Experiment 1

Characterization of Granular Samples by Sieve Analysis

Updated 07.18.2024

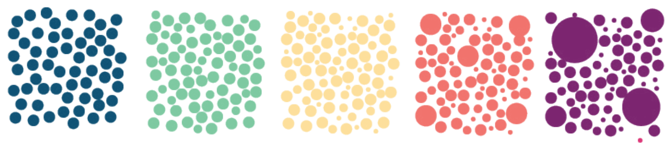
Purpose

To describe and classify granular samples based on physical attributes including grain size, shape, color, and sorting.

Principles

Particle size distribution of natural and artificial aggregates such as sand and soil is determined by a process known as sieving. Other physical attributes, including grain color, shape (roundness), sphericity, and packing can be observed using reflected and transmitted light microscopy and described using geotechnical terminology.

Aggregates that are well sorted have a nearly homogenous size and shape distribution while those that are poorly sorted have a heterogeneous size and shape distribution. A sample with a wide and even distribution of large to small grain sizes is considered well graded. For example, sand with an even mix of particles that are all between 0.25 and 0.5 mm is well sorted but poorly graded.



Grading	Very poorly	Poorly	Moderately	Well	Very well
Sorting	Very well	Well	Moderately	Poorly	Very poorly

Figure 1. Sorting and grading are inversely correlated.

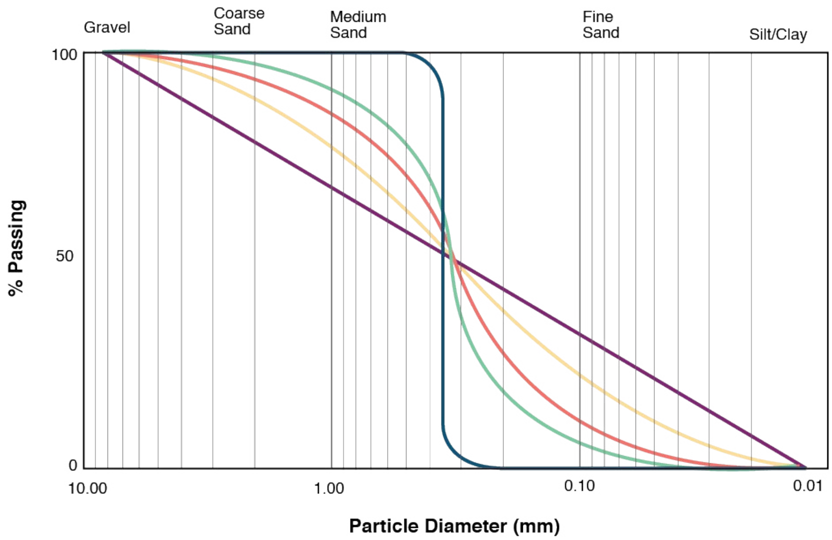


Figure 2. Graph of cumulative percent passing versus the logarithmic sieve size for each sorting/grading category in Figure 1.

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The physical properties of granular materials can be used as a means of classification for comparative purposes and to predict certain physical properties such as porosity, permeability, and capillarity of solid aggregated, porous building materials, e.g. mortars and plasters, concrete, stone, brick, and terra cotta.

Roundness

The roundness class has been adapted from geology as a way to describe particles. Roundness can be defined as "the degree of abrasion of a clastic (i.e., fragment of a larger whole) particle as shown by the sharpness of its edges and corners".[1]

[1] Julia A. Jackson Robert Latimer Bates, *Glossary of Geology,* (Falls Church, Virginia: American Geological Institute, 1980): 546.

Sphericity

Sphericity is a description of how close a particle approaches a perfect sphere. It is usually expressed as a ratio of the smallest to largest diameter of a particle.

In general, when the sphericity of a grain is visually estimated without a microscope, it is acceptable to describe it as having "high" sphericity or "low" sphericity:

$$\text{Ratio} = \frac{D_{smallest}}{D_{largest}} \qquad [1]$$

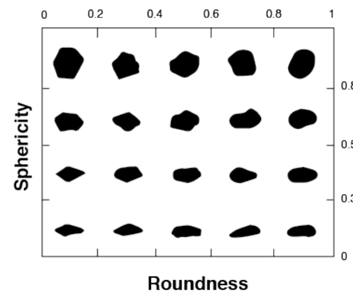


Figure 3. Sphericity vs roundness

	Term	Range	Description
Roundness	Very angular	0 - 0.2	The grain appears newly cleaved from a whole with very sharp edges. No abrasion at all is evident.
	Angular	0.2 - 0.4	The grain has sharp edges and corners with little or no abrasion.
	Sub-angular	0.4 - 0.5	The grain has some degree of angularity without sharp edges. To a large degree the original form is evident, but with apparent abrasion. The original faces remain without much abrasion—most change is evident at the edges and corners.
	Sub-rounded	0.5 - 0.6	The grain is partially rounded and exhibits a high degree of abrasion; there is good evidence of the original form of the grain. All edges and corners have rounded to smooth curves.
	Rounded	0.6 - 0.8	The grain is round or curving in shape and the edges and corners have smooth to broad curves. There is some evidence of the original faces of the grain (e.g.,some flat areas from the original grain may remain).
	Well rounded	0.8 - 1	The faces, edges, and corners of a grain have been significantly worn by abrasion. The entire surface of the grain consists of broad curves without any flat areas.
Sphericity	Very elongate	0 - 0.60	-
	Elongate	0.60 - 0.63	-
	Sub elongate	0.63 - 0.66	-
	Intermediate	0.66 - 0.69	-
	Sub-equant	0.69 - 0.72	-
	Equant	0.72 - 0.75	-
	Very equant	0.75 - 1.00	-

Table 1. Ranges for roundness and sphericity.

Color

The color of any object may be described in terms of the Munsell color order system, a system based on the color-perception attributes of hue, lightness, and chroma. The practice is limited to opaque objects, such as painted surfaces viewed in daylight by an observer having normal color vision. This practice provides a simple visual method as an alternative to the more precise and more complex method based on analytical procedures (e.g., spectrophotometer).

Munsell notation is written as a combination of letters and numbers by which the color of an opaque object may be specified with respect to Munsell hue (H), Munsell value (V), and Munsell chroma (C), written in the form Hue/Value/Chroma (Figure 5).

Munsell Notation

The Munsell hue, value, and chroma assigned to the color of a specimen by visually comparing the specimen to the chips in the Munsell Book of Color; (2) a notation in the Munsell color system, derived from luminous reflectance factor Y and chromaticity coordinates x and y, in the CIE system for standard illuminant C, by the use of scales defined by the Optical Society of America Subcommittee on the Spacing of the Munsell Colors.

Hue

The attribute of color perception by means of which a color is judged to be red, orange, yellow, green, blue, purple, or intermediate between adjacent pairs of these, considered in a closed ring (red and purple being an adjacent pair).

Munsell Hue

An attribute of color used in the Munsell color system to indicate the hue of a specimen viewed in daylight.

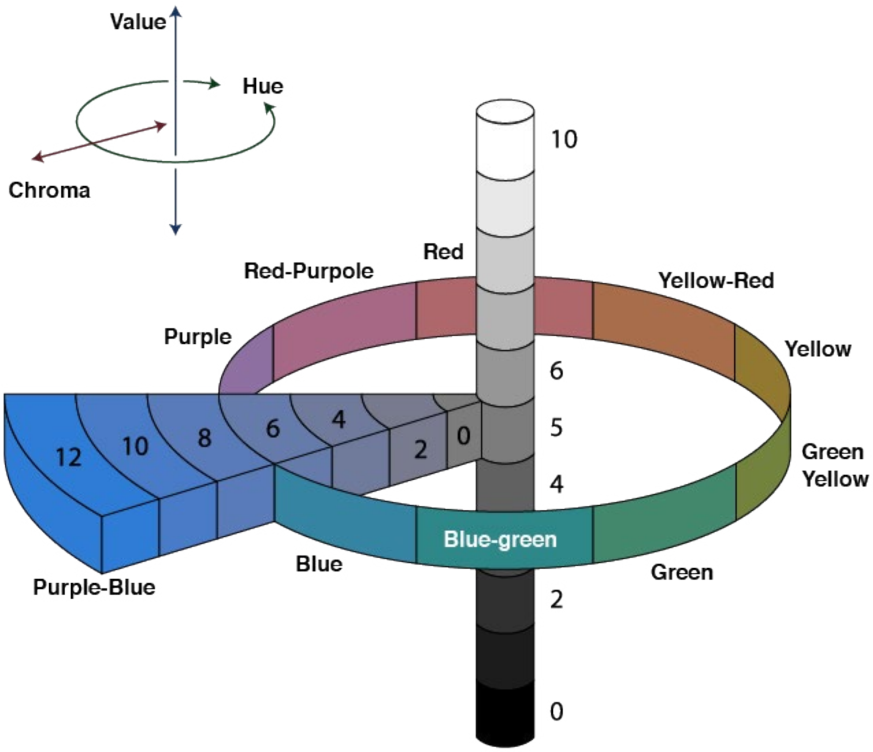
Lightness

The attribute of color perception by which a non-self-luminous body is judged to reflect more or less light.

Munsell Value

An attribute of color used in the Munsell color system to indicatethe lightness of a specimen viewed in daylight, on a scale extending from 0 for ideal black to 10 for ideal white, in steps that are visually approximately equal in magnitude.

Figure 4. Adapted from Munsell.com



Chroma
The attribute of color used to indicate the degree of departure of the color from a neutral color of the same lightness.

Munsell chroma
An attribute of color used in the Munsell color system to indicate the degree of departure of a color from a gray of the same Munsell value, in steps that are visually approximately equal in magnitude.

Munsell surface color perception solid
A spatial representation of colors in the form of a cylindrical coordinate system based on the three perceptual attributes: hue, lightness and chroma.

Methodology

Sampling Method

Mix bulk samples well to ensure a representative distribution of particles. Read *ASTM STP 447 B – Manual on Test Sieving Methods* for standard procedures and variations.

Equipment

- drying oven set at 60° C (± 5°)
- balance sensitive to 0.01 g
- 3" sieve stack: cover, № 8, 16, 30, 50, 100, & 200 sieves, and bottom pan
- sieve brush
- plastic weighing boats
- glass beaker
- Zeiss Stemi 305 stereo microscope with illuminator
- forceps (tweezers)
- fine-tip Sharpie® permanent marker
- wash bottle

Reagants & Samples

- sand A
- sand B

1. Preparation

1.1. Dry bulk sand samples for at least 24 hours at 60° (± 5°) C.[2]

[2] This has been completed prior to the lab.

2. Gravimetric Analysis

For each sand:

2.1. Label and weigh enough weighing boats (M_{CX}) to accommodate the initial bulk sample and each sieve stack fraction: 1 to hold original sample (M_{CT}) and 7 for the sieve stack and pan (M_{C8}, M_{C16} , etc. Use a fine-tip Sharpie® permanent marker for this. These weighing boats can be washed and re-used later by you in the semester.

2.2. Take a representative amount of the sample to be analyzed (approximately 90g). Weigh the sample and container (M_T) and determine the net sample weight (M_{ST}) on Table 4.

$$M_{ST} = M_T - M_{CT}$$

2.3. Place the sample in the top of the small hand-held sieve stack and cover. Agitate while paying particular attention to the [2] direction of shaking for a minimum of 10 minutes. Hold the sieve stack at a 20° angle from horizontal plane. Shake forward and backward in the plane of inclination approximately 150 times per minute (2.5 per second) and rotate the stack about 60 ° every 25 agitations (10 seconds at 2.5/sec). Do not shake up and down.

2.4. Empty each sieve and the bottom pan into each of the containers labeled and weighed in Step 2.1. Dislodge and retain all trapped grains from each sieve before weighing.

2.5. Weigh each filled container (M_X) and calculate the retained sample weight (M_{SX}) for each sieve and pan (weight of aggregate held on each sieve or pan):

$$M_{SX} = M_X - M_{CX} \qquad [3]$$

2.6. Calculate each fraction's weight percentage:

$$\% M_{SX} = \frac{M_{SX}}{M_{ST}} \times 100\% \qquad [4]$$

2.7. Sum the retained sample weights and determine the proportion of the original sample, as a percentage, that was lost ($\% M_L$) during sieving:

$$\% M_L = \frac{M_{ST} - \sum M_{SX}}{M_{ST}} \times 100\% \qquad [5]$$

The maximum error for the test should not exceed 0.1% of the weight of the original sample. If loss is greater than 0.1%, repeat.

2.8. From the weights measured in Step 2.5, calculate the percentage of the total test sample retained on ($\% M_{rt}$)and passing through ($\% M_{pt}$) each sieve. The total percentage retained ($\% M_{rt}$) for a given sieve by dividing the "total weight coarser" (includes the material retained on that particular sieve plus all sieves above) by the original sample's total mass:

$$\% M_{rt} = \frac{M_{coarser}}{M_{ST}} \times 100\% = \sum M_{SX\,(\text{on or above})} \qquad [6]$$

2.9. Calculate the total percentage passing ($\% M_{pt}$) for a given sieve represents the proportion of the original sample that is finer than the aperture of that sieve.

$$\% M_{pt} = 1 - M_{rt} \qquad [7]$$

3. Observations Under the Microscope

3.1. Place a small amount of each fraction of the sieved sample in a small weighing boat for observation. Wetting the sample using a wash bottle to dampen the aggregate may help with observation and provide insight into how the material will behave in a variety of conditions. Observe under the stereo microscope.

3.1. At a useful magnification, describe each sample fraction in terms of particle shape, color, and sphericity. Use appropriate geomorphological terms. Note the total magnification. This is calculated by multiplying the magnification of the eyepiece (10x), by the magnification of the objective (1x), and by the zoom (0.8x) in the case of the Zeiss Stemi 305 stereo-zoom microscope. Use these observations to complete Table 5.

3.1. With the naked eye and under natural light, use the Munsell Soil Color Book to find the average color of each sieved boat.

4. Cleaning

4.1. When finished with equipment, wash thoroughly and place neatly back on the class tray. Sands can be returned to their appropriate containers but do not mix the two sand samples together.

5. Plot a Particle Size Distribution Chart

Populate Table 6 with a photomicrograph per weighing boat for each sand.

Using the data collected in Table 3, create a Particle Grain Size Distribution graph. Overlay these onto one graph displaying the particle grain size distribution of the two samples. Sand A should be indicated with a blue line, sand B with a pink line. Use a spreadsheet software like Microsoft Office Excel® or Google Sheets® to set up a logarithmic graph for a sieve profile. The X-axis (horizontal) should be set as a logarithmic scale in order to display the results of the sieve analysis correctly.[3]

5.1. From Table 3, plot the "Screen size (μm)" for the X-axis and the $\%M_{pt}$ values for the Y axis in a scatter graph.

5.2. Right mouse over any part of the X-axis of your graph. A pop-up menu will appear. With the left mouse button, select **FORMAT AXIS**... A set of formatting options will appear. Make sure that the options for "Logarithmic scale" and "Values in reverse order" are enabled (Figure 5).

[3] Log graphs are useful to plot data that spreads across orders of magnitude in a limited space. The value of the screen size on the x-axis may range from 10,000 μm to 10μm (3 orders of magnitude), so we represent them in a logarithmic scale, saving us space on the x-axis.

Number	Log Base 10
1	0.0000
2	0.3010
3	0.4771
4	0.6021
5	0.6990
6	0.7782
7	0.8451
8	0.9031
9	0.9542
10	1.000

5.3. Edit and adjust properties as necessary.

5.4. Right click on the graph to **SAVE AS PICTURE** and attach to the report in Adobe Acrobat.

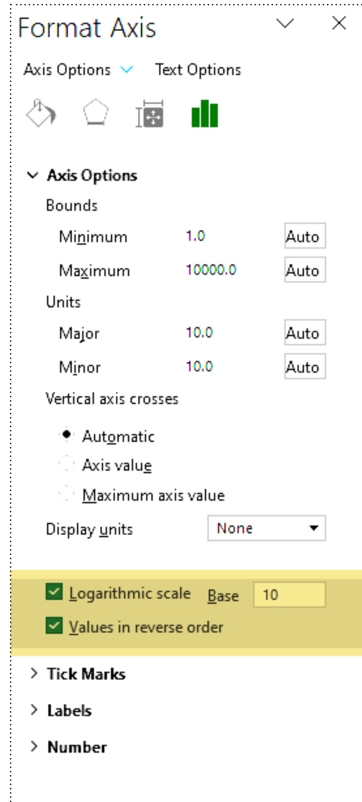


Figure 5. Settings for logarithmic scale andvalues in reverse order on Microsoft Excel.

References

ASTM C136-06 Standard Method for Sieve Analysis of Fine and Coarse Aggregates.

ASTM D75/D75M-09 Standard Practice for Sampling Aggregates.

ASTM D1535-12a Standard Practice for Specifying Color by the Munsell System.

ASTM STP 447 B Manual on Test Sieving Methods.

Bates, R. L. and Jackson, J. A. *Glossary of Geology*. Falls Church, Virginia: American Geological Institute, 1980.

Folk, R. L. *Petrology of Sedimentary Rocks*. Austin, Texas: Hemphill Publishing Co., 1974.

Munsell Soil Color Book. (In ACL)

Orton, Clive, Paul Tyers and Alan Vince. *Pottery in Archaeology*. Cambridge: Cambridge University Press, 1993.

Pettijohn, F. J. *Sedimentary Rocks*. New York: Harper, 1957.

Powers, M. C. "A New Roundness Scale for Sedimentary Particles." *Journal of Sedimentary Petrology*, v. 23 (1953).

	Mesh Openings			Wire Diameter		
US Sieve #	Inches (in)	Milimeters (mm)	Microns (μm)	Inches (in)	Milimeters (mm)	Microns (μm)
2-1/2"	2.50	63.0	63000	0.2165	5.50	5500
2"	2.00	50.0	50000	0.1988	5.05	5050
1-1/2"	1.50	37.5	37500	0.1807	4.59	4590
1"	1.00	25.0	25000	0.1496	3.80	3800
3/4"	0.750	19.0	19000	0.1299	3.30	3300
1/2"	0.500	12.5	12500	0.1051	2.67	2670
3/8"	0.375	9.5	9500	0.0894	2.27	2270
1/4"	0.250	6.3	6300	0.0717	1.82	1820
4	0.1870	4.750	4750	0.0606	1.54	1540
5	0.1570	4.000	4000	0.5390	1.37	1370
6	0.1320	3.350	3350	0.0484	1.23	1230
7	0.1110	2.800	2800	0.0430	1.10	1100
8	0.0937	2.360	2360	0.0394	1.00	1000
10	0.0787	2.000	2000	0.0394	0.937	937
12	0.0661	1.700	1700	0.0319	0.810	810
14	0.0555	1.400	1400	0.0285	0.725	725
16	0.0469	1.180	1180	0.0256	0.650	650
18	0.0394	1.000	1000	0.0228	0.580	580
20	0.0331	0.850	850	0.0201	0.510	510
25	0.0278	0.710	710	0.0177	0.450	450
30	0.0234	0.600	600	0.0154	0.390	390
35	0.0197	0.500	500	0.0134	0.340	340
40	0.0165	0.425	425	0.0114	0.290	290
45	0.0139	0.355	355	0.0097	0.247	247
50	0.0117	0.300	300	0.0085	0.215	217
60	0.0098	0.250	250	0.0071	0.180	180
70	0.0083	0.212	212	0.0060	0.152	152
80	0.0070	0.180	180	0.0052	0.131	131
100	0.0059	0.150	150	0.0043	0.110	110
120	0.0049	0.125	125	0.0036	0.091	91
140	0.0041	0.106	106	0.0030	0.076	76
170	0.0035	0.090	90	0.0025	0.064	64
200	0.0029	0.075	75	0.0021	0.053	53
230	0.0025	0.063	63	0.0017	0.044	44
270	0.0021	0.053	53	0.0015	0.037	37
325	0.0017	0.045	45	0.0012	0.030	30

Table 2. Wire mesh size.
The US standard sieve numbers as they correspond to the size of the wire mesh, determined by the size of the opening of the mesh and the diameter of the wire used to weave the mesh. The highlighted rows indicate those used in the standard sieve stack.

Data & Observations

	Sieve No.	Screen size µm	M_{CX} g	M_X (sample + container) g	M_{SX} $(M_X - M_{CX})$ g	$\%M_{SX}$ $\frac{M_{SX}}{M_{ST}} \times 100\%$	$\%M_{rt}$ $\sum M_{SX \text{ (on or above)}}$	$\%M_{pt}$ $1 - M_{rt}$
Sand A	8	2360						
	16	1180						
	30	600						
	50	300						
	100	150						
	200	75						
	pan	1						
Sand B	8	2360						
	16	1180						
	30	600						
	50	300						
	100	150						
	200	75						
	pan	1						

Table 3: Sieve data

Variable	Sand A	Sand B
M_{CT}		
M_T		
M_{ST}		
$M_L\%$		

Table 4: Aggregate results for sieve data

	Sieve No.	Color (Munsell)	Sorting	Sphericity	Roundness	Texture	Approximate magnification
Sand A	8						
	16						
	30						
	50						
	100						
	200						
	pan						
Sand B	8						
	16						
	30						
	50						
	100						
	200						
	pan						

Table 5: Properties

Sieve #	Sand A	Sand B
8		
16		
30		
50		

Sieve #	Sand A	Sand B
100		
200		
pan		

Table 6: Photomicrographs

Discussion

1. Interpret Figure 6 and describe the grain grading and sorting for each sand.

2. Using the Texture and Grain Percentage Charts (Orton), describe and compare the approximate grain size distribution with the actual sieve analysis performed.

3. Comment on ML and on any other errors.

4. What overall physical and mechanical properties might grain shape, size, and grading affect?

5. How does this experiment deviate from the procedure described in ASTM C136-06?