Soil Liquefaction – Instability during earthquakes

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Background:

It is important not only to teach 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. It is one of the major sources of damage from earthquakes. The College of Engineering is exploring new ways to bring engineering to pre-college students. This exercise models what happens in earthquakes, and how it 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, and 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 constructing large buildings.

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

Materials needed (per team):

- Large bowl with calibration for volume on side
- 16-8oz cups of sand (6300 grams per bowl)
- Measuring cup
- Water (2000 cc 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) to represent buildings (need calibration in inches on the side of the cans)
- 2 Ping pong balls
- Toy people, trucks, cars
- Scale to measure weight
- Small fan with weight on one blade (for shaking)
- Ruler

Procedure:

- Pour water into bowl
- Add sand and mix sufficiently that the sand is loose
- Place toys on the surface
- Place 1-2 cans on the surface to simulate the building(s) on the sand
- Fill in all values on worksheet as specified for each team
- Attach fan to side of bowl
- Time 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
    - Note – don't mix the sand between the timings, but if you do mix it re-collect the full sheet of information at that time and do the experiment again
- Once finished with the measurements, create a chart for all teams
- Graph output as appropriate
- Additional activity - Bury ping pong ball in the sand completely and perform the shaking one more time (where did the ball go?)

Discuss observations:

- Measurements – variation in results (why?)
- Size of building and how it affects the result (taller settles worse?)
- Time it takes to collapse partially or completely

Some things to discuss too:

- Structures sink unequally or differentially thus leading to major structural damage in earthquakes
- Small structures (trucks) sink similarly in quicksand
- Water becomes a layer on the surface and separates from the sand thus the sand densifies
- The ping pong ball will rise to the surface just as gas tanks at filling stations will during an earthquake