Liquefaction Activity

Target Age Group: 4th-5th grade

Background Information:
YouTube video clip (1:22) from The Weather Channel show "Hacking the Planet," with Dr. Ken Stokoe from The University of Texas at Austin explaining liquefaction:
https://www.youtube.com/watch?v=XVUgXJDHI3w

Objectives: In this activity, you will observe the effects of soils that liquefy during earthquake shaking, and you will test approaches to mitigating those effects. You will use the engineering design process to:

- Identify the problem associated with soil liquefaction during earthquakes
- Brainstorm solutions to reduce the effects of liquefaction
- Predict how your proposed solution will perform
- Test your solution and make observations
- Revise your solution based on observations from testing
- Share your results with others

Materials: Activity can be done as a demonstration in front of a larger class, or it can be done in small groups of 3-5 students. Each group or demonstration requires:

- 3 shoebox sized plastic bins (preferably transparent)
- Sand (e.g., bags of sand are sold at home improvement stores), enough to fill the bins half way
- 1 rubber mallet (optional)
- A weight with a base of approximately 2 to 4 sq. inches (e.g., a half-pint milk carton filled with marbles or gravel) to simulate the building sitting on the soil
- Materials for potential ground improvements (e.g., 3/8" or ½" diameter wooden dowels cut to various lengths from 1-4 inches, gravel, etc.)

Activity Directions:

1) To be done by the activity leader beforehand: Create three liquefaction testing bins. First, fill all three bins approximately half way with sand. One bin will remain dry sand. Add water to the other two bins until the sand is fully saturated and liquefiable[1]. You will have three bins ready for the following tests (Fig. 1):
    - Testing of a building on dry sand (to demonstrate no liquefaction during an earthquake)
    - Testing of a building on wet sand (to demonstrate the effects of liquefaction)
    - Testing of a building with ground improvements on wet sand (to test different ground improvement strategies)

[1] To tell if the soil is liquefiable, mix the sand and water so that it looks like wet sand. Then shake the bin or hit the sides of the bin with a mallet a few times. If the sand settles and puddles of water appear on the surface of the sand, then the sand is fully saturated and liquefiable. To "reset" the bin so it could be tested for liquefaction later, just use your hands to mix the sand and water together again until it just looks like wet sand. If you add too much water so that puddles appear on the top before you shake the bin, then just mix in more sand until you get a "wet sand" consistency.

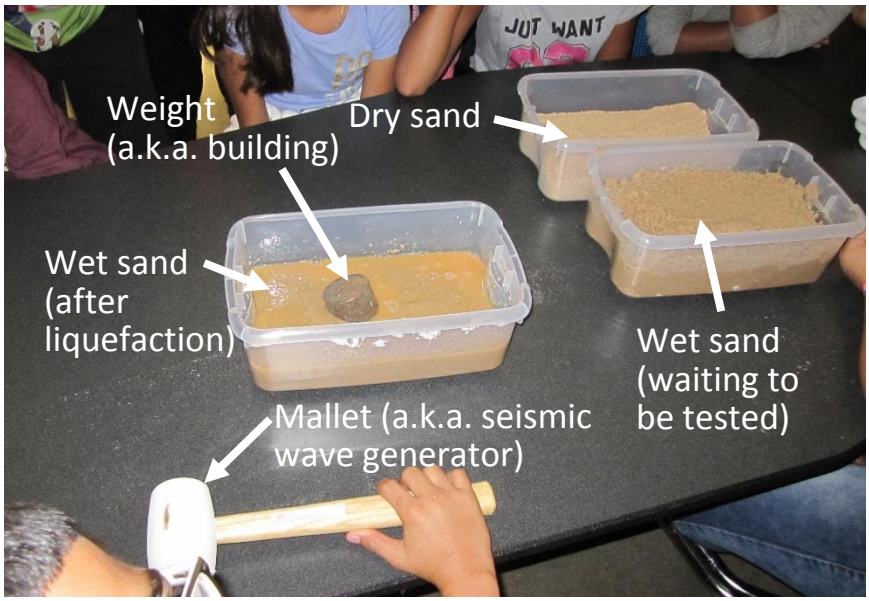


Figure 1: test setup

2) Put the weight (i.e., the building) on the dry sand. Simulate an earthquake by generating seismic waves in the soil using the rubber mallet to tap the sides of the bin. If you do not have a rubber mallet or you want the whole group involved, students can pound the table around the bin with their fists to create seismic waves. (Note for activities leaders: The building may settle a bit, but it should remain upright and generally unscathed. If you have a very tall weight with a small base area, your building may topple, in which case you may want a squatter weight for your building.)
    - Record your observations
3) Put the weight (i.e., the building) on the wet sand. Simulate an earthquake by creating seismic waves. (Note to leaders: the building should sink and water should rise to the surface of the sand and form puddles, indicating that liquefaction has occurred.)
    - Record your observations
    - Compare these observations to those from the dry sand bin
4) In small groups, brainstorm possible ways to prevent the building from sinking when liquefaction occurs (Note to leaders: some possible ideas include pushing piles, a.k.a. wooden dowels, into the ground under the building, putting a "raft" of horizontal dowels/beams in the ground beneath the building, using the gravel to densify the soil beneath the building, etc.)
5) Pick one of the ground improvement ideas to test. Draw a sketch of your proposed idea and predict how your proposed solution will perform when it is tested (i.e., what do you expect to happen to the building on the improved soil?). Construct your ground improvement idea in the remaining untested bin (Fig. 2).

Figure 2: Pushing piles (i.e., wooden dowels) into the soil beneath the building

6) Simulate an earthquake by creating seismic waves.
    - Record your observations
    - Compare these observations to the test on the wet sand with no ground improvements
    - Did your idea perform as you expected?
    - What improvements, if any, would you make to your idea if you were to try it again?
7) If time permits, you can continue improving and testing your ideas. Just mix the liquefied sand so it looks like wet sand, and it is ready to be tested again.
8) Present your findings to other groups (if working in groups)

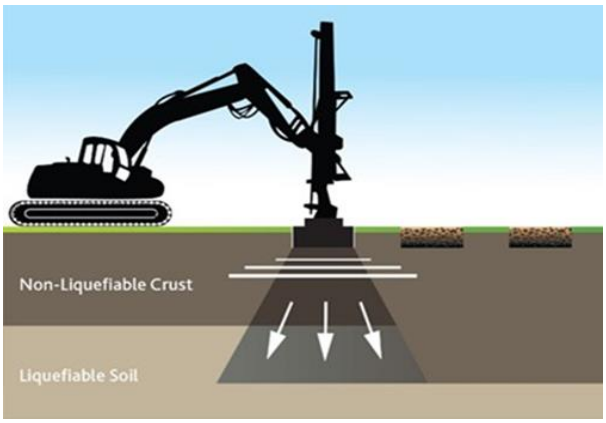
Additional Information:

See the effects of liquefaction in Christchurch, New Zealand and the research engineers are doing to try to prevent damage from liquefaction in the future (2:38): https://www.youtube.com/watch?v=O-nF04Jmn58&index=12&list=PLusVompxJ-58QrFkGGiavXKug0h50FGjY

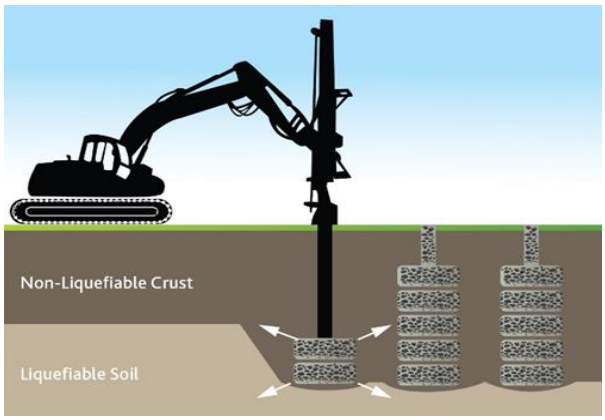
The T-Rex shaker truck from the University of Texas at Austin is used to create seismic waves in the ground to test liquefiable soils in the real world, much like you tested your models by generating seismic waves with a mallet. Different ground improvement techniques that were tested with the T-Rex shaker truck in Christchurch, New Zealand include:

- Rapid impact compaction of the soil (Fig. 3a)
- Piers make of rammed aggregates or low-mobility grout (Fig. 3b)
- Horizontal beams under the building (Fig. 3c)

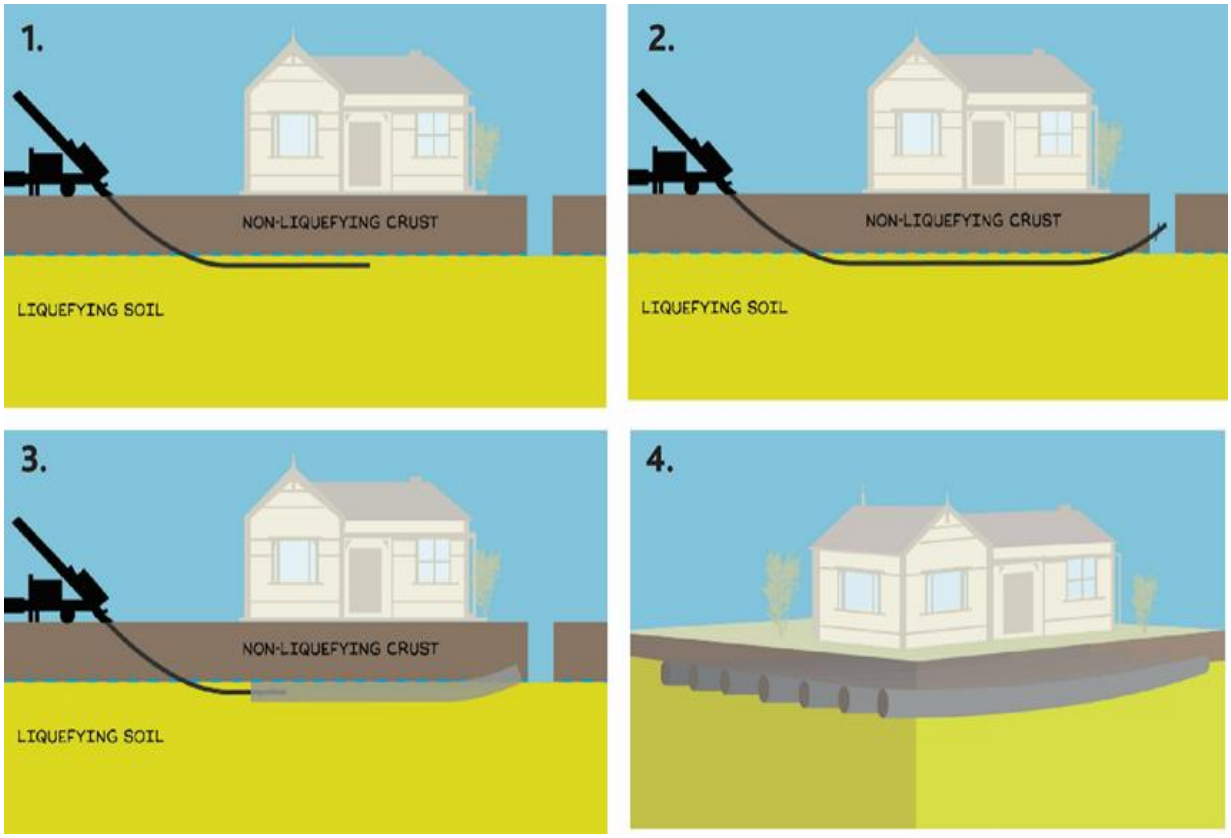
For more information on these ground improvement methods and how engineers used the T-Rex shaker truck to test them, see this video (3:37): https://www.youtube.com/watch?v=nXqaF-IJ4eo&index=14&list=PLusVompxJ-58QrFkGGiavXKug0h50FGjY



(a) Rapid Impact Compaction



(b) Rammed Aggregate Piers



(c) Horizontal beams under the building

Figure 3: Ground improvement techniques to reduce the impacts of liquefaction on buildings