ASELL SCHOOLS Advancing Science & Engineering through Laboratory Learning
LABORATORY LEARNING ACTIVITY

Composite materials

Introduction

Today's Laboratory unpacks how composite materials can respond differently to unbalanced forces.

Victorian Curriculum Outcome

Change to an object's motion is caused by unbalanced forces acting on the object; Earth's gravity pulls objects towards the centre of Earth (VCSSU103)

Checkout the racing car and surfboard

Giedo van der Garde driving the
Caterham CT03 at Sepang International Circuit.

https://commons.wikimedia.org/wiki/File:Giedo_van_der_Garde_2013_Malaysia_FP1.jpg

A surfer at the Cayucos Pier, Cayucos, California.
Photo: "Mike" Michael L. Baird.

https://commons.wikimedia.org/wiki/File:Surfer_at_the_Cayucos_Pier,_Cayucos,_CA.jpg

What could be the same between the materials used a modern racing car and surfboard?
(Hint: focus on the how each is made (manufactured).)

The car and surfboard are made from light materials, yet made strong. This allows for shaping and rigidity.

Composite Materials

A composite material is made from two or more materials, each with different physical or chemical properties. But when combined, the whole composite has properties that are different from the individual materials.

Some composite materials are mixtures, like cements, concrete, imitation granite and cultured marble sinks and countertops, and metal alloys.

Some composite materials have one material embedded inside the other material, for example, fiberglass, concrete with steel reinforcement, and mud bricks with straw reinforcement.

Some composite materials have the individual materials in separate and distinct layers.

Scientists and engineers are developing new composite materials because they can be stronger, lighter, or less expensive when compared to traditional materials.

Key ideas

Force – a push or a pull

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.

Aim

The composite materials activity enables you to experience and investigate the way combining the properties of two materials (polystyrene and gaffer tape) can result in a particular type of composite material. The properties of the composite are very different from the properties of the original. In the process, you will learn about tension and compression forces.

Why do we make composite materials?

These structures are stronger and lighter.

(Note: this question and answer is to test the students' understanding of the information that has been presented to them.)

Consider the similarity between these two pictures

A bacon, lettuce and tomato sandwich on toasted bread.
Photo: Steven Groves from Denver (CO), USA.
http://en.wikipedia.org/wiki/Sandwich#/media/File:BLT_sandwich_on_toast.jpg

Glass Aluminum Reinforced (GLARE) honeycomb composite sandwich structure.
Photo: NASA.
http://ballistics.grc.nasa.gov/Photographic%20Data/Images/glare_honeycomb.jpg

How do you think **sandwich composite materials** are made?

Layers of materials are "glued" together.

Your challenge

Today you are a scientist who has been paid to design a stronger composite product for as little cost as possible. The following demonstration is to prepare you for the task.

Part 1: Demonstration of the effectiveness of sandwich structures

Things to note from the demonstration:

- A polystyrene plank is not very strong. (Footnote [1])
- When additional materials are layered onto the polystyrene it becomes a composite material and its properties change – it becomes stronger.

[1] Styrofoam is a particular brand name for polystyrene.

Draw and label the equipment and what happened.

(et cetra)

Part 2: Comparison of three products: polystyrene on its own and 2 composite materials with different structures

Think about the demonstration you have just seen. Can you think of two different ways of making sandwich composite structures using the materials and equipment available to you?

Many possible answers here. Some include:

- Putting tape on both top and bottom
- Putting tape only on top
- Putting tape only on bottom
- Using partial strips of tape , etc

Re-do the demonstration with your group. You will need to work out a way of measuring the rigidity or how much bending there is for each individual weight added. Talk with your partner to decide how you will measure the amount of bending and how you will record the data in an appropriate table below. Your support structures need to be 21 cm apart (Footnote [2]).

Record the data in an appropriate table to show the difference between the polystyrene and the composite material structures 1 and 2.

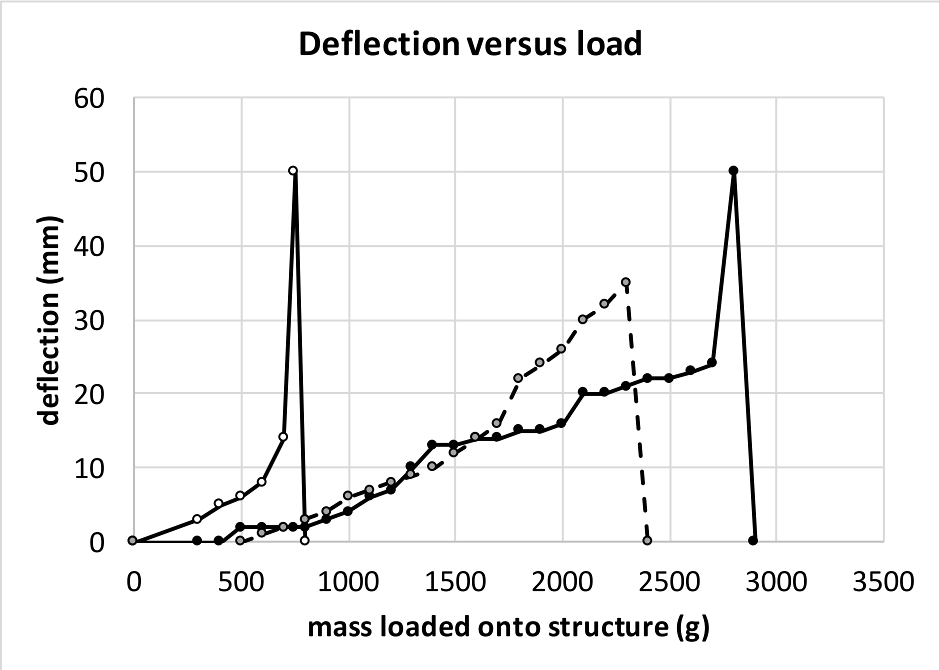
Some typical data

load (g)	bending no tape (mm)	bending tape top and bottom full width	bending tape bottom and half top
0	0	0	0
300	3	0	
400	5	0	
500	6	2	0
600	8	2	1
700	14	2	2
750	50	2	
800	(break)	2	3
900		3	4
1000		4	6
1100		6	7
1200		7	8
1300		10	9
1400		13	10
1500		13	12
1600		14	14

load (g)	bending no tape (mm)	bending tape top and bottom full width	bending tape bottom and half top
1700		14	16
1800		15	22
1900		15	24
2000		16	26
2100		20	30
2200		20	32
2300		21	35
2400		22	(break)
2500		22	
2600		23	
2700		24	
2800		50	
2900		(break)	
3000			

2 21 cm has been chosen because iot is the width of an A4cpage and is easy to set up. If you wish, you could use some other separation distance.

Graph the data to show the difference between the polystyrene and the composite material structures 1 and 2.
(Hint: put all the data on a single graph.)



Describe in words what was revealed through the data analysis of the graph.

The graph shows the typical deflection of the polystyrene (vertical axis) as load (weights, horizontal axis) are applied to the centre of the polystyrene.

The left-hand-most data are for polystyrene with no tape. The last data point is at 750 g. The polystyrene broke with a load of 800 g.

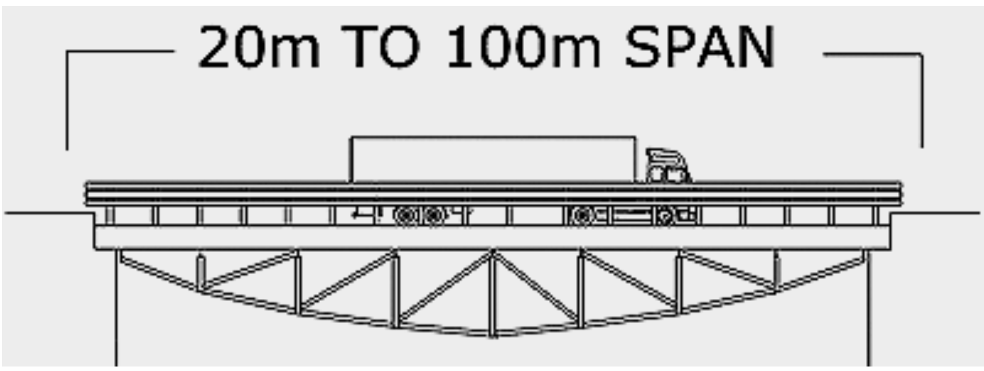
The right-hand-most data are for polystyrene with full-width tape on the bottom and top. The last data point is at 2800 g. The polystyrene broke with a load of 2850 g.

Part 3: Analysis of forces

Roofs and bridges have to span large gaps while supporting massive weight.

Consider the bridge below. The schematic diagram following is of a similarly designed bridge.

Steel frame truss bridge, located on the Southern Highway, Belize, Central America. Photograph © John Reid & Sons (Strucsteel) Ltd.
http://www.steel-bridges.com/under-truss-bridge.html

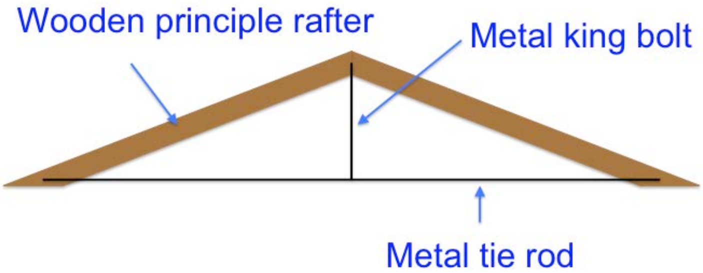


Steel frame truss bridge design. The concrete deck and the steel strusses form a composite structure. Diagram © John Reid & Sons (Strucsteel) Ltd.

http://www.steel-bridges.com/under-truss-bridge.html

Consider the roof/ceiling below. The schematic diagram following is of a similarly designed roof.

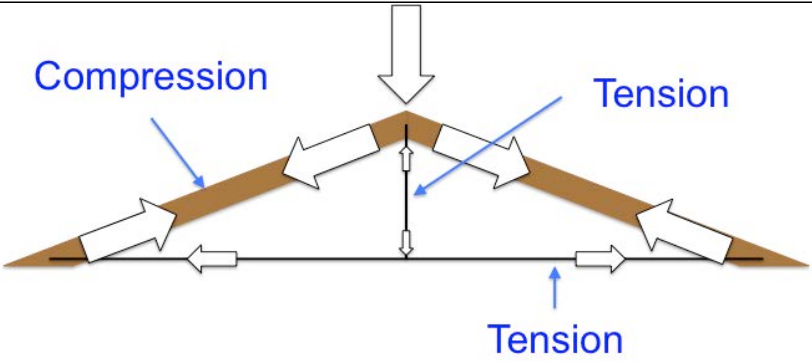
Composite truss roof, Tahoe Ridge House, California. Photograph © WA Design Inc
http://www.wadesign.com/newbuilding#/tahoe-ridge-house/



Simple composite truss roof

All these roofs and bridges have one element (or part) that spans the top of the structure and one element that spans the bottom of the structure.

Can you represent the main forces that you think are acting on these two elements of the structures?



How many elements span your polystyrene structure? Why do you think the polystyrene structure is relatively weak?

The polystyrene structure only has a single element.

Some students might realize that the top of the polystyrene is under compression, while the bottom is under tension as weight is applied.

How many elements span your sandwich structure? Can you represent why you think the sandwich structure works to alter the strength and rigidity?

Effectively only 2 elements span the sandwich structure.

The tape on the bottom is under tension as weight is applied.

Like the roof and bridges, the (mostly) top polystyrene is under compression. The tape on the top is effectively doing nothing.

What is the role of the tape and what properties make it work well?

The tape provides the fibre and a glue to fuse the layered sandwich materials. The tape is strong under tension.

Would one piece of tape above or below the polystyrene be as effective as two pieces of tape in a bridge structure?

One piece below is all that is needed. The top layer is ineffective at increasing the strength of the layered structure. The bottom layer could be reduced to an optimal amount (of strength for cost).

Discuss with your team, how a composite material might be used in boat hulls, swimming pools, race car bodies, surf boards, spacecraft and aircraft. Can you represent why you think an "open-sandwich" structure (similar to tape only on one side of the polystyrene) would perform better or worse than a regular sandwich structure (similar to tape on both sides of the polystyrene)?

In a bridge, the gravitational forces act downward. Hence the bottom layer is always under tension, and putting tape on the top does nothing as the top layer always under compression.

However, in boat hulls, swimming pools, race car bodies, surf boards, spacecraft and aircraft, panels are being flexed: forces push against the panels in both directions. Hence the reinforcing layer is needed on both sides.

Part 4: Challenge

Your job as a Scientist is to create a stronger composite material using the least amount of material (polystyrene and tape) to reduce cost.

Work with your group to design to strongest sandwich structure composite material using the least tape. Test each design for strength and rigidity to decide the best design.

Decide how you will collect your data for each trial and produce a report that describes the design that works best. Include evidence (data) and an explanation as to why (using diagrams and words).