3. SEDIMAGING HARDWARE

This chapter describes the Sedimaging system hardware. The hardware consists of the following subsystems as identified in Figure 3.1:

- 1. Sedimentation Column
- 2. Support Tower & Base
- 3. Positioning system

- 5. Connector & Drainage
- 6. Sediment Accumulator
- 7. Camera & Illumination
- 4. Pre-Segregation & Soil Release System
- 8. Computer & Monitor

Numbers shown in square brackets throughout this chapter refer to the labeled parts shown in Figures 3.1 through 3.6. For brevity, further references to figure numbers are omitted since the parts are easily located via the numbering scheme.

3.1 Sedimentation Column

The *sedimentation column* [1] is a 2.5 in. x 2.5 in. x 8 ft. aluminum square tube with 0.25 in. wall thickness. The sedimentation column is filled with water and the soil specimen is introduced at its top. The particles settle down through this column and into the accumulator below.

3.2 Support Tower & Base

The *support tower* [2] is a 4 in. x 6 in. x 6.5 ft. aluminum I-beam. The *base* [2] is a 1.5 ft. x 3.0 ft. x 0.5 in. aluminum plate. The support tower is bolted to the base. Together, they provide resistance to overturning of the sedimentation column.

3.3 Positioning System

The *positioning system* [3] consists of 2 *positioning brackets* [3a] and 5 *positioning clamp screws* [3b] per bracket. The positioning bracket is a 4 in. x 4 in. x 3 in. long aluminum square tube with 0.25 in. wall thickness. Two 0.25 in. diameter positioning clamp screws attach each bracket to the support tower. Three other 0.25 in. diameter screws per bracket have 0.625 in. diameter hard rubber contact pads on their ends to position the sedimentation column vertically and immobilize it. A *bubble level* [3c] and a 4 in. long *plumb bob* [3d] are used to check the verticality of the sedimentation column during initial system set-up.

3.4 Pre-segregation & Soil Release System

The acrylic *pre-segregation tube* [4a] is 18 in. long with 2.5 in. outside diameter and 0.25 in. wall thickness. One end of the tube is open and the other end is permanently capped by an acrylic circular disk of 0.5 in. thickness and 3.0 in. diameter. A 0.5 in. diameter *vacuum vent* (with vent cap) [4b] is located at the center of the circular disk. Opening the vent cap

releases the soil into the sedimentation column. *Rubber membranes* (party balloons with snipped ends) [4c] are used to create a vacuum inside the pre-segregation tube as will be explained in Chapter 6. A *soil funnel* [4d] with a 4 in. top diameter and a 0.7 in. spout diameter assists with pouring of soil into the pre-segregation tube. A *water container* [4e] fills the sedimentation column with 6000 mL of water. It also fills the pre-segregation tube with about 1000 mL of water. The soil container [4f] is a 3.5 in. diameter x 2.0 in. high aluminum canister. It is used to measure an appropriate volume of soil for transfer (through the funnel) to the pre-segregation tube and subsequently for sedimentation.

A *pre-segregation tube adaptor* [4g] is also made of acrylic. It is circular on top and square on the bottom. The pre-segregation tube adaptor mates the circular pre-segregation tube to the square sedimentation column. The square part of the adaptor contains a 0.3 in. diameter air vent on one side. It lines up with an identical hole in the sedimentation column. This vent releases air from the sedimentation column allowing the introduction of the soilwater mixture into the column. A 2.5 in. x 2.5 in. *square gasket* [4h] with a concentric 2.0 in. diameter hole prevents water from escaping between the sedimentation column and the pre-segregation tube adaptor. Similarly a *round gasket* [4i] with 2.5 in. outside diameter and 2.0 in. inside diameter is used to prevent leaks between the pre-segregation tube adaptor.

3.5 Connector & Drainage

Located beneath the sedimentation column is a *connector* [5a] to the sediment accumulator below. It consists of an outer 3 in. x 3 in. square tube with a 0.25 in. wall thickness and a 2.5 in. x 2.5 in. inner connector made from a square aluminum tube with 0.25 in. wall thickness. Two 2.875 in. outside diameter x 0.09375 in. diameter rubber O-rings are positioned in grooves inside the connector to prevent leaks between the sedimentation column and connector and between the connector and the sediment accumulator. A *drainage valve* [5b] with a socket cap screw for a valve stem has a 0.5 in. thread diameter and 1.75 in. length. The valve stem passes through the connector when in the "closed" position. A 0.375 in. outside diameter \times 0.0625 in. diameter O-ring surrounds the drainage valve stem to prevent leaks between the connector and the drainage valve is closed. When the drainage valve is opened by unscrewing it, water is released from the system through a flexible 0.25 in. inside diameter *drainage tube* [5c].

3.6 Sediment Accumulator

The sediment accumulator [6] consists of the sediment cartridge [6a], a cartridge pedestal [6b], the cartridge support [6c], lower accumulator clamps [6d] and upper accumulator

clamps [6e]. The sediment cartridge [6a] is a 2.5 in. x 2.5 in. x 1 ft. long aluminum tube of 0.25 in. wall thickness. Two 10.25 in. x 2.0 in. x 0.125 in. borosilicate (Pyrex[®]) glass windows are attached over openings on opposite sides of the sediment cartridge. The images of the sedimented soils are taken through these windows. The largest soil particles which settle at the very bottom of the sediment cartridge sit on top of the cartridge pedestal [6b] whose top surface is 0.5 in. above the bottom of the windows to provide an unobstructed view of the bottom of the sedimented soil column. The cartridge pedestal is milled down from a solid square aluminum bar originally having 2.5 in. x 2.5 in. cross section and 2.25 in. length. The pedestal is 2.0 in. x 2.0 in. in plan to fit precisely inside the sediment cartridge (above) and inside the cartridge support (below). A 2.875 in. outside diameter x 0.09375 in. diameter O-ring prevents leaks between the sediment cartridge and the cartridge pedestal. The pedestal sits atop the 2.5 in. x 2.5 in. x 7.0 in. x 0.25 in. wall cartridge support [6c]. The two lower accumulator clamps [6d] hold the sediment cartridge, the cartridge pedestal, and the cartridge support together while the two upper accumulator clamps [6e] hold the sediment cartridge together during a test.

3.7 Camera & Illumination

A 16.2 Mpix Nikon D7000 camera [7a] with and AF-S Micro NIKKOR 60 mm f/2.8G ED Nikon lens [7b] are used to capture the images. A UC-E4 Nikon computer cable [7c] connects the camera to a computer. An EH-5A Nikon AC power cord with EP-5 Nikon adaptor [7d] provides AC power. A bi-directional bubble level [7e] is used to level the camera. A 4 in. x 6 in. x 1.5 ft. aluminum support column [7f] holds the camera and lighting. A camera bracket [7g] is attached to the I-beam using 4 holding screws and the camera is attached to the bracket using a single camera mounting screw. The 0.25 in. diameter camera holding screws are used to adjust the camera in the x and y directions while the 0.25 in. diameter camera mounting screw adjusts the camera in the y and z directions. The lighting [7h] is attached to a light bracket [7i] fixed atop of the I-beam. The lighting removes shadows from the sediment cartridge. A 6 in. engineering scale [7i] assists in precisely determining the camera magnification.

3.8 Computer & Monitor

A microcomputer and monitor are used to control the camera and remotely capture images using software NK Remote by Breeze Systems and then to analyze the image and produce the grain size distribution curve through the computer program *sedimaging.exe*.



Fig. 3.1 Sedimaging system overview photographs. $_{41}$



Fig. 3.2 Positioning clamp system.





4b Vacuum vent

4a Pre-segregation Tube

4g Pre-segregation Tube Adaptor



Fig. 3.4 Pre-segregation and soil release system.





4. SEDIMAGING SOFTWARE

4.1 NKRemote

NKRemote by Breeze Systems (\$175) (<u>http://www.breezesys.com/index.htm</u>) facilitates remote control of Nikon digital SLR cameras from a microcomputer. It is ideally suited for Sedimaging as several of the program's features are utilized including:

a) Live view on a computer monitor of the scene in the camera's field of view.

b) Full control of all camera settings from the computer.

c) Digital zooming on a zone of interest in the field of view.

d) Remote manual focusing on a zone of interest, or on the full image.

e) Remote image capture and direct file storage to the computer hard drive.

4.2 Sedimaging.exe

Sedimaging.exe is an executable program that was developed at the University of Michigan using MATLAB by Mathworks. MATLAB is a high-level computer language that performs many mathematical tasks, particularly those involving matrix algebra, faster than traditional programming languages such as Fortran and C++. The Sedimaging program crops the image taken by NKRemote, performs the image processing and outputs the test results with minimal user interaction. Since Sedimaging.exe is a compiled executable program, the user does not use MATLAB directly and will not need to have it installed on the Sedimaging system's microcomputer.

5. SEDIMAGING SYSTEM SET-UP

5.1 System Location

The sedimaging system's current design requires 10 ft. clearance to permit installation of the pre-segregation tube above the sedimentation column. To attach the presegregation system, a ladder with a platform 5 ft. above the ground may be used, although any system deemed appropriate by the user may be used. The base should be located on as even a surface as possible. A leveling bubble should be used to find the permanent location. Shims may be used if necessary. However, shims can slip and re-leveling may be necessary. It is best to quasi-permanently affix the base using floor bolts to avoid having to re-level after initial installation.

5.2 Camera System Installation

- a. The required distance between the surface of the camera lens and the outside surface of the sediment accumulator window is 12.7 in. This distance is based on the 23.6 mm x 15.6 mm sensor size of the D7000 camera, the 60 mm camera focal length, and the nominal 5 in. required height of the sedimented soil column.
- b. Attach the camera bracket to the camera support column using four 0.25 in. diameter screws and nuts. These screws adjust the camera position in the plane parallel to the surface of the sediment accumulator window.
- c. Attach the camera to the camera bracket using a 0.25 in. diameter camera mounting screw. The distance between the camera and soil accumulator can be adjusted over a range of 2.2 in. by choosing different mounting holes on the bracket. Choose the hole that provides as closely as possible the required 12.7 in. camera lens to accumulator window distance.
- d. Insert the EP-5 Nikon adaptor into the battery compartment of the camera and connect the EH-5A Nikon AC power adaptor. Connect the adaptor to a laboratory power source.
- e. Connect the UC-E4 Nikon camera-to-computer cable to the camera's micro-USB socket. The socket can be found under a rubber panel of the D7000. Connect the other end of the cable to a free USB port on the computer.
- f. Level the camera using the bi-directional bubble level so that the surface of the camera lens is vertical. If the camera is not vertical adjust it using the camera mounting screw.

- 5.3 Sedimaging System Alignment
 - a. Use the bubble level and plumb bob to establish sedimentation column verticality. The plumb bob can be lowered on its string through the center of the sedimentation column. A top cap fits snugly into the top of the sedimentation column to position the string at dead center. The plumb bob should be lowered to within a few millimeters of the accumulator pedestal. Adjust the column location using the positioning clamp screws which are attached to the positioning bracket until column verticality is achieved. This happens when the plumb bob is directly above the center mark on the pedestal. Check with the bubble level placed on the outside of the column.

Advanced Problems and Troubleshooting: Disagreement between plumb bob and bubble level occurs only if the soil accumulator is not evenly clamped to the sedimentation column. A long straight edge with a cut-out for the connector can be used to see if the outside surfaces of the column and accumulator are parallel. If they are not, consider replacing the O-rings. Another possibility is that the clamping compressive forces are uneven on the two sides. The user can check this by "feel" when clamping down on both sides simultaneously. If this happens, and O-Rings are not worn, try rotating the accumulator 180 degrees. If the compression forces flip sides the nuts on the clamping rods require adjustment.

- b. Set the exposure mode of the camera to manual by turning the mode dial to < M >. Set the camera to autofocus by setting the AF mode switch to < AF >.
- c. Open < NKRemote > and adjust camera settings to the following (Figure 5.1 Step 1):

Shutter speed (Tv)	< 1/10 >							
Aperture size (Av)	< 3.2 >							
Sensitivity (ISO)	< 100 >							
Exposure compensation < none >								
Image quality	< JPEG Normal >							
Image size	< Large 4928x3264 >							
White balance	< Auto >							
Metering mode	< Matrix >							
Picture control	< Standard >							
Autofocus mode	< Single >							
Check the center focus point box from 39 focus point boxes.								

- d. Select < Camera > < Live View >. A full frame live view will appear on the monitor with a green frame at the center of the image. (Figure 5.1 Step 3)
- e. Fill the sediment accumulator with water so that the water level appears near the center of the green frame (Figure 5.2 Step 4). Click and drag the green frame so that it is slightly below the water line (Figure 5.2 Step 5) then double click the frame to see an expanded view (Figure 5.2 Step 6) (note: in NKRemote the expanded view includes some area outside of the green frame and this is why the green frame has to be dragged to a position somewhat below the water line). The water line should appear near the edge of the frame. If not, return to the full view and drag the green frame closer or farther from the water line such that in expanded view it will be close enough to the edge to allow the user to assess if the water line and the edge are parallel.
- f. If the water level is not parallel to the green line (Figure 5.2 Step 6), the camera must be leveled again using the bracket screws (not the camera screw). Note: this procedure aligns the camera in the lateral direction. It does not guarantee that the camera has zero upward/downward tilt towards the sedimentation column. The bidirectional bubble level on the camera must verify zero tilt in the direction towards the sedimentation column.
- g. Check if 5 in. (or slightly more) of the sediment accumulator above the cartridge pedestal is visible in the live view window. If not, adjust the elevation of the entire sedimentation column by unscrewing the positioning clamp screws and sliding the entire column up or down as necessary. Retighten the positioning clamp screws. This will require realignment of the system per step "a".
- h. Perform a final check of system alignment: In the live view window, check if the edge of the sedimentation column is perpendicular to the water line. If not, adjust the column until it is.
- 5.4 Establishing Image Scale
 - a. Place the thin metal scale vertically on the outside window of the sediment accumulator (Figure 5.3 Step 7).
 - b. Focus on the scale using the single arrows in NKRemote's live view. Double click on the green box to expand the view (Figure 5.3 Step 8).
 - c. Capture an image by clicking < Release > at the bottom of the live view screen (Figure 5.3 Step 9).

d. Open the captured image in the < Paint > accessory in MS Windows. Observe and record the number of pixels over a 1.00 in. scale distance. MS Paint provides cursor coordinates in pixel units making this easy. The camera magnification in units of pixels/mm is this number divided by 25.4.

Note: the placement of the scale on the outside of the accumulator window is much easier than placement on the inside and results in negligible differences in computed magnification (about 0.2 pixels/mm).

5.5 Recording Weights of Common System Components

The weights of two system components will be used repeatedly for computing the Partial Percentage of Fines (P%F). As such, they can be recorded and reused:

- a. Record the weight of the soil canister (W_c)
- b. Record the weight of the sediment accumulator when filled with water to the mark approximately 1 in. below the top of the window (W_{a+w}). Repeat this procedure 3 to 5 times to insure that the readings are consistent.





2

Picture control: Standard

Next Image ->

AF: AF-S 🗸 Single

Comment:

v

Inputting the camera settings from NKRemote's main window.

Opening the live view window.



Live view window will pop-up showing the sediment accumulator.

Fig. 5.1 Inputting the camera settings and opening the live view window.







- 7 Putting a scale on the sediment accumulator.
- Fine-tuning the focus using the single arrow keys from the zoomed view of the scale.
- 9 Captured image of the sediment accumulator with a scale.
- Fig. 5.3 Determining image magnification using a scale on the sediment accumulator window.

6. SEDIMAGING TEST PROCEDURE

This chapter assumes that the soil specimen contains only particles smaller than 2 mm (100% passing a #10 sieve). For soils containing particles larger than 2 mm please refer to procedures in Section 12. To determine the percentage of fines, the weight of the soil canister (W_c) and the weight of the sediment accumulator filled with water (W_{a+w}) should have been determined per instructions in Section 5.5. Sections 6.1 through 6.14, are all associated with correspondingly numbered figures.

- 6.1 Soil and Sedimentation Column Preparation
 - 1) Fill the soil canister with a dry specimen. For soils with a typical specific gravity (G_s) of 2.65 this will be approximately 450 g +/- 25 g.
 - 2) Weigh and record the weight of soil ($W_s = W_{s+c} W_c$).
 - 3) Fill the sedimentation column with 6000 mL of water.
- 6.2 Assembling the Pre-segregation Tube Adaptor
 - 4) Place the square gasket on top of the sedimentation column
 - 5) Slide the pre-segregation tube adaptor onto the sedimentation column making sure that the vent holes in the adaptor and sedimentation column line up.
 - 6) Lower the circular gasket into the adaptor
- 6.3 Placing Water and Soil into the Pre-Segregation Tube
 - 7) Fill the pre-segregation tube with water until about half full and using the funnel pour the soil specimen into the tube.
 - 8) Add additional water to the pre-segregation tube to the fill mark on the tube.
- 6.4 Installing the Rubber Membrane on the Pre-Segregation Tube
 - 9) Stretch a rubber membrane over the open end of the tube.
 - 10) Push the membrane into the tube while lifting one edge of the membrane so that a vacuum remains in the tube once the membrane snaps back onto the tube.
 - 11) Insure that a vacuum has been created by observing a concave surface in the membrane. The center of the membrane should be approximately 0.5 in. below the end of the tube. If 0.5 in. concavity has not been achieved try again.
- 6.5 Soil Pre-Segregation
 - 12) Invert the pre-segregation tube containing the soil and water mixture several times until the particles are well mixed then turn vertically with the membrane on the bottom.
 - 13) Hold the tube vertically with the membrane on the bottom for several seconds allowing the coarser particles to settle down. At this point, an optional step may be

added to remove excessive fines from the specimen. If the pre-segregation tube is inverted such that the open end is on top, the membrane can be removed and the dirty water can be syphoned or syringed from the tube (a turkey baster is recommended). The removed dirty water should be released over a #20 sieve to recover and return particles larger than 0.075 mm to the pre-segregation tube. In a related case, if a specimen contains small amounts of very low specific gravity particles such as organic debris, mica flakes or chips of shale rock, they should be permanently removed. Otherwise these objects would come to rest within the matrix of finer particles and the image processing would interpret the soil as being somewhat coarser than by sieving.

- 14) Roll the membrane off of the end of the tube.
- 15) Removal of the membrane creates an upward seepage gradient through the soil which will prevent the soil from slipping out of the tube.
- 6.6 Soil Release into the Sedimentation Column
 - 16) Lower the pre-segregation tube into the adaptor.
 - 17) Remove the vent cap from the top of the pre-segregation tube.
 - 18) The soil-water mixture immediately drops into the sedimentation column. Air from the top of the sedimentation column escapes through small holes in the side of the sedimentation column and adaptor.
- 6.7 Draining the Sedimentation Column
 - 19) Once approximately 3 to 4 mm of particles smaller than 0.075 mm have settled in the accumulator (this takes 5 to 10 minutes depending on the specimen particle sizes and gradation), open the drainage valve to allow water to drain completely from the column. The drainage can begin sooner if it is obvious that the entire soil specimen has settled in the accumulator.
 - 20) Complete drainage of the water (with fines) from the sedimentation column will occur in approximately 3 minutes. As just mentioned, some fines will have entered into the accumulator prior to opening the drainage valve. This is desirable for accurate determination of the percentage of fines in the specimen. The imaging will account for the fines that have settled in the accumulator.
- 6.8 Tapping the Column
 - 21-23) After drainage ends, tap the accumulator sharply once so that the top surface of the soil becomes perfectly flat. A ¼ in. Allen wrench is suggested for the task.
- 6.9 Focusing and Capturing an Image

- 24) Open the program NKRemote and select <Camera> then <Live view>. The live image appears with a green rectangular frame at the center of the image.
- 25) Double-click the area in the green frame. This expands the view of this area for closer inspection. Using the single arrows at the bottom of the screen will fine- tune the focus. Double clicking the image returns the full view. By clicking on a different part of the image other areas can be expanded and similarly inspected. If the camera and sedimentation column are properly aligned, all areas should be in focus after fine-tuning the focus on the center area. A lack of focus in other areas is an indication that either the camera or the sedimentation column or both are out of alignment and need to be realigned per instructions in Chapter 5.
- 26) Take an image of the soil column by pressing the <Release> button and immediately move to the next step.
- 6.10 Detaching Connector and Accumulator, Removing Water with Fines
 - 27) Release the sediment accumulator from the sedimentation column by pulling down on the two upper accumulator clamps.
 - 28) Lower and remove the detached connector and accumulator assembly.
 - 29) Using a large syringe (e.g. a turkey baster), remove all but about 3 inches of the dirty water from above the sedimented soil. Keep the syringe well above the soil surface and fill it slowly enough so as to not remove fines that settled prior to image capture. Steps 27 through 29 should be performed as rapidly as possible. Theoretically, all fines that had not settled prior to image capture should be removed during this step.
- 6.11 Refilling with Clean Water, Removing Connector and Weighing
 - 30) Using the syringe, refill the accumulator with clean water to the same level as was used to determine W_{wf+a} (Section 5.5).
 - 31) The water fill mark is indicated by the horizontal etched lines on the accumulator window frame.
 - 32) Detach the connector & drainage valve from the column.
 - 33) Weigh the sediment accumulator containing soil and water (W_{s+wf+a}).

Determine the partial percentage of fines (P%F) by:

 $P\%F = (W_s - W_{sa})/W_s \times 100(\%)$

where

$$W_{sa} = G_s[W_{s+wf+a} - W_{a+w}]/(G_s - 1)$$

For most silica sands, G_s is in the range between 2.64 and 2.69 in which case W_{sa} may be approximated by:

$$W_{sa} = 1.6[W_{s+wf+a} - W_{a+w}]$$

For the required 450 +/- 25 g soil specimen the error in P%F will be less than 0.5% by this approximation. However, use of a known G_s is always preferred.

Note: the term "partial percentage of fines" is used because other fines have settled in the accumulator and were photographed. The fines in the accumulator are accounted for by the image processing software. The Sedimaging program combines the two fines components to yield the total percentage of fines.

- 6.12 Inputing Soil and Image Information into the Sedimaging Computer Program
 - 34) Place the captured image file in the folder that contains the Sedimaging program < Sedimaging.exe >. Then open <Sedimaging.exe >. Dialog boxes will appear.
 - 35) Enter a soil name, file name, magnification, W_{s+c} and W_{s+wf+a} . Press "OK" after each entry.
 - 36) Enter the requested background data for the specimen.
- 6.13 Cropping the Sedimented Soil Image
 - 37) After pressing the last "OK" the sedimented soil image will appear. Click to create a cropping box. Adjust the box by stretching the little blue squares located on the edges of the box to encompass the soil area. Avoid cropping the image outside of the soil area.
 - 38) Right-click and select "Crop Image".
- 6.14 Viewing, Saving and Printing Sedimaging Results
 - 39) After cropping, the test results will automatically appear. Print and/or save the image as a jpg file.
- 6.15 Printing Results in Tabular Form
 - 40) Percents passing standard sieves are presented in tabular form.
- 6.16 Cleaning the System

Empty the sediment accumulator then rinse it and the pre-segregation tube, presegregation tube adaptor, and rubber gaskets. Occasional rinsing the sedimentation column interior is also recommended to remove leftover fines from interior walls.

The lower sediment accumulator clamps do not need to be opened except for very occasional cleaning. The tolerances are small enough that only very fine sands could fall into the gap between the window and pedestal. If they do, it will be visually apparent that a cleaning is necessary.



- 1 Filling the soil canister with a representative specimen of the soil.
- 2 Weighing the soil & canister.
- Filling the sedimentation column with 6000 mL of water.

Fig. 6.1 Soil and sedimentation column preparation.











Laying square gasket on top of the the sedimentation column.

-	
5	•
-	1

- Sliding pre-segregation tube adaptor onto the sedimentation column.
- 6 L

Lowering the circular gasket into the adaptor.

Fig. 6.2 Assembling the pre-segregation tube adaptor.





Pouring soil through funnel intothe pre-segregation tubeabout half pre-filled with water.



Filling tube with water up to mark.

Fig. 6.3 Placing water and soil into the pre-segregation tube.







0	St
	or

Stretching rubber membrane over open end of pre-segregation tube.



Pressing rubber membrane into tube while allowing air to escape.



Vacuum in tube results in membrane concavity.

Fig. 6.4 Installing the rubber membrane on the pre-segregation tube.











Rotating pre-segregation tube 180 degrees several times and shaking to mix soil very well in the water.



Allowing coarse-grained fraction of the sediment to Settle to the membrane-capped end of the tube.



Slipping the membrane off.



Saturated soil will not slip out of the tube because of the vacuum.

Fig. 6.5 Soil pre-segregation.



- 16 Pre-segregation tube with soil placed in adaptor.
 - Opening vent releases soil into the sedimentation column.
- 18

17

Soil-water mixture enters column in 1 to 2 seconds.

Fig. 6.6 Soil release into sedimentation column.





19

Opening drainage valve.



Emptying through drainage line.

Fig. 6.7 Draining the sedimentation column





- Taping the side of the sedimented column (once) to flatten the surface (if necessary).
- 22 Image of sedimented soil before the tap.
- 23
- Image of sedimented soil after the tap.



Fig. 6.8 Tapping the column.





- 24 Selecting an area to zoom in on.
- 25 Fine-tuning the focus using the single arrow keys.
- 26 Returning to full view to capture an image.

Fig. 6.9 Focusing and capturing an image.







29

Removing some dirty water.

Fig. 6.10 Detaching connector and accumulator, removing water with fines









- 30 & 31
 - 32
- Lifting and removing the connector.
- 33
- Weighing the accumulator with soil and water.

Fig. 6.11 Refilling with clean water, removing connector and weighing.

🚱 🔵 🗢 📕 🕨 Program	Sedimaging 34	Input Window				
Organize 🔹 🖬 Open	Share with 👻 E-mail Burn	Enter the Image File Name :				
Favorites E Desktop Downloads		Enter the Magnification (pix/mm) :				
Libraries	Sedimaging Soil Image	Enter the Weight of Canister (W_c) (grams) :				
Documents Music	Input Window	Enter the Weight of Dry Soil and Canister (W_s+c) (grams) :				
 Pictures Videos 	Enter the Material Name :	Enter the Weight of Accumulator filled with Water (W_aw) (grams) :				
	Enter the Pit Number :	Enter the Weight of: Soil in Accumulator + Final Water in Accumulator + Empty Accumulator (W_s+wf+a) (grams):				
	Enter the Pit Name :	35 OK Cancel				
	Enter the Date Sampled :					
	Enter the Name of Person who Sampled :					
	Enter the Date Tested :					
	Enter the Name of Person who Tested :					
	36 OK Cancel	Fig. 6.12 Inputting soil and image information into the sedimaging computer program.				



Fig. 6.13 Cropping the sedimented soil image.





0.05

0.05

Fig. 6.14 Viewing, saving and printing sedimaging results.

		MATERIAL			PIT NI	JMBER		PIT NAME				
												40
	DA	DATE SAMPLED SAM		AMPLED B	Y	DATE TEST	D	TESTED BY				
								-				
		RETAINED WEIGHT		FRA	CTIONAL % RETAIN	IED	CUMULATIVE % RETAI	NED	RESULTS % PASSING			
N	0.10			0.1617			0.0374		0.0374	99.96	26	
N(O. 20			37.5335			8.6803		8.7177	91.28	23	
N(O. 30			49.2523			11.3904		20.1081	79.89	19	
N(O. 40	39.5534					9.1474		29.2556	70.74	44	
N	O. 50	58.4619				13.5203		42.7759	57.22	41		
N	O. 60	51.4348				11.8952		54.6711	45.32	89		
N(O. 70	49.1940				11.3770		66.0480	33.95	20		
- N	O. 80			38.2821			8.8534		74.9014	25.09	86	
NC	D. 100			23.8296			5.5110		80.4124	19.58	76	
NC	D. 200			32.3944			7.4918		87.9042	12.09	58	

Fig. 6.15 Printing results in tabular form.

7. TRANSLUCENT SEGREGATION TABLE (TST) THEORETICAL CONCEPTS

7.1 Thresholding and Binary Image Creation

If the pixels representing each particle in an image can be counted the grain size distribution can easily be determined. In order to count the number of pixels in each particle, the particles need to be separated from the background by assigning different pixel values to the particles than to the background. This is accomplished by first converting the original 8-bit RGB color image to a gray scale image then converting the gray scale image to a binary image. The RGB color image has three color channels (red, green and blue) and each color has 256 shades ranging from 0 to 255. The grayscale image has 256 shades of gray from pure black to pure white. By contrast, a binary image has only two pixel values; black (0) and white (1). The RGB color image is converted to the grayscale image using the formula gray = (red + green + blue) / 3. Then, the grayscale image is converted to the binary image is smaller than the *threshold* value, the pixel value will be replaced by 0. On the other hand, if the pixel value of the grayscale image is larger than the *threshold* value, the pixel value becomes 1. Figure 7.1(b) shows a binary image created from a section of a TST image, Figure 7.1(a).

The *threshold* value can be set manually or set automatically by the *ImageJ* program. Because the translucent segregation table has very bright illumination coming from five 24 in fluorescent light bulbs in the light box beneath the translucent plate, the grayscale value of particle pixels is close to black (0) and the grayscale value of the background is nearly white (255) as was observed in Figure 7.1(a). This allows *ImageJ* to automatically convert the grayscale image to the binary image without setting the *threshold* value manually.

7.2 Euclidian Distance Map

The translucent segregation table does not prevent the particles from being in contact with each other; it only prevents small particles from hiding behind large particles by segregating them somewhat and, with user assistance, arranging them in a single layer. Separating the contacting particles is called *segmentation* in image processing and the *segmentation* method that *ImageJ* uses is *watershed segmentation* from a *Euclidian distance map* (*EDM*).

The *EDM* is generated by replacing each foreground (particle) pixel with a pixel value equal to that pixel's distance from the nearest background (light table) pixel.

7.3 Watershed Analysis

The *EDMs* can be viewed as drainage basins or "watersheds". Each drainage basin represents the pixel area of a particle. Each basin possesses local minima or *ultimate eroded points* (*UEPs*). *UEPs* are the peaks or local maxima of the *EDM*. At each of the *UEPs*, water starts to fill up the drainage basin. This process is called *dilation* in image processing. *Watershed segmentation* dilates each of the *UEPs* until a known edge of the particle is reached or until it hits the edge of the region of another *UEP*. This way, the *watershed segmentation* can identify the edges between adjacent contacting particles as shown in Figure 7.1(d).

The method is not 100% perfect. Occasionally, two particles are still counted as one and occasionally a long slender particle is interpreted as two. Watershed segmentation works best for rounded and subrounded particles and worst for irregularly shaped particles. Nevertheless, experience has shown very good overall agreement with sieving results as subsequently discussed.

7.4 Transforming 2D Particle Size Distribution to Grain Size Distribution

It should be recognized that the sieve size of particles will generally be different from that found in the TST. As shown in Fig. 7.2, if a soil particle is idealized as an ellipsoid having axial dimensions $d_1 < d_2 < d_3$ the sieve dimension is most closely related to d_2 with some contribution from d_1 while d_3 is less relevant. By contrast, since in the TST particles are more likely to lie with the short dimension d_1 vertical, the d_2 and d_3 dimensions dictate the computed size while d_1 is the irrelevant dimension. As a result it should be expected that the TST will predict a somewhat coarser soil than by sieve analysis. However, if the TST results are to mimic the sieve test, greater consideration in the image processing can be given to the d_2 dimension of particles.

Shown in Figure 7.3 are three approaches used to reduce the TST data. They are:

- Equivalent circular diameter, (d_{ec}) : Each particle is assumed to be circular in plan and having the same area as obtained by pixel counting in the TST image. The PPD is the diameter of the circle, d_{ec} and the particle is assumed to be spherical in 3-dimensions for purposes of computing the "% finer".
- *Minor equivalent ellipse axis* (d_{el-min}): Each particle is idealized as an ellipse in plan view having the same area as obtained by pixel counting in the TST

image. To fit each particle with an ellipse the centroid of the ellipse is made to coincide with centroid of the particle. The *PPD* is assumed to be $d_{\text{el-min}}$. To compute the "% finer" the volume may be assumed proportional to $d_{\text{el-min}}^{3}$, or better, proportional to $(d_{\text{el-min}}^{2})(d_{\text{el-max}})$.

Minimum feret dimension $(d_{\text{f-min}})$ the minimum feret dimension can be thought of as the smallest caliper distance or the shortest distance between two parallel lines both tangent to the particle on opposite sides. The *PPD* is assumed to be $d_{\text{f-min}}$. To compute the "% finer" the volume may be assumed proportional to $d_{\text{f-min}}^3$, or better, proportional to $(d_{\text{f-min}}^2)(d_{\text{f-max}})$.

In both the *minor equivalent ellipse axis* method and the *minimum feret dimension* method the vertical dimension (d_1) is assumed to be equal to the smaller plan view dimension, $d_{\text{el-min}}$ or $d_{\text{f-min}}$ for purposes of computing particle volumes.

Fig. 7.4 compares sieve test results with TST results using the three methods described above. As expected, the *equivalent circle* method yields the coarsest grain size curve and is least similar to sieve results. The *minor equivalent ellipse axis* method and the *minimum feret dimension* method yield virtually identical results and are much more similar to sieve results. Finally, Figure 7.5 shows that a slight improvement is achieved by using $(d_{el-min}^2)(d_{el-max})$ rather than d_{el-min}^3 to compute soil particle volumes for "% finer". As such, this method is presently recommended for use with the TST. However, it is also recommended that in future testing the bridge underpass heights be utilized to estimate d_1 thereby allowing all three particle dimensions to be used for computing particle volumes.

Note: Referring to Fig. 7.2, for a very flat disk-like particles (d_1 approaching zero) the difference between the sieve-based grain size and the TST-based *PPD* is a factor of $\sqrt{2}$ = 1.4. For perfect spheres, the sieve results and the TST methods should produce identical results. As such, the grain size curves will always be offset by a factor between 1.0 and about 1.4 with the former value expected for very rounded particles and the latter expected for very flat particles. The curves in Fig. 7.5 are offset by a factor of 1.2.

The TST.exe program discussed in Chapter 11 prints the results by both the *equivalent circular diameter* method and by the *minor equivalent ellipse axis* method. The difference between the two curves serves as an indication of the particle aspect ratios.



(a) Image from Light Table



(b) Binary Image



Fig. 7.1 Particle segmentation using ImageJ.



Fig. 7.2 Particle dimensions observed in the TST compared to sieve opening diameter.



Fig. 7.3 Definitions of particle diameter.



Fig. 7.4 Comparison of three methods for determining grain size from TST with sieve results.



Fig. 7.5 Comparison of TST results using only d_2 versus using d_2 and d_3 for computing particle volume.

8. TST HARDWARE

The Translucent Segregation Table (TST) hardware can be grouped into four subsystems as shown in the photographs in Figure 8.1:

1. Camera System;

3. Translucent Segregation Table;

2. Computer and Monitor;

4. Ancillary Supplies

Bracketed numbers in this chapter refer to the parts labeled in Figures 8.1 to 8.6.

8.1 Camera System

The camera system [1] consists of a 16.2 Mpixel Nikon D7000 [1a], an AF-S Micro NIKKOR 60 mm f/2.8G ED lens [1b], a bi-directional bubble level [1c], an EH-5A Nikon AC power cord with EP-5 Nikon adaptor [1d], the UC-E4 Nikon camera-to-computer cable [1e], a camera bracket [1f] and a ceiling bracket [1g]. The camera bracket is made from 2 aluminum pieces of dimensions 2 in. x 3 in. x 0.5 in. and 5 in. x 3 in. x 0.5 in. The first piece of the camera bracket is attached to the ceiling bracket with four 0.25 in. diameter screws while the second piece of the camera bracket holds the camera with another 0.25 in. diameter screws. The holding screw location can be adjusted to achieve different camera magnifications as dictated by the ceiling height. The ceiling bracket is a 3 in. x 24 in. x 0.5 in. aluminum bar which drop-mounts into a conventional drop ceiling panel.

8.2 Computer and Monitor

A microcomputer and monitor are used to control the camera and capture images remotely through NK Remote software. The computer analyzes the images and determines the grain size distribution by ImageJ and MATLAB software.

8.3 Translucent Segregation Table (TST)

The Translucent Segregation Table is the heart of the system. Its main component is a 36 in. x 36 in. x 0.375 in. square *translucent plate* [3a] made of white acrylic which is fixed to a 36 in. x 36 in. x 0.5 in. *transparent base* [3b]. The translucent plate acts as a diffuser for the light coming from below. It provides a bright and uniform background for the soil image. Scratches on this translucent surface do not appear in the images. The transparent base is attached to the underside of the translucent plate to stiffen the plate system. By increasing the plate rigidity displacements of the translucent plate caused by self-weight and the weight of soil are minimized. A 35 in. x 2 in. x 0.5 in. *top wall* [3c] has two 5.7 in. *handles* [3d] for lifting and inclining the plate caused by removing a 3 in. x 0.25 in. diameter *connector screw* [3e], the top plate can be lifted out to allow sweeping out the soil after testing. The connector screw extends from the top of the top wall to the transparent base and provides additional support to the plate system. A 35 in. x 2 in. x 0.5 in. x 2 in. x 0.5 in. aluminum

bottom wall [3f] is permanently attached to the translucent plate, the translucent base and slotted side walls. Two 4 in. x 2 in. *hinges* [3g] connect the bottom wall to the light box and allow the translucent plate, with all walls and bridges, to incline while still connected to the light box. Two 36 in. x 2 in. x 0.5 in. slotted aluminum *side walls* [3h] are permanently fixed to the lateral sides of the TST plate. They contain 18 0.375 in. x 0.5 in. x 0.5 in. matched slots for the bridges. Only some of the slots are used in any one test, but the large number of available slots provides great flexibility to achieve more uniform particle distribution.

The TST system comes with 13 interchangeable *segregation bridges* [3k] each being 36 in. x 0.375 in. x various heights. The different bridges provide different underpass heights, the equivalent of sieve opening sizes. The two bridge ends slide into the slotted side walls in various bridge combinations and spacings as deemed suitable for a particular specimen.

Two prismatic square 0.5 in. x 0.5 in. x 36 in. *cover bars* [3i] sit on top of the side walls and immobilize the segregation bridges using *tightening screws* [3j]. With a quarter turn, two of the tightening screws on each side release the cover bar entirely while the third screw on each side allows the cover bar to pivot out from the slotted side walls. This allows for bridge placement or removal.

Two 23 in. long L-channels serve as *support feet* [3m] for the inclined translucent plate assembly. During system transport, the two support feet are attached to the two side walls using two 0.25 in. threaded *immobilizing screws* [3n]. Two 0.5 in. *pivot screws and nuts* [3o] on the other end of the L-channels allow the support feet to rotate down into a vertical position for particle segregation. As a safety measure against accidental kick-out of the feet, the immobilizing screws are installed into threaded holes at the base of the light box. The *light box* [3l] is a 36 in. x 36 in. x 7 in. particle board frame. It houses five 24 in. *fluorescent lights* [3p]. A 7 in. high translucent acrylic *support column* [3q] stands at the center of the light box to provide additional support to the translucent plate assembly when the plate is in the lowered position.

8.4 Ancillary Supplies

A number of ancillary items assist in the performance of the TST test. They include a large *bowl* [4a] and *spoon* [4b] used to prepare soil and place it on the translucent plate. An *engineering scale* [4c] is used to determine the camera magnification. A *large brush* [4d] loosens soil clogs behind the segregation bridges and distributes soil evenly along the length of the bridges. A *small brush* [4e] performs the same task for smaller particles. A *rubber mallet* [4f] is employed to tap the corner of the light table after segregation to spread the soil particles into a single layer. A *squeegee* [4g] removes soil from the light table and a *dust cloth* (4h) wipes the translucent plate surface after a test.



Fig. 8.1 Translucent Segregation Table (TST) system overview.



Fig. 8.2 TST camera system.



3a, 3b Translucent Plate & Transparent Base

3c, 3d, 3e Top Wall, Handles & Connector Screw



Fig. 8.3 Translucent segregation table and bridges.







Fig. 8.5 Raised TST and lighting system.



Fig. 8.6 TST system supplies.