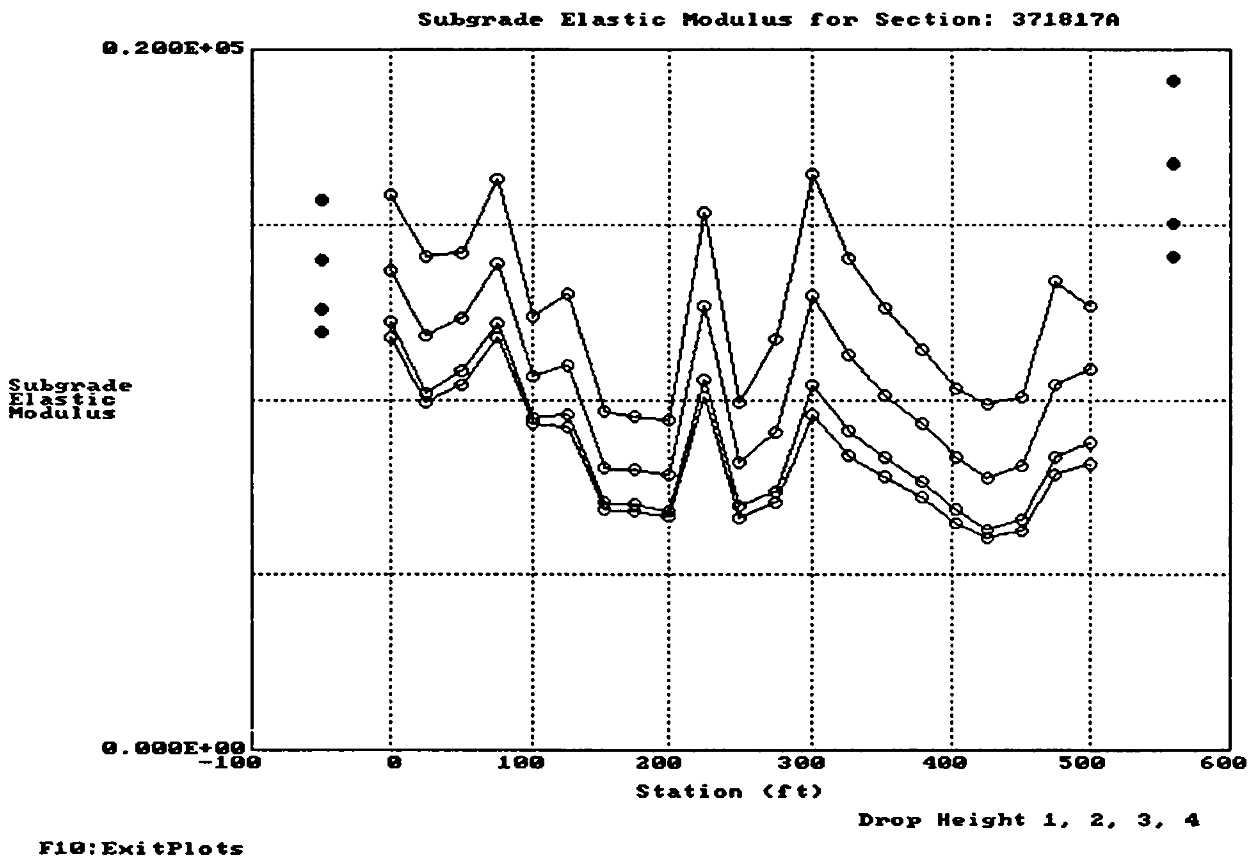

Figure 12 - Subgrade Modulus Versus Station Plot

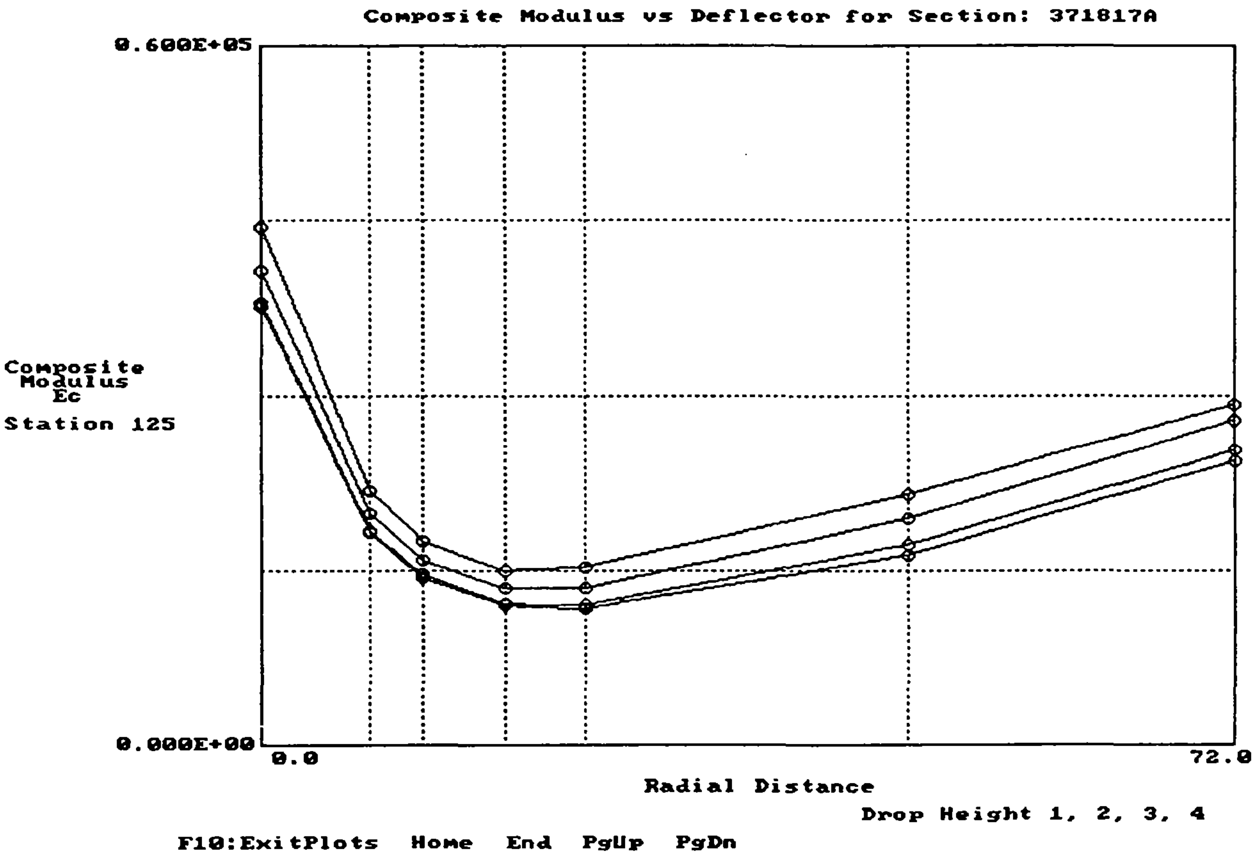

Figure 13 - Composite Modulus Versus Radial Distance
Plot - Flexible and Composite Pavements

Table 13

Tabular Summary of Subgrade Modulus and SN Values

371 817

FLEXIBLE Pavement Thickness Statistics

Data for section 371817A
Subsection 2
Drop height 2

Station	Subgrade Modulus	Effective SN
175	8039	3.10
200	7923	2.85
225	12706	2.80
250	8252	2.80
275	9107	2.70
300	13018	2.80
325	11299	2.85
351	10162	2.80
Overall Mean:	10063	2.84
Standard Deviation:	2074	0.12
Coeff Of Variation:	20.61%	4.08%

PgUp PgDn

APPENDIX A

FWDCHECK 2.00 Sample Output Files

Summary of Data for section 373807A
Analyzed by: SDR on 01-10-1991

UNCORRECTED Overall Deflection Statistics

Mean Values (mils/kip)

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	0.3076	0.2947	0.2754	0.2619	0.2414	0.1730	0.1279
	2	0.3325	0.3142	0.2964	0.2820	0.2596	0.1850	0.1379
	4	0.3652	0.3466	0.3267	0.3115	0.2887	0.2088	0.1505
1	1	0.2865	0.2745	0.2555	0.2396	0.2271	0.1634	0.1096
	2	0.3025	0.2878	0.2754	0.2641	0.2391	0.1705	0.1183
	4	0.3402	0.3236	0.3072	0.2941	0.2736	0.1975	0.1327

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	0.0236	0.0190	0.0110	0.0061	0.0076	0.0022	0.0166
	2	0.0227	0.0163	0.0140	0.0101	0.0046	0.0063	0.0173
	4	0.0116	0.0042	0.0021	0.0004	0.0027	0.0080	0.0160
1	1	0.0364	0.0353	0.0328	0.0286	0.0272	0.0155	0.0102
	2	0.0394	0.0380	0.0363	0.0340	0.0283	0.0161	0.0104
	4	0.0473	0.0450	0.0423	0.0394	0.0350	0.0212	0.0135

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	7.68%	6.44%	3.99%	2.31%	3.17%	1.27%	12.97%
	2	6.83%	5.20%	4.74%	3.57%	1.76%	3.38%	12.53%
	4	3.18%	1.22%	0.64%	0.11%	0.93%	3.82%	10.62%
1	1	12.69%	12.85%	12.85%	11.94%	11.96%	9.51%	9.34%
	2	13.02%	13.21%	13.17%	12.87%	11.85%	9.45%	8.80%
	4	13.91%	13.89%	13.78%	13.41%	12.78%	10.75%	10.17%

Rigid Pavement Deflection Statistics - 373807A
Subsection 1
Subsection begins at station 0
Subsection ends at station 320

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	0.2966	0.2848	0.2633	0.2443	0.2360	0.1699	0.1126
	2	0.3125	0.2980	0.2869	0.2760	0.2483	0.1772	0.1219
	4	0.3479	0.3320	0.3153	0.3020	0.2815	0.2047	0.1372

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	0.0349	0.0351	0.0334	0.0298	0.0272	0.0134	0.0110
	2	0.0386	0.0373	0.0344	0.0314	0.0267	0.0146	0.0107
	4	0.0458	0.0438	0.0415	0.0387	0.0337	0.0193	0.0129

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	11.78%	12.34%	12.70%	12.21%	11.51%	7.88%	9.79%
	2	12.34%	12.52%	12.00%	11.36%	10.77%	8.24%	8.74%
	4	13.16%	13.18%	13.17%	12.83%	11.97%	9.43%	9.38%

Rigid Pavement Deflection Statistics - 373807A
Subsection 2
Subsection begins at station 320
Subsection ends at station 410

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	0.2452	0.2359	0.2206	0.2116	0.1967	0.1426	0.1010
	2	0.2575	0.2437	0.2315	0.2204	0.2031	0.1493	0.1067
	4	0.2891	0.2734	0.2592	0.2490	0.2313	0.1685	0.1152

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	0.0380	0.0325	0.0308	0.0264	0.0223	0.0102	0.0050
	2	0.0386	0.0361	0.0342	0.0300	0.0247	0.0106	0.0054
	4	0.0494	0.0455	0.0409	0.0372	0.0317	0.0163	0.0071

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	15.51%	13.79%	13.96%	12.47%	11.36%	7.17%	4.93%
	2	14.98%	14.80%	14.79%	13.59%	12.16%	7.13%	5.08%
	4	17.10%	16.65%	15.78%	14.93%	13.69%	9.66%	6.17%

Rigid Pavement Deflection Statistics - 373807A
Subsection 3
Subsection begins at station 410
Subsection ends at station 500

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	0.2893	0.2745	0.2601	0.2480	0.2248	0.1601	0.1076
	2	0.3083	0.2925	0.2763	0.2635	0.2403	0.1674	0.1167
	4	0.3580	0.3386	0.3211	0.3066	0.2839	0.1992	0.1333

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	0.0122	0.0123	0.0099	0.0111	0.0076	0.0088	0.0070
	2	0.0123	0.0098	0.0104	0.0094	0.0067	0.0057	0.0041
	4	0.0218	0.0173	0.0150	0.0140	0.0121	0.0074	0.0068

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
1	1	4.22%	4.49%	3.79%	4.46%	3.37%	5.49%	6.47%
	2	3.99%	3.34%	3.75%	3.55%	2.81%	3.38%	3.50%
	4	6.08%	5.10%	4.67%	4.55%	4.28%	3.71%	5.10%

Outlier Statistics - 373807A

Subsection 1

Station	Height	Sensor	Number of Std. Dev.
15	2	1	-2.02
15	4	1	-2.27
15	4	2	-2.20
15	4	3	-2.14
15	4	4	-2.13
15	4	5	-2.11
43	1	4	-2.06
62	2	7	2.08
62	4	7	2.00
208	1	1	2.03
208	1	2	2.11
208	1	5	2.14
208	2	4	2.14
244	4	7	-2.03

Subsection 2

Station	Height	Sensor	Number of Std. Dev.

No deflection data for this subsection is more than 2.0 standard deviations from the subsection mean.

Subsection 3

Station	Height	Sensor	Number of Std. Dev.
566 (TP)	1	7	4.59
566 (TP)	2	5	2.39
566 (TP)	2	6	3.89
566 (TP)	2	7	8.21
566 (TP)	4	6	2.07
566 (TP)	4	7	4.19

Pavement Construction Information - 373807A

Material Code	Material Name	Layer Thickness
730	Portland Cement Concrete	9.5
332	Econocrete	4.0

RIGID Pavement Thickness Data - 373807A
(comparison of each calculation to the expected value)

Minimum expected thickness: 6.17
Maximum expected thickness: 10.92

Height	Station	Effective Thickness
1	15	12.50
2	15	12.50
4	15	12.50
1	43	12.50
2	43	11.75
4	43	11.75
1	185	11.00
1	305	11.00
1	346	12.50
2	346	11.75
4	346	11.75
1	366	11.00
1	389	12.50
2	389	12.50
4	389	11.75
1	412	11.00
1	426	11.00
1	566 (TP)	11.00

RIGID Pavement Thickness Statistics - 373807A

Drop height 1

Subsection	Station	Volumetric k	Effective Thickness
(TP)	-50	327	10.25
1	15	354	12.50
	43	361	12.50
	62	306	10.25
	77	325	10.63
	98	329	10.63
	124	373	10.25
	144	346	10.63
	164	327	10.63
	185	356	11.00
	208	288	9.88
	228	323	9.88
	244	371	10.63
	261	317	10.25
	280	348	10.63
	305	373	11.00
2	325	360	10.63
	346	408	12.50
	366	392	11.00
	389	431	12.50
3	412	348	11.00
	426	369	11.00
	450	339	10.63
	472	371	10.25
	492	345	10.25
(TP)	566	315	11.00
Subsection 1 Overall Mean:		340	10.75
Standard Deviation:		26	0.78
Coeff Of Variation:		7.59%	7.30%
Subsection 2 Overall Mean:		398	11.66
Standard Deviation:		30	0.99
Coeff Of Variation:		7.48%	8.46%
Subsection 3 Overall Mean:		354	10.63
Standard Deviation:		14	0.38
Coeff Of Variation:		4.09%	3.53%

RIGID Pavement Thickness Statistics - 373807A

Drop height 2

Subsection	Station	Volumetric k	Effective Thickness
(TP)	-50	307	9.88
1	15	348	12.50
	43	350	11.75
	62	281	10.25
	77	306	10.25
	98	305	10.63
	124	322	10.25
	144	328	10.25
	164	308	10.25
	185	335	10.63
	208	275	9.50
	228	301	9.88
	244	356	10.63
	261	310	10.25
	280	324	10.25
	305	357	10.63
2	325	342	10.63
	346	397	11.75
	366	372	10.63
	389	414	12.50
3	412	338	10.25
	426	340	10.63
	450	328	10.63
	472	333	10.25
	492	328	10.25
(TP)	566	292	10.63
Subsection 1 Overall Mean:		320	10.52
Standard Deviation:		26	0.73
Coeff Of Variation:		8.05%	6.93%
Subsection 2 Overall Mean:		381	11.38
Standard Deviation:		31	0.92
Coeff Of Variation:		8.27%	8.08%
Subsection 3 Overall Mean:		333	10.40
Standard Deviation:		6	0.21
Coeff Of Variation:		1.67%	1.97%

RIGID Pavement Thickness Statistics - 373807A

Drop height 4

Subsection	Station	Volumetric k	Effective Thickness
(TP)	-50	278	9.88
1	15	329	12.50
	43	317	11.75
	62	242	9.88
	77	259	10.25
	98	267	10.25
	124	288	9.88
	144	283	9.88
	164	262	9.88
	185	283	10.25
	208	247	9.50
	228	262	9.50
	244	329	10.25
	261	280	9.88
	280	283	9.88
	305	310	10.25
2	325	301	10.25
	346	354	11.75
	366	329	10.25
	389	382	11.75
3	412	279	9.88
	426	302	10.25
	450	281	10.25
	472	288	9.88
	492	273	9.50
(TP)	566	261	10.25
Subsection 1 Overall Mean:		283	10.25
Standard Deviation:		28	0.81
Coeff Of Variation:		9.79%	7.94%
Subsection 2 Overall Mean:		342	11.00
Standard Deviation:		35	0.87
Coeff Of Variation:		10.19%	7.87%
Subsection 3 Overall Mean:		285	9.95
Standard Deviation:		11	0.31
Coeff Of Variation:		3.87%	3.15%

Summary of Results

Section uniformity:
Subsections were identified within the section.
Subsection 1 boundaries occur at 0 ft. and 320 ft.
Subsection 2 boundaries occur at 320 ft. and 410 ft.
Subsection 3 boundaries occur at 410 ft. and 500 ft.

Comparing subsections:
Subsections 1 and 2: UNEQUAL means and EQUAL variances.
Subsections 2 and 3: UNEQUAL means and EQUAL variances.

Outliers - Test pits: 21 combinations at each test pit
All TP 1 data appears representative of section data.
6 height/sensor combinations at TP 2 DO NOT appear representative of section data.

Outliers - Section data: 546 total combinations within the section
14 height/sensor/station combinations are data outliers in subsection 1.
There are NO data outliers within subsection 2.
There are NO data outliers within subsection 3.

Structural capacity - Test pits: 3 combinations at each test pit
All results for TP 1 are within the range of expected values.
1 height(s) for TP 2 are NOT within the range of expected values.

Structural capacity - Section data: 78 total combinations within the section
17 height/station combinations are NOT within the range of expected values.

FWDCHECK 1.00 Sample Output File - Flexible Pavement

Summary of Data for section 371817A
Analyzed by: SDR on 01-10-1991

UNCORRECTED Overall Deflection Statistics

Mean Values (mils/kip)

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	1.5156	1.2534	1.0367	0.8269	0.6222	0.2335	0.1272
	2	1.6146	1.3409	1.1212	0.8980	0.6823	0.2553	0.1325
	3	1.7142	1.4334	1.2080	0.9776	0.7482	0.2819	0.1436
	4	1.7787	1.4880	1.2578	1.0213	0.7858	0.3007	0.1512
3	1	2.4343	1.9324	1.5444	1.1444	0.8055	0.2492	0.1286
	2	2.6480	2.1267	1.7283	1.3054	0.9296	0.2829	0.1372
	3	2.8237	2.2968	1.8916	1.4572	1.0577	0.3272	0.1491
	4	2.8270	2.3119	1.9172	1.4936	1.0958	0.3448	0.1535

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	0.4263	0.2886	0.2051	0.1252	0.0544	0.0186	0.0117
	2	0.4349	0.2974	0.2164	0.1350	0.0581	0.0250	0.0112
	3	0.4237	0.2990	0.2202	0.1344	0.0576	0.0298	0.0155
	4	0.3982	0.2897	0.2151	0.1317	0.0536	0.0348	0.0178
3	1	0.4899	0.3580	0.2579	0.1611	0.1108	0.0381	0.0222
	2	0.5248	0.3982	0.2978	0.1971	0.1344	0.0441	0.0242
	3	0.5563	0.4353	0.3379	0.2358	0.1632	0.0532	0.0268
	4	0.5472	0.4330	0.3415	0.2459	0.1720	0.0579	0.0276

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
0	1	28.13%	23.02%	19.79%	15.14%	8.74%	7.95%	9.19%
	2	26.93%	22.18%	19.30%	15.03%	8.51%	9.78%	8.45%
	3	24.71%	20.86%	18.23%	13.75%	7.70%	10.56%	10.78%
	4	22.39%	19.47%	17.10%	12.89%	6.82%	11.58%	11.75%
3	1	20.13%	18.52%	16.70%	14.07%	13.75%	15.31%	17.26%
	2	19.82%	18.72%	17.23%	15.10%	14.46%	15.58%	17.67%
	3	19.70%	18.95%	17.86%	16.18%	15.43%	16.26%	18.00%
	4	19.36%	18.73%	17.81%	16.46%	15.70%	16.78%	17.98%

Flexible Pavement Deflection Statistics - 371817A
Subsection 1
Subsection begins at station 0
Subsection ends at station 100

Mean Values (mils/kip)

CORRECTED

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	1.7695	1.4567	1.2075	0.9339	0.6847	0.2248	0.1210
	2	1.9160	1.5848	1.3256	1.0407	0.7696	0.2537	0.1282
	3	2.0295	1.6894	1.4237	1.1330	0.8495	0.2865	0.1379
	4	2.0323	1.6983	1.4380	1.1496	0.8696	0.2981	0.1405

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	0.2480	0.1643	0.1225	0.0793	0.0384	0.0154	0.0050
	2	0.2648	0.1774	0.1365	0.0911	0.0468	0.0156	0.0055
	3	0.2691	0.1845	0.1465	0.1016	0.0565	0.0170	0.0065
	4	0.2473	0.1734	0.1396	0.0998	0.0564	0.0167	0.0065

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	14.02%	11.28%	10.14%	8.49%	5.61%	6.86%	4.12%
	2	13.82%	11.19%	10.30%	8.76%	6.09%	6.13%	4.31%
	3	13.26%	10.92%	10.29%	8.97%	6.65%	5.95%	4.71%
	4	12.17%	10.21%	9.71%	8.68%	6.49%	5.60%	4.65%

Flexible Pavement Deflection Statistics - 371817A
Subsection 2
Subsection begins at station 100
Subsection ends at station 200

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	2.0845	1.7526	1.4552	1.1383	0.8403	0.2611	0.1191
	2	2.2870	1.9280	1.6144	1.2794	0.9508	0.2937	0.1261
	3	2.4502	2.0792	1.7525	1.4059	1.0582	0.3332	0.1399
	4	2.4598	2.0937	1.7710	1.4297	1.0828	0.3477	0.1448

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	0.2446	0.1992	0.1524	0.1124	0.0814	0.0249	0.0112
	2	0.2804	0.2383	0.1859	0.1415	0.1006	0.0252	0.0102
	3	0.3159	0.2686	0.2148	0.1688	0.1186	0.0288	0.0122
	4	0.3246	0.2755	0.2230	0.1787	0.1251	0.0302	0.0127

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	11.73%	11.37%	10.47%	9.87%	9.68%	9.52%	9.40%
	2	12.26%	12.36%	11.51%	11.06%	10.58%	8.58%	8.07%
	3	12.89%	12.92%	12.26%	12.01%	11.21%	8.64%	8.69%
	4	13.20%	13.16%	12.59%	12.50%	11.55%	8.67%	8.77%

Flexible Pavement Deflection Statistics - 371817A
Subsection 3
Subsection begins at station 200
Subsection ends at station 300

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	2.5864	2.0722	1.6255	1.1974	0.8165	0.2114	0.1017
	2	2.8369	2.2868	1.8301	1.3681	0.9472	0.2424	0.1087
	3	3.0062	2.4580	1.9953	1.5190	1.0751	0.2815	0.1167
	4	3.0121	2.4681	2.0145	1.5528	1.1107	0.2960	0.1207

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	0.2196	0.1645	0.1945	0.1412	0.1285	0.0502	0.0196
	2	0.2673	0.2020	0.2012	0.1628	0.1456	0.0598	0.0241
	3	0.2647	0.2156	0.2080	0.1738	0.1585	0.0699	0.0274
	4	0.2678	0.2198	0.2123	0.1793	0.1642	0.0764	0.0291

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	8.49%	7.94%	11.97%	11.79%	15.73%	23.76%	19.31%
	2	9.42%	8.83%	10.99%	11.90%	15.37%	24.68%	22.14%
	3	8.80%	8.77%	10.43%	11.44%	14.75%	24.84%	23.47%
	4	8.89%	8.91%	10.54%	11.55%	14.78%	25.82%	24.11%

Flexible Pavement Deflection Statistics - 371817A
Subsection 4
Subsection begins at station 300
Subsection ends at station 400

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
----	----	------	------	------	------	------	------	------
3	1	2.4720	1.9568	1.5485	1.1222	0.7680	0.2571	0.1408
	2	2.6942	2.1703	1.7498	1.2971	0.9016	0.2930	0.1503
	3	2.8922	2.3701	1.9381	1.4710	1.0471	0.3435	0.1646
	4	2.9112	2.4058	1.9866	1.5287	1.1035	0.3655	0.1697

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
----	----	------	------	------	------	------	------	------
3	1	0.3815	0.2919	0.2144	0.1353	0.0933	0.0224	0.0094
	2	0.3647	0.2850	0.2184	0.1451	0.1006	0.0219	0.0100
	3	0.3494	0.2774	0.2181	0.1517	0.1093	0.0233	0.0120
	4	0.3208	0.2563	0.2050	0.1451	0.1054	0.0253	0.0115

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
----	----	------	------	------	------	------	------	------
3	1	15.43%	14.92%	13.85%	12.06%	12.15%	8.72%	6.66%
	2	13.54%	13.13%	12.48%	11.18%	11.16%	7.48%	6.66%
	3	12.08%	11.70%	11.25%	10.31%	10.44%	6.78%	7.29%
	4	11.02%	10.65%	10.32%	9.49%	9.55%	6.93%	6.81%

Flexible Pavement Deflection Statistics - 371817A
Subsection 5
Subsection begins at station 400
Subsection ends at station 500

Mean Values (mils/kip)

Test Loc.	Drop Ht	CORRECTED Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	2.9363	2.3254	1.8174	1.2930	0.8953	0.2833	0.1541
	2	3.1660	2.5564	2.0431	1.4944	1.0491	0.3220	0.1655
	3	3.3806	2.7693	2.2569	1.6972	1.2184	0.3786	0.1790
	4	3.3651	2.7772	2.2841	1.7445	1.2690	0.4021	0.1842

Standard Deviations

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	0.1836	0.1861	0.1412	0.1075	0.0947	0.0261	0.0127
	2	0.2092	0.2090	0.1659	0.1336	0.1124	0.0373	0.0115
	3	0.2161	0.2204	0.1843	0.1590	0.1280	0.0436	0.0133
	4	0.2047	0.2112	0.1794	0.1585	0.1274	0.0433	0.0128

Coefficient of Variation

Test Loc.	Drop Ht	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7
3	1	6.25%	8.00%	7.77%	8.32%	10.58%	9.20%	8.21%
	2	6.61%	8.18%	8.12%	8.94%	10.72%	11.58%	6.93%
	3	6.39%	7.96%	8.17%	9.37%	10.50%	11.51%	7.42%
	4	6.08%	7.60%	7.85%	9.09%	10.04%	10.77%	6.95%

Outlier Statistics - 371817A

Subsection 1

Station	Height	Sensor	Number of Std. Dev.

No deflection data for this subsection is more than 2.0 standard deviations from the subsection mean.

Subsection 2

Station	Height	Sensor	Number of Std. Dev.

No deflection data for this subsection is more than 2.0 standard deviations from the subsection mean.

Subsection 3

Station	Height	Sensor	Number of Std. Dev.

No deflection data for this subsection is more than 2.0 standard deviations from the subsection mean.

Subsection 4

Station	Height	Sensor	Number of Std. Dev.

No deflection data for this subsection is more than 2.0 standard deviations from the subsection mean.

Subsection 5

Station	Height	Sensor	Number of Std. Dev.
560 (TP)	1	1	-9.49
560 (TP)	1	2	-6.86
560 (TP)	1	3	-6.56
560 (TP)	1	4	-5.16
560 (TP)	1	5	-3.29
560 (TP)	2	1	-8.99
560 (TP)	2	2	-6.82
560 (TP)	2	3	-6.48
560 (TP)	2	4	-5.18
560 (TP)	2	5	-3.63
560 (TP)	2	7	-2.19
560 (TP)	3	1	-9.20

Outlier Statistics - 371817A

Station	Height	Sensor	Number of Std. Dev.
560 (TP)	3	2	-7.02
560 (TP)	3	3	-6.53
560 (TP)	3	4	-5.12
560 (TP)	3	5	-3.99
560 (TP)	4	1	-9.24
560 (TP)	4	2	-7.07
560 (TP)	4	3	-6.57
560 (TP)	4	4	-5.15
560 (TP)	4	5	-4.09

Pavement Construction Information - 371817A

Material Code	Material Name	Layer Thickness
700	Asphaltic Concrete	4.5
302	Uncrushed Gravel	12.0

Depth to rigid foundation: 100.0 ft.

FLEXIBLE Pavement Thickness Data - 371817A
(comparison of each calculation to the expected value)

Minimum expected SN value: 2.41
Maximum expected SN value: 4.07

Height	Station	Effective SN
1	0	4.10
1	560 (TP)	4.45
2	560 (TP)	4.45
3	560 (TP)	4.35
4	560 (TP)	4.30

FLEXIBLE Pavement Thickness Statistics - 371817A

Drop height 1

Subsection	Station	Subgrade Modulus	Effective SN
(TP)	-50	15708	3.70
1	0	15853	4.10
	25	14077	3.45
	50	14190	3.75
	75	16275	3.80
2	100	12409	3.85
	125	13040	3.75
	152	9714	3.60
	175	9547	3.65
3	200	9428	3.30
	225	15372	3.25
	250	9938	3.20
	275	11732	3.15
4	300	16429	3.25
	325	14068	3.35
	351	12663	3.25
	377	11449	2.95
5	402	10373	3.10
	427	9912	3.00
	452	10120	2.95
	475	13382	2.90
	501	12677	3.10
(TP)	560	19113	4.45

	Subgrade Modulus	Effective SN
Subsection 1 Overall Mean:	15099	3.77
Standard Deviation:	1129	0.27
Coeff Of Variation:	7.48%	7.05%
Subsection 2 Overall Mean:	11178	3.71
Standard Deviation:	1806	0.11
Coeff Of Variation:	16.16%	2.99%
Subsection 3 Overall Mean:	11617	3.22
Standard Deviation:	2691	0.06
Coeff Of Variation:	23.16%	2.00%
Subsection 4 Overall Mean:	13652	3.20
Standard Deviation:	2138	0.17
Coeff Of Variation:	15.66%	5.41%
Subsection 5 Overall Mean:	11293	3.01
Standard Deviation:	1613	0.09
Coeff Of Variation:	14.28%	2.97%

FLEXIBLE Pavement Thickness Statistics - 371817A

Drop height 2

Subsection	Station	Subgrade Modulus	Effective SN
(TP)	-50	14008	3.65
1	0	13686	4.05
	25	11829	3.45
	50	12331	3.70
	75	13898	3.75
2	100	10685	3.80
	125	11016	3.70
	152	8084	3.60
	175	8039	3.60
3	200	7923	3.35
	225	12706	3.25
	250	8252	3.25
	275	9107	3.10
4	300	13018	3.25
	325	11299	3.30
	351	10162	3.20
	377	9357	3.00
5	402	8383	3.10
	427	7824	3.05
	452	8128	3.00
	475	10449	2.95
	501	10880	3.10
(TP)	560	16745	4.45

Subsection 1 Overall Mean:	12936	3.74
Standard Deviation:	1013	0.25
Coeff Of Variation:	7.83%	6.59%
Subsection 2 Overall Mean:	9456	3.67
Standard Deviation:	1616	0.10
Coeff Of Variation:	17.09%	2.61%
Subsection 3 Overall Mean:	9497	3.24
Standard Deviation:	2197	0.10
Coeff Of Variation:	23.13%	3.18%
Subsection 4 Overall Mean:	10959	3.19
Standard Deviation:	1587	0.13
Coeff Of Variation:	14.48%	4.13%
Subsection 5 Overall Mean:	9133	3.04
Standard Deviation:	1420	0.07
Coeff Of Variation:	15.55%	2.14%

FLEXIBLE Pavement Thickness Statistics - 371817A

Drop height 3

Subsection	Station	Subgrade Modulus	Effective SN
(TP)	-50	12599	3.70
1	0	12274	4.05
	25	10223	3.50
	50	10836	3.75
	75	12223	3.75
2	100	9501	3.80
	125	9588	3.70
	152	7096	3.55
	175	7034	3.60
3	200	6841	3.35
	225	10587	3.25
	250	7015	3.30
	275	7395	3.15
4	300	10450	3.30
	325	9144	3.35
	351	8415	3.25
	377	7725	3.05
5	402	6906	3.15
	427	6319	3.10
	452	6604	3.05
	475	8377	3.00
	501	8821	3.10
(TP)	560	15026	4.35

Subsection 1 Overall Mean:	11389	3.76
Standard Deviation:	1024	0.22
Coeff Of Variation:	8.99%	5.98%
Subsection 2 Overall Mean:	8305	3.66
Standard Deviation:	1432	0.11
Coeff Of Variation:	17.25%	3.03%
Subsection 3 Overall Mean:	7959	3.26
Standard Deviation:	1767	0.09
Coeff Of Variation:	22.20%	2.62%
Subsection 4 Overall Mean:	8934	3.24
Standard Deviation:	1165	0.13
Coeff Of Variation:	13.04%	4.06%
Subsection 5 Overall Mean:	7405	3.08
Standard Deviation:	1120	0.06
Coeff Of Variation:	15.13%	1.85%

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USAE Waterways Experiment Station

Louis M. Papet
Federal Highway Administration

John P. Hallin
Federal Highway Administration

Ted Ferragut
Federal Highway Administration

Frank R. McCullagh
Transportation Research Board

Expert Task Group

Paul D. Anderson
Mountainview Geotechnical Ltd.

Robert C. Briggs
Engineer of Pavement Management

Albert J. Bush, III
USAE Waterways Experimental Station

Billy G. Connor
Alaska Department of Transportation

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Engineer Research and Development

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Federal Highway Administration

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Alabama Highway Department

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