

SOIL LIQUEFACTION – INSTABILITY DURING EARTHQUAKES

STANDARDS

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

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.1.12.1
		A.1.4.2		A.1.8.2		A.1.12.2
		A.1.4.3		A.1.8.3		A.1.12.3
		A.1.4.4		A.1.8.4		A.1.12.4
		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.2.8.2		A.2.12.4
		A.2.4.3		A.2.8.3		
		A.2.4.4		A.2.8.4		
		A.2.4.5		A.2.8.5		
		A.2.4.6		A.2.8.6		
Physical Science (B)	Properties of ... materials	B.1.4.1	Properties and changes of properties in matter	B.1.8.1		
	Position and motion of objects	B.2.4.1				



		B.2.4.3				
					Motion and forces	B.4.12.2
Earth Science (D)	Properties of Earth materials	D.1.4.1	Structure of Earth system	D.1.8.2		
				D.1.8.3		
				D.1.8.4		
			Earth's history	D.2.8.1		
	Changes in Earth and Sky	D.3.4.1				
Science in ... Social Perspective (F)			Natural Hazards	F.3.8.1		
				F.3.8.2		
			Risks and Benefits	F.4.8.1		
				F.4.8.3		
					Natural and Human-induced hazards	F.5.12.1
						F.5.12.2
						F.5.12.3
						F.5.12.4
					Science and Technology in ... challenges	F.6.12.1
						F.6.12.2



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INTRODUCTION

Often, the Earth is viewed as being solid and immovable. However, during an earthquake, the Earth moves often to great depths. Ground that is now actually rock moves differently than rock and can cause more problems.

It is important not only to learn about geology of rocks and minerals, but also how we can use that knowledge for personal lives. Soil liquefaction is an important problem for cities built on sand because in earthquakes the soil underlying buildings will liquefy, causing buildings to sink differentially. Soil liquefaction is one of the major sources of damage from earthquakes. This activity models what happens in earthquakes, and how the earthquake may affect people in our cities.

Soil liquefaction is important whenever structures are built on saturated loose soils (sand). During strong ground motion from earthquakes, the sand will liquefy. When it does, the soil mixture acts like a fluid and the building built on top of it will sink. This was the reason for the extensive damage after earthquakes in Kobe, Japan, in 2001, and in Alaska in 1964. After the shaking stops, the sand grains settle, and the sand layer compacts. Geotechnical engineers and geologists study ways to stabilize structures built on such soils. What they learn can also be applied to other structures such as bridges and buildings. Similar ground motion can also occur during blasting. In other words, soil liquefaction is studied for planning how much load (foundation of the building) the soil can support when large buildings are constructed.

Terms:

- Density – how loose or compressed the sand is
- Unit weight – weight of sand per unit volume
- Water content – percentage of weight of water occurring in the voids in the soil

OBJECTIVE

Students will model and study liquefaction an example of the importance of understanding the effects of geologic processes on society.

MATERIALS (per group)

- Large bowl or dish pan with calibration for volume (in liters) on side 16-8oz cups of sand (6300 grams per bowl)
- Measuring cup (metric)
- Water (2000mL or 8-8 oz cups)
- Large spoon for mixing
- Stopwatch
- Assorted unopened cans of food (peas, mushrooms, etc.) with minimal water inside the can (short and tall cans, skinny and wide cans) to represent buildings (need calibration in centimeters on the side of the cans)
- 2 Ping-pong balls
- Toy people, trucks, cars



- Scale to measure weight of sand, water, and sand/water mixture, and weight of cans
- Small fan with weight on one blade (for shaking)
- Ruler

PROCEDURE (for students)

- 1) Assign a variety of starting conditions to the various groups.
- 2) Pour a measured amount of water into the bowl.
- 3) Add a measured amount of sand and mix sufficiently that the sand is loose.
- 4) Place toys on the surface.
- 5) Weigh the cans to be used in the model. Place 1-2 cans on the surface to simulate the building(s) on the sand.
- 6) Record conditions of the experiment on a data sheet. What values should be included?
- 7) Attach fan to side of bowl.
- 8) Time the fan running for 5, 15 and 35 seconds, stopping to measure amount “building” settles at each time (use ruler beside building to check it) – record settling at each time
- 9) Note – don’t mix the sand between the timings, but if you do mix it reenter the experimental conditions at that time and do the experiment again.
- 10) Once finished with the measurements, create a chart for all teams
- 11) Graph output as appropriate. What quantities should be graphed?
- 12) Additional activity - Bury ping pong ball in the sand completely and perform the shaking experiment one more time (where did the ball go?). Record the depth to which the ping-pong ball is buried. Record the time observations are made.

EVALUATION

- Discuss observations:
 - Measurements – How much variation is observed in results? What might cause the variations?
 - How might the size and shape of the building affect the results? For example, do taller buildings settle worse?
 - How much time does it take for a building to collapse partially or completely
- Other topics of discussion
 - Cans are different from buildings because they move as a single unit. How might buildings with a larger base (than a can) act?
 - What might happen to small structures? What items in the model represented small structures?
 - What happened to the water during the shaking?
 - What happened to the ping-pong ball? What structure might a ping-pong ball represent?

TEACHER NOTES

- Experimental conditions that need to be recorded include the density of sand (mass per unit volume, grams/liter or grams/mL), amount of water, amount of sand, percent water, masses of can “buildings,” shape of can “building” height and radius (perhaps expressed as a ratio of height to radius to describe the various shapes



quantitatively), starting depth of can “building,” depth of can “building” at each time, time of fan turning to shake the bowl, time until can “building” sinks completely, density of ping-pong ball, depth ping pong ball is initially buried to, time until ping-pong ball rises to surface.

- Make several graphs such as
 - 1) percent water (x axis) versus time of “building” collapse (y axis);
 - 2) shape of “building” (height/radius of can) (x axis) versus time of “building” collapse;
 - 3) mass of “building” (x axis) versus time of building collapse.Remember for each graph, only the two variables listed can change. Other variables need to stay constant. In situation 1), only “buildings” of the same mass and shape can be compared; in situations 2) and 3), only experiments with the same percent water can be compared; while in situation 3), only “buildings” with the same shape and varying masses can be compared. This means there must be many different experimental conditions assigned, so perhaps the experiments will have to be carried out several times to accommodate the combinations of variables. Decide these before hand with the help of the students and the materials available.
- Other topics of discussion
 - Structures can sink unevenly or differentially thus leading to major structural damage in earthquakes.
 - Smaller items (such as trucks) can sink as in quicksand.
 - Water becomes a layer on the surface and separates from the sand thus the sand becomes denser.
 - The ping pong ball will rise to the surface just as gas tanks at filling stations will during an earthquake.

