TPADANA 2.0: DRAFT USER'S MANUAL OF TPAD DATA ANALYSIS SOFTWARE

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1. SUMMARY

The Total Pavement Acceptance Device (TPAD) is a continuous pavement deflection test device. Since the device is designed for total acceptance of pavements, the researchers have combined the deflection testing with Ground Penetrating Radar (GPR), digital video, and Global Positioning System (GPS) technologies. Texas Department of Transportation (TxDOT) will use the final system for testing both new pavements and those scheduled for rehabilitation.

Since the release of the RDDana 1.0 software about three years ago, Texas A&M Transportation Institute (TTI) made several changes to the original RDDana 1.0 software based on the users' comments. TTI added new features, fixed some small bugs, and made the current software more stable and easier to use. After all these updates, the researchers propose to rename the RDDana software to TPADana, and define this new software as version 2.0. They made the following major updates for TPADana 2.0:

- Previously, the VC++6.0 compiler coded the old RDDana, but the new TPADana is updated to the Microsoft DOT.NET VC2010 compiler.
- The old version can analyze only one sensor but the new software automatically analyzes all three sensors.
- Added a new interface that will select which sensors must be shown on the chart.
- Added a new interface to define a subset of the data.
- On the View Type 1, user can input the detail and sub-detail chart's range.
- Added a new calculation feature of load transfer factor when sensor passing over a joint.
- Added control to show or not show the GPR data on the data view.
- Added functions to show the reference mark or stationary number with DMI (Distance Measuring Instrument).
- Always save the last project to help the user load data quickly.

This user's manual describes the data processing system, and uses the data collected in a 2012 survey of US 287 in the Wichita Falls District. The executable load module for this software and the associated data from US 287 are supplied with this manual.

All the field testing data for the input of the TPADana come from the TPAD's field testing software TPADscan. Before using this manual the user should have sokme basis ideas about the TPAD and the data collection software TPAD scan. The basics are provided below.

TPAD has the following integrated sensors and systems that are related to data acquisition:

- Three rolling geophone sensors for measuring the surface deflection under the rolling dynamic load.
- TPAD's dynamic load signal.
- GPR antenna for identifying layer thickness and identifying defects (such as trapped moisture).
- High-definition network camera to document the condition of the road.
- Distance encoder for the accurate distance measurements.
- Infrared sensor for getting the pavement surface temperature.
- GPS for permanent location of the test site.

The TPADscan software is specially designed and coded to collect and integrate all these data sets. TTI developed this data acquisition software to collect TPAD data; it is run on one laptop computer. After each field test, TPADScan will create the following four files:

- GPR raw data (also has DMI and GPS information); extension name is .DAT.
- RDD raw data (also has Infrared temperature and DMI information); extension name is .RDD.
- Digital video data file (also has DMI data imbedded); extension name is .IMG.
- GPS raw data file (also has DMI on trace number and time data); extension name is .GPS.

The detailed data structure inside each file type is given in the TPAD data acquisition user's manual. As an example, Table 1 lists the file size for the US287 field testing. The basic setting for the test was as follows:

- The deflection data collection rate is 1000Sample/s with four channels of data. Data are collected in the Time mode.
- Video collection rate is user-defined as typically 5 feet per frame; the video resolution is 1280 × 800, collected in distance mode.

- GPR collection rate is one trace per foot, and collected in distance mode.
- Every second, the researchers collect one GPS record and infrared data at the same rate.
- All the GPR and RDD digital resolution results are 16 bits.
- Based on the roughness of the test surface, the researchers normally test by 1.5 mph. For long test sections, however, they normally test at 2.0 mph. For research studies and special cases, TTI can test at 0.5 mph or 1.0 mph; from previous experience, they will obtain better data quality.

Table 1. File Size for the US287 Field Testing.

File Name	Comment	Speed (mph)	Length (miles)	GPR File (kbytes)	Video File (kbytes	RDD File (kbytes)	GPS File (kbytes)
SBTA	SB	2.0	5.0 miles	51,400	491,700	76,000	653
SBTB	SB	2.0	1,000 feet	2,010	22,460	3,175	26
SBTC	SB	3.0	1,000 feet	1,988	22,980	2,069	18
SBTD	SB	4.0	1,000 feet	1,972	23,380	1,614	14
SBTH	SB	1.0	500 feet	968	9,120	4,880	29

The above table and its settings show that the video size is more than 10 times the GPR data file size. For a 2.0-mph running speed, the RDD data file size is around 1.5 times the size of the GPR data.

Since the TPAD geophone data are processed in the frequency domain, the deflection data could not be collected in the distance mode. The TPAD data file size is only dependent on the user-defined sampling rate for collecting data. In contrast, the GPR and video data are collected in the distance mode; the file size is only tied to the tested distance and user-defined trace collection interval.

Table 1 shows that for a 5-mile data set, the file size is big; the one geophone sensors data reveal that there are around 9,267,000 data points. The current data processing software (TPADana) processes and displays the deflection, video, GPS, and temperature data. The GPR data can only be viewed together with other data by using the DMI synchronize technology. Currently the GPR data are processed with the PAVECHECK software, and users can refer to the separate manual of PAVECHECK. Future versions of this software will evaluate the integration of both data sets.

2. INSTALLATION OF TPADANA

SYSTEM REQUIREMENTS

RDDana has been developed for computer systems that meet the following requirements:

- Windows 2000 with Service Pack 3, Windows XP with Service Pack 2, or Windows 7.
- 4.0 GHz Processor.
- 2 GB RAM minimum
- 20 GB free hard drive space.
- 17-inch monitor with at least 1440 × 1024 resolution.

Most of the new computers meet these requirements. TTI researchers have not tested this software with the new Windows 8, but recommend using Windows 7.

Since the TPADana software handles large data sets, the researchers do not recommend that the user will run the software with the data in the external hard drive or USB flash drive. However, if the user prefers a USB 3.0 supported device, the data can be retained in the external device. It is best to load all of the data into a folder on the C drive.

TPADANA SETUP FILES

The following two files are available inside the TPAD setup folder:

- Setup.exe.
- TPADanasetup.msi.

Currently TTI distributes the TPADana setup software by the Windows 32-bit mode. Depending on the installed version of Windows, the installation behavior can be different. TTI recommends contacting Dr. Wenting Liu if installation problems occur.

The Microsoft VS2010 setup and deployment project created these two files. The user can click either of the files to start the installation process; the first screen (see Figure 1) will appear.

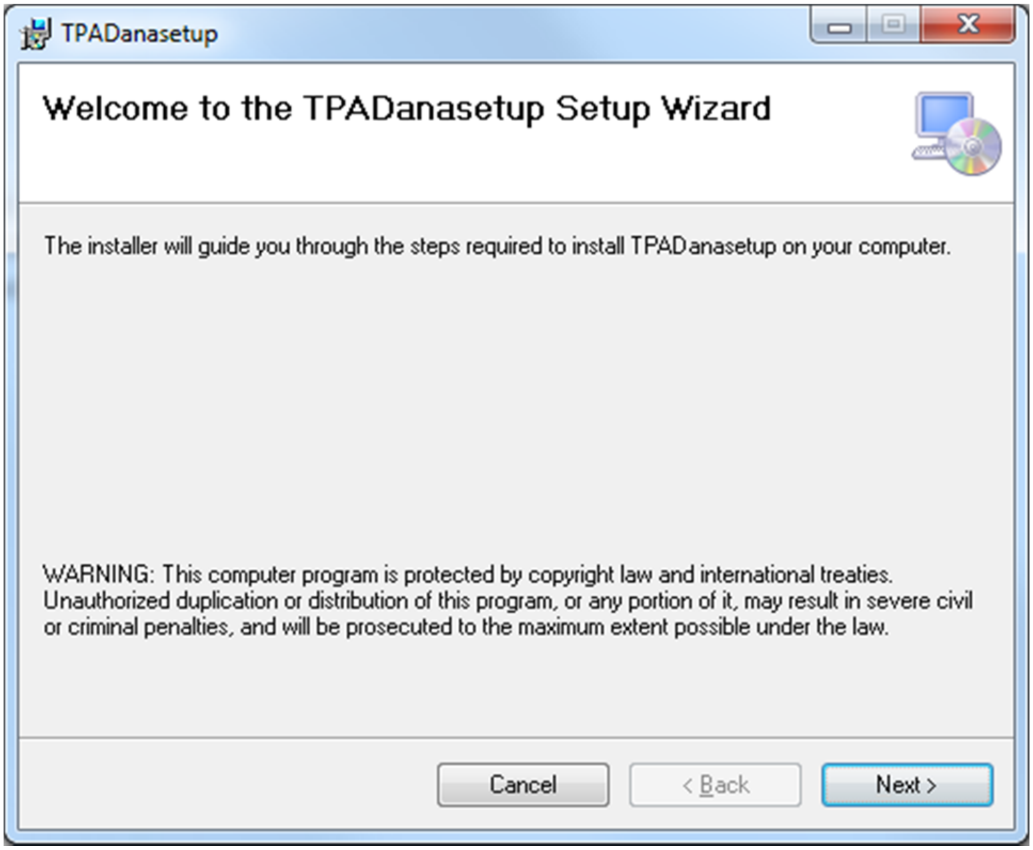


Figure 1. First Screen of the TPADana Setup Wizard.

Clicking the Next> button will bring the user to the next screen (see Figure 2).

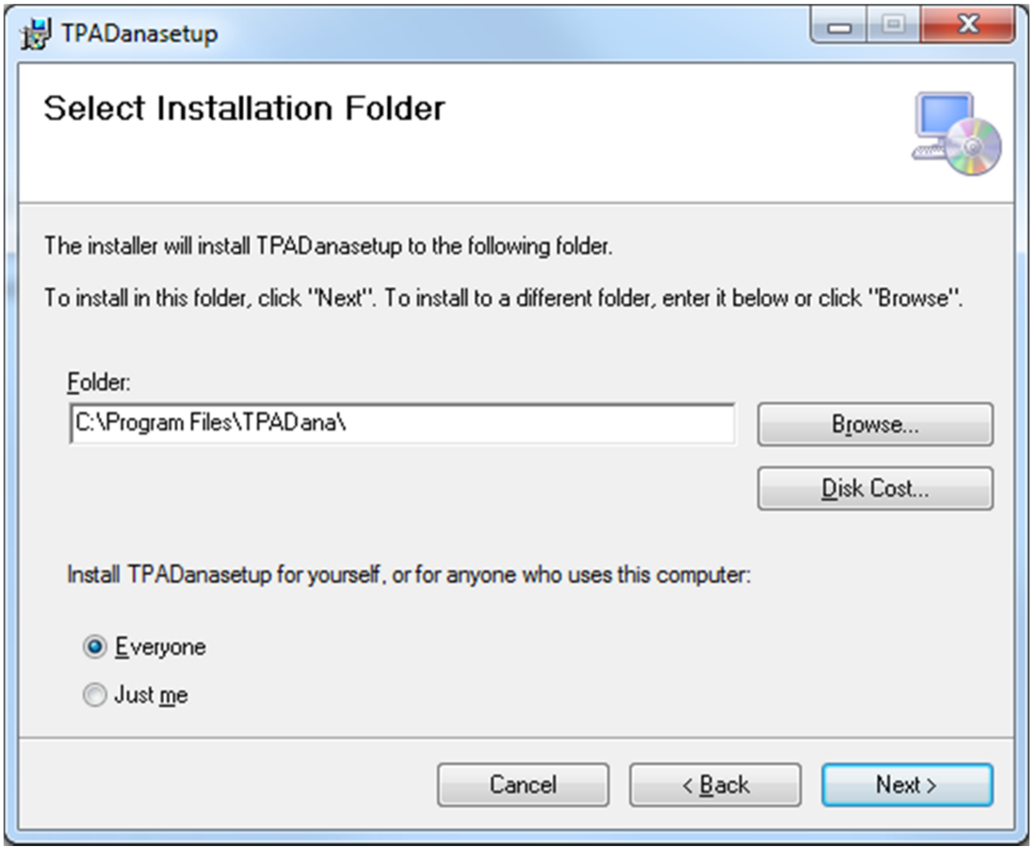


Figure 2. The Second Screen of the TPADana Setup Wizard.

In this step, the user can decide what folder to use for the installation. For the 32-bit Windows 7, the default folder is c:\Program Files\TPADana\; for the 64-bit Windows 7, the default folder is c:\Program Files(32)\TPADana\. Generally, the researchers do not change the default setting.

At the bottom of Figure 2, user can select “Everyone” or “Just me,” depending on who uses the computer. Since most personal computers have only one user, this option is not too important.

To change the installation folder, just click the “Browse…” button and the wizard will lead the user to select the new folder.

Underneath the “Browse…” button, the “Disk Cost…” button when clicked will show the dialogue box shown in Figure 3. This screen shows the computer’s available hard drive memory and size. It also tells the user how large the installation package is. Currently the installation size is 74 MB.

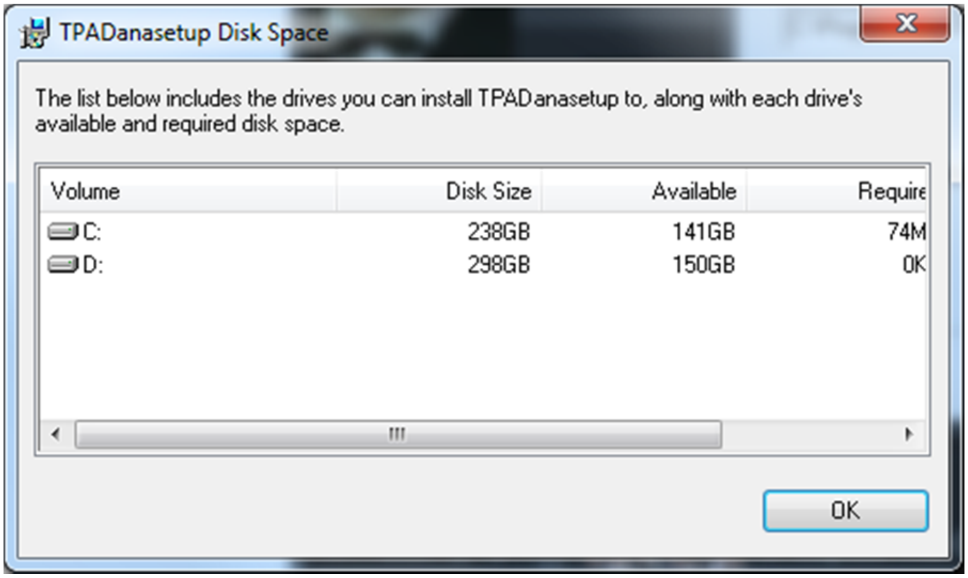


Figure 3. "Disk Cost…" Button Shows the Disk Space.

Figure 4 shows that the user can cancel, go back to change the installation settings, or click the Next> button to start copying the files to the computer.

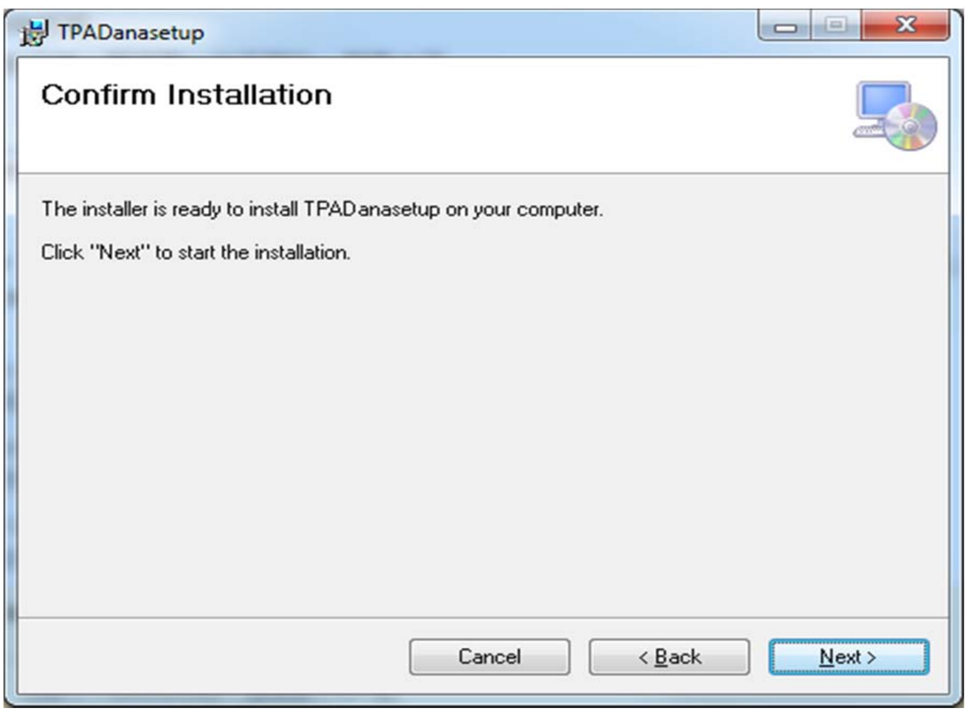


Figure 4. Confirm the Installation of the TPADana to Your Computer.

When the installation is complete, a dialogue box pops up to show that the TPADanasetup package has been successfully installed (see Figure 5). Clicking the "Close" button will close this dialogue box.

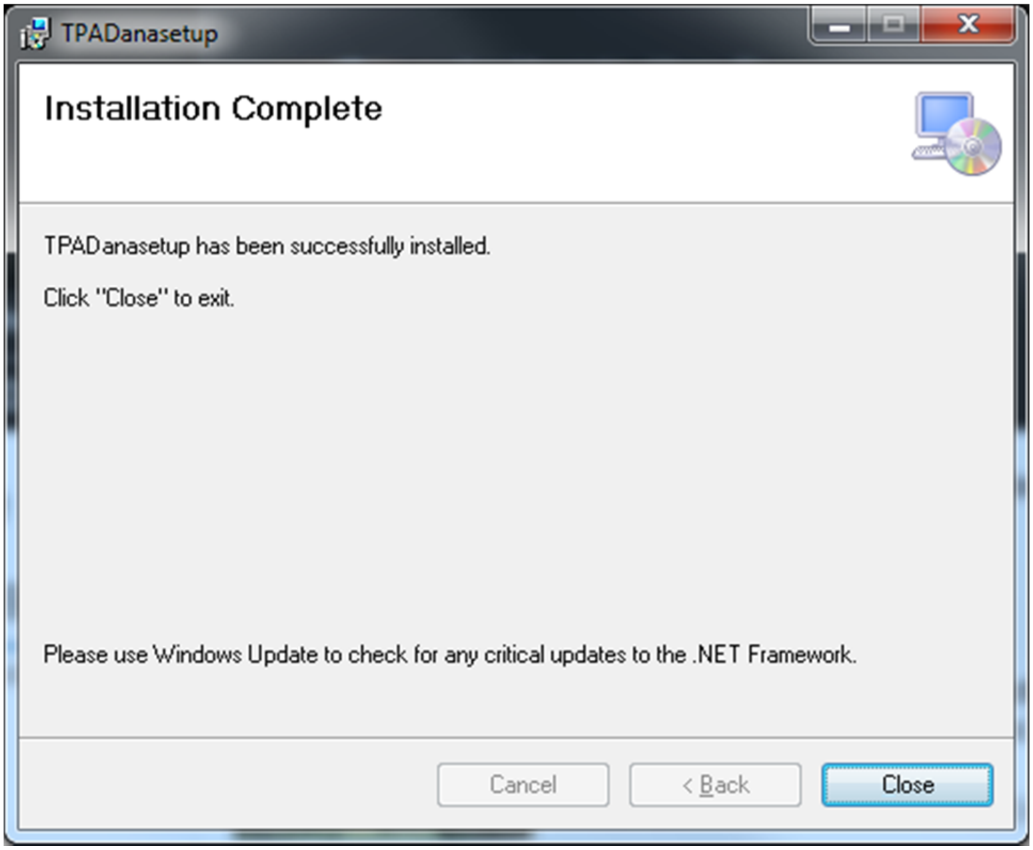


Figure 5. The Last Screen to Inform the User that the Installation Is Successful.

After the installation finished, on the desktop, there is a new icon  for starting the TPADana software. The user can opt to go to the Start menu and select "Start"→"All Programs" to find the program icon (see Figure 6).

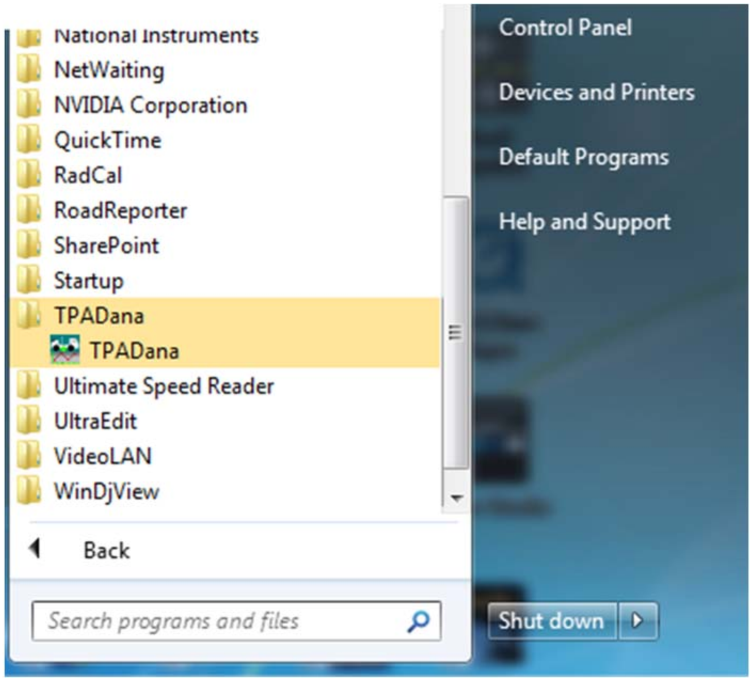


Figure 6. The Program Icon Showing that the TPADana Is Installed.

Since TTI or TxDOT researchers will use this software, their respective information technology departments handle the network administration duties that include oversight of software installation in agency-provided computers. Before installing any new software, the user must get the IT department's permission and clearance to do so.

In the c:\Program files\TPADana folder, the user can find the following installation files (see Figure 7).

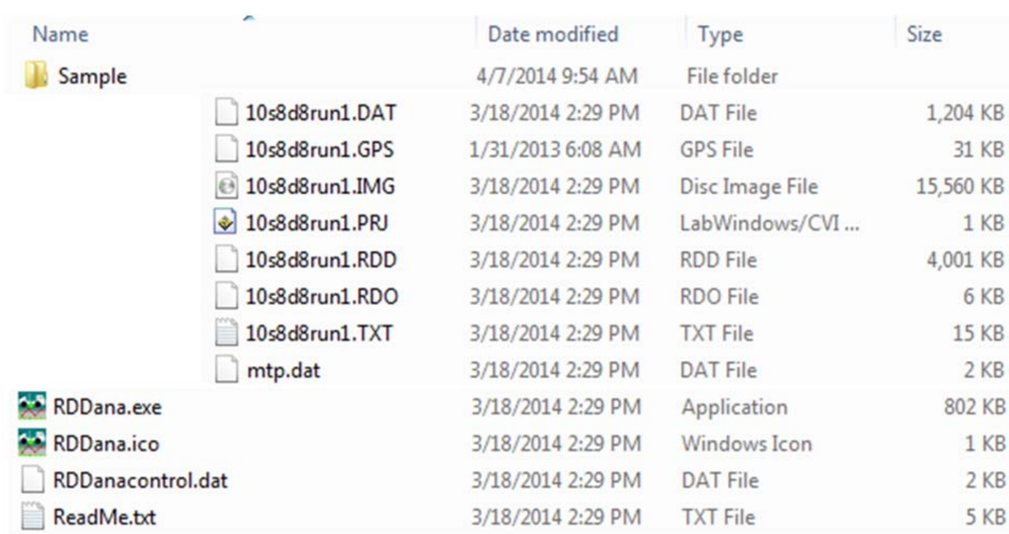


Figure 7. Files List in the Final Installation Folder.

3. RUN TPADANA

After the installation, the installed program icon  will appear on the desktop or in the program folder. Double-click on this icon to start the TPADana program and the first screen (see Figure 8) will appear. Figure 9 shows the main menu screen.

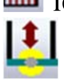
Figure 8. The Main Screen when the TPADana Is First Loaded.

Figure 9. Main Menu Screen of the TPADana Software.

All the functions can be accessed from the toolbar buttons. Table 2 describes the function of each button. To help the user memorize the meaning of each icon, the following list gives the definition of each symbol:

 icon is the symbol for the geophone.

 icon means the raw data.

 icon means dynamic load related items .

Φ icons means the power spectrum of the raw data.

 icon means "together," and shows the raw and filtered data in one chart.

Table 2. Meaning of Each Toolbar Button.

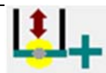
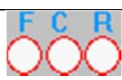
No.	Icons	Functions
1		**Program setup or options (click this button to show the option dialogue box) to set up the basic parameters for running this software**
2		**Loading the analysis file to be processed; this is the first step required to analyze test data**
3		Shows the raw load chart (buttons 9 and 10 are used for turning to other pages).
4		Shows the raw geophone chart
5		Shows the power spectrum chart for each 5000 raw load data points (buttons on #9, #10 are used for turning to other pages)
6		Shows the power spectrum chart for each 5000 raw geophone data points
7		Shows the raw and filtered load chart (buttons #9 and #10 are used for turning to other pages)
8		Shows the raw and filtered geophone chart
9		Turns to previous page for the operations from buttons 3 to 8
10		Turns to next page for the operations from buttons 3 to 8
11		Shows the final analysis result chart (deflection for each 10 kips dynamic loading)
12		**Selects the sensors for each chart, and also defines the length of the detail and sub-detail chart**
13		**Final Result view (Important: this displays the deflection and Video data on a single screen)**
14		Final Results view (similar to above but with different summary graphs)
15		Final Result view (Option–Showing the detail geophone and load signal on a single screen)
16		Final Results view (Option–Showing the detail geophone raw and filtered data on a single screen)
17		Turns to previous segment of data (each maximum segment size is 3,200,000)
18		Turns to next segment of data (each segment size is 3,200,000)

Table 2. Meaning of Each Toolbar Button (Continued).

No.	Icons	Functions
19		Since the data can be view as subsets, click this button to show the full loaded data on the result chart
20		Shows the chart of altitude above sea level, surface temperature, and survey speed vs. DMI
21		Saves the final result to disk for viewing of other software (like Excel®)
22		Changes the TTI format to UT Austin format for UT data analysis.
23		This button exits the program

The critical buttons used on every data processing sequence are those bolded in the above table (buttons 1, 2, 12, and 13). It is critical that the user becomes familiar with their operation.

- Buttons 1 and 2 are used for loading data files and setting the parameters in the analysis.
- Buttons 2 to 8 are used for viewing the raw and filtered data in chart form.
- Buttons 9 and 10 are used with buttons 2 to 8 for scrolling thru the data file.
- Button 11 is used for showing the deflection only. On this interface, user can also select the subset of the loaded data.
- Button 12 is used for selecting the sensors to display and for setting the detail chart's range.
- Buttons 13 to 16 are used for showing the analysis result in different formats.
- Buttons 17 and 18 are used for scrolling between different sections in the data file.
- Button 19 is for showing the full data set.
- Button 20 is used to display data such as temperature, vehicle speed, and elevation data.
- Button 21 is used to save a table of deflection versus DMI data into ASCII format, and Excel can use this data for report generation.
- Button 22 is used to transfer the raw TTI format data to raw UT Austin format. This feature is useful for the UT researchers to analyze the data with their existing software.

In the following section, we will discuss the function of each button in detail.

4. PROGRAM OPTION AND CONFIGURATION BUTTON 

Click Button 1 and the options available to process and display the TPAD data are displayed (see Figure 10).

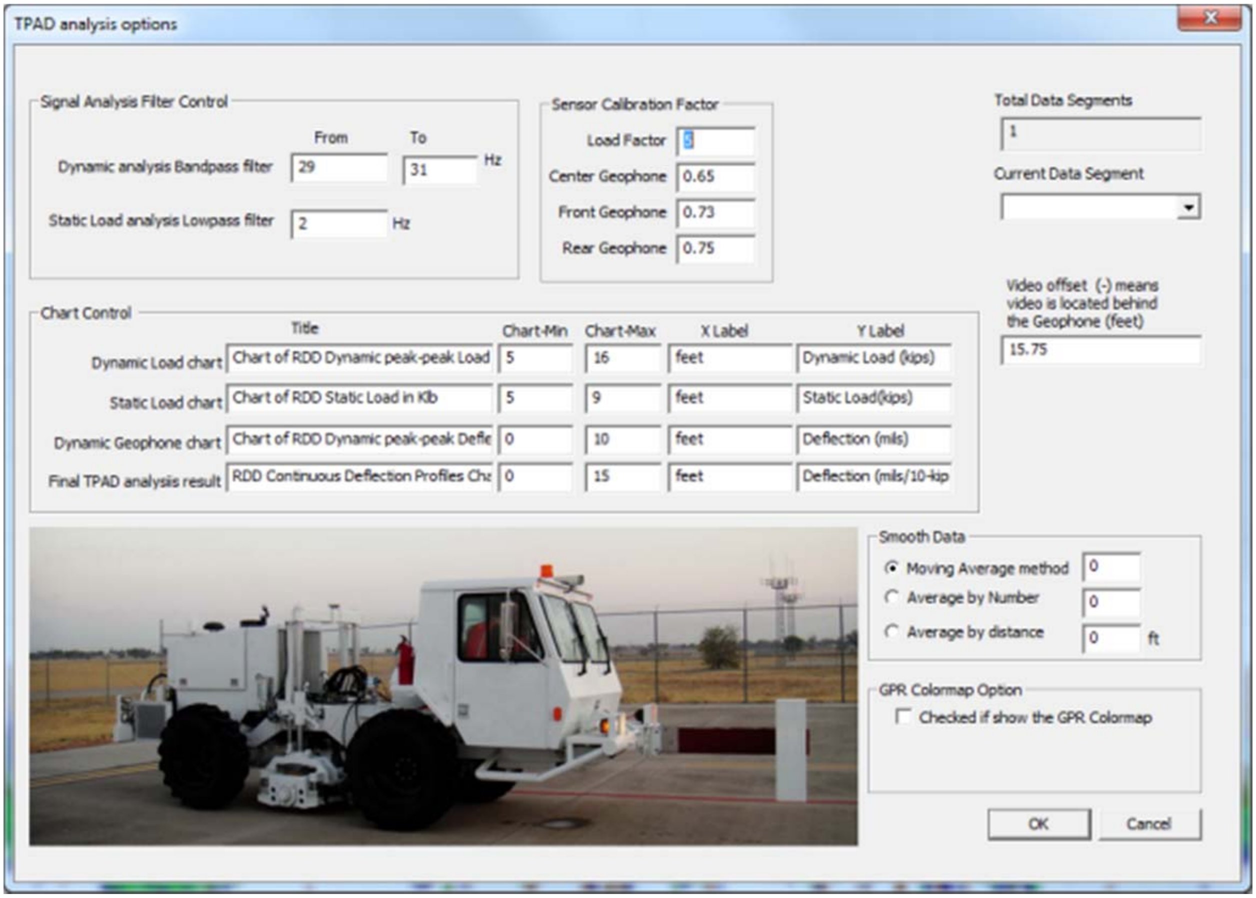


Figure 10. Program Setup or Options Screen.

This software is supplied with a data set collected on US 287, and stored in the folder "TestData" under the name US81SBTB.RDD. This is a short run of just over 1,000 feet in length. Section 5 describes how the raw data are loaded.

The total number of segments in the selected data set is displayed (for the provided short data set, this value is 1) in the upper right dropdown edit box shown in Figure 11. The maximum number of data points that can be displayed in one segment is 3.2 million points, with current TPAD speed and sampling rate that corresponds to roughly 9,000 feet of highway. For long runs such as US 287 in which over 5 miles of data were collected, the data are broken into three segments for viewing.

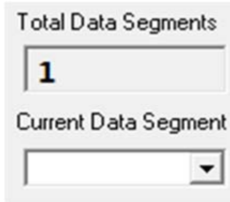


Figure 11. Showing the Total Number and Current Segment Selected.

In the top left dialogue box, the user can input the filter parameters to control how the raw data will be processed using digital software filter. Inside the software, a band-pass filter is used to remove unwanted noise, and to get the geophone and load peak to peak amplitudes.

The TPAD currently operates at a frequency of 30 Hz. To filter the data collected, a band-pass filter range of 29 Hz to 31 Hz is used to remove unwanted components of other frequencies. Only the signals in this frequency range will be accepted for analysis. A 2 Hz low pass filter is recommended for getting the static load. Both filters are set in the Signal Analysis Filter Control box shown in Figure 12. Normally, the user does not change these.

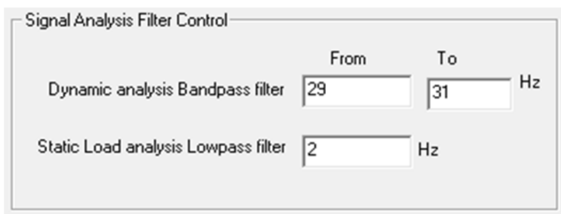


Figure 12. Filter Parameters.

The top middle box in Figure 13 contains the sensor calibration factors. The unit of the load calibration factor is 5.0 kips/V, and the current geophone calibration factors are in V/(in/sec). The units of the geophone calibration factor are tied to velocity; the result is deflection in mils (1/1000 of an inch). The software converts the geophone output into deflection in mils. The UT research team provided these calibration factors. The frequency of calibration needs to be determined, and until the sensors are recalibrated, these factors should not change.

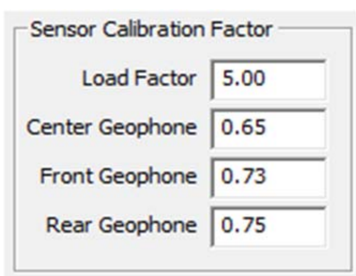


Figure 13. Sensor Selection and Calibration Factor Input Screen.

In the middle right portion of the dialogue box shown in Figure 14, the user is asked to input the offset distance from the loading wheels to the video image. Since the video camera is mounted in front of the TPAD vehicle, the image from the camera does not match the TPAD's deflection test location. The goal is to provide an offset so the user can view the pavement condition at the location of high deflections. At this moment at value of 15.75 feet in input, this is the distance from the center of the load wheels to directly under the GPR antenna, this will be revised at a later date. With this value, the program automatically lines up the GPR and deflection data in the main output screen shown later in Figure 30. The supplied offset is automatically subtracted from the video DMI reading to each display chart. This offset number is user defined. This value also depends on where the camera is installed. A negative value means that the camera is behind the RDD geophone sensors.

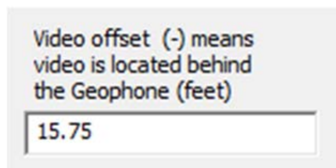


Figure 14. Offset Parameters Input Screen.

The user is provided with three options to smooth the geophone deflection data (see Figure 15). Once selected as shown in Figure 15 the smooth data are plotted as a red line on top of the raw data. When traveling at 2 mph with a data collection system operating at 1000 Hz and a 30 Hz loading frequency, the TPAD collects approximately one deflection point for every 1 inch of travel. Figure 15 provides the user with options to down sample, and smooth these data plots. The down sample data can also be output to Excel for further data analysis and display (Button 21). For the third option here, the software automatically averages the deflection reading within giving distance, and the DMI reading for this section's average is the middle point DMI.

If 0 is input, the software turns off the smooth function and does not generate a smooth data plot.

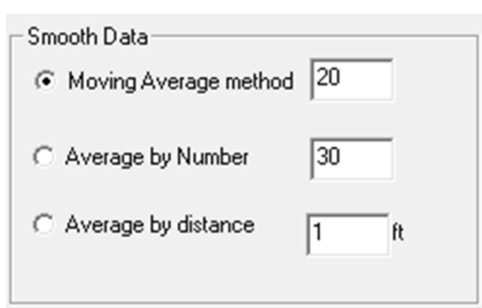


Figure 15. Options to Smooth Raw Deflection Data.

In the middle of the option dialogue box (Figure 16), the user can control the output data charts. Specifically, the user can define the chart title, minimum and maximum values, and the x-y label of each chart.

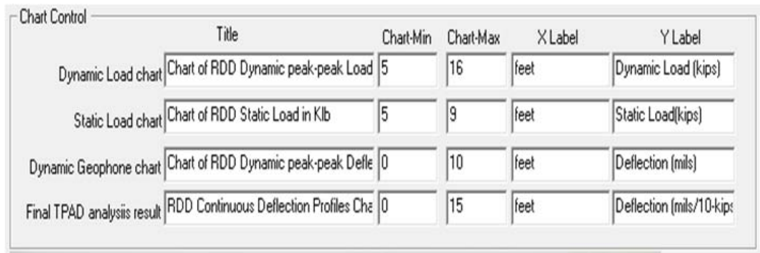


Figure 16. Output Chart Control Parameters.

The bottom line in Figure 16 is the scale applied to the deflection plot; with the current settings, the scale will be set from 0 to 15 mils. Clearly depending on the size of the deflections generated, the user may wish to modify this scale. At the bottom right of the option dialogue box (Figure 17), the user can control the GPR data that will be displayed in the final view mode.

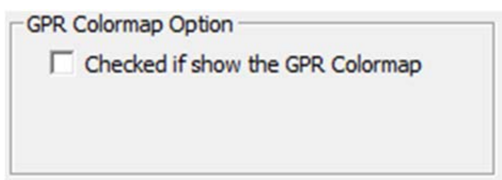


Figure 17. GPR Colormap View Control.

5. LOADING RAW DATA USING BUTTON 2 

LOADING THE RAW DATA FILE

This  button from the main menu is used for loading the TPAD raw test data file collected using the TTI data acquisition system TPADscan. When the user clicks this button, the Open File dialogue box shown in Figure 18 appears.

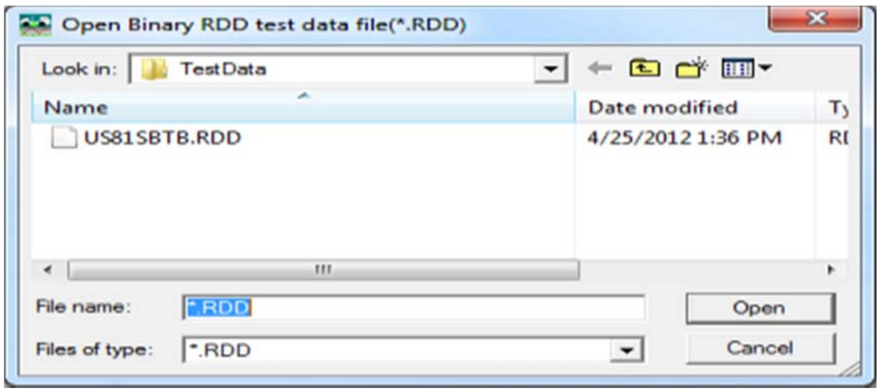
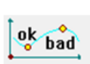


Figure 18. Open File Dialogue Box.

The RAW data files are collected using the TTI data acquisition software. The TPAD field test file is given the extension name of .RDD; this file is in binary format and cannot be edited or viewed with any other software. In the background, the software actually reads four files: the RDD geophone file, the video file, the GPR file, and the GPS file.

After the user selects the raw data file from the dialogue box in Figure 18, then clicks the "OK" button, data processing will begin. The screen shot shown in Figure 19 is automatically displayed as a plot of normalized sensor deflection in mils versus distance in feet. At each location, the geophone displacements and the test loads are computed. The deflections are normalized to the level of 10 kips. At any time during the data processing sequence, the user can return to this initial screen by clicking the  button (Button 11).

At the top left of the chart, showing the legend of the chart, three line colors respectively denote the RDD three sensors (center, front, and rear RDD sensor). In Figure 20, the TPAD geophone sensors' arrangement chart shows that the center sensor is located between two dynamic loading wheels, and other front and rear sensors are located 24 inches from the center sensor.

Based on several years' experience, the measured dynamic loading of TPAD is variable as shown in Figure 21. This load data was collected during testing conducted at the TxDOT freight services facility (FSF) near Austin's main airport with the TPAD running with 0.5 mph. In this test, the researchers set the dynamic load at 10 kips peak to peak, but the tested dynamic load's variance is around 3 kips.

In the software, all of the deflection results are normalized to 10 kips dynamic loading. From Figure 19, on the top left corner, the Y-axle is marked as "Deflection (mils/10 kips)." In this figure, the smoothed center sensor's curve is shown in red. This option can be turned off, as previously mentioned.

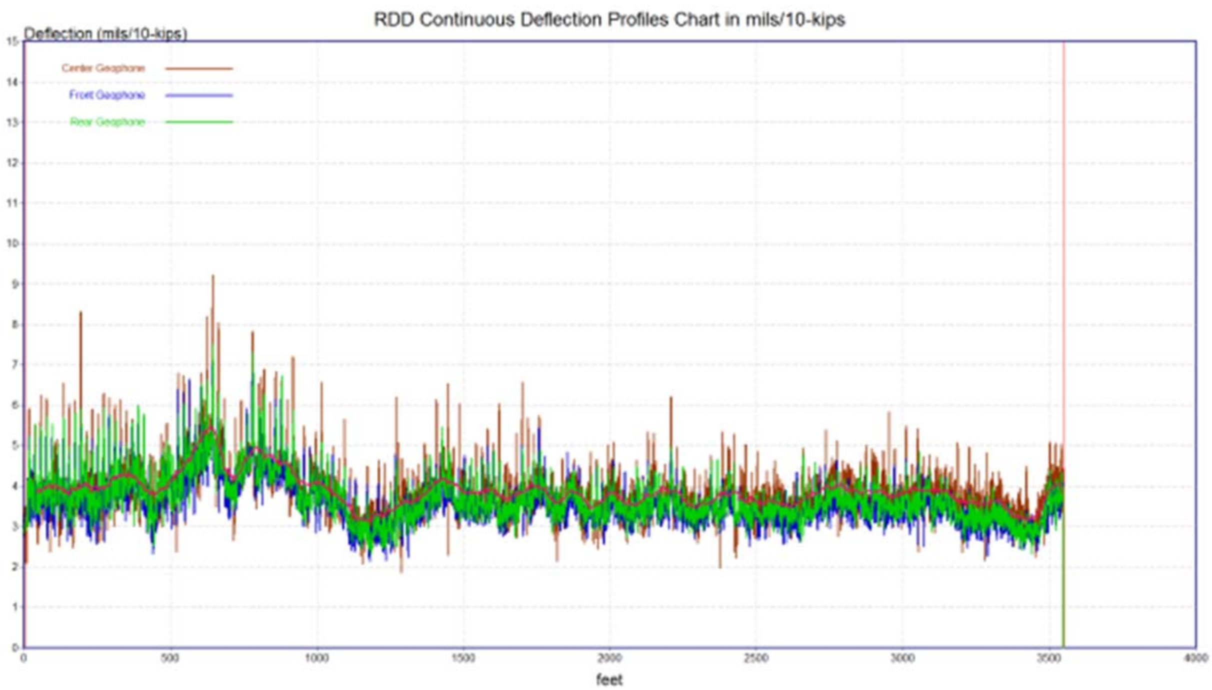


Figure 19. Plot of Raw Data (Blue Line) and Filtered Data Using the Options Selected in Figure 15.

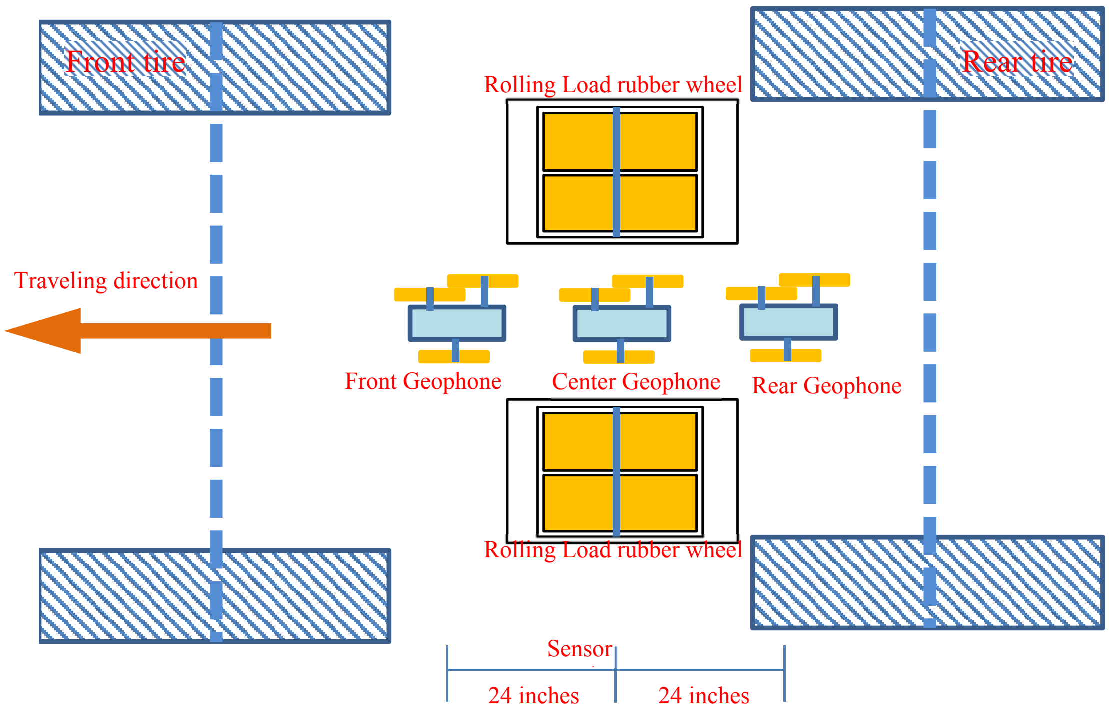


Figure 20. Illustration of TPAD Sensors Arrangement.

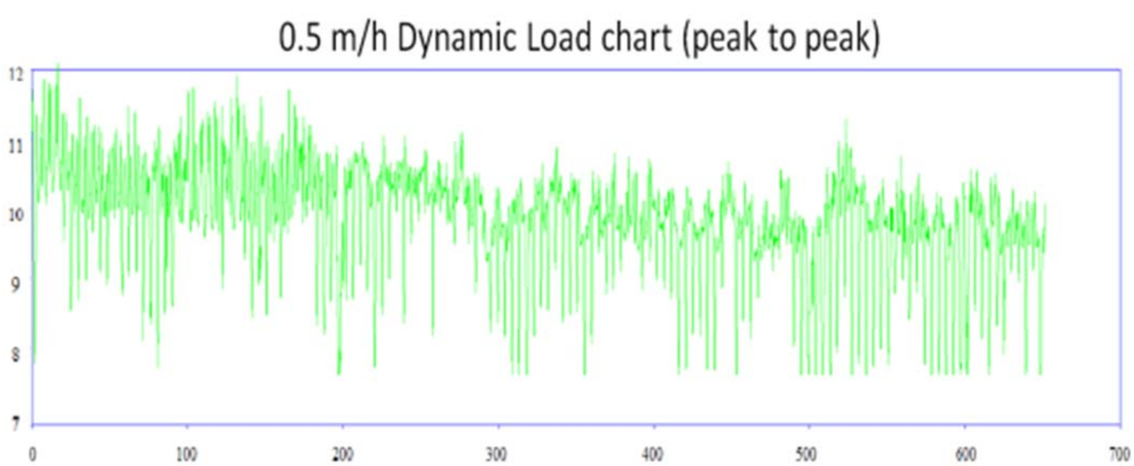
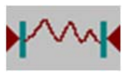


Figure 21. Dynamic Load for 0.5 Mph Running Speed Tested at Airport.

DEFINE THE SUBSECTION

When the data are first loaded, the entire data set is displayed. The user can define the subsection by using Ctrl + first mouse click on the chart to define the left limit, and Ctrl + second mouse click to define the ending limit. Figure 22 demonstrates the use of this function. After the user clicks on the chart and defines the limit, the chart's title as well as the bottom left and right will update the new subsection information. If the user is not satisfied with the selected subsection, he/she can redo it.

On the main toolbar, the button  will automatically reset the subsection back to the full section of data.

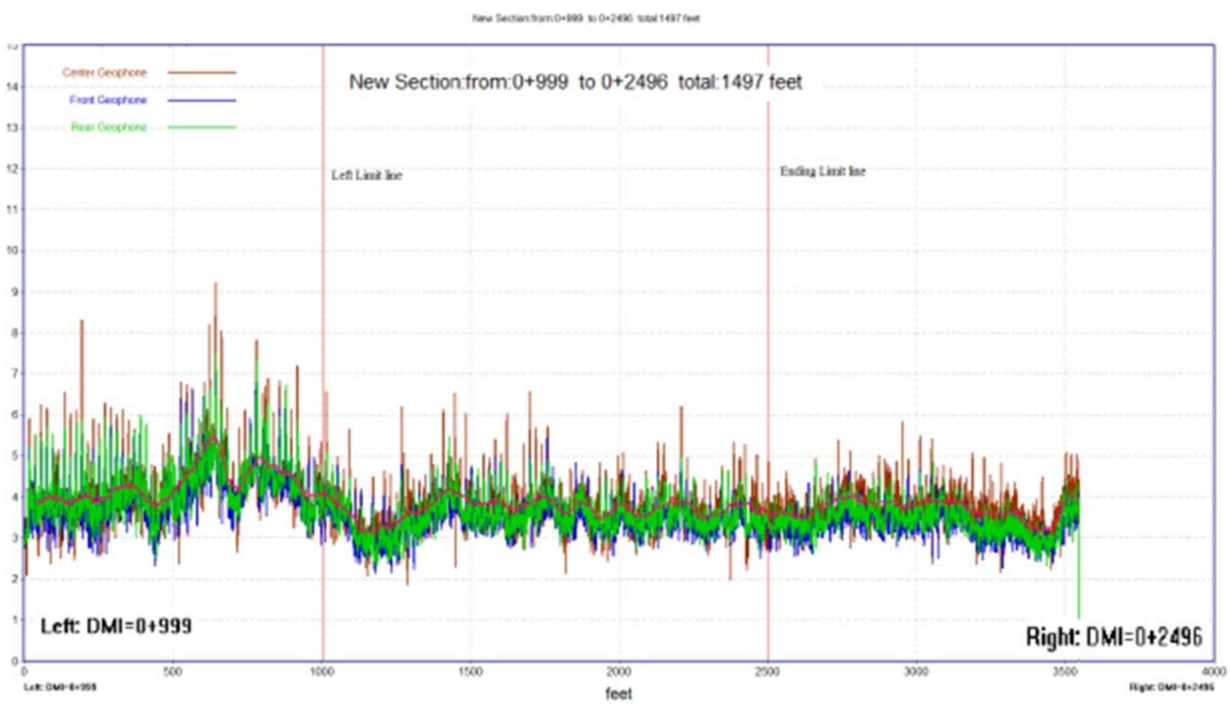


Figure 22. User Defines the Subsection.

DEFINE THE SENSORS TO BE DISPLAYED ON EACH DEFLECTION PLOT 

As in Figure 19, all three sensors are displayed on the chart. However, the user can select the sensor that should be shown on the chart using the button  (Button 12 in Table 2). When the user clicks this button, the View Control dialogue box will show up (see Figure 23) for selecting the sensors for each chart, and for defining the length of the detail and sub-detail chart.

On the left part of the dialogue box, the user can select the sensor that will be shown on the final deflection charts. In the middle part, the user can select the sensor for the detail and sub-detail chart (these are the two addition plots shown at the lower right of the main display plot shown in Figure 30, described later). The radio button is for selecting the sensor that will be used for the concrete pavement joint transfer efficiency calculation. In general, the user selects the rear sensor for the joint transfer calculating. At the bottom of the dialogue box, the user can also select the file name for saving the calculation result.

At the right side of the dialogue box, the user can define the length of the detail and sub-detail chart in the data view section.

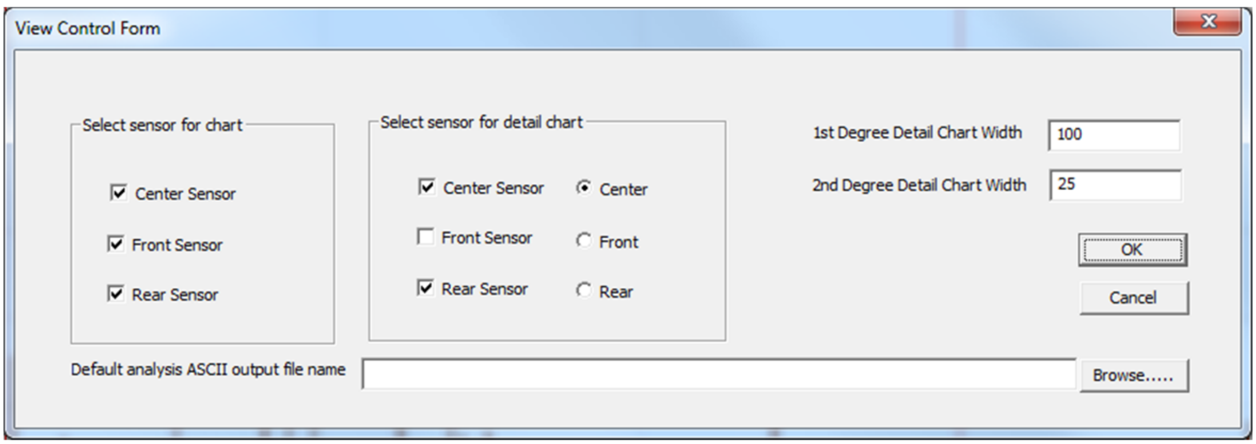
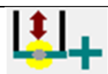


Figure 23. View Control Dialogue Box.

6. VIEWING THE RAW AND FILTERED DATA

This section will cover the information on how to view the raw and filtered data using the following buttons from Table 2.

Table 3.Key buttons for Filtering TPAD data (extracted from Table 2) .

No.	Icons	Functions
3		Shows the raw load chart (buttons 9 and 10 are used for turning to other pages)
4		Shows the raw geophone chart
5		Shows the power spectrum chart for each 5000 raw load data points (buttons 9 and 10 are used for turning to other pages)
6		Shows the power spectrum chart for each 5000 raw geophone data points
7		Shows the raw and filtered load chart (button on #9,10 are used for turning to other pages)
8		Shows the raw and filtered geophone chart
9		Turns to previous page for the operations from buttons 3–8
10		Turns to next page for the operations from buttons 3–8

BUTTON FOR SHOWING THE RAW LOAD CHART 

When the user clicks the  button, the raw data are loaded. The user then selects the  button, and the raw load data chart shown in Figure 24 is displayed. On the top left corner, the information shows the data point range displayed on this screen. The buttons  and  can be used to turn to other pages. This chart shows the raw load signal versus the DMI in feet. This is the beginning of the data file; the TPAD is not moving. All the DMI values in Figure 24 are zero and the load signal is a perfect sine wave. When turn to other pages using the  button Figure 25 is displayed, then the change in the load signal with time is shown and the DMI is no longer zero.

 # 3 Button from Table 3 will show the raw load data (Figure 24).

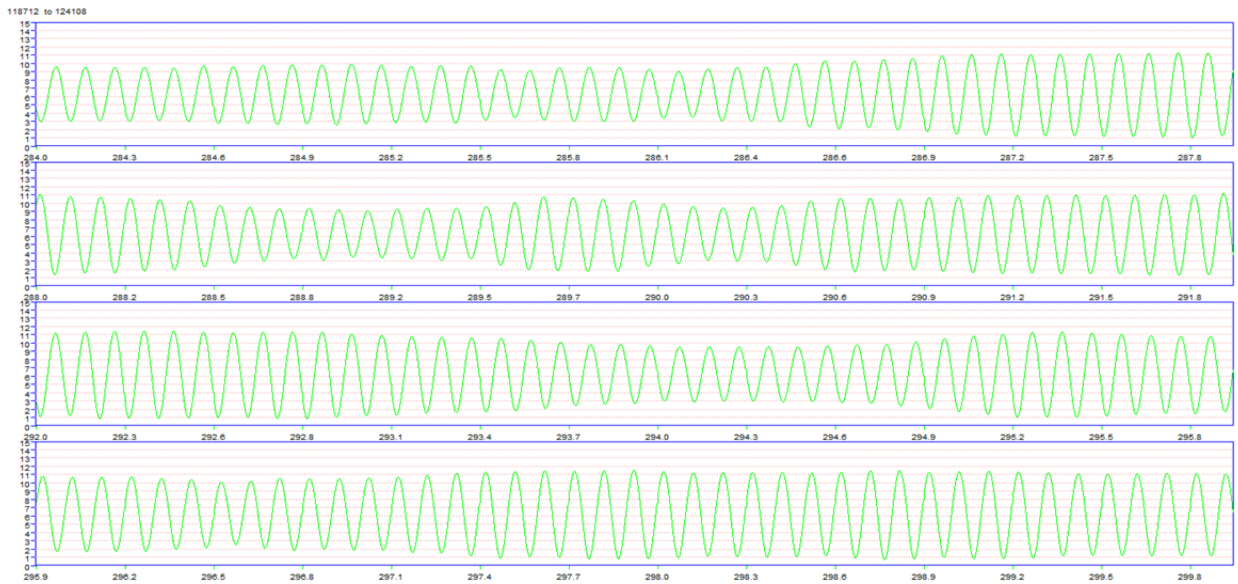


Figure 24. Raw Load Data Chart (DMI vs. Load in Kip).

 #4 button from Table 3 will show the raw geophone data (Figure 25). The geophone data are rougher than the load signal.

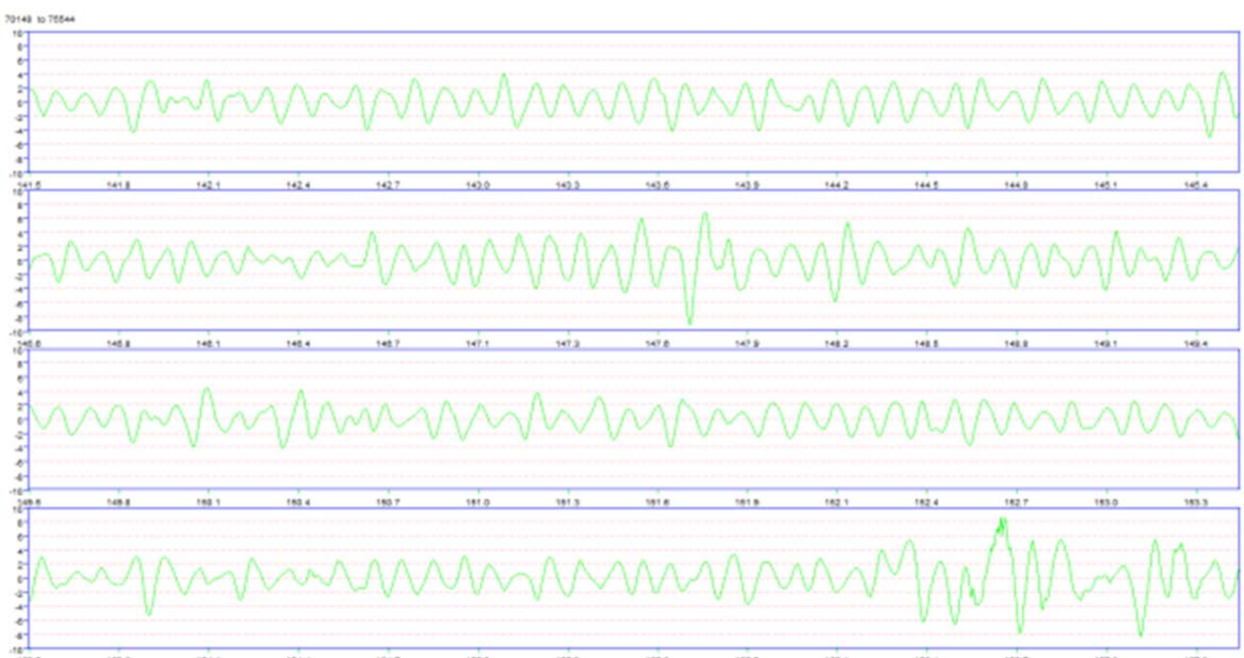


Figure 25. Raw Geophone Data Chart (Y-Axis in Mils, X-Axis in Feet).

#5 button from Table 3 will show the power spectrum chart of raw load data (Figure 26).

The power spectral density (PSD) describes how the power of a signal or time series is distributed with frequency. It is a method for defining the noise-to-signal ratio where the value at 30 Hz (the input loading frequency) should be significantly different from that observed at other frequencies (background noise). The power spectrum shows the strength of the variations (energy) as a function of frequency. It shows at which frequencies the variations are strong, and at which frequencies the variations are weak. The unit of PSD is energy per frequency (width), and it is possible to obtain energy within a specific frequency range by integrating PSD within that frequency range. Computation of PSD is done directly using the method called Fast Fourier Transform or computing autocorrelation function and then transforming it.

When the user clicks the button , the PSD chart of raw load time series will show on the screen (see Figure 26). The analysis is currently performed on each 5000 data points (this segmenting option is currently under review). Figure 26 shows the data point from 65,000 to 70,000 (accordingly, the DMI is from 126.49 feet to 141.09 feet). The chart's Y-axis is in log10 unit, and the X-axis is in frequency. This chart shows the dynamic load frequency is exactly 30 Hz.

Buttons and can be used to turn to other pages. Each page covers 5000 data points.

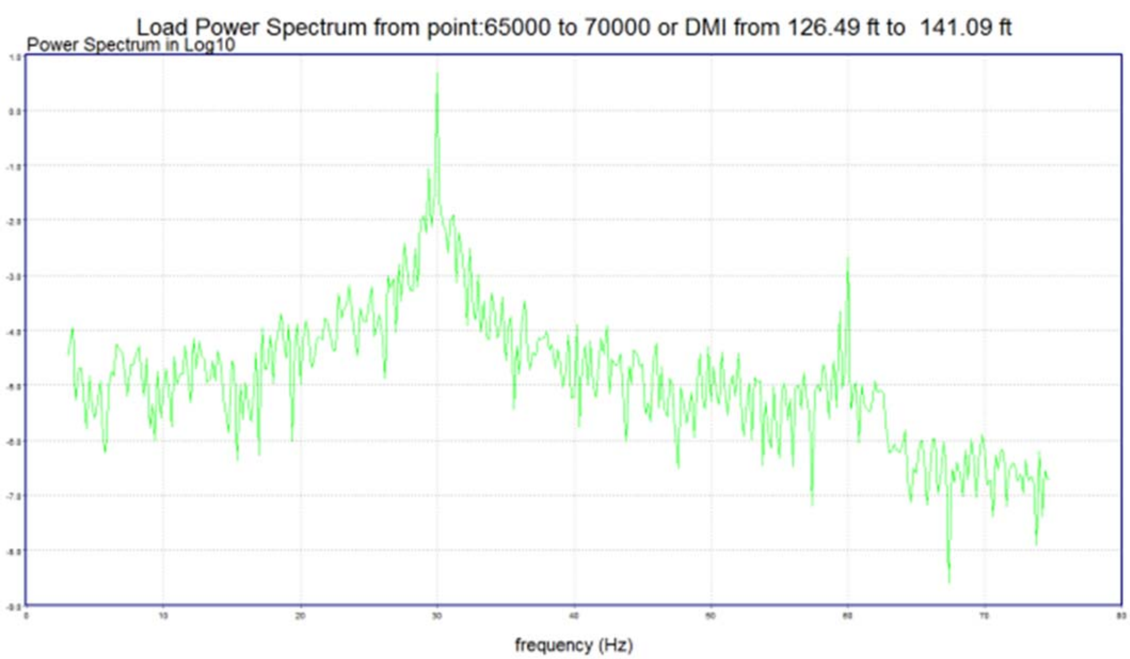


Figure 26. Power Spectrum Chart of Raw Load Signal.

 #6 button from Table 3 will show the power spectrum chart of raw geophone data (Figure 27).

Similar to Figure 26, the  button is used for showing the geophone's Power Spectrum chart as in Figure 27. We can see the geophone power spectrum is more noise than the load (Figure 26).

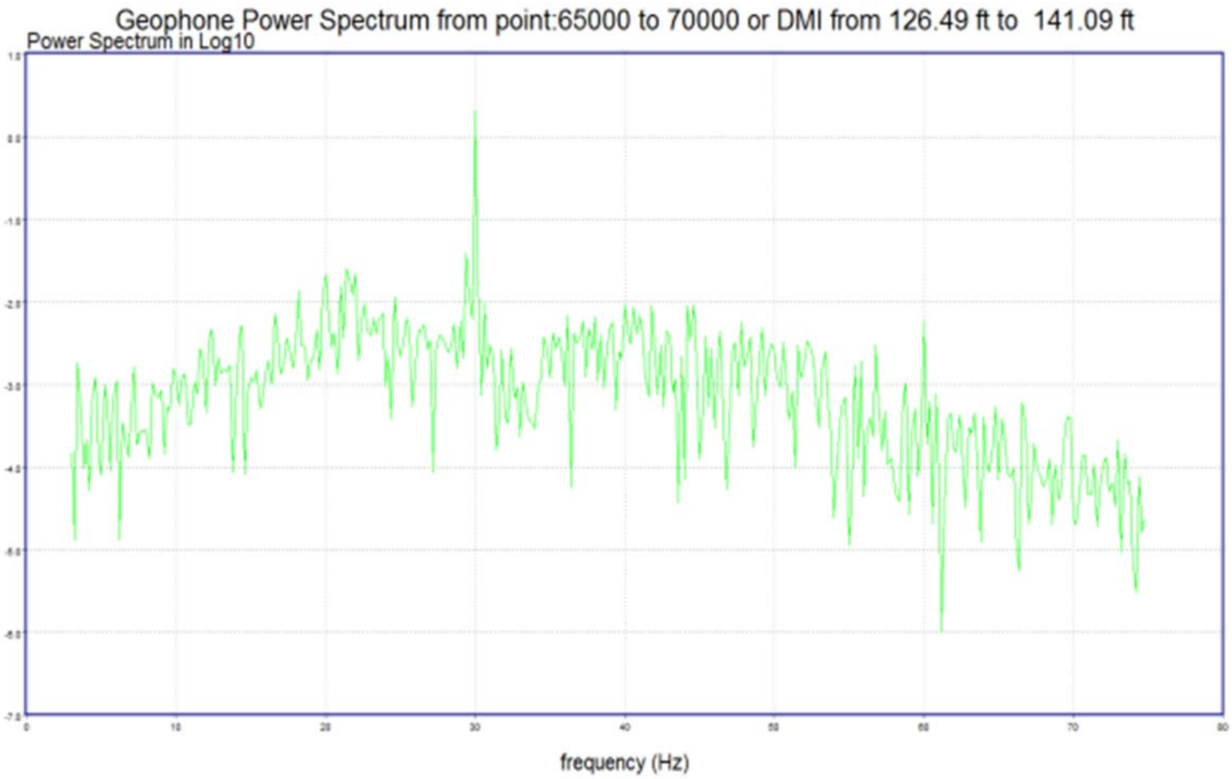
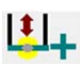


Figure 27. Power Spectrum Chart of Raw Geophone Signal.

 #7 button from Table 3 will show the raw and filtered load data (Figure 28).

This button's operation is very similar with the  button as in Figure 24, except that when clicking this button, the chart will show the raw and filtered data together in one chart as in Figure 28. Note that filtered data are blue while the raw load data are green. Since the researchers used the 29~31 Hz band filter, the static load component is removed, and the filtered data vibrate around the zero. On the filtered load signal, the red dot specifies the peak location that will be used to calculate the final deflection result.

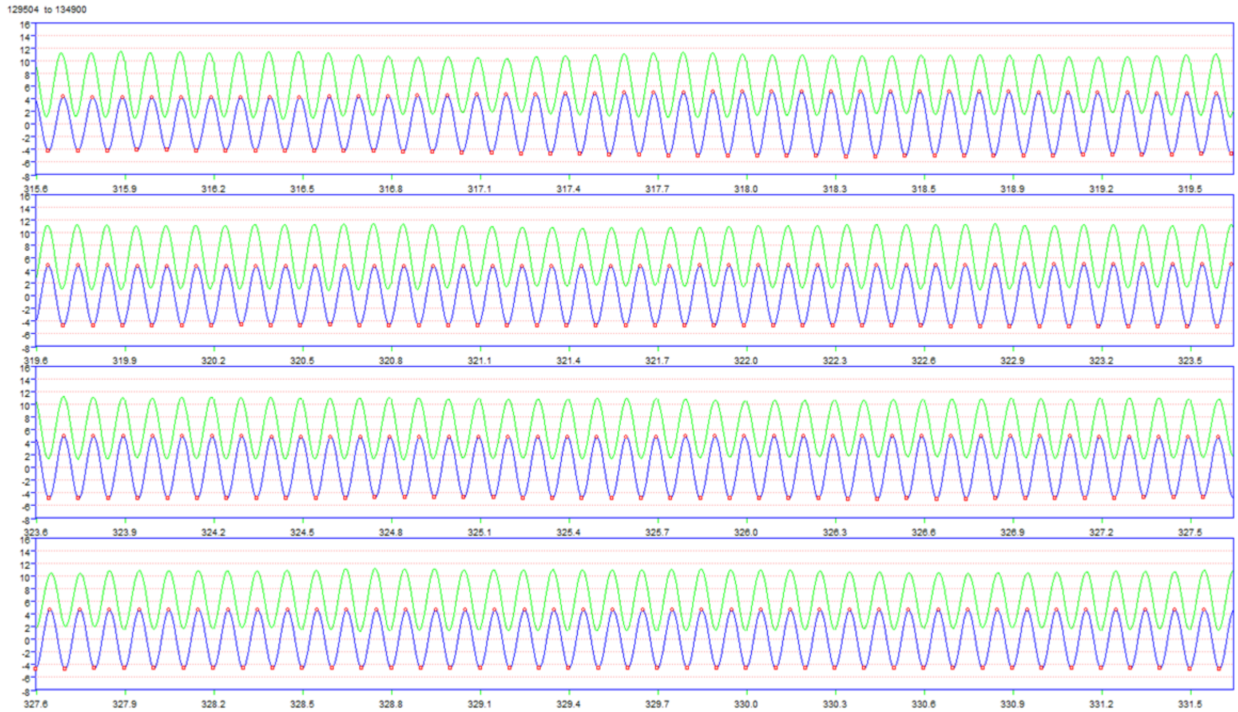


Figure 28. Chart of Raw and Filtered Load Data.

 #7 button from Table 3 will show the raw and filtered geophone data (Figure 29).

This button's operation is very similar with button  as in Figure 28, except that this button is used for showing the chart of the geophone's raw and filtered data (see Figure 29).

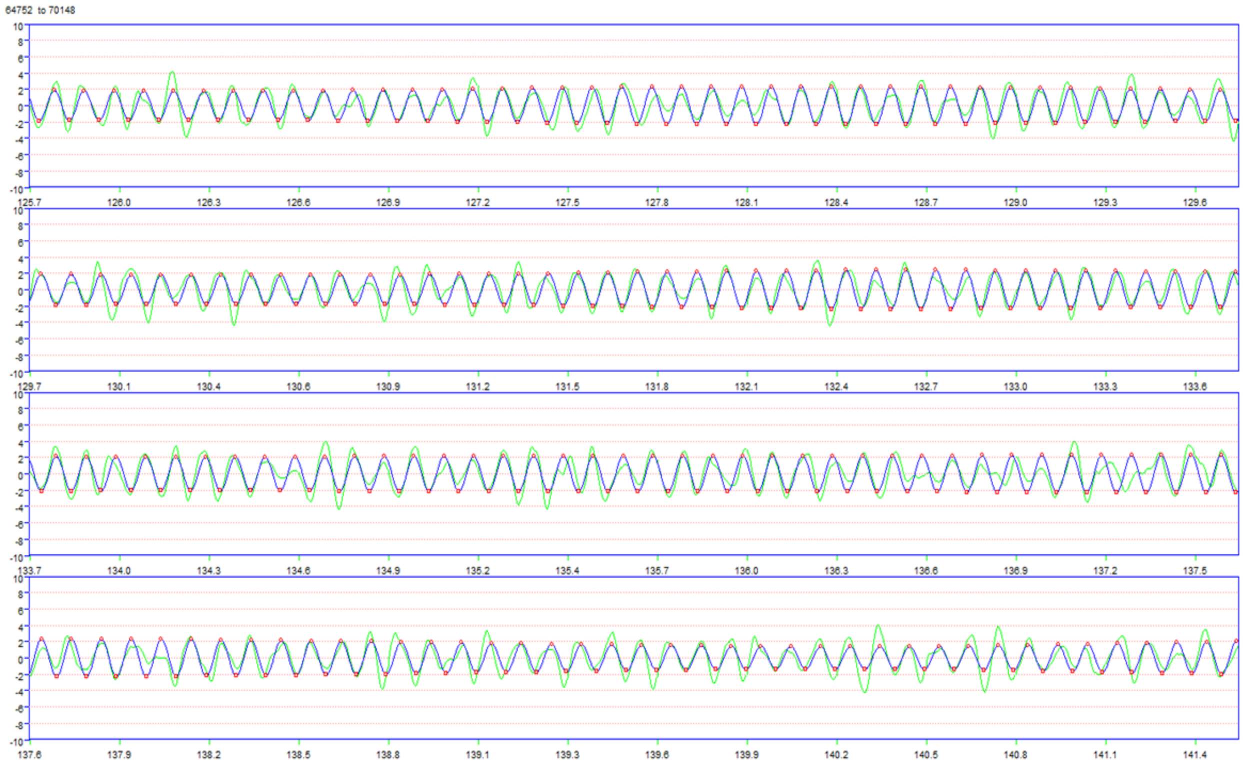


Figure 29. Chart of Raw and Filtered Geophone Data.

7. FOUR DATA VIEWING FORMATS

COMBINED FINAL RESULT VIEW TYPE-1 

After the data are loaded as in Chapter 5, the user clicks on  and the combined final results screen shown in Figure 30 will be displayed. The top part of this screen shows the final deflection result as in Figure 19; on the upper right side, the user can find the GPS, DMI, and the deflection value in mils when moving the mouse inside the chart. On the bottom left side of the screen, the video frame shows the video with the DMI value on the left bottom corner in miles and feet.

This view of the data is potentially the most useful to the user. Once the mouse is clicked in the top graph, two lower graphs are generated. The upper graph shows the first grade detail deflection plot, where the total length of data is 50 feet (25 feet on either side of the selected location). The lower graph shows a zoomed-in option on this graph, where the length is covered with a deflection plot of approximately 10 feet (5 feet on either side of the selected locationFigure 23 is used to change the length of section displayed in this plot.In the middle of Figure 30, a GPR colormap view is synchronized with the RDD data. Both the RDD and GPR colormap’s vertical red lines show the same DMI (at the same location); the current video frame also has the same DMI as the others.

. In Figure 17 the user is given to display or remove the GPR from the main display, Figure 30 shows the display with the GPR button checked, with no GPR activated Figure 31 is displayed.

Figure 30. The Combined Final Result View Screen Mode-1 (with GPR).

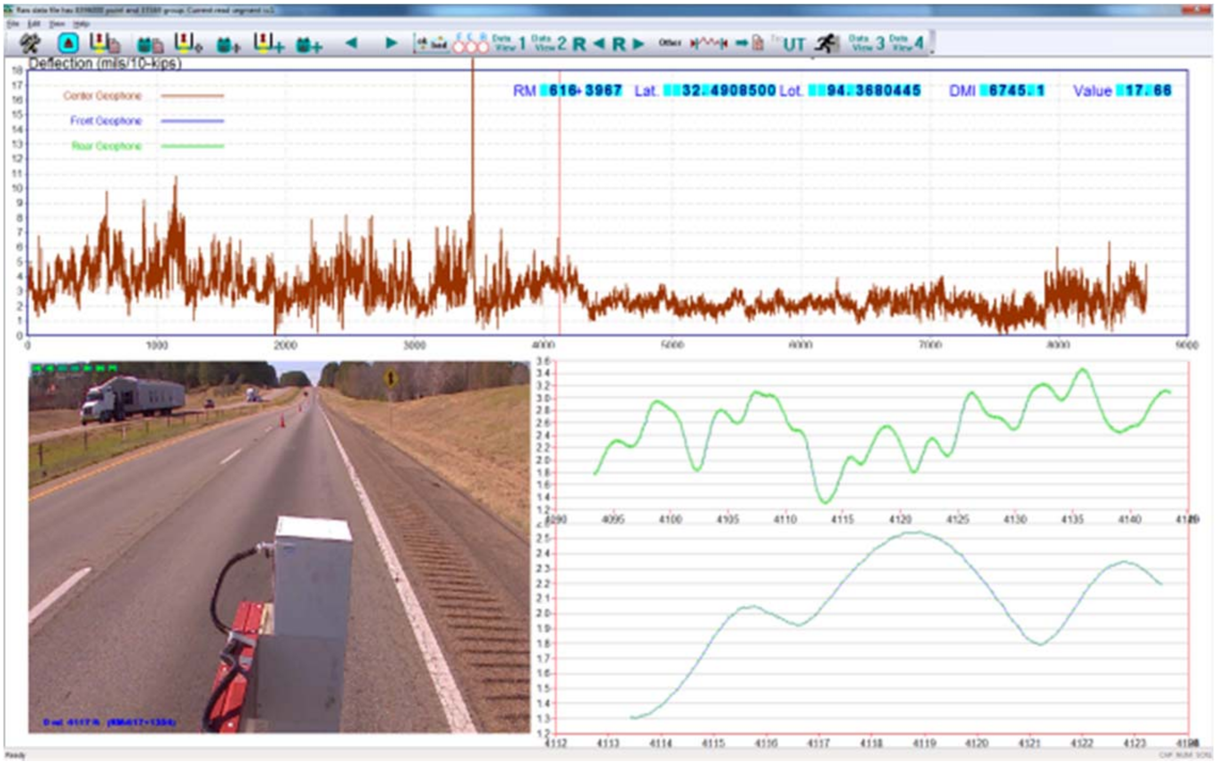


Figure 31. The Combined Final Result View Screen Mode-1 (without GPR).

If the user moves to any of these three charts, the DMI value and the "Value" field will show the deflection value of the mouse location.

The overlap buttons on the video frame can be used to control the Play mode of the video. The functions of all buttons are listed below:

 Go to the first frame of video

 Play the video backwards

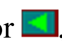
 Go to previous video frame

 Go to next video frame

 Play the video forward

 Go to the last frame of video

 Save the current frame to JPEG image file

When the user plays the video by using button  or , the vertical red line showing the current location on the result chart also moves together with the video.

The most useful keyboard commands are the Z and X keys. The Z key will run backward while the X key will run forward.

COMBINED FINAL RESULT VIEW TYPE-2

In Figure 32, the data view shows the deflection plot in the upper part of the screen and an enlarged video image of the highway surface. Clicking on any location in the deflection plot will cause the image from that location to be displayed. The big frame of the video is very helpful for the user to find the location.

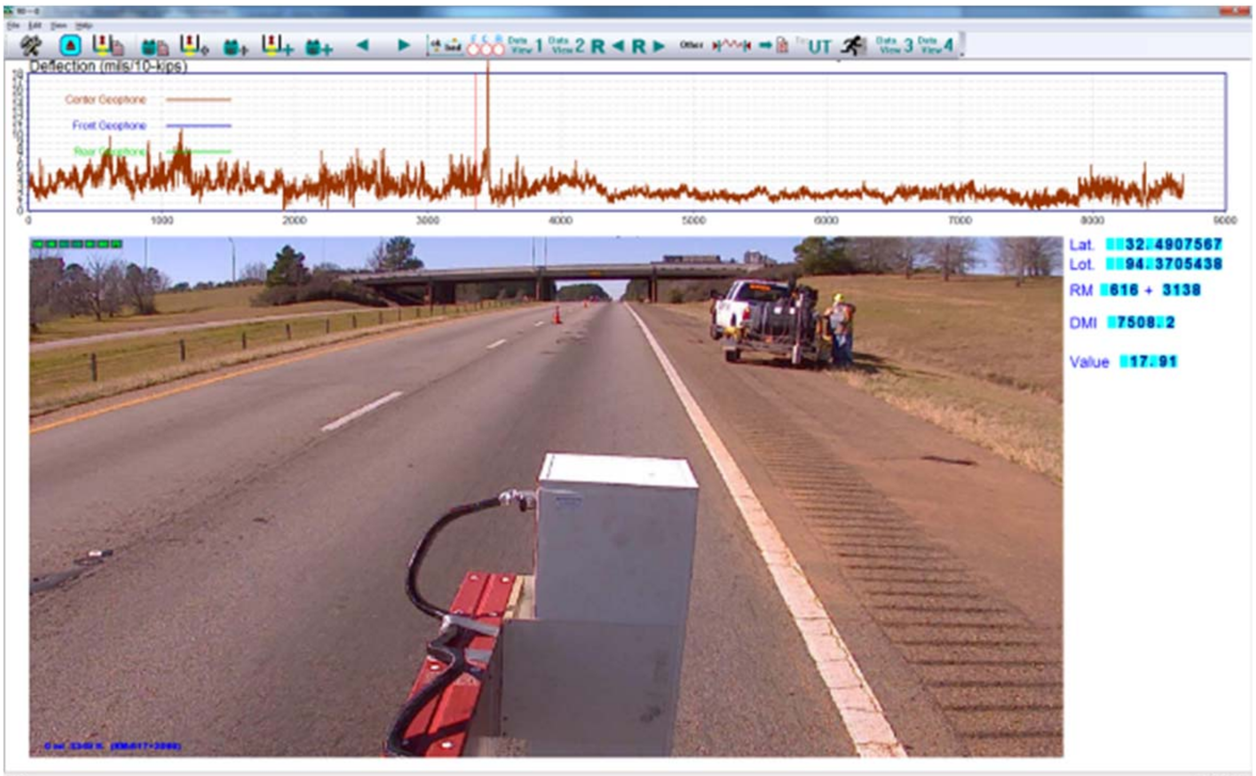


Figure 32. Display with the Data View 2 Option.

COMBINED FINAL RESULT VIEW TYPE-3

In Figure 33, the data view shows the deflection plot in the upper part of the screen and the video image of the highway surface in the left bottom corner. However, on the right bottom corner, there are two plots showing the load (top) and the geophone data (bottom), with both raw and filtered data at the current location. The current location is selected by the user by “mouse clicking” in the upper deflection plot. The location slected is marked with the vertical red line.

Also on the filtered data wave, the user can see the green dot that denotes the peak location for calculating the final result.

Figure 33. Display with the Data View 3 Option.

COMBINED FINAL RESULT VIEW TYPE-4 

In Figure 34, this data view shows the deflection plot in the upper part of the screen and video image of the highway surface in the left bottom corner. On the right bottom corner, however, there are two plots showing the detail deflection chart (top) and the raw and filtered geophone data (bottom) at the current location. Also on the filtered data wave, the user can see the green dot that denotes the peak location for calculating the final result.

Figure 34. Display with the Data View 4 Option.

8. DMI AND REFERENCE MARKER LIST

All the figures in Chapter 7 (Figures 30 to 34) have reference mark fields for marking the test location. Figure 35 is a sample screenshot.

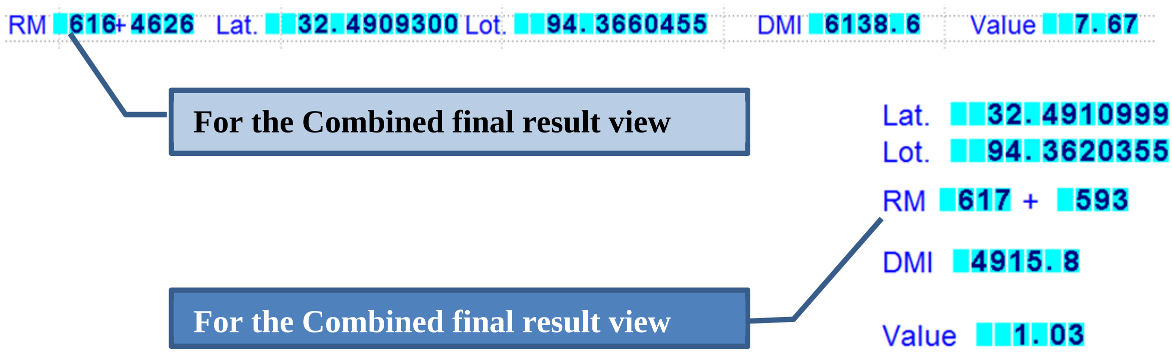


Figure 35. Reference Mark Is Added to All Four Views.

When the TPAD collects data using the TTI data acquisition software TPADscan, the device collects and saves the DMI and GPS data, but not the reference marker data. For most of the engineers, the reference marker is a better way to figure out the location.

Currently, when the TPAD operator collects data, he will write down the DMI and reference marker list by overlooking the roadside for any reference marker. Figure 36 shows a typical mile post in Texas (also known as reference marker or RM).

Figure 36. An Example of a Typical Mile Post (Reference Marker).

Figure 37 is an example of the DMI and reference marker list. The left side is the DMI reading and the right side is the reference marker. Chapter 8 will discuss how to input this information into the TPADana software to get the reference marker reading and the DMI reading previously shown in Figure 35.

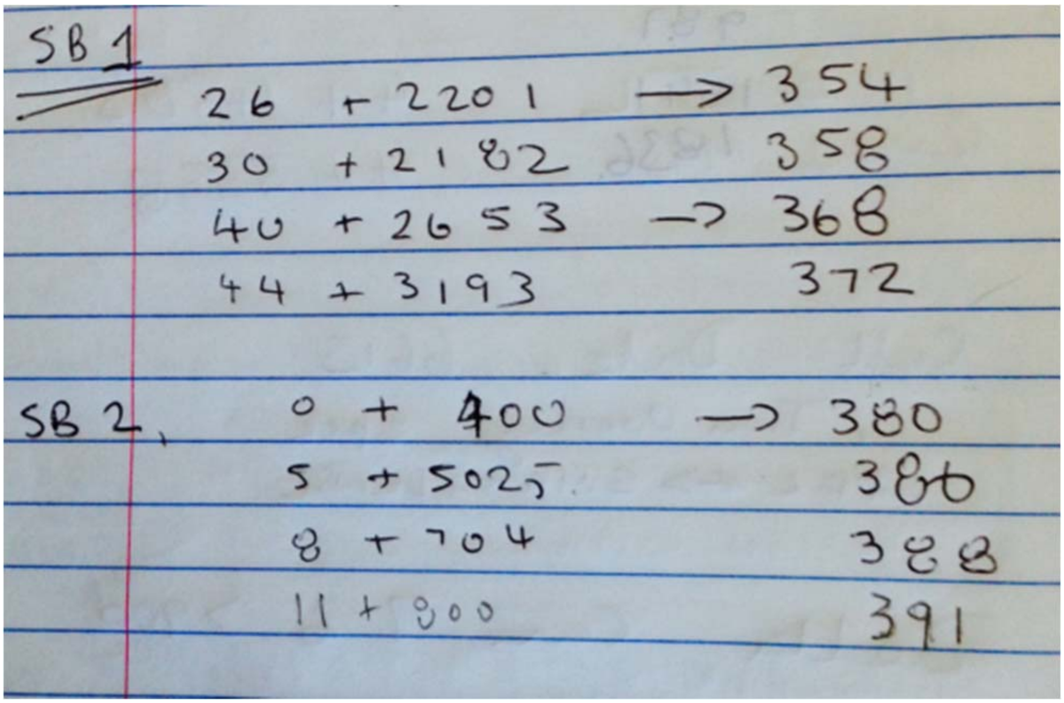


Figure 37. An Example of a Field Test Record Showing the DMI and RM List.

The current TPADana software can coordinate the GPR’s DMI test data with the following three kinds of pavement reference methods:

- Normal reference marker, RM.
- Texas Reference Marker, TRM.
- Station reference marker, STA.

The first method is the most popular way for the engineer to reference data to the normal reference marker. The reference marker usually refers to the mile post beside the road as shown in Figure 36. If the user selects this reference method, the format is defined as mile + feet. For instance, 398 + 4872 means 398 miles and 4872 feet.

The Texas Reference Marker is similar to the normal reference marker, but the format is different. For instance, the above normal reference marker RM: 398 + 4 872 will be TRM:398 + 0.9227. It means 398.9227 miles, or 398 + 0.9227 x 5280 = RM:398 + 4872.

The last format is used for the pavement construction reference purpose defined as unit 100 feet. For instance, STA:398 + 56 means 398 * 100 + 56 = 39856 feet; 100 feet is a manageable length for construction.

The TPADana software has the ability to coordinate the DMI to any of these three kinds of reference methods.

Each GPR trace has a DMI location in terms of miles and feet. It is desirable to tie this to the meaningful reference for engineers. When doing this connection, the user must identify reference markers (for the station method, here is a station marker) during data collection by:

- Writing the DMI down as the GPR van passes the reference marker.
- Putting a mark in the data and checking the video file later to get the most accurate possible DMI for each RM or STA.

Future versions of this software could rely more on GPS technology to do this combination. Currently, to achieve this tie-in, the user needs to:

1. Create a DMI and RM (or TRM and STA) file as shown below with a character between them. Use any ASCII editor software to create this file and save it with a *.RMM extension. The first two lines are used for comments or something else, and the define lines start from the third line.
2. Save this RMM reference define file to the same folder as other data, and make sure the file name is the same as the RDD data file name.
3. Once this tie-in is available, the software automatically computed the RM (or TRM and STA) for each DMI location. This information is displayed in all four kinds of view as shown in Figure 35.

If the users prefer the normal reference marker (RM), the file format will be:

Figure 37 shows that for the southbound, the normal reference marker matching the DMI define file is:

SH6 SB test section −1 Tested at 3/16/2014
We use the normal Reference marker to match the DMI
26 + 2201 × 354 + 0
30 + 2182 × 358 + 0
40 + 2653 × 368 + 0
44 + 3193 × 372 + 0

Also, if the user prefers the Texas Reference Marker format, below is an example of the ".RMM" file supplied with the same data as in Figure 37. In this case the TPAD's DMI value will be linked to the existing Texas Reference Markers (TRM). ,

SH6 SB test section -1 Tested at 3/16/2014
We use the Texas Reference marker to match the DMI
26 + 2201 T 354 + 0.001
30 + 2182 T 358 + 0.23
40 + 2653 T 368 + 0
44 + 3193 T 372 + 0

If this test section is currently is under construction, the permanent mileposts are still not installed, but only the temporary station markers are used for the construction management. Below is an example of the ".RMM" file, define the DMI is tied to the station

(STA):

SH6 SB test section -1 Tested at 3/16/2014
We use the Texas Reference marker to match the DMI
0 + 20 S 4520 + 0
0 + 520 S 4525 + 10
0 + 1020 S 4530 + 33
0 + 1720 S 4537 + 52

The first two lines are for titles or comments. Other lines for DMI and TRM (RM, STA) are paired lists. The first is the DMI value, and the value behind X or x (X for RM, T for TRM, and S for STA) is the reference marker. For DMI, user can use the following formats:

2 + 1700 (means 2 miles and 1700 feet)

2.32197 (means 2.32197 miles)

9. OTHER FUNCTIONS

BUTTONS FOR SHOWING OTHER INFORMATION Other

Figure 38 shows that the TPAD is equipped with an infrared surface temperature sensor and an accurate GPS antenna on top of the loading wheel. GPS is necessary for the user to record the test location. In case the user wants to go back to the site and find that location, GPS is the best tool for locating problem areas. Since the concrete pavement's properties are related to slab temperature when tested, it is necessary to show the measured value in the software used. The infrared surface temperature sensor does this.

Figure 38. Infrared Sensor and the GPS Antenna.

The button Other is used to show this information. By clicking this button, the user will see the screen shown in Figure 39. The figure shows that there are four locations where the pavement surface temperature is lower than the other areas, and the temperature drops nearly 25 °F. These four locations are marked with red circles. When the researchers viewed the video frames at these locations, they found that the temperature dropped when the TPAD passed under a bridge. Figure 40 shows the video frames for the four low surface temperature locations.

The middle chart of Figure 39 shows the height above seal level in feet. Since the level data are obtained from the GPS system, the GPS has poor signal reception when the TPAD passed under the bridge. Compared with the top temperature chart, the researchers noticed that when the temperature dropped, the GPS reading under the bridge has an error and the level data point fluctuated more than at any other location.

The bottom chart shows the TPAD running speed along the path (or DMI). Note that the TPAD's speed was close to 2.0 mph, and this reading matches the specified test speed of 2 mph.

Sometime, when the TPAD crossed the bridge, the researchers stopped the TPAD's vibration and drove faster than 2.0 mph to cross the bridge quickly. In this case, they found the data from the speed chart. Sometimes for safety reasons, the TPAD stopped and waited until the correct traffic control was established . The user can also find the stop location from the speed chart.

Figure 39. Other Information Chart (Surface Temperature, Sea Level, and Running Speed).

Figure 40. Video Frames Showing the TPAD Going under the Bridge.

BUTTONS FOR OUTPUT OF THE FINAL ANALYSIS RESULT

If the user wants to download the data into other software such as Excel, this button is used to output the analysis result to an ASCII format. The output format has two columns, one of which is DMI while the other is the deflection per 10 kips. DMI is recorded in feet, and the deflection is in mils/10 kips. This operation is very simple and will not be covered in detail here.

BUTTONS FOR OUTPUT OF RAW DATA TO UT AUSTIN FORMAT To: UT

Since UT Austin has already worked on this topic for a long time, the TTI researchers wanted to share the data with the UT system, and change TTI's TPAD format to UT Austin's format.

TTI researcher took a long time to figure out the UT Austin format. The main problem is that UT Austin's Labview® software output the data according to the old Mac format. The sequence for saving the raw sensor and DMI data is reversed to the normal Windows® format. Finally, the researchers managed to put this code inside the software package.

It is easy to use: click the button, then the Open File dialogue box will appear (see Figure 41). Then after the user clicks the "OK" button, the conversion process will start. Based on the file size, the conversion process takes a while. Conversion is finished when the toolbar button begins to respond to the mouse's actions. When the user browses the raw data folder, there will be the two extra new files for the UT Austin analysis system. For example, if the user selects US81NBTB.RDD file as the input as in Figure 41, then the two new files are:

- US81NBTB_A.DAT is the sensors and DMI raw data file (32-bit floating point data format).
- US81NBTB_C.DAT is the DMI processed data format (two columns, time and distance in feet, in 64 bits).

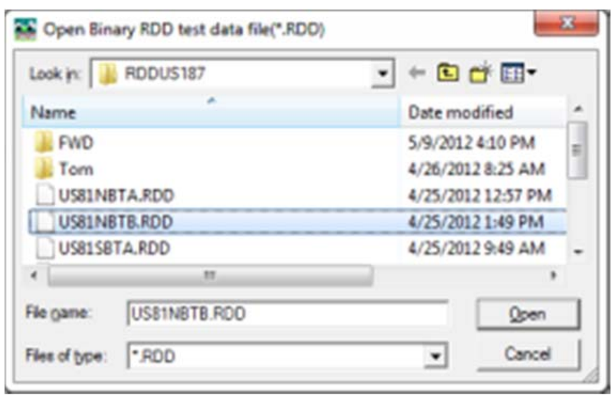


Figure 41. Open File Dialogue Box.