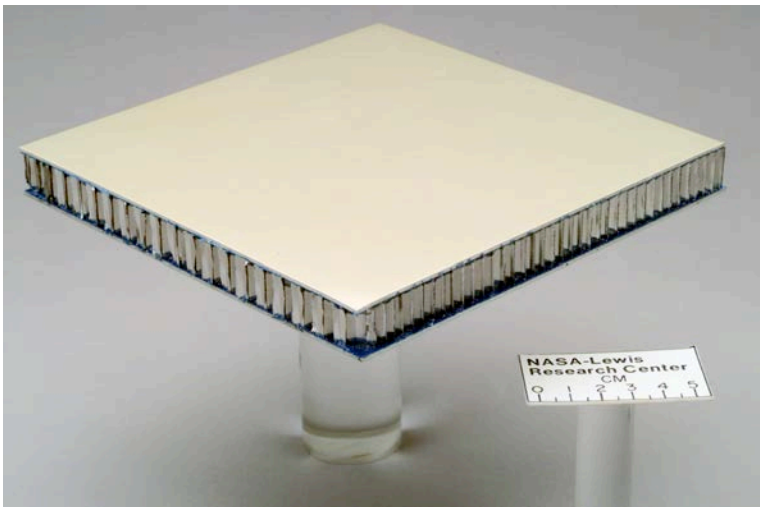
Honeycomb Structures (Guided Inquiry)

Introduction

A common aim of materials scientists and engineers is to create materials with the greatest strength and the minimum weight and minimum amount of materials (minimum cost). Honeycomb sandwich structures are often used to achieve these outcomes and are used in aerospace, automotive, housing, packaging, sports-equipment and other industries. These structures have an arrangement of tubes (or channels) sandwiched between two walls.



Glass aluminum reinforced (GLARE) honeycomb composite sandwich structure.
Photograph has been used and redistributed under an educational non-commercial licence by permission of NASA.
<https://commons.wikimedia.org/wiki/File:Glare_honeycomb.jpg>

Cardboard is often made by sandwiching a sheet of corrugated cardboard between two sheets of thick paper. In corrugated cardboard, the open sections run **parallel** to the walls.

Forces applied at right angles to the honeycomb channels will cause the structure to deform.

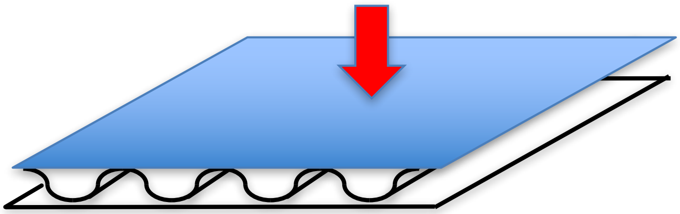
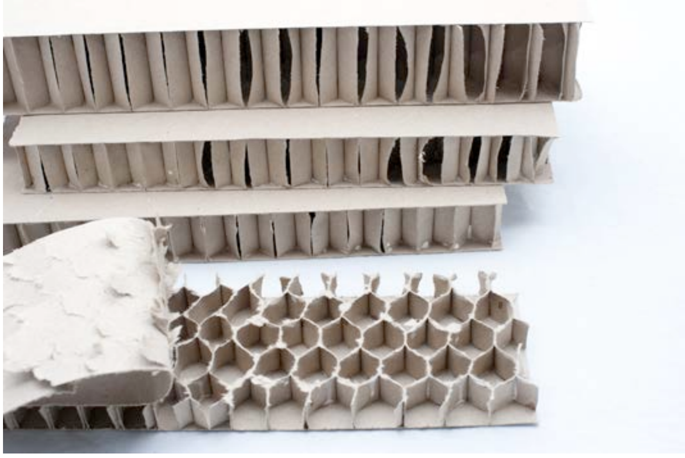


Diagram of corrugated cardboard.
Diagram by Kieran F Lim.

In some other structures the open tubes are arranged at **right angles** to the walls. These tubes can be different shapes in cross section. They could be circles, squares, triangles or hexagons (like honeycomb).



Honeycomb pattern for strength in cardboard. Image by sciencestockphotos.com. <http://sciencestockphotos.com/free/engineering/slides/cardboard_strength.html>

Key ideas

Force - A force is a push or a pull. A force can cause movement in an object or cause compression, tension or torsion within the object.

Impact - Impact or impact force is a shock or large force applied for a very short time.

Compression force – a push that squeezes an object to try to make it smaller or shorter.

Tension force – a pull stretches an object to try to make it bigger or longer.

Strength – The ability of a material to resist breaking when a force is applied.

Strength to mass ratio - This is a measure of the strength of a material compared to its mass.

Investigation - A scientific process of answering a question, exploring an idea or solving a problem that requires activities such as planning a course of action, collecting data, interpreting data, reaching a conclusion and communicating these activities

Variable - Something that can change.

Dependent variable - Variable that changes in response to changes in the independent variable and that is observed or measured.

Independent variable - Variable that is deliberately changed.

Controlled variables - Variables that are kept constant.

Fair test - When testing different materials all the variables except the one being tested need to be kept the same.

Equipment and materials

- Kirigami honeycomb template
- Paper, cardboard, straws
- Scissors
- Craft knives
- Glue
- Rulers
- Pencils
- Weights, bricks

Investigation

In this activity, your task is to choose a question about the strength of honeycomb structures and then you will formulate a hypothesis based on scientific knowledge. Once you have your question you need to design a way to answer it by constructing the different honeycomb structures out of paper, cardboard and glue and testing their strength. You will ensure that your tests will be fair and provide data relevant to answering your question. You will collect, analyse and evaluate the data communicating your findings appropriately.

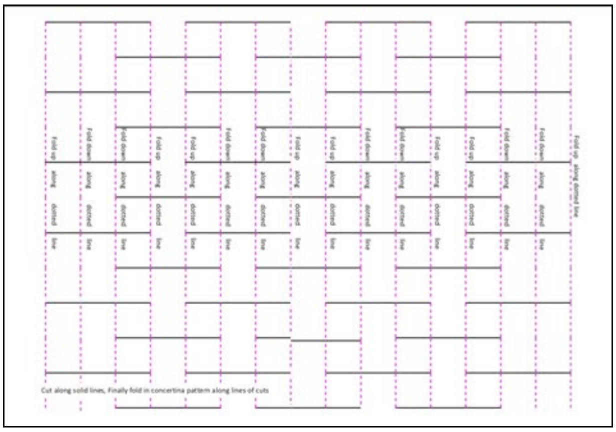
Hazards

Cutting materials with scissors or blades poses the risk of cuts. Care should be taken to keep hands and fingers out of the way. Always cut way from yourself. Make sure sharp objects are stored safely when they are not being used.

Testing the sandwich materials with loads has potential for injury. Care must be taken. Ensure all people are at a safe distance.

Kirigami hexagonal honeycomb structure

The Japanese art of kirigami involves both cutting and folding sheets of paper to obtain three-dimensional shapes. Recently, scientists used kirigami to create shape-shifting materials, which could have large shape and volume changes and with extremely directional, tuneable mechanical properties [Footnote [6]].



Template for kirigami hexagonal honeycomb structure.
Diagram by Kieran F Lim.

[6] Neville, R. M., Scarpa, F., & Pirrera, A. (2016). Shape morphing Kirigami mechanical metamaterials. *Scientific Reports*, **6**, Article number 31067. doi:10.1038/srep31067. Retrieved 10 October 2017 from <https://www.nature.com/articles/srep31067>.

Using an A3-sized version of the Kirigami honeycomb template, construct a honeycomb structure. First, fold along the dotted lines to make two folds up, two folds down, and repeating this pattern.

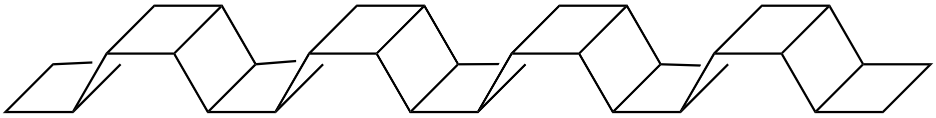


Diagram by Kieran F Lim.

Next cut along the solid lines. Then fold in a concertina pattern along the lines of the cuts.

The kirigami hexagonal honeycomb structure. Detail from Figure 2 of Neville, Scarpa, and Pirrera (2016).
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<https://www.nature.com/articles/srep31067>

Finally, glue (or staple) the flaps together to form a hexagonal honeycomb structure.

A hexagonal honeycomb structure. Image by sciencestockphotos.com. <http://sciencestockphotos.com/free/engineering/slides/cardboard_strength.html>

Make a prediction of the load that can be supported by the glued kirigami honeycomb structure.

Weigh a book or other solid flat object and place that on the glued kirigami honeycomb structure. Add weights to the book or other solid flat object until the structure collapses. What was the total mass on the load? Is this what you expected?

Scientific question

There are many scientific questions that could be asked about honeycomb structures.

- How does the strength of the honeycomb structure depend on the number of tubes or open channels?
- Does the strength of the honeycomb structure depend on the hexagonal cross-sectional shape of the tubes or open channels? What if the tubes or open channels were triangular, or square or circular?
- What would happen if we had separate tubes, but not connected or glued to each other?

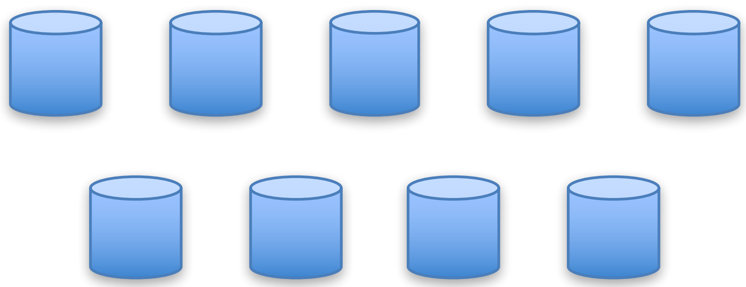
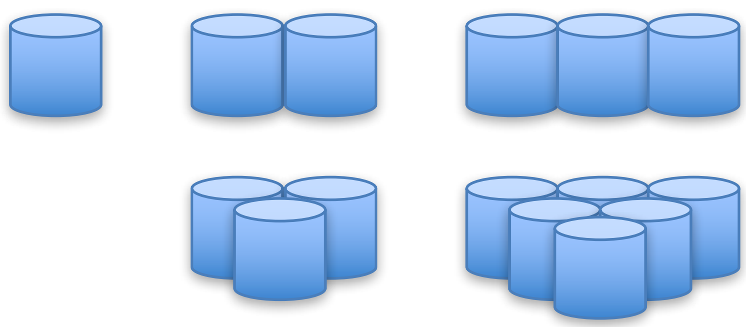


Diagram by Kieran F Lim.

- Does the strength of the honeycomb structure depend on whether the tubes are glued or joined together?



What load can be supported by a number of joined identical "tubes"?
Diagram by Kieran F Lim.

Your teacher will lead a discussion to decide which scientific questions will be investigated. Your group will then decide how to investigate that question.

The scientific question that my group will investigate is:

A hypothesis is a testable "educated-guess" answer to a scientific question. A hypothesis leads to one or more predictions that can be tested by an investigation.

Our hypothesis is:

Remember to think about variables that will need to be controlled to ensure a "fair test". Decide which variables you will keep the same (controlled variables) which variable you will change (independent variable) and which variable you will measure (dependent variable).

Our **independent variable** is:

The independent variable will vary depending on the scientific question and hypothesis.

Our **dependent variable** is:

The maximum load that can be supported before the structure fails.

Our **controlled variables** are:

The controlled variables are all the variables that are kept unchanged. These might include the cross-sectional shape of the honeycomb tubes or open channels, the height and other dimensions of each honeycomb tube or channel, the type of glue used. This is a non-exhaustive list and will vary depending on the scientific question and hypothesis.

We will use the following **experimental procedure**. (If appropriate, make a drawing of your proposal.)

Are there any **safety** issues to consider?

- Sharp objects. Care should be used with craft knives and scissors to keep fingers clear while cutting. Both craft knives and scissors are sharp and care that they are not poked into skin or eyes. Students must wear safety glasses/goggles.
- Bricks and weights. Keep clear when supporting bricks and weights on honeycomb structures. Ensure experiment is set up on secure bench so the bricks and weights do not crash to the floor and keep feet clear.

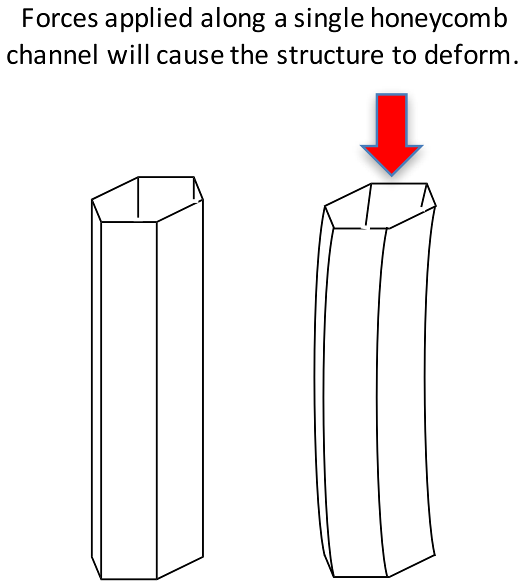
Results

What happened? Record your observations or measurements.
(Hint: put all the data on a single graph.)

Discussion

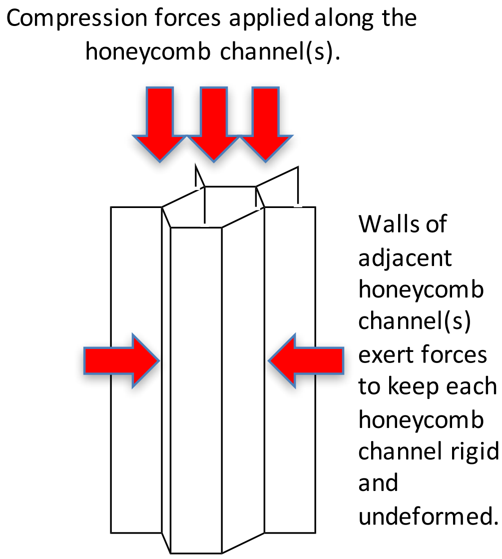
What trend(s) can be observed in your data?
(Hint: Use appropriate scientific language and representations.)

Draw a picture representing what happens when load is placed on a single honeycomb tube or channel.



A single honeycomb tube or channel will deform and collapse.
Diagram by Kieran F Lim.

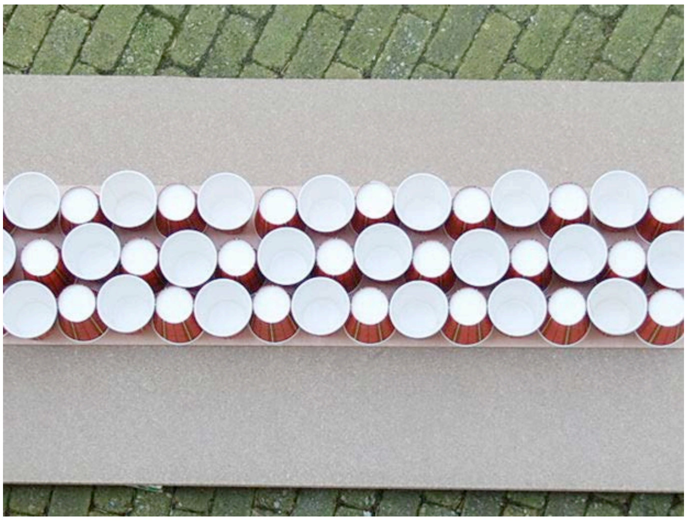
Draw a picture representing what happens when load is placed on a set of linked honeycomb tubes or channels.



The walls of adjacent honeycomb tubes or channels act to prevent central honeycomb tube deforming.
Diagram by Kieran F Lim.

Extension

Construct a honeycomb structure using coffee cups [Footnote [7]]. Gaffer tape should be used to stick the tops of the cups together (lengthwise) and continue around the bottoms of the cups (also lengthwise). Also use gaffer tape to make some crosswise bindings.



Coffee cup - honeycomb sandwich structure.
Photograph by bertus52x11, and used under a Creative Commons Generic (CC BY-NC-SA 2.5) licence.
<http://www.instructables.com/id/Coffee-Cup-Honeycomb-Sandwich-Structure/>

Make a prediction of the load that can be supported by the coffee cup honeycomb structure.

[7] bertus52x11 (n.d.). Coffee cup - honeycomb sandwich structure. Retrieved 10 October 2017 from <http://www.instructables.com/id/Coffee-Cup-Honeycomb-Sandwich-Structure/>.

Test the maximum load that can be supported by the coffee cup honeycomb structure. What was the total mass on the load? Is this what you expected?

Conclusion

What conclusions can be supported by your data and other thoughts and observations?

Acknowledgements

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