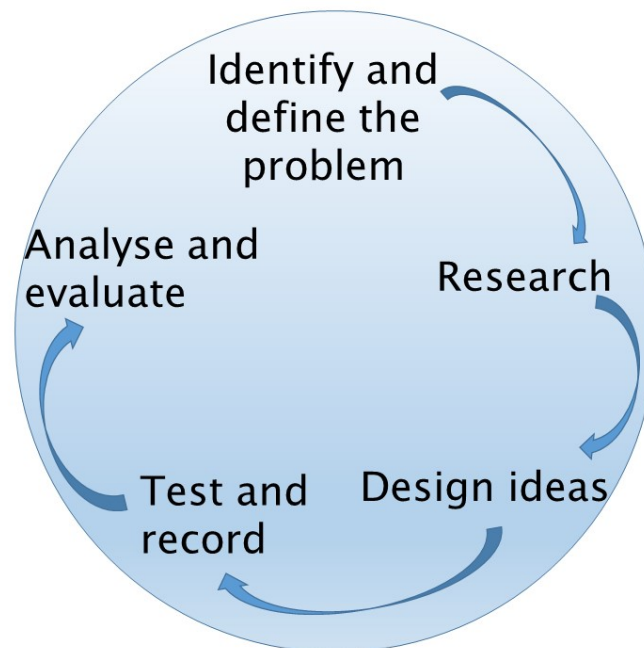


The Challenge

Designing earthquake resistant buildings can be lifesaving, especially for people living near tectonic boundaries. Your job is to investigate the causes of earthquakes and their effects on different ground types and building designs. You should select a particular location that you think would benefit from better earthquake engineering and design a building that would be suitable for this location.

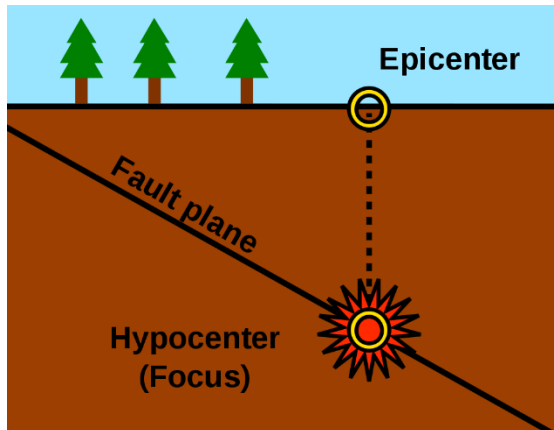


Background Information

Earthquakes can be devastating, destroying structures and buildings and taking lives. In 2017 there were 12,527 earthquakes recorded with a magnitude of 4 or higher globally. The deadliest of which was a 7.3 magnitude earthquake which occurred on November 12, killing 630 people in Iran and 10 in Iraq. Interestingly, Russia and New Caledonia both experienced earthquakes of similar depth and magnitude of that in Iran in 2017 and had no fatalities.



Figure 1. Devastation caused by the Iran - Iraq Earthquake of 2017. (By Tasnim News Agency, 2017)



Earthquakes are caused by fault movement. This can occur on a micro to mega scale. Most earthquakes that cause damage are due to movement of tectonic plates, however volcanic activity, and crustal adjustments can also cause earthquakes. Earthquakes have also been linked to anthropogenic causes, such as fracking and mining.

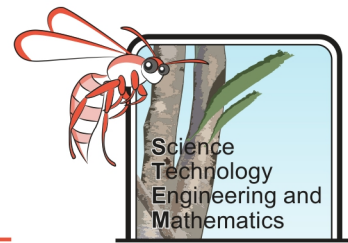
Figure 2. Diagram of the epicenter of an earthquake, where movement along a fault plane has caused it. (Hocevar, 2014)



Figure 3. Three story building on springs in North Carolina to dampen earthquake waves. (Shustov, 1999)

Damage caused by earthquakes can be catastrophic economically for families, businesses and whole countries. With infrastructure and buildings often having to be completely rebuilt. The design of buildings is therefore of paramount importance to avoid being damaged.

Due to the causes of earthquakes some countries are much more likely to experience them. This makes it easier for governments to decide if they should prioritise earthquake engineering to protect their people. Unfortunately a lot of the current designs that do work well are very costly, and unaffordable for many.



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Background Research

1. What causes earthquakes? Add labelled diagrams/pictures to aid your explanation.

Suggested site: <https://www.science.org.au/curious/earth-environment/what-causes-earthquake>

2. Which type of earthquake waves cause most devastation to houses, and how do they move?

Suggested site: <https://www.sciencelearn.org.nz/resources/340-seismic-waves>

3. Where did the three most devastating earthquakes occur last year, in terms of fatalities?

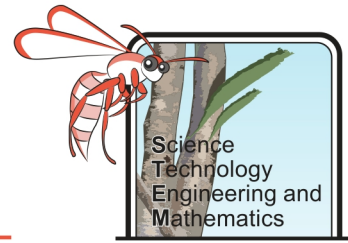
Location	Number of fatalities

Suggested site: https://en.wikipedia.org/wiki/List_of_earthquakes_in_2018

4. Where did the 5 strongest earthquakes occur last year?

Location	Magnitude

Suggested site: https://en.wikipedia.org/wiki/List_of_earthquakes_in_2018



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5. What are the top 3 most earthquake prone countries?

Suggested site: <https://www.skymetweather.com/content/earth-and-nature/10-earthquake-prone-countries-in-the-world/>

6. What is the gross domestic product (GDP) of those countries?

Country	GDP

Suggested site: [https://en.wikipedia.org/wiki/List_of_countries_by_GDP_\(nominal\)](https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal))

7. Describe and explain other hazards caused by earthquakes.

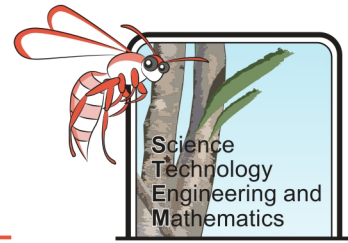
Hazard	How an earthquake can cause it	Damage it can cause
Tsunami		
Liquefaction		
Fire		
Landslide		

Suggested site: <https://earthquake.usgs.gov/learn/glossary/?term=earthquake%20hazard>

8. What are the common causes of death/ injury by an earthquake?

Suggested site: http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/earthquake_effects.html

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Where in the World?

Objective

To explore the relationship between earthquake location and tectonic plates through use of GIS (Geographical Information Systems) and secondary data.

There are two possible methods for this investigation.

Option 1 – Using secondary data and paper maps

Equipment

- List of recent earthquakes with location, magnitude and depth data (can be accessed on Wikipedia or through Geoscience Australia).
- Map of the world with longitude and latitude lines on it
- Sticky dots or different coloured pens

Method

1. Locate the epicenter of the each of the earthquakes on the map using the latitude and longitude coordinates. (+ Latitude = North, - latitude = South. + longitude = East, - Longitude = West)
2. Place a sticky dot, or mark on the location with a pen.

Option 2 – Using secondary data and Google maps

Equipment

- Computer
- Access to Google maps
- Access to the USGS site or Wikipedia
- Excel

Method

1. Create a spreadsheet in Excel with the following headings: Magnitude, Latitude, Longitude and Depth (km). Use information from Wikipedia, add details for earthquakes for the past year.

Or

go to the USGS website and in the earthquake catalogue create a new search request - <https://earthquake.usgs.gov/earthquakes/search/>

- Select custom for the magnitude and set to 6
- Select custom for date and time (1 year).
- Select World under Geographic location
- Under the Output tab select CSV file

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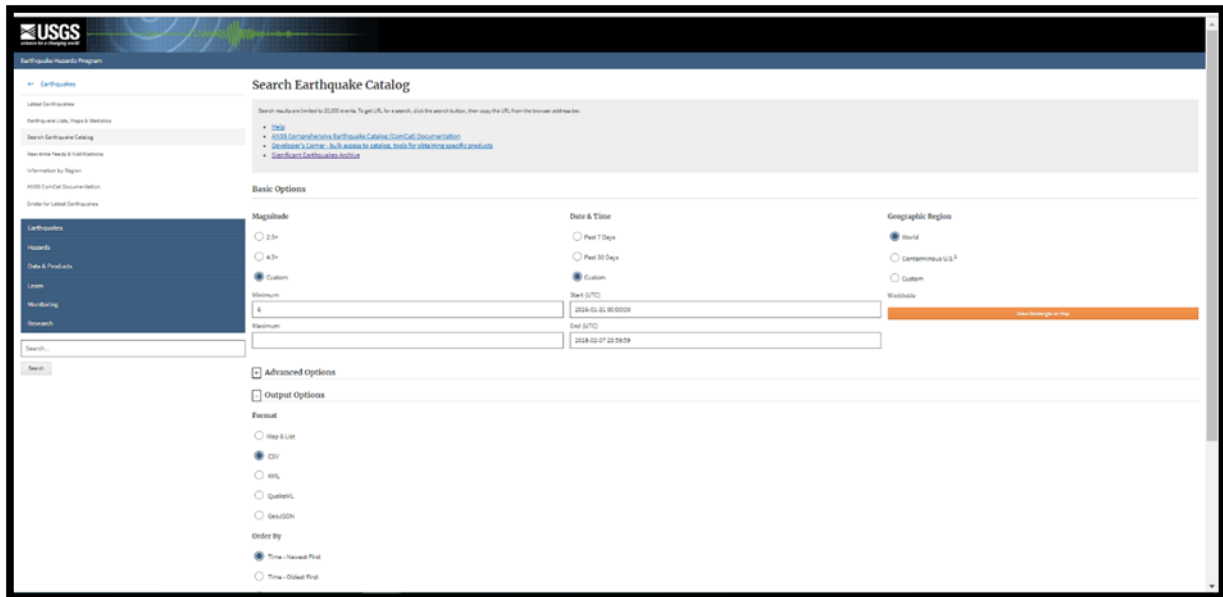
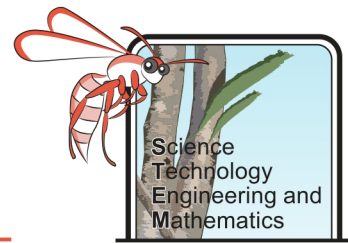


Figure 4. Screenshot showing what to select on the USGS Earthquake catalogue.

2. Open Google maps and click on the menu tab. Then select “My Places.”

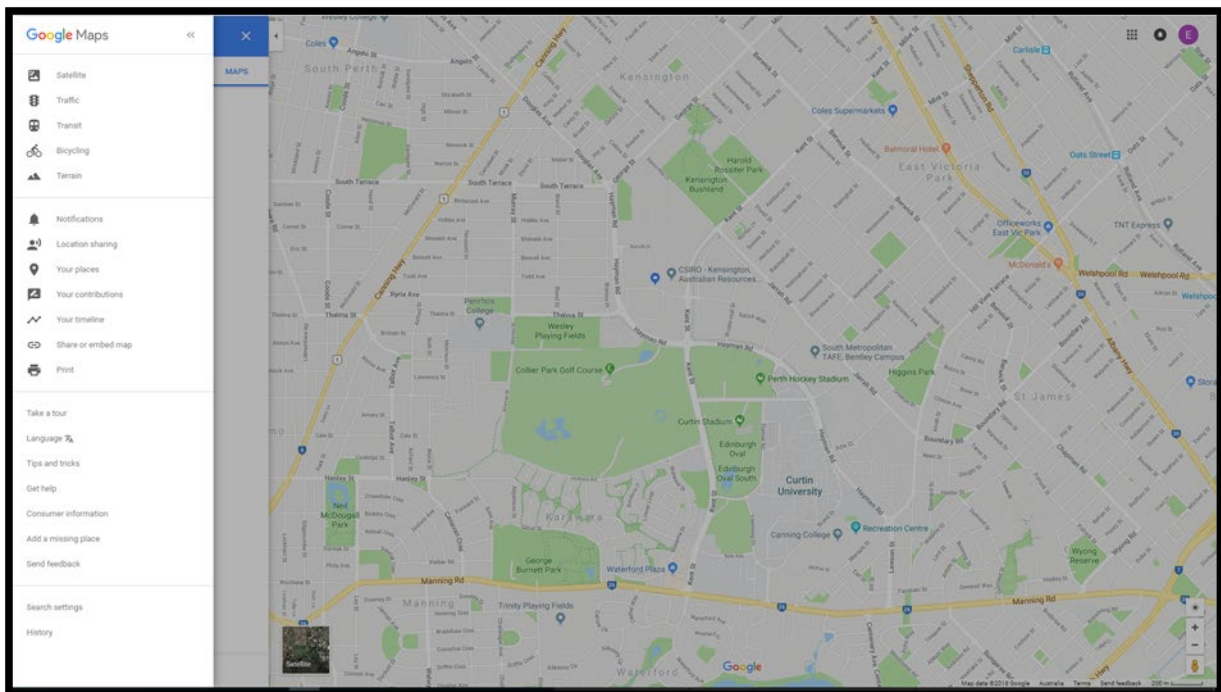


Figure 5. Screen shot of google maps showing the menu bar.

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3. Next select Maps -> create map.

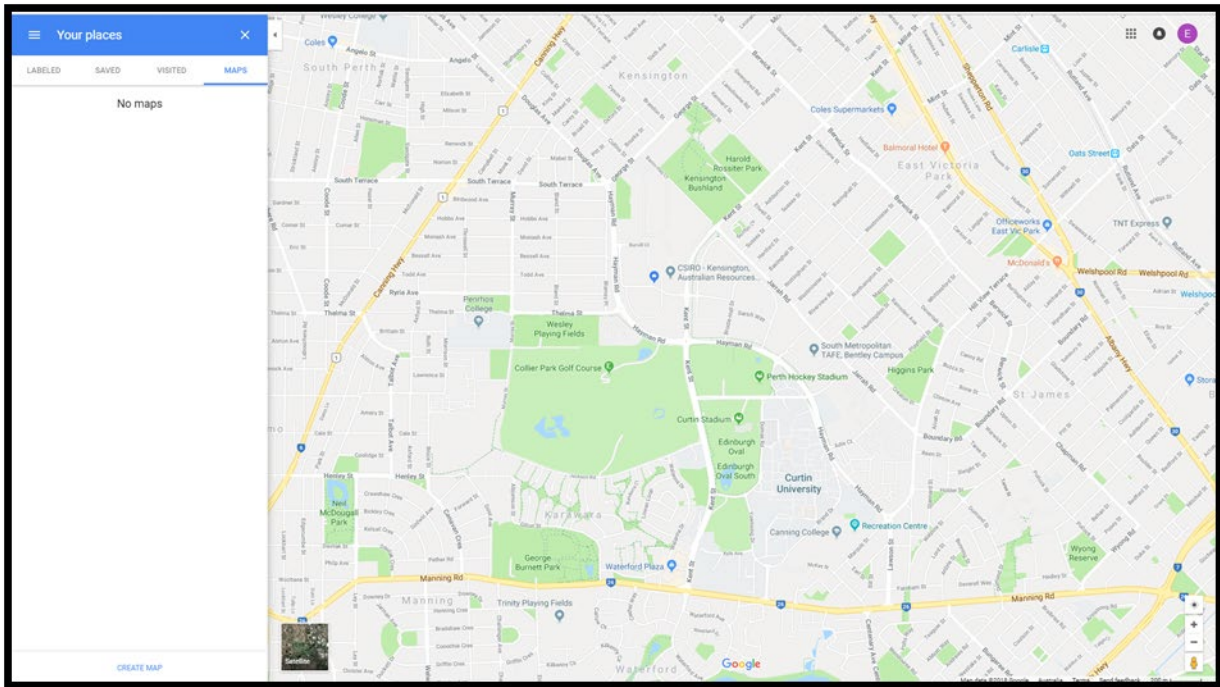


Figure 6. Screenshot of Google maps, select MAPS on the top bar, then CREATE MAP at the bottom of the menu bar.

4. Now you can either individually add each data point by selecting “add marker” tool (highlighted in yellow circle) OR you can import data directly from your spreadsheet by selecting “import”.

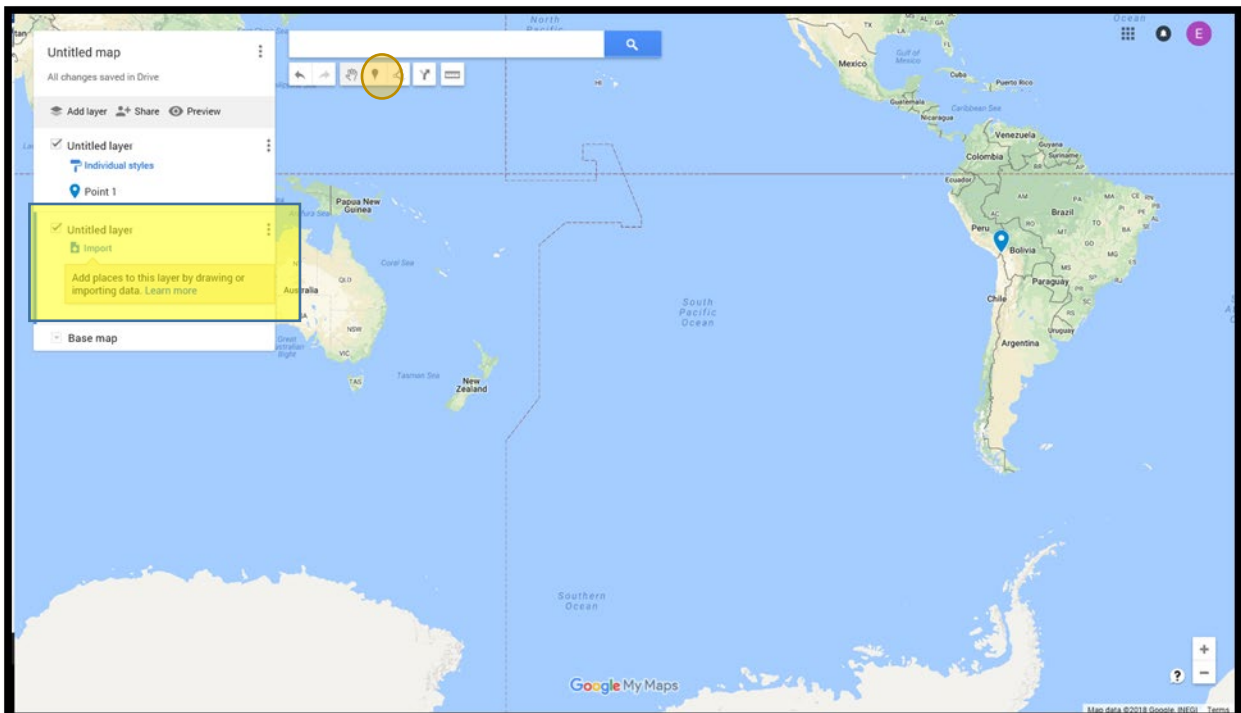
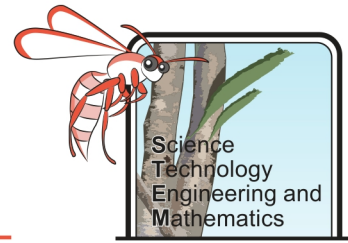


Figure 7. Screenshot highlighting where to select if you wish to add individual data points manually, or where to select if you wish to import a whole CSV file.

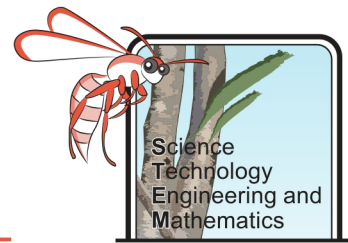
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Results and Analysis

1. Connect the data points, where you feel it is appropriate, either on your paper map or on Google maps using the drawing tool – attach a copy of this to your work.
2. Compare your outline to a map of tectonic plates of the world. What do you notice?

3. Are there any countries that look particularly at risk of earthquakes, with numerous plate boundaries passing through them? If so, which ones?



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Earthquake Energy

Objective

To be able to calculate the energy released by different magnitude earthquakes.

Background

Earthquakes are generally reported by their magnitude, or more correctly – Moment Magnitude. This is a modified version of the Richter scale which was devised in the 1930s by Charles Richter.

You will have heard the magnitude of earthquakes being reported on the news, and probably have a good understanding that the larger the earthquake the more energy – and therefore the more destructive power it has. However, the earthquake magnitude is not measured on a linear scale, in fact for each unit of increase (1, 2, 3...) the earthquake will be **10** times bigger and release around **31.6** times more energy.

Complete the table below to show how much bigger each earthquake is and how much more energy it releases. You may wish to use the USGS “How much bigger...” online calculator to help.

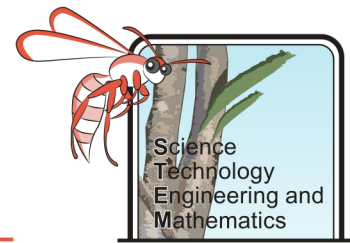
Results

Magnitude	Times bigger than magnitude 1	Times stronger than a magnitude 1 (energy released)
1	1	1
2	10	31.6
3	100	
4		
5		
6	100,000	
7		
8		
9		

Extension: Re-write the table expressing the numbers in scientific notation.

How much more energy does a magnitude 8 earthquake release compared to a magnitude 4?

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Case Studies

Objective

To be able to explain the design features of buildings which have enabled them to withstand earthquakes.

With increasing population size more and more people are living in seismically unstable areas and are at risk of being affected by earthquakes. Better building designs are much more in demand, and new ideas, to prevent building collapse, are being engineered.

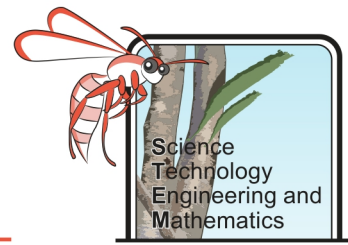
Research the following engineering ideas to explain the principles behind the design and how it will help to reduce structural failure caused by earthquakes.

Add any extra ideas to the table that you find during your research.

Results

Principle	How it works	Example of building using this design (give location as well)
Steel-reinforced concrete		
Suggested site: https://www.concreteshowindia.com/blog/reinforced-concrete-structures-are-much-safer-in-earthquake-zones/		
Base isolation systems		
Suggested site: https://en.wikipedia.org/wiki/Base_isolation		
Diagonal bracing		
Suggested site: https://science.howstuffworks.com/engineering/structural/earthquake-resistant-buildings3.htm		
Tuned mass damper		
Suggested site: https://practical.engineering/blog/2016/2/14/tuned-mass-dampers-in-skyscrapers		
Springs		
Suggested site: https://science.howstuffworks.com/engineering/structural/earthquake-resistant-buildings4.htm		

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Principle	How it works	Example of building using this design (give location as well)
Earthquake curtains Suggested site: https://www.wired.co.uk/article/earthquake-resistant-curtain-building		
Flexible materials (e.g. bamboo) Suggested site: https://www.exploratorium.edu/faultline/damage/building.html		

Analysis

1. Which, if any, of the designs have worked (withstood numerous earthquakes)?

2. Which design ideas will be better for countries with a low gross domestic product? Explain your answer.

3. Which design idea do you think will be utilised the most in the future? Explain your answer.

Flexural Strength Testing

Objective

To investigate the flexibility of different materials, and analyse their suitability as a building material for earthquake prone zones.

Equipment

- Four lengths of different material of the same or very similar dimensions (around 30 mm x 300 mm x 3 mm) e.g. steel rule, wooden ruler, plastic, clay, ceramic tile etc. N.B. although glass is a common building material, for health and safety reasons we do not recommend using it for this investigation.
- Blocks/supporting pins
- Slotted masses (increments of 50 g)
- Ruler
- Safety glasses

Method

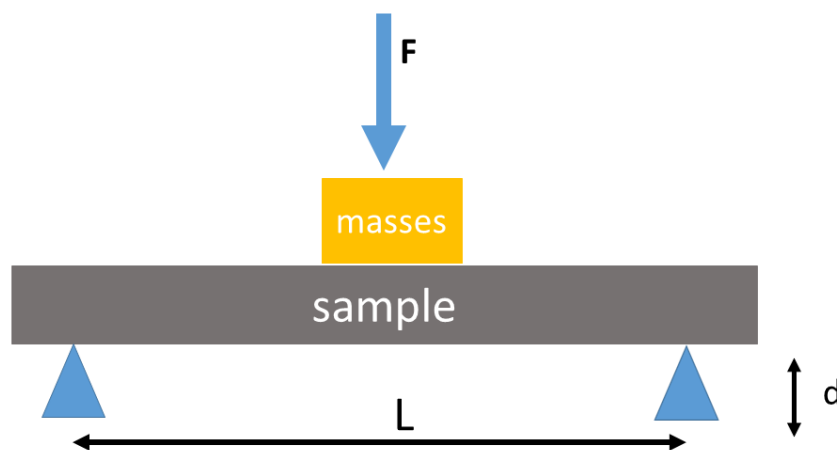
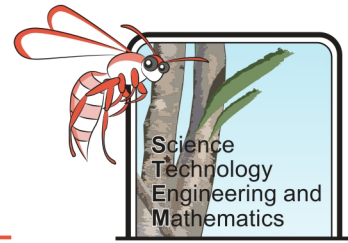


Figure 8. Suggested set up to test the flexural strength of materials.

1. Place the sample onto two blocks/supporting pins, as pictured.
2. Measure the length of the space from block/pin to block/pin (the length, L).
3. Measure the height from the table to the bottom of the sample (the distance, d) using the ruler and record in the results table.
4. Place a 50 g mass on the middle of the sample, ensuring it is an equal distance from both blocks/supporting pins. Measure the new distance (d) from the table and calculate the deflection.
5. Keep adding 50 g masses and calculating the deflection after each new mass is added until you have reached 500 g, or the material looks like it will break (do not break the material!).
6. Repeat for all materials making sure that the length is the same for each – you will need a table for each sample.

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Results and Analysis

Material: _____

Material: _____

Mass (g)	Distance from table (mm)	Deflection (original distance from table – new distance from table) (mm)		Mass (g)	Distance from table (mm)	Deflection (original distance from table – new distance from table) (mm)
0				0		
50				50		
100				100		
150				150		
200				200		
250				250		
300				300		
350				350		
400				400		
450				450		
500				500		

- Plot the results on a scatter graph, with mass along the x-axis and average deflection up the Y-axis, ensuring you make it clear which material is which (use different colours, or shapes for data points), and add lines of best fit to the data (remember lines do not have to be straight.)
- If you are plotting your graph in Excel or Google Sheets add the line equations.

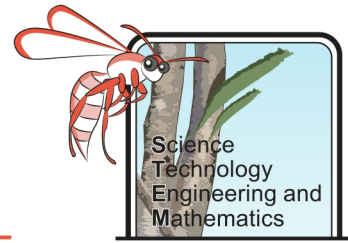
1. Which material was the most flexible (had the largest deflection)?

2. Which material was the least flexible?

3. How do the materials compare in price? – Try to use actual data to answer this question.

Material	Price

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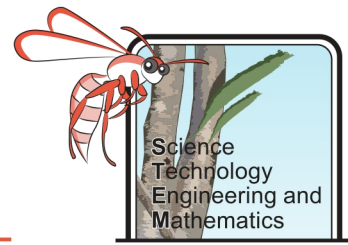


4. Do all the materials have a similar trend line on your scatter graph?

5. Which material do you think would be best to use to allow the building to sway rather than crack and crumble? Use your data to justify your decision.

6. Which material (s) would you suggest using to build a more earthquake resistant building? Use your data to justify your answer.

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Modelling Liquefaction

Objective

To investigate the behaviour of different ground types when shaken, and relate that to engineering considerations for building in an earthquake prone zone.

Equipment

- 1 x transparent storage box/ large Tupperware box
- Sand and soil
- Rocks
- Water
- 2 x ping pong balls
- Model house (you could make a small one from Lego or Duplo)

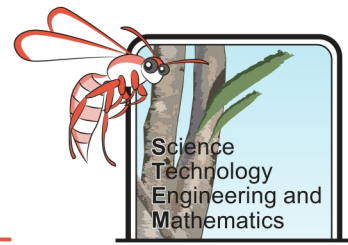
Method

1. If you have not already – research liquefaction in response to an earthquake. Use a labelled diagram to explain your answer.

Suggested site: <https://depts.washington.edu/liquefy/html/what/what1.html>

2. Pour enough sand into the box so that it is around 8 – 12 cm high.
3. Bury the ping pong balls in the sand and place the house on top of the sand.
4. Shake or tap on the side of the container for 30 seconds to simulate an earthquake. Make sure that you try to use the same force and speed throughout.
5. Record your observations, taking photos/videos if possible.
6. Remove the house and ping pong balls and slowly add water to the sand to dampen it, there should be no water visible on the surface. Ensure the sand is evenly damp throughout. Record how much water you added.
7. Re –bury the ping pong balls and place the house back on top of the sand.
8. Shake the container using the same speed and force as in step 4 to simulate an earthquake.
9. Record your observations, taking photos/ videos if possible.
10. Empty the container of sand and repeat the experiment using the substrates suggested in the results table.
11. Record your observations for each test.

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Results and Analysis

1. Record your results in the table below.

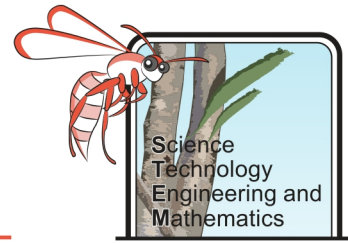
Substrate	Observations
Dry Sand	
Wet Sand	
Dry Soil	
Wet Soil	
Dry sand with rocks in it	
Wet sand with rocks in it	

2. Which substrate was most affected by liquefaction?

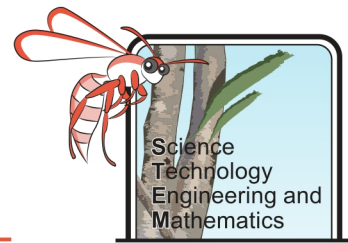
3. Which substrate was least affected by liquefaction?

4. What happened to the ping pong balls when the “earthquake” hit, and why do you think that happened? Use scientific understanding to aid your explanation.

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5. Which substrate would you rather build your house on: granite, sandstone or unconsolidated sand/ silt? Use your data and observations as well as scientific knowledge and understanding to explain your decision.



Strength of Shapes

Objective

To investigate which shapes are strongest and also most likely to withstand applied forces from different directions, to relate this to building design in an earthquake prone area.

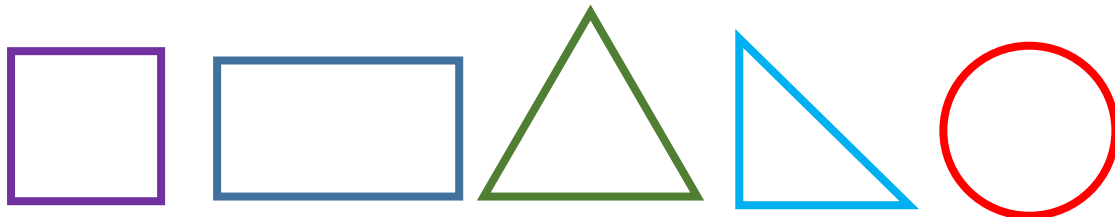
Equipment

- Straws
- String
- Scissors

Method

1. Create the following shapes, endeavouring to make them similar in size:
 - A square
 - A rectangle
 - An equilateral triangle
 - A right angled triangle
 - A circle

Thread the string through the straws and tie a knot at every corner, ensuring good tension.



2. Test the strength of the shapes by applying forces in different directions sequentially to, model the stresses caused by an earthquake. Record your observations in the table below.

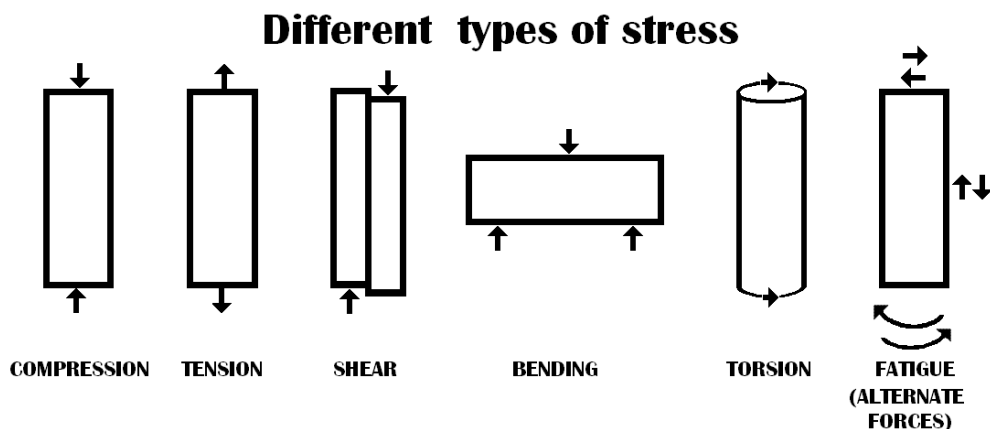
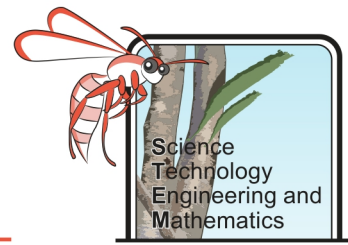


Figure 9. Different stress types which can be caused by an earthquake on a building. (Almazi, 2016)

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3. Add straws to each to turn them into three dimensional objects of about the same height.

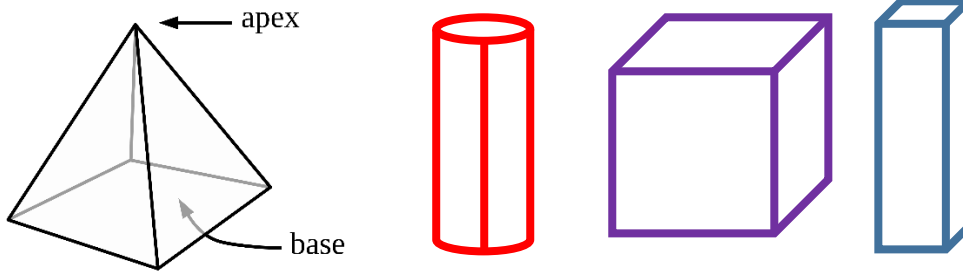


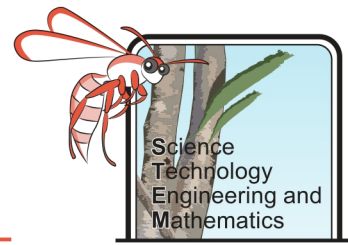
Figure 9. Pyramid and prisms

4. Re- test the these three dimensional objects for their response to different stresses, recording your results in the table.

Results

Shape	How it was affected by each type of stress					
	Compression	Tension	Shear	Bending	Torsion	Fatigue
Square						
Rectangle						
Equilateral triangle						
Right angle triangle						
Circle						
Shape	How it was affected by each type of stress					
	Compression	Tension	Shear	Bending	Torsion	Fatigue
Cube						
Rectangular prism						
Pyramid						
Right angle triangle prism						
Cylinder						

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Assuming that each of the three dimensional shapes could be buildings (and therefore the surfaces would be walls), calculate their surface area and volume, showing your working.

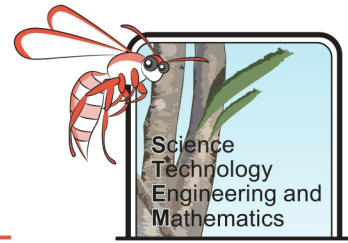
Shape	Surface area (cm ²)	Volume (cm ³)
Cube		
Rectangular prism		
Pyramid		
Right angled triangle prism		
Cylinder		

Analysis

1. Which shape(s) were strongest under compression?

2. Which shape(s) resisted tension best?

3. Which shape(s) resisted bending most?



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4. Which shape(s) resisted torsional forces the most?

5. Overall which shape was the strongest?

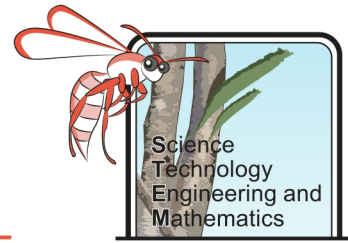
6. Calculate the surface area to volume ratio for the shapes used.

Shape	Surface area (cm ²)	Volume (cm ³)	Surface area:Volume
Cube			
Rectangular prism			
Pyramid			
Right angled triangle prism			
Cylinder			

7. Using your calculations which shape would give the largest amount of living space for materials used to build it?

8. Which would be the best for building in an earthquake prone zone? Justify your answer.

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Protostorming

Objective

Protostorm a model of an earthquake resistant building to be tested on a “shake plate”, to gain better understanding of structural strength and consider how to improve your designs.

Equipment

Your teacher will give you a range of materials to choose from.

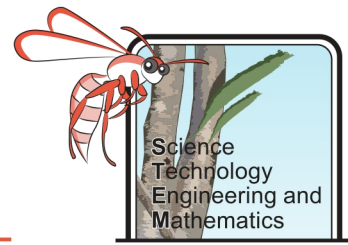
Method

1. Using the equipment available to you build a structure that you think will withstand an earthquake (to be tested on the shake plate) – you only have 15 minutes to complete this task.
2. After this time test your structure on the shake plate, timing how long it stays standing. (If your building is standing well, start adding weight to test its strength).
3. You now have 10 minutes to make improvements/build a new structure.
4. Test your new/improved structure on the shake plate. (If your building is standing well, start adding weight to test its strength).

Evaluation

How much better was your new/improved structure compared to your first structure? Add labelled photos/diagrams to show what changes you made and explain why they worked. Also add the length of time the structure stayed standing.

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Designing and Building an Earthquake Resistant Building

Objective

To select a particular global location that you think would benefit from better earthquake engineering and design and create a model building that would be *suitable for this location*.

Equipment

Your teacher will give you a range of materials to choose from.

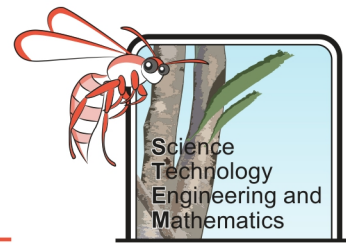
Method

1. First decide which country/ location you think would most benefit from earthquake engineering assistance.
2. Find out more about the country/location, such as
 - What is the maximum and average magnitude of earthquakes in the location?
 - Is there a high risk of tsunami/landslide in the location if there is an earthquake nearby?
 - Do they have a high or low gross domestic product?
3. Research design ideas/materials and consider their strengths and weaknesses *in relation to your chosen location*. Record these in results table one.
4. Now draw and label some design ideas, comparing the pros and cons of each. Either fill these into table two or use CAD.
5. Choose the best design for your chosen location and complete the project plan (below), ensuring you have completed the risk assessment table. Show this to your teacher and make any necessary changes before making the model building.

Planning

Table 1: Earthquake resistant design and material comparisons.

Design/Material	Strengths	Weaknesses
Steel reinforced concrete		
Base isolation systems		
Diagonal bracing		
Tuned mass damper		
Springs		



Science
Technology
Engineering and
Mathematics

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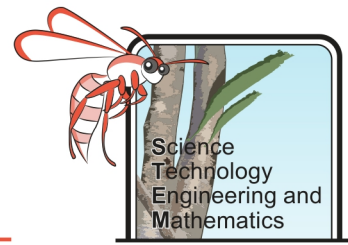
Design/Material	Strengths	Weaknesses
Earthquake curtains		
Flexible materials		

Table 2: Draw and label possible designs below, outlining their pros and cons.

Design	Pros	Cons

Chosen design: _____

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Project Planning:

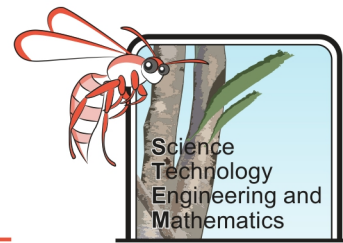
Equipment

Method

Risk assessment

Hazard	Risk	Prevention
e.g. chopping wood	Could cut fingers/ hand	Use equipment with care and under supervision. Keep focused. Use the right equipment.

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Don't forget to have your project plan signed off by your teacher before commencing construction!

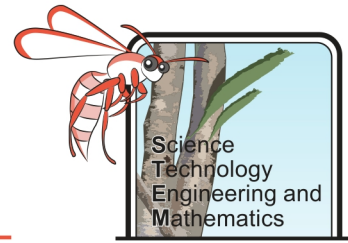
Testing the Design

Test your design using a shake plate or just by shaking the building vigorously. If your chosen location was near the sea, test the buildings ability to withstand a tsunami, by putting it in a tray of sand and pouring lots of water in quickly (do this outside to avoid possible mess). You could also add model trees and toy cars to the tray to represent what may get smashed into the building during a tsunami.

Evaluation

1. How well did your design stand up to the test (s)?

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2. What were the strengths and weaknesses of your design?

3. What improvements could you add to your design? . Create a labelled diagram of your modified design below – highlighting the modifications.