**0-6005-P2**

# CTR Post-Processing Software for Calculating Peak-to-Peak Dynamic Deflections from the Voltage Signals Generated by the RDD Rolling Sensors

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*TxDOT Project 0-6005: Developing a Testing Device for Total Pavements Acceptance*

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# Introduction to the Software

As part of the development of the Total Pavement Acceptance Device (TPAD), CTR created post-processing software for calculating the dynamic deflections of the pavement from the output of the rolling dynamic deflectometer (RDD) rolling sensors. To analyze the data, the software performs these steps: (1) load raw voltage signals of the RDD rolling sensors, (2) apply the composite infinite impulse response and finite impulse response filters, (3) apply field or lab determined calibration factors to calculate peak-to-peak deflections over a time interval determined by a testing speed, (4) normalize the dynamic deflections to a force level selected by the data processor with dynamic force-time data (normally a peak-to-peak force level of 10 kips), (5) average the converted rolling sensor deflections over a selected distance, and (6) apply a moving average. Figure 1 presents a flow chart of the post-processing software.

Note that running this software requires the MS Windows® operating system (Windows XP, Windows Vista, or Windows 7) and software packages IGOR PRO and Matlab. The CD accompanying this manual contains the CTR software to load onto the user's computer: "TPAD ana_ver 2.0_TxDOT.pxp" and "Analysis.m."

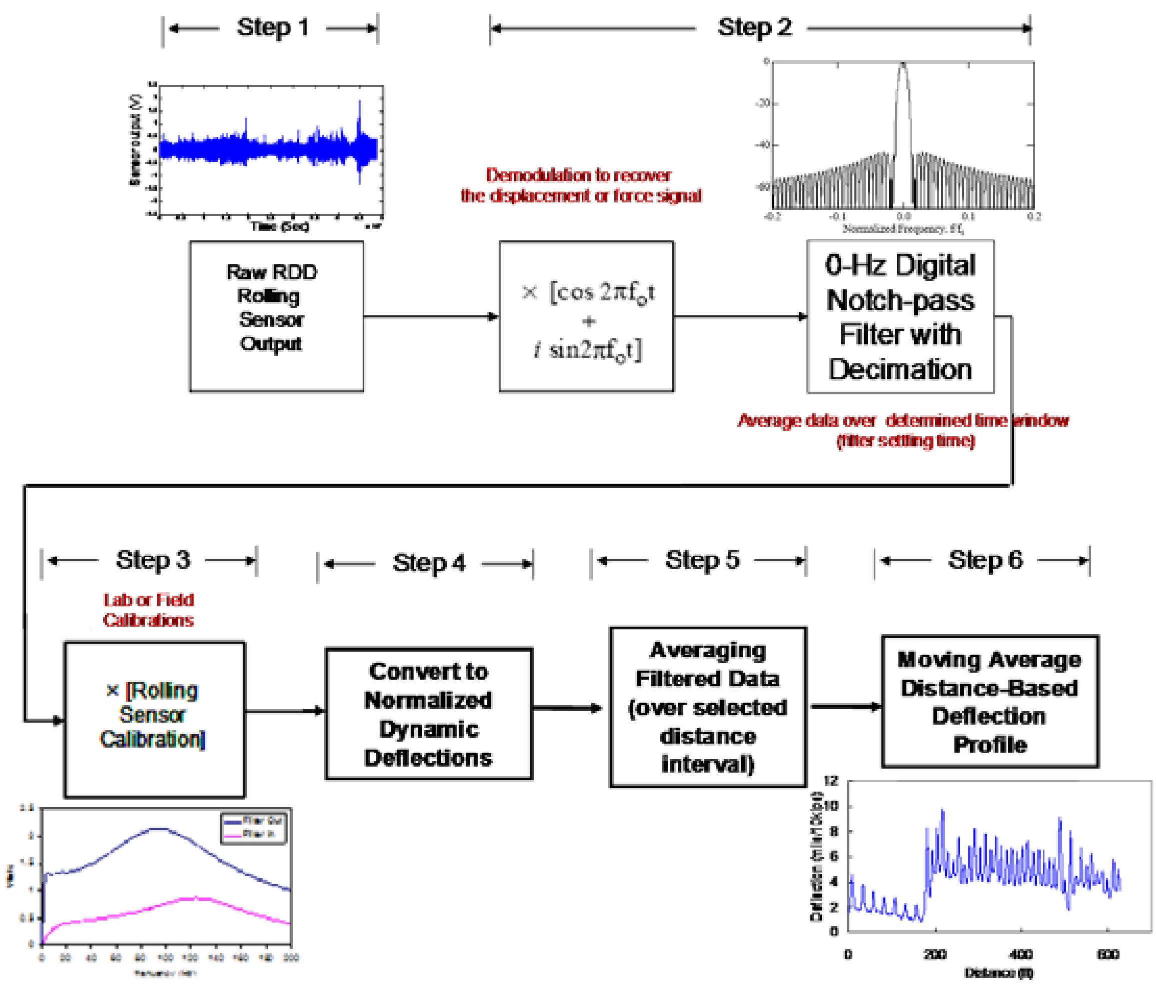


**Figure 1: Flow Chart of the 6-Step Data Analysis Procedure Used to Calculate Normalized Peak-to-Peak Dynamic Displacements from the Rolling Sensor Outputs**

## Time-Based Data Analysis

IGOR software is used for the time-based data analysis performed in Steps (1), (2), (3), and (4). The initial programming was completed by Dr. James Bay; details are in TxDOT report 1422-3F (Bay and Stokoe, 1998). Figure 2 shows a screen shot of when IGOR is opened. The steps for the time-based analysis are as follows.

(1) Raw data needs to be loaded. To load raw data, click “Load general binary file” in the “Load waves” submenu under the Data tab, as shown in Figure 3. For the CTR data processing, raw data consists of two parts: “File name_A. DAT” and “File name_C. DAT”. A data collector assigns the file name when recording the raw data. “File name_A. DAT” consists of one force and up to three geophones and “File name_C. DAT” is data from the distance measurement instrument. The data type of A. DAT is single float and C. DAT is double float. When “Load General Binary Data” is clicked, the screen shown in Figure 4 appears. Both raw data files, A. DAT and C. DAT, need to be loaded separately.


**Figure 2: Screenshot of IGOR When Opened**

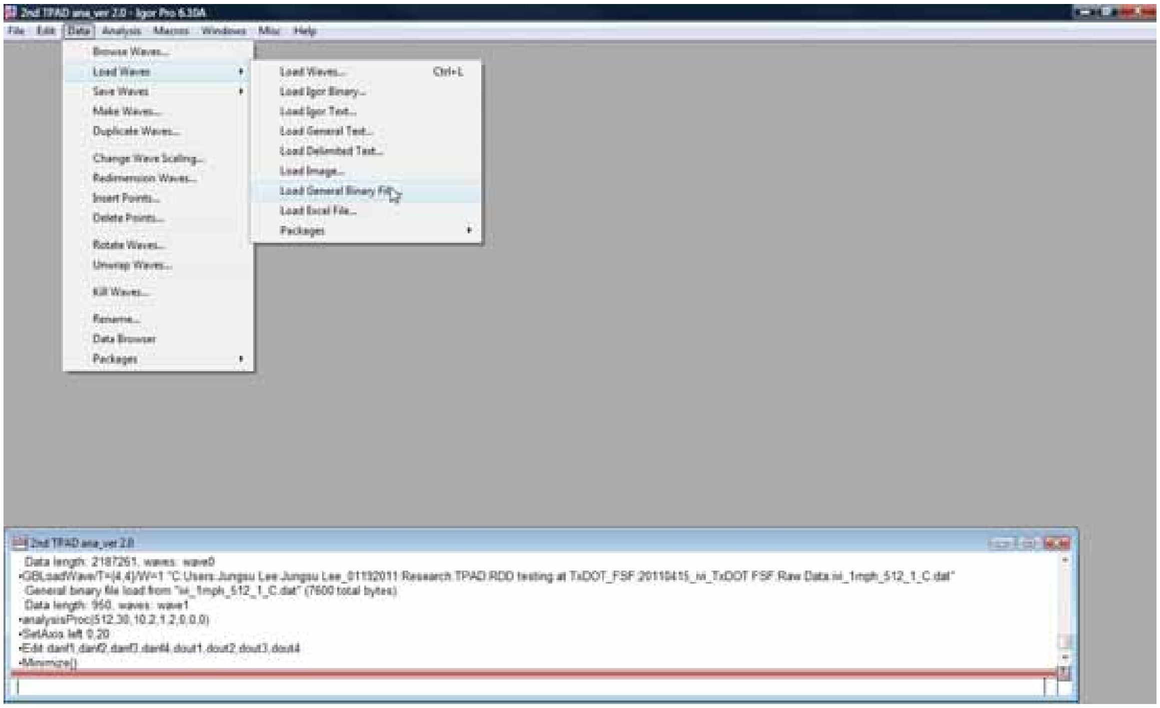

**Figure 3: Screenshot of IGOR to Load Raw Data**

(2) After choosing the data type in the Input File dialog box (see Figure 4), the path to the raw data needs to be determined. To determine the path, click the “File” button and select a general binary file to load. After loading the two types of raw data (“File name_A.DAT and File name_C.DAT) separately, click the the “Do It” button.

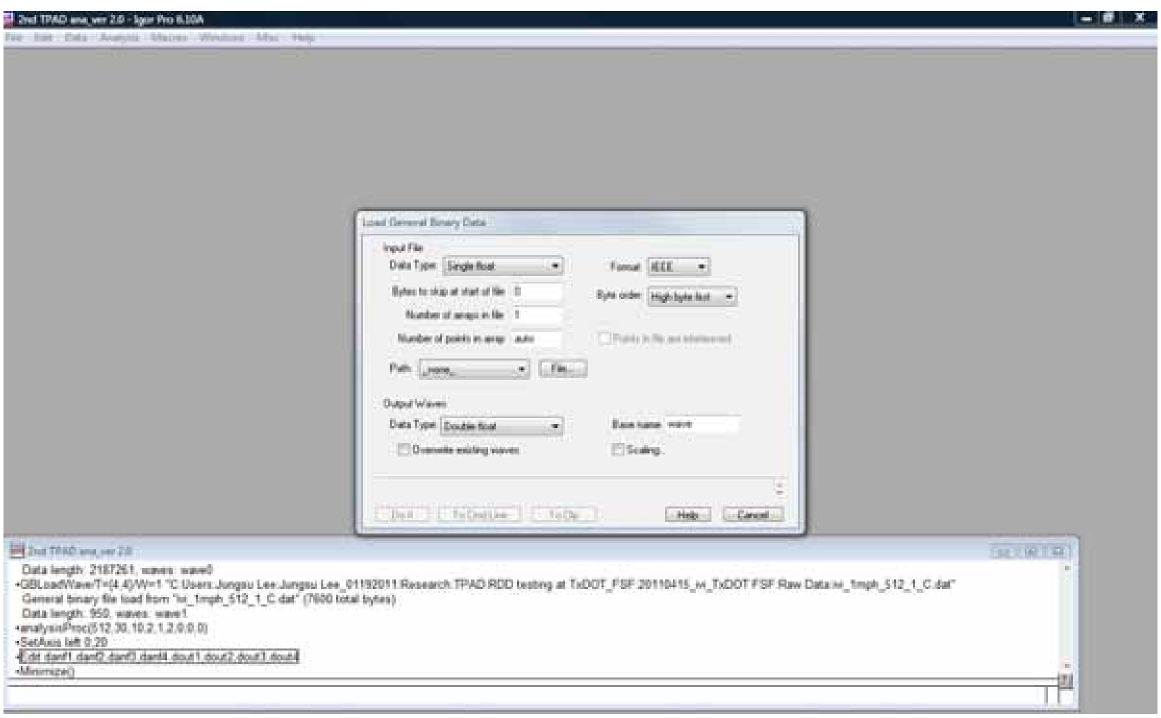

**Figure 4: Screenshot of IGOR When “Load General Binary Data” Is Clicked**

(3) After loading the two types of raw data, click "analysisProc" under the Macros tab; the screen shown in Figure 5 will appear. Testing parameters such as sampling frequency, operating frequency, nominal peak-to-peak dynamic force, and time resolution can be selected. Among parameters, the sampling frequency should be the same as the frequency used while collecting the raw data (default is 1000 Hz). The time resolution varies with the testing speed. In general, the time resolutions of 1, 0.5, and 0.33 seconds are used, respectively, at testing speeds of 1, 2, and 3 mph (default is 0.5 seconds). Normally, an operating frequency of 30 Hz (vibrating frequency), a normalization peak-to-peak dynamic force of 10 kips, and a minimum dynamic force of 2 kips are used and designated as default values. The attenuator is installed to avoid sending voltages that are too large for the data acquisition system and the default is "in". After setting all parameters, click the "Continue" button.

(4) The data analyzed in IGOR needs to be imported as a .txt file for distance-based moving average analysis. Click "New Table" under the Windows tab and choose "danf1", "danf2", "danf3", and "dout1". They are measurements for center (danf1), front (danf2), and rear (danf3) rolling sensors and the distance (dout1) measurement, respectively. Figures 6 and 7 present screen shots of when "New Table" is clicked and a new table is made. The table can be copied and pasted in a text file by using keyboard shortcuts "Ctrl A", "Ctrl C", and "Ctrl V". The name of the text file should be "F1", as designated by an operator so that the text file can be imported to Matlab and be used in "Analysis.m".

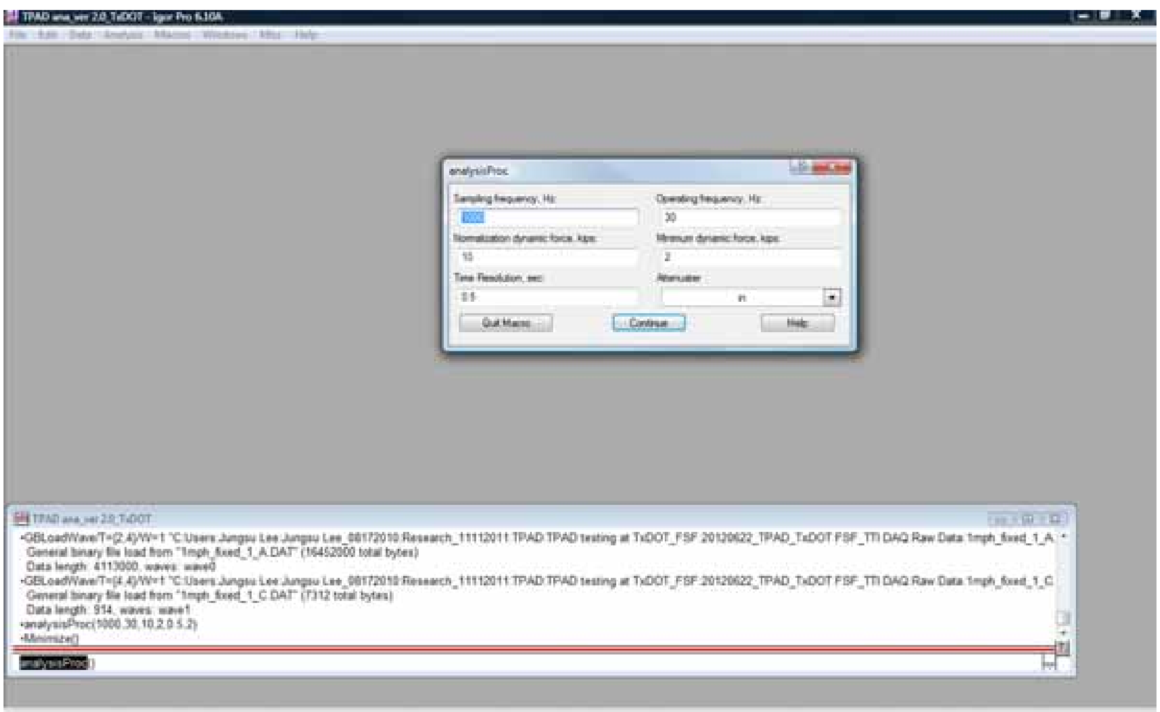


**Figure 5: Screenshot of IGOR When "AnalysisProc" Is Clicked**

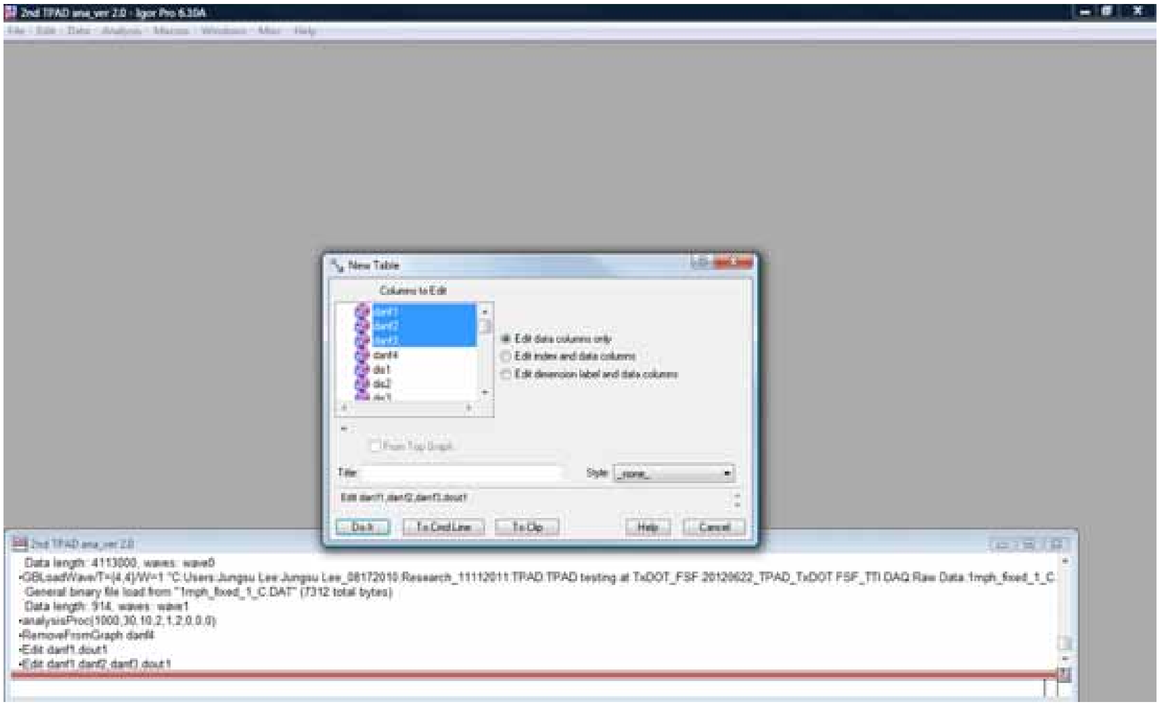

**Figure 6: Screenshot of IGOR When "New Table" Is Clicked**

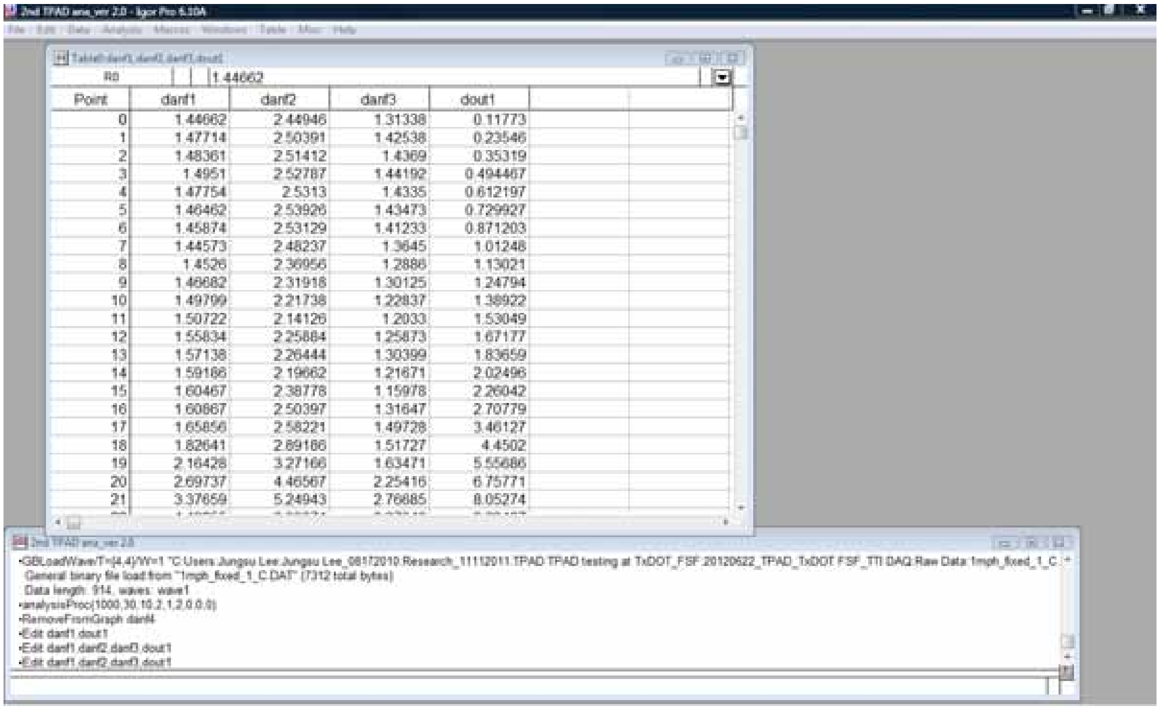

**Figure 7: Screenshot of IGOR When "New Table" Is Made**

## Distance-Based Moving Average Analysis

After IGOR finishes the time-based analysis, Matlab performs the distance-based moving average analysis, as follows:

(1) The time-based analyzed data saved in the text file (F1.txt) needs to be imported into Matlab. Click the "Load data file" button to import the text file "F1", as shown in Figure 8. By importing the "F1.txt" file, the F1 table consisting four columns is created as shown in Figure 9. The first, second, third, and fourth columns of F1 are time-based analyses of the center, front, and rear rolling sensors and distance measurements, respectively.

(2) Open the "Analysis.m" file by clicking "Open" under the File tab. Figure 10 presents a shot of the screen after opening the "Analysis.m" file.

(3) Note: The center rolling center analysis is conducted first; Step 7 provides the specific inputs for then running an analysis of the front and rear sensors. To analyze the center rolling sensor, go to the "Analysis.m" dialogue box and type "dist=F1(:,4)", "amp=F1(:,1)", and "critic(i)=3.0*i+0.0", and then click the "Save and Run" button as shown in Figure 11. The deflections are averaged over a 3-ft distance. Figure 12 shows a screenshot of the Matlab main screen after clicking the "Save and Run" button. Many arrays are generated, as the figure indicates. Under the list of arrays, click "deflection" and copy and paste the array to an Excel spreadsheet, thus creating column A. Click "distance" and copy and paste the array to Excel spreadsheet to create column B. Note that the user needs to create the column headings **0 ft, Deflection,** and **Distance** (see Figure 13).

(4) Return to the "Analysis.m" box and then change "critic(i)=3.0*i+1.0" to move the averaged distance window by 1 ft. Click the "Save and Run" button. As in the previous step, go to the Matlab main screen's list of arrays and click "deflection" and then copy and paste the array to the Excel spreadsheet to create column C. Again, click "distance" and copy and paste the array to the Excel spreadsheet to create column D. Note that the user needs to create the column headings **1 ft, Deflection,** and **Distance** (see Figure 13).

(5) Return to the "Analysis.m" dialogue box and then change "critic(i)=3.0*i+2.0" to move the averaged distance window by another 1 ft. Click the "Save and Run" button. Again, go to the Matlab main screen and click "deflection" and then copy and paste the array to the Excel spreadsheet, creating column E. Click "distance" and copy and paste the array to the Excel spreadsheet, creating column F. Note that the user needs to create the column headings **2 ft, Deflection,** and **Distance** (see Figure 13).

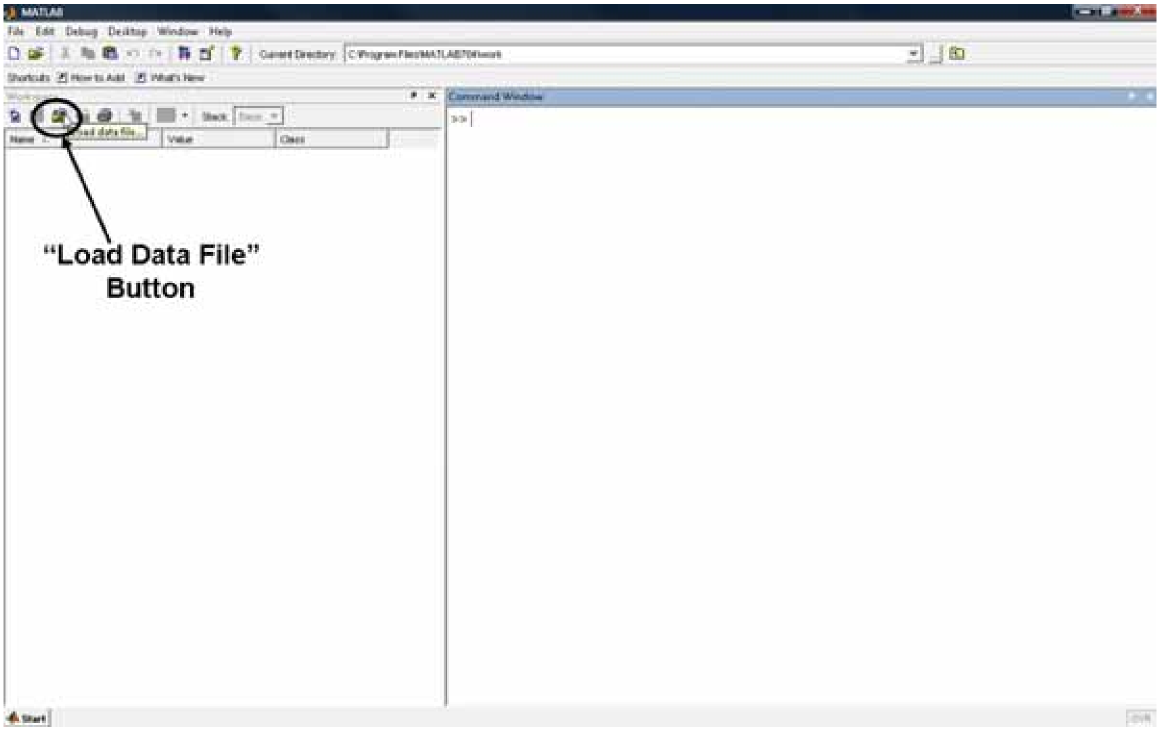


Figure 8: Screenshot of Matlab Importing the "F1.txt" File

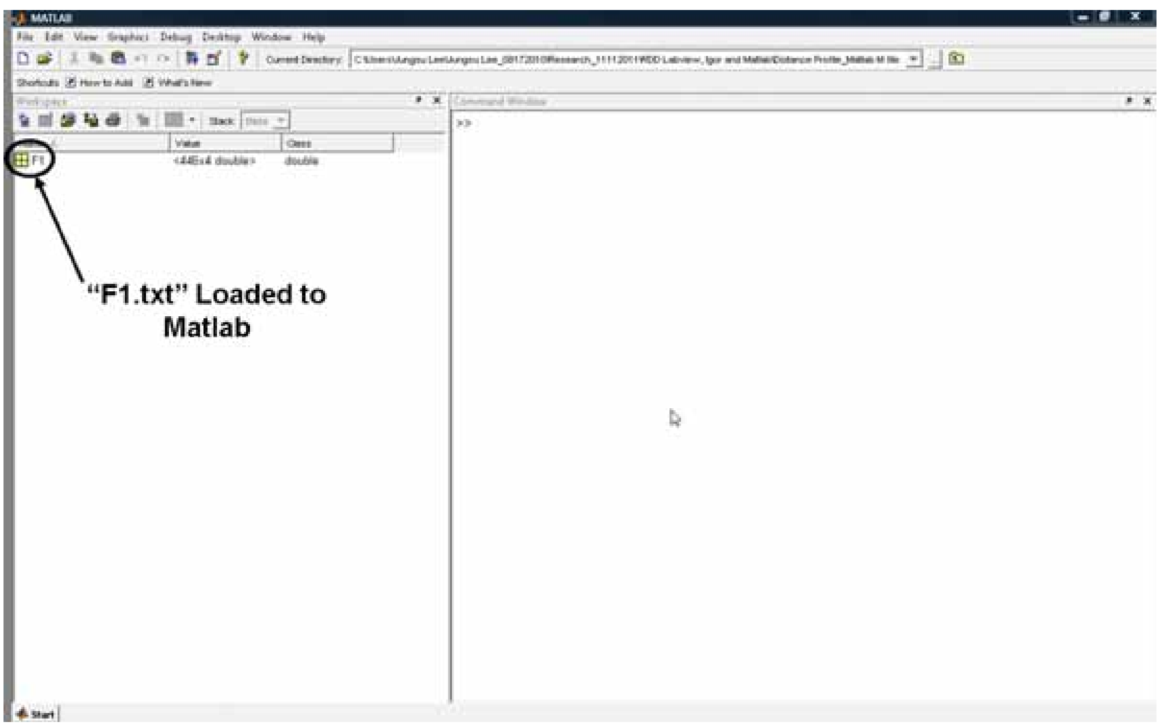


Figure 9: Screenshot of Matlab after Importing the "F1.txt" File

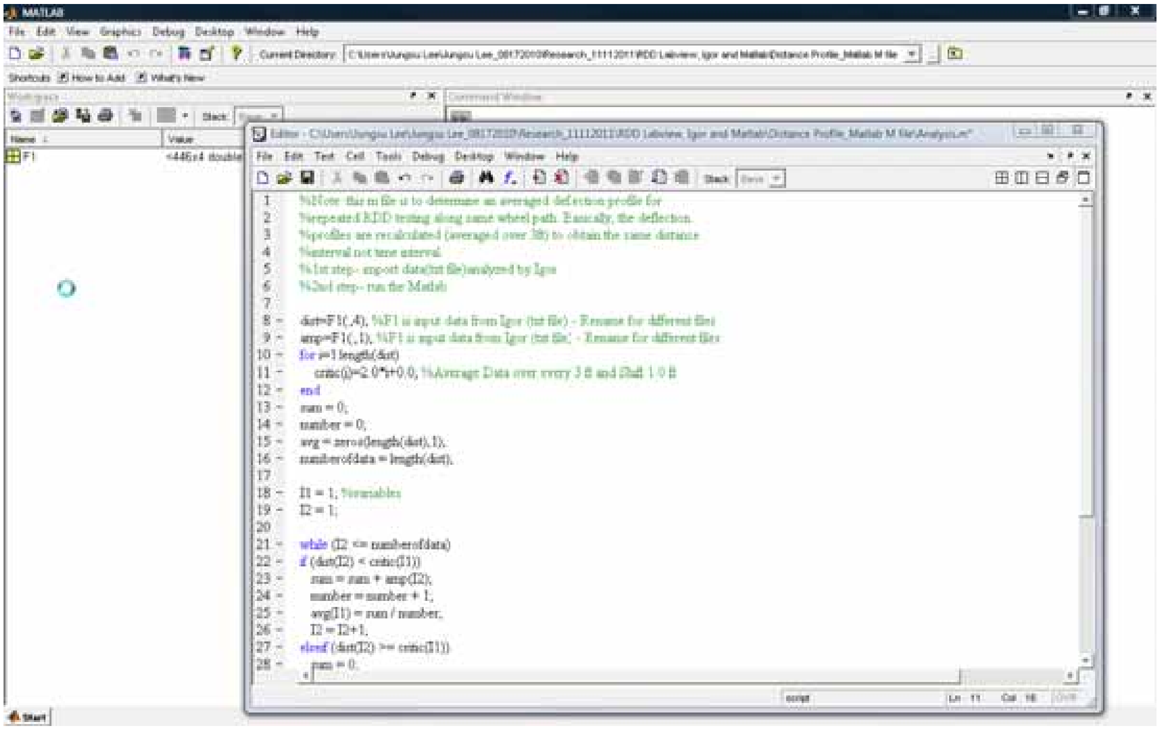

Figure 10: Screenshot of Matlab after Importing the “Analysis.m” File

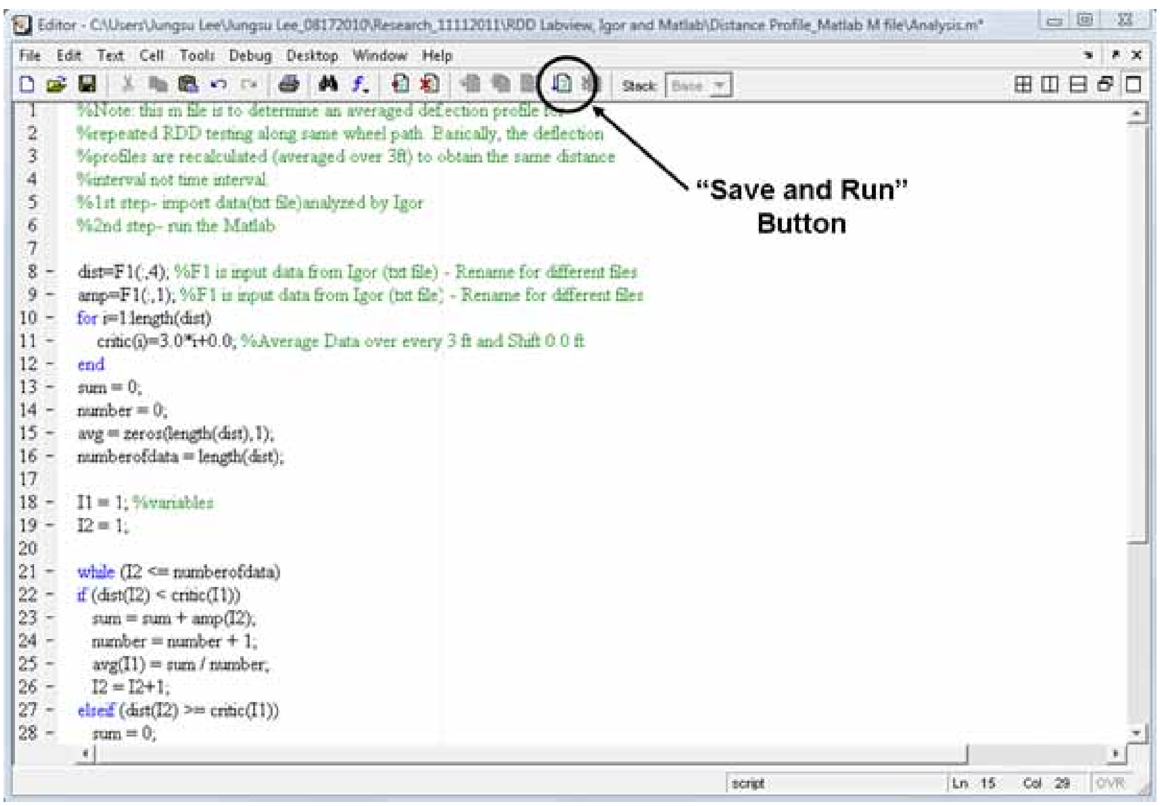


Figure 11: Screenshot of the “Save and Run” Button in the “Analysis.m” Box

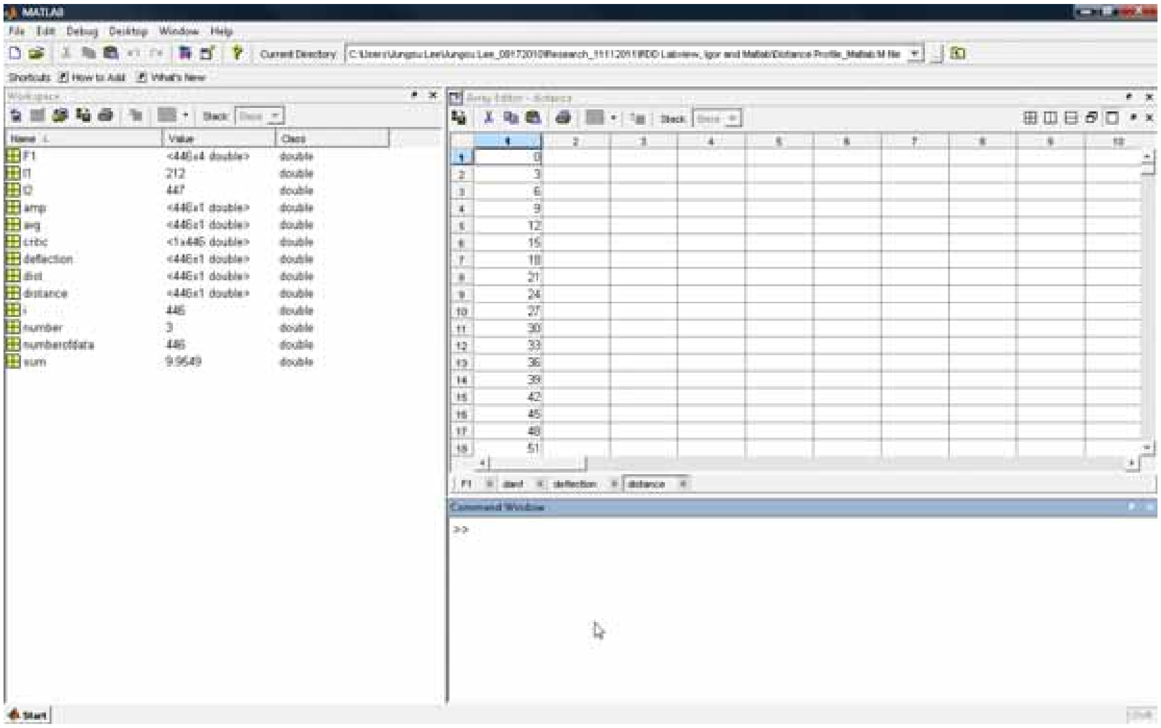


**Figure 12: Screenshot of Matlab after Clicking the "Save and Run" Button**

(6) In the spreadsheet, create two final deflection and distance columns (columns G and H), adding the column headings **All, Deflection,** and **Distance.** Columns G and H will be populated with data from Columns A through F. First, copy the data from Columns A and B and paste under the corresponding headings of G and H. Then copy the data from Columns C and D and paste directly under the pasted data from A and B. Under that, paste data copied from Columns E and F. Lastly, select Columns G and H and sort by the Distance column to arrive at the final distance-based moving average data. The plot can be drawn in the Excel spreadsheet. Figure 13 presents the Excel spreadsheet with one example of a deflection profile.

(7) For a front rolling sensor, type these specifications into the "Analysis.m" box: "dist=F1(:,4)", "amp=F1(:,2)". Then repeat steps (3), (4), (5), and (6). For a rear rolling sensor, type "dist=F1(:,4)", "amp=F1(:,3)" and repeat steps (3), (4), (5), and (6).

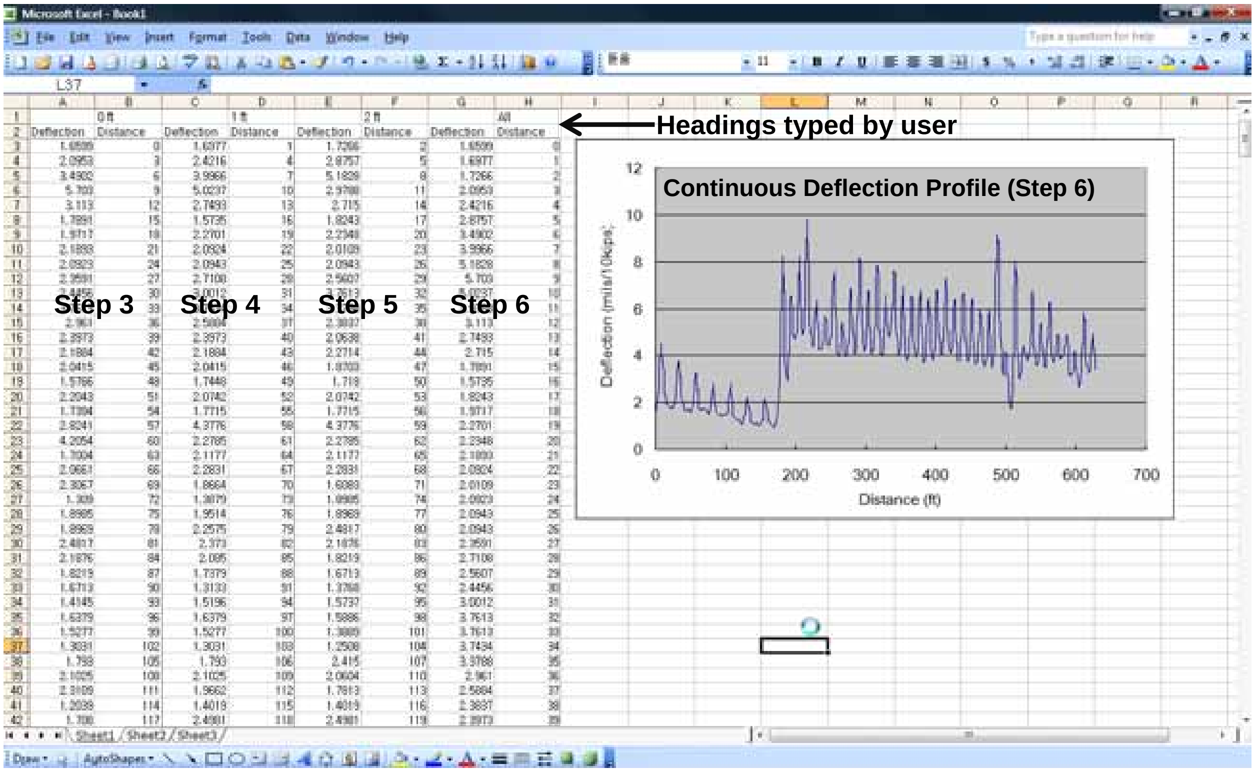


**Figure 13: Excel Spreadsheet after Sorting and Drawing Deflection Profile**

# Reference

Bay, J. A., and Stokoe, II, K. H., (1998), “Development of a Rolling Dynamic Deflectometer for Continuous Deflection Testing of Pavements,” Publication Report No. FHWA/TX-99/1422-3F, FHWA/Texas Department of Transportation, Center for Transportation Research.