PaveScan® MDM Manual

MN36-743 Rev A

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FCC Notice for U.S. Customer

Canadian Requirements for RSS-220

Declaration of CE Conformance

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Chapter 1: Overview

The Mix Design Module is designed to work with the Mix Design Module Hardware Kit to obtain dielectric values of gyratory-compacted samples and cores. The dielectric values obtained from the samples can then be used to create a mix calibration. The mix calibration numbers are used by the PaveScan® RDM 2.0 system to convert field dielectrics to compaction values.

Unpacking Your System

The following items are needed to make measurements:

1 - Model 42600 Sensor

1 - Toughpad computer with docking station

1 - Concentrator Box with power supply

1 - Cable to attach Toughpad to Concentrator box

1 - Cable to attach Sensor to Concentrator box

2 - White 5.9 x 5.9 x 1.45 inch (150 mm x 150 mm x 37.0 mm) blocks

1 – 5.9 inch (150 mm) diameter metal plate

1 - Plastic frame that fits over the bottom of the sensor

1 - Verification cylinder

Setup

1 Make all the necessary cable connections:

a) Connect cable from Sensor to the Concentrator Box.

b) Connect cable from the Concentrator Box to the Toughpad computer docking station.

2 Place the plastic frame over the Sensor, ensuring it clicks into place.

3 Place one of the white blocks inside the frame.

Two important things to note related to the setup:

- The location of the setup should be free of obstacles within a radius of 1 foot (30 cm) around the sensor.
- The cable needs to be positioned below the bottom of the white block within the 1 foot (30 cm) radius surrounding the sensor.

Hardware setup showing frame over sensor with white block nestled inside frame and the cable below the level of the bottom of the white block.
Note, the black cable is below the bottom of the white block.

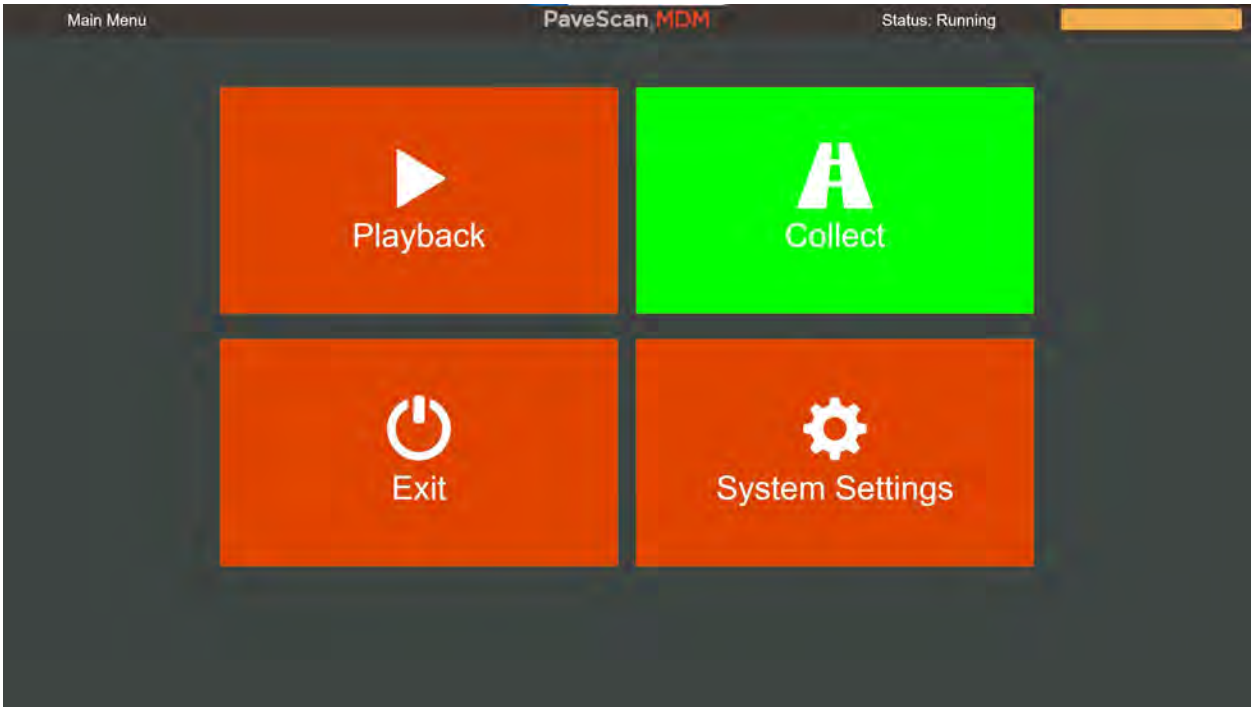
4 Once this is done, press the power button on the concentrator box and turn on the computer. The sequence in which these are done doesn't matter.

- The Main menu of the Mix Design Module will appear on the screen once the computer is fully booted up.

Main Menu

The main menu consists of four buttons, shown below. The **Collect** button in the upper right corner is initially grayed out and will turn green once the sensor is detected.

- If the button does not turn green after 15 seconds, power off the concentrator box, check to make sure the batteries in the concentrator box have more than 1 bar and check to make sure the cable connections are tightened sufficiently. Only hand tighten the connectors.



Main Menu: First screen seen when starting the Mix Design Module.

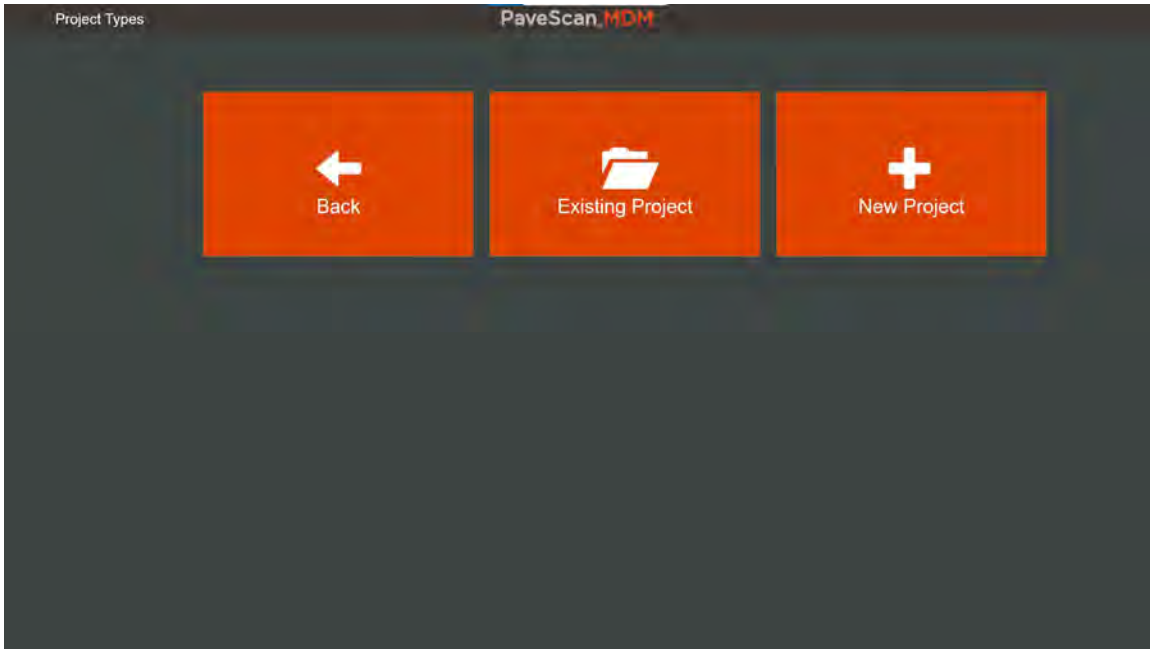
Collect Measurements

1 To initiate the sequence needed to make measurements, press the green **Collect** button.

- The sensor detection screen appears and indicates the serial # of the sensor.
- The **Detect Again** button can be pressed if no sensor serial number appears. This is very uncommon, though.
- If the **Collect** button turns green, then the sensor is detected.

Sensor Detection Screen

2 Press the **Next** button and in the screen that appears select an existing project or create a new one.

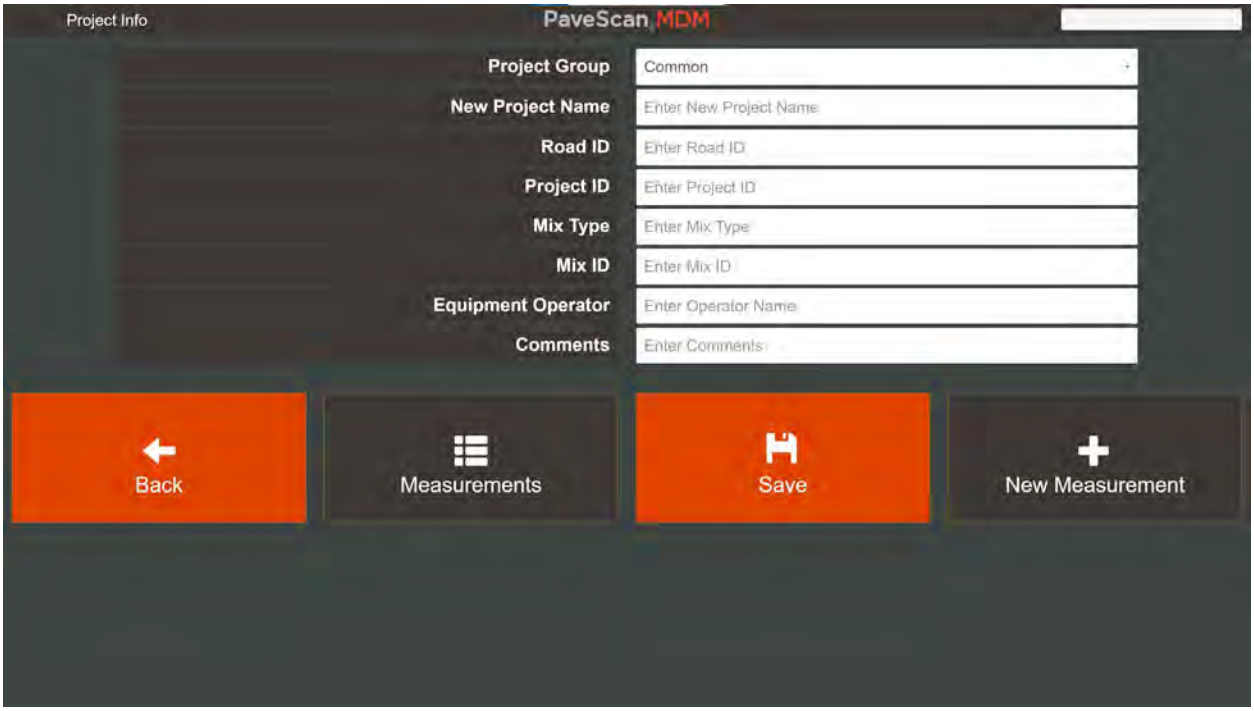


Project Type Screen: Select either an existing project or create a new one.

3 After pressing either **Existing Project** or **New Project**, the Project Info screen appears. The intent of organizing measurements into projects is to provide a way to group measurements for the purpose of generating a calibration equation relating dielectric to compaction. A list of entries is shown.

Project Group: Projects can be organized by assigning to different groups. One practical use is to create a new project group for each paving job and all calibrations done for the paving job will be contained in projects belonging to that project group.

Project groups are created in the File Management area which is accessed from System Settings on the Main Menu.

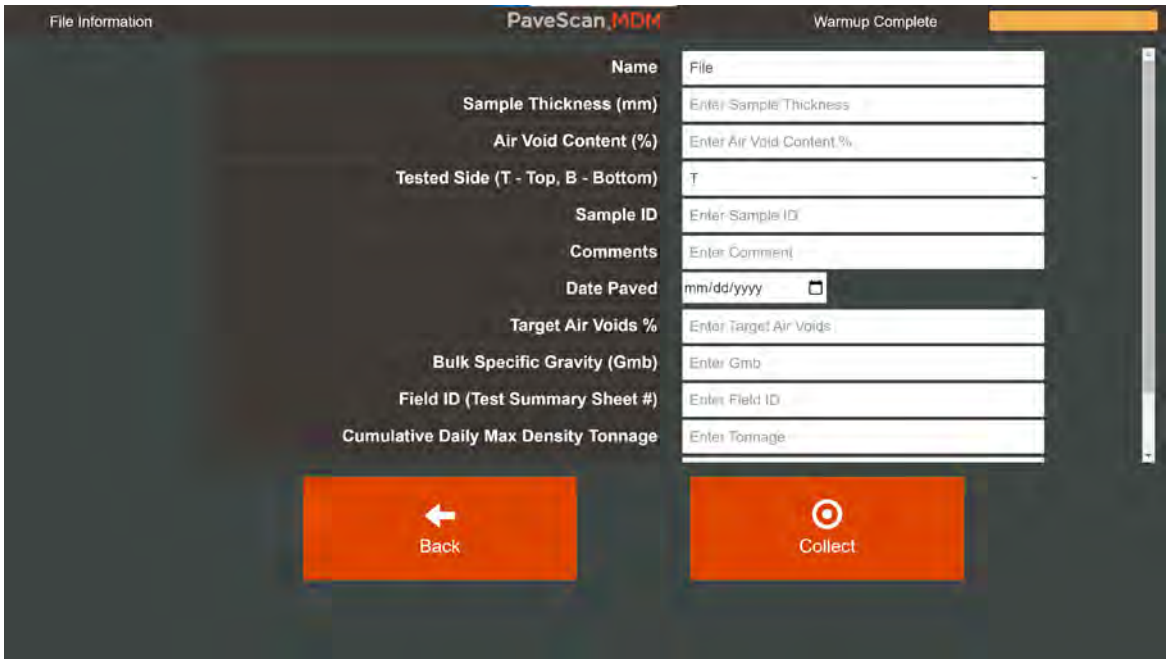


Project Information Screen: For new projects a new project name must be entered and saved. Other entries are optional

4 The other entries are saved with the project and provide a convenient way to keep all the information together. The only entry that is necessary to fill out is the Project Name. Once the desired entries are filled, press **Save** and then **New Measurement**.

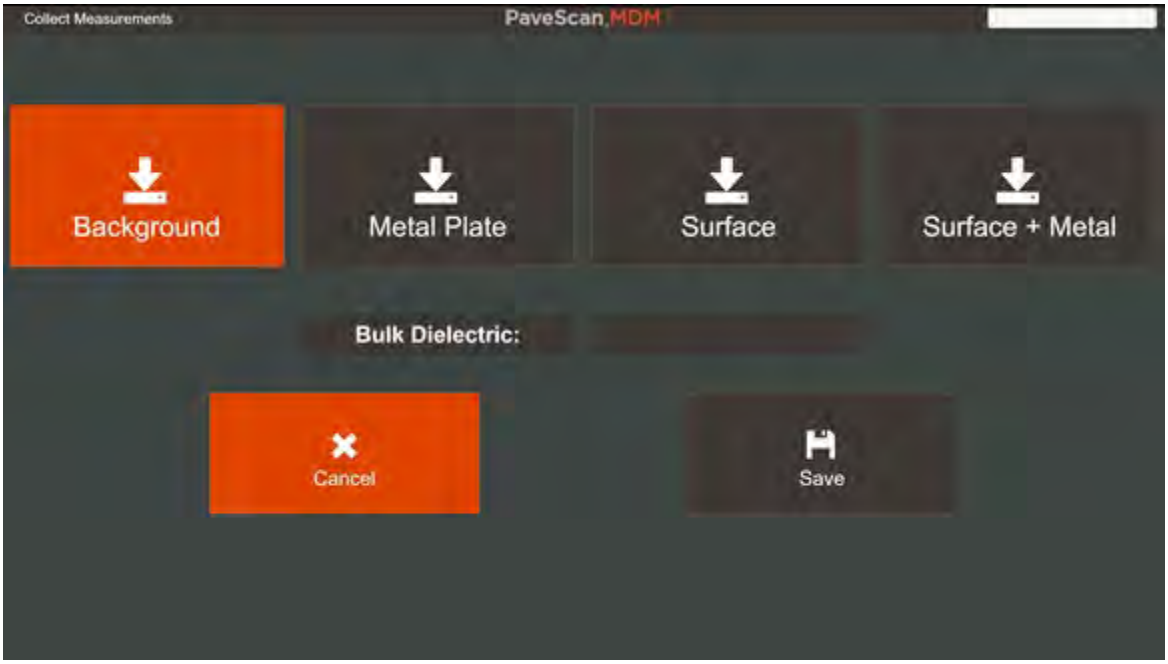
5 After pressing **New Measurement**, the File Information screen shown appears. It has entries for information that can be tied to each measurement.

- The Name and Sample Thickness fields must be filled in before a measurement can be made.
- The Air Void Content field needs to be entered if the dielectric measurement will subsequently be used to generate a calibration between dielectric and % voids. The Air Void Content field can be filled out after the dielectric measurement is made.



File Information Screen: Enter all information associated with a measurement here.

6 There is a 2-minute warm-up period before the first measurement can be made. Once the warm-up time is completed, the **Collect** button turns red. Press the **Collect** button. The screen that appears has four buttons, one button for each measurement.

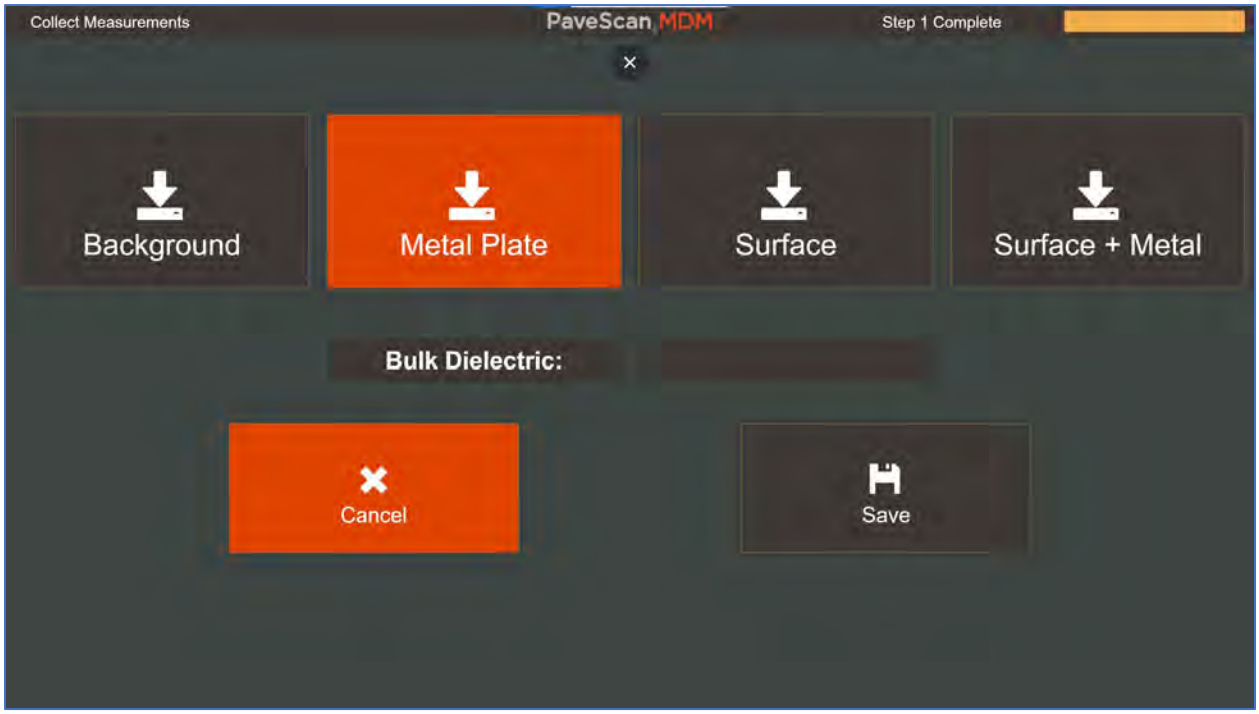


Measurement Screen: Press successive buttons from left to right to perform the four measurements (Background, Metal Plate, Surface, and Surface plus Metal) necessary to calculate the Bulk Dielectric.

7 Prior to pressing the **Background** button, place a second white block on top of the first white block, making sure the edges align. Then, press the **Background** button.

Setup for the Background measurement.

8 Once the background measurement, which only takes a few seconds, is completed, the **Metal Plate** button will turn red.



Once the background measurement is completed, the **Metal Plate** button turns red.

9 For the metal plate calibration, remove the second white block and in its place, align the metal plate.

Setup for metal plate measurement. There is only one white block beneath the metal plate.

10 Once the metal plate is in place, press the **Metal Plate** button and wait several seconds for this measurement to complete.

11 When it is completed, the **Surface** button appears. This indicates that the sample should be placed on the white block.

- Position the sample on the white block so it is centered as accurately as possible. This is relatively easier to accomplish than one may think because the gyratory-compacted sample diameters are within a couple mm of the width of the white blocks.

Setup for Surface measurement.

12 After the sample is in place, press the **Surface** button and wait for the measurement to finish.

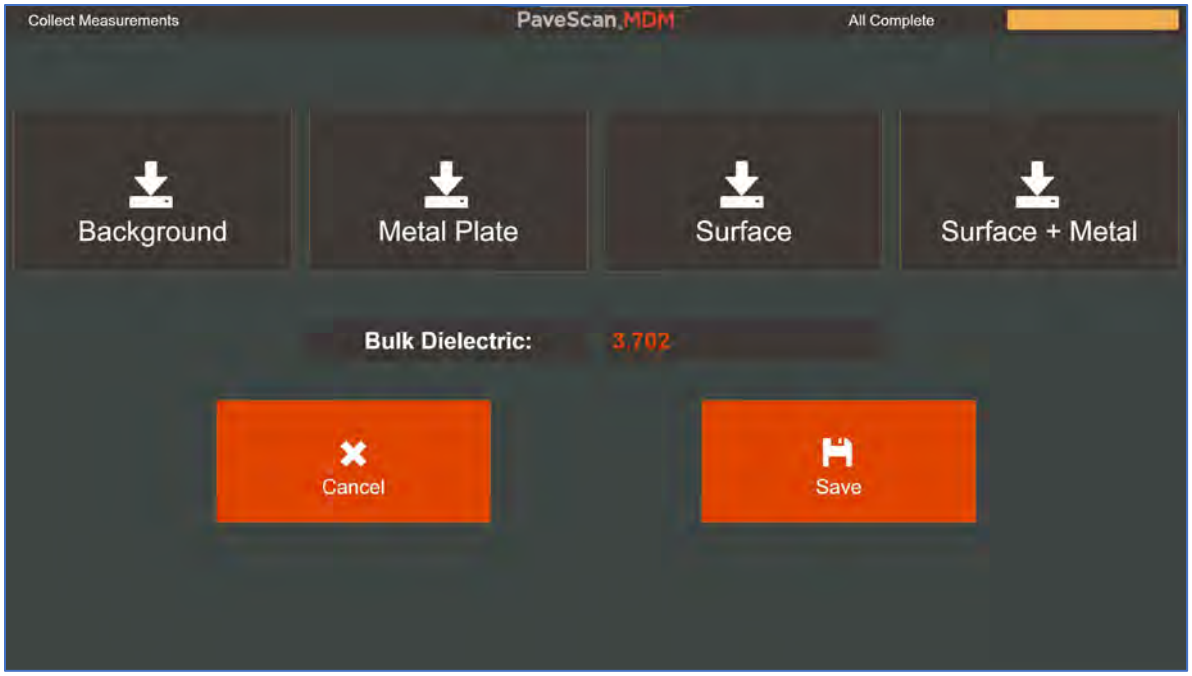
a) When the **Surface + Metal** button turns red, without moving the sample, place the metal plate on the top of the sample so it is centered as accurately as possible, as shown below. Make sure that the sample position on the white block does not change.

b) If the sample position has shifted, press the **Cancel** button and restart the measurement sequence.

Setup for Surface+Metal measurement.

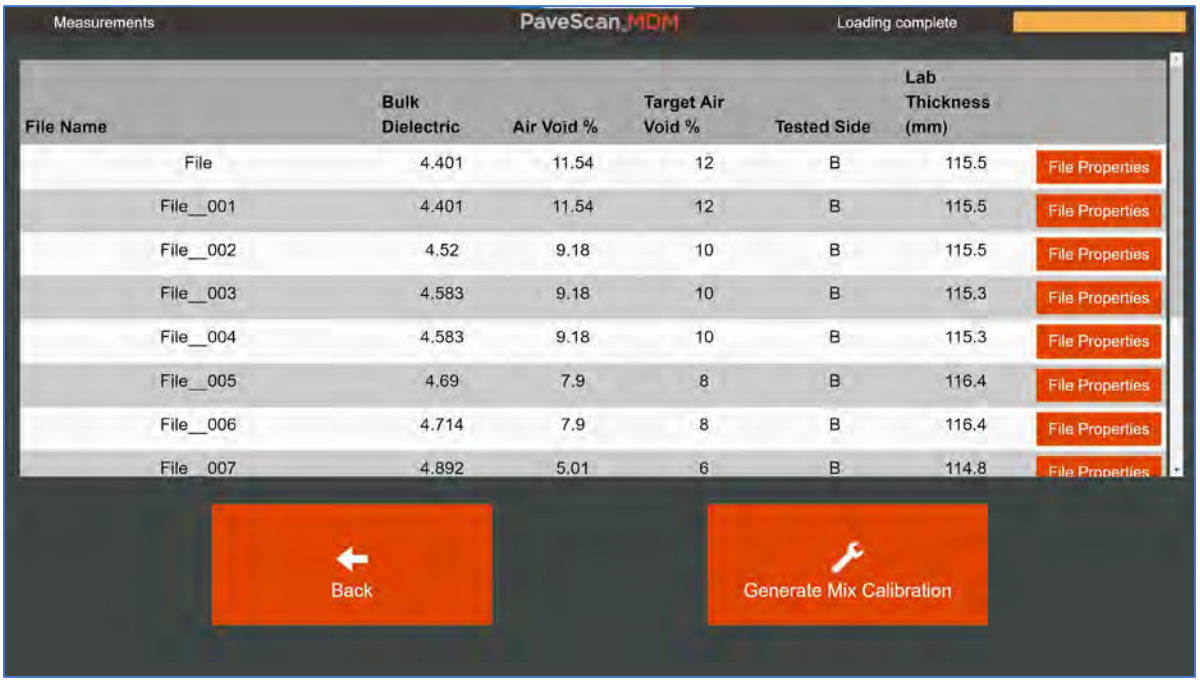
13 With the metal plate in place, press the **Surface+Metal** button. When this measurement concludes, the calculated bulk dielectric appears.

- Press **Save** to save the measurement.
- If you don't want to save this measurement, press **Cancel**.
- Pressing either button returns you to the File Information screen. Multiple dielectric measurements can be made in this manner. Each dielectric measurement is saved in its own file.



Bulk dielectric appears after the Surface+Metal measurement is completed.
Press **Save** or **Cancel**.

14 Once all the dielectric measurements are made on all the samples, they can be viewed by pressing the **Back** button in the File Information screen. This returns you to the Project Information screen where you can press the **Measurements** button and view all the measurements belonging to the project you loaded or created.



File Name	Bulk Dielectric	Air Void %	Target Air Void %	Tested Side	Lab Thickness (mm)	
File	4.401	11.54	12	B	115.5	File Properties
File__001	4.401	11.54	12	B	115.5	File Properties
File__002	4.52	9.18	10	B	115.5	File Properties
File__003	4.583	9.18	10	B	115.3	File Properties
File__004	4.583	9.18	10	B	115.3	File Properties
File__005	4.69	7.9	8	B	116.4	File Properties
File__006	4.714	7.9	8	B	116.4	File Properties
File__007	4.892	5.01	6	B	114.8	File Properties

Measurements Screen showing all the measurements belonging to a project.

15 Press the **File Properties** button next to the associated measurement to view and edit information associated with each measurement. Press the **Generate Mix Calibration** button to proceed to the Core Calibration screen which is used to generate a calibration equation between the Air Void % and the measured dielectric.

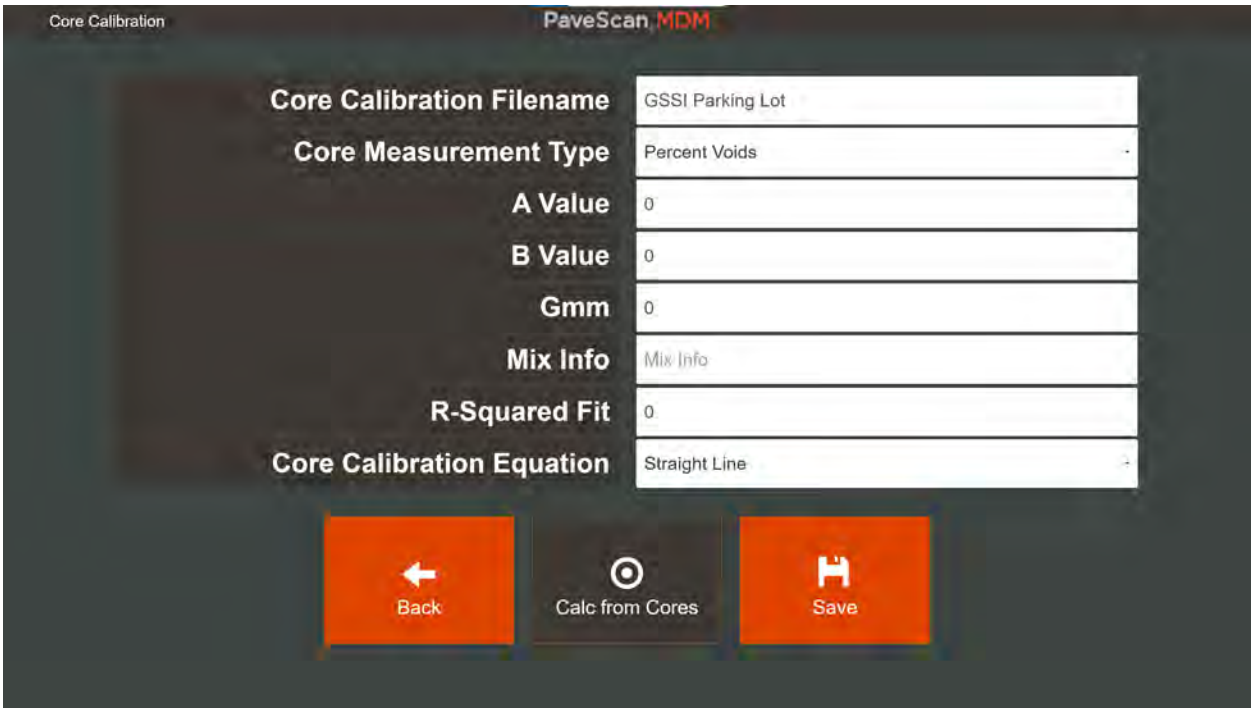
Generating a Mix Calibration

A mix generation can be calculated from the measurements in a project by pressing the **Generate Mix Calibration** from the Measurements Table.

Note: The Measurements Table is accessed from the Project Info screen, which is available during collection and playback of projects.

1 After pressing the **Generate Mix Calibration** button, the Core Calibration screen appears. By default, a new core calibration file is generated.

- The new file needs to be saved before the core calibration equation can be calculated. So, make any necessary adjustments to the Filename or Mix Info and press **Save**.
- When this is done, the **Calc from Cores** button turns red, signifying that it is available.



Core Calibration screen. Press **Save**, then press **Calc from Cores** to generate a calibration equation.

Core Measurement Type: The core physical property that is to be correlated to dielectrics. The core measurement type used in the Mix Design Module is % Voids.

A Value: This is the first value used in the equation relating dielectric to another physical property (see Appendix A for details)

B Value: This is the second value used in the equation relating dielectric to another physical property (see Appendix A for details)

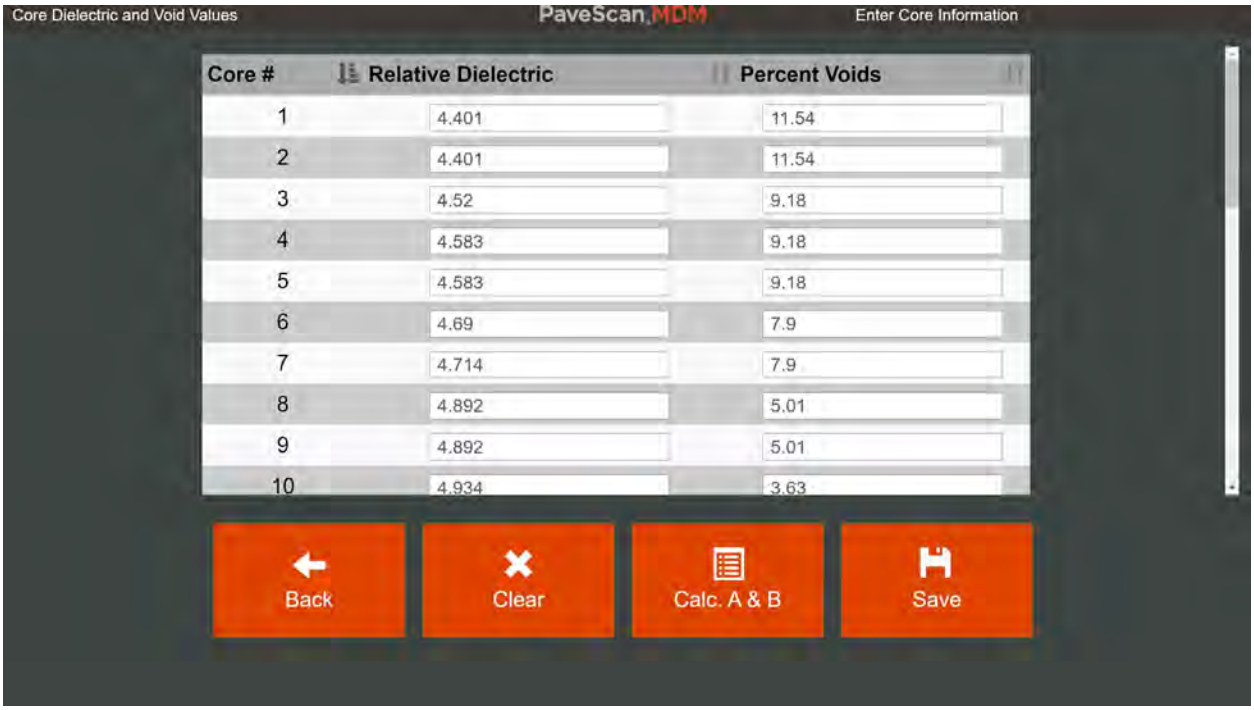
Gmm: "Gravity, mix maximum" which is the maximum specific gravity of the mix. This value is necessary when converting from % Voids or % Compaction to density and visa-versa.

Mix Info: An optional field for entering in mix information, such as an ID or mix name.

R-Squared Fit: This is for information purposes-only and is auto-generated when the **Calc from Cores** button is pressed. It provides a good indication of confidence level that the calculated equation is useful. Values less than 0.6 – 0.7 lead to low confidence levels.

Core Calibration Equation: There are two types of core calibration equations: Exponential and Straight Line. The type entered must match the type used to calculate the A and B values. ***Use of the Straight Line equation type is highly recommended***. See Appendix A for details on how these values are derived.

2 Press the **Calc from Cores** button. The Core Dielectric and Void Values table appears containing all the measurements from the file.

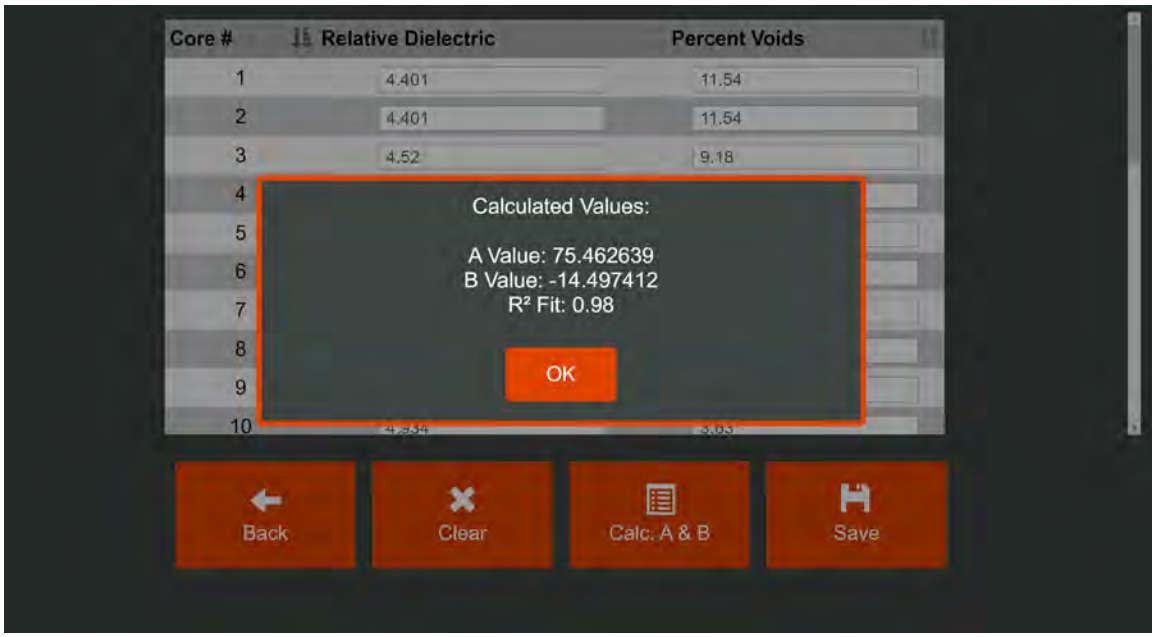


Dielectrics and associated %Voids from all the measurements in the project. These values are used to generate the calibration equation.

3 Press the **Calc. A & B** button and the least-squares fit line will be generated from the measurements.

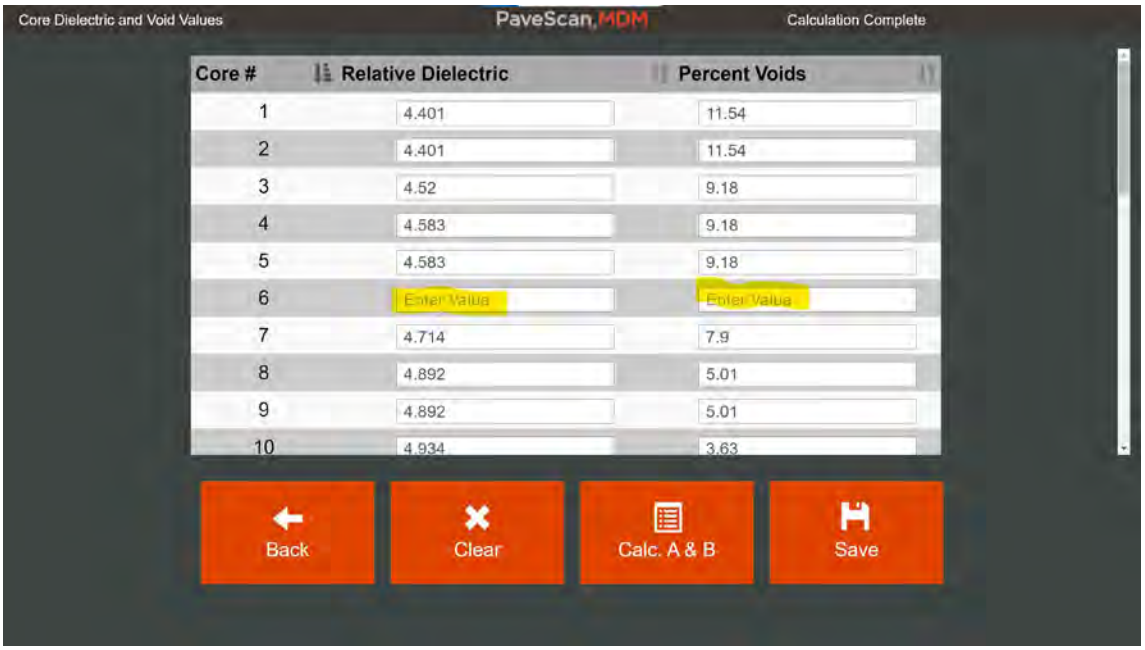
- The A and B values shown correspond to the linear coefficients forming the line from the equation Y = A + BX. The Y value of the equation corresponds to % Voids and the X value is dielectric.

- After pressing **OK** to close the pop-up window, press the **Save** button to save the calibration equation.



Popup showing equation for best-fit line based on the measurements in the table.

4 Occasionally, it is desirable to remove one or more measurements from the calibration. This is easily done by clicking on the desired measurement and removing all the numbers for the dielectric and percent voids. This "blanks" out the row. Then press the **Calc. A & B** button to calculate the calibration from the remaining numbers.



Values can be removed from the list by clicking on the column entries and erasing all the numbers.

Playback

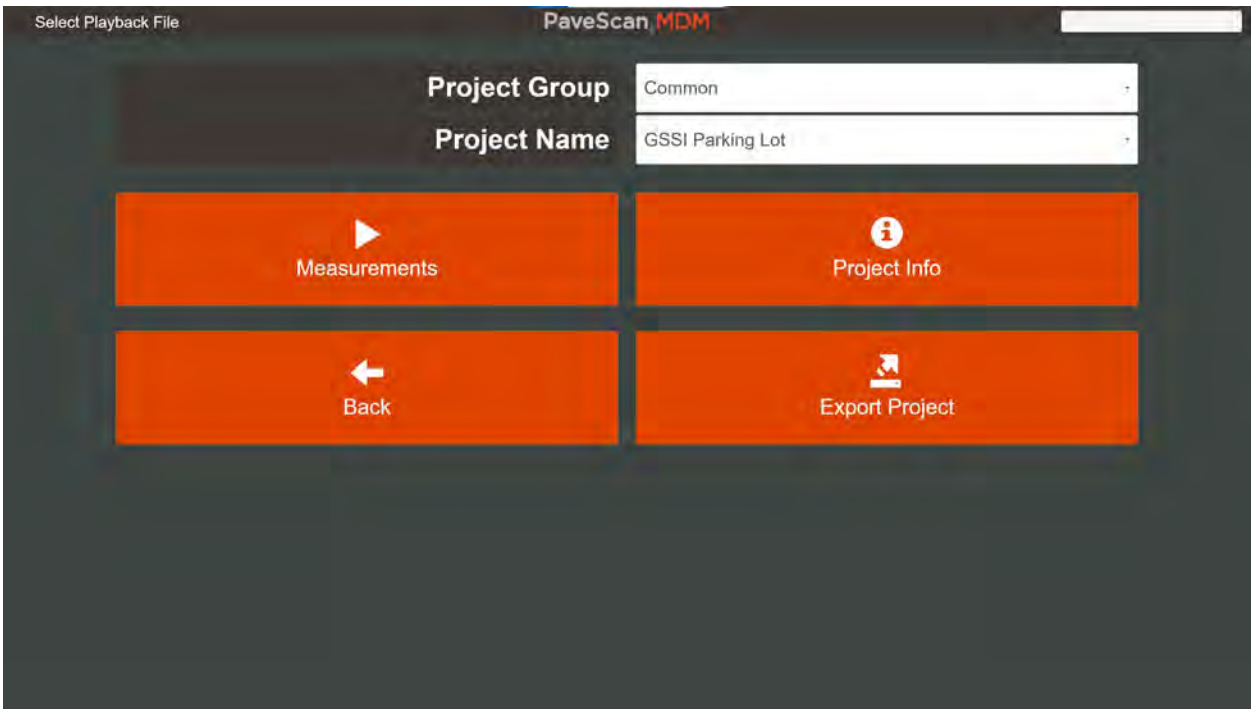
Previously generated projects can be viewed, edited, used to generate calibration equations, and exported in the playback mode.

1. To access the playback mode, press the **Playback** button from the Main Menu. This opens up the Select Playback File screen.

2. Use the dropdown lists provided for Project Group and Project Name to select any previously generated project.

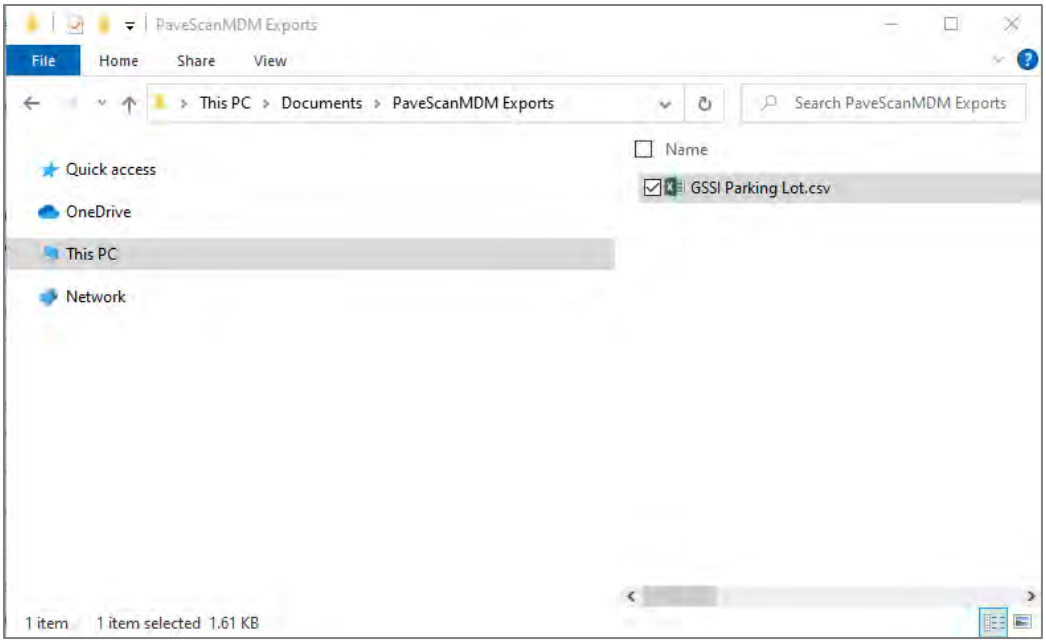
3. Then press the **Measurements** button to view the measurements and optionally generate a core calibration file.

4. Press the **Project Info** button to view and edit the previously entered project information.



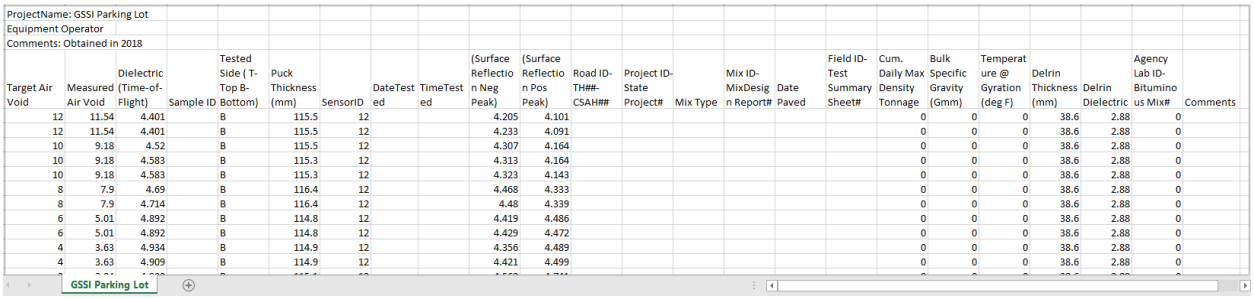
Playback Screen: User can view projects, measurements, and export measurement data.

5. The currently selected project measurement data is exported to a CSV file when the **Export Project** button is pressed. The exported filename is the name of the project. The location of the file is the folder PaveScan MDM Exports located in the Documents folder.



Location of exported project file.

6 The exported file contains the user-entered information in the File Information screen as well as the measured values.



ProjectName: GSSI Parking Lot
Equipment Operator
Comments: Obtained in 2018

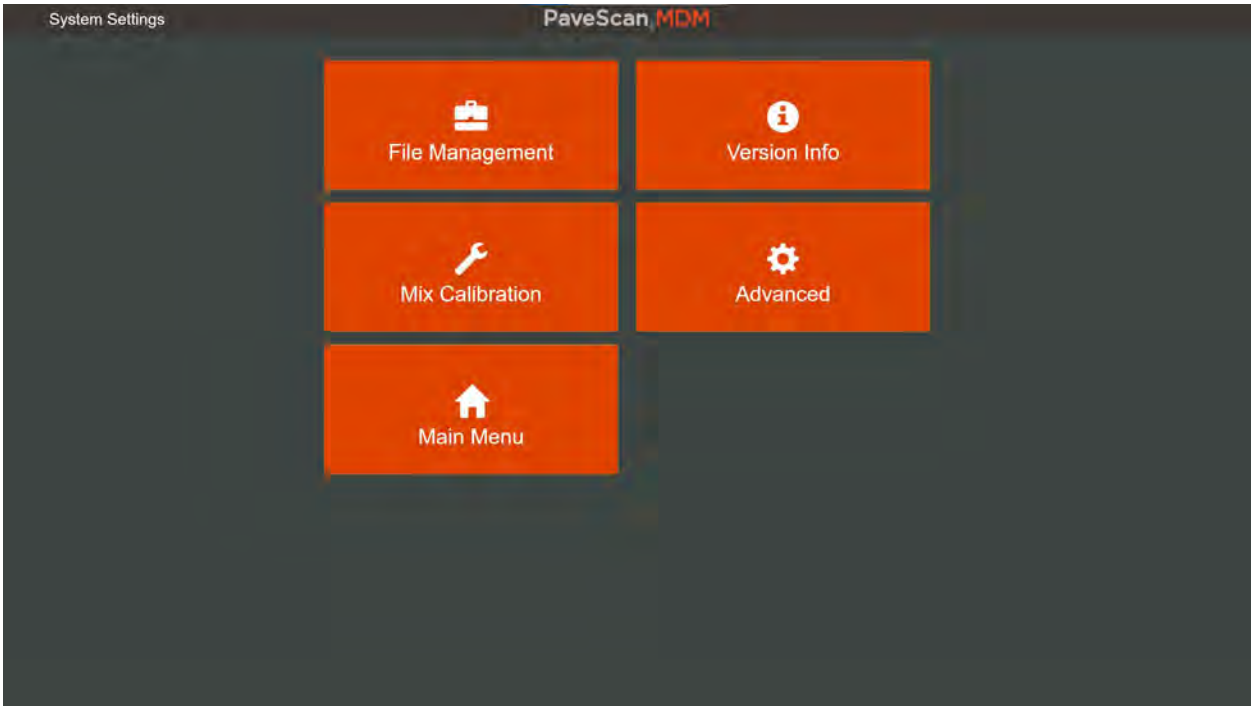
Target Air Void	Measured Air Void	Dielectric (Time-of-Flight)	Sample ID	Tested Side (T-Top B-Bottom)	Puck Thickness (mm)	SensorID	DateTested	TimeTested	(Surface Reflection Neg Peak)	(Surface Reflection Pos Peak)	Road ID-TH##-CSAH##	Project ID-State Project#	Mix Type	Mix ID-MixDesign Report#	Date Paved	Field ID-Test Summary Sheet#	Cum. Daily Max Density Tonnage	Bulk Specific Gravity (Gmm)	Temperature @ Gyration (deg F)	Delrin Thickness (mm)	Delrin Dielectric	Agency Lab ID-Bituminous Mix#	Comments
12	11.54	4.401		B	115.5	12			4.205	4.101							0	0	0	38.6	2.88	0	
12	11.54	4.401		B	115.5	12			4.233	4.091							0	0	0	38.6	2.88	0	
10	9.18	4.52		B	115.5	12			4.307	4.164							0	0	0	38.6	2.88	0	
10	9.18	4.583		B	115.3	12			4.313	4.164							0	0	0	38.6	2.88	0	
10	9.18	4.583		B	115.3	12			4.323	4.143							0	0	0	38.6	2.88	0	
8	7.9	4.69		B	116.4	12			4.468	4.333							0	0	0	38.6	2.88	0	
8	7.9	4.714		B	116.4	12			4.48	4.339							0	0	0	38.6	2.88	0	
6	5.01	4.892		B	114.8	12			4.419	4.486							0	0	0	38.6	2.88	0	
6	5.01	4.892		B	114.8	12			4.429	4.472							0	0	0	38.6	2.88	0	
4	3.63	4.934		B	114.9	12			4.356	4.489							0	0	0	38.6	2.88	0	
4	3.63	4.909		B	114.9	12			4.421	4.499							0	0	0	38.6	2.88	0	

Exported project file as it appears in Excel.
(Column width adjustment and word wrap has been applied in Excel)

System Settings

System Settings are accessed by pressing the **System Settings** button in the Main Menu. The Main Menu is the screen that appears when the system is started up and can always be accessed by pressing the **Back** button as many times as is necessary (the user may have to press the back button for each screen that appears after initially pressing the back button).

The screen showing five buttons containing various System Setting options appears after pressing the **System Settings** button in the Main Menu.

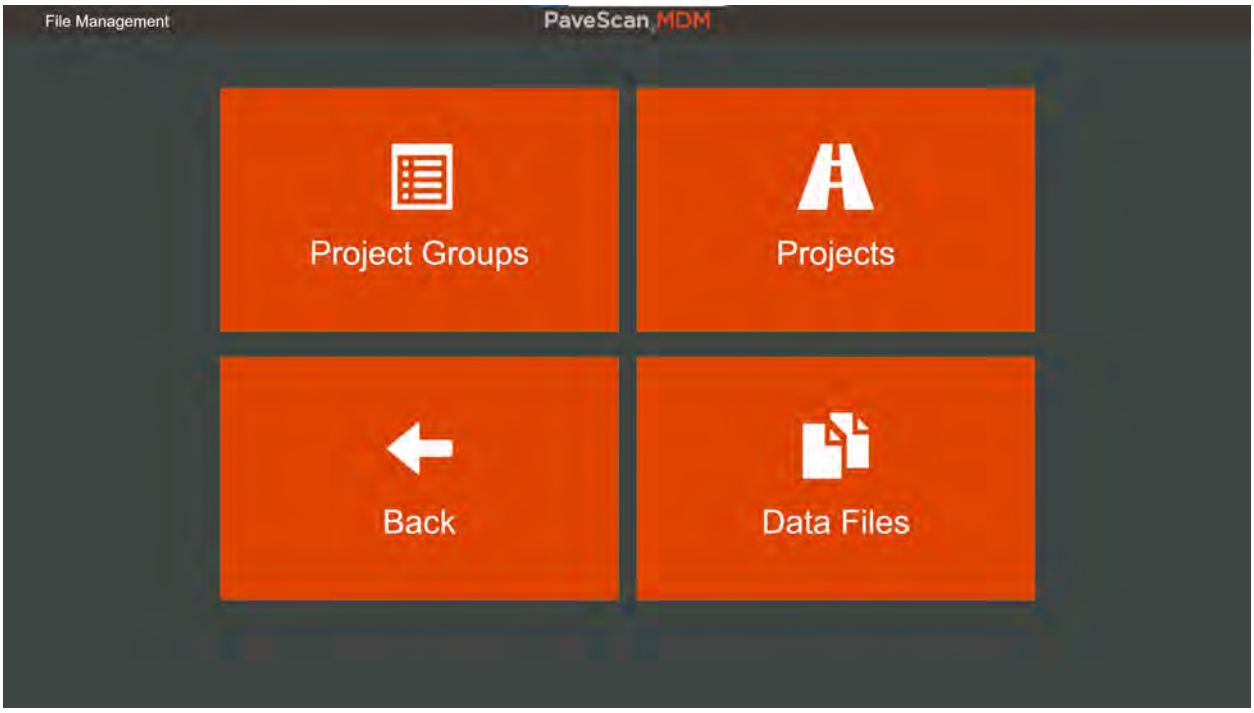


System Settings Screen

Each System Setting option is described below.

System Settings -> File Management: Provides access to Projects and Measurements. Each measurement is stored in its own file. Projects and measurement files can be edited and removed.

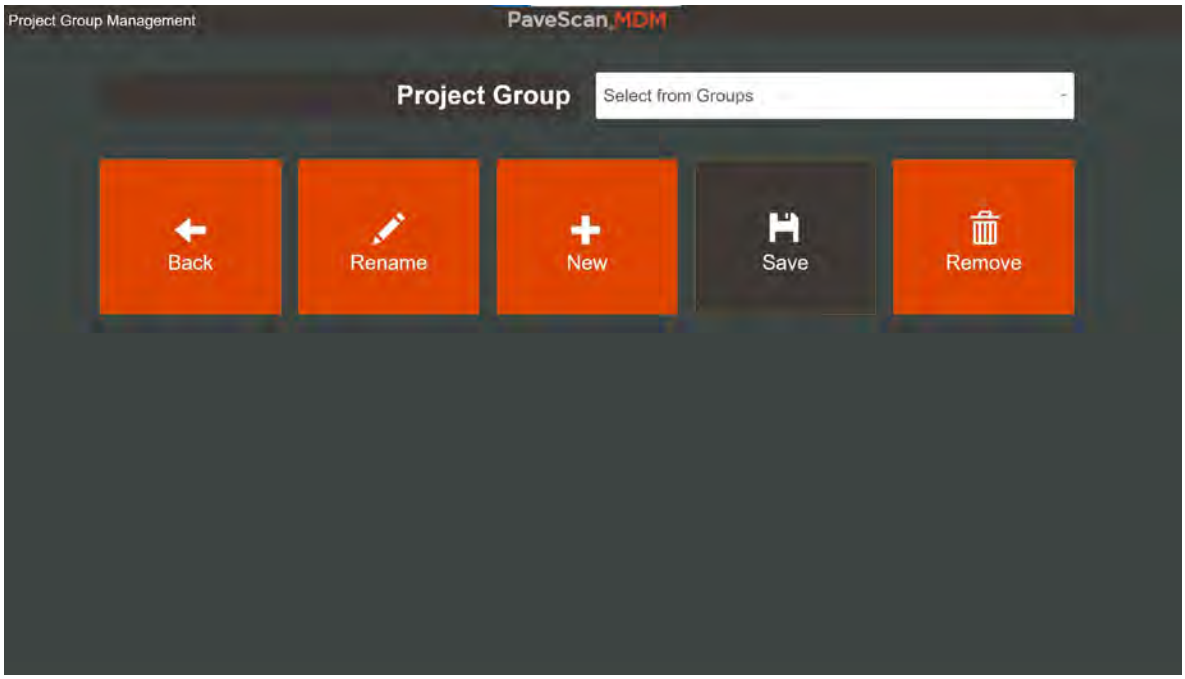
The File Management screen contains buttons to access and edit Project Groups, Projects and specific measurement files.



File Management Screen providing full access to Project Groups, Projects, and Files.

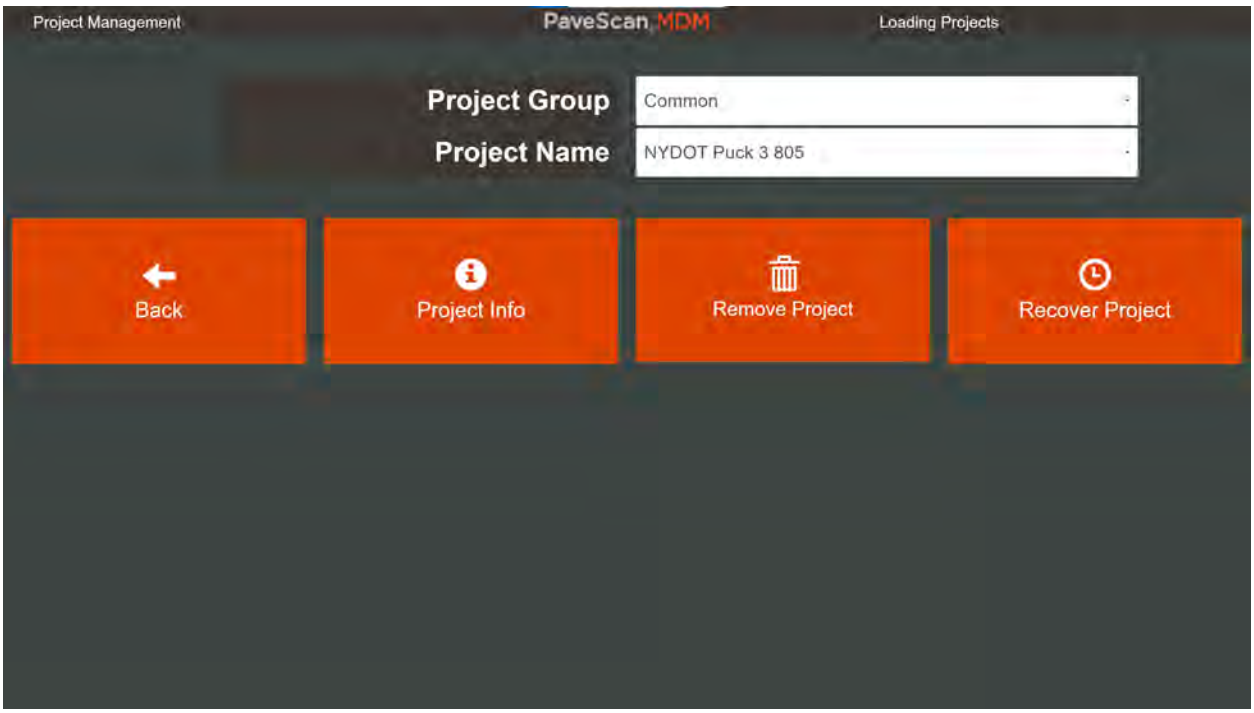
Project Groups: Pressing the **Project Groups** button opens a screen which provides access to Project Groups. Project Groups can be renamed, created or removed.

Note: The "Common" project group is the default project group for the Mix Design Module. It cannot be renamed nor removed.



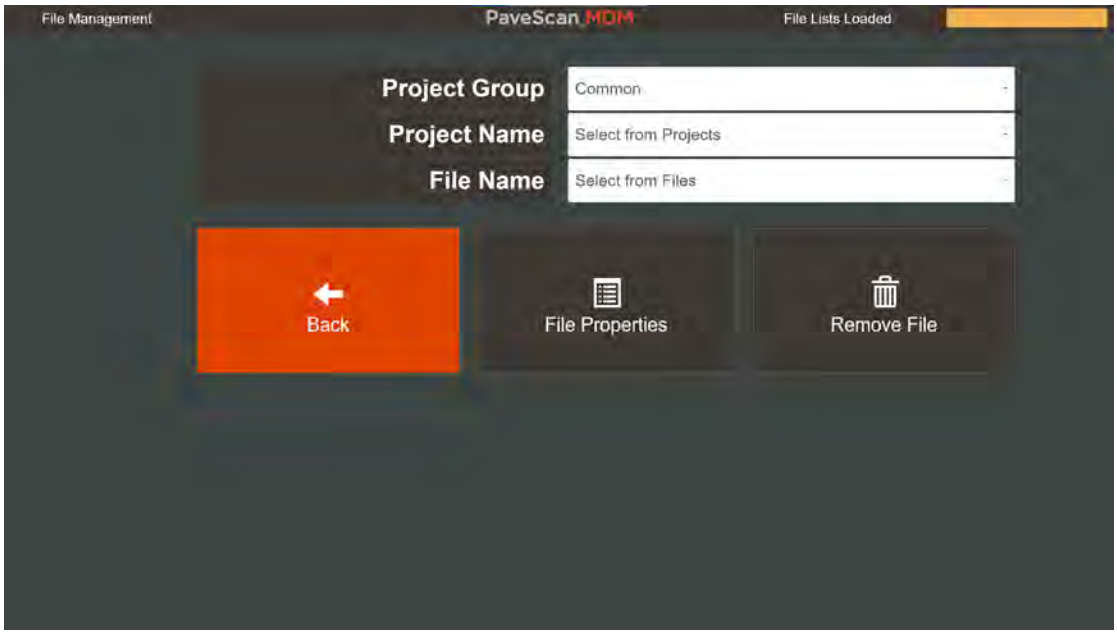
Project Group Management Screen: Create, rename or remove project groups here.

Projects: Pressing the **Projects** button in the File Management screen brings you to a screen that allows you to select specific projects. Once the project is selected using the drop-down list, press the **Project Info** button to edit project information, including the project name. Or press the **Remove** button to remove the project from the list. Projects that have been removed can be recovered later by pressing the **Recover Project** button.



Project Management Screen: Allows editing of project info, project removal, and project recovery.

Data Files: Pressing the **Data Files** button in the File Management screen brings you to a screen that allows you to view and edit specific measurement properties and remove measurement files. Select the Project Group and Project that the file belongs to, then select the filename from the dropdown list. This is a good location to add the % voids values to measurement files if they were not available when the measurement was obtained.

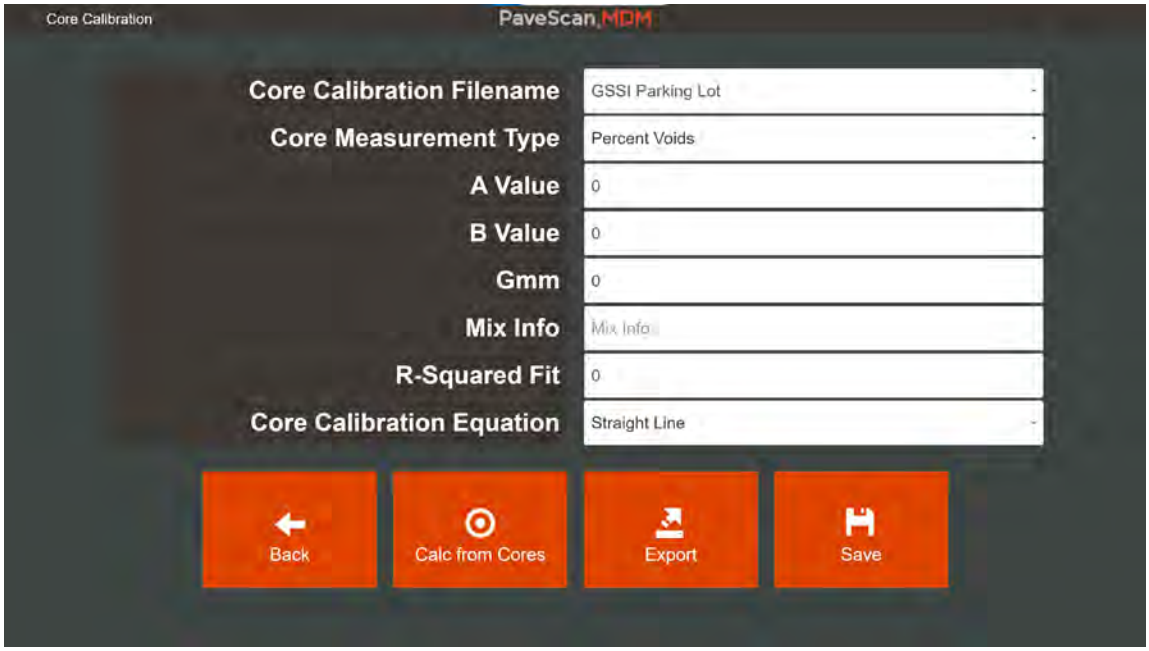


File Management Screen: Allows editing of measurement file properties and file removal.

System Settings->Main Menu: This button brings you back to the PaveScan MDM start-up screen.

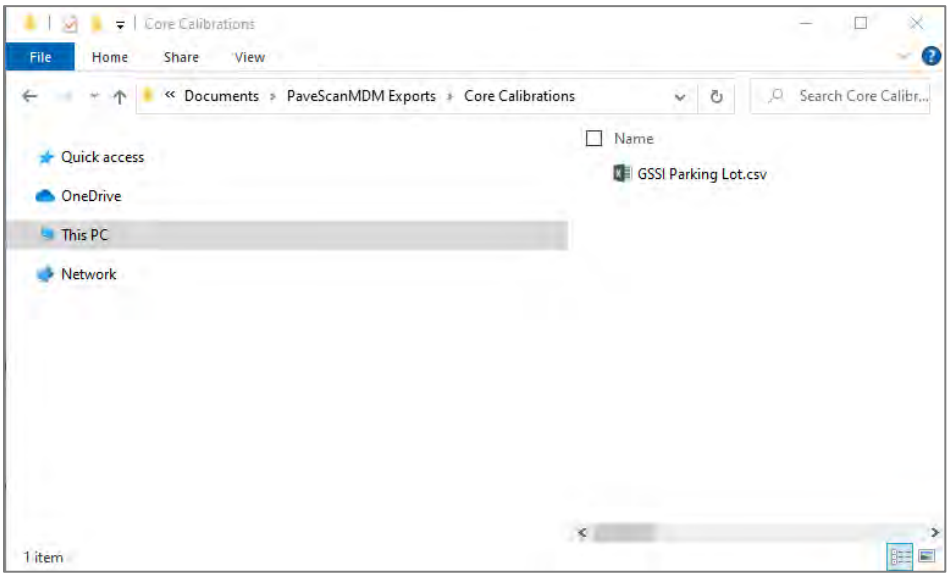
System Settings -> Version Info: Pressing this button shows the current PaveScan MDM version installed on the Toughpad.

System Settings-> Mix Calibration: Pressing this button brings up the Core Calibration screen. All previously collected Core Calibrations can be viewed, edited, and exported.



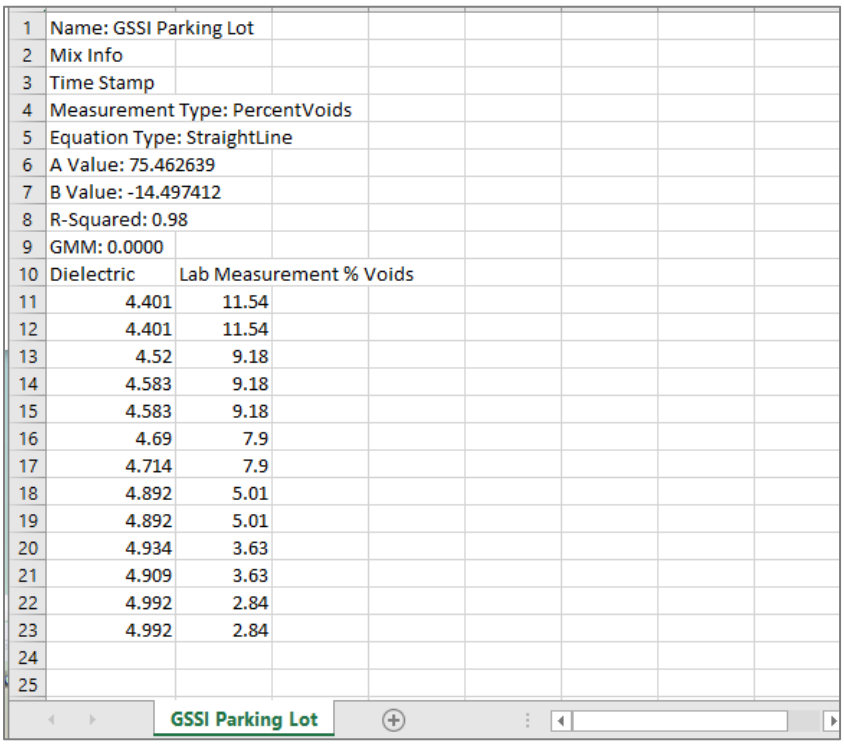
Core Calibration Screen accessed from System Settings.
All existing core calibrations can be viewed, edited and exported.

Press the **Export** button to export the currently selected core calibration. The exported Core Calibration files are located in a subfolder named Core Calibrations within the PaveScan MDM Exports folder.



Exported Core Calibration Files are located in subfolder Core Calibrations in the PaveScan MDM Exports folder.

The exported file is in a CSV format. The first nine rows of this file contain core calibration information as well as the calibration coefficients that are used in PaveScan RDM to convert field measured dielectrics to % Voids.

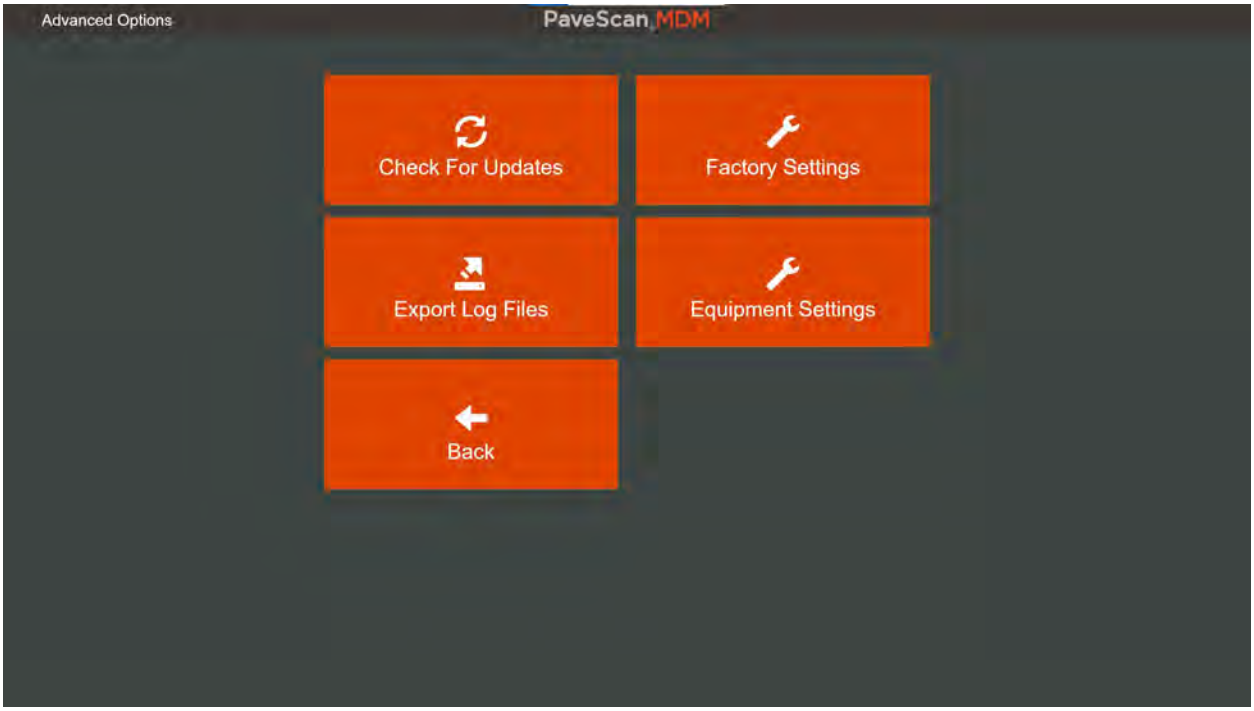


1	Name: GSSI Parking Lot	
2	Mix Info	
3	Time Stamp	
4	Measurement Type: PercentVoids	
5	Equation Type: StraightLine	
6	A Value: 75.462639	
7	B Value: -14.497412	
8	R-Squared: 0.98	
9	GMM: 0.0000	
10	Dielectric	Lab Measurement % Voids
11	4.401	11.54
12	4.401	11.54
13	4.52	9.18
14	4.583	9.18
15	4.583	9.18
16	4.69	7.9
17	4.714	7.9
18	4.892	5.01
19	4.892	5.01
20	4.934	3.63
21	4.909	3.63
22	4.992	2.84
23	4.992	2.84
24		
25		

GSSI Parking Lot

Example of an exported Core Calibration file as it appears in Excel.

System Settings->Advanced: Pressing this button opens a screen that provides four options that are not typically accessed during normal usage.



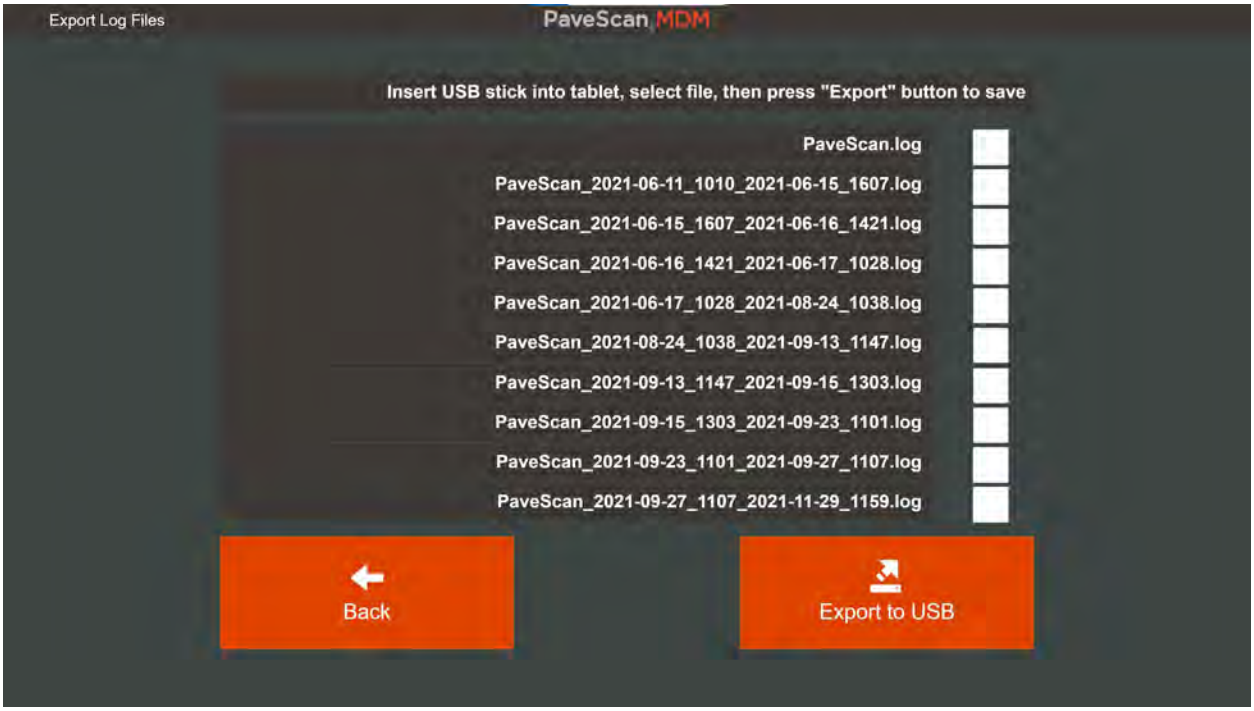
Advanced Options Screen: These are typically not accessed during normal Mix Design Module usage.

Advanced Options->Check For Updates: Press this button to find the firmware version installed on the sensor and if necessary update the sensor firmware. Note, this button is grayed out if the sensor isn't connected and powered up.

Advanced Options->Export Log Files: Press this button to access and export files that collect information related to computer instructions the program executes while the Mix Design Module is being used.

- These log files help the software technical support staff understand issues that may arise related to the software. If you encounter unexpected problems while using PaveScan MDM and contact technical support at GSSI you may be asked to export log files and send them to GSSI (or upload them to a shared folder).

- The Export Log Files screen is self-explanatory. Place a flash drive in the USB slot of the Toughpad, select the log files the technical support staff specifies, then press the **Export to USB** button.



Export Log Files Screen: Provides a way to easily export log file information that the technical staff at GSSI can analyze to help understand any trouble you may be having with the Mix Design Module.

Advanced Options->Factory Settings: Access to these settings are password protected and hence very rarely needed. If access is needed, you will be provided the password by GSSI technical support staff.

Advanced Options->Equipment Settings: These are factory established values associated with the white blocks and should not be modified unless directed by GSSI's technical support staff.

Advanced Options->Back: Pressing this button brings you back to the System Settings screen.

Chapter 2: Recommended Measurement Strategy

Equipment Verification Measurements

It is recommended that the user make the first and last measurement of the day with the HDPE verification cylinder. The cylinder has a known dielectric and therefore can be used to ensure the equipment is performing properly. Create a project just for these measurements so they can be recorded and used as a reference in the future. The HDPE verification cylinder will have a measured thickness and dielectric range written on its side. The measured dielectric needs to be within the range specified.

Sample Thickness Measurements

The sample thickness must be measured to the nearest 0.25 mm. Errors on sample thickness measurement result in errors in calculated dielectric. Measure the sample thickness using calipers making 4 separate measurements at 4 locations between the ends of the sample. Make a measurement, rotate the sample 90 degrees, make another measurement and so on. Then take an average of the measurements to obtain the average sample thickness and use this value in the File Information screen.

Sample Preparation

Samples need to be completely dry. If they've been subjected to density measurements which involved soaking the sample in water, they must be vacuum-dried or carefully oven-dried at a maximum of 60C prior to making dielectric measurements. Additionally, brush the flat surfaces of the sample to remove any loose aggregate. Then check to ensure that the metal plate rests on the flat surfaces of the sample without tilting. The metal plate should be in full contact with the flat surfaces when placed on them.

of Measurements Per Sample

It is recommended that at least 4 measurements be made per sample. The recommended measurement sequence is as follows:

1 Measurement noting the side of the sample facing you.

2 Repeat measurement with same side facing you.

- If this measurement differs from the first measurement by more than 0.02, make another repeat measurement and use the two measurements that are the closest.

3 Rotate sample approximately 90 degrees so that the sample side originally facing you now faces to the left. Then make a measurement.

4 Repeat measurement with same side facing you.

5 If this measurement differs from the previous measurement by more than 0.02, make another repeat measurement and use the two measurements that are the closest.

If you encounter many repeat measurements that vary by more than 0.02, then you may be located in an area with a high amount of external interference. Move equipment to a different location for making measurements.

Sample Diameter and Thickness Guidelines

The samples used with the Mix Design Module may be gyratory-compacted mix or cores. The design of the Mix Design Module constrains the sample size that will produce accurate dielectrics. The sample diameter must be at least 150 mm.

Measurements may be made over a range of sample thicknesses. Recommended sample thicknesses for gyratory-compacted mix are 75 – 120 mm. Thicker samples have less dielectric error associated with thickness error, so if possible, manufacture and measure pucks 100 mm or greater in thickness.

At this time, less than a dozen cores that have field dielectrics measured prior to extracting have been subsequently measured with the Mix Design Module. It's an area of active research. Core measurements agree to a large extent with the field-measured dielectrics. There are outliers. The bottoms of the cores need to be saw cut to provide a smooth surface. The minimum thickness for core measurements with the Mix Design Module depends on the measured core's dielectric and is provided in the table below. The maximum core thickness is 120 mm.

Table of Core Dielectrics and Minimum Valid Core Thickness For Measurement with the MDM.

Core Dielectric	Minimum Thickness (mm)
4.0	37.5
4.5	35.4
5.0	33.5
5.5	32.0
6.0	30.6
6.5	29.4
7.0	28.4

Recommended Gyratory Sample or Core Variability for Calibration Equation Generation

When measuring a group of pucks or cores for the purpose of generating a calibration equation, it is important to ensure that amongst the samples there is a sufficient range in %Voids. The reason for this is that the calibration itself is a straight line and the slope and intercept of this line depend on different measurement values spread out on this line.

The table below has been generated from a series of calibrations performed on sets of pucks with widely varying dielectrics. The values in the rightmost column below are recommendations for minimum dielectric range amongst the cores or gyratory-compacted samples. The wider the dielectric range, the more accurate the calibration. Check the R-squared fit of the calibration. Low R-squared values indicate poor calibration. Puck calibrations from gyratory compacted asphalt with % voids ranging from 2-12% typically generate calibrations with R-squared values greater than 0.9. Field core R-Squared values may be lower. Poor R-Squared values would be less than 0.7.

Table of Minimum Dielectric Ranges Recommended for Core or Puck Calibration

Dielectric at 5% Voids	Low Core or Puck Dielectric (10 % Voids)	High Core or Puck Dielectric (4% Voids)	Dielectric Range
4.0	3.8	4.05	0.25
4.5	4.2	4.55	0.35
5.0	4.65	5.075	0.425
5.5	5.075	5.6	0.525
6.0	5.5	6.1	0.6
6.5	5.95	6.6	0.65
7.0	6.375	7.15	0.775

The minimum number of pucks or cores for calibration purposes is 6. There should be two with low range dielectrics, two mid-range dielectrics, and two high range dielectrics.

Frequently Asked Questions (FAQs)

The sensor is connected, but the Collect button doesn't turn green. What can the problem be?

- It may take some time to connect with the sensor. Wait at least 15 seconds after powering up the concentrator box.
- Check to make sure the power button on the concentrator box is lit up. If it is not, press it in. Pressing it in will power up the sensor. Then wait 15 seconds.
- Turn the power off on the concentrator box by pressing the power button. Check all four cable connections to make sure they are secure, then power up the concentrator box by pressing the power button. Wait 15 seconds.
- Check the battery power levels if using batteries. At least one battery should have more than 1 bar showing in the storage display on the end of the battery.

Are the sensors sensitive to external interference?

- Yes, the sensors are sensitive to interference from cell phones, nearby cell phone towers, and other transmitting towers. There is a way to test to see if the location where the measurements are to be made is subject to excessive interference. Simply make a series of repeat measurements (5 to 10) with a gyratory-compacted sample taking care not to rotate the sample between measurements. If the dielectric measurements often differ by more than 0.02, then the location where the measurements are being made has excessive external interference and the location of the measurements should be changed. Note, it may be possible that the excessive external interference varies from day to day or based on the time of day. This is one reason that at least 2 measurements are recommended for each sample orientation.

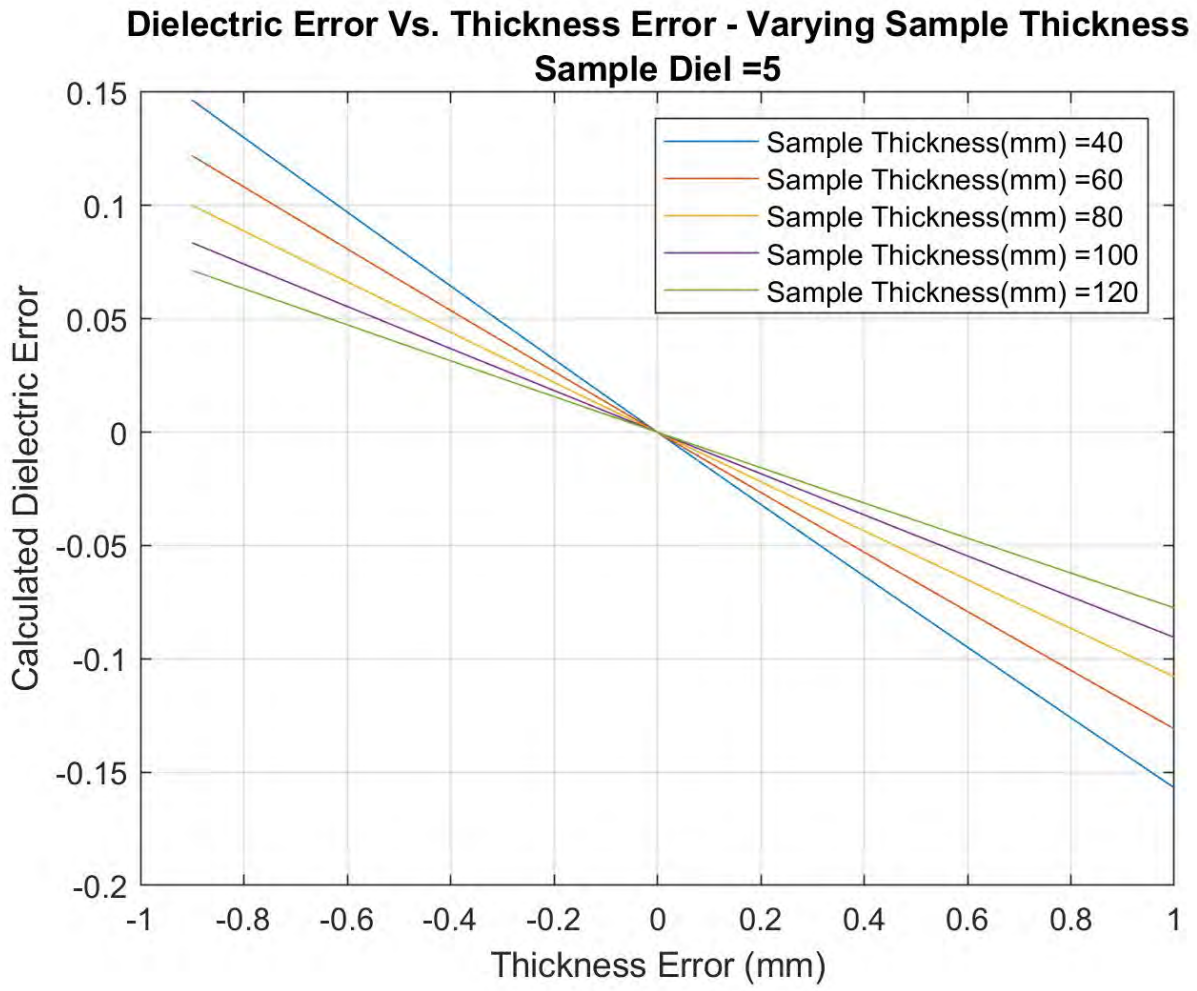
How stable is the sensor calibration?

- The bulk dielectric is calculated from travel-time measurements. All time calibration is performed at the factory and does not need to be redone during the lifetime of the sensor. The verification cylinder is only provided for the purpose of verifying the sensor is working properly.

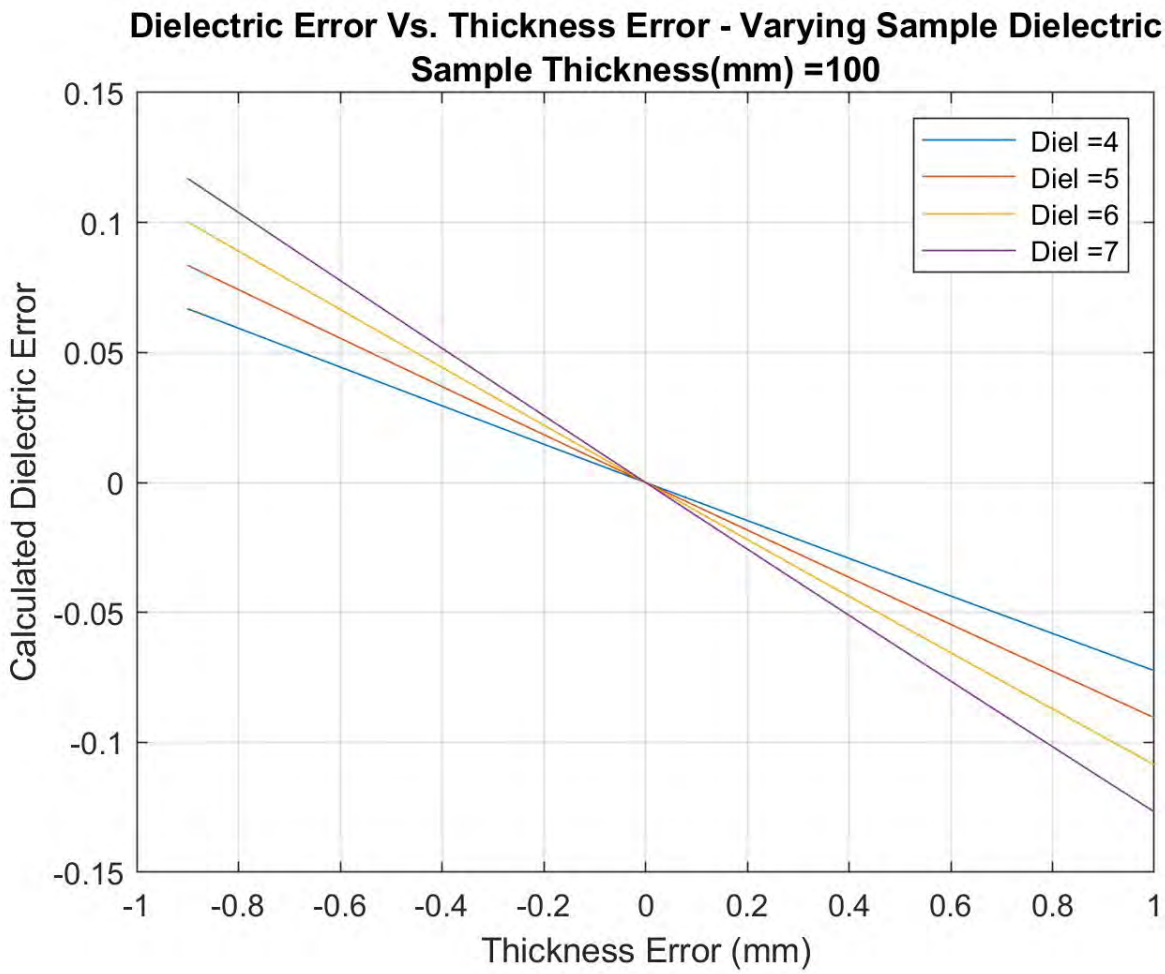
How sensitive is the dielectric measurement to thickness measurement errors?

- Accurate measured thickness is necessary to produce accurate dielectrics. As an example, observing the accompanying chart, for a sample dielectric of 5 and thickness of 100 mm, a 1mm measured thickness error translates to about a 0.09 error in dielectric.

  When the same thickness measurement error of 0.1 is applied to a sample with a thickness that is only 40 mm, the dielectric error is about 0.15. This shows how critical accurate sample thickness measurements are in order to obtain accurate dielectrics.



The chart below shows that thickness errors impact dielectric errors increasingly as the dielectric of the sample increases. For a sample thickness of 100 mm the calculated dielectric error associated with a 1mm thickness error varies from 0.07 to 0.125 as the sample dielectric increases from 4 to 7.



Why is the minimum recommended thickness for gyratory-compacted samples much greater than the minimum thickness for cores?

- Recent measurements have been made with gyratory-compacted samples from the same mix and thicknesses of 115 mm and 60 mm. An observed dielectric bias of about 0.06 was noted. The dielectrics of the 60 mm samples were on average 0.06 lower than the 115 mm pucks. It is likely that the contribution to the surface texture, which is on the order of a fraction of a mm, is the cause of the difference. The surface texture possesses a much lower dielectric than the bulk of the sample. Therefore, it is a greater proportion of the total path that the radar travels through in the case of the 60 mm thick samples compared to the 115 mm samples. The act of saw-cutting the cores removes the impact of the surface texture from one side of the core from the measurement of the dielectric. Keep in mind, measurements of cores are an area of active research. Part of this research involves assessing the accuracy of the measured dielectrics of cores using the MDM.

There are two additional dielectric values appearing in the exported data: “Dielectric (Surface Reflection Neg Peak)” and “Dielectric (Surface Reflection Pos Peak)”. What to these values represent and are they useful?

- Initial research with the Mix Design Module focused on obtaining dielectrics from the surface reflection of the samples seeing as the dielectrics in the field are calculated from surface reflections. It was found that these dielectrics did not often match dielectrics observed in the field. It is assumed that the surface texture and variability is contributing to a greater extent in the measurement compared to when the sensor is much further away from the surface. Consequently, they are not currently used and are there only for legacy purposes and the faint hope that at some point in the future they will provide some useful additional information. One consideration is how these calculated dielectrics change when a sample is measured before and after application of temperature change or drying. For this scenario, the absolute dielectric is not of importance, but how much it changes.

What type of variability is typical when calculating a calibration equation and how can I assess if it is valid?

1. For cores, no dielectric to air void calibrations have been performed, so no guidance can be provided regarding the variability.

2. For gyratory-compacted samples, however, many calibrations have been performed. For gyratory-compacted samples, with 100 mm thickness, you should expect R-Squared values 0.9 or higher. For cases where the R-Squared values are less:

    - Check to make sure the range in sample dielectrics is sufficient (see section “Recommended Gyratory Sample or Core Variability for Calibration Equation Generation” for details).

    - Is there an “outlier” that is biasing the linear fit? If so, then consider removing the outlier and recalculating the calibration.

- Are the samples sufficiently dried? Greater variability in the dielectric measurements has been observed when samples have been measured following SSD measurements and weren't sufficiently dried.
- Recheck the measured thicknesses to make sure no errors in thickness were entered.
- Were there any errors in % Void measurements?

3 In terms of validity, the R-Squared value is currently the best assessment of the confidence in the calibration. Obviously, there is less confidence in low R-Squared values, especially for cases where the R-Squared values are less than 0.7.

Does it matter if measurements are made on the top side or bottom side of the sample?

- The bulk dielectric measurements are made using the travel time of a radar pulse that propagates through the sample, reflects off the far side, and is received back on the surface measured. Effectively, the dielectric is measured from the entire sample length, so measurements need to be made only on one side.

Software Updates

The MDM application is updated from time to time to add features and fix issues. The new software can be downloaded from the Resources section at https://www.geophysical.com in the form of a .ZIP file. Scroll down to the row related to PAVESCAN 2.0 and click on the “Download Update” link.

The downloaded zip file contains the updated program and detailed instructions on how to install the update.

Appendix A – Calculation of % Voids, % Compaction, or Density from Dielectric

There are two equation types that currently can be used in the PaveScan MDM to calculate another physical property, such as % Voids, % Density, or Compaction from Dielectric.

1 The exponential equation takes the form: $P = Ab^{ed}$

2 The linear equation uses the form: $P = A + Bd$

where:

P = the measured physical property from the core, which can be density, % voids, or % compaction;

A = value obtained from least-squares fit exponential or linear curve of P versus dielectric calculated from a number of calibration cores;

B = value obtained from least-squares fit exponential or linear curve of P versus dielectric calculated from a number of calibration cores;

e = natural logarithm; and

d = dielectric value;

Note: The linear equation method is the recommended method.

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