Non-Destructive Evaluation of Iowa Pavements Phase 2:

Development of a Fully Automated Software System for Rapid Analysis/ Processing of the Falling Weight Deflectometer Data

Final Report February 2009

Center for Transportation Research and Education

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Final Report February 2009

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EXECUTIVE SUMMARY

This study is a follow-up to the IA DOT Project (CTRE Project 04-177), Nondestructive Evaluation of Iowa Pavements - Phase 1. The objective of this Phase II study is the development of a fully-automated software system for rapid processing of the FWD data accompanied by a user manual. The software system can automatically read the FWD raw data collected by the Iowa DOT's JILS-20 type FWD machine, process and analyze the collected data with the rapid prediction algorithms developed during the phase I study. This report, which can also be used as a user-manual for the software, contains examples or case studies for all three pavement types (flexible, rigid, and composite) illustrating the step-by-step procedure in using the software.

Some of specific features of the fully-automated software system described in this report are summarized below:

- A comprehensive pavement structural analysis toolbox incorporating all three common pavement types (flexible, rigid, and composite)
- Capability of automatically reading the FWD raw data collected by the JILS-20 type FWD machine that Iowa DOT owns
- Integration of all the Artificial Neural Network (ANN) models developed as part of Phase I research into a comprehensive unified framework
- Rapid backcalculation of pavement layer moduli and prediction of critical pavement responses from FWD data (100,000 deflection basins analyzed in less than a second)
- Useful for both project-level and network-level pavement structural evaluation
- Visualization of results through automatic plotting capability
- Commonly used Import/Export options for transporting data
- Automatic generation of output statistics

INTRODUCTION

Evaluating structural condition of existing, in-service pavements is a part of the routine maintenance and rehabilitation activities undertaken by the most Departments of Transportation (DOTs). In the field, the pavement deflection profiles (or basins) gathered from the nondestructive Falling Weight Deflectometer (FWD) test data are typically used to evaluate pavement structural condition. FWD testing is often preferred over destructive testing methods because it is faster than destructive tests and does not entail the removal of pavement materials. This kind of evaluation requires the use of backcalculation type structural analysis to determine pavement layer stiffnesses and as a result estimate pavement remaining life. Although the Office of Special Investigations at Iowa DOT has collected the FWD data on regular basis, the pavement layer moduli backcalculation techniques used so far have been cumbersome and time consuming. Thus, there was a need for more efficient and faster methods.

During the first phase of the Iowa (DOT) Project (CTRE Project 04-177), "Nondestructive Evaluation of Iowa Pavements-Phase I", advanced yet easy-to-use backcalculation models were developed using the ANN methodology (Ceylan et al, 2007). ANNs are very adaptable and support the real-time applications of the developed models. These ANN models are capable of predicting pavement layer stiffnesses as well as pavement critical responses (forward modeling) from FWD test results. For the three pavement types, over 300 models in total were developed for varying input parameters. The primary pavement types considered were flexible (conventional and full-depth), rigid, and composite.

Predicted flexible pavement parameters were, E_{AC} -modulus of hot-mix asphalt (HMA) or asphalt concrete (AC), K_b -base modulus parameter, E_{Ri} -subgrade resilient modulus, ϵ_{AC} -tensile strain at the bottom of asphalt layer, ϵ_{SG} -compressive strain at the top of subgrade, and σ_D -subgrade deviator stress.

For rigid pavements, E_{PCC} -modulus of portland cement concrete (PCC), k_s -coefficient of subgrade reaction, σ_{PCC} -tensile stress at the bottom of the PCC layer, and radius of relative stiffness (RRS) were predicted.

In the case of composite pavements (CPs), where an AC surface is overlaid on top of an existing PCC pavement, E_{AC} , E_{PCC} , ks, σ_{PCC} (tensile stress at the bottom of the PCC), and ε_{AC} were predicted.

The developed methodology was successfully verified using results from long-term pavement performance (LTPP) FWD test results, as well as Iowa DOT FWD field data. All successfully developed ANN models were incorporated into a Microsoft Excel spreadsheet-based backcalculation software toolbox with a user-friendly interface. The phase I study also concluded that the developed nondestructive pavement evaluation methodology for analyzing the FWD deflection data would be adopted by Iowa DOT pavement and material engineers and technicians, who do not employ any preferable FWD backcalculation analysis technique.

OBJECTIVES

This phase II follow-up study of IA DOT Project (CTRE Project 04-177) focused on the development of a fully-automated software system for rapid processing of the FWD data. The software system can automatically read the FWD raw data collected by the JILS-20 type FWD machine that Iowa DOT owns, process and analyze the collected data with the algorithms being developed during the phase I study. This system smoothly integrates the FWD data analysis algorithms and the computer program being used to collect the pavement deflection data. With the implementation of the developed software system the FWD data can be filtered, processed and analyzed on-the-fly.

PROGRAM USER MANUAL

The password-protected, Excel-based software toolbox was developed using Microsoft Visual Basic programming language and Excel macros. In case of troubleshooting, the user is requested to change the macro security (Tools \rightarrow Macro \rightarrow Security) to the "medium" or "low" level to allow macros to run. The Excel spreadsheets provide the user interaction for data editing and pasting, displaying results, charts, and tables, and for displaying statistical information. The Excel sheets include a main menu, analysis menu (for each pavement type), plotting menu, and summary menu.

Program Main Menus

The program starts by displaying the main menu (Figure 1). As a first step, users are expected to select the pavement type (conventional, full-depth flexible, composite or rigid pavements) by clicking on it to activate the selected pavement analysis Excel sheet/interface. There are six Excel pavement analysis sheets, including the conventional flexible pavement analysis module with 9-kip and variable FWD load, the full-depth flexible pavements analysis module with 9-kip and variable FWD load, and the composite and rigid pavement analysis module with 9-kip FWD load, and the composite and rigid pavement analysis module with 9-kip FWD loading. The software toolbox is programmed to give warning messages if the user clicks anywhere else.

While working with the toolbox, all other Excel features are accessible, including open, close, copy, paste, save, save as, print, and print settings. When the user quits the toolbox, all the charts and results for the analysis, except the last data entered, will be deleted. To retain the results, they should be copied into another spreadsheet.

The ANN information buttons in Figure 2 provide the user general information about the ANN models employed. Six Excel Spreadsheets as shown in Figure 3 appear upon clicking "ANN info show" button. Each of Excel sheets as shown in Figure 4 contain the ANN model information such as the ranges of the data used in the development of ANN models. These Excel sheets can be hid again by clicking on "ANN info hide".

Flexible		
Pavements	Composite Pavements	Rigid Pavements
currenticural Hexilde Analysis (Olip) currenticural Hexilde Analysis (variade boxo	Al overlaid PBB Analysis	Stat on Grade Analysis
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sclaimer: This tool is for demonstration purposes only. opyright: Dr. Hall Ceylan, Iowa State University, email: heeylan@iasta Alper Guchi, Iowa State University, email: alper@iastate.edu M. Birkan Bayrak, Iowa State University, email: birkan@iast	ne.edu ANN IN are.edu ANN IN	IFO SHOW



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	M. Birkan Bayrak, Iowa State University, email: birkan@iastate.edu	

Figure 2. ANN Information button in main menu



Figure 3. Screenshot of main menu on choosing ANN info show option

		4 Deflec	tions-Eac			4 Deflec	tions-Eri			6 Deflec	tions-Eac			6 Deflec	tions-Eri			7 Deflect	tions-Eac		7 Deflections-Eri				
Deflection	4	4	4	4	4	4	4	4	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	
Def-His	0.3175553	0.31474452	0.30357527	0.29185452	0.3175553	0.31229141	0.22	0.20552225	0.2726454	0.26269119	0.27555065	0.25267917	0.2726454	0.2726414	0.25450761	0.25975147	0.2726414	0.2726414	0.25170457	0.24739108	0.2726414	0.26910228	0.26680548	0.25703109	0.27264
Def-Hay	116,2279	112.4325	118,2528	125.764	116.2274	117,7832	122.0254	124.3797	116.2274	112.0127	119.0698	122.2015	116.2274	117.0621	121.6729	127.3482	116.2279	112.51	129,5239	122.6226	116.2279	112,1922	128,1237	125.0367	116.227
Hec-His	2	2	2	3	3	3	2	3	3	3	3	2	3	2	3	3	2	2	2	2	2	2	2	2	2
Hac-Hay	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	23	28	28	28	28	28	28
Lood-His	44	44	44	44	44	44	44	44	44	44	44	44	64	64	64	64	64	64	64	64	64	64	64	44	44
Land-Haz	105	105	105	106	106	194	126	126	\$26	126	126	126	116	116	116	116	115	116	115	115	105	105	105	105	105
E-His	100000	103030	103030	103030	1203	1100	1103	1000	101010	502020	591010	991010	1000	1000	1000	1090	110303	110303	110303	110303	1020	1080	1010	5010	160800
E-Hex	\$030309	6020209	6010100	6010103	15080	15060	15060	15000	6000000	6060600	6000000	6000000	15103	15100	15100	15100	6101010	6001010	6101010	6101010	15000	15000	15000	15000	\$00000
Waightfile	4141	4141	4141	4141	4141	4141	4141	4141	4261	4261	4261	4261	4261	4261	4261	4261	4721	4721	4721	4221	4221	4221	4221	4221	4211
	02	22	52	102	02	22	52	102	02	22	52	102	02	22	52	102	02	22	52	102	02	22	52	102	02
1	2.77461	13,28991	8.419391	-1.402421	4.71E-01	-2.572769	-5.598957	-5.178228	-12,29745	-37.9673	-59.51105	-41.92102	-5.82456	-7.543364	-9.458497	-67,01115	7.524997	14.01233	24,8419	\$7.69955	-41,31042	-57.50967	-70.7619	-82.51126	9.292-0
2	-4.42228	-6.959422	-7.010349	-1.494642	-5.972-01	-2.85E-01	-2.12462	-2.950485	10.162.03	11.95151	6.1266	2.416-01	1.881797	2.503599	3.324698	17.22242	-12.26729	-15.24723	-15.76547	-2.050126	14.61777	11.94524	11.00292	18.07071	-1.6747
>	-1.092-01	-5.924786	-5.780467	-4,537799	-1.164783	-4.282-01	-1.375498	2.247925	2.194149	6.259124	2.76175	9.041651	2.646-01	2.2%-01	9.545-02	-10.66167	-5.025042	-10.64151	-12.87695	-7.272156	3.122224	4.993210	4.921642	3.904059	-1.46196
4	2.042471	2.534976	2.691547	-6.001224	-1.451329	-1.416367	-2.62304	-2.22502	-5.010274	1,522176	1.455451	6.129465	-2.316-01	-2.015-01	-1.010405	-16.11059	-2.299197	-7.697657	-10.79434	-4.179477	-5.215-01	1.901984	1.74925	9.012-01	-1.5228
5	2.742667	17.72988	\$2.47515	14.64121	-1.190356	-1.232643	-2.096422	-6.759973	-8.418927	-5.642159	-4.990178	-2.076128	1.845-01	6.525-02	-8.76E-01	-12.46109	1.225932	-2.611218	-7.122196	-12.23573	-4.761502	-1.36082	-1.405928	-7.558922	-1.0171
6	-2.64E-01	-2.401075	-4.922-01	-6.023117	-3.775-01	8.29E-01	9.112-01	1.791549	-0.520905	-12.07040	-12.94946	-12.07503	6.215-01	4.928-01	-5.35E-01	-6.056917	3.723042	5.205-01	-2.358644	-2.729799	-9.122942	-4.352664	-3.905011	-7.763726	-6.562-1
7	1.025019	5.91E-01	2.956782	4.745	5.60E-01	1.404105	4.171529	5.0502F	-5.071251	-19.02399	-22.89147	-23.105.02	2.259116	2.962263	9.946-01	-2.451495	8.174849	11.25103	9.2901	5.907231	-11.69792	-11.12492	-10.29205	-14.4245	1.11075
	6.050022	6.031537	12.12225	15.37191	20.025.09	41.19523	54,00364	63.39924	2.316-02	7.63E-01	2.415-01	4,73656	4.516562	5.501092	1.569519	1.206212	10.65439	32.27297	\$1.49770	\$2.09135	-14.42547	-28.01662	-20.7252	-25.01124	1.50201
•	0.920527	10.70556	\$2.04620	17.27221	-4.24E-01	-5.412-01	-2.039794	-0.60E-02	-6.09E-01	-9.22E-01	-2.69E-01	-8.89E-01	-4.032011	-4.671660	-6.540752	-1.966743	-1.662-01	-5.025-01	-1.103735	-1.312929	-2.268-01	1.062-01	-3.396-01	-1.422071	1.05020
10	1,016906	7.094249	4.900752	5.096366	1.962144	2.416-02	-2.93E-01	-5.950426	-1.21E-02	-1.035925	-2.522249	-6.952922	21.97660	22.22242	41,24697	46.96591	-2.37E-03	-1.245-02	1.011292	0.072-01	-2.945-01	-4.672-01	3.332-01	2.355-02	-9.505-1
11	-2.026002	-1.501020	-5.692-01	-4.978462	4.226403	5.370902	5.733371	2.919222	-19.22924	-25.70959	-29.23591	-22.19668	-8.294451	-4.949155	-5.769924	-6.169292	5.593422	12.23964	17.33083	27.03725	24.79655	60.0163	70.09402	97.95035	2.71179
12	-4.561045	-14.05016	-7.039099	-7.196364	7.09578	17.70469	25.92925	26.25912	-5.292774	-9.074725	-12.00262	-12.64159	-1.69E-01	-2.753676	-2.759109	-1.343992	-9.932-01	2.047206	-2.915-01	-2.437412	4.201615	9.016696	6.546012	1.010913	7.70115
12	1.621113	2.298319	1.472-01	2.020164	1.124722	5.79E-01	6.76E-01	7.205-01	-5.062-01	+2.220244	-5.051204	-4.675571	2.109240	-1.759921	-1.967522	-1.99E-01	-4.12E-01	1.652-01	-6.912-02	1.14957	1.701742	3.21509	4.373159	6.742-01	-2.6467
14	-2.395-01	-6.522-01	-1.201960	1254962	2.62E-03	-6.592-01	-6.092-01	-1.057246	4.03097	5.025724	4.522992	4.55075	5.129292	2.054649	2.040294	3.494602	1.175151	2.405-01	9.125-92	5.022-01	3.575027	3.007012	2.016622	0.225-01	1.502-0
15	2.396253	2,798652	11.12141	17.60393	49.59423	84.82952	119.6405	120.9910	0.040704	12.04602	15.54121	16.25725	6.379545	0.42020	9.577405	9.503915	1.965075	1.149449	2.171697	3.723597	4.993161	2.794040	5.317013	5.202279	1.12031
16	26.5421	30.10125	64.19322	43.11342	-3.16103	-1.275-01	-9.642-01	-99.37464	12.49303	20.90572	26.19337	20.20707	7.10055	16.20125	20.21357	20.24691	2.524909	1.227442	2.570	5.027092	5.447213	2.537054	5.465610	5.22699	2.31910
17	2.224201	12.293	17.7721	23.77547	4.936142	4.092-01	6.235595	10.04058	0.52E-01	1.193922	1.662791	2.501606	4.928-02	5.156-02	5.010-02	2.295-01	1.140712	1.543746	1.71529	4.735946	2.192544	1.72398	1.167511	6.910709	1.7715
10	-9.642299	-10.41552	-7.954074	-6.656269	99.47593	11.16547	99.0294	21.61017	-3.65E-01	-4.592-01	-9.95E-01	-9.76E-01	-1.91E-01	-1.05E-01	-2.67E-01	-4.15E-01	-1.295664	5.21124	6.265420	2.992337	-5.025260	9.264519	15.00267	31,20736	1.01092
19	-10.78696	-36.68081	-46.22959	-49.05691	\$4.20394	22.0799	27.866.00	49.31643	11.03205	21.50170	20.52071	\$1.91577	\$9.20822	04.90450	105.9561	127.9691	-1.949207	-6.274596	-5.529002	5.295-01	4.902-02	3.302-01	1.925-01	5.402-01	1.56722
20	6.72E-03	5.60E-01	2.0196.03	7.022-01	7.492-01	1.072310	1.901935	14640	10.20449	15.51517	10.465.01	22.47329	-26.63103	-26.4942	-20.05520	-32.29676	-0.65E-02	2.545-01	1.125449	-4.205-01	-2.661200	-1.271057	-1.649459	-5.692-01	-1.09561
21	-2.375-01	-5.73E-01	-0.152-01	-7.70E-01	-6.510-01	-1.166306	-0.540-01	-1.010903	4.040124	0.241415	11.0736	20.40355	-4.752405	-12.99792	-15.45431	-17.29805	4.797205	0.23089	14.2757	10.11074	0.172016	9.268945	10.5460	0.262035	7.072-0
22	7.320215	12.3246	29.02235	\$9,31248	42.34924	74.00146	92.44573	\$21,7998	3.762653	6.41017	10.65562	16.27156	7.660309	3.66E-01	-2.492939	-2.510452	17.47371	24.12017	26.76742	29.61591	1.762-01	-6.602-01	-0.702-01	-1.540460	-2.525-1
20	22.75471	62.05413	74.00301	86.46339	-14.14621	-16.37321	-20.89665	-23.44174	5.010-01	2.405501	4.011267	0.917192	15.116.95	12.02052	13.21056	15.53441	0.129993	14.14476	16.69770	25.5430	6.225-01	3.028-01	3.892-01	2.075-01	3.7963
24	4.696789	15.22615	25.024	20.10326	2.393320	-1.902-01	6.677369	11.7712	-2.45196	-4.937155	+6.672920	-7.014164	19.24002	27.23729	32.00978	37.19233	4.894060	9.75454	12.05524	10.5947	7.450-01	5.925-01	5.04E-01	1.102-02	2.37561
25	-9.992284	-16.54515	-15.113.09	-17.46452	13.52200	16.26623	26.51912	22.05235	-0.674547	-15.17652	-21.00269	-22.765.05	20.05504	41.56224	57.11090	65.04734	4.210-01	4.524600	0.067114	9.842671	-2.728-01	-3.928-01	-1.276-01	2.001455	1.02054
26	-23.070	-52.76477	-69.4724	-72.32514	19.00229	20.90975	46.30929	\$3.54554	2.51E-01	0.15E-01	1.262700	1.050102	-3.73E-02	1.045-01	6.000-02	1.502-01	-1.020706	7.556-01	2.060972	4.101472	3.002-01	3.910-01	5.67E-01	2.67386	1.79102
27	1.922-01	0.432-01	7.040-01	1.592-01	2.97E-01	7.546-01	1,211040	1.160561	-0.45E-01	-6.31E-01	-1.094635	-1477744	-1.54E-01	-1.612-01	-3.52E-01	-5.130-01	-0.225310	-10.79201	-11.00190	-19.2001	-1.167657	-9.692-01	-9.662-01	4.650-01	0.246-0
20	-4.612-01	-7.192-01	-5.50E-01	-3.862-01	-2.56E-01	-2.51E-01	-5.76E-01	-1.090931	10.32442	10.51421	\$6.0096	20.91462	47.01964	68.60352	03.76446	102.1053	-17.19446	-36.69809	-46.32000	-64.6789	-2.551429	-2.111010	-2.306296	-4.021702	6.40E-C
29	-10.38627	-22.32575	-10.56469	-31.56446	6.461207	0.64509	2.997743	99.6596	-29.10455	-\$1.732.92	-52.13749	-50.55132	-19.10579	-10.45107	-19.60561	-21.54192	7.225-01	1.205026	1.555602	1.060391	-3.329055	-4.324905	-4.076316	0.042-02	-5.520-4
20	-16.65079	-24.55973	-41.21991	-54.2002	1.522-01	-4.67342	-4.649994	-5.625170	-11.77301	+22.19903	+22.04020	-20.4996	-2.940319	-0.510846	-9.510797	-9.10517	-0.01E-01	-5.71E-01	-3.23E-01	-1.091060	3.420367	4.201345	5.627902	6.372196	-9.840-
I4 ¥ Þ	HAM	AIN MEN	JU ∖FD	ANN /F	D ANN	(9) / CFI	P ANN /	CFP AN	IN (9) 🔏	RGD AN	IN / COI	IP ANN	1	5.05.01	1.000.00	1 450 44			N. ANTIF	10.0000			<		>

Figure 4. Sample Excel sheet showing ANN model information

Flexible Pavement Analysis, Plotting, and Summary Menus

Pavement analysis menu consists of three main sections: inputs, analysis tool, and outputs. The user can provide the software with the information required for analysis in the inputs section of the pavement analysis menu. The analysis tool allows the user to process the data and analyze with several functions. The results of analysis are provided in the outputs section of the pavement analysis menu. Typical layouts of the conventional and full depth flexible pavement analysis menus are shown in Figure 5.

	FWD Deflections (mils)								Asphalt Concrete Thickness (inch)	Granular Base Thickness (inch)	FWD Load (kip)	IOWA STATE UNIVERSITY	4 Deflections-Eac (psi) (D0-D12-D24-D36)				
Location	0-0	0-8	0-12	0-18	0-24	0-36	0-48	0-60	b 10	h 68	Load		0%	2%	5%	10	
1	4.20	4.12	4.00	3.85	3.69	3.37	2.92	2.54	10.00	15.00	9.00	A	,206	3,464,372	5,490,016	4,98	
2	4.01	3.95	3.82	3.69	3.52	3.21	2.80	2.43	10.00	15.00	9.00	anaivsi	S (.398	4,086,686	5,492,850	5,255	
3	3.81	3.74	3.62	3.49	3.32	3.04	2.63	2.29	10.00	15.00	9.00		422	4,999,505	5,547,630	5,410	
4	3.90	3.85	3.70	3.53	3.33	3.01	2.51	2.10	10.00	15.00	9.00	Taal	1,287	5,531,364	5,610,073	4,98	
5	3.70	3.62	3.49	3.35	3.16	2.82	2.39	1.98	10.00	15.00	9.00		,285	5,916,772	5,766,072	5,05	
6	3.52	3.43	3.32	3.16	3.00	2.67	2.25	1.89	10.00	15.00	9.00		J., J., 666	6,072,748	5,868,578	5,105	
7	4.28	4.15	3.97	3.75	3.52	3.05	2.47	2.04	10.00	15.00	9.00		5,378,133	5,333,085	4,983,778	4,618	
8	4.16	4.02	3.84	3.64					10.00	15.00	9.00	Run R	5	4		711	
9	3.98	3.84	3.67	3.48		nr	וור	te	10.00	15.00	9.00		5,	utr) I I † (
10	3.86	3.61	3.41	3.20	∎ ∎	11	Ju	U	10.00	15.00	9.00			MUP	Mu	- P90	
11	3.85	3.56	3.37	3.17	2.94	2.58	2.18	1.90	10.00	15.00	9.00	of Transportation	4,442,951	5,066,733	4,913,110	4,732	
12	3.42	3.19	2.99	2.78	2.56	2.22	1.88	1.60	10.00	15.00	9.00		4,607,598	5,119,091	4,968,762	5,00	
13	4.17	4.11	3.93	3.73	3.52	3.06	2.51	2.03	10.00	15.00	9.00	Main Menu	6,203,462	5,695,319	5,267,740	4,665	
14	3.91	3.85	3.69	3.52	3.29	2.90	2.38	1.93	10.00	15.00	9.00		6,489,489	5,810,668	5,525,128	4,84	
15	3.72	3.64	3.48	3.32	3.11	2.71	2.22	1.81	10.00	15.00	9.00	Commission	6,460,400	5,890,689	5,540,405	4,908	
16	3.27	3.26	3.17	3.07	2.96	2.71	2.35	2.02	10.00	15.00	9.00	Flaxible Parament	6,737,500	5,906,961	5,838,769	5,814	
17	3.12	3.10	3.01	2.92	2.81	2.58	2.22	1.93	10.00	15.00	9.00	(9 (ip)	6,737,500	6,188,993	6,013,668	5,828	
18	2.98	2.95	2.87	2.79	2.67	2.44	2.12	1.83	10.00	15.00	9.00		6,737,500	6,401,095	6,195,770	5,836	
19	3.87	3.76	3.62	3.46	3.28	2.92	2.47	2.06	10.00	15.00	9.00	Real-	6,631,152	5,778,986	5,638,202	4,922	
20	3.64	3.53	3.41	3.25	3.07	2.74	2.32	1.92	10.00	15.00	9.00	PEOIS	6,696,171	5,980,596	5,777,017	5,019	
21	3.54	3.43	3.30	3.15	2.98	2.67	2.26	1.85	10.00	15.00	9.00		6,715,399	6,051,662	5,827,691	5,058	
22	3.25	3.19	3.09	2.97	2.86	2.67	2.30	2.18	10.00	15.00	9.00	Summary	6,737,500	6,065,315	5,909,814	5,811	
23	3.11	3.05	2.97	2.86	2.75	2.57	2.23	1.94	10.00	15.00	9.00		6,737,500	6,225,625	6,048,358	5,835	
24	3.01	2.94	2.85	2.74	2.63	2.47	2.13	1.84	10.00	15.00	9.00	Fifter	6,737,500	6,397,724	6,191,425	5,83	
25	4.30	4.21	4.04	3.82	3.60	3.15	2.58	2.08	10.00	15.00	9.00		5,948,259	5,556,492	5,116,523	4,547	
26	4.16	4.07	3.90	3.72	3.49	3.07	2.52	2.07	10.00	15.00	9.00	Open FWD Dat File	6,172,018	5,696,175	5,300,171	4,676	

(a)

	FWD Deflections (mils)								Asphalt Concrete Thickness (inch)	FWD Load (9 kip)	IOWA STATE UNIVERSITY		4 Deflections-Eac (psi) (D0-D12-D24-D36)			
Location	0-0	0-8	0-12	0-18	0-24	0-36	0-48	0-60	H	Land	S Tomat	0%	2%	5%	10%	0%
1	4.20	4.12	4.00	3.85	3.69	3.37	2.92	2.54	12.00	• 🔺		,901,387	875,353	3,258,738	2,987,289	-451
2	4.01	3.95	3.82	3.69	3.52	3.21	2.80	2.43	12.00	• A	naivsis	,084,559	1,279,548	3,671,258	3,276,064	-359
3	3.81	3.74	3.62					2.29	12.00	9	,, ,	152,869	2 398 044	4 112 425	3 623 881	-174
4	3.90	3.85	3.70	lr	۱n	ı ıf	2	2.10	12.00	9	Taal	,233,084		4	4 -	188
5	3.70	3.62	3.49		יץי	u	0	1.98	12.00	9	1001	310,974		utD	uτs	558
6	3.52	3.43	3.32	3.16	3.00	2.67	2.25	1.89	12.00	9.00		5,501,145	0,110,000	4,010,000	4,000,000	866
7	4.28	4.15	3.97	3.75	3.52	3.05	2.47	2.04	12.00	9.00		3,589,970	3,474,169	3,283,413	2,788,782	1,406
8	4.16	4.02	3.84	3.64	3.42	2.97	2.41	1.96	12.00	9.00	Dun	3,758,228	3,667,058	3,479,386	2,990,525	1,459
9	3.98	3.84	3.67	3.48	3.25	2.82	2.29	1.84	12.00	9.00	ЛАЛ	3,793,279	3,752,750	3,631,632	3,178,558	2,033
10	3.86	3.61	3.41	3.20	2.99	2.64	2.23	1.91	12.00	9.00		3,323,965	3,495,861	3,463,860	3,165,831	4,263
11	3.85	3.56	3.37	3.17	2.94	2.58	2.18	1.90	12.00	9.00	of Transportation	3,152,830	3,336,386	3,287,794	3,055,375	5,072
12	3.42	3.19	2.99	2.78	2.56	2.22	1.88	1.60	12.00	9.00		3,211,565	3,357,119	3,322,261	3,169,761	7,804
13	4.17	4.11	3.93	3.73	3.52	3.06	2.51	2.03	12.00	9.00	Main Menu	4,126,982	3,716,354	3,384,432	2,960,140	699
14	3.91	3.85	3.69	3.52	3.29	2.90	2.38	1.93	12.00	9.00		4,496,583	4,141,166	3,844,844	3,365,007	870
15	3.72	3.64	3.48	3.32	3.11	2.71	2.22	1.81	12.00	9.00	Analysis (9 fin)	4,484,154	4,324,846	4,151,018	3,636,100	1,542
16	3.27	3.26	3.17	3.07	2.96	2.71	2.35	2.02	12.00	9.00		6,737,306	1,710,566	4,956,924	4,590,374	-278
17	3.12	3.10	3.01	2.92	2.81	2.58	2.22	1.93	12.00	9.00	74	6,737,376	2,880,211	5,348,853	4,850,782	-107
18	2.98	2.95	2.87	2.79	2.67	2.44	2.12	1.83	12.00	9.00	Prots	6,737,368	4,250,443	5,832,364	4,990,720	143
19	3.87	3.76	3.62	3.46	3.28	2.92	2.47	2.06	12.00	9.00		4,828,979	4,262,372	3,961,738	3,496,152	613
20	3.64	3.53	3.41	3.25	3.07	2.74	2.32	1.92	12.00	9.00	Summary	5,100,676	4,829,180	4,502,802	3,998,716	963
21	3.54	3.43	3.30	3.15	2.98	2.67	2.26	1.85	12.00	9.00		5,253,437	5,064,112	4,754,214	4,251,377	1,116
22	3.25	3.19	3.09	2.97	2.86	2.67	2.30	2.18	12.00	9.00	Filter	6,735,013	2,596,348	5,174,494	4,720,052	-76
23	3.11	3.05	2.97	2.86	2.75	2.57	2.23	1.94	12.00	9.00		6,737,355	2,878,345	5,413,568	4,899,982	-48
24	3.01	2.94	2.85	2.74	2.63	2.47	2.13	1.84	12.00	9.00	Open FWD Dat File	6,736,902	4,188,371	5,835,197	4,989,701	245
25	4.30	4.21	4.04	3.82	3.60	3.15	2.58	2.08	12.00	9.00		3,943,260	3,509,983	3,219,938	2,799,762	655
()	FD AC (9)/														>
										(b)						

Figure 5. Flexible pavement analyses menus: (a) conventional, (b) full depth

After selecting one of the pavement types from the main menu, a general information window appears. Its purpose is to get information that represents a project site at the beginning of each analysis (see Figure 6.). The user is required to fill in the information to continue with pavement analysis.

General information inputs will be displayed with each graph at the end of the analysis to identify the project information.

Project Name
Project Location
Date and Time
Temperature
Comments
Continue

Figure 6. General information window

At the next step, the user is expected to enter the FWD deflection data and other required inputs. These include pavement layer information (layer thicknesses), and FWD load (for variable FWD load analysis). Depending on the pavement type, the number of layers can be changed. The input requirements for conducting conventional flexible pavement analyses include FWD deflection data, asphalt concrete thickness, granular base thickness, and FWD load. The input requirements for conducting full depth asphalt pavement analyses are same as those for conventional flexible pavement analyses except that granular base thickness is not required. If any of the required parameter is missing, the program will display an error message which reads "No Data" in the results section.

The default units used in the program are US customary units. FWD deflection data (D_0 till D_{60}) should be entered in mils (10^{-3} inches), layer thickness in inches, and FWD load should be in kips. The program will not run correctly if the inputs are entered in different units or if they are out of range. The user is requested to refer to the report for the appropriate ranges of these parameters. Reported results are pavement layer modulus values, strains, and stresses. Modulus and stress values are reported in psi and strains are reported in micro-strains (x 10^{6}).

User can enter the FWD deflection database manually or obtain those directly from the JILS-20 type FWD raw data files clicking "Open FWD data file". The "Open FWD data file" command

allows the user to load the FWD raw data files and extract the FWD deflections required as inputs to the automated analysis software as shown in Figure 7. The software allows two types of flexible pavement analysis based on FWD loading amplitude; 9-kip-constant FWD load analysis and variable FWD load analysis. As shown in Figure 8(a), the raw FWD deflection data corresponding to the raw FWD loads are extracted and inputted into the program under variable FWD load analysis. The 9-kip-constant FWD load analysis in Figure 8(b) uses the FWD deflection data normalized to 9 kip-constant FWD load



Figure 7. Screen shot of FWD data extraction through open FWD data file button: (a) choosing raw FWD file, (b) FWD data extracted

			FW	VD Defle	ctions (m	Aaphalt Concrete Thickness (inch)	Granular Base Thickness (inch)	FWD Load (kip)			
Location	0-0	D - 8	0-12	0-18	0-24	0-36	0-48	0-60	h AC	h 68	Load
1	3.69	3.42	3.21	2.85	2.57	2.07	1.66	1.32			5.88
2	5.55	5.07	4.73	4.23	3.77	3.01	2.41	1.89			8.59
3	7.37	6.60	6.23	5.58	4.99	3.96	3.16	2.46			11.67
4	8.90	7.95	7.49	6.73	6.00	4.75	4.34	2.98			14.33
5	3.27	3.41	3.21	2.85	2.57	2.06	1.64	1.27			5.93
6	5.95	5.10	4.77	4.28	3.84	3.03	2.42	1.88			8.64
7	7.21	6.65	6.23	5.60	5.02	3.96	3.19	2.44			11.55
8	7.73	7.97	7.48	6.71	6.00	4.80	3.82	3.00			14.28

(a)

			F۷	VD Defle	ctions (n	Asphalt Concrete Thickness (inch)	Granular Base Thickness (inch)	FWD Load (kip)			
Location	0-0	0-8	0-12	0-18	D-24	0-36	0-48	0-60	h AC	h 68	Load
1	5.65	5.23	4.91	4.36	3.93	3.17	2.54	2.02			9.00
2	5.81	5.31	4.96	4.43	3.95	3.15	2.53	1.98			9.00
3	5.68	5.09	4.80	4.30	3.85	3.05	2.44	1.90			9.00
4	5.59	4.99	4.70	4.23	3.77	2.98	2.73	1.87			9.00
5	4.96	5.18	4.87	4.33	3.90	3.13	2.49	1.93			9.00
6	6.20	5.31	4.97	4.46	4.00	3.16	2.52	1.96			9.00
7	5.62	5.18	4.85	4.36	3.91	3.09	2.49	1.90			9.00
8	4.87	5.02	4.71	4.23	3.78	3.03	2.41	1.89			9.00

(b)

Figure 8. Extracted FWD data: (a) variable FWD load analysis, (b) 9-kip-constant FWD load analysis

Once the FWD deflection data is entered, the user has the option to check the data for anomalies using the data preprocessing unit (Filter command button) for filtering the data. It is optional to use the filtering window. Figure 9. shows the available options for filtering. The two options are:

- Range Check: Deflection basin should form a bowl shape and, therefore, deflections should be in decreasing order. Data that falls outside this range are red colored.
- Model Check: ANN models are normalized according to the model ranges and, therefore, any input outside the range used in ANN training will form a poor quality input. As a result, the model check will determine the outliers and color them in red.

The filtering is applied by changing the color of the input parameter to red (see Figure 10). The analysis results from filtered data are also shown with red color in charts (see Figure 11). Therefore, results for these parameters are also calculated. With this approach, engineers will have a better understanding of the sources of errors.



Figure 9. Filter options menu

			FY	ND Defle	ections (n	iils)			Asphalt Concrete Thickness (inch)	Granular Base Thickness (inch)	FWD Load (kip)	IOWA STATE UNIVERSITY		4 Deflection (D0-D12-	15-Eac (psi) D24-D36)	^
Location	0-0	0-8	0-12	0-18	0-24	0-36	0-48	0-60	H AC	h 68	Load		096	2%	5%	16
1	4.20	4.12	4.00	3.85	3.69	3.37	2.92	2.54	10.00	15.00	9.00	CHILE				
2	4.01	3.95	3.82	3.69	3.52	3.21	2.80	2.43	10.00	15.00	9.00	3 Could Criciones				
З	3.81	3.74	3.62	3.49	3.32	3.04	2.63	2.29	10.00	15.00	9.00	8.5				
4	3.90	3.85	3.70	3.53	3.33	3.01	2.51	2.10	10.00	15.00	9.00					
5	3.70	3.62	3.49	3.35	3.16	2.82	2.39	1.98	10.00	15.00	9.00	Total Data Set: 42				
6	3.52	3.43	3.32	3.16	3.00	2.67	2.25	1.89	10.00	15.00	9.00					
7	4.28	4.15	3.97	3.75	3.52	3.05	2.47	2.04	Filter Opti		×					
8	4.16	4.02	3.84	3.64	3.42	2.97	2.41	1.96	E a constant	11.		Run				
9	3.98	3.84	3.67	3.48	3.25	2.82	2.29	1.84	IV Range C	.neck						
10	3.86	3.61	3.41	3.20	2.99	2.64	2.23	1.91	Model Cl	heck						
11	3.85	3.56	3.37	3.17	2.94	2.58	2.18	1.90	🔲 Curvatu	re Check		of Transportation				
12	3.42	3.19	2.99	2.78	2.56	2.22	1.88	1.60								
13	4.17	4.11	3.93	3.73	3.52	3.06	2.51	2.03			ок	Main Menn				
14	3.91	3.85	3.69	3.52	3.29	2.90	2.38	1.93	10.00	15.00	9.00					
15	3.72	3.64	3.48	3.32	3.11	2.71	2.22	1.81	Microsoft E	xcel		Romantional				
16	3.27	3.26	3.17	3.07	2.96	2.71	2.35	2.02	Eiltering Cor	mpleted III. Total Filte	red data is> 2/42	Floxible Parament				
17	3.12	3.10	3.01	2.92	2.81	2.58	2.22	1.93	r inconing con			(9 (ip)				
18	2.98	2.95	2.87	2.79	2.67	2.44	2.12	1.83		ОК						
19	3.87	3.76	3.62	3.46	3.28	2.92	2.47	2.06		10.00	0.00	Dista				
20	3.64	3.53	3.41	3.25	3.07	2.74	2.32	1.92	10.00	15.00	9.00	PSUCS				
21	3.54	3.43	3.30	3.15	2.98	2.67	2.26	1.85	10.00	15.00	9.00					
22	3.25	3.19	3.09	2.97	2.86	2.67	2.30	2.18	10.00	15.00	9.00	Suggery				
23	3.11	3.05	2.97	2.86	2.75	2.57	2.23	1.94	10.00	15.00	9.00					
24	3.01	2.94	2.85	2.74	2.63	2.47	2.13	1.84	10.00	15.00	9.00	Filter				
25	4.30	4.21	4.04	3.82	3.60	3.15	2.58	2.08	10.00	15.00	9.00					
26	4.16	4.07	3.90	3.72	3.49	3.07	2.52	2.07	10.00	15.00	9.00	Open FWD Dat File				
H 4 F	N CFP	AC (9)	/												<	>

(a)

			F)	ND Defic	ections (n	nils)			Asphalt Concrete Thickness (inch)	Granular Base Thickness (inch)	FWD Load (kip)	IOWA STATE UNIVERSITY	4 Deflection (D0-D12-	ns-Eac (psi) D24-D36)	^
Location	0-0	D-8	0-12	0-18	0-24	0-36	0-48	0-60	h AC	h 68	Load	0%	2%	5%	16
1	4.20	4.12	4.00	3.85	3.69	3.37	2.92	2.54	10.00	15.00	9.00	Cratte			
2	4.01	3,95	3.82	3.69	3.52	3.21	2.80	2.43	10.00	15.00	9.00	Staulus Pretonts			
3	3.81	3.74	3.62	3.49	3.32	3.04	2.63	2.29	10.00	15.00	9.00				
4	3.90	3.85	3.70	3.53	3.33	3.01	2.51	2.10	10.00	15.00	9.00				
5	3.70	3.62	3.49	3.35	3.16	2.82	2.39	1.98	10.00	15.00	9.00	Total Data Set: 42			
6	3.52	3.43	3.32	3.16	3.00	2.67	2.25	1.89	10.00	15.00	9.00				
7	4.28	4.15	3.97	3.75	3.52	3.05	2.47	2.04	Filter Opt						
8	4.16	4.02	3.84	3.64	3.42	2.97	2.41	1.96		back		Кин			
9	3.98	3.84	3.67	3.48	3.25	2.82	2.29	1.84	iter Kange C						
10	3.86	3.61	3.41	3.20	2.99	2.64	2.23	1.91	Model Ci	neck		lowa Department			
11	3.85	3.56	3.37	3.17	2.94	2.58	2.18	1.90	🗖 Curvatu	re Check		of Transportation			
12	3.42	3.19	2.99	2.78	2.56	2.22	1.88	1.60			L				
13	4.17	4.11	3.93	3.73	3.52	3.06	2.51	2.03			ок	Main Menu			
14	3.91	3.85	3.69	3.52	3.29	2.90	2.38	1.93	10.00	15.00	9.00				
15	3.72	3.64	3.48	3.32	3.11	2.71	2.22	1.81	10.00	15.00	9.00	Conventional			
16	3.27	3.26	3.17	3.07	2.96	2.71	2.35	2.02	10.00	15.00	9.00	Flaxible Pavement			
17	3.12	3.10	3.01	2.92	2.81	2.58	2.22	1.93	Microsoft Ex	cel	×	(9 (jip)			
18	2.98	2.95	2.87	2.79	2.67	2.44	2.12	1.83	Filtering Com	pleted!!! Total Filter	ed data is> 9/42				<u> </u>
19	3.87	3.76	3.62	3.46	3.28	2.92	2.47	2.06	_	·		Plots			
20	3.64	3.53	3.41	3.25	3.07	2.74	2.32	1.92	 	OK					
21	3.54	3.43	3.30	3.15	2.98	2.67	2.26	1.85				Sugar			<u> </u>
22	3.25	3.19	3.09	2.97	2.86	2.67	2.30	2.18	10.00	15.00	9.00				<u> </u>
23	3.11	3.05	2.97	2.86	2.75	2.57	2.23	1.94	10.00	15.00	9.00				<u> </u>
24	3.01	2.94	2.85	2.74	2.63	2.47	2.13	1.84	10.00	00.01	9.00	Filter			
25	4.30	4.21	4.04	3.82	3.60	3.15	2.58	2.08	10.00	10.00	3.00				
20	4.16	4.07	3.90	3.72	3.49	3.07	2.52	2.07	10.00	00.01	3.00	Open FIVE Dat File			~
H 4 F	M \ CFP	AC (9)	/											<	>
										(b)					

Figure 10. Filtering the FWD data: (a) range check, (b) range and model check



7 Deflection - AC Modulus Prediction

Figure 11. Sample pavement analysis results identifying analysis results from FWD data that falls outside filtering range

After preprocessing the data, clicking the "Run" button will activate a neural network-based analysis of pavements. The program will analyze model by model for the pavement properties. The ANN models employed for flexible pavement analysis are 4, 6, 7, and 8 deflection models with 0%, $\pm 2\%$, $\pm 5\%$ and $\pm 10\%$ noise. Each model has a different number of input parameters depending on the number of deflections. The purpose of introducing noisy patterns in the development of each model was to provide more robust networks that can tolerate the noisy or inaccurate deflection patterns collected from the FWD deflection basins. The detail descriptions of each model are provided in phase I project report (Ceylan et al, 2007).

For each model, the analysis results will be displayed on the right side of the screen. The user should scroll right to see all results. Also, disabled menu commands of plots and the summary will be activated. The conventional flexible pavement analysis results are E_{AC} -modulus of AC, K_b -base modulus parameter, E_{Ri} -subgrade resilient modulus, ε_{AC} -tensile strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the top of subgrade, and σ_D -subgrade deviator stress. The full depth flexible pavement analysis results are E_{AC} -modulus of AC, E_{Ri} -subgrade resilient modulus, ε_{AC} -tensile strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the top of subgrade, and σ_D -subgrade resilient modulus, ε_{AC} -tensile strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the top of subgrade, and σ_D -subgrade resilient modulus, ε_{AC} -tensile strain at the bottom of asphalt layer, ε_{SG} -compressive strain at the top of subgrade, and σ_D -subgrade deviator stress.

Figure 12 illustrates the sample analysis results of a conventional and a full depth flexible pavement. Failure to supply all the input parameters will be reflected in the results column of that model. The program will automatically write "No Data." For example, if D_{48} is missing in the input data, then all six- and eight-deflection model columns will display the error message of "No Data."

At the end of each column, statistical information regarding that model is presented (see Figure 13.). The collection of these statistics is summarized in summary sheets.



Figure 12. Sample Excel sheet outputs of flexible pavement analysis: (a) conventional, (b) full-depth

	JNIVERSITY		4 Deflectio	ns-Eac (psi) .D24-D36)			4 Deflection	ons-Eri (psi) -D24-D36)			4 Deflecti (D0-D12-	ions-K (psi) -D24-D36)		
Location		0%	2%	5%	10%	0%	2%	5%	10%	0%	2%	5%	10%	0%
		5,837,793	2,869,659	4,072,610	3,666,773	-129	1,274	1,615	3,193	1,894	2,082	3,781	5,259	5,413,138
		5,898,991	4,355,569	4,496,663	3,987,184	124	1,122	1,823	3,185	1,943	2,757	4,863	6,922	5,459,898
		5,838,379	5,193,935	4,830,372	4,281,029	445	1,153	1,998	3,184	2,447	4,985	5,803	7,101	5,446,535
		6,730,921	6,060,596	5,852,932	5,085,998	1,064	3,071	3,858	5,752	12,173	12,716	11,988	8,784	6,695,800
		6,731,745	6,137,574	5,879,580	5,120,352	1,398	4,120	4,800	6,346	12,765	12,974	12,192	8,680	6,709,121
		6,736,795	6,226,403	5,953,644	5,226,999	1,477	4,771	5,436	7,085	13,064	13,094	12,358	9,484	6,728,656
		6,626,582	6,041,129	5,754,582	5,037,018	1,514	3,545	4,677	6,393	12,555	12,863	11,967	8,321	6,725,548
		6,588,483	6,043,129	5,684,056	5,057,589	1,936	4,518	5,554	7,068	12,962	12,764	11,656	8,610	6,697,665
		6,609,326	6,056,991	5,637,900	5,107,871	2,411	5,733	6,503	7,962	13,028	12,793	11,448	9,264	6,707,172
		6,724,977	2,283,807	5,489,244	4,041,840	-388	1,494	1,438	2,753	1,878	2,053	4,524	2,755	6,670,524
		6,720,859	2,564,135	5,458,264	4,274,015	-318	1,267	1,576	2,882	1,889	2,532	4,853	3,874	6,661,258
		6,724,788	3,190,814	5,458,016	4,527,168	-248	1,140	1,692	2,975	1,973	4,004	6,086	5,519	6,674,341
		6,737,485	4,670,367	5,529,023	5,460,092	-186	1,262	2,387	3,638	3,414	8,986	8,244	9,993	6,734,366
		6,737,497	5,154,658	5,584,627	5,639,863	-156	1,645	2,712	3,593	9,134	12,053	10,878	10,268	6,736,525
		6,737,498	5,859,215	5,758,910	5,690,307	77	2,633	2,843	4,510	11,343	12,973	11,860	10,035	6,736,924
	AVERAGE	6,350,305	5,339,434	5,508,208	5,000,658	945	2,640	3,233	4,835	8,261	9,739	9,495	8,424	6,264,63
	STDEV	623,113	1,059,948	435,888	528,246	1,331	1,582	1,538	1,561	4,518	3,653	2,714	1,931	633,722
	cv	10%	20%	8%	11%	141%	60%	48%	32%	55%	38%	29%	23%	10%
H 4 🕨 I	CFP AC (9	0/								v			<	

Figure 13. Sample Excel sheet output statistics of pavement analysis

The plot button will be enabled after the backcalculation analysis is complete. The plot option window appears after clicking on the plot button (see Figure 14). With this window, the user can select the models to display on charts. Selected models will be plotted in the form of backcalculated parameter versus FWD test location. Provided that the data is from a specified section, the first data will be represented as the starting point, and each subsequent data is assumed to correspond to FWD test locations along the path of the pavement system. Filtered data from the preprocessor will be displayed in red, whereas all others will be in blue. The upper right corner will display a textbox containing general information about the project. Figure 15 and Figure 16 illustrate color-coded conventional and the full depth flexible pavement analysis results, respectively, from 4-deflection ANN model with 0 % noise.

Plots Option			
CFP FD RGD CP			
🔽 9 kip 🔲 5	i-21 kip		
4 Deflection Models			
Eac (Virgin)	🗌 Eac (2%)	🗌 Eac (5%)	🗌 Eac (10%)
K (Virgin)	🗌 К (2%)	🗌 К (5%)	🗌 К (10%)
🔲 Eri (Virgin)	Eri (2%)	🗆 Eri (5%)	Eri (10%)
Strain AC	Strain SG	Deviator Stress	
C Deflection Medale			
E Deflection Models	Eac (2%)	Eac (5%)	Eac. (10%)
K (Virgin)	Γ K (2%)	Γ K (5%)	Γκ (10%)
Eri (Virgin)	Eri (2%)	Eri (5%)	Eri (10%)
Strain AC	Strain SG	Deviator Stress	1 211 (1070)
je oddinac) Derain Sa	Deviator Scress	
7 Deflection Models	E 5 (001)	E 5 (5%)	E 5-2 (10%)
F Eac (virgin)	Eac (2%)	Eac (5%)	
K (Virgin)	I K (2%)	K (5%)	K (10%)
Eri (Virgin)	Eri (2%)	Eri (5%)	Eri (10%)
🔲 Strain AC	🔲 Strain SG	Deviator Stress	
8 Deflection Models			
🔲 Eac (Virgin)	🗌 Eac (2%)	🗌 Eac (5%)	🗌 Eac (10%)
🔲 K (Virgin)	🗌 К (2%)	🗌 К (5%)	🗌 K (10%)
🔲 Eri (Virgin)	🗌 Eri (2%)	🗌 Eri (5%)	🗌 Eri (10%)
🔲 Strain AC	🔲 Strain SG	🔲 Deviator Stress	
	Select All		Show Plots

Figure 14. Plot option window



Figure 15. Sample Excel plots for conventional pavement analysis results



Figure 16. Sample Excel plots for full-depth asphalt pavement analysis results

The Summary button within the pavement analysis Excel spreadsheet is disabled until the "Run" button is clicked. It summarizes the statistical output information for each model. It opens up a new Excel sheet with tables of each output and summary statistics for every model (see Figure 17). The reported statistical information include:

- Average (or mean value): The average value along the section.
- Standard deviation: A common measure of the dispersion. It shows how widely the data is spread from the mean value.
- Coefficient of variation (CV): CV is a measure of the dispersion of probability distribution. It is the ratio of the standard deviation to the mean. It allows the user to



compare the CV of populations that have different mean values. It is reported as a percentage.

Figure 17. Output statistics summary sheet for flexible pavement: (a) conventional, (b) fulldepth

Rigid Pavement Analysis, Plotting, and Summary Menus

Similar to flexible pavement analysis menu, the rigid pavement analysis menu consists of three main sections: inputs, analysis tool, and outputs as shown in Figure 18. Required input parameters for rigid pavement analysis are deflection data, pavement layer information (layer thicknesses, degree of bonding, and estimated moduli ratio), and FWD load. To simplify the ANN-based backcalculation methodology, PCC layer and base layer thicknesses are combined into one thickness value (effective PCC thickness) through the concept of equivalent thickness (Ceylan et al, 2007). While conducting the analysis, the effective PCC thickness can be automatically calculated from pavement layer information and used in the backcalculation analysis.

The analysis tool functionalities in the rigid pavement analysis menu are identical to those in flexible pavement analysis menu except two additional functions-"equation" and "show normalization." The "Equation" button, once clicked, is meant to provide the equations sheet as shown in Figure 19. This equation sheet summarizes the equations used for calculation of effective PCC thickness for fully bonded PCC layers, unbonded PCC layers and partially bonded PCC layers. The "show normalization" button is enabled only after the backcalculation analysis is complete. The raw FWD deflection data corresponding to the raw FWD loads are normalized to the 9-kip constant FWD load during backcalculation analysis. As shown in Figure 20, the normalized FWD data can be shown or hid in rigid pavement analysis menu by clicking "show normalization" or "hide normalization." Preprocessing the data for rigid pavement analysis such as obtaining and filtering the FWD data is same as that for flexible pavement analysis.



Figure 18. Rigid pavement analysis menu

Effective thickness for fully bonded PCC layers as: \mid



Figure 19. Screen shot of Equations sheet

										INPUTS					
		н	/D/FN	/D Del	flectio	ins (m	ils)		HVD/FVD Load (kips)	Effective Thickness (calculated) (inch)	PCC Thickness (inch)	Base Thickness (inch)	Degree of Bonding (%)	Estimated Moduli Ratio	Stab o And
Location	D-6	D-8	D-12	D-18	D-24	D-36	D-48	D-66	Load	A	Arec	A error	8	(E sur IE see)	
1	2.23	2.17	2.10	2.01	1.92	0.00	0.00	0.00	9.34	10.24	10.20	4.00	0	0.20	
2	2.69	2.62	2.53	2.42	2.29	2.07	1.81	0.00	12.18	10.24	10.20	4.00	0	0.20	R
3	3.26	3.18	3.06	2.94	2.78	2.50	2.18	1.90	14.67	10.24	10.20	4.00	0	0.20	
4	2.34	2.28	2.20	2.12	2.03	1.84	1.70	0.49	9.22	10.24	10.20	4.00	0	0.20	
5	2.79	2.71	2.61	2.50	2.37	2.14	1.88	1.77	11.94	10.24	10.20	4.00	0	0.20	Total Data S
6	3.49	3.40	3.28	3.13	2.95	2.71	2.34	2.07	14.81	10.24	10.20	4.00	0	0.20	
7	2.79	2.74	2.64	2.55	2.42	2.20	1.92	0.00	9.26	10.24	10.20	4.00	0	0.20	ман
8	3.48	3.44	3.33	3.20	3.05	2.80	2.47	2.15	11.88	10.24	10.20	4.00	0	0.20	
9	4.14	4.07	3.94	3.81	3.62	3.30	2.87	2.52	14.71	10.24	10.20	4.00	0	0.20	Equ
10	2.88	2.83	2.74	2.63	2.51	2.29	2.20	1.96	9.43	10.24	10.20	4.00	0	0.20	54
11	3.52	3.47	3.36	3.22	3.08	2.79	2.46	2.39	12.26	10.24	10.20	4.00	0	0.20	Norma
12	4.12	4.04	3.91	3.77	3.58	3.26	2.87	2.74	14.78	10.24	10.20	4.00	0	0.20	
13	2.64	2.59	2.51	2.41	2.30	2.12	1.88	0.59	9.36	10.24	10.20	4.00	0	0.20	P.
14	3.32	3.27	3.16	3.03	2.88	2.61	2.29	2.25	12.10	10.24	10.20	4.00	0	0.20	
15	4.07	3.97	3.83	3.69	3.53	3.23	2.84	2.53	14.52	10.24	10.20	4.00	0	0.20	See
16	2.61	2.56	2.48	2.36	2.23	1.99	1.72	1.49	9.43	10.24	10.20	4.00	0	0.20	
17	3.49	3.41	3.30	3.17	3.01	2.71	2.35	2.09	12.18	10.24	10.20	4.00	0	0.20	Z;
18	4.03	3.95	3.79	3.67	3.44	3.06	2.64	2.33	14.94	10.24	10.20	4.00	0	0.20	
19	2.56	2.51	2.42	2.31	2.20	2.01	1.95	1.74	9.57	10.24	10.20	4.00	0	0.20	Open FIO
20	3.22	3.13	3.02	2.92	2.78	2.53	2.24	2.20	12.43	10.24	10.20	4.00	0	0.20	
21	3.81	3.75	3.59	3.47	3.30	3.04	2.65	2.31	15.22	10.24	10.20	4.00	0	0.20	
22	2.54	2.50	2.43	2.33	2.23	2.06	1.82	1.76	9.27	10.24	10.20	4.00	0	0.20	
23	3.21	3.16	3.07	2.95	2.82	2.57	2.24	1.99	12.26	10.24	10.20	4.00	0	0.20	
24	3.85	3.76	3.64	3.50	3.34	3.07	2.68	2.36	14.97	10.24	10.20	4.00	0	0.20	
25	2.92	2.86	2.76	2.66	2.52	2.26	2.18	1.90	9.29	10.24	10.20	4.00	0	0.20	
26	3.69	3.62	3.51	3.36	3.18	2.87	2.49	2.34	12.18	10.24	10.20	4.00	0	0.20	
27	4.30	4.20	4.05	3.87	3.66	3.29	2.86	2.39	14.78	10.24	10.20	4.00	0	0.20	
4 F FI	\ Rigi	id Pav	/eme	nt Ai	nalysi	s/									

(a)

																INPU	TS							
		н	VD/FV	/D De	flectio	ons (m	ils)		HVD/FVD Load (kips)				9 kip M	lorma	lizatio	n			Effective Thickness (calculated) (inch)	PCC Thickness (inch)	Base Thickness (inch)	Degree of Bonding (%)	Estimated Moduli Ratio	58a8 A
Locatio	D-0	D-8	D-12	D-18	D-24	D-36	D-48	D-66		D-6	D-8	D-12	D-18	D-24	D-36	D-46	D-60	Load					(E sur IE rec]	
1	2.23	2.17	2.10	2.01	1.92	0.00	0.00	0.00	9.34	2.15	2.09	2.02	1.94	1.85	0.00	0.00	0.00	9.00	10.24	10.20	4.00	0	0.20	
2	2.69	2.62	2.53	2.42	2.29	2.07	1.81	0.00	12.18	1.99	1.94	1.87	1.79	1.69	1.53	1.34	0.00	9.00	10.24	10.20	4.00	0	0.20	
- 3	3.26	3.18	3.06	2.94	2.78	2.50	2.18	1.90	14.67	2.00	1.95	1.88	1.80	1.71	1.53	1.34	1.17	9.00	10.24	10.20	4.00	0	0.20	
4	2.34	2.28	2.20	2.12	2.03	1.84	1.70	0.49	9.22	2.28	2.23	2.15	2.07	1.98	1.80	1.66	0.48	9.00	10.24	10.20	4.00	0	0.20	
5	2.79	2.71	2.61	2.50	2.37	2.14	1.88	1.77	11.94	2.10	2.04	1.97	1.88	1.79	1.61	1.42	1.33	9.00	10.24	10.20	4.00	0	0.20	Total Da
6	3.49	3.40	3.28	3.13	2.95	2.71	2.34	2.07	14.81	2.12	2.07	1.99	1.90	1.79	1.65	1.42	1.26	9.00	10.24	10.20	4.00	0	0.20	44
7	2.79	2.74	2.64	2.55	2.42	2.20	1.92	0.00	9.26	2.71	2.66	2.57	2.48	2.35	2.14	1.87	0.00	9.00	10.24	10.20	4.00	0	0.20	ma
8	3.48	3.44	3.33	3.20	3.05	2.80	2.47	2.15	11.88	2.64	2.61	2.52	2.42	2.31	2.12	1.87	1.63	9.00	10.24	10.20	4.00	0	0.20	
9	4.14	4.07	3.94	3.81	3.62	3.30	2.87	2.52	14.71	2.53	2.49	2.41	2.33	2.21	2.02	1.76	1.54	9.00	10.24	10.20	4.00	0	0.20	64
10	2.88	2.83	2.74	2.63	2.51	2.29	2.20	1.96	9.43	2.75	2.70	2.62	2.51	2.40	2.19	2.10	1.87	9.00	10.24	10.20	4.00	0	0.20	
11	3.52	3.47	3.36	3.22	3.08	2.79	2.46	2.39	12.26	2.58	2.55	2.47	2.36	2.26	2.05	1.81	1.75	9.00	10.24	10.20	4.00	0	0.20	Nor
12	4.12	4.04	3.91	3.77	3.58	3.26	2.87	2.74	14.78	2.51	2.46	2.38	2.30	2.18	1.99	1.75	1.67	9.00	10.24	10.20	4.00	0	0.20	
13	2.64	2.59	2.51	2.41	2.30	2.12	1.88	0.59	9.36	2.54	2.49	2.41	2.32	2.21	2.04	1.81	0.57	9.00	10.24	10.20	4.00	0	0.20	
. 14	3.32	3.27	3.16	3.03	2.88	2.61	2.29	2.25	12.10	2.47	2.43	2.35	2.25	2.14	1.94	1.70	1.67	9.00	10.24	10.20	4.00	0	0.20	
15	4.07	3.97	3.83	3.69	3.53	3.23	2.84	2.53	14.52	2.52	2.46	2.37	2.29	2.19	2.00	1.76	1.57	9.00	10.24	10.20	4.00	0	0.20	5
16	2.61	2.56	2.48	2.36	2.23	1.99	1.72	1.49	9.43	2.49	2.44	2.37	2.25	2.13	1.90	1.64	1.42	9.00	10.24	10.20	4.00	0	0.20	
17	3.49	3.41	3.30	3.17	3.01	2.71	2.35	2.09	12.18	2.58	2.52	2.44	2.34	2.22	2.00	1.74	1.54	9.00	10.24	10.20	4.00	0	0.20	
18	4.03	3.95	3.79	3.67	3.44	3.06	2.64	2.33	14.94	2.43	2.38	2.28	2.21	2.07	1.84	1.59	1.40	9.00	10.24	10.20	4.00	0	0.20	
19	2.56	2.51	2.42	2.31	2.20	2.01	1.95	1.74	9.57	2.41	2.36	2.28	2.17	2.07	1.89	1.83	1.64	9.00	10.24	10.20	4.00	0	0.20	Open .
20	3.22	3.13	3.02	2.92	2.78	2.53	2.24	2.20	12.43	2.33	2.27	2.19	2.11	2.01	1.83	1.62	1.59	9.00	10.24	10.20	4.00	0	0.20	
21	3.81	3.75	3.59	3.47	3.30	3.04	2.65	2.31	15.22	2.25	2.22	2.12	2.05	1.95	1.80	1.57	1.37	9.00	10.24	10.20	4.00	0	0.20	
22	2.54	2.50	2.43	2.33	2.23	2.06	1.82	1.76	9.27	2.47	2.43	2.36	2.26	2.17	2.00	1.77	1.71	9.00	10.24	10.20	4.00	0	0.20	
23	3.21	3.16	3.07	2.95	2.82	2.57	2.24	1.99	12.26	2.36	2.32	2.25	2.17	2.07	1.89	1.64	1.46	9.00	10.24	10.20	4.00	0	0.20	
-24	3.85	3.76	3.64	3.50	3.34	3.07	2.68	2.36	14.97	2.31	2.26	2.19	2.10	2.01	1.85	1.61	1.42	9.00	10.24	10.20	4.00	0	0.20	
25	2.92	2.86	2.76	2.66	2.52	2.26	2.18	1.90	9.29	2.83	2.77	2.67	2.58	2.44	2.19	2.11	1.84	9.00	10.24	10.20	4.00	0	0.20	
26	3.69	3.62	3.51	3.36	3.18	2.87	2.49	2.34	12.18	2.73	2.67	2.59	2.48	2.35	2.12	1.84	1.73	9.00	10.24	10.20	4.00	0	0.20	
27 I ► ►	4.30 Rigi	4.20 id Pa	4.05 veme	3.87 nt A	3.66 nalysi	3.29 is /	2.86	2.39	14.78	2.62	2.56	2.47	2.36	2.23	2.00	1.74	1.46	9.00	10.24	10.20	4.00	0	0.20	>
																(b)							

Figure 20. Screen shot of inputs in rigid pavement analysis menu: (a) hide normalization, (b) show normalization

Similar to flexible pavement analysis, the program can analyze model by model by clicking the "Run" button after preprocessing the data. The ANN models employed for rigid pavement analysis are 4-, 6-, 7-, and 8-deflection models with 0%, $\pm 2\%$, $\pm 5\%$ and $\pm 10\%$ noise. Each model has a different number of input parameters depending on the number of deflections. The purpose of introducing noisy patterns in the development of each model was to provide more robust networks that can tolerate the noisy or inaccurate deflection patterns collected from the FWD deflection basins. Detailed descriptions of each model are provided in phase I project report (Ceylan et al, 2007).

For each model, the analysis results will be displayed on the right side of the screen. The user should scroll right to see all results. Also, disabled menu commands of Plots and Summary will be activated after the analysis is complete. The rigid pavement analysis results are E_{PCC} -modulus of PCC, k_s-coefficient of subgrade reaction, σ_{PCC} -tensile stress at the bottom of the PCC layer, and radius of relative stiffness (RRS)

Figure 21 illustrates the sample analysis results from a rigid pavement run. Figure 22 illustrates color-coded rigid pavement analysis results of 4-deflection ANN model with 0 % noise which are generated from the plotting function. Figure 23 illustrates sample Excel sheet with the output tables and their statistics for every model generated by clicking "summary" button.

			‡ Deflect	tinn Mudel (DO-D‡-	D12-D1#-D24-D36-I	D48-D60)			
	C	nofficent of Subgr	edo Roactina (pridi	.)		PCC M=4	ulur (pri)		Radiur af Rolativo Stiffnosr (inch)
acatia			5x	JR.X	E rec	2x		Mx	<u>RR5</u>
1	1,111	1,111	1,113	3,171	1,292,568	1,838,745	1,441,837	1,834,362	47
00200		755	76	754	6,573,181	5,712,582	5,512,425	5,545,425	52
	297	224	225	224	16,533,361	15,575,554	15,482,535	14,582,581	52
00000	236	(15	422	421	8,575,584	5,887,847	5,582,861	5,497,459	33
5.5	213	10	111	175	15,212,61	15,272,547	15,211,135	15,142,557	56
00600	217	285	285	201	16,563,861	15,575,285	15,536,236	14,201,630	59
8.7.8	383	541	552	558	5,895,582	2,697,554	2,514,518	2,517,545	33
00000	151	145	145	141	15,175,141	15,683,417	14,851,885	49,798,999	57
	165	153	158	156	15,845,334	15,518,425	44,822,548	49,154,471	55
10	116	115		97	15,743,675	15,521,455	46,400,056	14,855,858	65
11	141	128	127	125	45,788,555	15,213,925	45,849,566	14,665,688	61
12	145	197	135	195	16,698,657	15,138,343	45,787,538	14,652,222	53
13	264	368	975	363	7,757,885	5,252,358	5,147,144	4,672,897	33
14	152	136	135	195	16,210,504	15,248,425	46,041,405	14,152,242	61
15	153	152	151	147	16,519,859	15,346,858	15,824,233	15,004,165	57
16	211	103	113	- 10	15,721,851	14,225,175	15,545,868	19,162,129	51
17	175	165	163	163	14,516,715	15,197,383	14,751,422	19,655,862	53
18	214	151	151	158	14,274,852	14,756,115	14,443,735	15,618,684	51
19	154	122	125	121	16,746,588	15,407,015	46,598,565	45,565,868	65
20	154	111	191	197	15,741,545	16,03,01	15,481,412	15,518,281	81
21	105	971	177	477	16,645,425	15,013,015	45,235,483	14,102,505	55
222	155	124	124	125	45,742,822	46,563,857	15,511,511	15,144,518	63
23	172	165	164	162	15,588,211	15,574,572	45,458,959	14,881,125	56
24	177	- 171	168	167	15,548,544	35,131,212	45,515,151	14,175,835	55
25	127	115	117	115	16,623,131	8,40,43	45,248,556	14,141,133	н
26	155	143	141	197	15,514,146	15,697,461	16,854,475	45,754,455	55
27	151	114	114	182	19,818,685	15,527,785	13,883,683	12,497,599	51
28	115	113	114	113	46,758,758	16,313,333	45,172,197	14,851,517	65
29	125	114	114	114	16,725,225	16,256,631	45,885,251	44,214,214	63
30	127	115	128	115	16,728,585	16,216,558	45,738,734	14,553,881	62
2031.0	1,115	1,118	1,117	1,117	721,218	1,003,730	5,125,862	4,313,333	15
32	211	1,147	1,842	1,813	4,628,711	3,155,783	5,481,542	3,534,564	26
2020 (22)	107	166	166	165	16,748,652	16,715,285	16,745,528	46,534,000	
2034	557	676	638	697	6,853,853	5,571,516	2,353,582	5,116,726	52
003500	245	225	227	225	16,183,133	15,741,427	14,587,515	14,158,433	51
36	210	214	285	214	46,667,524	46,014,210	45,664,475	44,622,742	54
	10	112	11	112	15,245,425	16,538,133	16,631,282	15,6/6,363	
	135	123	124	122	15,748,154	16,592,218	46,784,755	45,697,004	
	141	123	123	128	16,745,413	15,458,435	16,561,635	45,367,348	64
40	141								
	241			271	13,522,435	12,333,813	12,538,385	4 558 929	
2015	157			4927	9,828,331	447	3,00,203	1,310,373	227
4 1	N Rigid Pay	ement Analys	sis /						

Figure 21. Sample Excel sheet of rigid pavement analysis outputs



Figure 22. Sample Excel sheet rigid pavement analysis charts

		Statistics			Detailr				Statistics			Deteilr	
Prediction	A <u>verage (pritis</u>)	S <u>td Dav (prifin</u>)	CT	Hadal	D <u>eflectio</u> n	Haira	Prediction	Average (pri)	Std Dav (pri)	CT	Hadal	D <u>eflectio</u> n	Hairs
	235	211	33%	RGD-4	4	0		14,160,415	3,423,313	24%	RGD-4	4	0
k	233	208	8375	RGD-4	4	2	Ercc	13,360,405	2,990,586	22%	RGD-4	4	2
	240	207	36%	RGD-4	4	5		12,552,625	2,473,368	20%	RGD-4	4	5
	229	210	32%	RGD-4	4	10		11,051,464	2,252,624	20%	RGD-4	4	10
	248	241	37%	RGD-6	6	0		13,504,037	4,303,368	.36%	RGD-6	6	0
	272	282	104.55	RGD-6	6	2		12,884,259	5,362,198	42%	RGD-6	6	2
	263	283	105%	RGD-6	6	5		12,558,210	5,020,503	40%	RGD-6	6	5
	271	281	104.55	RGD-6	6	10		11,705,695	4,611,061	.39%	RGD-6	6	10
	253	235	2.75	RGD-7	7	0		13,402,738	5,107,288	.38%	RGD-7	7	0
	2385	314	106%	RGD-7	7	2		12,731,537	5,498,104	4.3%	RGD-7	7	2
	237	.316	107%	RGD-7	7	5		12,308,881	5,095,901	41%	RGD-7	7	5
	296	309	105%	RGD-7	7	10		11,704,016	4,717,350	40%	RGD-7	7	10
	248	237	35%	RGD-8	8	0		13,522,435	4,828,931	36%	RGD-8	8	0
	273	280	10.7%	RGD-8	8	2		12,933,819	5,242,769	4.55	RGD-8	8	2
	274	282	10.7%	RGD-8	8	5		12,630,996	5,080,209	40%	RGD-8	8	5
	271	275	102%	RGD-8	8	10		11,847,938	4,560,379	.88%	RGD-8	8	10
		Statistics			Datailr				Statistics		Det	tailr	1
P <u>rødictin</u> n	<u>Avorago (in)</u>	Statistics Std Dav (in)	C¶.	Madal	Dotailr D <u>ofloctio</u> n	Haire	P <u>radictin</u> a	Average	Statistics Std Dev	C¶.	Det <u>Hadel</u>	tailr D <u>aflactio</u> n]
P <u>rødictio</u> n	<u>Avorago (in)</u> 50	Statirticr Std Dav (in)	 /?%	Hedel RGD-4	Dotailr D <u>ofloctiu</u> n 4	<u>Haire</u> 0	P <u>redictin</u> a		Statistics Std Dav //		Det <u>Medel</u> RGD-4	tailr D <u>eflectiu</u> n 4	
P <u>redictio</u> n RRS	<mark>Average (in)</mark> 50 51	Statistics Std Dav (in) M M	<u>C</u> ¥ 18% 28%	Hedel RGD-4 RGD-6	Dotailr D <u>ofloction</u> 4 6	<u>Hairs</u> 0 0	P <u>radictin</u> a	Average 1,30 1,35	Statistics Std Dav M N	<u>CT</u> //%: //%:	Det <u>Hedel</u> RGD-4 RGD-6	tailr D <u>eflectio</u> n 4 6	
P <u>rødictio</u> n RRS	<mark>Avorago (in)</mark> 50 51 51	Statistics Std Dav (in) M M M		Hedel RGD-4 RGD-6 RGD-7	Dotails D <u>offoction</u> 4 6 7	0 0 0	P <u>rodiction</u> &PCC	Average 120 125 124	Statistics Std Dov 14 15 15 15	<u>CT</u> 11% 12% 12%	Det <u>Hedel</u> RGD-4 RGD-6 RGD-7	<mark>ailr</mark> D <u>əfləctio</u> n 4 6 7	
P <u>redictin</u> RRS	Average (in) 50 5/ 5/ 5/	Statistics Stal Dov (in) N H 15 H		Hedel RGD-4 RGD-6 RGD-7 RGD-8	Deteilr D <u>eflection</u> 4 6 7 8	<u>Майге</u> 0 0 0	P <u>rodictio</u> s gPCC	Average 130 135 134 135	Statistics Std Dov M N N N N N N N N	<u>CT</u> //ts: /Cts: /Cts: /255:	Hedel RGD-4 RGD-6 RGD-7 RGD-8	teile D <u>eflection</u> 4 6 7 8	
P <u>rødictin</u> RRS	Average (in) 50 51 51 51 51	Statistics Stat Dave (in) N H K K M	 18% 28% 28%	Hedel RGD-4 RGD-6 RGD-7 RGD-8	Dotailr D <u>offoctin</u> e 4 6 7 8	ника Мика 0 0 0 0 0	P <u>rodictio</u> n &PCC	<u>Average</u> 100 105 104 105	Statistics Std Daw H K K K		Hadol RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>eflection</u> 4 6 7 8	
P <u>redictio</u> n RRS	Average (in) 50 51 51 51 51	Statistics Std Dov (in) M M J5 M	CT 18% 28% 27%	Hedel RGD-4 RGD-6 RGD-7 RGD-8	Deteilr D <u>eflection</u> 4 6 7 8	0 0 0 0	P <u>rodictin</u> s &PCC	Average 120 125 124 125	Statistics Std Dov M K K K	<u>C7</u> //ts: /C5: /C5: /25:	Det Hedel RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>eflectio</u> e 4 6 7 8	
P <u>radictin</u> s RRS	Average (in) 50 51 51 51 51	Statistics Std Dav (in) M M M M M M	C ¥ 184 284 284 284	Hadol RGD-4 RGD-6 RGD-7 RGD-8	Details Deflection 4 6 7 8	0 0 0 0	P <u>rodictin</u> s &PCC	<u>Avorego</u> 120 125 124 125	Statistics Std Dov M K K K	C T //ts: /Cos: /Cos: /205	Det Madel RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>eflectio</u> n 4 6 7 8	
P <u>radictin</u> RRS	Avereqe (in) 50 51 51 51	Statistics 5td Dev (is) N N N N N N N	07 184 284 284 274	Hadal RGD-4 RGD-6 RGD-7 RGD-8	Dotails D <u>offication</u> 4 6 7 8	• <u>Haire</u> 0 0 0	P <u>rodictin</u> &PCC	Average 120 125 124 125	Statutic Statut M K IF K		Hadal RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>aflactin</u> s 4 6 7 8	
P <u>redictin</u> RRS	Average (in) 50 51 51 51	Statistics Std Dav (in) M M M M	C7 <i>Ra:</i> 28a: 27a: 27a:	Hadal RGD-4 RGD-6 RGD-7 RGD-8	Dotails Defloction 4 6 7 8	• <u>Haire</u> 0 0 0	P <u>rodictio</u> s	<u>Avereqe</u> 120 125 124 125	Statistics Std Day H K F K		Hadal RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>aflactin</u> s 4 6 7 8	
P <u>redictin</u> RRS	<u>Ανογγοφοία</u> 50 51 51 51	<u>Stetistics</u> <u>Std Dav (in)</u> <i>N</i> <i>H</i> <i>K</i> <i>H</i>	07 1811 2811 2811 2811	Hedel RGD-4 RGD-6 RGD-7 RGD-8	Datailr D <u>aflactio</u> 4 6 7 8	- <u>Heire</u> 0 0 0	P <u>rodictin</u> s grcc	<u>Averence</u> 1200 1205 1204 1205	Statistics Std Day H K Fr K	07 185 185 185 185	Det Hade1 RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>eflection</u> 4 6 7 8	
P <u>radictin</u> s RRS	Average (in) 50 81 51 51 51	Statistics Std Day (in) N H N N N N	07 184 284 284 284 284	Hedel RGD-4 RGD-6 RGD-7 RGD-8	Detail: Deflection 4 6 7 8	- <u>Heirs</u> 0 0 0	P <u>rodictin</u> s gPCC	<u>Average</u> 120 125 124 125	Statistics Std Day H K K K K	27 182 182 182 182	Det Hedel RGD-4 RGD-6 RGD-7 RGD-8	teilr D <u>offactio</u> 4 6 7 8	
P <u>radiction</u> RRS	Average (in) 50 51 51 51 81	Statistics Std Dav (in) N H K M	CT 1897 2897 2897 2897 2897	Hedel RGD-4 RGD-6 RGD-7 RGD-8	Deteilr D <u>aflectin</u> 4 6 7 8	8 10 10 10 10 10 10 10 10 10 10 10 10 10	P <u>redictin</u> s GPCC	<u>Aver 440</u> 130 135 134 135	Statistics Std Day H K F K	<u>C7</u> //tr: /Cc: /Cc: /2c:	Det Madel RGD-4 RGD-7 RGD-7 RGD-8	teilr D <u>aflactio</u> 4 6 7 8	
P <u>rodiction</u> RRS	Average (in) 50 51 51 51	<u>Statistics</u> <u>Std Dav (ia)</u> <i>N</i> <i>H</i> <i>K</i> 5 <i>H</i>	67 1897 2897 2897 2997	Hadal RGD-4 RGD-6 RGD-7 RGD-8	Detsilr D <u>affection</u> 4 6 7 8	Naire 0 0 0	P <u>rodictin</u> GPCC	<u>Avereq</u> 120 125 124 125	Statistics Std Dar M K F K	<u>C7</u> ///// //C7 //C7 //C7	Det Madel RGD-4 RGD-6 RGD-7 RGD-8	teib D <u>aflactin</u> s 6 7 8	
P <u>redictin</u> e RRS	<u>Ανογγαφο (in)</u> 50 51 51 51	Statistics <u>Std Dar (in)</u> N H K H	07 184 284 284 284 284	Hadal RGD-4 RGD-6 RGD-7 RGD-8	Dottilr D <u>offiction</u> 4 6 7 8	0 0 0 0	P <u>rodictin</u> s GPCC	<u>Avereq</u> 120 125 124 125	Statistics Std Day M N N N N S	CT <i>Its:</i> <i>Its:</i> <i>Its:</i> <i>Its:</i>	Date of the second seco	teitr D <u>aflactin</u> e 6 7 8	
P <u>redictio</u> RRS	Average (in) 50 51 51 51 51	Statistics Std Dav (in) N M K M	67 1847 2847 2847 2847 2847 2847	Hadal RGD-4 RGD-6 RGD-7 RGD-8	Detteilr D <u>affactien</u> 4 6 7 8	8 <u>Heirs</u> 0 0 0	P <u>redictin</u> gPCC	Average 130 125 134 135	Statistics Std Day M K K K	CT Mrs Kar Kar Lar	Det Hadol RGD-4 RGD-6 RGD-7 RGD-8	teibr D <u>aflaction</u> 4 6 7 8	
P <u>rodictio</u> RRS	Average (in) 50 51 51 51 51	Statistics Std Dav (in) N H K M	07 Re: 2007 2007	Hedel RGD-4 RGD-6 RGD-7 RGD-8	Detsilr D <u>affectim</u> 4 6 7 8	8 <u>Heire</u> 0 0 0	P <u>redictin</u> gpcc	<u>Aver 440</u> 120 125 124 125	Statistics Std Day H K F K	07 115 175 175 125	Beb-4 RGD-4 RGD-6 RGD-7 RGD-8	teibr D <u>aflaction</u> 4 6 7 8	

Figure 23. Output statistics summary sheet for rigid pavement analysis

Composite Pavement Analysis, Plotting, and Summary Menus

The AC overlaid PCC-type composite pavement analysis menu also consists of three main sections: inputs, analysis tool, and outputs as shown in Figure 24. Required input parameters for composite pavement analysis are deflection data, pavement layer information (layer thicknesses, PCC modulus predictions, and coefficient of subgrade reaction predictions), and FWD load. The analysis tool functionalities in composite analysis menu are identical to those in flexible pavement analysis menu. This means preprocessing of the data for composite pavement analysis is same as that for flexible pavement analysis.

Similar to flexible and rigid pavement analysis, the program analyzes the data model by model by clicking the "Run" button after preprocessing the data. The ANN models employed for composite pavement analysis are 4-, 6-, 7-, and 8- deflection models with 0%, $\pm 2\%$, $\pm 5\%$ and $\pm 10\%$ noise. Each model has a different number of input parameters depending on the number of deflections and a different level of noise to provide more robust networks. Detailed descriptions of each model are provided in phase I project report (Ceylan et al, 2007).

For each model, the analysis results will be displayed on the right side of the screen. The user should scroll right to see all results. Also, disabled menu commands of plots and the summary will be activated. The composite pavement analysis results are E_{AC} -modulus of AC, E_{PCC} -modulus of PCC, k_s -coefficient of subgrade reaction, ε_{AC} -tensile strain at the bottom of asphalt

layer, and σ_{PCC} -tensile stress at the bottom of the PCC layer.

Figure 25 illustrates sample analysis results for a composite pavement section. Figure 26 illustrates color-coded composite pavement analysis results of 4-deflection model with 0 % noise which are generated from the plotting function. Figure 27 illustrates sample Excel sheet with tables of each output and their statistics for every generated model by clicking "summary" button.

			FV	D Deflec	tions (n	nils)			Asphalt Concrete Thickness	Portland Cement Concrete	Epcc Prediction (psi	k Prediction (psi/in)	IOWA STATE UNIVERSITY	Eac 4 Defi	rations- (psi) D12-D2	4-036)	(D0-
Location	D-6	D-8	D-12	D-18	D-24	D-36	D-48	D-66	h ac	Arec	Erec			an a	2%	52	10.2
- 1	2.50	2.19	2.08	1.99	1.93	0.00	0.00	0.00	10.00	10.00		Δn	aiveie	3,362,500	3,353,907	3,236,212	1,667,776
2	3.01	2.61	2.46	2.36	2.24	2.05	2.05	0.00	10.00	10.00			ury 515	1,094,929	1,218,713	1,685,600	2,051,545
3	3.65	3.15	2.98	2.86	2.71	2.44				10.00							17
•	2.98	2.63	2.45	2.31	2.16	1.89	Iľ	סר	DUtS	10.00		Т			1140	SU 1 4	· 🗨 🚪
5	3.82	3.31	3.09	2.91	2.74	2.38		<u>- </u>		10.00					นน	JUU	.3 🚪
6	4.57	3.94	3.69	3.49	3.25	2.85	2.35	2.20	10.00	10.00				100,720	101,710	001,900	1,001,016
7	3.41	3.07	2.88	2.72	2.54	2.17	2.00	0.00	10.00	10.00				1,352,596	1,449,436	1,693,213	1,819,741
8	4.31	3.87	3.65	3.43	3.19	2.72	2.23	2.12	10.00	10.00			Duu	1,105,947	1,174,549	1,406,344	1,668,527
9	5.16	4.59	4.35	4.08	3.77	3.22	2.61	2.28	10.00	10.00			лил	896,930	913,876	1,121,740	1,398,118
10	3.42	2.84	2.63	2.43	2.23	1.95	1.92	0.00	10.00	10.00			A lowe Department	788,556	785,320	787,003	1,231,608
- 11	4.30	3.55	3.28	3.03	2.80	2.41	2.02	0.00	10.00	10.00			of Transportation	618,524	630,006	612,382	950,001
12	5.22	4.30	3.98	3.68	3.39	2.92	2.47	2.27	10.00	10.00				510,503	520,648	468,596	772,525
13	3.62	3.10	2.91	2.78	2.62	2.35	1.99	0.00	10.00	10.00			Main Monu	868,732	884,403	1,017,604	1,687,890
14	4.55	3.87	3.65	3.49	3.28	2.92	2.50	2.43	10.00	10.00				699,010	704,099	816,814	1,299,901
15	5.40	4.60	4.33	4.13	3.88	3.46	2.96	2.54	10.00	10.00			AB overlaid PBB	589,797	592,823	617,571	1,041,449
16	4.36	4.00	3.79	3.57	3.33	2.89	2.38	2.25	10.00	10.00			Analysis	1,320,104	1,445,332	1,691,148	1,775,915
17	5.37	4.88	4.60	4.35	4.04	3.48	2.85	2.53	10.00	10.00				954,938	1,000,727	1,221,770	1,521,681
18	6.40	5.80	5.48	5.16	4.79	4.12	3.39	2.76	10.00	10.00			Plots	804,055	807,461	998,277	1,366,211
19	3.28	2.88	2.71	2.55	2.35	2.01	1.83	0.00	10.00	10.00				1,209,993	1,246,118	1,454,823	1,733,784
20	4.22	3.67	3.46	3.25	3.03	2.57	2.06	2.01	10.00	10.00			<i>a</i>	909,064	943,089	1,105,775	1,478,793
21	5.08	4.40	4.13	3.89	3.60	3.05	2.46	2.13	10.00	10.00			SAMMARY	725,749	732,568	813,302	1,192,898
22	3.59	3.32	3.13	2.97	2.79	2.45	2.13	0.00	10.00	10.00				1,589,074	1,733,017	1,866,006	1,931,907
23	4.51	4.12	3.88	3.69	3.45	3.03	2.50	2.31	10.00	10.00			Filter	1,118,251	1,195,768	1,477,969	1,734,275
24	5.42	4.93	4.67	4.42	4.12	3.59	2.99	2.48	10.00	10.00				966,616	1,015,771	1,252,962	1,567,502
25	3.50	3.11	2.91	2.73	2.51	2.12	1.96	0.00	10.00	10.00			Open FUD Dat File	1,213,689	1,265,179	1,470,533	1,712,143
26	4.57	3.98	3.76	3.51	3.23	2.72	2.19	2.06	10.00	10.00				877,848	895,150	1,054,565	1,382,285
27	5.50	4.78	4.50	4.20	3.87	3.27	2.61	2.28	10.00	10.00				704,097	700,976	751,639	1,114,770
28	4.60	4.18	3.92	3.65	3.38	2.85	2.47	0.00	10.00	10.00				1,130,058	1,200,019	1,409,063	1,622,218
ты	Comp	osite F	aveme	nt Ana	ilysis /											<	>

Figure 24. Composite pavement analysis menu

	Eac 4 Defle	ections- (psi) D12-D2	24-036)	(D0-		Epcc 4 Defle (D0-D12-	ections- (psi) D24-D36)			ks 4 Deflect (D0-D12-	ions- (psiłin) D24-D36)	
Location	ar .	2%	5.2	10.2	ar	2%	5.2	10%	ar	2%	5.2	MC2°
4	1,234,639	1,265,899	1,519,102	1,836,437	9,499,322	9,147,157	7,792,633	7,546,496	202	203	216	222
5	891,216	913,423	1,029,944	1,530,668	7,592,611	7,316,779	6,347,208	6,670,237	161	163	166	172
6	736,423	737,415	837,433	1,267,516	6,556,046	6,322,297	5,875,011	5,209,243	132	137	139	143
7	1,352,596	1,449,436	1,693,213	1,819,741	6,640,353	6,151,698	5,603,228	5,720,321	192	190	195	192
8	1,105,947	1,174,549	1,406,344	1,668,527	4,863,962	4,565,452	4,171,684	4,222,728	158	156	157	156
9	896,930	913,876	1,121,740	1,398,118	3,955,277	3,847,150	3,549,299	3,210,390	136	135	136	133
10	788,556	785,320	787,003	1,231,608	7,535,960	7,621,437	6,794,030	6,905,758	224	222	229	238
11	618,524	630,006	612,382	950,001	5,874,340	5,792,261	5,562,333	4,883,209	186	183	186	185
12	510,503	520,648	468,596	772,525	4,839,293	4,876,478	4,723,546	4,086,396	153	151	150	152
13	868,732	884,403	1,017,604	1,687,890	11,212,355	10,343,529	8,756,121	7,517,044	133	136	158	161
14	699,010	704,099	816,814	1,299,901	8,355,041	8,233,398	7,226,994	6,521,882	111	112	126	129
15	589,797	592,823	617,571	1,041,449	7,019,359	7,006,064	6,377,420	4,795,449	94	92	99	105
16	1,320,104	1,445,332	1,691,148	1,775,915	5,101,984	4,773,213	4,430,351	4,192,110	138	139	141	132
17	954,938	1,000,727	1,221,770	1,521,681	4,133,066	4,026,434	3,722,162	2,998,709	116	120	121	110
18	804,055	807,461	998,277	1,366,211	3,347,803	3,386,332	3,077,044	2,582,748	100	104	103	93
19	1,209,993	1,246,118	1,454,823	1,733,784	6,703,043	6,368,631	5,743,087	5,955,298	218	217	222	222
20	909,064	943,089	1,105,775	1,478,793	5,374,990	5,096,446	4,533,829	4,456,015	169	167	169	169
21	725,749	732,568	813,302	1,192,898	4,423,493	4,315,517	3,873,046	3,591,367	144	143	144	145
22	1,589,074	1,733,017	1,866,006	1,931,907	7,366,460	6,922,938	6,353,703	6,471,687	148	150	156	152
23	1,118,251	1,195,768	1,477,969	1,734,275	6,075,579	5,604,080	5,148,606	4,339,281	119	123	129	118
24	966,616	1,015,771	1,252,962	1,567,502	4,488,521	4,417,099	4,034,015	3,103,407	106	111	111	99
25	1,213,689	1,265,179	1,470,533	1,712,143	5,548,079	5,269,105	4,743,724	4,858,034	218	216	219	215
26	877,848	895,150	1,054,565	1,382,285	4,208,145	4,031,352	3,700,352	3,838,214	173	170	174	168
27	704,097	700,976	751,639	1,114,770	3,654,947	3,629,093	3,277,411	3,212,183	141	139	141	138
28	1,130,058	1,200,019	1,409,063	1,622,218	3,775,932	3,456,469	3,376,836	3,671,105	163	159	162	157
29	822,980	828,926	974,988	1,250,888	3,011,004	2,960,112	2,794,933	2,649,789	126	125	127	119
30	662,059	614,149	788,781	1,077,938	2,555,561	2,404,246	2,358,640	1,696,826	106	108	111	99
31	830,329	848,417	1,013,213	1,507,917	7,812,279	7,512,331	6,454,643	6,659,213	129	134	143	144
(F H)	Comnosit	e Pavemen	t Analysis	/								

Figure 25. Sample Excel sheet outputs of composite pavement analysis



Figure 26. Sample Excel sheet charts of composite pavement analysis

Prodiction Av.		20000			Datailr				Statistics			Detailr	
	eerage (pri)	Std Dav (pri)	C7	Hadal	D <u>eflectin</u> n	Hairs	P <u>rodiction</u>	Average (pri)	Std Dav (pri)	C7	Hadal	D <u>eflectin</u> n	Heis
	1.038,278	414,020	40%	CPDR-4	4	0		5,788,655	2,337,869	40%	CPDR-4	4	0
Eac 🤇	1093,033	444,615	41%	CPDR-4	4	2	Ercc	5,541,871	2,063,233	3781	CPDR-4	4	2
1	1,257,428	456,117	.76%	CPDR-4	4	5		4,377,317	1,756,498	.75%	CPDR-4	4	5
1	1522,628	233,506	1927	CPDR-4	4	10		4,604,157	1,703,022	.8781	CPDR-4	4	10
	1,113,742	551,508	58%	CPDR-6	6	0		4,111,025	3,345,763	31%	CPDR-6	6	0
1	1,408,363	371.373	63%	CPDR-6	6	2		4,532,784	3,613,534	79%	CPDR-6	6	2
	1, 182, 329	655,874	55%	CPDR-6	6	5		4,554,528	3,258,623	7274	CPDR-6	6	5
	1,354,267	402,321	30%	CPDR-6	6	10		4,052,316	3,034,113	75%	CPDR-6	6	10
	1,250,312	648,010	5274	CPDR-7	7	0		4,010,109	3,608,751	30%	CPDR-7	7	0
	1471,269	345,234	64.%	CPDR-7	7	2		4,438,591	3,744,437	84.%	CPDR-7	7	2
	1.378,167	624,481	45%	CPDR-7	7	5		4,688,601	3,733,943	80%	CPDR-7	7	5
1	1495,359	361,232	24.%	CPDR-7	7	10		4,136,721	3,067,744	74.W	CPDR-7	7	10
	1,108,669	5M, 662	46%	CPDR-8	8	0		4, 178, 338	2,300,627	63%	CPDR-8	8	0
1	1400,777	352,400	61%	CPDR-8	8	2		4,106,327	3,195,405	78%	CPDR-8	8	2
1	1,460,520	731,687	58%	CPDR-8	8	5		3,338,622	2,339,533	748°	CPDR-8	8	5
	1,550,613	406,533	28%	CPDR-8	8	10		4,212,302	2,833,110	67%	CPDR-8	8	10
Hute: Ea	ac predictions	ere limited to rea	qar batusan 1,		3000,000 p	ri. <i>B</i>	ack •-	te: Epcc predictin	statistics	nger betueen	1,000,000 au	4 12,000,00	• pri.
Hute: Eg	ac prodictions prage (psifin)	statistics Statistics Std Day (prifin)	qar batusan 1,	Hadel	Datailr Daflactins	ri. B	P <u>redictin</u> s	to: Epcc prodictin	Statistics Statistics	nger between	1,000,000 Dot <u>Hadol</u>	d 12,000,00 tailr D <u>ofloctin</u> n	• pri.
Mate: Eg	ec predictions <u>erage (prifin</u>) <i>156</i>	stelinited to rea Statistics <u>Std Dev (psilin)</u> /(22	ger betueen 1, 	<u>Madel</u> CPDR-4	3000,000 p. Dotailr D <u>ofloctin</u> a 4	ri. B	P <u>rediction</u>	to: Epcc prodictin Avorago	Statistics Statistics Std Dov		<u>Der</u> <u>Hedel</u> CPDR-4	tailr D <u>ofloctiu</u> n 4	• pri.
Hate: Eg P <u>radiction</u> Avan k.	ec prodictions orage (prifin) 156 156	ere limited to rea <u>Statistics</u> <u>Std Dev (prifin)</u> /Q2 <u>/</u> 28	CT 34.% 82%	Hadal CPDR-4 CPDR-4	Dotails Dotails D <u>offoctin</u> s 4 4	ri. 8 <u>Haire</u> 0 2	P <u>rodictin</u> s	te: Epcc prodiction Average 34 34	st are limited to re Statistics Std Dev g g	<u>CT</u> 26% 23%	Hadel CPDR-4 CPDR-6	4 12,000,00 tailr D <u>offoctin</u> s 4 6	• pri.
Hete: Eg	oc prodictions 	ere limited to rea Statistics Std Dev (psilin) 102 128 125	007 botuoon 1, 017 017 027 027	Hadal CPDR-4 CPDR-4 CPDR-4	Dotailr D <u>offoctin</u> n 4 4 4	•i. 8 <u>Haire</u> 0 2 5	P <u>rodictina</u> Sac	te: Epcc prodiction Avorage 34 34 32	Statistics Statistics Std Dov g g g g	 	<u>Hadal</u> CPDR-4 CPDR-6 CPDR-7	12,000,00	• pri.
Hete: Eg	ac prodiction 156 156 156 161 158	ere limited to rea Statistics Std Dev (prilin) 1/22 1/28 1/25 1/27	07 botuoon 1, 07 84% 82% 78% 78%	Hadel CPDR-4 CPDR-4 CPDR-4 CPDR-4 CPDR-4	Dotails Dotails D <u>offoction</u> 4 4 4 4	ri. // 0 5 	<mark>Predictina</mark> δac	te: Epcc prodiction Avorage 34 34 37 32 32	Statistics Statistics Std Dov 9 8 8 8 8 8	 283 233 243 243	Det Madel CPDR-4 CPDR-6 CPDR-7 CPDR-8	tailr D <u>eflectin</u> s 4 6 7 8	• pri.
Hate: Eg	ac prodictions 156 156 161 158 205	ere limited to rea Statistics <u>Stat Dev (prifin)</u> 128 128 125 127 178	CT SAN RAN RAN RAN RAN RAN RAN	Hadel CPDR-4 CPDR-4 CPDR-4 CPDR-4 CPDR-4 CPDR-6	3000,000 pJ Doteilr D <u>offoctin</u> s 4 4 4 4 4 6	ri. // //////////////////////////////////	P <u>rodictina</u> Sac	Arorago M M M M M M M M M M M M M M M M M M M	Statistics Statistics Stil Dar S S S S S S S S S S S S S	 28% 23% 24% 25% 26%	Det Hadel CPDR-4 CPDR-6 CPDR-7 CPDR-8 CPDR-8 CPDR-4	teitr Deflection 4 6 7 8 4	• pri.
Hate: Eg	ac prediction 156 156 161 168 205 238	Statistics Statistics 1/02 1/	CT SAN BAN RAN RAN RAN BAN BAN BAN	Hadal CPDR-4 CPDR-4 CPDR-4 CPDR-4 CPDR-6 CPDR-6	Deteile Deflection 4 4 4 4 6 6	ri. // Hairs 0 2 5 10 0 2	<mark>Prodictin</mark> α P <u>rodictin</u> α δac	Arorago M M M M M M M M M M M M M M M M M M M	Statistics Statistics State	 	Date Hadal CPDR-4 CPDR-6 CPDR-7 CPDR-8	teilr D <u>offoction</u> 4 6 7 8 4 6	• pri.
P <u>redictin</u> s Aven	ac predictions 156 156 161 153 205 233 255	Statistics Statistics 5td Dav (prifin) 1/22 1/28 1/27 1/28 1/27 1/76 2/16 2/29	CT SAS SAS SAS SAS SAS SAS SAS SAS	Hads1 CPDR-4 CPDR-4 CPDR-4 CPDR-4 CPDR-6 CPDR-6 CPDR-6	Deteile Deflection 4 4 4 4 6 6 6 6	ri. // Maire 0 2 5 10 0 2 5 5	P <u>rediction</u> Sac gpcc	Average M M M M M M M M M M M M M M M M M	Statistics Statistics 3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	07 265 265 265 245 245 245 265 365 365	Date Hedal CPDR-4 CPDR-6 CPDR-7 CPDR-8 CPDR-8 CPDR-8 CPDR-8 CPDR-8 CPDR-8 CPDR-8 CPDR-8 CPDR-7	4 12,400,00 teilr 0 offoction 4 6 7 8 4 6 7 7	• pri.
Rete: Ea	ac predictions 156 156 161 158 205 238 255 256	Stetistics <u>Stetistics</u> <u>Stetistics</u> <u>128</u> <u>128</u> <u>128</u> <u>123</u> <u>178</u> <u>216</u> <u>229</u> <u>224</u>	CT SAL SAL SAL SAL SAL SAL SAL SAL	Hadat CPDR-4 CPDR-4 CPDR-4 CPDR-4 CPDR-6 CPDR-6 CPDR-6 CPDR-6	Doteilr Doteilr Dafloction 4 4 4 4 6 6 6 6 6	ri. // 0 2 5 10 0 2 5 10	<mark>Predictin</mark> a δac σPcc	Average 34 34 34 37 38 39	Statistics Statistics g	07 265 275 275 275 275 275 275 275 275 275 27	Det Hedel CPDR-4 CPDR-6 CPDR-8 CPDR-8 CPDR-8 CPDR-8 CPDR-9	4 12,400,40 D<u>eflection</u> 4 6 7 8 4 6 7 8	• pri.
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Figure 27. Output statistics summary sheet for composite pavement analysis

SUMMARY

In summary, the following are some of the significant features of the fully-automated ANNbased, user-friendly pavement structural analysis software system:

- A comprehensive pavement structural analysis tool incorporating all three common pavement types (flexible, rigid, and composite)
- Capability of automatically reading the FWD raw data collected by the JILS-20 type FWD machine that Iowa DOT owns
- Integration of all the ANN models developed as part of Phase I research into a comprehensive unified framework
- Rapid backcalculation of pavement layer moduli and prediction of critical pavement responses from FWD data (100,000 deflection basins analyzed in less than a second)
- Useful for both project-level and network-level pavement structural evaluation
- Visualization of results through automatic plotting capability
- Commonly used Import/Export options for transporting data
- Automatic generation of output statistics

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