AUSTRALIAN EARTH SCIENCE EDUCATION

Soil Mechanics Teacher Guide

Earth & Space Science Curriculum Link:
Describe the key processes of the rock cycle and examine how properties of rocks reflect their formation and influence their use.

Geomechanics Focus:
Applying rock cycle knowledge to construction: Understanding soil behaviour and its impact on ground stability and design.

Background Information

The rock cycle explains how rocks form and change over time. Weathering and erosion break rocks into sediments that eventually form soils. The properties of soils depend on the rocks they originated from and how the particles interact with each other and with water.

In geomechanics, understanding soil behaviour is essential for designing stable structures such as buildings, roads, and dams. Two important soil types are granular soils (such as sand and gravel) and cohesive soils (such as clay). Their key differences are shown in Figure 1.

Granular materials can behave in surprising ways. When loose, the particles can move freely and flow like a liquid. When packed together, they interlock and can support weight like a solid. Granular materials can also jam, where particles form stable arches that stop movement even when space is available for them to flow. This behaviour is important in soil stability and in the design of structures such as silos and foundations.

When granular materials are fully saturated with water, they may also experience dilation. When pressure is applied, the grains rearrange and require slightly more space to move past one another, temporarily increasing the pore space between particles. A similar effect can be observed when stepping on wet sand near the shoreline. When you step on saturated sand, the grains shift and dilate, drawing water downward and sometimes creating a dry patch around your foot.

Cohesive soils behave differently because they are made of extremely small particles with large surface areas. These particles attract each other through electrochemical forces and interact strongly with water, allowing them to stick together. As a result, cohesive soils tend to resist movement and hold their shape when stressed. However, they can also be sensitive to changes in moisture. When water content increases, cohesive soils may soften and lose strength; when they dry, they can shrink and crack. These behaviours are important for engineers to consider when designing foundations, slopes, and earth structures.

You can watch the demonstration video here.
A presentation for the following activity is provided in this teaching package.

Granular	Cohesive
	

Granular

- e.g., sand or gravel
- Can act like liquid and solid
- Fast drainage
- Low moisture sensitivity
- Excellent load-bearing after compaction

Cohesive

- e.g. clay, silty clay
- Can resist movement because of particle bonding & water pressure
- Slow drainage
- High moisture sensitivity
- High stability after compaction

Figure 1: Properties of granular vs cohesive soils

Aim

Students will investigate the contrasting behaviours of granular and cohesive soils using household materials to understand how soil type influences ground stability and construction design.

Materials

Per small group (figure 2)

- Smarties (alternatively, use a granular material like dried chickpeas, pasta, or rice)
- Container (Tupperware or ice cream tub)
- Full bottle of water or oil (for load demonstration)
- Plastic bottle with lid
- Coarse sand (or other granular material)
- Food dye
- Transparent straw
- Bowl
- Spoon
- Custard powder or cornflour
- Water in a measuring jug

Figure 2: Materials

Safety Notes

- Ensure containers are stable to avoid spills
- Use an alternative granular material instead of Smarties if you are in a no-food laboratory or if students have allergies.
- Handle water and powders carefully to present slipping hazards
- Supervise students during pouring and tapping to avoid breakage or mess

Method

Run through the PowerPoint presentation provided in the teaching package.

Activity 1A: Granular flow vs Jamming experiment

- Pour smarties from one container to another to show liquid-like behaviour.
- Place a full water bottle or bottle of oil on settled smarties to show solid-like behaviour.
- Fill a plastic bottle with smarties.
- Invert the bottle over a container. Observe initial flow and jamming (figure 3).
- Tap the bottle to restart flow and note repeated jamming.
- Discuss why jamming occurs and its relevance to soil arching and silo design.

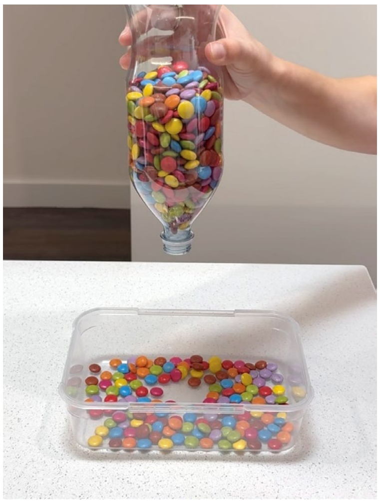

Figure 3: Jamming of smarties in bottle

Activity 1B: Granular dilation demonstration (optional extension)

- Put a hole in a plastic bottle lid, no larger than the diameter of a straw.
- Fill the bottle with granular material (in this case, coarse sand).
- Add water until the sand is fully saturated so that all pore spaces are filled.
- Insert a straw into the opening.
- Squeeze the bottle and observe what happens to the water level (figure 4).

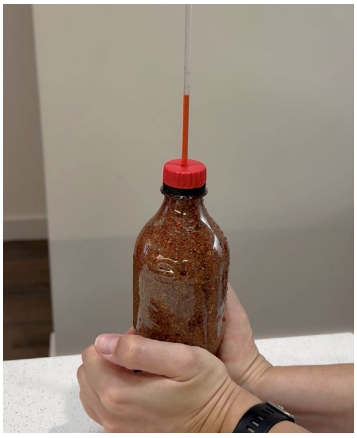

Figure 4: squeezing a bottle containing water-saturated coarse sand

Observation: Instead of rising, the water level in the straw drops when the balloon is squeezed.

Note: this demonstration can also be done with a balloon or rubber glove instead of a water bottle.

Activity 2: Cohesive soil analogy

- Use a spoon to mix custard powder or cornflour with water to create a paste (figure 5).
- Observe resistance of the fluid against the spoon.
- Roll the mixture into a ball while moving it. Observe solid-like behaviour.
- Stop moving. Observe transition back to liquid.
- Optional: add a small amount of water gradually while mixing with a spoon to see how the mixture changes its behaviour.

Figure 5: cornflour mixed with water

Results

Students observe:

- Granular materials can behave like liquids when loose and solids when packed.
- Jamming occurs due to particle arching, supporting weight above.
- Saturated granular materials can dilate when compressed, temporarily increasing pore space and drawing water into the material.
- Cohesive materials resist movement due to particle bonding and pore pressure effects.

Experiment	Observation
Granular Flow	*Smarties pour easily between containers, behaving like a liquid when loose*
Jamming	*When the bottle is inverted, flow stops as particles form an arch across the opening; tapping restarts flow briefly.*
Granular dilation	*When the saturated granular material in the bottle is squeezed, the water level in the straw drops instead of rising.*
Cohesive behaviour	*Mixture resists movement when stirred or rolled (solid-like) but flows when left still (liquid-like).*

Discussion

1. Why do granular materials like the smarties sometimes behave like a liquid and sometimes like a solid?
   Granular materials can flow like a liquid when particles are loosely packed and can move freely. When they settle into a dense arrangement with many contact points, they behave like a solid because the particles interlock and resist movement. This dual behaviour is important in soil mechanics and explains why sand can both flow and support loads.

2. What causes “jamming” in the bottle experiment, and why is this phenomenon useful in

geotechnical engineering?
Jamming occurs when particles form an arch across the opening, transferring the load to the sides of the container. This prevents further flow even though the opening seems large enough. In geotechnical engineering, similar particle interlocking improves soil stability, especially when combined with geogrids, which help lock particles in place and prevent movement under loads.

3. In the bottle experiment, why does the water level in the straw drop when the granular material is compressed instead of rising?
When pressure is applied to the bottle, the granular particles rearrange and move slightly apart from each other. This process is called dilation, where grains require more space as they shift under stress. Because the particles temporarily need more space, water is drawn into the pore spaces between them. As water moves into these spaces, the water level in the straw drops rather than rising.

4. How does the custard (cornflour and water) experiment help us understand the behaviour of cohesive soils like clay?
The custard mixture demonstrates how cohesive soils resist movement due to particle bonding and pore pressure effects. When you apply shear (move the spoon or roll the ball), particles rearrange and water moves into voids, creating resistance. If water is limited, negative pore pressure holds particles together, making the mixture behave like a solid. When shear stops, it flows again, similar to clay under stress.

Extension

Imagine you are a civil engineer tasked with designing the foundation for a large building on a site with both sand and clay soils. What challenges might arise from these soil types, and what strategies could you use to ensure the ground is stable and safe for construction?
Use reliable sources to answer this question. Remember to reference your sources.

- *Load-bearing capacity: Sand drains well but can shift; clay holds water and can swell/shrink.*
- *Differential settlement: Mixed soils can settle unevenly under load.*
- *Stabilisation methods: Use geogrids or geotextiles to lock granular particles, improve compaction, and prevent movement. For clay, consider drainage systems or chemical stabilisation (lime/cement treatment).*
- *Water management: Prevent excess water in clay to avoid swelling and instability.*

Possible sources:

ProChemical TX. (n.d.). Building on different soils: Impact on construction. Retrieved January 6, 2026, from https://prochemtx.com/stabilization-methods/construction-on-different-soils/

Capstone Civil. (n.d.). Advanced soil stabilization techniques in civil projects. Retrieved January 6, 2026, from https://capstonecivil.com.au/advanced-soil-stabilization-techniques-in-civil-projects/

StrataGlobal. (n.d.). What is a geogrid? Retrieved January 6, 2026, from https://www.strataglobal.com/media_blog/what-is-a-geogrid/

References:

Introduction to Geotechnical Engineering. (2020, Apr 10). Dilation and Contraction [Video]. Youtube. https://www.youtube.com/watch?v=XCOPNMDhXkM

Tensar, a division of CMC. (2020, Apr 2). Soil mechanics kitchen experiment I Geotechnical Engineering I TGC Episode 13 [Video]. Youtube. https://www.youtube.com/watch?v=x0Ffm6mfEgc&t=208s

The Action Lab. (2025, Mar 16). This Material Gets Bigger When You Squish It [Video]. Youtube. https://www.youtube.com/watch?v=Pw3AvKcHeTw&t=302s

What Geomechanics Is and Why It Matters

Geomechanics is the study of how soil, rock, and Earth materials behave, forming a critical foundation for the design and performance of modern infrastructure. It enables engineers and planners to develop safe, efficient, and sustainable structures, such as buildings, tunnels, roads, and dams, by providing accurate ground models and an understanding of how the ground responds to natural and human-induced changes. Geomechanics also contributes to public safety by helping identify and manage geohazards such as landslides, sinkholes, and ground instability, supporting climate resilience, sustainable development, and the global energy transition. Through proactive ground assessment and risk evaluation, geomechanics helps prevent infrastructure failures, reduce project delays, and lower financial and social costs. Careers in geomechanics span a wide range of roles, including field investigations, laboratory testing, data analysis, and engineering design, with entry pathways commonly through geology, civil engineering, and environmental science. Alternative routes, such as experience in construction, surveying, or environmental monitoring, also provide effective foundations for moving into the field. Professionals develop skills in technical analysis, communication, critical thinking, and multidisciplinary collaboration, supporting informed decision making across infrastructure and environmental projects.

Soil Mechanics

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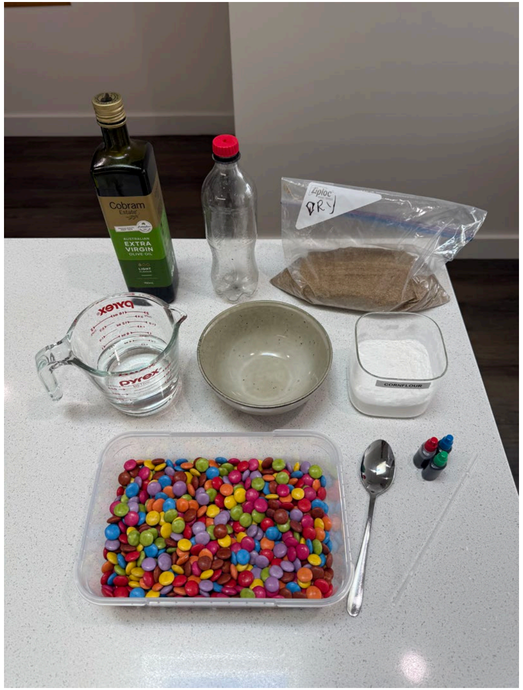
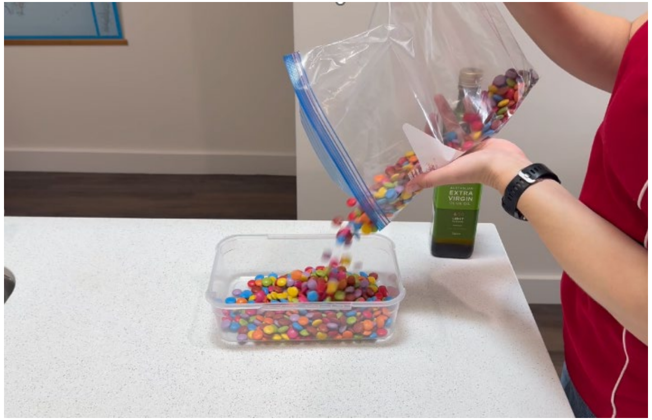
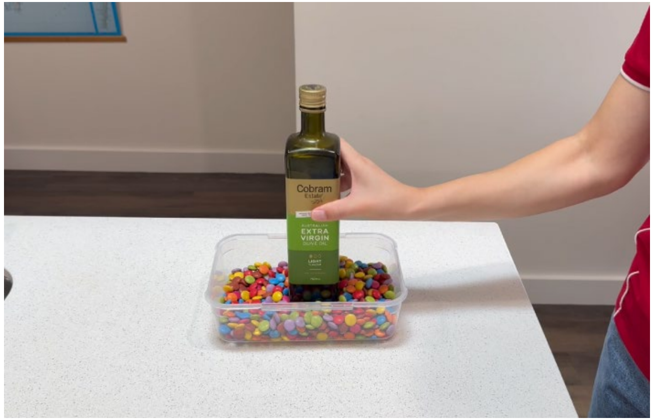
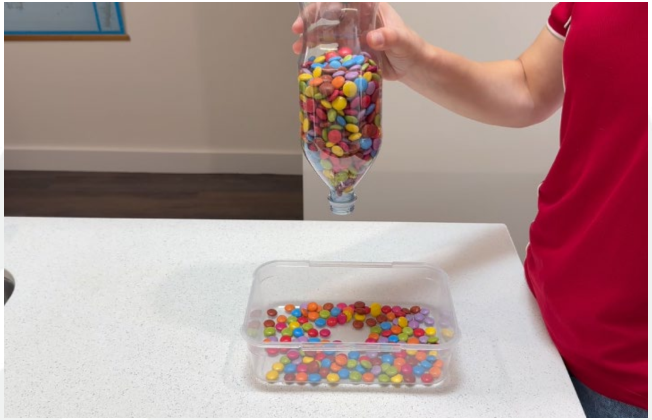


Activity 1A: Granular flow vs jamming







Activity 1B: Granular dilation

Activity 2: Cohesive soil analogy

Summary

You've seen that:

- You've seen that granular materials can act like liquids or solids
- Jamming occurs due to particle interlocking
- Saturated granular materials can dilate when compressed, temporarily increasing pore space and drawing water into the material.
- Cohesive materials resist movement because of bonding and pore pressure.

Discussion

If you were designing a building foundation on sand and clay, what challenges would you face? How would you stabilise the ground?

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