



SLAB IMPULSE RESPONSE (SIR)

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SYSTEM REFERENCE MANUAL 2008



SLAB IMPULSE RESPONSE TEST NDE-360



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1.0 INTRODUCTION

The **Slab Impulse Response (Slab IR)** method is used primarily to identify and map subgrade voids below slabs-on-grade and behind walls and tunnel liners, although it also sees use in general condition evaluation of structural elements. This method is excellent for evaluating the repair of slab subgrade support conditions by comparing the support conditions before and after repairs. The Slab IR method is often used in conjunction with Ground Penetrating Radar [GPR] for subgrade void detection and mapping.

The Slab IR method has been used on slabs of a wide range of thicknesses, but is most effective on thinner slabs (less than 12 inches thick). The method is generally limited to slab thicknesses of less than about 20-24 inches in thickness for most applications.

An alternate application of the Slab IR method is in the general evaluation of the condition of concrete structures. In this application, the method is used to look for low-stiffness areas associated with hidden damage such as honeycomb, void, and cracking. The method can be used for a fast evaluation of structural conditions, with a more detailed investigation then performed with Impact Echo or Ground Penetrating Radar.

The Slab IR system consists of several basic components. These components include the NDE-360 computer, an instrumented 3 lb hammer, a geophone and a Wilcoxon velocity transducer. Details of the hardware and its usage are included in Section 5.0.

The data is collected and initially analyzed in the NDE-360 SIR software package. For many applications, this level of analysis will be all that is needed. For some applications, however, additional analysis will be needed. This post-collection analysis is performed with the Windows WinTFS software, which runs on any Windows-based computer and has a number of specialized Slab IR analysis tools built-in. This manual covers step-by-step hardware assembly, software setup, data acquisition, data analysis, and output generation.

1.1 Organization and Scope of Manual

This operation manual for the Olson Instruments NDE-360 Slab IR system includes all required instruction for the use of the software and hardware included with the system. Also included is a troubleshooting guide for the system to help overcome any problems experienced or answer any questions. If any problems with the system appear that are not covered in this manual, please call Olson Instruments at the number included in the front of this manual. Note that training in the use of the system by Olson Instruments personnel is recommended for the most effective operation of this system.



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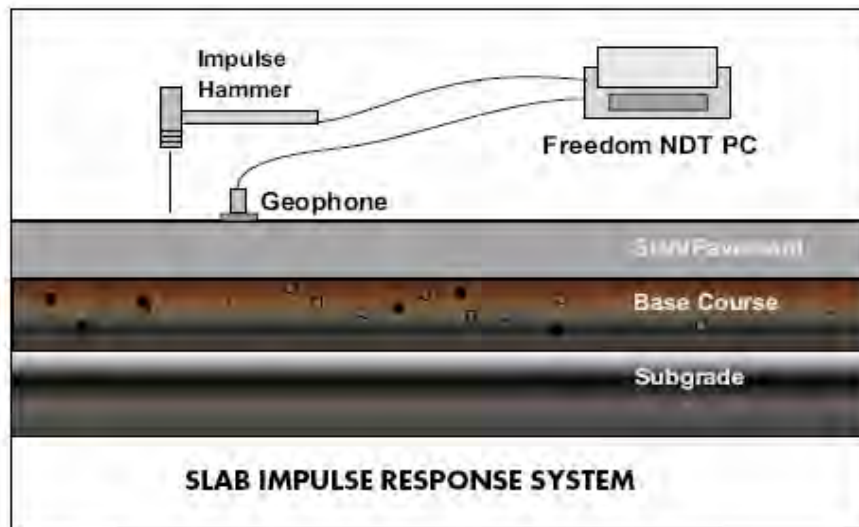
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1.2 Test Methodology

The Slab IR system is purchased as an option to the OLSON NDE-360 data collection and analysis platform. When the system is purchased, Olson Instruments personnel will properly set up the system. Each setup is based on the customer's option requests.

Slab Impulse Response (Slab IR) – Slab IR investigations are usually performed to identify subgrade voids below slabs-on-grade. The method is excellent for evaluating the repair of slab subgrade support conditions by comparing the support conditions before and after repairs. The elements that can be tested include concrete slabs, pavements, runways, spillways, pond and pool bottoms, and tunnel liners. The Slab IR method is often used in conjunction with GPR for subgrade void detection and mapping. In addition, the Slab IR test method can be used on other concrete structures to quickly locate areas of delamination or void in the concrete or masonry, if the damage is relatively shallow. Slab IR can be performed on reinforced and nonreinforced concrete slabs as well as asphalt or asphalt-overlay slabs. The schematic below shows the field setup used in Slab IR investigations.



The Slab IR method requires access only to the top (or front) surface for receiver locations and hammer hitting. The receiver is mounted to the surface of the slab or wall adjacent to the impact location and generally 3-4 inches away. In a Slab IR investigation, the slab top or wall is impacted with an impulse hammer and the response of the slab is monitored by a geophone placed next to the impact point. The hammer input and the receiver output are recorded by an Olson Instruments NDE-360 equipped with the Slab Impulse Response software package option. In easy access areas, 400-600 Slab IR tests can be performed in an 8 hour work day.



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For the processing part, Fast Fourier Transform (FFT) operations performed by the Slab IR software in our NDE-360 transform the impulse force and vibration velocity response time domain signals to produce a plot of mobility (vibration velocity/pounds force). After transformation to the frequency domain, the transfer and coherence curves are automatically generated by the Slab IR software. Analysis of the mobility plot provides information on the subgrade support conditions and/or surface stiffness/mobility within a radius of 0.5 to 1.0 foot from the test point, depending on slab thickness.

Support condition evaluation includes two measurement parameters. First, the dynamic stiffness is calculated. The initial slope of the mobility plot indicates the quasi-static flexibility of the system. The steeper the slope of the initial part of the mobility plot, the more flexible and less stiff the system is. Second, the shape and/or magnitude of the mobility plot above the initial straight line portion of the curve is an indication of support condition. The response curve is more irregular and has a greater mobility for void versus good support conditions due to the decreased damping of the slab vibration response for a void. The presence of a high amplitude, low frequency spike in the mobility plot is an additional indication of void conditions.

The Slab IR method is used to determine the support conditions of the slab and to map out the aerial extent of any void or poor support condition zones, but the method cannot determine the thickness of any voids found. Collecting Slab IR data at multiple, densely-spaced locations can improve the conclusions by mapping relative areas of higher and lower mobility. However, relatively low mobility does not indicate the absence of a subgrade void, but qualitatively indicates that such an area appears to be more solidly supported than an area with relatively high mobility. For thick slabs (thickness > 2 ft), the interpretation of the Slab IR data becomes difficult because the stiffness of the system is controlled by the slab itself and not by the support conditions under the slab.



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2.0 HARDWARE

The SIR system with the NDE-360 platform consists of several basic components packaged into a padded carrying case. The padded case stores the NDE-360 data acquisition platform, battery charger, Wilcoxon velocity transducer, instrumented hammer, and cables. A description of each of these components as well as their connection and operation is included in the following sections.



2.1 Hardware Component Listing







Component Name	QTY	Description
 <p>1) Olson Instruments NDE-360 Platform</p>	1	Platform for data acquisition, analysis and display of SE/IR time domain data
 <p>2) Wilcoxon Velocity Transducer and cable</p>	1	To receive the Slab IR time domain data (for use on any angle surfaces, including vertical or inverted surfaces)
	1	The SIR An impact source is an instrumented 3 lb hammer



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3) Instrumented Hammer		
Component Name	QTY	Description
	1	4 heads for the instrumented hammer (each head has different hardness)
4) Heads for Instrumented Hammer		
	1	To receive the SIR velocity time domain data (to be held on flat slab surfaces only, up to +/- 20 degrees from level)
5) Geophone		
	2	BNC Extension Cables for Wilcoxon and Instrumented Hammer
6) BNC Cable		
	1	Female to Female BNC adaptor
7) BNC Adaptor		
	2	Connect a BNC cable and a 4 pin input channel from the NDE-360 system
8) BNC to 4 Pin Adaptor Cable		
	1	To connect the 3 Pin to Phone Plug Cable to the channel on the amplifier on the Freedom Data PC



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9) Phone Plug to 4 Pin Adaptor		
 <p>A black, rectangular power supply/charger with a coiled black cable attached to the top. The device has some text and a small label on its front face.</p>	1	Power supply/charger for the NDE-360 platform.
10) Power Supply/Charger		
 <p>A yellow and white card reader device with a blue label on the front. Next to it is a small, red and white compact flash card.</p>	1	To transfer the SE/IR data files to the analysis computer
11) Card Reader and Compact Flash Card		



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2.2 Basic Components and Maintenance of NDE-360 Platform

Battery Charging: The power supply/charger (Item 10) must be plugged into the NDE-360 system for charging the battery. Typically, the battery will charge over night.



NDE-360 and Power Supply/Charger



Time required for a fully charge of battery is 8 hours. Fully charged battery will power the NDE-360 system for 6-7 hours.



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Location of Battery: The panel housing the battery is located on the back of the NDE-360 system. Move the switch to remove the battery cover if battery needs to be replaced.



Do not expose the NDE-360 system or the battery to water.

Channel Arrangement: The NDE-360 system is equipped with 4 channels. There are two 4 pin connectors per each channel. Channel 1 is located on the left hand side of the NDE-360 system (it is typically located near the Impact Echo channel which is not used in the SIR test). The top row of channels (the row toward the front screen) includes channels with highpass filter. The bottom row of channels (the row toward the back side) includes wideband channels which are typical channels used in the SIR test.

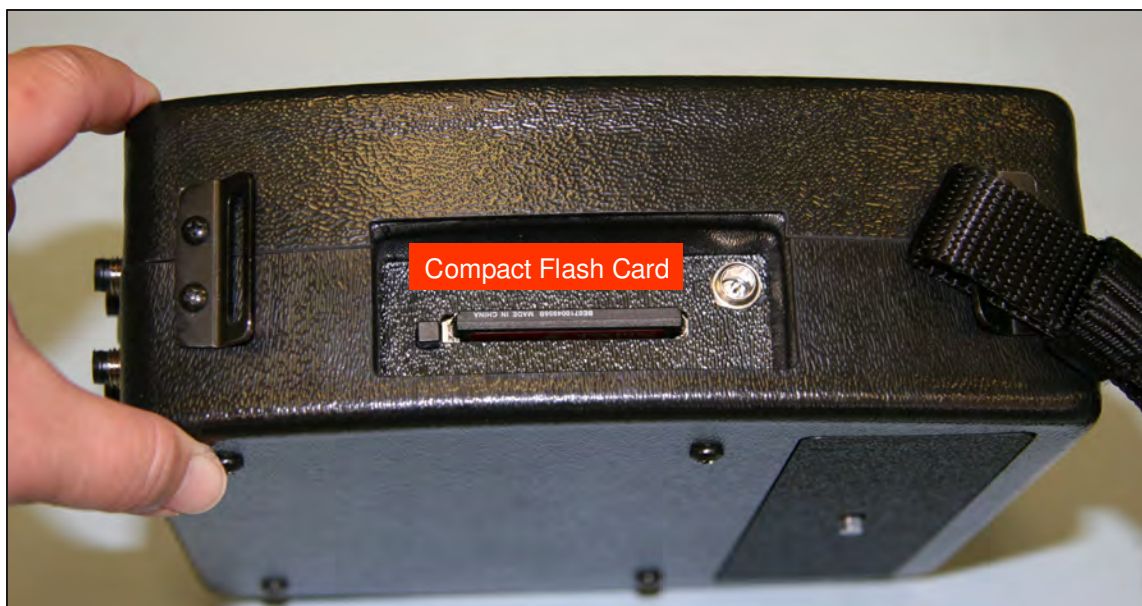




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Data Storage: A compact flash card is used to store the SIR data files. In addition, the master program controlling the SIR test is stored in the compact flash card. The system must start up with the compact flash secured in place. The card should be located on the left side of the NDE-360 system if looking at the front screen.



If the compact flash card is missing from the system, the system will not allow the test to continue. Do not remove the compact flash card while the system is turned on.

NDE-360 Operation Notes: The NDE-360 system is a self-contained data conditioning, collection, basic processing and data display platform usable for a number of types of NDT tests. The system was designed to make it user friendly and easy to handle and operate by a single operator. The main screen can be navigated using a touch screen feature.



Never impact the screen with any sharp object!



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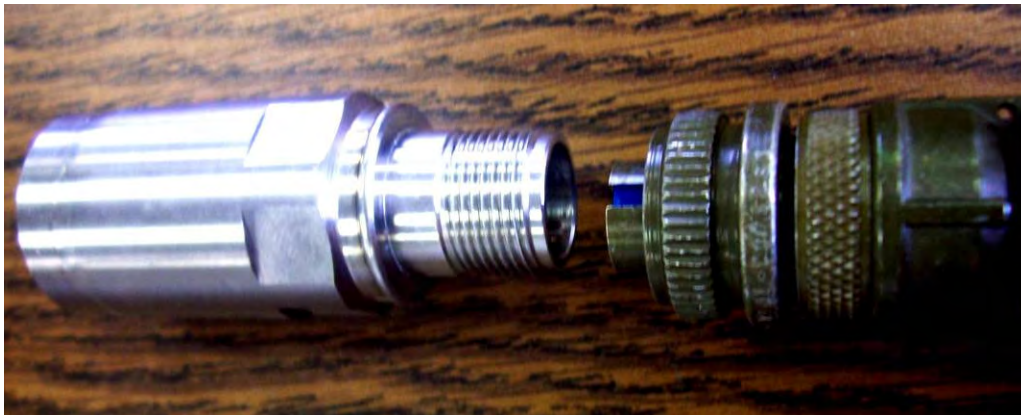
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2.3 Hardware Setup

Wilcoxon Velocity Sensor

Connect the 2-pin MS connector cable to the Wilcoxon velocity transducer by aligning the keyway on the connector with the key on the transducer and then hand-tighten the connection



Next, if needed, attach the female BNC adaptor to the BNC end of the Wilcoxon cable by aligning the pin with the hole and gently connecting the two pieces. This connection will have a locking mechanism that will prevent over-tightening the connection. Next, if needed, attach the other end of the female BNC adaptor to a BNC cable. Follow the same procedure as before when connecting these two cables.

Now attach the BNC cable to the 4 pin adaptor cable using the same procedure as before when connecting these two cables.





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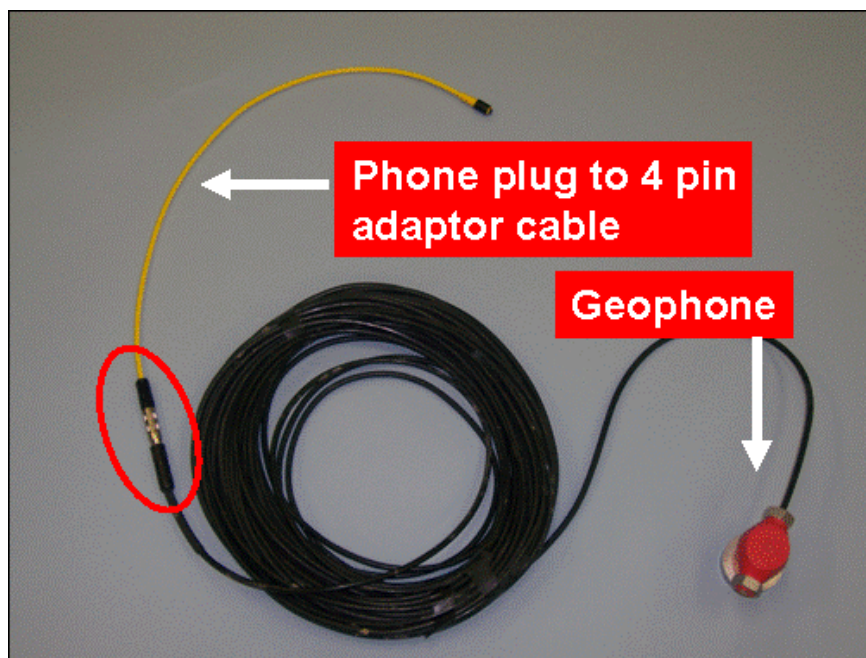
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Insert the 4 pin adaptor cable into a wideband channel (located in a row of channels close to the back side of the unit). The default channel used by the transducers (Wilcoxon or geophone) in the software for SIR is Channel 3.



Geophone Velocity Sensor

Connect the Phone Plug to 4 Pin Adaptor (Item 9) to the geophone (Item 5)



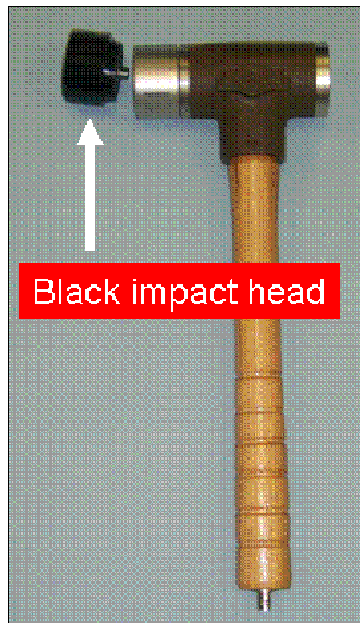


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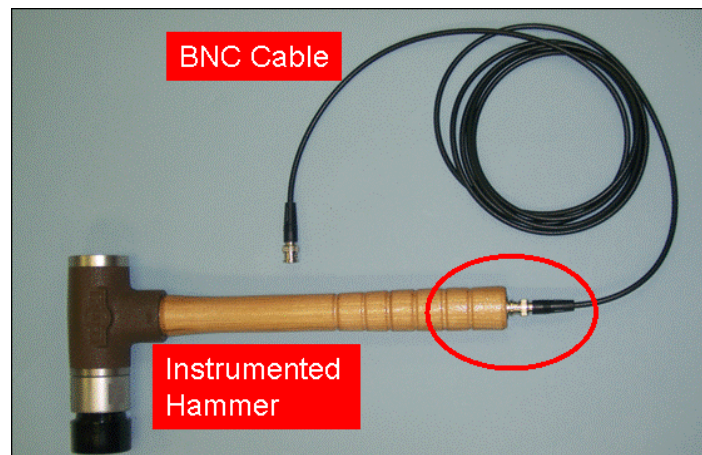
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For the SIR test, an instrumented 3 lb hammer is typically used. Screw in the impact head (Item 4 in Section 2.1) to the instrumented hammer (Item 3). The most common used head for the SIR tests is the black head. The red tip is typically used for thicker slabs (greater than about 18 inches).



Connect the BNC Cable (Item 6) to the BNC connector on the end of the instrumented hammer



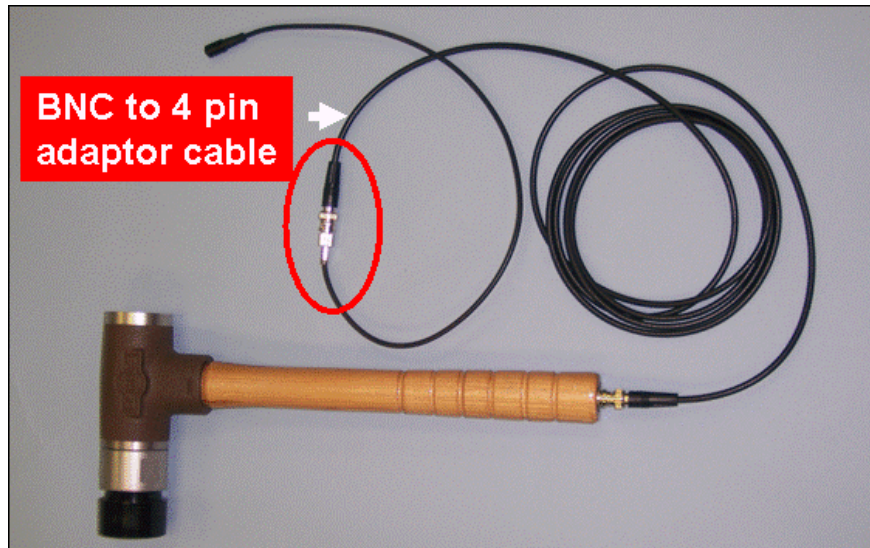


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Connect the other end of the BNC cable to the BNC to 4 pin adaptor cable (Item 8)



Connect the 4 pin adaptor end of the BNC to 4 pin adaptor cable to Channel 4 (wideband) on the NDE-360 platform

Connect the 4 pin adaptors of the extension cables to the wideband channels (in this case, channels 3 and 4) on the NDE-360 platform. For flat slabs or other horizontal surfaces, use the geophone. For angled surfaces and walls, use the Wilcoxon. The velocity transducer is connected Channel 3 and the instrumented hammer to Channel 4.





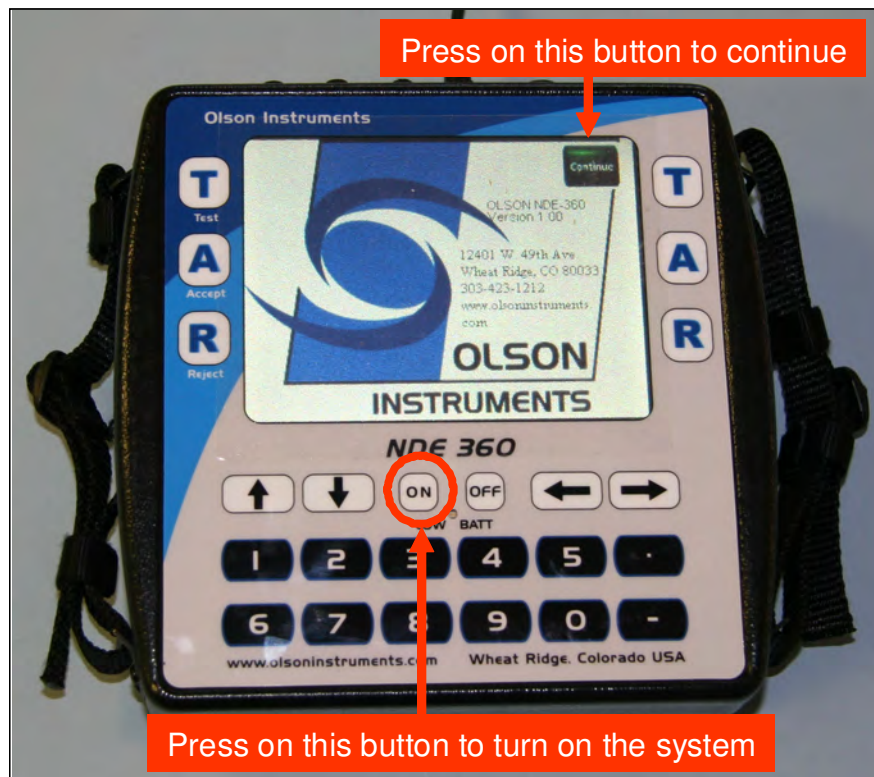
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3.0 SIR DATA ACQUISITION

1. Turn on the NDE-360 system (with the hardware in Section 2.0 connected). Make sure that the compact flash card is secured in place. The master software to run the system is located in the compact flash card, along with the key file that determines the system configuration. Press on the “Continue” button on the upper right corner of the screen. If the compact flash card is not in place, the “Continue” button will not appear on the screen.



If the continue button disappears from the screen, turn off the system and insert the compact flash card in place and turn the system on again.



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- Press on the “SIR” option. The options included in the unit may be different depending on the installed options. The picture below shows the screen with SE (Sonic Echo), IE (Impact Echo), SASW, Slab IR (Slab Impulse Response), SE/IR (Sonic Echo/Impulse Response) and UPV (Ultra Sonic Pulse Velocity) options.



- Press on the “Param” button to setup the data parameters, if needed. Note that the unit is loaded up with the default parameters which are appropriate for most of the SIR tests.





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4. In the parameter setup screen, the user can change the following parameters by touching the button to toggle the value. Touch the “Back” button after the parameter setup is complete.
- Change Date/Time. This option allows the user to enter the correct date and time of testing
 - Time/Point or Sampling Rate means how often (in time domain) the system will acquire data points within a given data trace. Normal SIR settings for this are 200 microseconds/point This means the system will acquire data at 200 microsecond intervals. **This parameter can not be changed after the data is taken.**
 - Points Per Record is number of sampling points for each waveform. The higher this value, the more data is acquired in each waveform. The total time of a record is affected by both the Sample Rate and the Record Size. **This parameter can not be changed after the data is taken.**
 - # Recs. Number of Record is a total number of SIR data records you want to save. **This parameter can not be changed after the data is taken.**
 - Pre-Trigger is number of points before the triggering point that data collection starts. In this case, the pre-trigger is 100 points (or $100 \times 200 \text{ us} = 20000 \text{ us}$). **This parameter can not be changed after the data is taken.**
 - Trigger Level % is the minimum signal amplitude (in terms of percentage full scale) to trigger data acquisition. In this case, the trigger level was set at 6%. Therefore, the system will start acquiring data once the absolute amplitude of the signal exceeds 0.6 volt. **This parameter can not be changed after the data is taken.**
 - Channel Setup. For the SIR test, two channels (connected to the Wilcoxon velocity transducer or geophone velocity transducer and the instrumented hammer) will be used. Any of the 4 wideband channels can be used for the SIR test. However, the default parameter is loaded with Ch 3 for Wilcoxon/Geophone (Velocity) and Ch 4 for an instrumented hammer (Force). Typically the channel connecting to the instrumented hammer will be used as a trigger channel and SREF (reference) channel.

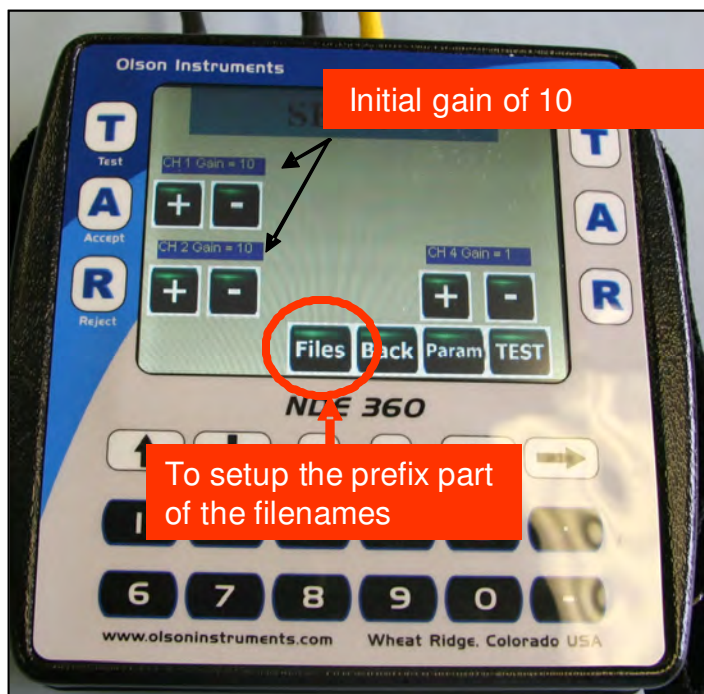




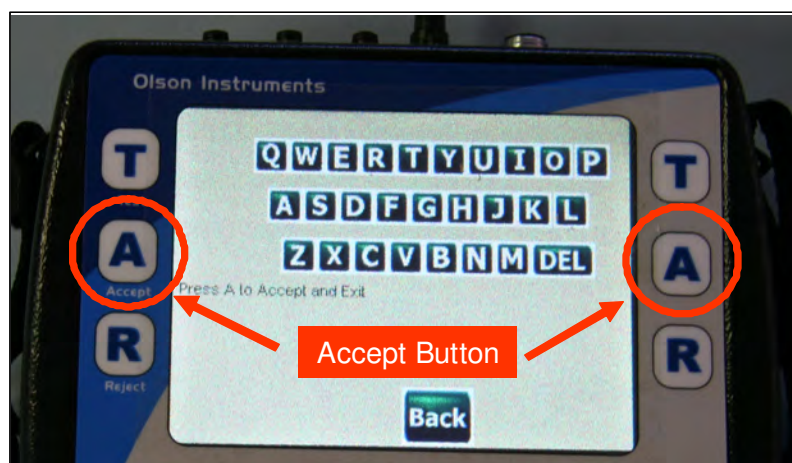
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5. After the channel setup is complete in the parameter setup menu (Step 4) press the “Back” button to return. Next, the gain control for the channel should be set by touching the + button to increase the gain value and the – button to reduce the gain value. It is recommended that a gain of 1-10 be initially used for both the hammer and velocity channels.



6. The filename arrangement of the NDE-360 uses a fixed prefix of letters and a suffix of number. The prefix can be set at the beginning of any test. If the prefix is not changed, a higher suffix number will be added to the current prefix for the new filename. To change the prefix, press on the “Files” button and press number 5 and then number 1. Then a virtual keyboard will appear on the screen and the user can change the prefix part of the filename. Press the “A” button on either side to accept the new prefix of the filename.





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- Now, the system is ready to acquire the SE data. Press on the “Test” button to start testing.



- The NDE-360 system will then wait for the data. Note that the voltage of the SIR time domain data on the trigger channel (usually the hammer) has to exceed the trigger level in order for the system to start taking data. Hit the hammer on the slab or wall next to the velocity transducer.

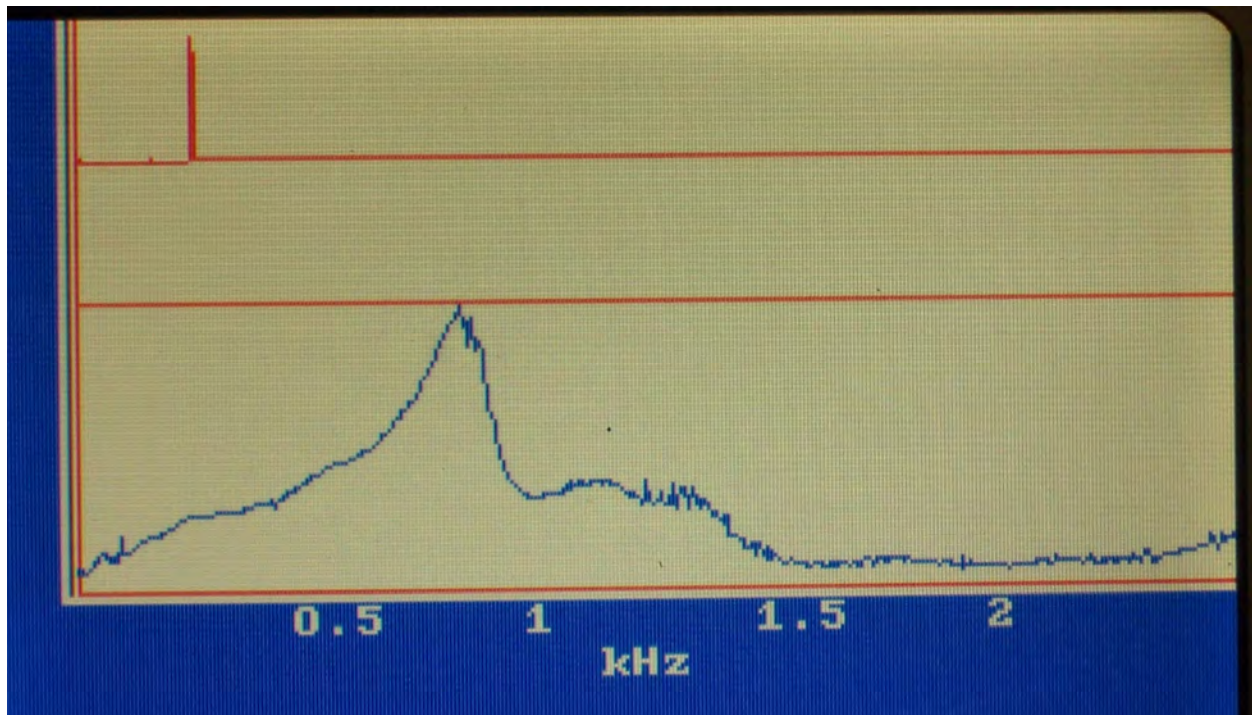




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9. If the system does not receive data for 1 minute, the test will be canceled and the user can press any key to go back to the previous menu. This happens if the gain value is too low or if the channels are not connected correctly. Try either increasing the gain value of the instrumented hammer channel or decreasing the trigger level and re-test the file. If the system receives the SIR data, it will display the SIR time domain data for one channel in the top half (hammer is pictured below) and the transfer function mobility data in the bottom half of the screen with the percentage full scale of the maximum amplitude shown below the plot. The desirable percentage full scale is between 5 – 90 %. At this point, press the “A” button to accept the data or the “R” button to reject the data currently displayed on the screen. Use the “T” button to switch to the next channel for time domain trace display of the velocity transducer.



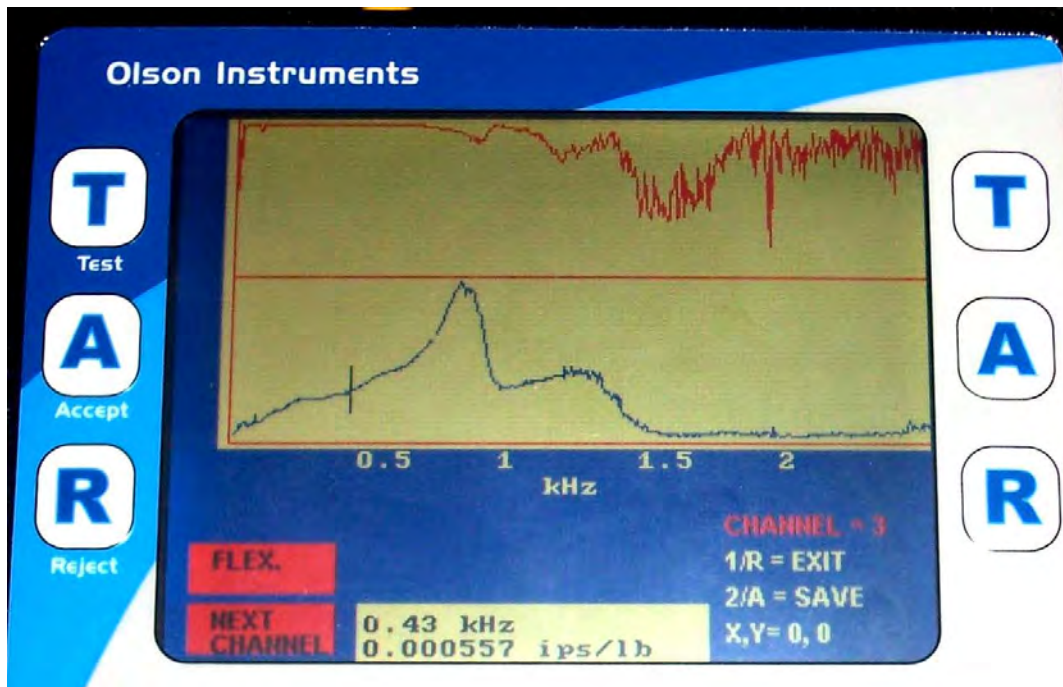
10. Repeat Steps 8 and 9 until all the records are collected.
11. To perform more SIR tests, repeat Steps 7 – 10.



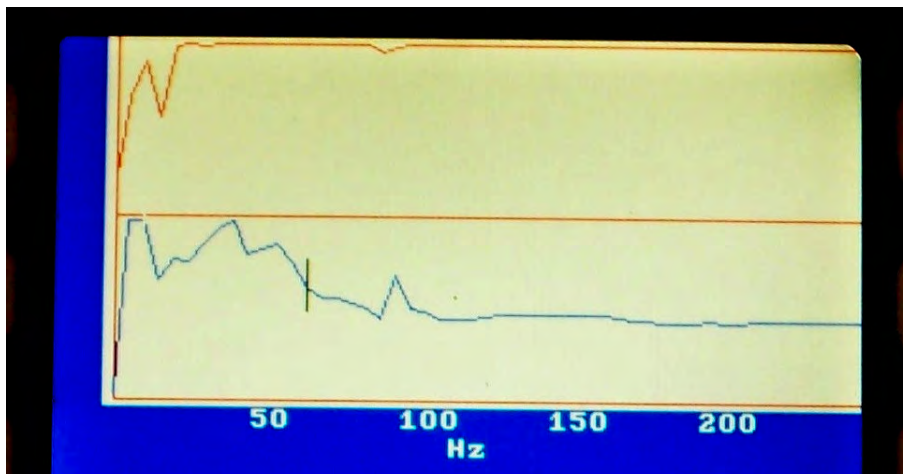
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12. Basic analysis tools included in the NDE-360 system for SIR data include the ability to read off the calibrated mobility values at any frequency using the combination touch/arrow cursor. The plot below shows a mobility value of 0.000557 inches per second per pound force at a frequency of 430 Hz. Note that the coherence plot (data quality versus frequency) is also displayed in the upper half of the display.



The software also allows the display and readout of flexibility values for low-frequency flexibility. The flexibility plot is accessed by pressing the touch-screen button, and is set to show 1/10 th of the frequency range of the mobility plot.





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13. The data can be recalled in the NDE-360 system by pressing the “File” button on the main screen and then select Option 2.

14. The data files on the compact flash card can be moved to the analysis computer for post-data analysis.

Note: The Slab IR test is a “point by point” test and usually can be performed in a grid fashion. The transducer typically does not require coupling agent between the transducer and the tested structure. However, a firm force (hand push) is required to push the transducer down to the tested structure to reduce the amount of air in between. A coupling agent can also be used for rough surfaces.



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4.0 WinTFS Software

This section covers step-by-step instructions for post data analysis and output generation for the Windows WinTFS software.

4.1 WinTFS Software Installation

1. Prerequisite software (NIDAQ version 7.4 or higher) prior to installing the WinTFS software is required. The NIDAQ drivers can be located in the enclosed CD or downloaded at:

<http://joule.ni.com/nidu/cds/view/p/id/319/lang/en>

If retrieving files from the web, download the file named NIDAQmx8.1.ZIP. Unzip the file and install the NIDAQ program. Note that an account (free of charge) may be required to proceed to the download page.



Failing to install the prerequisites will result in an error when running the WinTFS software

2. Uninstall the previous version or delete “c:\program files\olsoninstruments\WinTFS\WinTFS.exe” if the older file exists
3. Run “Setup.exe” from the Olson Instruments install CD
4. Follow the default setup
5. After finishing the installation, the “WinTFS.exe” file will be found on: drive C:\Program Files\Olson Instruments\WinTFS\ . The shortcut to the WinTFS.exe can be located on the desktop/



Failing to uninstall the previous version of the WinTFS software will prevent the installation of the new version

4.2 Software Updates

For updates to software, the only file that is necessary is the WinTFS.exe file. This file must be copied into the C:\Program Files\Olson Instruments\WinTFS directory. If not, the shortcut on the desktop references the old version of WinTFS. Simply replace the existing WinTFS.exe by copying and pasting the new version into the directory.



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4.3 Software Uninstallation

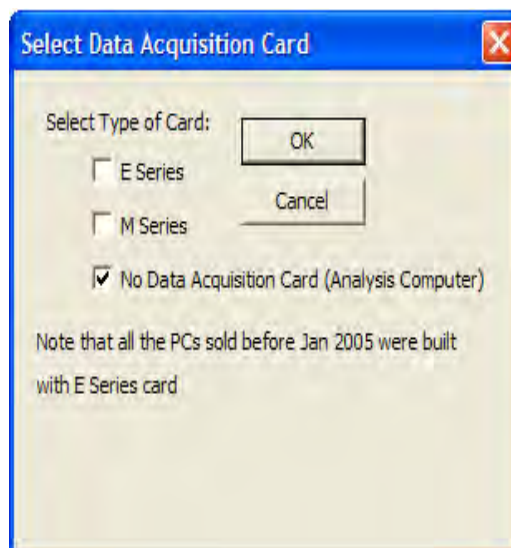
The followings are steps to uninstall the WinTFS Software

1. Click on Start/Settings/Control Panel
2. Select "Add/Remove Programs"
3. Highlight WinTFS, select "Remove"
4. The uninstall process will begin automatically, removing all installed components including the shortcut.

4.4 First Time Executing the WinTFS Software

If the WinTFS software is executed for the first time, the program detects missing software key (OlsonWinTFSKey.dat). The program will display a warning that the software key file is missing and will only enable two options on the main menu. Select the "Software Key" button and then enter the software key attached to the case of the installation disk. Exit the software and restart the software.

Now the software will detect missing parameter file (SIRdefault.prm is missing) and then will automatically generate the default file. The user will notice an applet shown below for the type of acquisition card. Select "No data Acquisition Card" option to continue.





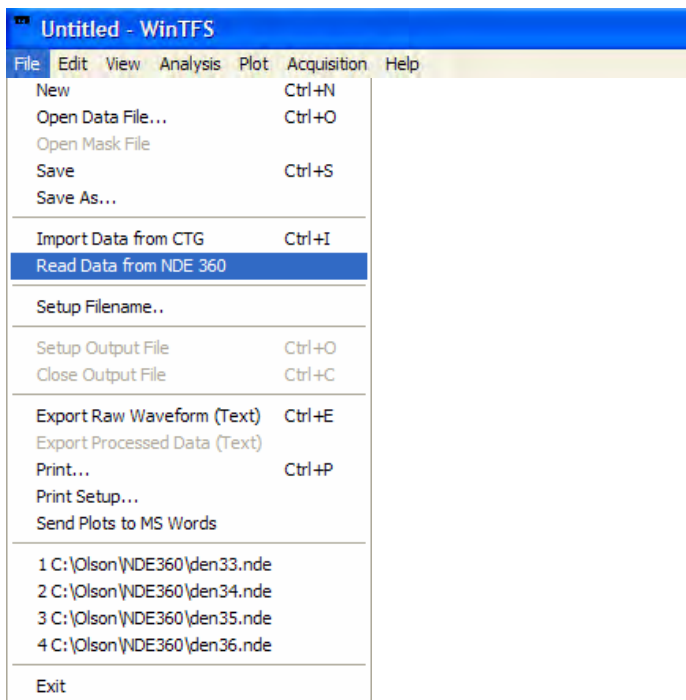
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4.5 SIR Data Recall

1. **Read the Data file:** To read the data file, go to File/Read Data from NDE-360 and select the filename to analyze.





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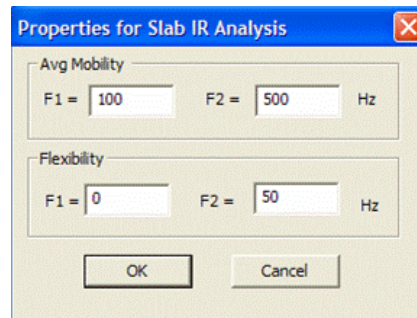
5.0 Step-by-Step Guide to WinTFS Slab IR Data Analysis

5.1 General Description of Traces

After recall of a given record, the data can be analyzed. The top trace displays the current time domain record for one of the two channels. The second trace displays an average coherence of accepted records and the last trace displays either mobility or flexibility of the data (depending on the setting – See Section 5.2).

5.2 Flexibility - Mobility

To toggle between the mobility and flexibility, go to Analysis/Mobility-Flexibility (or press F9). The frequency range of mobility or flexibility can be changed by going to Analysis/Slab IR Mobility-Flexibility Properties. Values of flexibility and mobility, along with the mobility and flexibility plot shape, are used to determine the condition of the structure being tested and locate voids. This is described in detail in Section 6.



5.3 Output File

To turn on the output file (text format), go to File/Setup Output File and give the file any name. The software will automatically record the filename, mobility within the selected frequency range, flexibility within the selected frequency range, and the ratio to the output file as columnar ASCII text. Also included will be the X-Y coordinates entered during data collection. This output file can be recalled in Excel or other plotting programs for further processing and 2D/3D data presentation.



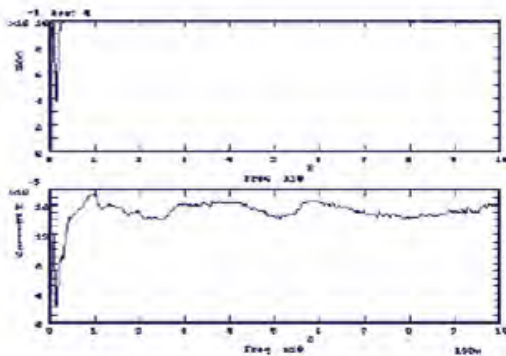
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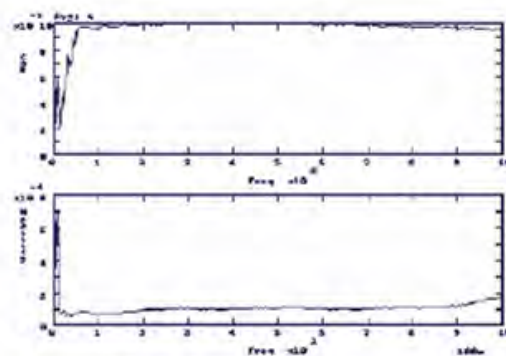
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6.0 Slab IR Data Interpretation

The Slab IR method is used to determine the support conditions of the slab and to map out the aerial extent of any void or poor support condition zones, but the method cannot determine the thickness of any voids found. Collecting Slab IR data at multiple, densely-spaced locations can improve the conclusions by mapping relative areas of higher and lower mobility. However, relatively low mobility does not indicate the absence of a subgrade void, but qualitatively indicates that such an area appears to be more solidly supported than an area with relatively high mobility. For thick slabs (thickness > 2 ft), the interpretation of the Slab IR data becomes difficult because the stiffness of the system is controlled by the slab itself and not by the support conditions under the slab. The figure below shows example mobility results from subgrade with voids and sound subgrade. The top traces are coherence and the bottom traces are mobility plots.



Subgrade with Voids



Solid Subgrade

Parameters used in the Slab IR data interpretation include: [from ASTM Standard of Practice for Impulse Response – Work in Progress]

- **Average Mobility.** The average mobility between 100 – 800 Hz is related directly to density, elastic modulus, and thickness of the plate element. A reduction in the plate thickness results in an increase in mean mobility. Cracking or honeycombing in the concrete will reduce rigidity thus an increase in mean mobility.
- **Mobility Slope.** The mobility of honeycomb concrete shows increasing mobility with increasing frequency over the frequency range of 100 – 800 Hz whereas the solid concrete shows a relatively constant mobility over the same frequency range.



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- Peak to Mean Mobility Ratio. This value is called “ratio” for short in this program. This ratio is the indication of subgrade voids. When this value exceeds 2.5, loss of support beneath slab on grade is indicated.



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SLAB IMPULSE RESPONSE TEST NDE-360



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1.0 INTRODUCTION

The **Slab Impulse Response (Slab IR)** method is used primarily to identify and map subgrade voids below slabs-on-grade and behind walls and tunnel liners, although it also sees use in general condition evaluation of structural elements. This method is excellent for evaluating the repair of slab subgrade support conditions by comparing the support conditions before and after repairs. The Slab IR method is often used in conjunction with Ground Penetrating Radar [GPR] for subgrade void detection and mapping.

The Slab IR method has been used on slabs of a wide range of thicknesses, but is most effective on thinner slabs (less than 12 inches thick). The method is generally limited to slab thicknesses of less than about 20-24 inches in thickness for most applications.

An alternate application of the Slab IR method is in the general evaluation of the condition of concrete structures. In this application, the method is used to look for low-stiffness areas associated with hidden damage such as honeycomb, void, and cracking. The method can be used for a fast evaluation of structural conditions, with a more detailed investigation then performed with Impact Echo or Ground Penetrating Radar.

The Slab IR system consists of several basic components. These components include the NDE-360 computer, an instrumented 3 lb hammer, a geophone and a Wilcoxon velocity transducer. Details of the hardware and its usage are included in Section 5.0.

The data is collected and initially analyzed in the NDE-360 SIR software package. For many applications, this level of analysis will be all that is needed. For some applications, however, additional analysis will be needed. This post-collection analysis is performed with the Windows WinTFS software, which runs on any Windows-based computer and has a number of specialized Slab IR analysis tools built-in. This manual covers step-by-step hardware assembly, software setup, data acquisition, data analysis, and output generation.

1.1 Organization and Scope of Manual

This operation manual for the Olson Instruments NDE-360 Slab IR system includes all required instruction for the use of the software and hardware included with the system. Also included is a troubleshooting guide for the system to help overcome any problems experienced or answer any questions. If any problems with the system appear that are not covered in this manual, please call Olson Instruments at the number included in the front of this manual. Note that training in the use of the system by Olson Instruments personnel is recommended for the most effective operation of this system.



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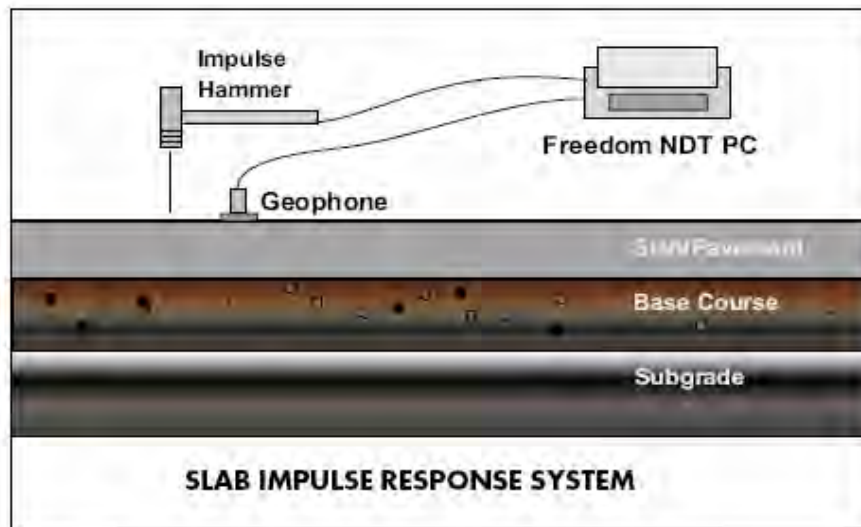
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1.2 Test Methodology

The Slab IR system is purchased as an option to the OLSON NDE-360 data collection and analysis platform. When the system is purchased, Olson Instruments personnel will properly set up the system. Each setup is based on the customer's option requests.

Slab Impulse Response (Slab IR) – Slab IR investigations are usually performed to identify subgrade voids below slabs-on-grade. The method is excellent for evaluating the repair of slab subgrade support conditions by comparing the support conditions before and after repairs. The elements that can be tested include concrete slabs, pavements, runways, spillways, pond and pool bottoms, and tunnel liners. The Slab IR method is often used in conjunction with GPR for subgrade void detection and mapping. In addition, the Slab IR test method can be used on other concrete structures to quickly locate areas of delamination or void in the concrete or masonry, if the damage is relatively shallow. Slab IR can be performed on reinforced and nonreinforced concrete slabs as well as asphalt or asphalt-overlay slabs. The schematic below shows the field setup used in Slab IR investigations.



The Slab IR method requires access only to the top (or front) surface for receiver locations and hammer hitting. The receiver is mounted to the surface of the slab or wall adjacent to the impact location and generally 3-4 inches away. In a Slab IR investigation, the slab top or wall is impacted with an impulse hammer and the response of the slab is monitored by a geophone placed next to the impact point. The hammer input and the receiver output are recorded by an Olson Instruments NDE-360 equipped with the Slab Impulse Response software package option. In easy access areas, 400-600 Slab IR tests can be performed in an 8 hour work day.



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For the processing part, Fast Fourier Transform (FFT) operations performed by the Slab IR software in our NDE-360 transform the impulse force and vibration velocity response time domain signals to produce a plot of mobility (vibration velocity/pounds force). After transformation to the frequency domain, the transfer and coherence curves are automatically generated by the Slab IR software. Analysis of the mobility plot provides information on the subgrade support conditions and/or surface stiffness/mobility within a radius of 0.5 to 1.0 foot from the test point, depending on slab thickness.

Support condition evaluation includes two measurement parameters. First, the dynamic stiffness is calculated. The initial slope of the mobility plot indicates the quasi-static flexibility of the system. The steeper the slope of the initial part of the mobility plot, the more flexible and less stiff the system is. Second, the shape and/or magnitude of the mobility plot above the initial straight line portion of the curve is an indication of support condition. The response curve is more irregular and has a greater mobility for void versus good support conditions due to the decreased damping of the slab vibration response for a void. The presence of a high amplitude, low frequency spike in the mobility plot is an additional indication of void conditions.

The Slab IR method is used to determine the support conditions of the slab and to map out the aerial extent of any void or poor support condition zones, but the method cannot determine the thickness of any voids found. Collecting Slab IR data at multiple, densely-spaced locations can improve the conclusions by mapping relative areas of higher and lower mobility. However, relatively low mobility does not indicate the absence of a subgrade void, but qualitatively indicates that such an area appears to be more solidly supported than an area with relatively high mobility. For thick slabs (thickness > 2 ft), the interpretation of the Slab IR data becomes difficult because the stiffness of the system is controlled by the slab itself and not by the support conditions under the slab.



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2.0 HARDWARE

The SIR system with the NDE-360 platform consists of several basic components packaged into a padded carrying case. The padded case stores the NDE-360 data acquisition platform, battery charger, Wilcoxon velocity transducer, instrumented hammer, and cables. A description of each of these components as well as their connection and operation is included in the following sections.



2.1 Hardware Component Listing







Component Name	QTY	Description
 <p>1) Olson Instruments NDE-360 Platform</p>	1	Platform for data acquisition, analysis and display of SE/IR time domain data
 <p>2) Wilcoxon Velocity Transducer and cable</p>	1	To receive the Slab IR time domain data (for use on any angle surfaces, including vertical or inverted surfaces)
	1	The SIR An impact source is an instrumented 3 lb hammer



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3) Instrumented Hammer		
Component Name	QTY	Description
	1	4 heads for the instrumented hammer (each head has different hardness)
4) Heads for Instrumented Hammer		
	1	To receive the SIR velocity time domain data (to be held on flat slab surfaces only, up to +/- 20 degrees from level)
5) Geophone		
	2	BNC Extension Cables for Wilcoxon and Instrumented Hammer
6) BNC Cable		
	1	Female to Female BNC adaptor
7) BNC Adaptor		
	2	Connect a BNC cable and a 4 pin input channel from the NDE-360 system
8) BNC to 4 Pin Adaptor Cable		
	1	To connect the 3 Pin to Phone Plug Cable to the channel on the amplifier on the Freedom Data PC



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9) Phone Plug to 4 Pin Adaptor		
 <p>A black, rectangular power supply/charger with a coiled black cable attached to the top. It has some text and a logo on the front panel.</p>	1	Power supply/charger for the NDE-360 platform.
10) Power Supply/Charger		
 <p>A yellow and blue card reader device with a compact flash card inserted into its slot. The card is red and white.</p>	1	To transfer the SE/IR data files to the analysis computer
11) Card Reader and Compact Flash Card		



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2.2 Basic Components and Maintenance of NDE-360 Platform

Battery Charging: The power supply/charger (Item 10) must be plugged into the NDE-360 system for charging the battery. Typically, the battery will charge over night.



NDE-360 and Power Supply/Charger



Time required for a fully charge of battery is 8 hours. Fully charged battery will power the NDE-360 system for 6-7 hours.



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Location of Battery: The panel housing the battery is located on the back of the NDE-360 system. Move the switch to remove the battery cover if battery needs to be replaced.



Do not expose the NDE-360 system or the battery to water.

Channel Arrangement: The NDE-360 system is equipped with 4 channels. There are two 4 pin connectors per each channel. Channel 1 is located on the left hand side of the NDE-360 system (it is typically located near the Impact Echo channel which is not used in the SIR test). The top row of channels (the row toward the front screen) includes channels with highpass filter. The bottom row of channels (the row toward the back side) includes wideband channels which are typical channels used in the SIR test.

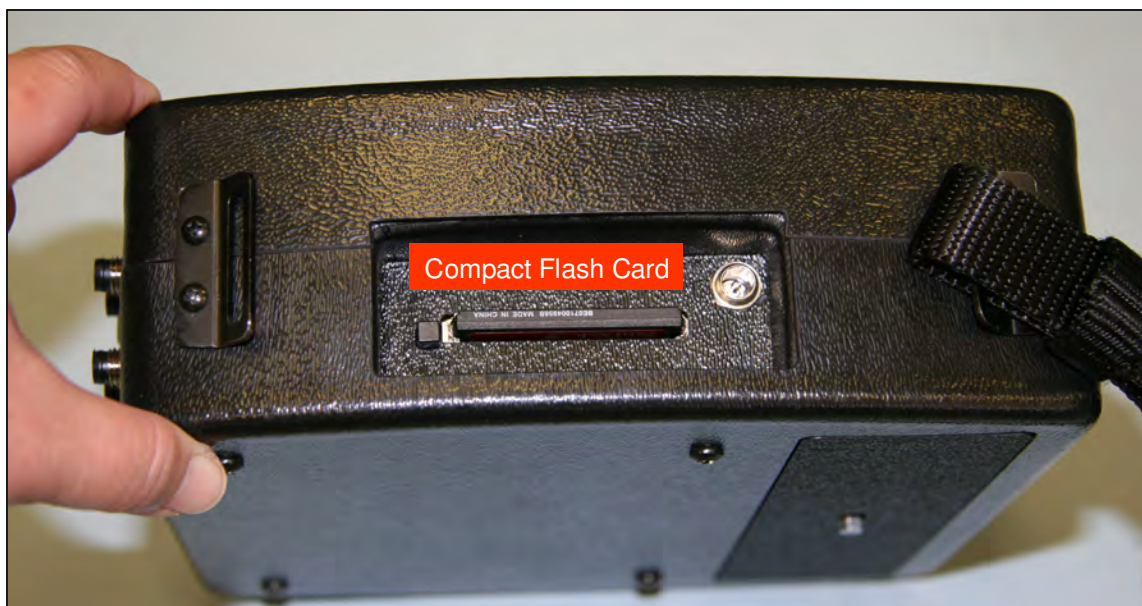




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Data Storage: A compact flash card is used to store the SIR data files. In addition, the master program controlling the SIR test is stored in the compact flash card. The system must start up with the compact flash secured in place. The card should be located on the left side of the NDE-360 system if looking at the front screen.



If the compact flash card is missing from the system, the system will not allow the test to continue. Do not remove the compact flash card while the system is turned on.

NDE-360 Operation Notes: The NDE-360 system is a self-contained data conditioning, collection, basic processing and data display platform usable for a number of types of NDT tests. The system was designed to make it user friendly and easy to handle and operate by a single operator. The main screen can be navigated using a touch screen feature.



Never impact the screen with any sharp object!



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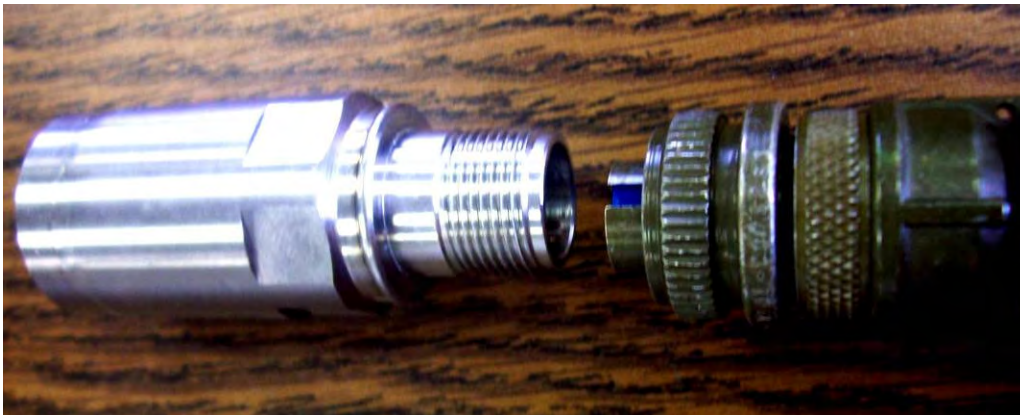
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2.3 Hardware Setup

Wilcoxon Velocity Sensor

Connect the 2-pin MS connector cable to the Wilcoxon velocity transducer by aligning the keyway on the connector with the key on the transducer and then hand-tighten the connection



Next, if needed, attach the female BNC adaptor to the BNC end of the Wilcoxon cable by aligning the pin with the hole and gently connecting the two pieces. This connection will have a locking mechanism that will prevent over-tightening the connection. Next, if needed, attach the other end of the female BNC adaptor to a BNC cable. Follow the same procedure as before when connecting these two cables.

Now attach the BNC cable to the 4 pin adaptor cable using the same procedure as before when connecting these two cables.





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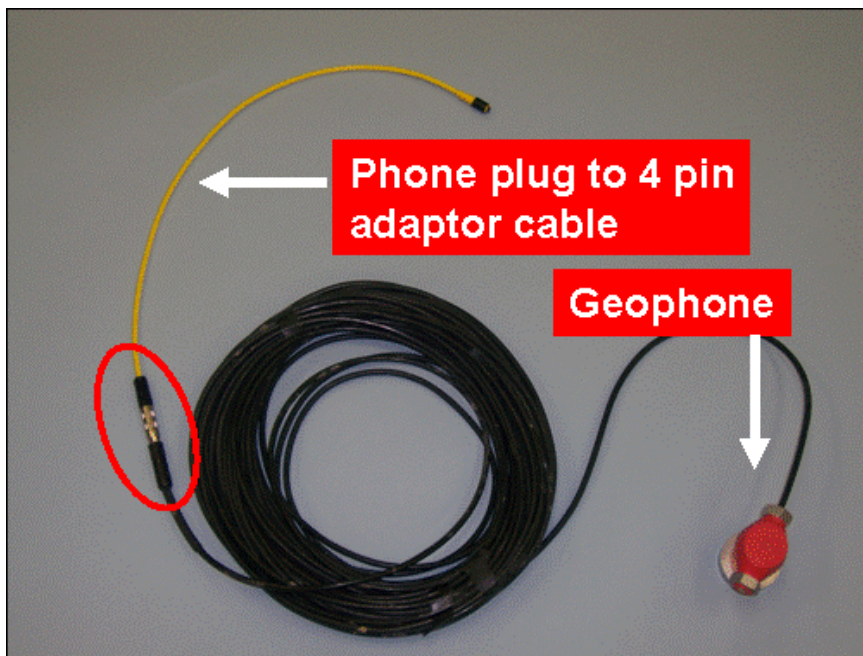
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Insert the 4 pin adaptor cable into a wideband channel (located in a row of channels close to the back side of the unit). The default channel used by the transducers (Wilcoxon or geophone) in the software for SIR is Channel 3.



Geophone Velocity Sensor

Connect the Phone Plug to 4 Pin Adaptor (Item 9) to the geophone (Item 5)



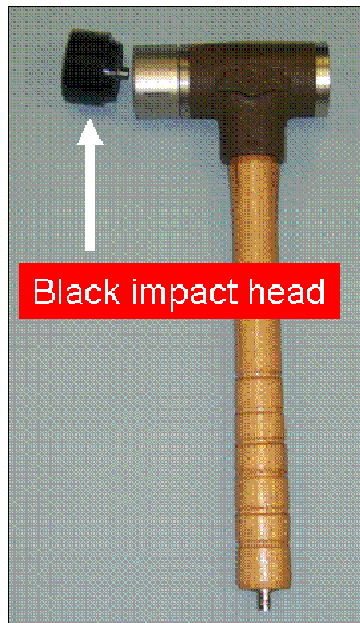


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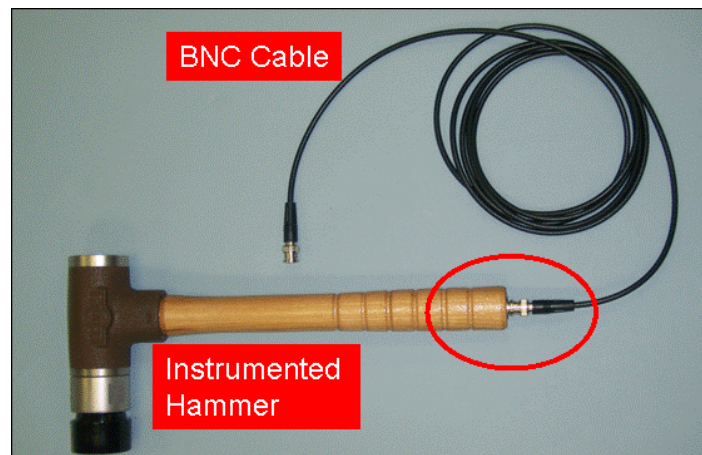
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For the SIR test, an instrumented 3 lb hammer is typically used. Screw in the impact head (Item 4 in Section 2.1) to the instrumented hammer (Item 3). The most common used head for the SIR tests is the black head. The red tip is typically used for thicker slabs (greater than about 18 inches).



Connect the BNC Cable (Item 6) to the BNC connector on the end of the instrumented hammer



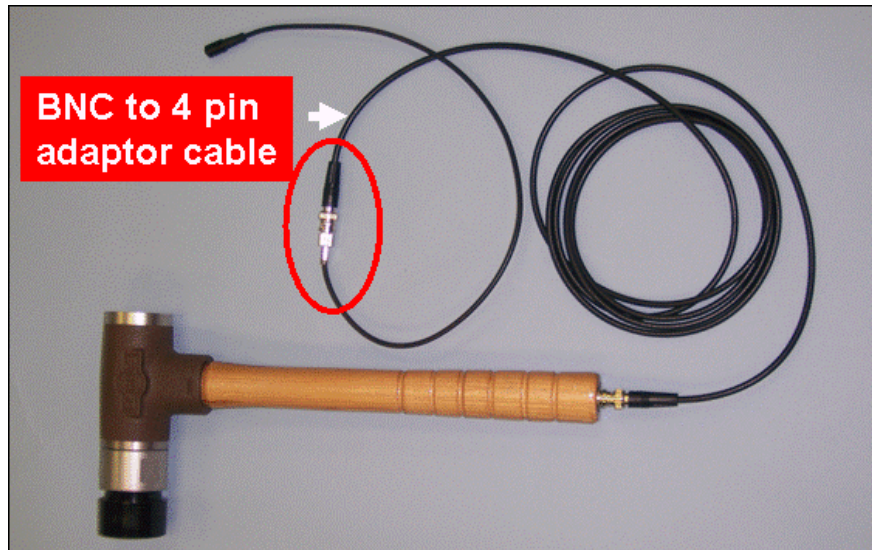


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Connect the other end of the BNC cable to the BNC to 4 pin adaptor cable (Item 8)



Connect the 4 pin adaptor end of the BNC to 4 pin adaptor cable to Channel 4 (wideband) on the NDE-360 platform

Connect the 4 pin adaptors of the extension cables to the wideband channels (in this case, channels 3 and 4) on the NDE-360 platform. For flat slabs or other horizontal surfaces, use the geophone. For angled surfaces and walls, use the Wilcoxon. The velocity transducer is connected Channel 3 and the instrumented hammer to Channel 4.





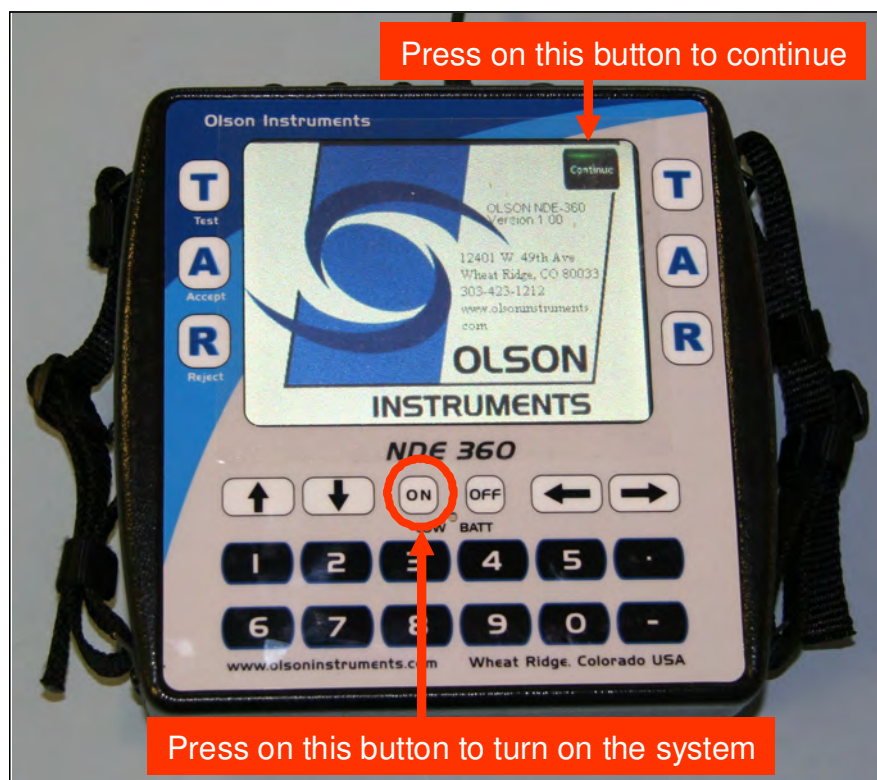
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3.0 SIR DATA ACQUISITION

1. Turn on the NDE-360 system (with the hardware in Section 2.0 connected). Make sure that the compact flash card is secured in place. The master software to run the system is located in the compact flash card, along with the key file that determines the system configuration. Press on the “Continue” button on the upper right corner of the screen. If the compact flash card is not in place, the “Continue” button will not appear on the screen.



If the continue button disappears from the screen, turn off the system and insert the compact flash card in place and turn the system on again.



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2. Press on the “SIR” option. The options included in the unit may be different depending on the installed options. The picture below shows the screen with SE (Sonic Echo), IE (Impact Echo), SASW, Slab IR (Slab Impulse Response), SE/IR (Sonic Echo/Impulse Response) and UPV (Ultra Sonic Pulse Velocity) options.



3. Press on the “Param” button to setup the data parameters, if needed. Note that the unit is loaded up with the default parameters which are appropriate for most of the SIR tests.





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4. In the parameter setup screen, the user can change the following parameters by touching the button to toggle the value. Touch the “Back” button after the parameter setup is complete.
- Change Date/Time. This option allows the user to enter the correct date and time of testing
 - Time/Point or Sampling Rate means how often (in time domain) the system will acquire data points within a given data trace. Normal SIR settings for this are 200 microseconds/point This means the system will acquire data at 200 microsecond intervals. **This parameter can not be changed after the data is taken.**
 - Points Per Record is number of sampling points for each waveform. The higher this value, the more data is acquired in each waveform. The total time of a record is affected by both the Sample Rate and the Record Size. **This parameter can not be changed after the data is taken.**
 - # Recs. Number of Record is a total number of SIR data records you want to save. **This parameter can not be changed after the data is taken.**
 - Pre-Trigger is number of points before the triggering point that data collection starts. In this case, the pre-trigger is 100 points (or $100 \times 200 \text{ us} = 20000 \text{ us}$). **This parameter can not be changed after the data is taken.**
 - Trigger Level % is the minimum signal amplitude (in terms of percentage full scale) to trigger data acquisition. In this case, the trigger level was set at 6%. Therefore, the system will start acquiring data once the absolute amplitude of the signal exceeds 0.6 volt. **This parameter can not be changed after the data is taken.**
 - Channel Setup. For the SIR test, two channels (connected to the Wilcoxon velocity transducer or geophone velocity transducer and the instrumented hammer) will be used. Any of the 4 wideband channels can be used for the SIR test. However, the default parameter is loaded with Ch 3 for Wilcoxon/Geophone (Velocity) and Ch 4 for an instrumented hammer (Force). Typically the channel connecting to the instrumented hammer will be used as a trigger channel and SREF (reference) channel.

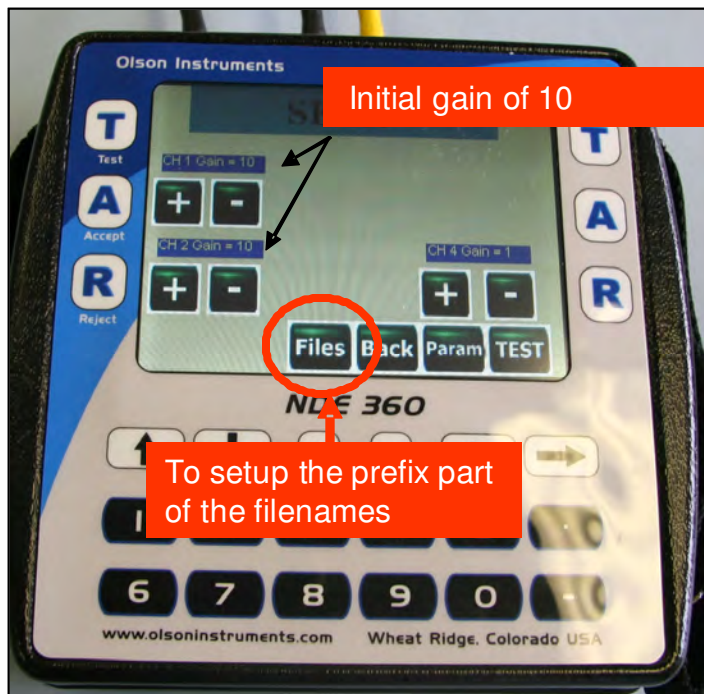




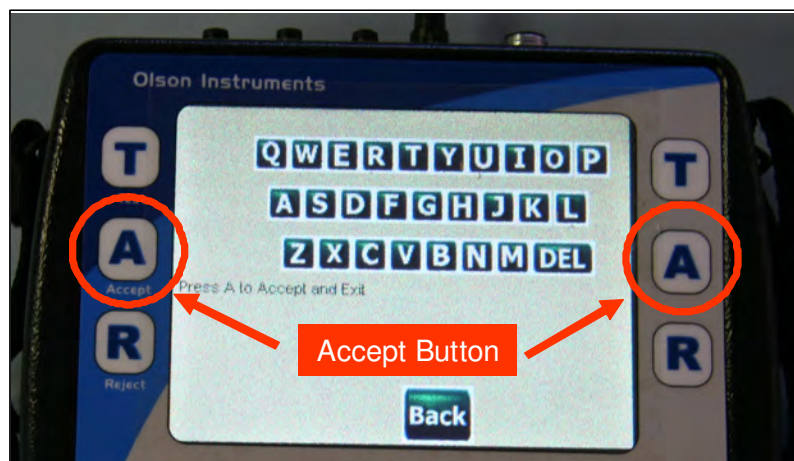
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5. After the channel setup is complete in the parameter setup menu (Step 4) press the “Back” button to return. Next, the gain control for the channel should be set by touching the + button to increase the gain value and the – button to reduce the gain value. It is recommended that a gain of 1-10 be initially used for both the hammer and velocity channels.



6. The filename arrangement of the NDE-360 uses a fixed prefix of letters and a suffix of number. The prefix can be set at the beginning of any test. If the prefix is not changed, a higher suffix number will be added to the current prefix for the new filename. To change the prefix, press on the “Files” button and press number 5 and then number 1. Then a virtual keyboard will appear on the screen and the user can change the prefix part of the filename. Press the “A” button on either side to accept the new prefix of the filename.





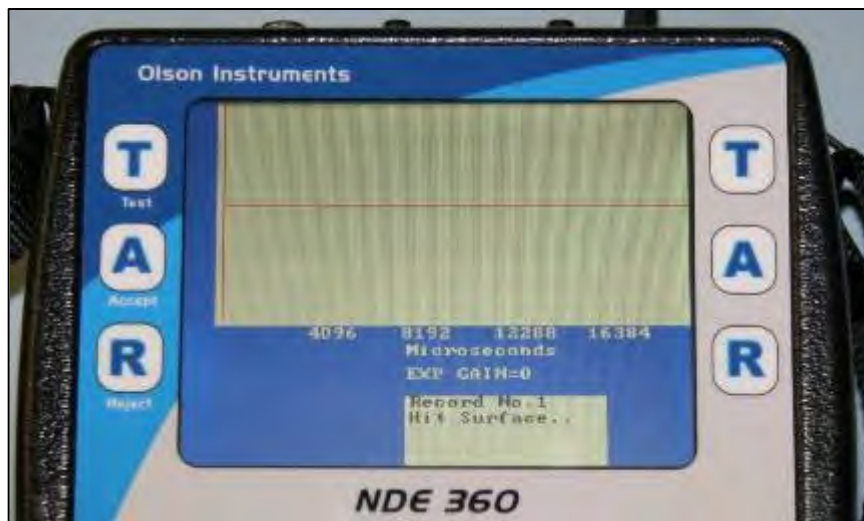
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- Now, the system is ready to acquire the SE data. Press on the “Test” button to start testing.



- The NDE-360 system will then wait for the data. Note that the voltage of the SIR time domain data on the trigger channel (usually the hammer) has to exceed the trigger level in order for the system to start taking data. Hit the hammer on the slab or wall next to the velocity transducer.

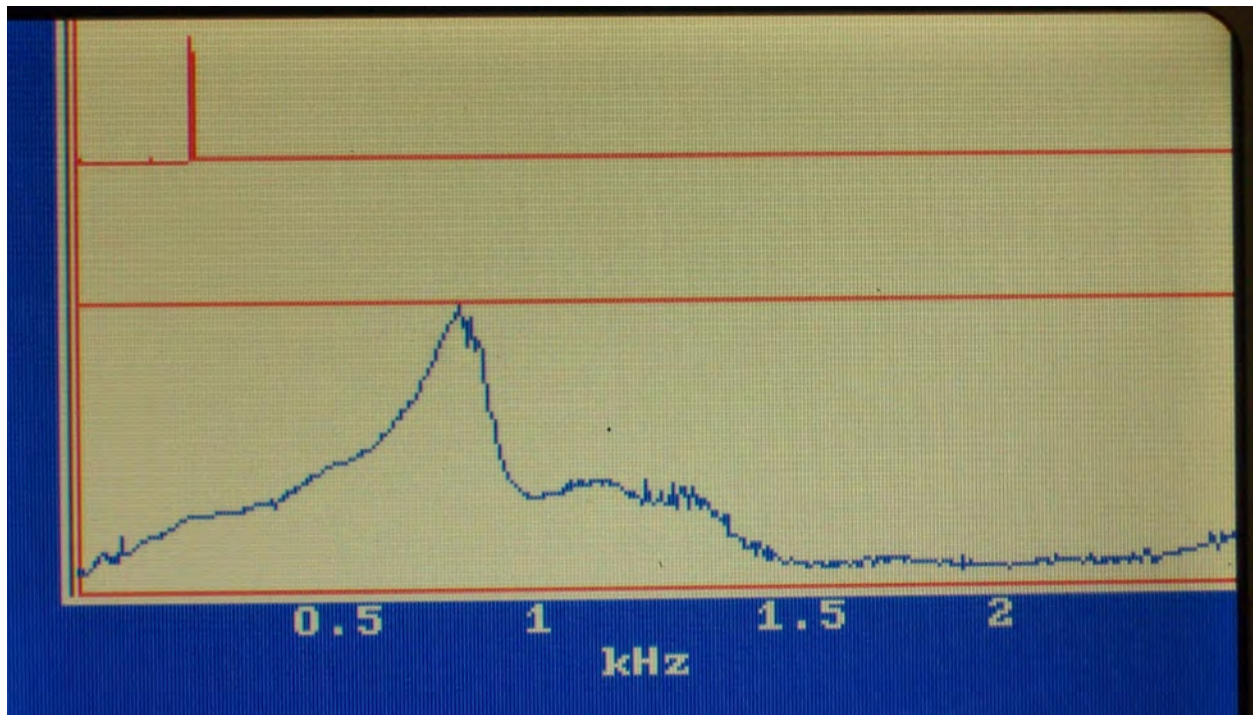




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9. If the system does not receive data for 1 minute, the test will be canceled and the user can press any key to go back to the previous menu. This happens if the gain value is too low or if the channels are not connected correctly. Try either increasing the gain value of the instrumented hammer channel or decreasing the trigger level and re-test the file. If the system receives the SIR data, it will display the SIR time domain data for one channel in the top half (hammer is pictured below) and the transfer function mobility data in the bottom half of the screen with the percentage full scale of the maximum amplitude shown below the plot. The desirable percentage full scale is between 5 – 90 %. At this point, press the “A” button to accept the data or the “R” button to reject the data currently displayed on the screen. Use the “T” button to switch to the next channel for time domain trace display of the velocity transducer.



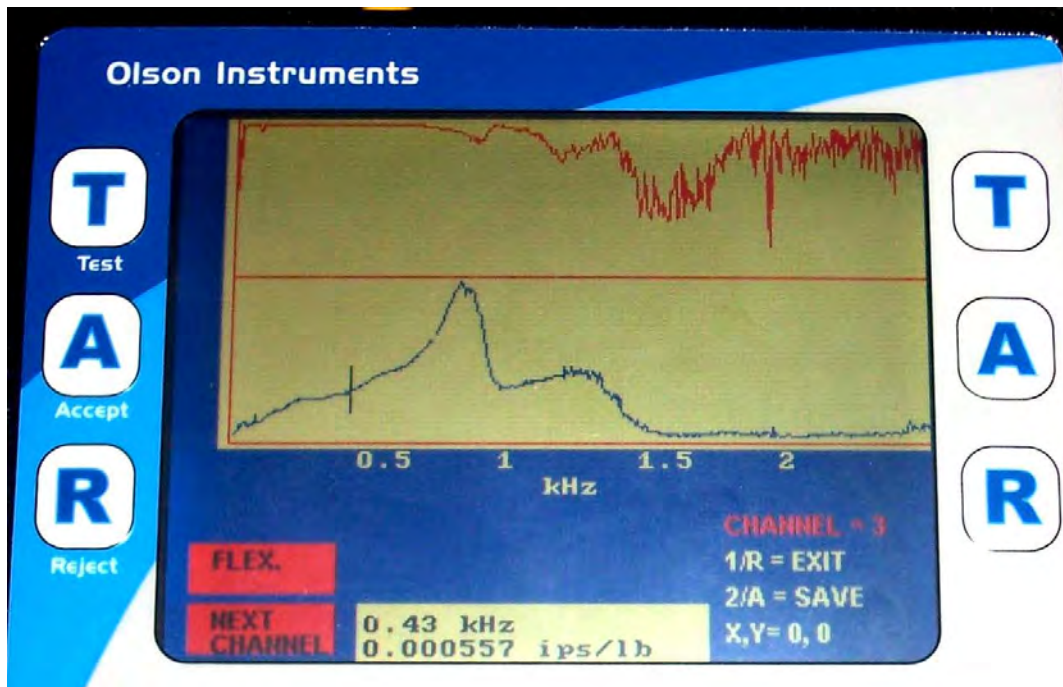
10. Repeat Steps 8 and 9 until all the records are collected.
11. To perform more SIR tests, repeat Steps 7 – 10.



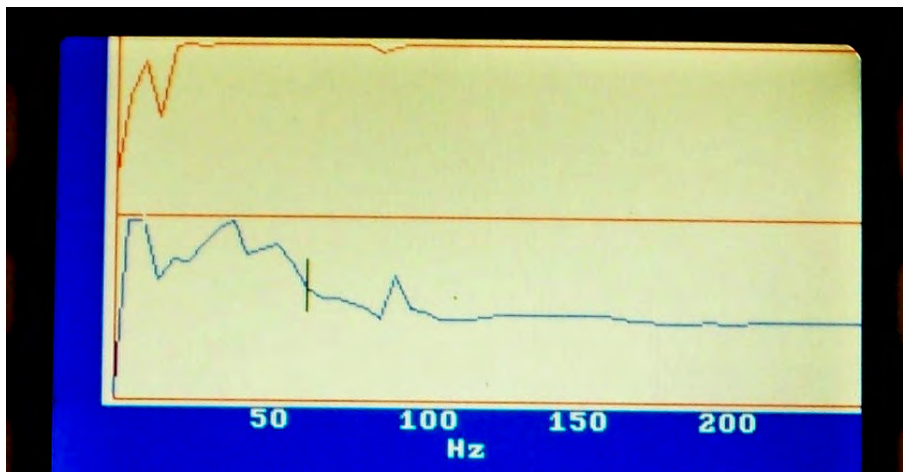
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12. Basic analysis tools included in the NDE-360 system for SIR data include the ability to read off the calibrated mobility values at any frequency using the combination touch/arrow cursor. The plot below shows a mobility value of 0.000557 inches per second per pound force at a frequency of 430 Hz. Note that the coherence plot (data quality versus frequency) is also displayed in the upper half of the display.



The software also allows the display and readout of flexibility values for low-frequency flexibility. The flexibility plot is accessed by pressing the touch-screen button, and is set to show 1/10 th of the frequency range of the mobility plot.





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13. The data can be recalled in the NDE-360 system by pressing the “File” button on the main screen and then select Option 2.
14. The data files on the compact flash card can be moved to the analysis computer for post-data analysis.

Note: The Slab IR test is a “point by point” test and usually can be performed in a grid fashion. The transducer typically does not require coupling agent between the transducer and the tested structure. However, a firm force (hand push) is required to push the transducer down to the tested structure to reduce the amount of air in between. A coupling agent can also be used for rough surfaces.



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4.0 WinTFS Software

This section covers step-by-step instructions for post data analysis and output generation for the Windows WinTFS software.

4.1 WinTFS Software Installation

1. Prerequisite software (NIDAQ version 7.4 or higher) prior to installing the WinTFS software is required. The NIDAQ drivers can be located in the enclosed CD or downloaded at:

<http://joule.ni.com/nidu/cds/view/p/id/319/lang/en>

If retrieving files from the web, download the file named NIDAQmx8.1.ZIP. Unzip the file and install the NIDAQ program. Note that an account (free of charge) may be required to proceed to the download page.



Failing to install the prerequisites will result in an error when running the WinTFS software

2. Uninstall the previous version or delete “c:\program files\olsoninstruments\WinTFS\WinTFS.exe” if the older file exists
3. Run “Setup.exe” from the Olson Instruments install CD
4. Follow the default setup
5. After finishing the installation, the “WinTFS.exe” file will be found on: drive C:\Program Files\Olson Instruments\WinTFS\ . The shortcut to the WinTFS.exe can be located on the desktop/



Failing to uninstall the previous version of the WinTFS software will prevent the installation of the new version

4.2 Software Updates

For updates to software, the only file that is necessary is the WinTFS.exe file. This file must be copied into the C:\Program Files\Olson Instruments\WinTFS directory. If not, the shortcut on the desktop references the old version of WinTFS. Simply replace the existing WinTFS.exe by copying and pasting the new version into the directory.



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4.3 Software Uninstallation

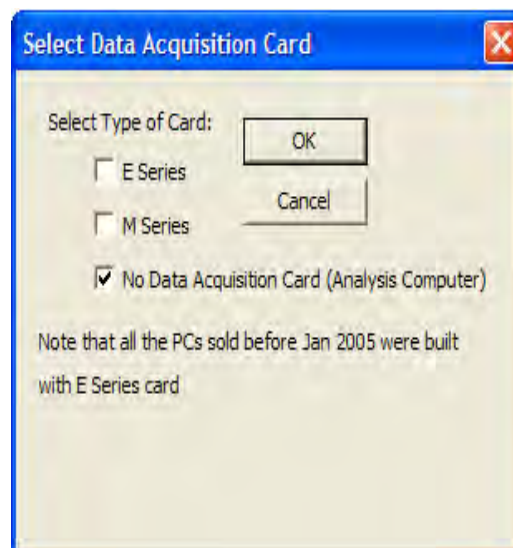
The followings are steps to uninstall the WinTFS Software

1. Click on Start/Settings/Control Panel
2. Select "Add/Remove Programs"
3. Highlight WinTFS, select "Remove"
4. The uninstall process will begin automatically, removing all installed components including the shortcut.

4.4 First Time Executing the WinTFS Software

If the WinTFS software is executed for the first time, the program detects missing software key (OlsonWinTFSKey.dat). The program will display a warning that the software key file is missing and will only enable two options on the main menu. Select the "Software Key" button and then enter the software key attached to the case of the installation disk. Exit the software and restart the software.

Now the software will detect missing parameter file (SIRdefault.prm is missing) and then will automatically generate the default file. The user will notice an applet shown below for the type of acquisition card. Select "No data Acquisition Card" option to continue.





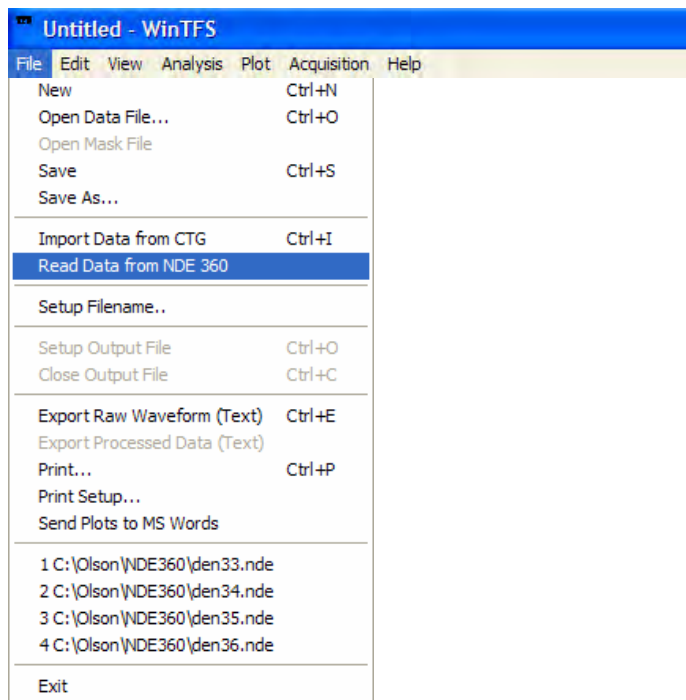
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4.5 SIR Data Recall

1. **Read the Data file:** To read the data file, go to File/Read Data from NDE-360 and select the filename to analyze.





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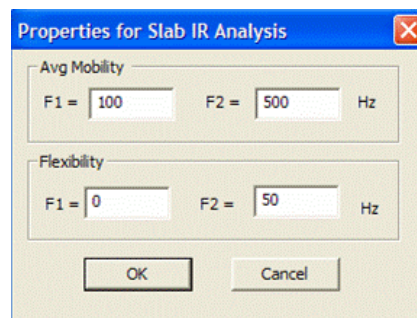
5.0 Step-by-Step Guide to WinTFS Slab IR Data Analysis

5.1 General Description of Traces

After recall of a given record, the data can be analyzed. The top trace displays the current time domain record for one of the two channels. The second trace displays an average coherence of accepted records and the last trace displays either mobility or flexibility of the data (depending on the setting – See Section 5.2).

5.2 Flexibility - Mobility

To toggle between the mobility and flexibility, go to Analysis/Mobility-Flexibility (or press F9). The frequency range of mobility or flexibility can be changed by going to Analysis/Slab IR Mobility-Flexibility Properties. Values of flexibility and mobility, along with the mobility and flexibility plot shape, are used to determine the condition of the structure being tested and locate voids. This is described in detail in Section 6.



5.3 Output File

To turn on the output file (text format), go to File/Setup Output File and give the file any name. The software will automatically record the filename, mobility within the selected frequency range, flexibility within the selected frequency range, and the ratio to the output file as columnar ASCII text. Also included will be the X-Y coordinates entered during data collection. This output file can be recalled in Excel or other plotting programs for further processing and 2D/3D data presentation.



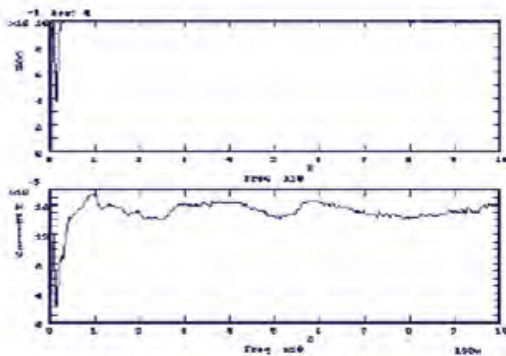
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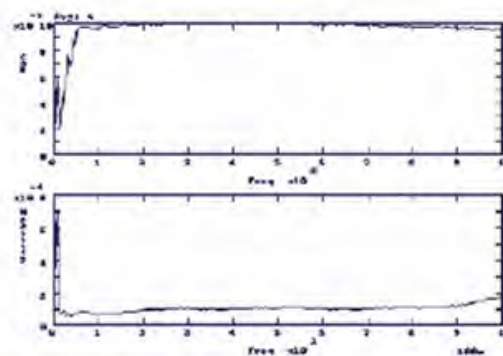
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6.0 Slab IR Data Interpretation

The Slab IR method is used to determine the support conditions of the slab and to map out the aerial extent of any void or poor support condition zones, but the method cannot determine the thickness of any voids found. Collecting Slab IR data at multiple, densely-spaced locations can improve the conclusions by mapping relative areas of higher and lower mobility. However, relatively low mobility does not indicate the absence of a subgrade void, but qualitatively indicates that such an area appears to be more solidly supported than an area with relatively high mobility. For thick slabs (thickness > 2 ft), the interpretation of the Slab IR data becomes difficult because the stiffness of the system is controlled by the slab itself and not by the support conditions under the slab. The figure below shows example mobility results from subgrade with voids and sound subgrade. The top traces are coherence and the bottom traces are mobility plots.



Subgrade with Voids



Solid Subgrade

Parameters used in the Slab IR data interpretation include: [from ASTM Standard of Practice for Impulse Response – Work in Progress]

- **Average Mobility.** The average mobility between 100 – 800 Hz is related directly to density, elastic modulus, and thickness of the plate element. A reduction in the plate thickness results in an increase in mean mobility. Cracking or honeycombing in the concrete will reduce rigidity thus an increase in mean mobility.
- **Mobility Slope.** The mobility of honeycomb concrete shows increasing mobility with increasing frequency over the frequency range of 100 – 800 Hz whereas the solid concrete shows a relatively constant mobility over the same frequency range.



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- Peak to Mean Mobility Ratio. This value is called “ratio” for short in this program. This ratio is the indication of subgrade voids. When this value exceeds 2.5, loss of support beneath slab on grade is indicated.