University of Victoria
Department of Geography

GEOG103 Introduction to Physical Geography

LABORATORY 4: SLOPE STABILITY AND MASS WASTING

<u>Introduction:</u>

Natural slopes are essentially the product of down-slope driving force, or shear stress (τ), and upslope resisting force, or shear strength (S), at work on Earth surface materials. In addition to gravity acting on slope materials, other factors and erosive agents are at work, such as water, snow, ice, air, and vegetation growth. Under certain conditions (i.e., when τ > S), rock materials, sediment, and/or soil mass move down slope. This is called 'mass wasting' or 'mass movement' and it occurs in a variety of landscapes (e.g., riverbanks, mountain slopes, steep yards, beach bluffs, etc.). This material provides an important supply to down-slope landforms (e.g., debris fans, soil creep, talus slopes, solifluction lobes) and, eventually, river systems.

This assignment will introduce you to some fundamental techniques used to characterize some physical properties of sediments that are important for mass wasting. The second part of the assignment focuses on assessing the stability of materials on sloped surfaces.

Three samples of local sediment will be on display. Each is distinct in terms of grain size, sorting, and source location. The purpose of this lab is to characterize the <u>physical properties of each sediment</u> including various properties that relate to potential mass wasting. You will accomplish this by interpreting results of the following laboratory experiments.

You may work in pairs, but you must submit **an individual report** for this lab.

<u>Notes</u>:

- *USE CARE in your experiments. Aim to produce repeatable results. Sloppy work = sloppy data!*
- *<u>Do not contaminate (mix) samples</u>. Place all samples in the respective collection dishes for drying. Be sure to clean up all workspaces when finished.*
- *Once again, **plagiarism** will not be tolerated.*

Experiment 1: Physical properties of local sediments

<u>Sediment texture</u>: describes the sizes and shapes within a sediment sample. This provides important information on the conditions of transport and the environment of deposition (e.g., energy level, dominant mode of transport, depositional setting). For instance, <u>mean grain size</u> typically indicates the energy of the transporting environment, or 'competence' (i.e., maximum size that can be transported). The <u>degree of roundness and sorting</u> provide further information on the 'persistence' of that energy level in the environment. For example, coastal sands on high-energy beaches are typically rounded and well sorted into a narrow range of sizes due to the persistence of wave action. Fluvial sands, though also rounded, are usually less well sorted and contain some fines due to discharge (and hence, energy) fluctuations common in most river systems.

We will also see in Experiments 2 & 3, that texture also plays an important role in determining shear strength (S, the upslope force that resists mass wasting) of sediments on sloped surfaces.

Analysis & Questions

1. Describe the 'feel' of each sediment using hand texturing. Simply take a pinch of each sample and work it between your fingers. You should feel that each sample is slightly different due to grain size variations (e.g., gritty, sticky, slippery, etc.). This qualitative technique is used often by geomorphologists to get a quick and dirty estimate (pardon the pun) of grain size variations in a sample. (3 marks)

2. Using a magnifying lens, ruler, sample photos and referring to the lab handouts, describe the dominant (mean) grain size category for each sample being as descriptive as possible (e.g., fine gravel, clay, very fine sand, medium silt, or silt to coarse sand mixture). Silts can be distinguished from clays by a lesser degree of cohesion. To test this, wet a small sample in your palm and attempt to roll a ribbon. The higher the clay content, the longer the ribbon. Dry clay will feel 'silky' or slippery whereas you will notice a slight grittiness in coarser silts. (3 marks)

3. Describe the shape and sorting of each sample. Shape can be described using the following terms: *rounded, angular, or platy* (flat & elongated) and can be assessed visually (see fig. below) or sensed by hand (e.g., 'gritty' usually makes for some type of angular sediment). Sorting refers to the range of grain sizes present in a sample. For instance, a 'poorly sorted' sample has a large range of grain sizes and a 'well sorted' sample consists largely of one grain size. Refer to the figures below or information in the handout to help you with this. (6 marks)

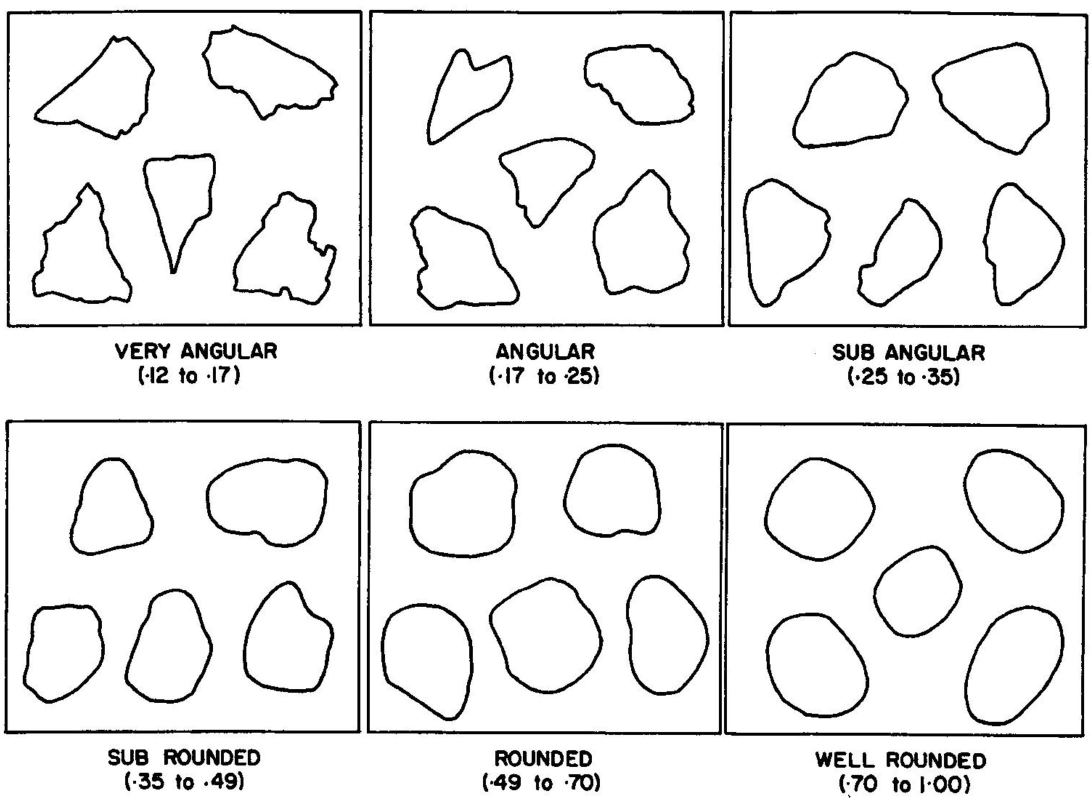
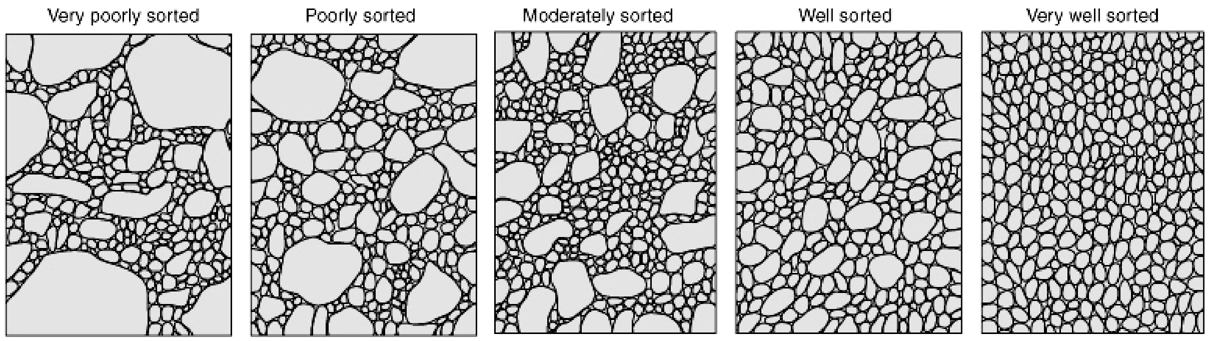


Figure 5-6. Silhouette comparison diagram for sand grain roundness. Numbers given below the names are the quantitative limits to the classes according to the Waddell formula. The boundary between subangular and subrounded corresponds to the borderline between the mature and supermature stages of textural maturity (Folk 1951 and see subsection of text). (After Shepard and Young 1961)



4. Using information gathered in questions 1 to 3, try to interpret and explain the environment of deposition for all 3 samples (e.g., a coastal sand, a river gravel, etc.). Think about sediment properties in different settings and refer to other sources of information (e.g., readings, text, sedimentology texts, references below) to support your interpretation. Also recall back to the stream table lab and how sediments were eroded, moved and deposited. (6 marks)

Experiment 2: Mechanics of Mass Wasting

The following experiments will provide some basic information on the mechanics of mass wasting using measures of the internal friction angle, including the angle of repose and angle of sliding friction, which describe the stability of unconsolidated sediments on sloped surfaces.

Experiment 2a: Angle of Repose

The angle of repose is the maximum slope angle at which sediment grains will remain stable. For instance, you may have noticed that talus cones (or scree slopes) in mountain regions or sand dune slip faces have a distinctive form or steepness. Slope angles for unconsolidated sediments choose a characteristic angle that is a function of grain size, sorting, shape, moisture content and reflects the internal friction angle in that particular arrangement of sediment particles.

Materials: Funnel apparatus (o-ring, stand, funnel, piece of paper), sediment samples 1-3, ruler or inclinometer (e.g., protractor, Abney level), sediment tray.

Procedure: Groups should rotate amongst sample stations to complete this experiment.

a. For each sample, set up the funnel apparatus as shown. Place a piece of paper inside the funnel and adjust opening to control rate of fall (this will vary for each sediment size). Adjust the height of the funnel outlet to be no more than a few cm above the tray or sediment pile at all times. Be as consistent as possible in your procedure as the size and shape (and hence, angle) of the cone depends on the size of the funnel opening, height of fall, and rate at which sediment is poured.

b. Pour each sample slowly onto a flat surface allowing a depositional cone to form. Continue pouring until the cone reaches a stable form (i.e., several cm high) where slope angle does not appear to change with further addition of sediment.

c. Measure or calculate the slope at 2 different locations, record and repeat the process 2 more times for each sample. Put your results on the board and give them to the lab instructor who will enter them into a class spreadsheet. Place your sediment back in the sample containers. Do not contaminate (mix) samples please.

Experiment 2b: Angle of Sliding friction

The angle of sliding friction is the maximum angle to which sediment may be tilted before failure or sliding of the sediment occurs. Like the angle of repose, this angle is a proxy measure of the internal friction angle. We will measure it directly in this experiment using the tilt table apparatus.

Materials: Tilt table apparatus, sediment samples, angle support (e.g., book, piece of wood, rubber stopper), protractor or inclinometer, sediment collection tray.

Procedure:

a. Each group must complete the tilt table experiment for each sediment sample. Note that each tilt table is textured with the corresponding sediment.

b. With the tilt table in a level, flat position, pour a thin layer of sediment on top of the textured surface. Smooth the sediment with a straight edge to obtain a uniform distribution on the textured surface. Do not 'pack' the sediment and remove any excess sediment. Aim for a thickness of approximately 5 to 10 mm.

c. Slowly increase the angle of the table until mass wasting of most of the sediment occurs (again, be as consistent as possible in your procedure). Measure precisely the slope angle at which this occurs and record your results.

d. Repeat the process 2 times for each sample and give the angle measurements to the lab instructor who will enter them into the class spreadsheet.

e. Sweep off the tilt table and clean up the sediment. Place your sediment back in the sample containers. Do not contaminate (mix) the samples please.

f. Repeat steps b-d with moist sand (only). Sweep the tilt table and place moist sediment in the separate collection bin (not back with the dry sand).

g. Unless stated otherwise, please use the class dataset for your lab section to answer the following questions.

Analysis & Questions

5. For both angle of repose and angle of sliding friction, calculate the mean (i.e. average) for the class dataset for your lab section. Present your results in a table. Discuss how your results compare with the class dataset? (6 marks)
6. Describe the differences in the angle of repose between the three samples, and explain whether or not grain size appears to influence the angle of repose. (3 marks)
7. Describe the differences in the angle of sliding friction between the three samples, and explain whether or not grain size appears to influence the angle of sliding friction. (3 marks)
8. Compare angles of repose to angles of sliding friction for each of the three samples, and explain any similarities or discrepancies. (6 marks)
9. Discuss any other factors or limitations (i.e., experimental procedures, errors, etc.) that may have affected your results. (2 marks)
10. Moisture affects internal friction by altering the shear strength of sediments. Discuss how the addition of moisture to the sand sample affected the angle of sliding friction for the class dataset for your lab section. Explain how the amount of moisture in natural, sandy sediment may affect its susceptibility to failure from low moisture content to high. (8 marks)

11. It is possible to estimate whether or not a slope is stable or unstable (about to fail) using the Factor of Safety (F_s) where F_s is the ratio of resisting to driving forces within the sediment body. **As this ratio gets smaller, the slope will begin to fail**.

    One of the best ways to understand a complex formula, such as the Factor of Safety, is to isolate each independent variable (e.g. e.g. γ, θ, ϕ, etc.) and discuss how increasing or decreasing that one variable can affect the magnitude (increase or decrease) and direction (+ or -) of the dependent variable (e.g. F_s).

    The Factor of Safety for a 1m wide column can be estimated using the following formula:

$$F_S = \frac{c' + [(\gamma_d z_d + \gamma_{sat} z_w - \gamma_w z_w) \cos\theta * \tan\phi]}{(\gamma_d z_d + \gamma_{sat} z_w) \sin\theta}$$

where,
γ_d = specific weight of dry soil [assume a value of 15 kN/m^{-3}]
γ_w = specific weight of water [assume a value of 9.81 kN/m^{-3}]
γ_{sat} = specific weight of saturated soil [assume a value of 20 kN/m^{-3}]
z_d = depth of dry soil in the column [assume a value of 1.5m]
z_w = depth of wet soil in the column [assume a value of 1.0m]
θ = slope angle (in degrees)
ϕ = internal friction angle (in degrees)
c' = cohesive force [assume a value of 0, i.e no cohesion]

Notice that we have controlled the values for γ, z and c so that we can see what happens to F_s when we vary θ and ϕ. Complete the following:

a) Define each of c, γ, θ and ϕ.This will require some research on your part, **and** you must cite your sources. (8 marks)
b) Describe what happens to F_S when ϕ is set to 40°, but θ goes from 20° to 40° (requires two calculations). Identify which scenario is more stable and discuss why this change occurs based on your definitions. (6 marks)
c) Describe what happens to F_S when θ is set to 30°, but ϕ goes from 25° to 45° (requires two calculations). Identify which scenario is more stable and discuss why this change occurs based on your definitions. (6 marks)
d) Discuss what might happen to F_S if z_d decreased to 0m and z_w increased to 3.0m and all other variables are controlled and c = 0. (2 marks)
e) Discuss what might happen to F_S if c increased and all other variables are controlled. (2 marks)

TOTAL 70 MARKS

DUE DATE: Beginning of your next scheduled lab in the week of March 9th in the 103 drop box.
LATE PENALTY: 25% per day.

Supplemental Readings:

Lewis, D.W. & McConchie, D. (1994). Texture of detrital sediments. Ch.5 in Practical Sedimentology. p. 114-127. Chapman & Hall: New York.

Folk, R.W. (1999). Sedimentary Petrology. an excellent online text on the properties of sediments and sedimentary rocks at: http://www.lib.utexas.edu/geo/folkready/folkprefrev.html

Leeder, M. R. (1982). Sedimentology: process and product. Boston: Allen & Unwin, Available in McPherson Library, QE571 L42