SLOPE STABILITY LAB

STANDARDS

See summary of National Science Education Standards.
Original: http://books.nap.edu/readingroom/books/nses/

Standard concept	General Standard	Specific Standard	General Standard	Specific Standard	General Standard	Specific Standard
Grade Level		K-4		5-8		9-12
Science as inquiry (A)	Abilities … to do … inquiry	A.1.4.1	Abilities … to do … inquiry	A.1.8.1	Abilities … to do … inquiry	A.1.12.2
		A.1.4.2		A.1.8.2		A.1.12.3
		A.1.4.3		A.1.8.3		A.1.12.4
		A.1.4.4		A.1.8.4		A.1.12.5
		A.1.4.5		A.1.8.5		A.1.12.6
				A.1.8.6		
				A.1.8.7		
				A.1.8.8		
	Understandings about … inquiry	A.2.4.1	Understandings about … inquiry	A.2.8.1	Understandings about … inquiry	A.2.12.2
		A.2.4.2		A.2.8.3		A.2.12.4
Physical Science (B)	Properties of … materials	B.1.4.1				
Earth and Space Science (D)	Properties of Earth materials	D.1.4.1	Structure of Earth system	D.1.8.3		
			Earth's history	D.2.8.1		
Science in … social perspectives (F)			Natural hazards	F.3.8.1	Natural and human induced hazards	F.5.12.1
				F.3.8.2		

SLOPE STABILITY LAB

INTRODUCTION

Hills are made of various types of rocks. Some hills are made large layers of strong rock; others are made of unconsolidated sands. The slope of the hillside depends on the type of rock and the conditions. Landslides occur when a rock is not strong enough to resist the force of gravity (http://www.geo.arizona.edu/K-12/azpepp/education/activity/gravity.fig3.jpg) that pulls it closer to the center of the Earth.

OBJECTIVE

The purpose of this activity is for the student to investigate both slope stability and landslides. The exercise consists of creating sand and gravel "mountains", measuring slopes, and testing the effects of water on slope stability. Students will investigate

- How gravity affects slope stability.
- How and why water can alternately strengthen and weaken a material.
- How packing of rock and soil particles affects susceptibility to landslides.

MATERIALS

- Sand, clean and uniform in grain size (600 ml)
- Sand, used for building or cement mixtures (600 ml)
- Gravel, uniform in size (200 ml)
- 1-400 ml beaker
- 1-100 ml graduated cylinder
- 1-50 ml graduated cylinder
- 1-pie plate (shallow, ~8 inch container) or flat-bottomed plastic container
- 8 oz plastic cup with small perforations in bottom or watering can
- Newspaper
- Paper towels
- 1-compass
- 1-ruler

PART I BUILD THE STEEPEST MOUNTAIN

PROCEDURE student directions

1) How steep is that mountain?
   a) Using the dry sand in the plastic container, build a hill and investigate its steepness, or "a*ngle of repose*," the maximum angle at which a slope of loose material (such as soil or sand) remains stable.
      i) How can you express steepness? (Think of the slope of a line on a graph.)
      ii) How can you measure steepness?
      iii) How can you be sure your measurement is correct?
   b) From the same materials, can you build a steeper mountain?
   c) Do other people's hills have the same steepness?
      i) What could cause variations?

d) Are there other changes you could make to test steepness using the same materials? Discuss them, and then try them.
e) Do other materials produce hills of the same steepness?
   i) With the group, discuss other materials you could try to use for hills and any possible variations.
   ii) Of these other materials, would some be important to the general public? Why?
   iii) Design experiments to compare the various types of hills in order to investigate slope stability.
      (1) In designing the experiment, start by listing all the possible variables (things you can change or that can be changed).
      (2) Pick one of the variables to change, keep the others unchanged. If you want, have other groups pick other variables to change for faster comparisons of results.
      (3) Quantify all variables and measurements.
      (4) As you perform the experiment, record all those quantities and measurements. A table is a compact way to record quantities.
      (5) Repeat the experiment exactly as you already did to help identify any unknown variables or mere variations in the experiment that you are not controlling.
      (6) Compare results with others

TEACHER NOTES: Possible answers to questions in procedure

1) Mountain steepness
   a) Angle of repose
      i) Expression of steepness
         (1) Rise over run ($\Delta y/\Delta x$)
         (2) Angle from horizontal (or vertical) (http://www.geo.arizona.edu/K-12/azpepp/education/activity/repose.fig2.jpg)
      ii) Measurement of steepness
         (1) Expression of the slope: measure a vertical distance and divide that by a corresponding change in horizontal distance, $\Delta y/\Delta x$.
         (2) *Measure the angle of repose using a clinometer made from a protractor with a weighted piece of string tied at the center of the circle to show the vertical (plumb).*
      iii) Correctness of measurement
         (1) Repeat the measurement several times.
   b) Build a steeper mountain?
      i) Try different ways of pouring the sand to make the hill.
      ii) Try more or less sand.
      iii) Brace the hill against container walls
      iv) Remeasure the steepness.

Original procedure (http://www.geo.arizona.edu/K-12/azpepp/education/activity/la.html)

PROCEDURE STUDENT instructions

1. Measure 400 ml of dry sand into a beaker.
2. Slowly pour the sand into the center of a pie plate lying on a flat surface. *Be careful, you are trying to achieve a sand mountain with the MAXIMUM slope*. Quick pouring will result in a flat low lying hill.
3. Measure the angle of repose of the sand mountain (Angle of Repose = degrees from the horizontal).
4. Repeat steps 2-3, four times to average out errors in measurement. Record your measurements in Table 1.
5. Incline the pan by placing a block under one end and repeat steps 2-4. The angle of inclination is not important; however, the experiment will proceed better if the angle is less than 45 degrees.
6. Compare your results! Is there any significant difference between the angle of repose for the mountains built on the flat or inclined surface? Briefly discuss your results.

PART II. BUILD A WET-SAND MOUNTAIN.

HYPOTHESIS TESTING:

- How do you think the sand will behave if it is wet with water?
- Will the slopes be steeper or shallower? Why?
- Will there be any other changes?

PROCEDURE: Student instructions

1) Measure 400 ml of dry sand into a beaker.
2) Dump the sand into a pie pan and add 50 ml of water.
   a) Mix the sand and water so that the sand grains appear wet.
3) Carefully pour the sand into the center of another pie plate. Pour slowly because you are trying to achieve a wet sand mountain with the MAXIMUM slope.
4) Measure the angle of repose of the sand mountain.
5) Repeat steps 2-4, four times to average out errors in measurement. Record your measurements in Table 1.

TABLE 1:

Trial	**1**	**2**	**3**	**4**	**Average**
Dry Sand on Flat Surface					
Dry Sand on Inclined Surface					
Wet Sand on Flat Surface					

PART III. COMPRESSED WET-SAND MOUNTAIN.

PROCEDURE Student instructions

1) Using your hands on your wet sand mountain from Part II, compress the sand and form a somewhat symmetrical sand mountain with the maximum slope that you can achieve.
2) Measure the angle of repose of the sand mountain.
   a) Angle of Repose = ________________________

EVALUATION

- What changes did you observe in the maximum slope angle for the wet and dry sand?
- How might the water affect the sand to cause this change?

IV. MASS-MOVEMENTS AND THE EFFECTS OF THE ADDITION OF WATER.

PROCEDURE STUDENT instructions

1) Using the 100 ml graduated cylinder, slowly pour water onto the top of your wet sand mountain. (Be sure to record the amount of water you pour!)
   a) While pouring the water, you should see some settling in the beginning followed by mass-movements.
2) Sketch the shape of the mass-movement.
   a) Be sure you show the texture of the landslide at the toe of the slide (hummocky lobes).
   b) This texture is the same texture you should look for prior to purchasing property at the base of a hill! Houses built on active landslides don't hold up very well.
3) Keep adding water until the sand mountain collapses. Record the total amount of water added to the dry sand. Don't forget the initial 50 ml from Part II!
   a) Total Amount of Water Added To Sand ______________________________

V. WET SAND AND GRAVEL MIXTURE

There are many different types of rocks that fail during a landslide. The strength of a rock depends on how well each grain within the rock is bound to the other grains in the rock. To understand rock strength more completely it is useful to repeat the procedures in Part III and IV using a mixture of 200 ml of gravel and 200 ml of sand. Record you results below.

PROCEDURE STUDENT instructions

1) Measure 200 ml of dry sand and 200 ml dry gravel into a beaker.
2) Dump the sand into a pie pan and add 50 ml of water. Mix the sand, gravel and water so that the sand grains appear wet.
3) Put the wet-mixture back in the beaker and pack it down tightly. Record the total volume of sand, gravel and water below.
   i) 200 ml sand + 200 ml gravel + 50 ml water = ___________ ml of sand, gravel and water mixture.

4) Carefully pour the sand mixture into the center of a pie plate. You are trying to achieve a mountain with the MAXIMUM slope.
5) Measure the slope of the mountain as a ratio of rise/run.
   i) Slope = ____
6) Measure the angle of repose of the mountain.
   i) Angle of Repose =____
7) Keep adding water until the sand mountain collapses. Record the total amount of water added to the dry sand. Don't forget the initial 50 ml!
8) Total Amount of Water Added To Sand Before The Landslide =
   ____

PART VI. MATH LINK

The loose, well sorted sand has approximately 48% porosity while a mixture of equal parts sand and gravel has approximately 40% porosity. Use the total volume of water added to each of the materials before it failed in a landslide to calculate the percent saturation of each material when it failed.

EQUATIONS

Volume of Pore space = percent porosity X volume of materials.

Saturation = volume of pore space filled with water divided by the total volume of pore space.

Example: If you have 100 ml of dry sand that has 30% porosity:
The volume of pore space in the sand = .30 * 100 ml = 30 ml

If the sand failed in a landslide after adding 20 ml of water:
The saturation of the sand at failure = 20 ml water /30 ml pore space = .667 or 66.7%

Calculate the following for your sand and other mixtures of materials:

Volume of Pore Space in Sand = ____

Saturation of Sand at Failure = ____

Volume of Pore Space in Sand and Gravel Mix =______________________________

Saturation of Sand and Gravel Mix at Failure = ____________________________

Compare the saturation levels just before the landslide for the sand with those of the sand-gravel mixture.

Can you think of some reasons why they might be different?

TOPICS FOR FURTHER DISCUSSION:

1) How does the steepness of a slope affect the processes of erosion and deposition?
   a) Design sandbox experiments to investigate these processes.
2) Ties to reclamation of mined lands
   a) Where in a mined area do you find slopes?
   b) What might mining companies do to reduce erosion and visual impact of slopes in these areas?
   c) Design sandbox experiments to model and test effectiveness of some of these techniques.

TEACHER NOTES: Possible answers to questions posed above

1) Processes of erosion
2) Ties to reclamation of mined lands
   a) Where are slopes
      i) Open pit, waste rock dumps, heap leach piles, other?
   b) Mining company reduction of erosion
      i) "Recontouring" of slopes (making steep slopes into gentler slopes),compaction of loose material, revegetation of slopes, "naturalizing" slopes, restratification of rock, introduction of "raptor boulders", other?.