

Jelly/biscuit modelling of how earthquake waves amplify and devastate Demonstrating how seismic shaking depends on local geology

When earthquakes strike, how much the ground shakes where you are, depends on three things:
1) how big the earthquake was (its magnitude);
2) how far away you are from the earthquake;
3) the site effects – your local geology.

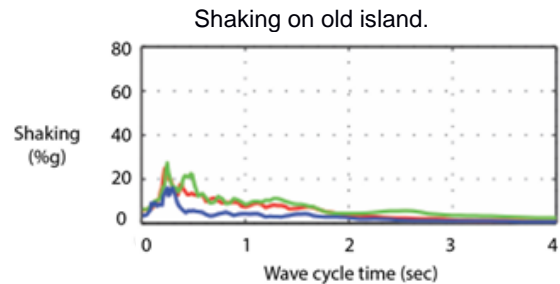
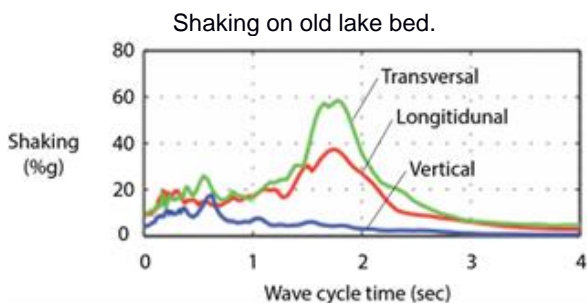
Set up the experiment the day before. In a baking tray, make a model landscape using biscuits and jelly. Create an area with foundations on solid

bedrock (biscuit) and an area of soft sediments (jelly). Give the jelly a few hours to set (e.g. in a fridge). Your model represents a place like Mexico City where the central part of the city is built on solid rock but the rest of the city is built on soft lake bed sediments. This means that different parts of the city only a few hundred metres apart respond very differently to earthquake shaking.



The jelly/biscuit model used to demonstrate seismic site amplification (video - http://www.earthlearningidea.com/Video/Mexico_City.html)
(Photo and video copyright Paul Denton BGS creative commons.)

On your jelly/biscuit model, construct two identical towers (from biscuits or wooden blocks). Then shake the tray by hand, very gently at first and then gradually increase the shaking. This sets up a strong resonance in the weak jelly layer and the shaking is greatly amplified, causing the building on jelly foundations to collapse, while the building on solid foundations is hardly shaken at all.



Graphs from UNAM preliminary report.

The graphs show the ground motions recorded during the M7.1 earthquake, 120km from Mexico City on 19th September, 2017 on two sites close together in Mexico City, one on the old lake bed and one on solid bedrock.

The back up

Title: Jelly/biscuit modelling of how earthquake waves amplify and devastate

Sub-title: Demonstrating how seismic shaking depends on local geology

Topic: Modelling the effect of earthquake seismic waves on buildings.8

Age range of pupils: 13-16 years

Time needed to complete activity: 20 mins.

Pupil learning outcomes: Pupils can:

- understand how the effects of earthquakes are not the same everywhere;

- understand the concept of frequency and resonance, how a small vibration that matches the natural shaking frequency of an object can be amplified into a large vibration;
- see how scientists try to understand and create models to understand the effects that they see in the world around them.

Context:

The shaking by an earthquake depends upon how far away you are from the earthquake because seismic waves decrease in amplitude with distance due to geometric spreading, i.e. the same wave spreading out over a larger volume, and attenuation, when seismic energy is lost to heat as the wave passes through a material.

The central part of Mexico City has been constructed on the site of the ancient Aztec city of Tenochtitlan which was built on an island in a lake. When the Spanish expanded Mexico City in the 17th and 18th centuries, they drained the lake and continued building on the soft lake bed sediments around the solid island core.

All materials have a natural stiffness or strength and their own mass. This means that when they are shaken they will naturally want to shake at a particular frequency (called the **natural frequency**). If the material is stiff, this frequency is high, if it is weak the frequency is low. In sedimentary basins a few hundred metres thick, the natural frequency of weak sediments (like the lake bed sediments in Mexico City) is about 0.5-1 Hertz (one cycle every 1-2 seconds). If seismic waves enter this basin from a distant earthquake with about this frequency they can be greatly amplified by a factor of up to ten times compared to the surrounding strong hard bedrock (where the natural frequency can be tens of hertz).

Following up the activity:

Investigate resonance by shaking jelly babies mounted on spaghetti at different frequencies. Read how scientists use mathematical models of the geology under big cities to predict how much shaking will occur during a nearby earthquake, and use this information to improve building codes.

Underlying principles:

- The shaking of seismic waves is characterised by their frequency (number of cycles per second) or their period (time between cycles).
- Seismic waves are physical vibrations in the ground that can travel hundreds of km.
- 'Natural frequency' is the frequency at which an object or body will shake, if left on its own
- Resonance is where a small vibration can be amplified into a large vibration if the frequencies of a driving signal and a body's natural frequency are similar.

Thinking skill development:

Observation leads to a conceptual model which leads to a physical or mathematical model.

Resource list:

- baking tray, jelly, biscuits (stackable) (enough for one demonstration model)
- (for follow up) jelly babies, uncooked long spaghetti (enough for three pieces of spaghetti and three jelly babies per pupil)

Useful links:

New York Times article:

<https://www.nytimes.com/interactive/2017/09/22/world/americas/mexico-city-earthquake-lake-bed-geology.html>

Blog post: <http://temblor.net/earthquake-insights/mexico-city-building-collapses-experts-on-drop-cover-and-hold-on-or-run-5340/>

(advanced) Nature paper on modelling:

<https://www.nature.com/articles/srep38807>

Earthlearningidea activities: For two simple activities related to this topic see: *Quake shake – will my home collapse? When an earthquake strikes – investigate why some buildings survive and others do not and Shaken but not stirred? How earthquakes affect buildings.*

Source: Paul Denton of the British Geological Survey (pdenton@bgs.ac.uk).

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