

User's Manual

# RapidAir 457

Version 3 – USB, Digital Camera



## RapidAir 457 Version 3.0

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### Warnings

Do not attempt to open the RapidAir 457 control unit (PC), the monitor, the controller, the X-table or any other part of the RapidAir 457 system. Do not try to format, re-partition, or in any other way alter the contents or structure of the hard disk of the control unit except to install the required MS-Excel 2007 or newer on the hard disk.

**Be careful when placing X-table; it needs room to move – place it some distance from the wall!**

When the X-table is moving keep your hands away.

In case of emergency, you find a switch button on the front of the controller. Pushing the button down the X-table will stop immediately! Push it up again, you will be able to move the table again.



Controller front; switch in NORMAL position



Emergency position; switch down!

Do not start any analysis or move the X-table before having checked that the objective of the camera does not hit any of the four tightening screws of the sample holder when moving.

In order for RapidAir to function correctly don't change the screen resolution (must be 1600x1200). Don't use a screen saver and do not use any power save function. RapidAir is setup with the correct screen resolution, and without screen saver and power save options.

Do not try to connect the RapidAir 457 system in any other way than what is described in the installation guide. Do not touch, or in other ways get in contact with, the cords and connections on the back of the control unit, when the system is connected to the electrical supply.

Warranty for the RapidAir 457 system will expire immediately if any of the above-mentioned rules have been violated without written consent of Concrete Experts International, or any other damage on the RapidAir 457 system caused by abuse or improper use.

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## About the RapidAir 457 system version 3.0

RapidAir 457 is an automated image analysis system performing analysis of the air void distribution of hardened concrete according to the ASTM C 457: “Standard Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete” method A and B, and EN 480-11: “Admixtures for concrete, mortar and grout – test methods – Part 11: Determination of air void characteristics in hardened concrete”.

The RapidAir 457 system includes a PC control unit, a 20.1” color LCD monitor, a digital camera, a microscope objective mounted on a moving stage, and a user friendly software designed to guide the user through the air void testing.

The pixel resolution of the RapidAir system is around 2 $\mu$ m, field of view around 1.5x1.2mm and the magnification about 100x.

The concrete samples to be analyzed using automatic analysis performed by RapidAir 457 are prepared using a surface contrast enhancement technique, where the final result is a black surface with white air voids.

RapidAir 457 determines the volume of air (vol%), the specific surface, the spacing factor, the void frequency, and the average chord length in approx. 15 minutes. All parameters are provided for < 0.5 mm chords, < 1.0 mm chord, and all chords.

RapidAir 457 also calculates the parameters modal chord length, and the zero-order standard deviation of a lognormal representation of the normalized chord length frequency versus the chord length.

For the EN 480-11 analysis, RapidAir 457 furthermore calculates the air-bubble distribution from which the parameter “micro air content” is determined. The “micro air content” is equivalent to the air content that can be attributed to air-bubbles of diameters less than 0.300 mm.

Following the analysis and calculation, a select test report can be printed. The user may select from three different report types: ASTM C 457 with SI-units, ASTM C 457 with US-units, and EN 480-11, and from two different paper formats: Letter Size and A4.

The RapidAir 457 system operates in a MS-Windows XP or higher environment. Operation of the RapidAir system requires that MS-Excel 2007 or higher be installed on the PC control unit, and that a printer is connected to the PC control unit either directly or via a network. MS-Excel 2007, and a printer are **NOT** supplied with the RapidAir 457 system.

The RapidAir monitor is set up to a screen resolution of 1600 x 1200 pixels in order to work with two full image frames on the screen at the same time. It is **NOT** recommended to change the screen resolution.

## Installation of RapidAir 457

Remove the items and protection attached to the X-table. The following items are attached: Light device, spring device for sample holder, focusing knob and transporting feet.

The RapidAir 457 X-table should be placed on a horizontal, level, and vibration-free surface. To achieve a level position of the X-table unit, replace the “transporting” rubber feet (remove the black rubber from steel plates) with the four adjustable rubber feet supplied. Once the X-table has been placed properly the chords and cables between the different units, and the power outlets should be connected.

The following connection should be made:

1. Connect the camera (mini-USB) to the PC or laptop using the cable marked “1”.
2. Connect the controller to the X-table’s stepper motors using the cables marked “2x and 2y”. The cables have a 37 pin female connector in one end, and two Amphenol C16-3 female connectors in the other ends. Connect the Amphenol connector marked “2x” to the receptor on the X-table marked “x”, and connect the Amphenol connector marked “2y” to the receptor on the X-table marked “y”. Connect the female connector to the controller box.
3. Connect the controller to one of the PC’s USB ports on the back of the PC using the cable marked “3”.
4. Connect the monitor to the PC control unit.
5. Connect the keyboard, and the mouse to the PC control unit.
6. Connect all of the unit’s power supply chords to a power outlet. Use the cable, and transformer unit marked “4” to connect the controller to a power outlet. Use the cable marked “5” to connect the fluorescent ring illumination unit to a power outlet, and mount the fluorescent ring illumination over the objective and tubus by tightening the pinol-screw (already installed). Connect the Mascot power supply to the controller using the cable marked “6”.

When the above connections have been made, the PC control unit should be powered up, and **MS Excel 2007 or higher version and a printer should be installed.**

The focusing level of the objective is present by CXI and is about 11.2mm above the sample surface.

The RapidAir 457 system is now ready for operation by activating the RapidAir icon on the desktop. The software has been pre-installed and setup, and the X-table has been aligned and optimized prior to delivery (see attached folder with documentation).

**The RapidAir 457 system is protected from illegal copying by an opening key. In case the system prompts for the opening key enter the key ID found in Appendix 8 of this manual.**

## Sample holder

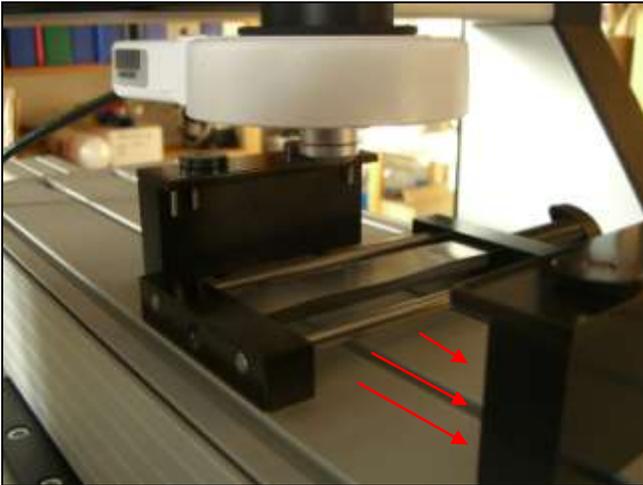
Step 1: Prepare the sample holder by loosening the two screws of the sample holder bar nearest to you. Move it apart, so far that you can place a sample in between. Place the spring device between the bars.

Step 2: Place the sample on the spring device in such a way that the upper left corner is pressed into the two pins of the bar. Now move the sample to fit the third pin.

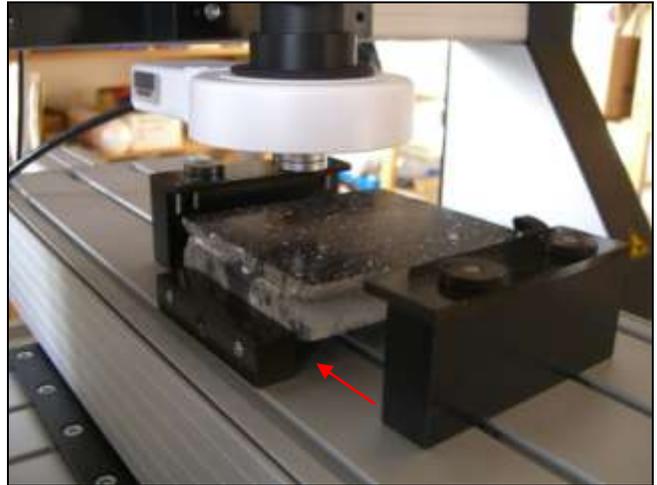
Step 3: Move the other bar towards the sample until the horizontal "lid" are a couple of mm over the sample. Tighten the two screws!

Step 4: Finally tighten the spring by turning the handle...without violence!

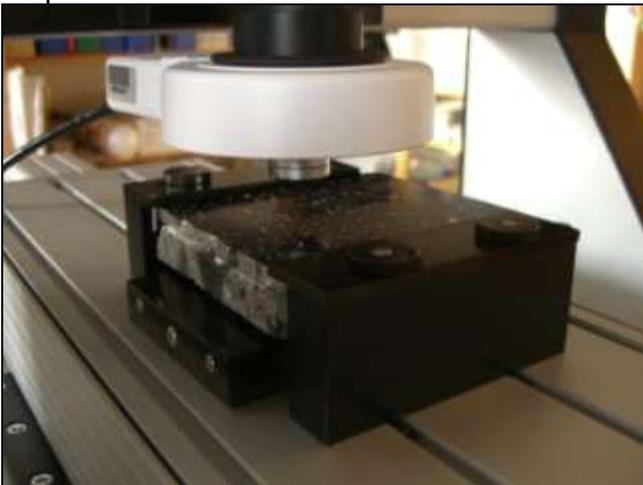
Usually you do NOT need to loosen the bar with the pins!



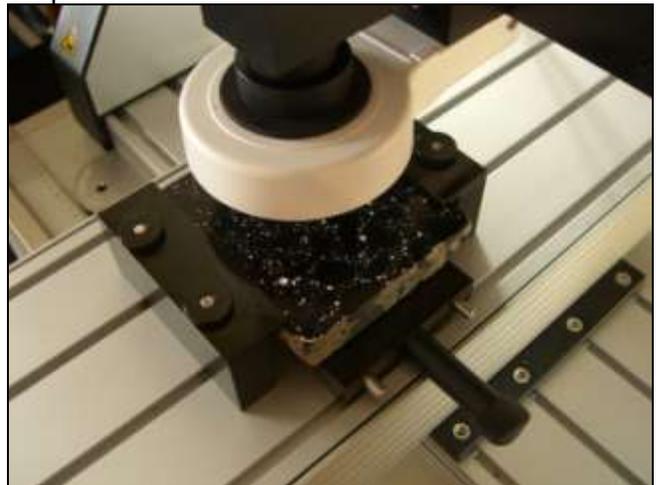
Step 1



Step 2



Step 3



Step 4

## The Controller

The RapidAir system comes with a controller unit. You find the RapidAir system No. as well as the controller No. on top of the controller.

On the front of the controller you find the following:

1. Mini USB plug: To be connected to the PC.
2. One pin plug: To be connected to the Mascot Power Supply.
3. Red/green lamps: Blinking when contact between the RapidAir software and the controller is established. If not blinking; restart the software.
4. Single green lamp: Steady green when the controller is powered up. The light will fade in case the emergency switch is used.
5. Emergency switch: Normal position up; emergency position down. When pushed down the X-table STOPS immediately. The X-table can be moved again when the switch is placed in the normal position again.



*Controller front; switch in NORMAL position*



*Emergency position; switch down!*

On the back side of the controller you find the following:

- 43 pin plug: To be connected to the X-table.

## Reinstallation of RapidAir Software

In case the RapidAir software needs to be reinstalled follow the instructions below.

PC & Software requirements:

Pentium 4 or higher

Minimum 20.1" monitor

Screen resolution: 1600 x 1200 pixels

Windows XP and Excel 2007 or higher

1. Setup your new PC with Windows and Excel
2. Attach a printer to the PC unit
3. Turn on the computer
4. Insert the supplied RapidAir-CD
5. Open the RA-Install dir called "RapidAir\_Install\_3.0\_B17\_FTDI"
6. Press RapidAir\_setup and follow the directions to install correctly
7. When done insert the supplied ImagingControl CD and install the camera driver for the DFK 72AUC02 USB camera (the camera must be connected to the PC in order for the software to find the camera automatically)
8. Create subdirectories in dir C:\RapidAir: called Frames, and Test\_Reports
9. Print the RapidAir manual found on the CD-rom
10. Turn of the PC
11. Read the manual!

Connect the RapidAir system as described above in "Installation of RapidAir 457". Turn on your PC

Your RapidAir 457 system can now be operated by activating the RapidAir icon on the desktop.

The RapidAir system is protected from illegal copying by a opening key. **When starting up the program for the first time the system prompts for the opening key – enter the key ID found in Appendix 8 of your RapidAir Manual.**

Line up your windows in RapidAir as seen in the manual on page 7

**Before running any analysis the RapidAir system must be setup correctly by inserting the setup parameters in the Setup Menu** – for setting up the system please see page 15 of the Manual! It is crucial to determine the field of view and know the spindle rise of your system before setting it up. The spindle rise of your system is 4mm. The field of view can be measured by placing a small 2mm precision ruler under the objective and measure the width and height of the image. Make sure that you see the entire field of view by enlarging the frame of the raw image! The preset width of the image is measured to **1.5mm and height 1.2mm**. These numbers and the spindle rise are used in the calculation of the pixel size and step. Don't change any other of the numbers in the setup at this stage.

Before running any analysis check whether the table is moving correctly by studying the images on the monitor when the table is moving. **In the first line of the traverse the images must move from right to left!** The easiest way of doing this study is to go to the "X-table and traverse window of the Setup Menu". Go to "Manual Positioning" and ad 1 to the number in the "Field X". The table will now move one step in X direction. If the images do not fit together the X and Y connector may be connected incorrectly and must be switched. Press save and close the window.

Now your RapidAir system should be up running

## Operating RapidAir 457

Turn on the PC, open the RapidAir software, turn on the controller and ring light on the X-table. The RapidAir 457 software (Figure 1) can be operated using the drop-down menus in the same fashion as other MS-Windows based software. The software interface consists of an X-Table window (Figures 1 and 2), a Raw Image window and an Analysis Image window. The “Raw Image” shows the image as it appears through the camera namely black and white. The “Analysis Image” is the threshold (manipulated) image where air voids should be set as green. The background of this window is black. The green color is used for an easier threshold setting between air voids and background.

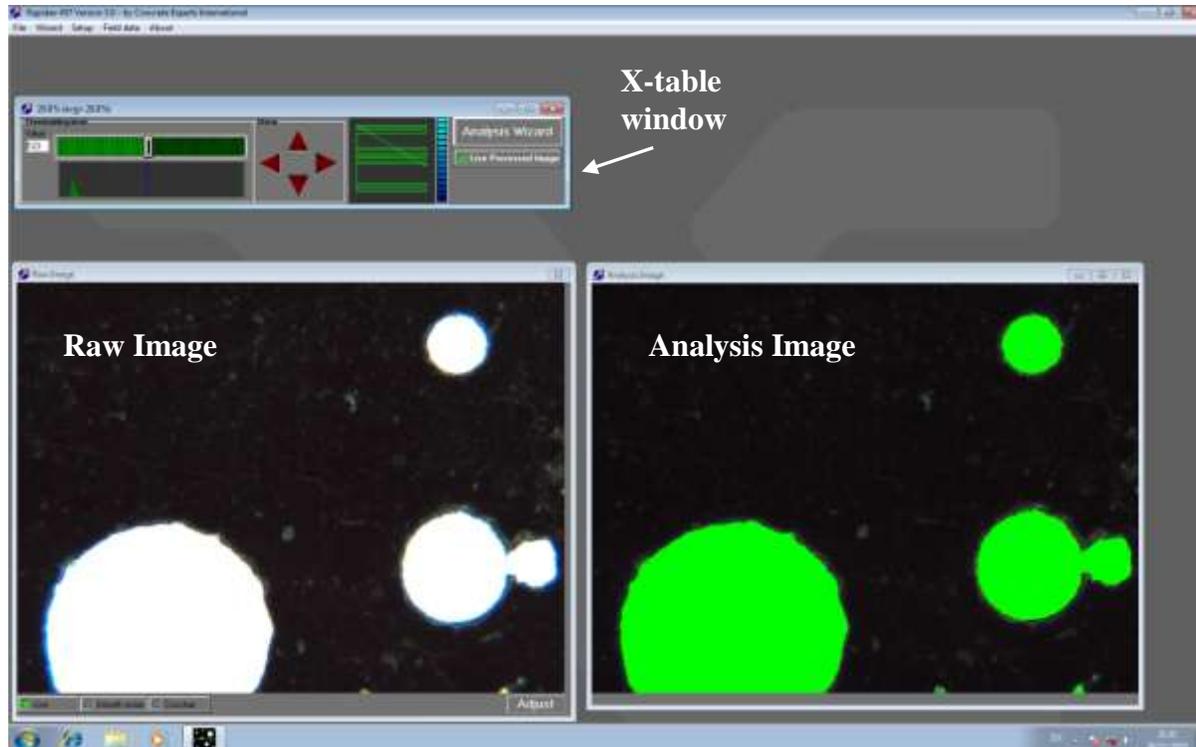


Figure 1. The software interface contains three windows: X-table, Raw Image and Analysis Image

The X-Table window (Figure 2) contains threshold bar with slider, histogram, arrows for moving the X-table check box, traverse pattern, timer, a button called “Live processed image” for frequent updates of the Analysis Image, and a button for starting the Wizard. The movement of the X-table is activated by pressing the arrows and the table will move in the given direction. Note that the direction of movement seen on the monitor is not the same as the actual movement of the X-table. The operator has to be familiar with that by learning.

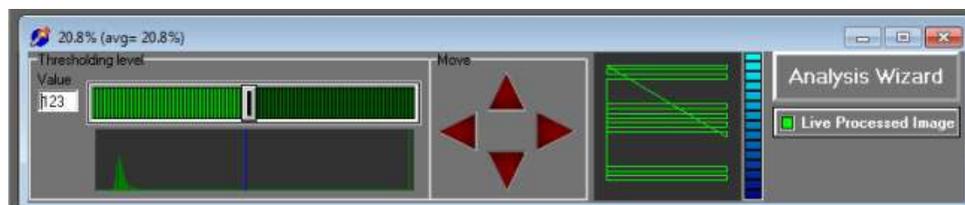


Figure 2. X-Table window. During analysis the area% of air is indicated in the blue bar. The histogram shows black to the left, white with one line to the right. The chosen threshold value is shown with a blue line.

For the daily operation when performing analyses and generating reports only the menu-point Analysis Wizard needs to be used. The Analysis Wizard is started by clicking on “Wizard” in the top menu or by pressing the “Analysis Wizard”-button in the “X-Table”-window on the desktop (Figures 1 and 2). The “Analysis Wizard” will guide the operator through an air void analysis or the printing/viewing of analysis by prompting the operator for the required input and actions.

**Note:** the analysis will run very slow if “Live processed image” is checked and the voids will appear with shadows. It does not influence the analysis but in order to speed up the analysis it should be unchecked during analysis!

### **The Analysis Wizard**

The first window of the Analysis Wizard prompts the operator to select “Air Void Analysis, linear traverse ASTM or EN”, “Air Void Analysis, Modified Point Count ASTM”, “Print or View Data” or “Create Composite Image” (Figure 3). Select “Air Void Analysis” to perform either a linear traverse or point count analysis according to either ASTM or EN and press “Next” to setup the analysis. Select “Print or View Data” to print or view a report with the results of an air void analysis. Select “Create Composite Image” to create a composite image from images collected during analysis.

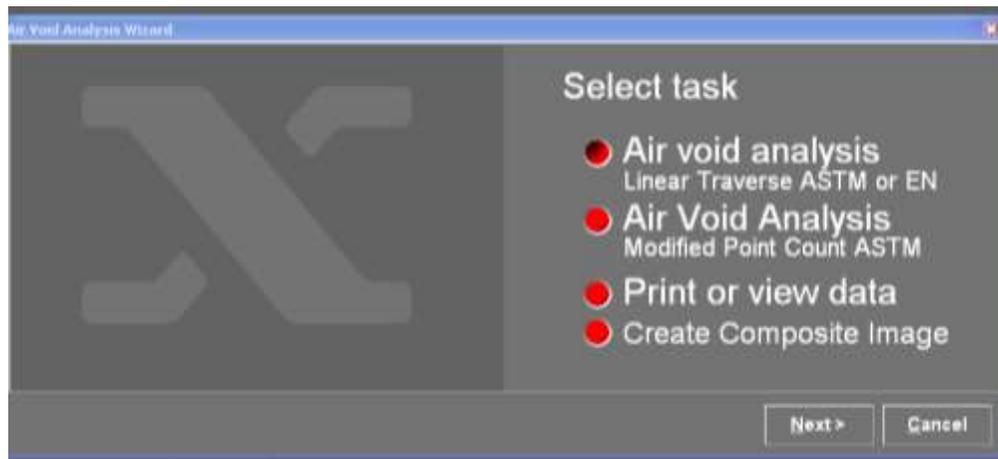


Figure 3. Analysis Wizard – Select Air void analysis, Print or view data or Point Count

### *Air Void Analysis, linear traverse*

#### Principle of Analysis:

The linear traverse analysis is a fully automatic analysis. The operator simply follows the wizard and starts the analysis. RapidAir is measuring traversed air voids as cord lengths and after final analysis a report is generated. The operator may choose to save images along the entire traverse line (this is however not recommended at normal daily work). The images saved may either be the raw images or the processed images including the analysis line. The images can be stitched together as a composite image using the included software “RapidBrowse” from the Wizard (Figure 3).

#### Automatic Linear Traverse:

Select Air void analysis, linear traverse and the Analysis Wizard prompts the operator for a number of miscellaneous information related to the sample to be analyzed (Figure 4). The operator can enter information about the following:

Test laboratory, Sample ID, Project ID, Operator ID, Originator ID, Remarks, Remarks modal  
The analysis date will automatically be assigned to the front page of the test report.

Figure 4. Analysis Wizard – Air void analysis step 2

When the information has been entered, press the “Next”-button to move to the next Wizard window.

The Analysis Wizard now prompts the operator to select the report type, and the paper format (Figure 5). The available options for report type are ASTM C 457 with SI units, ASTM C 457 with US units, combined with both SI and US units, and EN 480-11. If the “EN traverse” box is checked the Rapid Air will perform a “strict” EN 480 analysis on a 100x150mm sample, with 4 lines at the top (outer surface, 4 lines at the bottom and 4 lines minimum in the center – all with a 6 mm line separation; length of traverse min. 1200mm). Therefore, if the “EN traverse” box is checked make sure that the traverse length and sample size are as required to allow for required 6 mm line separation. If this requirement are not fulfilled the following message will appear “Error – Sample too small to space lines 6mm. Uncheck EN480 checkbox to run an ordinary traverse”. If the EN check-traverse box is unchecked the test will be performed as an ordinary linear traverse but reported as required in the EN 480 standard. The available paper formats are A4, and letter size. Choose the combination that suits your needs best, and Press the “Next”-button to move to the next wizard window.

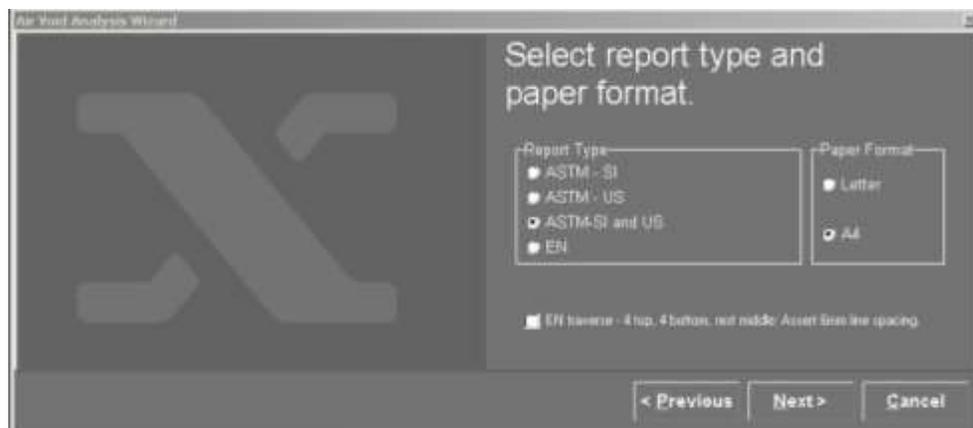


Figure 5. Analysis Wizard – Air void analysis step 3

The Analysis Wizard now prompts the operator to select the image that is to appear on the front page of the report (Figure 6). This feature requires of course that an image of the entire sample surface has been taken prior to analysis and saved on the computer or network. The front page image should be a jpg-image with an aspect ratio of 3:4.

The image is selected by entering the image path or by browsing the file system. If no image is to appear on the report check the “No image”-button.

Press the “Next”-button to move to the next Wizard window. If the operator collects images during analysis the created composite image can later be copied and pasted into the report.



Figure 6. Analysis Wizard – Air void analysis step 4

The Analysis Wizard now prompts the operator to select the file name under which the analysis results will be saved (Figure 7). The file name is selected by entering a path or by browsing the file system. If an already existing filename is used a warning will appear “Press Yes or No to overwrite”. Press the “Next”-button to move to the next Wizard window.

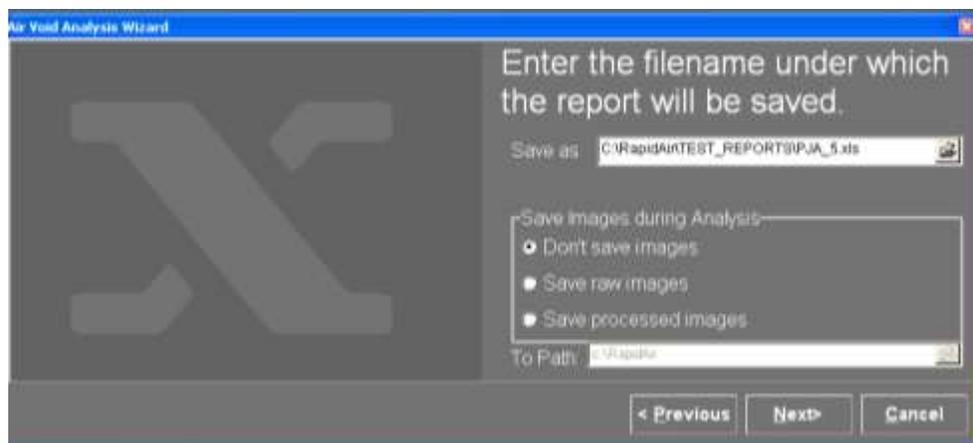


Figure 7. Analysis Wizard – Air void analysis step 5

At this stage the operator may choose to save all images from the analysis. Those “Save raw images” to save raw images, those “Save processed images” to save images including the traverse line. Default is “Don’t save images”. The images are saved as jpg. Select the path where the images shall be saved. **Don’t save images into an already used directory and don’t save them directly on C:\!**

The Analysis Wizard now prompts the operator to enter the paste content in volume % of the sample to be analyzed (Figure 8). Enter the paste content from e.g. the mix design, directly by using the keyboard or the “calculator-keyboard” that are activated by clicking the small calculator icon to the right of the paste content field. The paste content may also be imported from point counting data by checking the “Use point count file” and entering the file name. The paste content from the point count will show up in the bottom of the window. Press the “Next”-button to move to the next Wizard window. **NOTE:** This later operation requires the operator already has performed a point count before starting the linear traverse analysis (see page 14-15).



Figure 8. Analysis Wizard – Air void analysis step 6

The Analysis Wizard now prompts the operator to enter the desired traverse length<sup>1</sup> in mm (Figure 9). Enter the traverse length either by using the keyboard or by using the mouse, and the “calculator-keyboard” that are activated by clicking the small calculator icon to the right of the paste content field. Press the “Next”-button to move to the next Wizard window.

<sup>1</sup> ASTM C 457 and EN 480 each require a minimum traverse. Please consult the relevant standard to find the traverse length required for the particular sample.

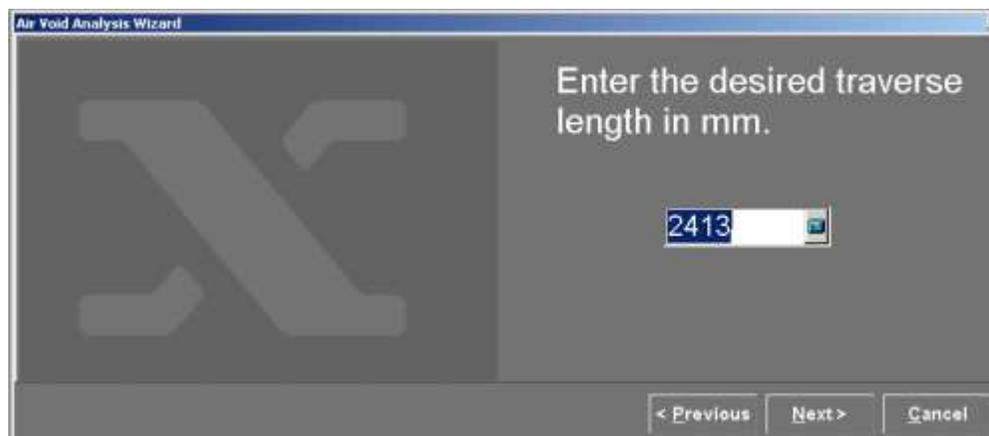


Figure 9. Analysis Wizard – Air void analysis step 7

The Analysis Wizard now prompts the operator to enter the dimensions of the sample to be analyzed and the area of the sample that will be analyzed, all in units of mm (Figure 10). Enter the sample size and the area to be analyzed by using the keyboard, or by using the mouse and the “calculator-keyboard” that is activated by clicking the small calculator icon to the right of the paste content field. **Note:** Remember that the outer about 10 mm of the sample should normally not be included in the analysis due to difficulty in obtaining highest quality sample preparation here. Press the “Next”-button to move to the next Wizard window.



Figure 10. Analysis Wizard – Air void analysis step 8.  
Length equals X and width Y on Figure 19.

The Analysis Wizard now prompts the operator to enter the number of traverse lines per video frame  $(1-10)^2$  (Figure 11). Enter the traverse lines per video frame either by using the keyboard or by using the mouse, and the “calculator-keyboard” that are activated by clicking the small calculator icon to the right of the paste content field. Press the “Next”-button to move to the next Wizard window.

<sup>2</sup> ASTM and EN 480 only allow one line of traverse per video frame.

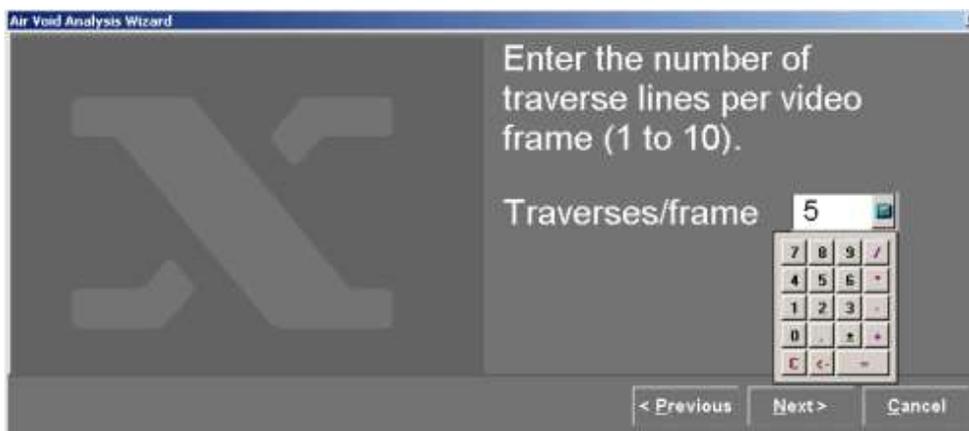


Figure 11. Analysis Wizard – Air void analysis step 9

The Analysis Wizard now prompts the operator to make sure the sample is in focus, and to set the threshold level to the value that best isolates the air voids as green object on a black background on the “Analysis Image” (Figure 12). The threshold level is set in the threshold window by moving the slider back and forth. When the threshold is set correct the size of the air voids on the “Analysis Image” should have the same size as on the live “Raw Image”. If a green rim is observed at the void periphery the threshold values is set too low and has to be raised to the point where no green rim is observed! The threshold value is too low when a large number of small white dots (noise) appear in the “Analysis Image”. When the threshold has been set, make sure that the sample is correctly placed in a level position with the camera directly above the upper left hand corner of the area to be traversed. Now press the “Next”-button in the threshold window to initiate the analysis.

When the analysis has been initiated the selected number of traverses per video frame will appear across the Analysis Image as evenly spaced blue probe lines. Where a line intersects an air void (white pixels) it turns red showing the actual length of the chord being measured.

The analysis will end by the X-table moving to its starting position while a report file is saved in MS-Excel format (.xls). Wait for the program to tell you that the report has been generated (it takes few seconds!) before moving to the next analysis.

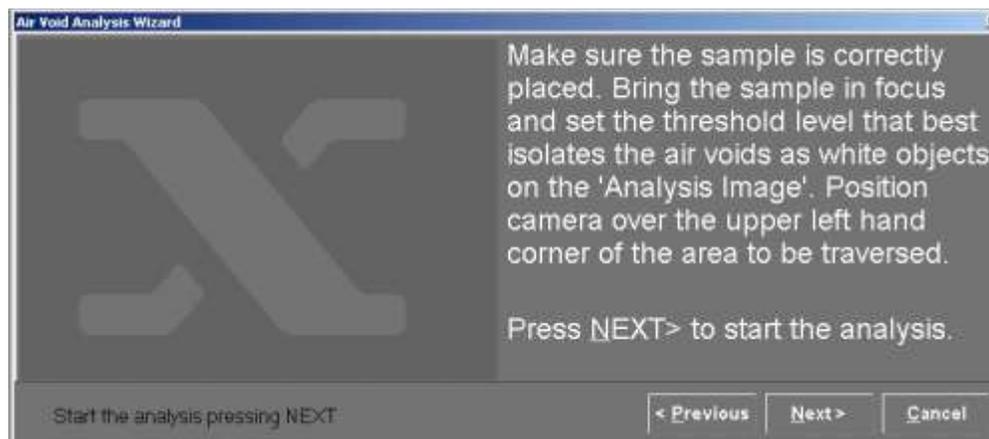


Figure 12. Analysis Wizard – Air void analysis step 10

The analysis may be aborted by pressing “Stop Analysis” in the top menu. If “Stop Analysis” is activated the X-table will stop and the software will prompt the operator to decide if a report should be

generated. When the operator has made a decision by pressing either the “Yes”-button or the “No”-button the X-Table will return to the starting position in the upper left corner.

### Pause an Analysis

If the operator wishes to view a field of view for e.g. focusing reasons the analysis can be paused. Point to the “Analysis Image” and press the left mouse button. The analysis will pause; you can then either Yes or No to continue. This feature may also be used if e.g. you wish to change a sample to its companion sample and continue the analysis as if it was one sample. This may be the case when a sample is too small to be analyzed according to the Standard and the front and backside must be analyzed in order to meet the requirements.

### *Air Void Analysis, modified point count*

#### Principle of Analysis:

The point count procedure is a semi-automatic analysis. Initially an ordinary point count is performed where the operator makes a choice; what is aggregate, cement paste or air voids while RapidAir moves the table. When having performed the point count the operator can stop and simply use the counted paste content in a fully automatic linear traverse analysis. The operator can also continue and make RapidAir count the entire amounts of voids along the line and calculate the results according to the ASTM standard. Whether you select the one or the other the operator may chose to save images along the entire traverse line. The images are saved with the line and can then be used to manually count the voids ☺ and/or to create a composite image of the analysis area. The composite image may be generated using the included software “RapidBrowse” from the Wizard (Figure 3).

#### Semi-automatic Point Count:

If “Air Void Analysis, Modified Point Count” is selected in the “Analysis Wizard”-window (Figure 3) a semi-automatic point count of the sample can be performed in order to analyze the sample according the ASTM C 457 modified point count procedure B or simply to calculate the paste content.

**Important: The initial point count must in most cases be performed on the non-black and white lapped surface using either the ring illumination attached to the X-table or an external incident light source (not included in the RapidAir 457 system).** The operator must evaluate which light source is the best.

Press “Air Void Analysis, Modified Point Count” to start the analysis (Figure 3) and the first window of the point counting asks for a name of the .CSV result file (comma separated file), analysis area and number of point to be counted (Figure 13). Name the file and consult the standard in order to set a proper analysis area and number of points to be counted.

The data saved in the CSV. file is just raw data and the file in itself is not used as a result report. The paste content calculated based on the point count may be imported into the linear traverse analysis (see above) and used in this calculation. The data may also be used in the calculation of air void structure according to the ASTM procedure B and will then appear in an Excel report format.

Position the starting point!

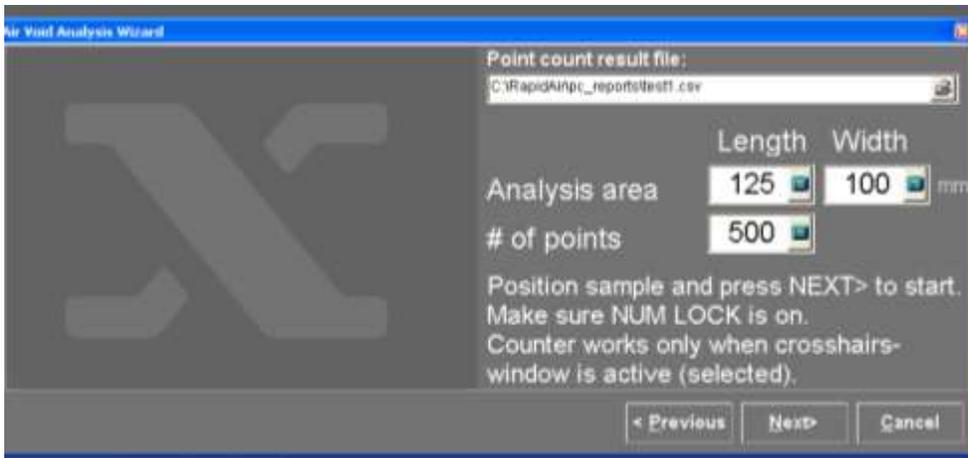


Figure 13. Point Count – step 1

Press “Next” and the second window of the point counting will appear (Figure 14) as well as a crosshair on the Raw Image (Figure 15). The color of the crosshair may be changed by pressing “c” on the keyboard until the desired color appears. Pressing “x” on the keyboard stop and restart the counting.

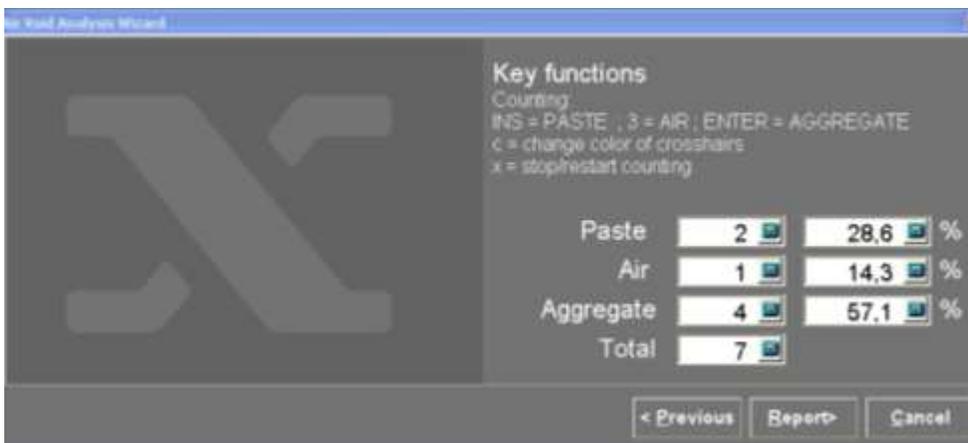


Figure 14. Point count – step 2

Count the three phases, paste, air and aggregate by pressing INS for paste, 3 or 7 for air (depends on keyboard) and ENTER for aggregate. Every time a button is pressed the X-table will move in steps calculated from the inserted data, analysis area and number of points to count. Count data and calculated % are visible during the point counting.

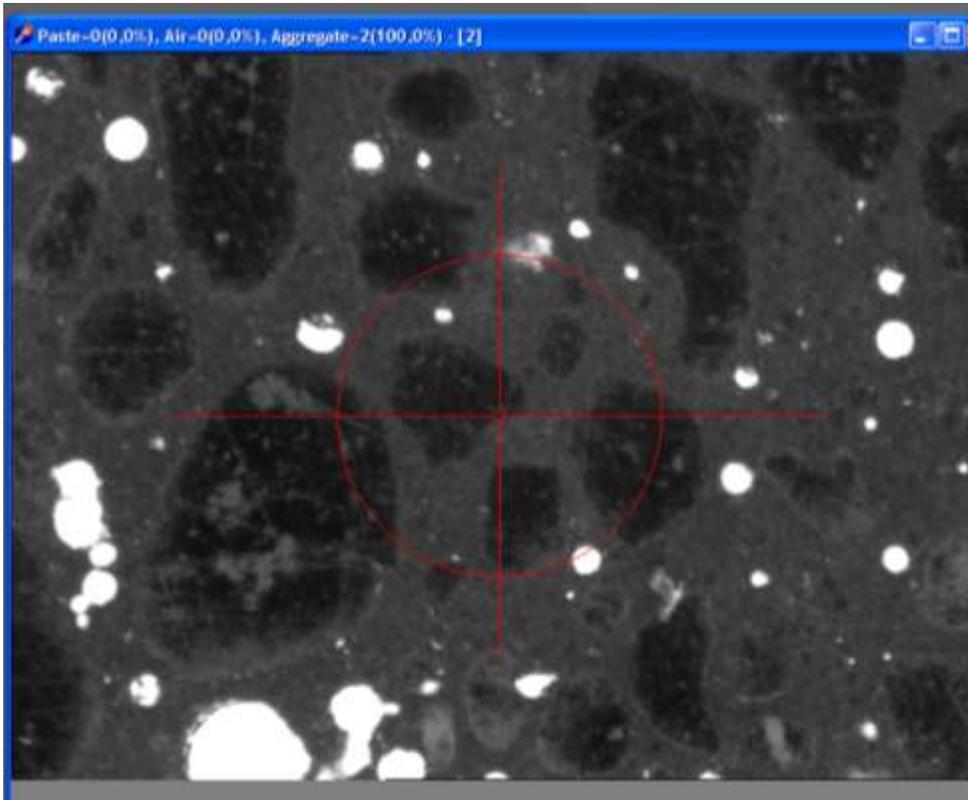


Figure 15. Point Count – Raw Image (active window) with red crosshair. The counting could here be done on a black and white surface due to the transparency of the black color.

If the operator decides to stop the point count before reaching the desired number of analysis points press “report” (Figure 14), and the data will be saved in the .CSV file. The .CSV file cannot be opened in the RapidAir software but when using the .CSV file in the Air Void Linear Traverse Analysis the paste% will appear in the “Paste Content” window (Figure 8) and on the test report.

When the desired number of point (Figure 14) has been reached the analysis will stop and the operator must press “Next”. The operator is then prompted to select between 2 tasks, namely “Save point count” or “Perform ASTM C457 procedure B” (Figure 16).

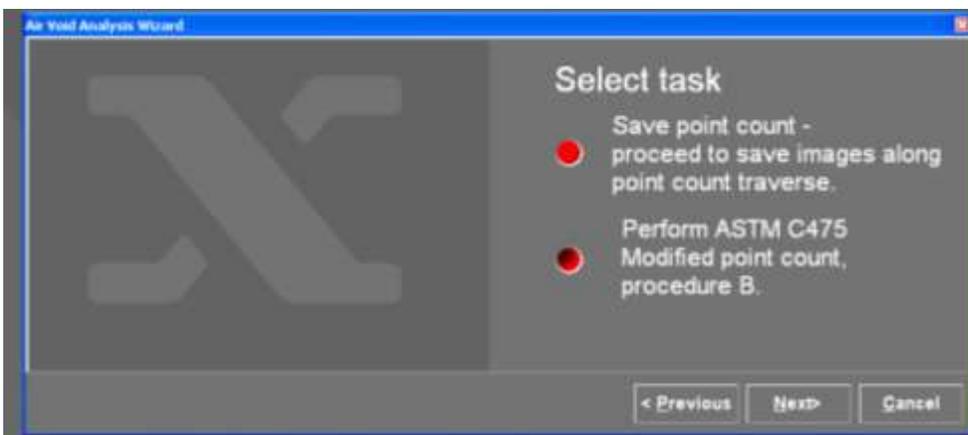


Figure 16 Select point count tasks

If selecting “Save point count” the point count data will be saved in a CSV. file and the following window (Figure 17) will appear:

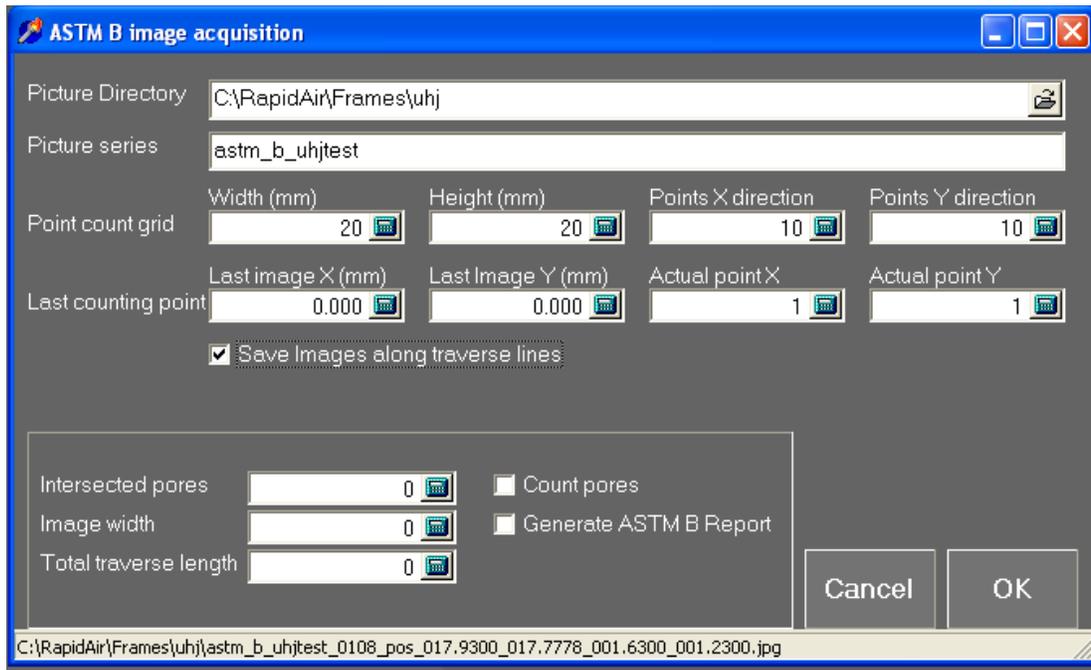


Figure 17 Image acquisition after point counting

The operator has now the possibility to further supplement the point count analysis by saving images along the entire line by which the point count has been performed. The images will be saved with the traverse line visible and without the point counting gaps. The operator has then the possibility to either manually count all the voids along the entire line and/or to create a composite image of the surface analyzed (see later).

Press “Cancel” if you don’t want to save images.

If you want to save images create a directory where you want the images to be saved (you should NOT save the images directly on C:\ - Windows don’t like it and you may crash the PC and NOT either in the C:\RapidAir directory!). NOTE: Don’t use the same directory name for different image savings because the images will be named with the same numbers every time an acquisition is started. The images must always be named “astm\_b\_” – you can then give an additional name e.g. astm\_b\_sampleXX. The images are saved as jpg. Don’t change anything in “Point count grid” and “Last counting point”, these numbers are given by the software based on the last performed point count analysis. Make sure the “Save Images along traverse lines” are checked. The field in the lower left part of the window shall not be used in this analysis! Press “Next” and the X-table will return to the point count starting point and start collecting images. When finished the X-table again returns to the starting point.

When finished the point counting the operator returns to the Wizard (Figure 3).

#### Modified Point Count Procedure B:

If selecting “Perform ASTM C457 procedure B” the point count data will be saved in a CSV. file and the following window (Figure 18) will appear:

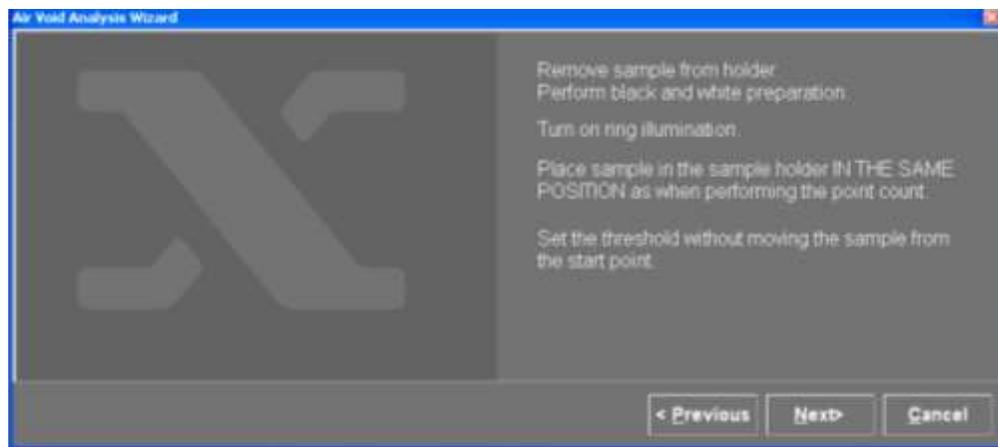


Figure 18 Guidelines for performing Modified Point Count

The window highlights some guidelines for performing the modified point count procedure B. If the point count has been performed on a non-black and white concrete surface then remove the sample from the holder. Perform the black and white surface enhancement. Turn on the ring illumination (if not already on), and place the sample in the holder in the same position as when performing the point count (use the three spacers on the sample holder to ensure position). Set the threshold without moving the sample from the start point! It is important that the above guidelines are followed because according to the standard the total number of voids has to be counted on the exact same line as used during point counting. Press “Next” when ready and the operator will be prompted for report information (Figure 19).

Figure 19 Report information

Press “Next” and the operator will be prompted for file name of the Excel file which will be generated from the analysis (Figure 20).

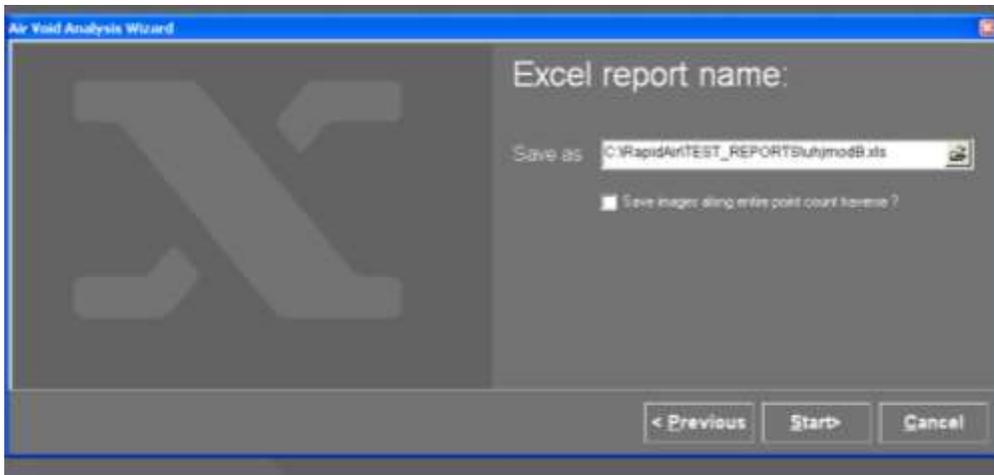


Figure 20 Report naming

Check if all the images along the entire point count traverse wishes to be saved.

Press “Next” and a window somewhat similar to Figure 17 appears (Figure 21).

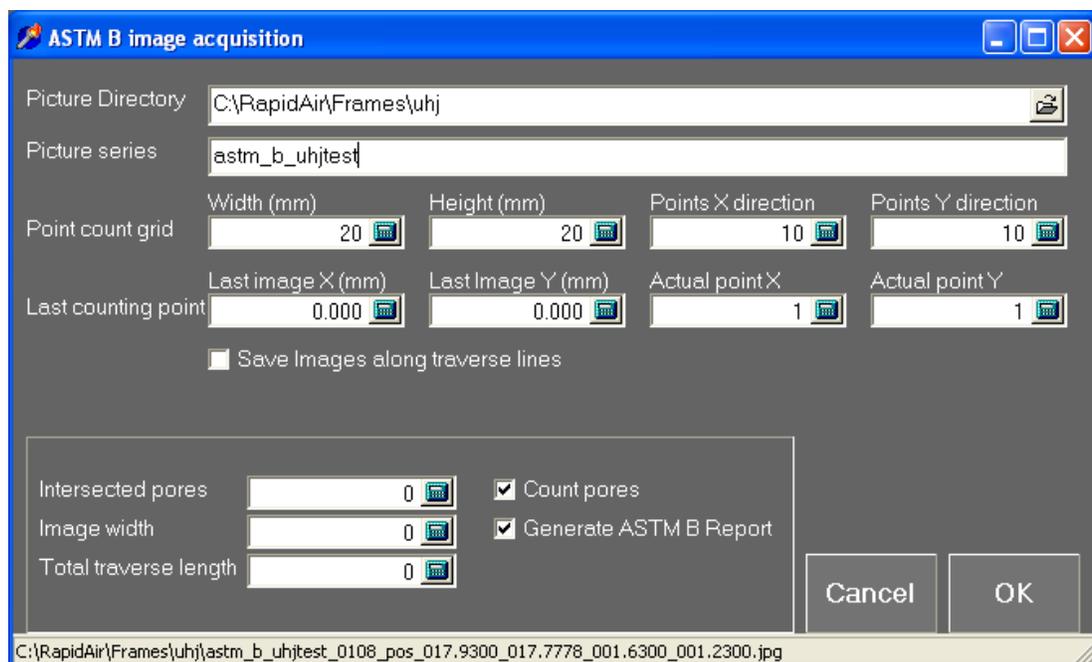


Figure 21 Pore counting and generating of ASTM C457 modified point count, procedure B report.

If the operator wishes to save image along the entire line the procedure is as describe above but remember to check the “Save Images along traverse line”. Note the boxes “Count pores” and “Generate ASTM B report” is already checked by RapidAir! Press “OK” and RapidAir will start counting all voids being traversed by the line. The number of voids being traversed will be indicated during analysis in the field “Intersected pores”. When the analysis is done an Excel report will be generated and the X-table returns to the starting point. Open the Wizard (Figure 3) and press “Print or View Data” to see the report.

### *Print or view data*

If Print or View data is selected in the “Analysis Wizard”-window (Figure 3) the operator will be prompted to select the file name of the report to print or view (Figure 22). The file name can be selected either by entering the path of the file using the keyboard or by browsing the file system. The file name of the last performed analysis will always appear when opening this window.

The operator must select by clicking the appropriate button if the report is to be printed or viewed. If the “Print”-button is selected, MS-Excel will open and the report will appear on the screen in Print Preview mode. To print the report, press the “Print”-button. Examples of reports are shown in Appendix 5.

If the “View”-button is selected, the file will open in MS-Excel.

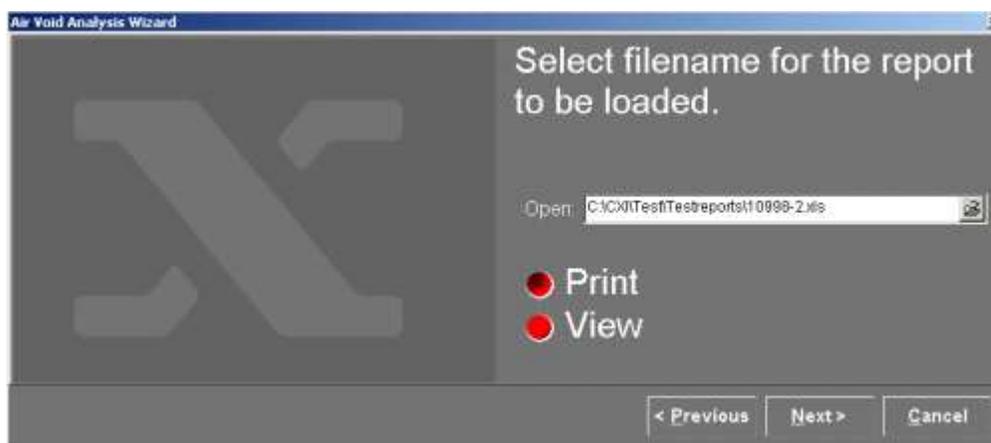


Figure 22. Analysis Wizard – Print or View data step 2

### *Create Composite Image*

If the operator has saved images during the analysis they may be stitched together as a composite image using the RapidBrowse program included in the RapidAir software. Select “Create Composite Image” from the Wizard (Figure 3) and the RapidBrowse program will open (Figure 23).

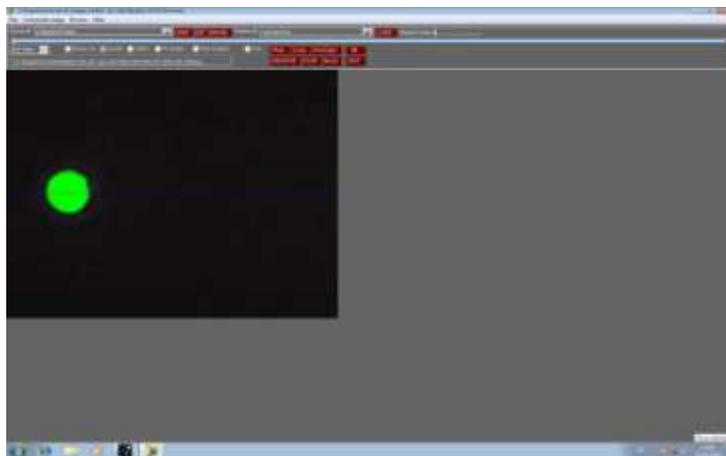


Figure 23. Interface of RapidBrowse

Select the “Source directory” – the directory where the images are saved. Press “LOAD” and all the images will be loaded in one pile. Press “Composite Image” and check “Invert x-table Y”, “Flip upside down” and “Enhance lines” before choosing the format of the composite image (Figure 24).

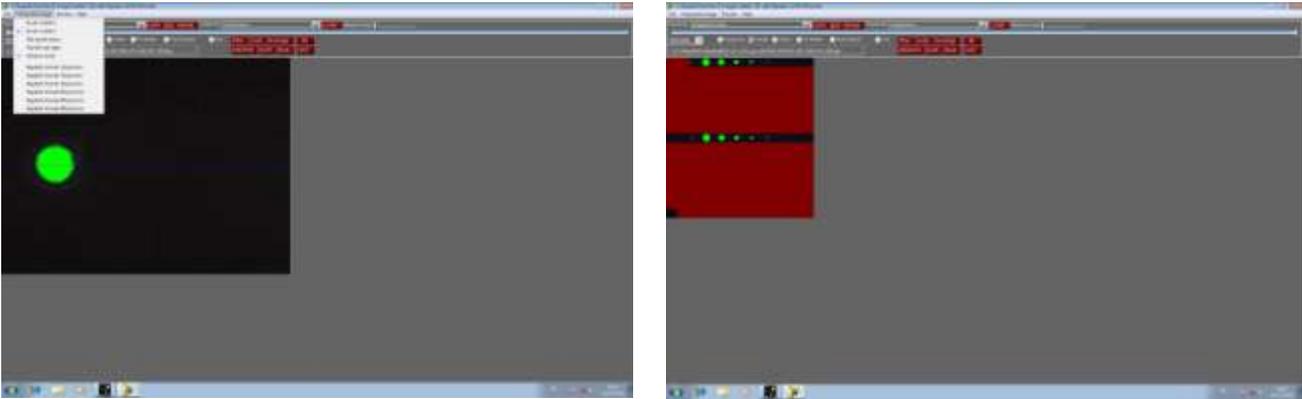


Figure 24. Creating the composite image. Check Invert x-table Y and flip upside down before choosing format. The image to the right shows a stitched image of CXI's reference sample.

When choosing format, e.g. 20 pix/mm, a little counter starts moving from left to right. When done, the composite image will occur in the window.

Pres “File” and save the image. The image will be saved as a jpg.

If the traverse lines during analysis were close enough the composite image will occur as fully stitched image, if not a red row will occur between the image rows. The width of the red row is in scale and indicates the gap between the individual traverse lines.

## ***The Drop Down Menu's***

### *The File Menu*

The File Menu contains only the option “Exit”. Select “Exit” to shut down the RapidAir 457 software.

### *The Setup Menu*

The Setup Menu contains the option “Camera Select”, “Camera Setting”, “X-table and Traverse”, “Stepper Controller” and “Test Parameters”

### Camera Select

Select the option “Camera Select” to open the “Device Settings”-window (Figure 25).

**The camera on the RapidAir has the device name: DFK 72AUC02; when selecting the device name the system prompts the Serial number. Select Video Format: RGB32 (1280x1024) and Frame Rate: (FPS) 17.50002. These parameters are optimized and preset by CXI at delivery of the RapidAir 457 system.**

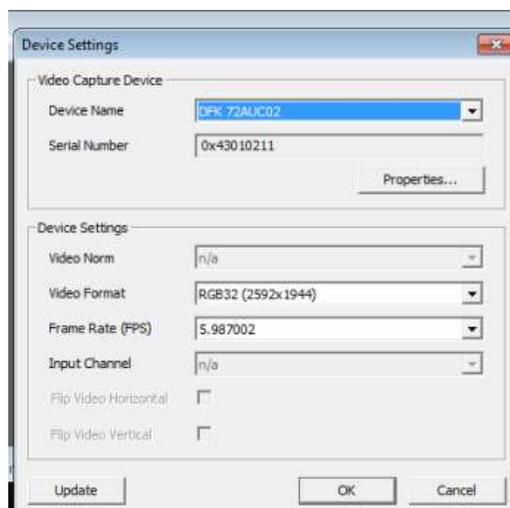


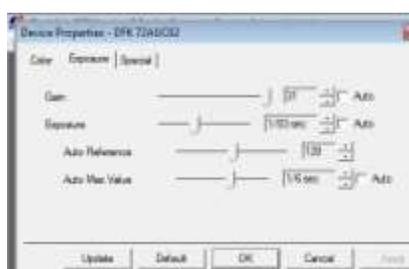
Figure 25. The “Camera Select”-window.

## Camera Setting

Select “Camera Setting” for setting the colors and exposure conditions of the camera.



Color



Exposure



Special

Color: make sure that the White balance is checked OFF. If not uncheck, and press OnePush

Exposure: Set Gain to 31. Exposure is present to 1/83 sec – can be changed if you feel you get a better image with another setting. Make sure all Auto check boxes are unchecked!

Special: Not used for RapidAir

## X-table and traverse

Select the option “X-table and traverse” to open the “Traverse Setup”-window (Figure 26a). This window contains preset values controlling the spatial calibration of the RapidAir 457 system.

At the bottom of the window the dialog between the X-table and software can be viewed.

All the values in “Traverse Setup”-window are optimized and preset by CXI at delivery of the RapidAir 457 system, and should therefore **NOT** be changed (*In particular the spatial calibration values in the “Scale- area of the “Traverse Setup”-window are important not to change!*). Changing the preset values in “Traverse Setup”-window may result in malfunction of the RapidAir 457 system and/or incorrect analysis results. Therefore, **it is highly recommended before starting to use the RapidAir 457 system that a screen dump is taken that includes the “Traverse Setup”-window.**

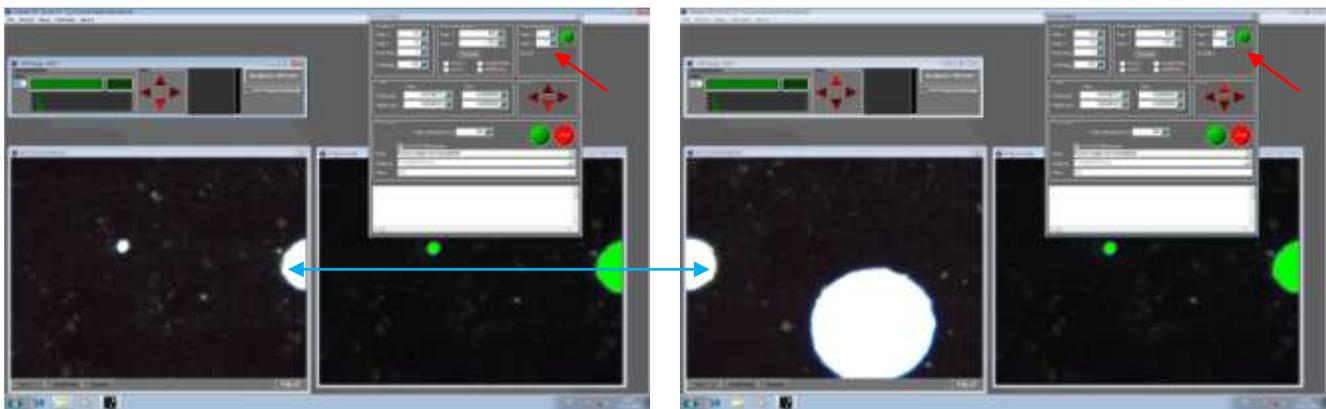
CXI maintains a record of the preset values of all systems delivered. Therefore, in case of uncertainty about the values in the “Traverse Setup”-window contact CXI.

In the “Traverse”-area of the “Traverse-Setup”-window the parameters “Fields X”, “Fields Y”, “Probe lines”, and “Total fields” are found. The parameters shown are calculated based on the operator’s input in the Analysis Wizard. “Fields X” is the number of fields (frames) that the X-table will travel in direction X. “Fields Y” reflects the number of times that “Fields X” is repeated, i.e. if “Fields X” has the value 44 and “Fields Y” has the value 7, then the X-table will travel 7 times across the sample in direction X each time analyzing 44 fields. The 7 paths across the sample will be evenly spread in the Y-direction (in case of the ASTM standard). The parameter “Total Fields” is the product of “Fields X” and “Fields Y”. The parameter “Probe lines” indicates the number of evenly spread lines of analysis (traverse lines) on each frame. Probe should have a value between 1 and 10.

In the “Steps per full field”-area of the “Traverse-Setup”-window the “Steps X”-value indicates the number of steps in the X-direction required to move the right end of the traverse line of a frame to the left end of the traverse line. The value in “Steps X” must never be 1. If for some reason it is 1 press “Calculate” and the correct number will appear.

In the “Manual positioning”-area of the “Traverse-Setup”-window the X-table can be moved to a specific location by entering values for “Fields X” and “Fields Y”. By pressing the “Go”-button the X-table will move to the position indicated by “Fields X” and “Fields Y”, e.g. the value of Fields X is set to 25, and the value of “Fields Y” is set to 10 the X-table will move to the 25<sup>th</sup> frame in the 10<sup>th</sup> traverse line.

If the operator wants to study image by image continue to add 1 to the number in the “Field X” in between pressing “Go”. The X-table will now move only one frame at a time allowing the operator to study the images or to check that the system exactly moves the correct length in order to perform the line traverse.



Step 1: Starting position 1.1

Step 2: Table has moved to position 2.1

In the “Scale”-area of the “Traverse-Setup”-window the spatial calibration of the RapidAir 457 system is found. The pixel size is determined based on measurement of the size of the field of view (768 x 576 pixels - width (direction X) and the height (direction Y)) using a 2.00 mm scale focused under the objective (ex. mm width/768 & mm height/576).

The values underneath the “Step”-caption represent the step lengths that the software uses in calculations. The values represent the minimum step length that the X-table is capable of traveling in the X-direction (width) and Y-direction (height). The number is calculated based on the spindle rise of

the X-table in the following manner: ex. If the spindle rise is 4mm the step in both X and Y direction is:  $4/(360/1.8/16) = 0.00125000$ .

In the “Move”-area of the “Traverse-Setup”-window the X-table can be moved in a given direction by pressing either of four arrows.

In the “Processing”-area of the “Traverse-Setup”-window the parameter “Settle time” is found. “Settle time” represents the time that the camera is in a fixed position before each frame is grabbed. “Settle time” should have the value 200 ms (milliseconds). Too short values of “Settle time” will result in erroneous analysis results, while too large values will result in prolonged analysis time.

### Stepper Controller

Select the option “Stepper Controller” to open the “CXI\_STEP Motor Controller interface (Figure 26b). This window contains preset values controlling the X-table movement of the RapidAir 457 system.

Changing the preset values in “Stepper Controller”-window may result in malfunction of the RapidAir 457 system and/or incorrect analysis results. Therefore, **it is highly recommended before starting to use the RapidAir 457 system that a screen dump is taken that includes the “Stepper Controller”-window.**

The X-table can be moved either by pressing the 4 arrows in the upper left corner or by dragging the two nuts of the “Adjust Position” field.

In the “Motor Parameters”-area the minimum speed (Vmin), maximum speed (Vmax), and the acceleration (Acc) of the stepper motors are set. The settings should be Vmin=100, Vmax=4000, and Acc=100. Torque is set to 80%.

The X-Tables accuracy can be tested by checking the “Test Pattern” box. The table should then move in a regular and steady pattern. The position of the pattern can be seen in the “Position and Target” field.

The LED knobs are not of any use in this version of the RapidAir system.

**NOTE: In order for the X-table to move the system must be powered up – the Volt meter must show 24V! Also you must see the message “Found device: CXI\_STEP – Opened Successfully”! If you don’t see this message then turn the PC off and start over again!**

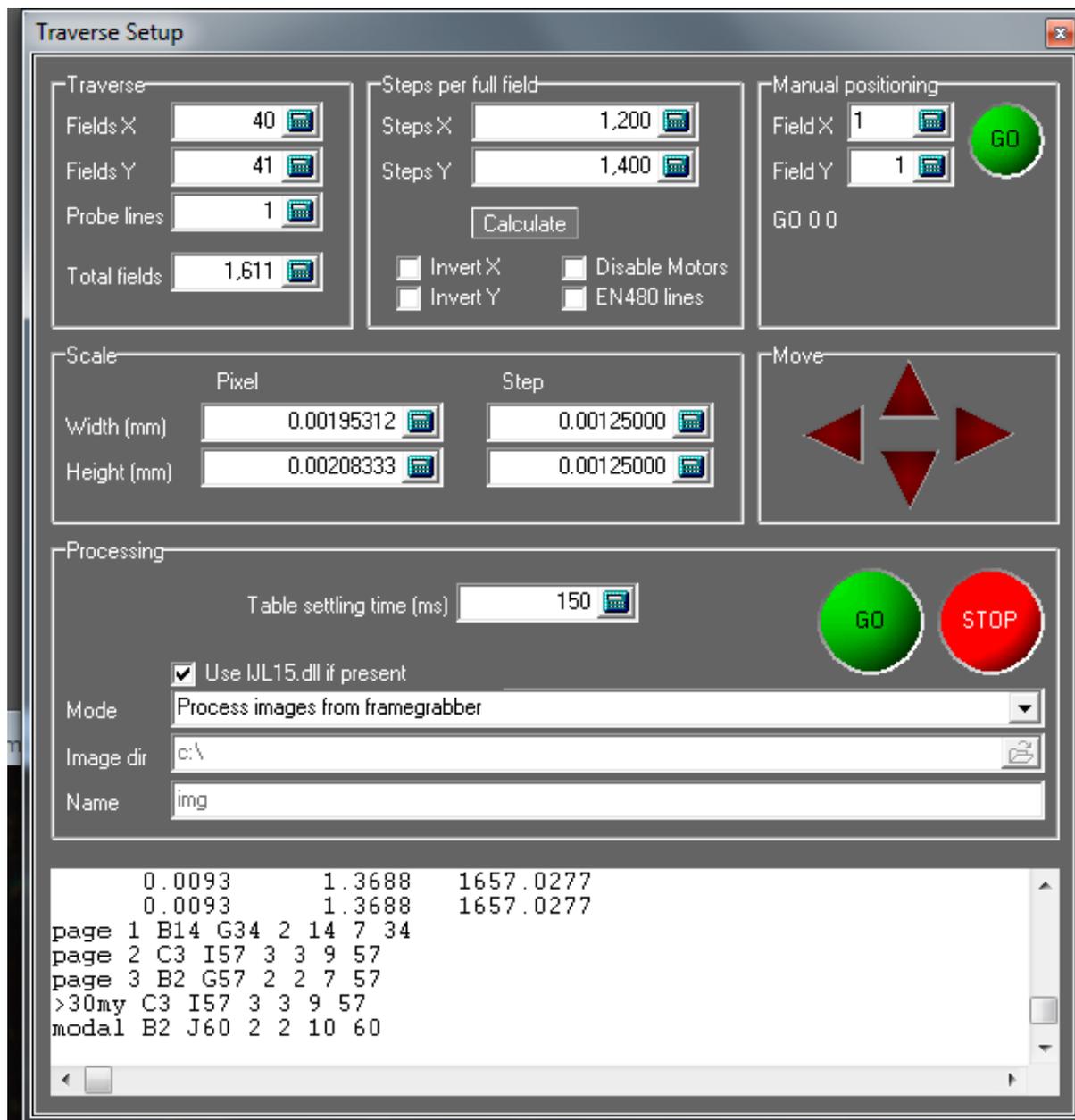


Figure 26a. The "Traverse setup"-window. Generally do not change anything in the Traverse Setup.

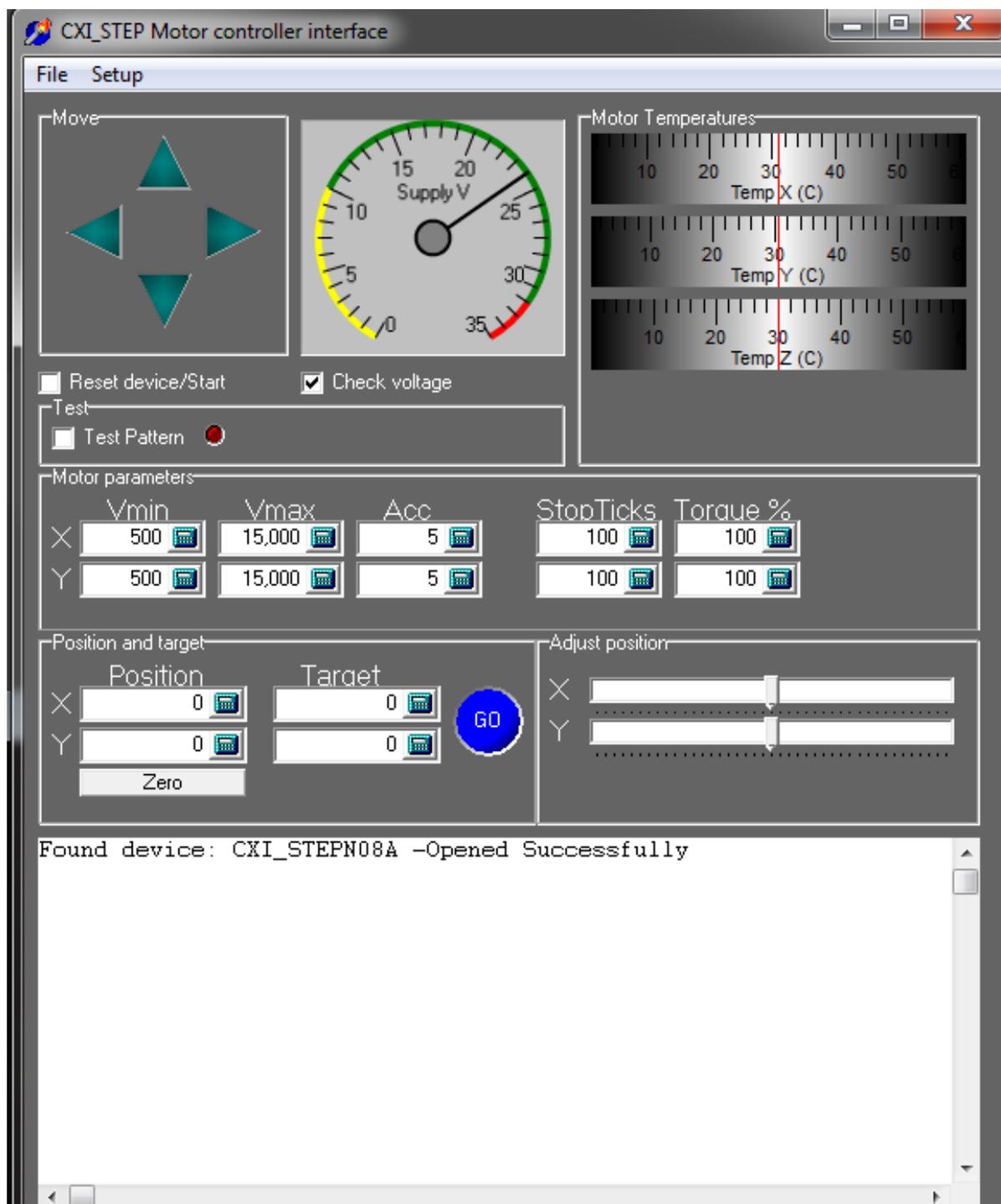


Figure 26b. The “Stepper Controller”-window. Generally do change anything in this window!

#### Test parameters

Select the option “Test parameters” to open the “Test Parameters”-Window (Figure 27). Here some of the input and selections that the operator is making as he/she goes through the step of the Analysis Wizard can be viewed.

It is not recommended that any parameters be changed from within the “Test Parameters”-Window.

Test lab	CXI
Sample Id	Test sample
Project no	testing
Operator id	Claus Pade
Originator id	CP
Paste content %	30
Traverse length (mm)	2,413
Sample length (mm)	125
Sample width (mm)	100
Traversed length (mm)	80
Traversed width (mm)	80

OK

Figure 27. The “Test Parameters”-Window

### *The About Menu*

The about menu contains information about the current version of the RapidAir 457 software installed.

## Principle of Linear Traverse Analysis

The RapidAir 457 system operates according to ASTM C 457 procedure A - linear traverse or EN 480.

After careful preparation of the concrete sample (see Appendix 1 and 2) the sample is placed in the sample holder. Loosen the two tightening screws of the sample holder bar nearest to you and place the sample on the spring device in such a way that the sample is aligned in the holder. Move the bar in position and tighten the two screws and level the sample by gently turning the nub of the spring device until the sample is fastened in the sample holder. The sample is now in level (if the sample preparation is performed correct!). The Analysis Wizard of the RapidAir 457 system is now selected. Once the Analysis Wizard process is essentially complete, i.e. all inputs are provided, the sample has been positioned, and the threshold intensity level has been set, the sample should be positioned as illustrated in Figure 28 with the camera in the starting position indicated by the green circle with a black X.

When the analysis is initiated the X-table will move the camera over the sample in a meandering fashion as indicated by the green arrowhead lines. The number of traverse lines needed to reach the traverse length specified will be evenly spaced over the area of analysis. When the specified length of traverse has been reached the X-table will return to the position from where the analysis was initiated and a report file will be generated.

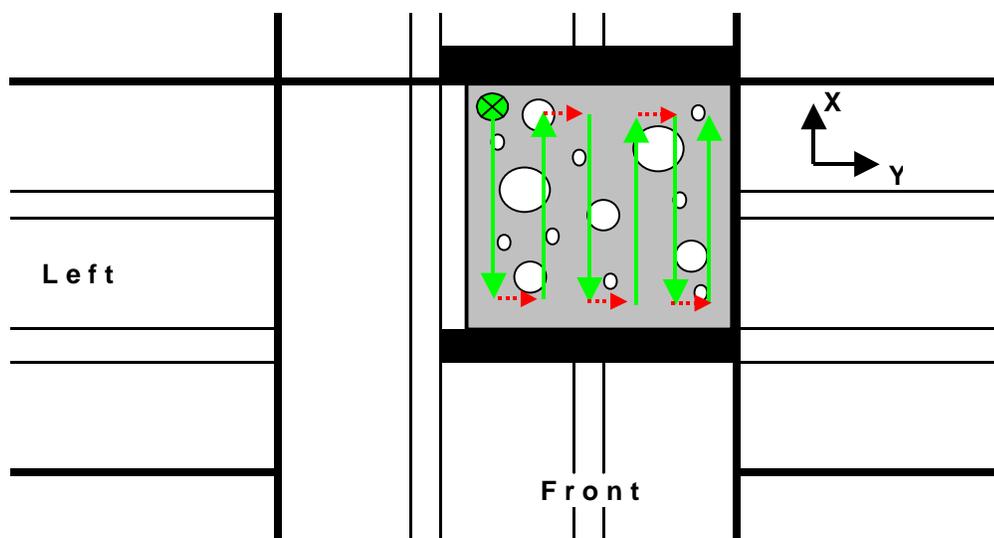


Figure 28. Sketch showing a sample positioned on the X-table. X- and Y-directions are as indicated. Direction X equals length and Y width on Figure 10.

During the analysis the X-table moves in carefully calculated step lengths so that the edges of two consecutive grabbed video frames match each other. Chord lengths are recorded along one-pixel wide lines across the frames (Figure 29). The active pixel range of 768 is indicated by the blue pixel line on the analysis image (binary image). If the line intersects an air void it turns red.

Air voids that extent from one frame into another frame does not pose a problem for the results, as the software remembers the previous frame and continues white pixel arrays into the next frame.

The software will automatically regard both white and black pixel arrays of 1, 2 and 3 pixels as noise. The amount of three white pixel arrays is however recorded under the raw data tap in the report file.

However, the three pixel arrays are not included in the calculations and plots. As the pixel size is about 2 microns the lower cut off corresponds to chords about 8 microns (4pixels x 2microns).

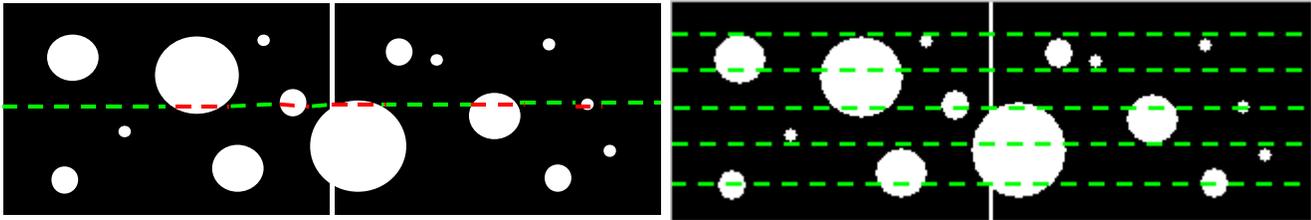


Figure 29. Sketches showing the same two frames with one probe line (left) and five probe lines (right). The red color of the line(s) where they intersect air voids is not shown (left image only).

**Note:**

Information about the vol% of air (white) in each frame, and the accumulated average vol% of air of all frames are shown in the top bar of the threshold window during analysis. The vol% of air is constantly averaged during analysis, and the number can then be compared to the % air calculated from the linear traverse. The numbers are not included in the reports.

## Documenting accuracy of measurements

In order to document the accuracy of RapidAir, the "Analysis Image" including the "analysis line" may be saved during analysis.

**How to**

Start the RapidAir software

Press "Setup"

Press "X-table and traverse" and the window "Traverse Setup" appears (Figure 30).

Move to the bottom part of the window called "Processing". This part of the setup contains three subjects titled "Mode", "Image dir" and "Name".

Select "Mode" and 4 possibilities appears (Figure 30):

Process images from frame grabber

Process from frame grabber, save images to disk

Process from frame grabber, save processed images to disk

Process raw images from disk

The 1st option is default. When this option is selected NO images will be saved during analysis. If the 2nd option is selected the "Raw Image" (the left image) will be saved during the analysis. If the 3rd option is selected the "Analysis Image" with the analysis line (the right image) will be saved during the analysis. This allows the operator to see the exact position of the analysis line and the threshold setting of the image. If the 4th option is chosen an analysis can be performed based on earlier saved images.

To document the accuracy of RapidAir select the 3rd option (remember though to reset to the default setting again after the documentation, because the large amount of images saved during a normal analysis takes place on the hard disk, and slows down the analysis time).

When you select to save images you also have to specify a path where you want the images saved. In "Image dir" choose "C:\RapidAir\Frames"

"Name" shows the three first letters of the image name, here called "img" (don't change this unless you have a good reason to do so). The images are saved as a "jpg" file.

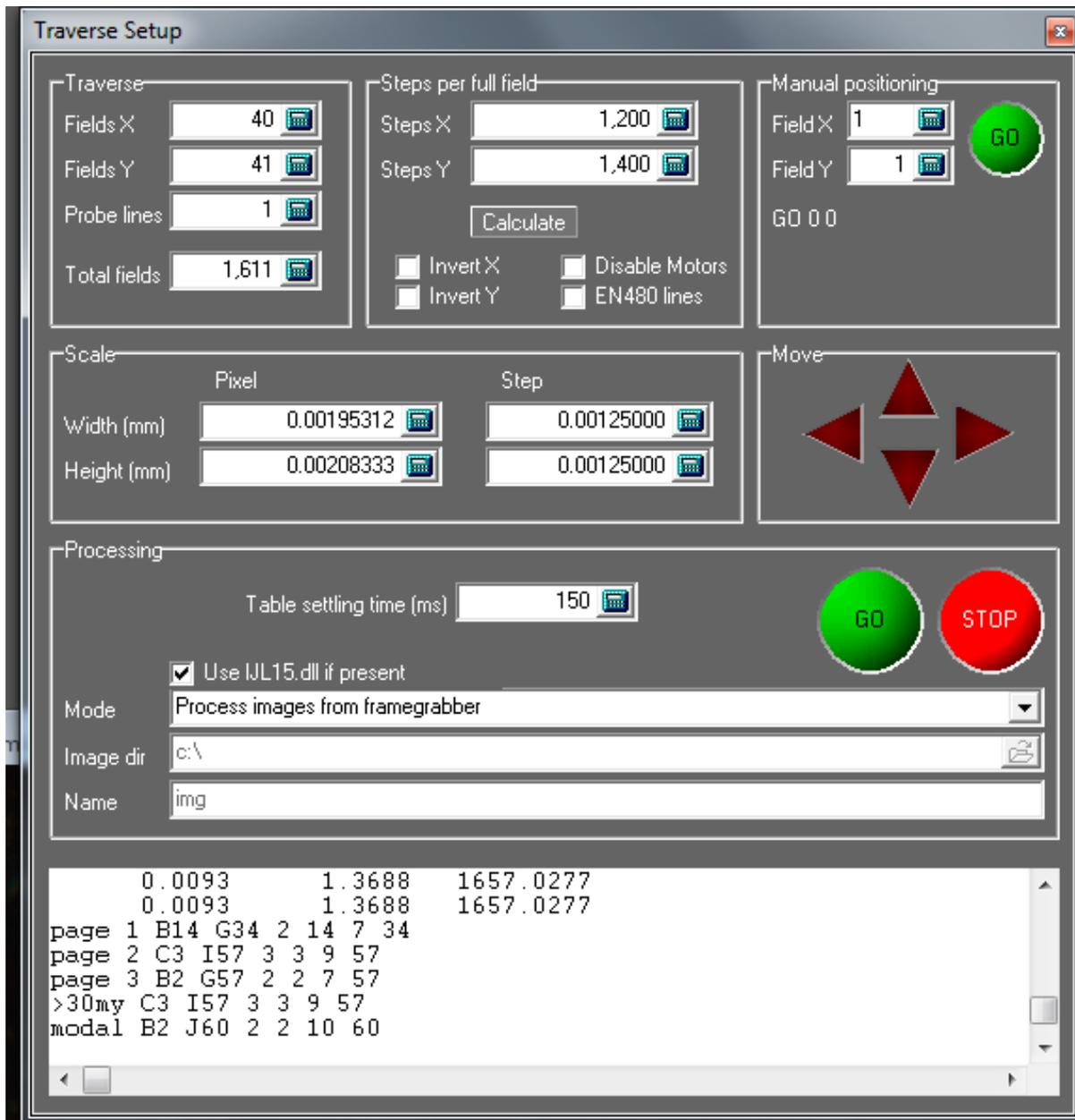


Figure 30 Example of the Setup Traverse window. The lower "Processing" part of the window is useful when images must be saved as e.g. for documentation of the analysis.

If you now press go, the table starts moving and at the same time images are collected. Press stop when you have what you wanted. You can now look at the images via windows or use the RapidBrowse to stitch the images together. This way of collecting images is useful when calibrating the system.

## Reporting

The air void system can be analyzed according to three different standards, ASTM C457 procedure A and B & EN 480-11. As described the type of standard to be used is selected before starting up the analysis.

All reports present data according to the respective standards.

The linear traverse report also presents data about the modal chord length, average chord length and zeroth-order log standard deviation (reference: Roberts, L.R. & Scheiner, P. 1981. Microprocessor-based Linear Traverse Apparatus for Air-Void Distribution Analysis. In: Proc. 3th ICMA, Texas, pp. 211-227). This calculation is not required by any of the standards but is included in the software because some RapidAir customers make use of these parameters in research.

Basically this calculation is a curve fitting. The equation, to which the observed chord lengths up to 0.500 mm are fitted, contains two parameters "the modal chord length" and the "Zeroth order log standard deviation". The "modal chord length" is the most frequently observed chord length according to the model, and the "zeroth order log standard deviation" is a parameter telling you how broad and skewed the observed distribution is. The "deviation of best fit" is the sum of squared errors, i.e. the squared distance from the individual observation to the best fit curve - it gives an idea of how well the observed data fits the model.

The ASTM linear traverse standards also include a page called >30  $\mu\text{m}$ . This page is equal to page 2 but returns results based on chord length in the interval 30-4000  $\mu\text{m}$ . Note: this calculation is NOT part of the ASTM standard but made on request of some customers to compare to manual readers.

The last page of the reports is called Raw Data. The data dumped here is the actual data measured during analysis. You find "Number of Pixel in Array" and "Number of Observations of Array".

In order to back calculate you may multiply the "Number of Pixel in Array" with the pixel resolution and then getting the length of the chord: 100pixels in array x 0.001953125mm = 0,19mm.

## Appendix 1 – Example of grinding/lapping procedure

1. Sample is cut to size in concrete saw (max. 20mm thick) - as close to plane parallel as possible! The brand of the saw blade is important! In order not to ruin the concrete too much the saw blade should be with a continuing rim having a fine cutting edge of diamonds!
2. The first step of sample preparation is grinding. This step should remove damage from sawing and ensure that the surface is completely plane:
3. Draw a grit on the surface to be grinded using a piece of yellow chalk (“crayon”).
4. The sample is grinded using equipment with e.g. fixed diamonds (250 microns); Struers LaboPol or Buehler’s ALPHA™ and BETA™ Grind until the yellow grit is just removed (the trick with the yellow grid helps the operator in knowing when the surface is plane!).

*It is recommended to use cellulose based varnish after this coarsest diamond step and between every other grinding step! The use of varnish makes it easier to prepare the surface and prevents damage on paste and void edges. Use a low viscosity varnish e.g. Zaponlak – German brand. Dilute the varnish 1:5-10 with acetone. Paint the varnish unto the surface and remove excess amount. The varnish layer must be very thin and smooth. When the varnish is dry (goes very fast) continue grinding. The varnish is removed by immersion in acetone after the final grinding step.*

5. A new grit is drawn on the sample.
6. Grind the sample using fixed diamonds (125 microns). Check the surface condition in the stereoscope! When the sample is plane and without damage from sawing continue with the final lapping:
7. The sample is now lapped using silicon carbide powder on a cast iron steel plate according to the following procedure:
8. Start with e.g. grit 320, then 600, and 800 silicon carbide powder suspended in a solution of glycerin, super-plasticizer, plasticizer or sulfo-soap (suspension medias) and water. Use about 1:2 liquid suspension media : water - one large tee-spoon of powder to 100 ml solution. The solution is poured onto the lapping device, and the sample is polished for 5-10 minutes. The time depends on the condition of the concrete. The finer the silicon carbide powder the less suspension media should be used; but you have to adjust the procedure according to your equipment and concrete condition.
9. The sample may finally be lapped with grit 1000 or 1200 silicon carbide powder suspended in a solution of 1:3 or 1:4 liquid suspension media : water - one large tee-spoon of powder to 100 ml solution. The solution is poured into the lapping device, and the sample is polished for 5-10 minutes.

**Very important:** In order not to block the pores with dirt the sample must be cleaned with a soft brush (paint brush with natural hair) under running water between each step.

**IMPORTANT:** *This procedure must be adjusted according to the available polishing equipment etc. Never use polishing cloths when preparing the concrete! The surface will end having relief and be too shiny and therefore difficult to cover black!*

## Appendix 2 – Sample Preparation using BaSO<sub>4</sub> powder : Example 1

The step-by-step sample preparation procedure using BaSO<sub>4</sub> powder is given below (steps 1-8).

1. Traditional grinding/lapping as described in ASTM C 457 (see Appendix 1), but may include a final lapping using grit 1200 powder – the resulting surface being plane and smooth with sharp void edges, no relief, and no saw marks. The lapping quality is checked under the stereomicroscope before proceeding to step 2.
2. Surface is colored black using either a hard stamp pad with ink or a broad tip marker pen. If using a stamp pad add a reasonably amount of ink (not too much) to the pad and tap the stamp pad against the surface until surface is black. If using a marker pen drag the pen over the surface in slightly overlapping strokes. Let dry, turn the sample 90° and repeat. In both cases be careful not to fill voids with ink! It is checked under the stereomicroscope that the surface is fully and uniformly covered with black. Quartz grains may be difficult to cover with a marker pen – if not covered, color the sample one more time or try another brand of marker pen!
3. The black color must be dry before applying white powder. If having used ink the sample must be placed in an oven and be heated to max. 55°C (131°F). This takes a minimum of 30 minutes. The black of a marker pen dries almost immediately.
4. Sprinkle about one t-spoon of white fine-grained BaSO<sub>4</sub> on the black surface. Take a small, very hard rubber stopper and tap the white powder into the air voids. Tap for about 2 minutes until all voids appear filled.
5. Drag a fine edged wooden ice stick or the edge of the rubber stopper along the surface removing most of the white powder. Dragging the spatula should be performed in few drags applying a hard pressure. Be careful not to ruin or scratch the black coating.
6. Move the palm of your hand in circular movements until the white voids appear in sharp contrast to the black paste and all dust is removed. The hand should be cleaned after each circular movement, in order not to initiate a grinding action of the black. If this happens the powder will become gray and it will be difficult to set the threshold later on.
7. The quality of the contrast enhancement is checked under the stereomicroscope. Voids should be fully filled, and no hazy white regions should be found on the surface.
8. In the final step voids/cavities in aggregate as well as obvious cracks are colored black under the stereomicroscope using a marker pen. If very large voids are found in the aggregate they may be covered by a piece of black tape.

## Appendix 3 – Sample Preparation using Zinc Paste: Example 2

The step-by-step sample preparation procedure using zinc paste is given below (steps 1-10).

1. Traditional lapping as described in ASTM C 457 (see Appendix 1), but may include a final lapping using grit 1200 powder – the resulting surface being plane and smooth with sharp void edges, no relief, and no saw marks. The lapping quality is checked under the stereomicroscope before proceeding to step 2.
2. Surface is colored black using either a hard stamp pad with ink or a broad tip marker pen. If using a stamp pad add a reasonably amount of ink (not too much) to the pad and tap the stamp pad against the surface until surface is black. If using a marker pen drag the pen over the surface in slightly overlapping strokes. Let dry, turn the sample 90° and repeat. In both cases be careful not the fill voids with ink! It is checked under the stereomicroscope that the surface is fully and uniformly covered with black. Quartz grains may be difficult to cover with a marker pen – if not covered, color the sample one more time or try another brand of marker pen!
3. The black color must be dry before applying white powder. If having used ink the sample must be placed in an oven and be heated to max. 55°C (131°F). This takes a minimum of 30 minutes. The black of a marker pen dries almost immediately.
4. A white zinc paste is carefully applied/massaged onto the 55 °C warm surface using a finger or rubber spatula. The zinc paste used is a mixture of zinc oxide (40% by weight) in Vaseline. The surface should be warm enough for the zinc paste to melt on the surface and flow by itself into the voids.
5. The sample is cooled to room temperature, e.g. by placing the sample in a refrigerator at 5°C for approximately 10 minutes.
6. Excess zinc paste is removed from the surface using a straight edge (blade from Stanley knife or equivalent). The straight edge is moved at a slow steady speed over the sample surface with the edge in small angle to the surface. The process is repeated until the zinc paste is removed. Be careful not to damage the thin black color film on the surface.
7. The surface is now gently rubbed with mineral oil using the tip of a finger, and the oil is removed with the straight edge.
8. Optional! - Cornstarch powder is padded onto the surface. The starch is absorbing excess mineral oil on the surface while sticking to the zinc paste in the voids. Excess cornstarch is removed from the surface by the straight edge. Other white to off-white powders are considered to be equally effective provided they are neither too coarse nor too fine grained. For instance, when this method of contrast enhancement was originally developed by Gudmundsson and Chatterji in the late 1970s a mono-disperse 3-micron gypsum powder was used.
9. The quality of the contrast enhancement is checked under the stereomicroscope. Voids should be fully filled, and no hazy white regions should be found on the surface.
10. In the final step voids/cavities in aggregate as well as obvious cracks are colored black under the stereomicroscope using a marker pen. If very large voids are found in the aggregate they may be covered by a piece of black tape.

## **Appendix 4 - Equipment and Chemicals**

### **RapidAir 457 Air Void Analyzer**

Concrete Experts International ApS  
Gøngehusvej 242  
DK-2950 Vedbæk  
Denmark  
Tel. +45 2835 0660  
E-mail [uhj@concrete-experts.com](mailto:uhj@concrete-experts.com)  
Contact: Ulla Hjorth Jakobsen

### **Materials for Blackening the samples (examples):**

#### **Black Ink #199 PO**

Performance Coating Corp.  
1606 Manning Boulevard  
Levittown, PA 19057  
Tel. 215 945 4915, Fax. 215 945 9401  
E-mail [performance.coatings@verizon.net](mailto:performance.coatings@verizon.net)  
Contact: Mr. Ernest Korchak

#### **Permanent Black Marker Pens**

SANFORD "Major Impact" No. 06001 Black, USA  
Marks-a-lot #0888x, Brea CA 92821  
Sharpie, Fine Point, No. 30000, Sanford

### **Materials for Whitening the air voids (examples):**

#### **Procedure with white powder (Appendix 2, Procedure 1 in the RapidAir Manual):**

##### BaSO<sub>4</sub> powder

AppliChem: Bariumsulfat, Cas No: 7727-43-7; A4911,1000; [www.applichem.de](http://www.applichem.de)

Jtbaker: [www.jtbaker.com](http://www.jtbaker.com)

Micrometals: [www.micrometals.com](http://www.micrometals.com)

*Must be very fine 2µm or less*

Hard rubber stopper

Steel spatula & wooden stick

#### **Procedure with zinc paste (Appendix 3, Procedure 2 in the RapidAir Manual):**

##### White Zinc Paste 40%

May be homemade ex.:

Zinc Oxide powder (ZnO) 9358-01 from J.T. Baker

Purchased @ VWR 1-800-932-5000, Cat.# J4358-1, 500ml@ \$11.35

Vaseline (100% pure petroleum Jelly) from Chesebrough Pond's USA  
Purchased @ Walmart Store or any other drug store

Mineral Oil, U.S.P. Intestinal Lubricant  
Cumberland Swan, Smyrna, TN 37167  
Purchased @ Walmart Store or any other drug store

Cream Corn Starch, 100% pure  
Dial Corporation, Scottsdale, AZ 85254  
Purchased @ any supermarket

Stanley knife blade, Model HB, 25mm 0.98"wide, 7 Point Razor  
OLFA Japan  
Purchased @ McMaster-Carr (732) 329-3200, Cat# 24995A72, 1 pack @ \$ 22.05

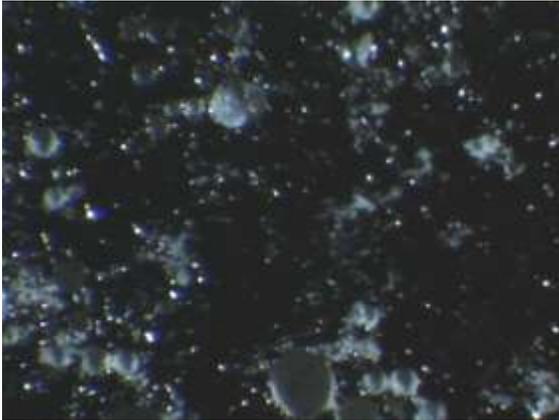
**Accessories need to have:**

Yellow Lumber Crayon  
Purchased @ Grainger (603)668-7161, Cat# 5W542, 12 crayons @ \$8.18

Purple Knight "Nitrile" Gloves from Shild Master  
Purchased @ Fisher Scientific 1-800-766-7000, large Cat# 19050247D, Med. Cat# 1905247C

Zaponlak  
Varnish applied to surface during sample preparation. German brand.

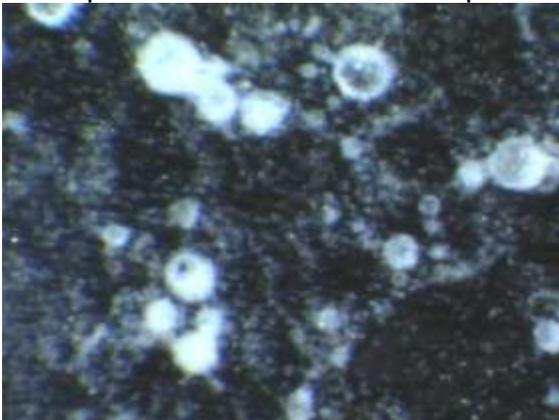
## Appendix 5 - Examples of Bad & Good Sample Preparation



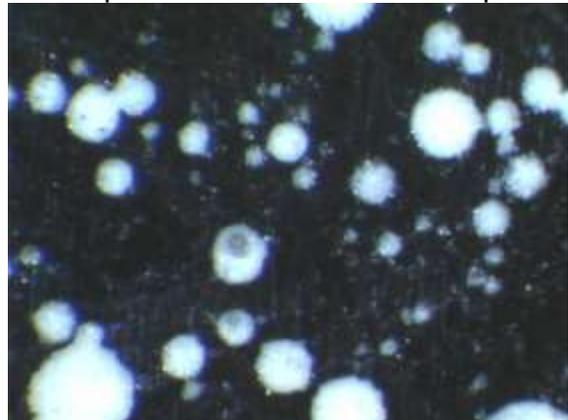
Bad polished area without Zinc paste



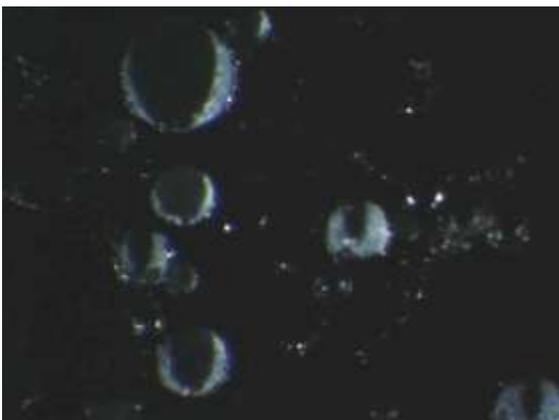
Good polished area without Zinc paste



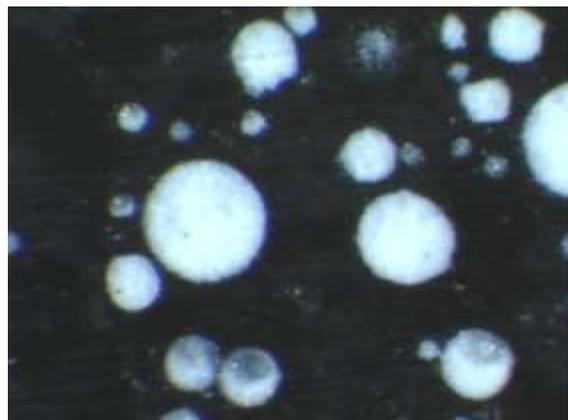
Bad polished area with Zinc paste



Good polished area with Zinc Paste

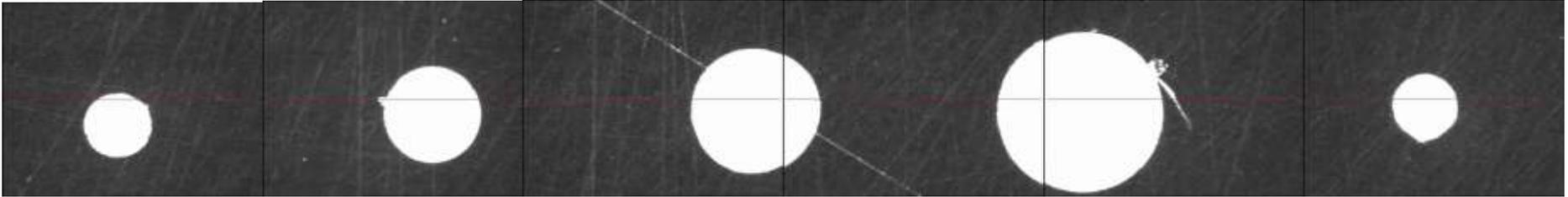


Good polished area without Zinc paste

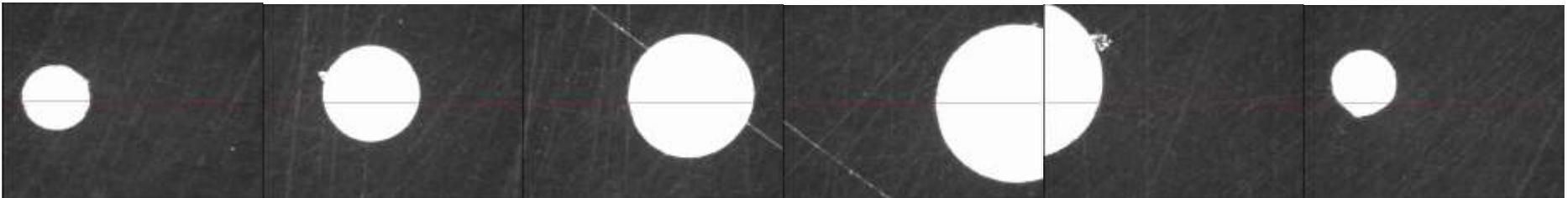


Good polished area with Zinc paste

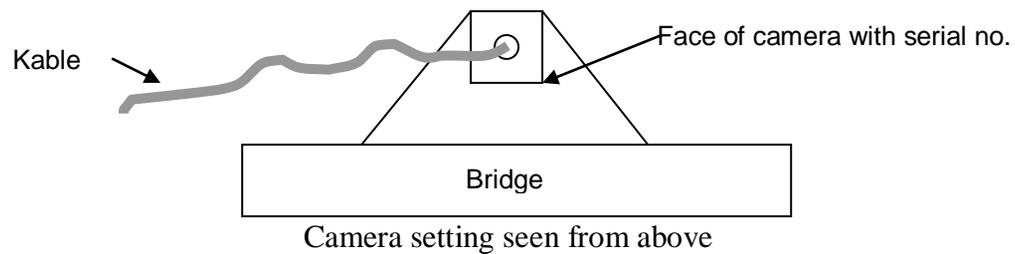
## Appendix 6 – Camera Alignment



Camera is aligned – voids are slightly overlapping (10 pixels) and are on a line!



Camera is NOT aligned – voids are NOT on a line! Un-tighten the camera using a hex key (right side of the tubus).



Be careful not to drop the camera under this procedure! The side of the camera with serial no. must be parallel to the bridge of the X-table!

## **Appendix 7 – Report Examples**

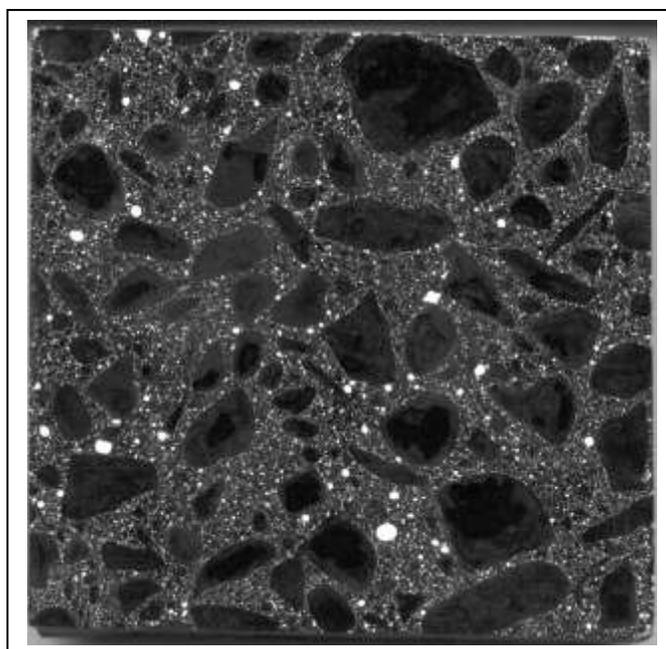
(ASTM 457 with SI units followed by EN 480 with SI units)

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# Air Void Analysis of Hardened Concrete

Calculated According to ASTM C 457 Procedure A

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Sample ID: Test sample                      Date: 13-08-2002

Project No: testing                              Operator: Claus Pade

Originator: CP                                      Threshold: 141

File Name: C:\RapidAir457\reports\test-sample-01.xls

Test Laboratory: CXI

Sample ID: Test sample

---

Sample Size (mm x mm):	100 x 100	Length Traversed (mm):	2413.9
Paste Content (%):	30	Area Traversed (mm x mm):	80 x 80

---

### Chord Length Distribution - Table

Class No.	Chord size (microns)	Number of Chords in Class	Number of Chords in Percent	Air Content in Class	Cumulated Air Content
1	0-10	1	0.13	0.000	0.000
2	10-20	57	7.60	0.040	0.040
3	20-30	88	7.60	0.090	0.130
4	30-40	54	7.20	0.080	0.210
5	40-50	50	6.67	0.090	0.300
6	50-60	72	9.60	0.160	0.460
7	60-80	90	12.00	0.250	0.720
8	80-100	73	9.73	0.270	0.980
9	100-120	57	7.60	0.260	1.240
10	120-140	40	5.33	0.220	1.460
11	140-160	25	3.33	0.160	1.610
12	160-180	20	2.67	0.140	1.750
13	180-200	16	2.13	0.130	1.880
14	200-220	8	1.07	0.070	1.950
15	220-240	8	1.07	0.080	2.020
16	240-260	7	0.93	0.070	2.090
17	260-280	6	0.80	0.070	2.160
18	280-300	8	1.07	0.100	2.260
19	300-350	10	1.33	0.130	2.390
20	350-400	6	0.80	0.090	2.480
21	400-450	8	1.07	0.140	2.620
22	450-500	3	0.40	0.060	2.680
23	500-1000	31	4.13	0.870	2.810
24	1000-1500	5	0.67	0.240	3.790
25	1500-2000	5	0.67	0.360	4.160
26	2000-2500	2	0.27	0.180	4.340
27	2500-3000	0	0.00	0.000	4.340
28	3000-4000	0	0.00	0.000	4.340

Air Content (%): 4.34

Specific Surface ( $\text{mm}^{-1}$ ): 28.64

Spacing Factor (mm): 0.188

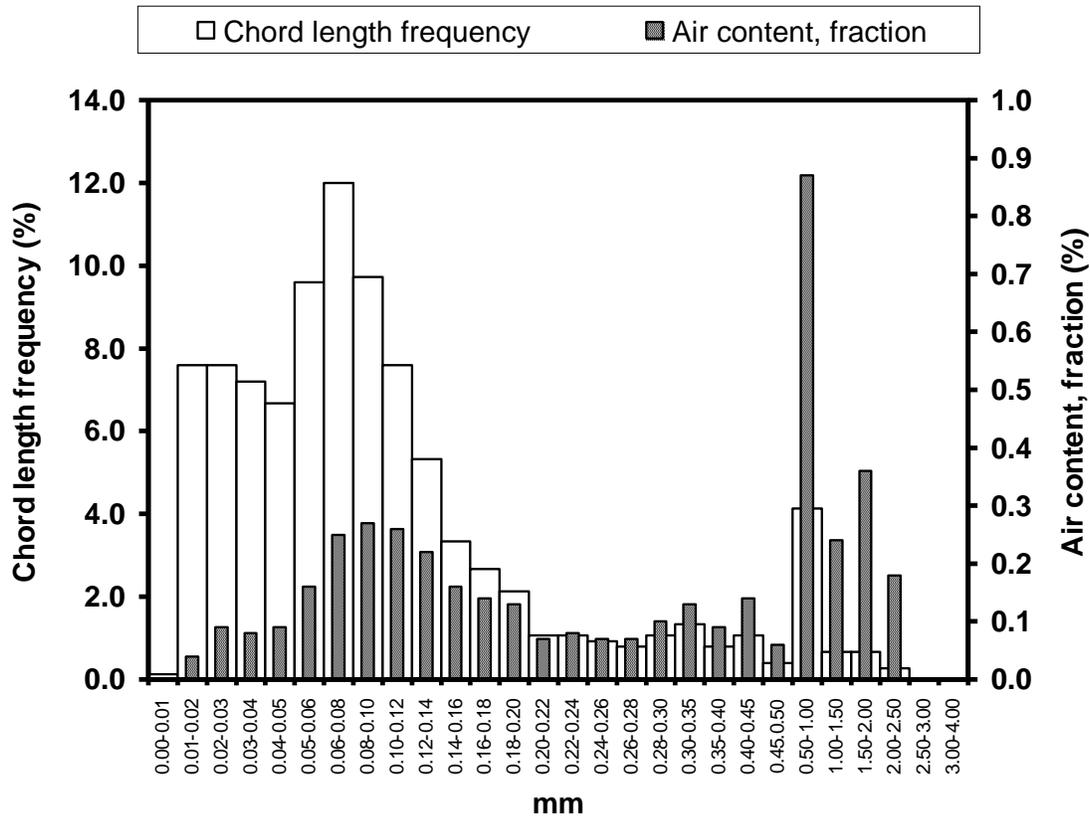
Void Frequency ( $\text{mm}^{-1}$ ): 0.31

Average Chord Length (mm): 0.140

Paste to Air Ratio: 6.91

---

Sample ID: Test sample

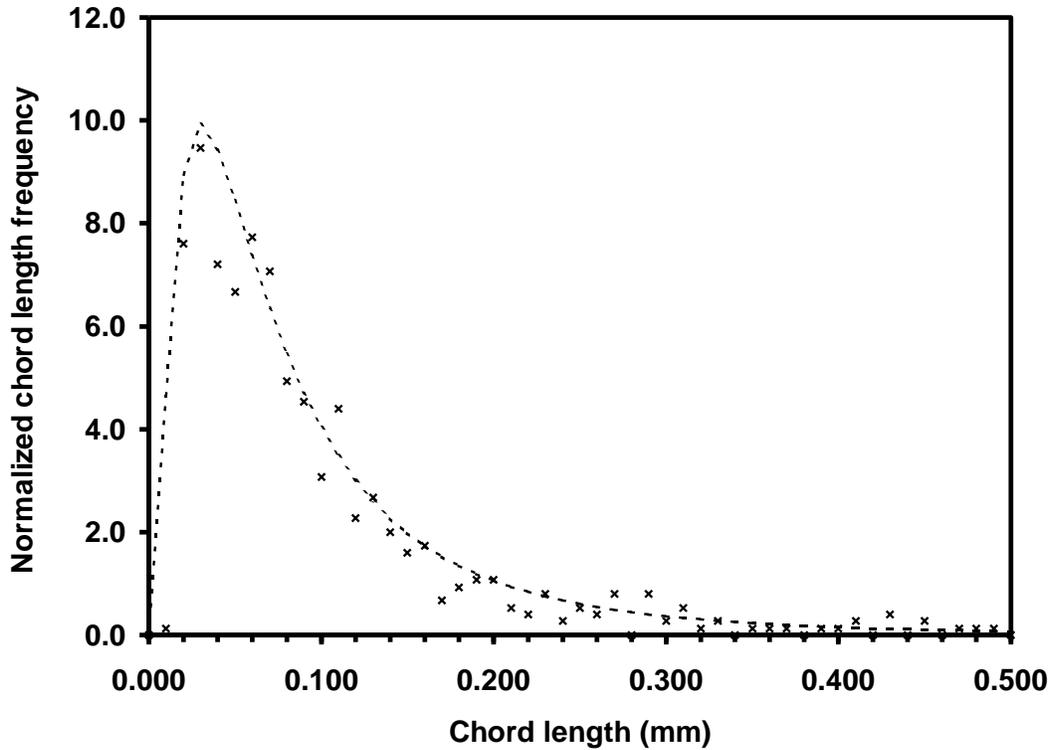


Air Void Parameter	Chords < 0.5 mm	Chords < 1.0 mm	All Chords
Number of Voids	707	738	750
Percent of Total Number of Voids	94.3	98.4	100
Length of Air Traversed (mm)	64.73	85.68	104.75
Percent of Total Length of Air Traversed	61.8	81.8	100
Air Content (%)	2.68	3.55	4.34
Average Chord Length (mm)	0.092	0.116	0.140
Paste to Air Ratio	11.19	8.45	6.91
Specific Surface (mm <sup>-1</sup> )	43.69	34.453	28.64
Void Frequency (mm <sup>-1</sup> )	0.293	0.306	0.310
Spacing Factor (mm)	0.153	0.171	0.188

Remarks: none

Sample ID: Test sample

### log-normal distribution



Air Void Distribution Parameters	in	mm
Modal Chord Length	0.00119	0.0301
Average Chord Length	0.0055	0.1400
Zeroth-Order Log Standard Deviation	0.0014	0.895
Deviation of Best Fit (sum of squares)	185	

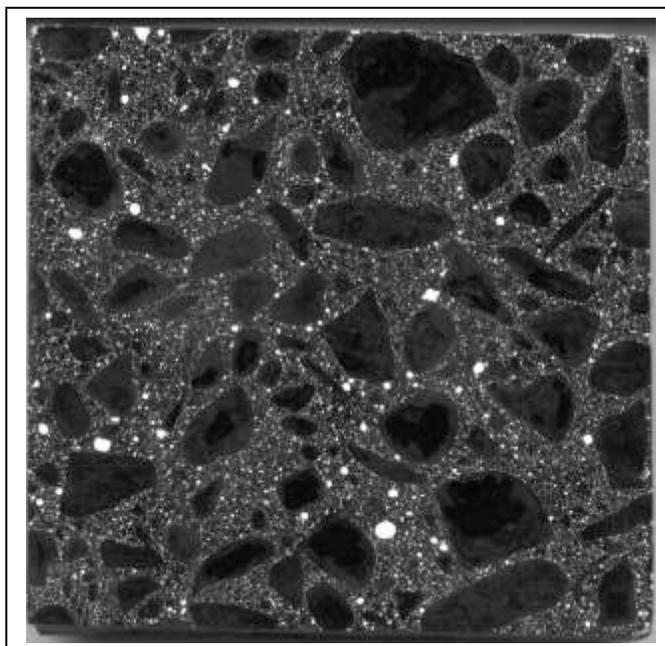
Remarks: none

---

# Air Void Analysis of Hardened Concrete

Calculated According to EN 480-11

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Sample ID: Test sample                      Date: 13-08-2002

Project No: testing                              Operator: Claus Pade

Originator: CP                                      Threshold: 141

File Name: C:\RapidAir457\reports\test-sample-02.xls

Test Laboratory: CXI

---

Sample ID: Test sample

---

Sample Size (mm x mm): 100 x 100      Length Traversed (mm): 2413.9  
 Paste Content (%): 30      Area Traversed (mm x mm): 80 x 80

---

### Chord Length Distribution - Table

Class No.	Chord size (microns)	Number of Chords in Class	Number of Chords in Percent	Air Content in Class	Cumulated Air Content
1	0-10	3	0.39	0.000	0.000
2	10-20	73	9.55	0.040	0.050
3	20-30	90	11.78	0.100	0.140
4	30-40	65	8.51	0.100	0.240
5	40-50	66	8.64	0.120	0.360
6	50-60	81	10.60	0.180	0.540
7	60-80	90	11.78	0.260	0.800
8	80-100	65	8.51	0.240	1.040
9	100-120	47	6.15	0.210	1.250
10	120-140	27	3.53	0.150	1.400
11	140-160	24	3.14	0.150	1.550
12	160-180	21	2.75	0.150	1.690
13	180-200	10	1.31	0.080	1.770
14	200-220	11	1.44	0.100	1.870
15	220-240	8	1.05	0.080	1.940
16	240-260	3	0.39	0.030	1.980
17	260-280	9	1.18	0.100	2.080
18	280-300	7	0.92	0.080	2.160
19	300-350	10	1.31	0.140	2.300
20	350-400	5	0.65	0.080	2.370
21	400-450	10	1.31	0.180	2.550
22	450-500	0	0.00	0.000	2.550
23	500-1000	30	3.93	0.850	2.660
24	1000-1500	5	0.65	0.240	3.650
25	1500-2000	2	0.26	0.140	3.790
26	2000-2500	0	0.00	0.000	3.790
27	2500-3000	1	0.13	0.110	3.900
28	3000-4000	1	0.13	0.160	4.060

Air Content (%): 4.06

Specific Surface ( $\text{mm}^{-1}$ ): 31.17

Spacing Factor (mm): 0.178

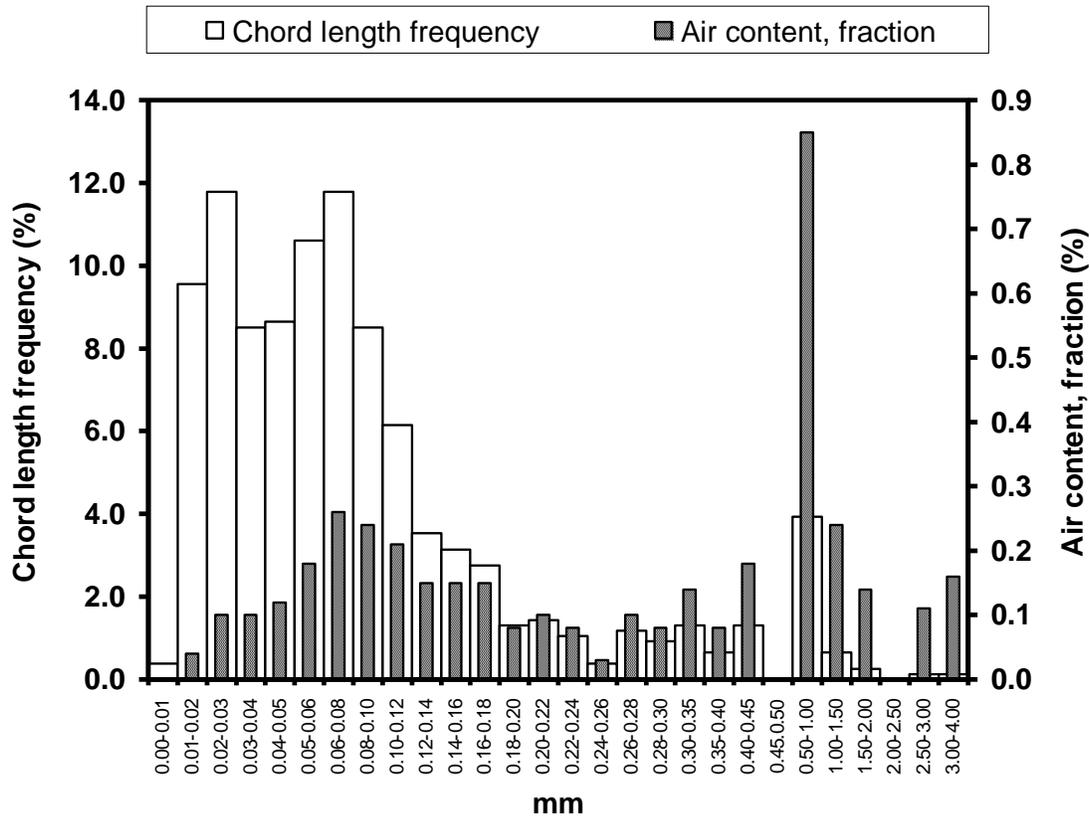
Void Frequency ( $\text{mm}^{-1}$ ): 0.32

Average Chord Length (mm): 0.128

Paste to Air Ratio: 7.39

---

Sample ID: Test sample



Air Void Parameter	Chords < 0.5 mm	Chords < 1.0 mm	All Chords
Number of Voids	725	755	764
Percent of Total Number of Voids	94.9	98.8	100
Length of Air Traversed (mm)	61.57	82.15	98.04
Percent of Total Length of Air Traversed	62.8	83.8	100
Air Content (%)	2.55	3.40	4.06
Average Chord Length (mm)	0.085	0.109	0.128
Paste to Air Ratio	11.76	8.82	7.39
Specific Surface (mm <sup>-1</sup> )	47.10	36.76	31.17
Void Frequency (mm <sup>-1</sup> )	0.300	0.313	0.320
Spacing Factor (mm)	0.145	0.163	0.178

Remarks: none

Sample ID: Test sample

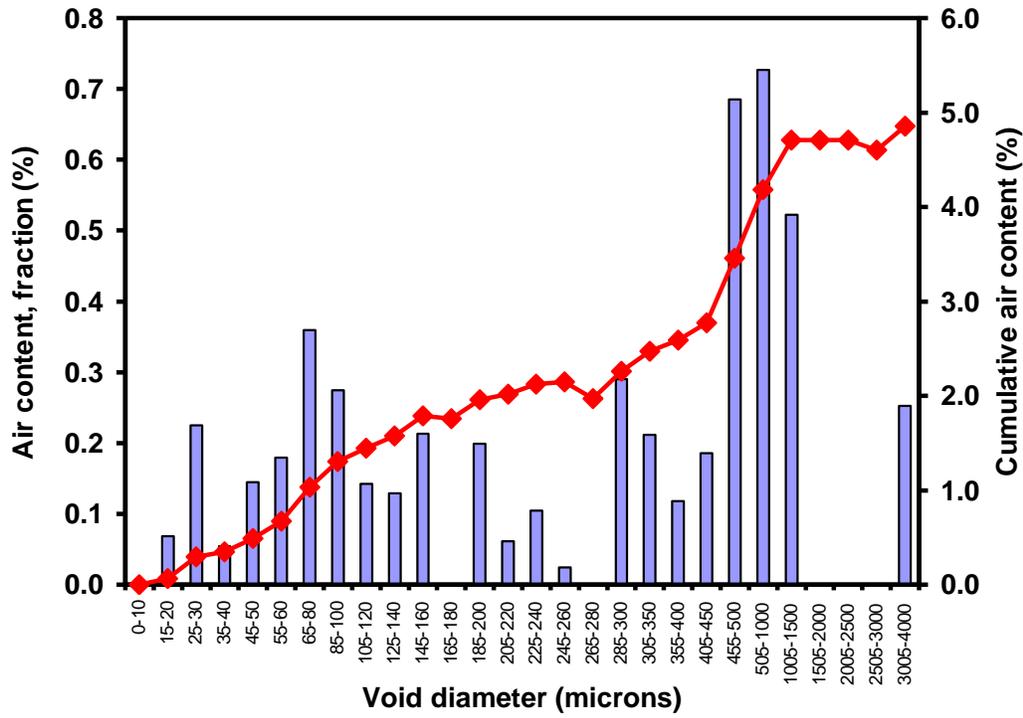
### Determination of air void distribution

Column	1	2	3	4	5	6	7	8	9	10
Subject	Class	Class width	Recorded number of chords in class	Chord frequency	Fraction encountered	Possible total	Voids in class	Void volume	Air content	Cumulative air content
Units		Microns		mm-1	mm2	mm-3	mm-3	mm3	%	%
	1	0-10	31	0.01284	0.0001178	109.01773	18.599	5.24E-07	0.001	0.00
	2	15-20	60	0.02486	0.0002749	90.41849	18.497	4.19E-06	0.008	0.01
	3	25-30	75	0.03107	0.0004320	71.92142	7.214	1.41E-05	0.010	0.02
	4	35-40	92	0.03811	0.0005890	64.70730	13.625	3.35E-05	0.046	0.06
	5	45-50	92	0.03811	0.0007461	51.08243	21.728	6.54E-05	0.142	0.21
	6	55-60	64	0.02651	0.0009032	29.35464	11.715	1.13E-04	0.132	0.34
	7	65-80	97	0.04018	0.0022780	17.64001	8.089	2.68E-04	0.217	0.56
	8	85-100	67	0.02776	0.0029060	9.55124	4.628	5.24E-04	0.242	0.80
	9	105-120	42	0.01740	0.0035340	4.92338	2.635	9.05E-04	0.238	1.04
	10	125-140	23	0.00953	0.0041630	2.28877	0.127	1.44E-03	0.018	1.06
	11	145-160	25	0.01036	0.0047910	2.16170	0.480	2.14E-03	0.103	1.16
	12	165-180	22	0.00911	0.0054190	1.68184	0.997	3.05E-03	0.304	1.46
	13	185-200	10	0.00414	0.0060470	0.68508	0.127	4.19E-03	0.053	1.51
	14	205-220	9	0.00373	0.0066760	0.55848	0.105	5.58E-03	0.058	1.57
	15	225-240	8	0.00331	0.0073040	0.45374	0.245	7.24E-03	0.177	1.75
	16	245-260	4	0.00166	0.0079330	0.20888	-0.178	9.20E-03	-0.164	1.59
	17	265-280	8	0.00331	0.0085610	0.38712	0.072	1.15E-02	0.082	1.67
	18	285-300	7	0.00290	0.0091890	0.31558	0.155	1.41E-02	0.218	1.89
	19	305-350	10	0.00414	0.0257200	0.16107	0.077	2.24E-02	0.173	2.06
	20	355-400	6	0.00249	0.0296500	0.08383	-0.027	3.35E-02	-0.091	1.97
	21	405-450	9	0.00373	0.0335800	0.11103	0.111	4.77E-02	0.530	2.50
	22	455-500	0	0.00000	0.0375000	0.00000	-0.021	6.54E-02	-0.138	2.36
	23	505-1000	30	0.01243	0.5910000	0.02103	0.019	5.24E-01	0.991	3.35
	24	1005-1500	5	0.00207	0.9830000	0.00211	0.002	1.77E+00	0.266	3.62
	25	1505-2000	2	0.00083	1.3760000	0.00060	0.001	4.19E+00	0.252	3.87
	26	2005-2500	0	0.00000	1.7690000	0.00000	0.000	8.18E+00	-0.157	3.71
	27	2505-3000	1	0.00041	2.1620000	0.00019	0.000	1.41E+01	0.164	3.88
	28	3005-4000	1	0.00041	5.5020000	0.00008	0.000	3.35E+01	0.252	4.13

Micro Air Content (%): 1.89

Sample ID: Test sample

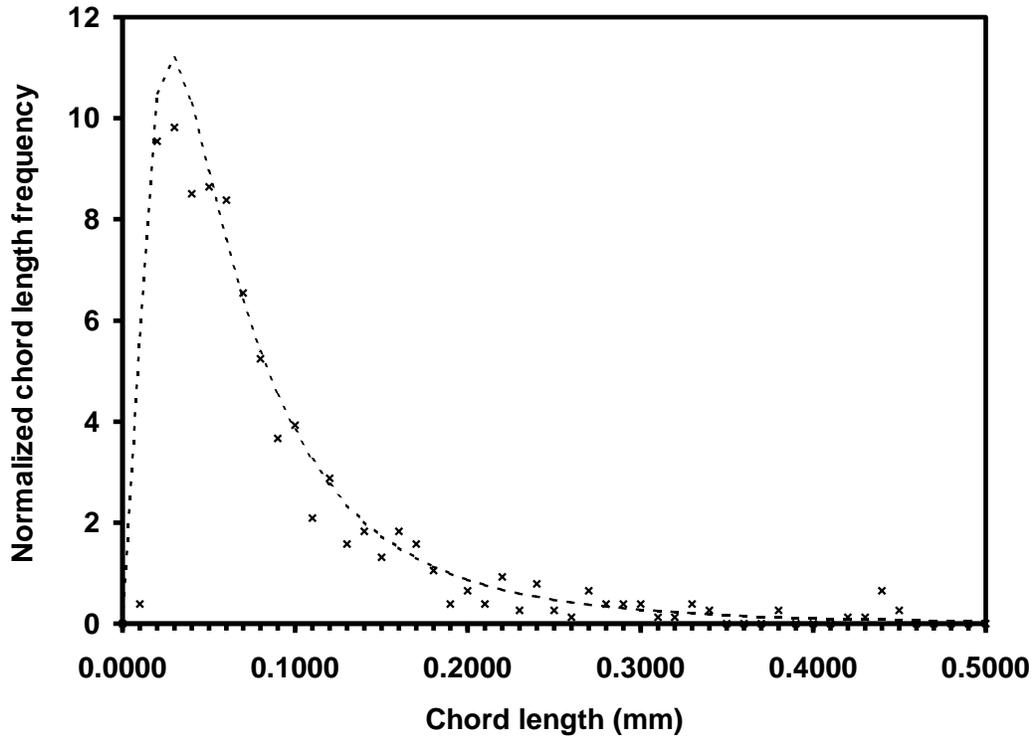
### Air Void Distribution according to EN-480



Air Content (%):	4.88
Specific Surface (mm <sup>-1</sup> ):	45.85
Spacing Factor (mm):	0.108

Sample ID: Test sample

### log-normal distribution



Air Void Distribution Parameters	in	mm
Modal Chord Length	0.00109	0.0277
Average Chord Length	0.0051	0.128
Zeroth-Order Log Standard Deviation	0.0014	0.874
Deviation of Best Fit (sum of squares)	190	

Remarks: none

## Appendix 8 – Software Key and Serial Numbers

Software version	
Software Key	
RapidAir 457 serial number	
X-table number	
ImagingSource - Camera serial number	
ImagingControl software	
Controller serial number	
PC control unit	