

Fundamentals of Composite Sandwich Panels

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Abstract

This laboratory exercise investigates the fundamental aspects of designing composite sandwich panels. Composite sandwich panels are used in applications that required a light weight, high strength structure. Common applications of sandwich panels that students maybe familiar with are surfboards, wake boards, and corrugated cardboard. Sandwich panels are often used in aerospace applications, such as wing flaps, aircraft floors and overhead storage bins. Students build, test and analyze the strength and stiffness of composite sandwich panels from readily available materials.

Objectives:

Teach students basic principals involved in the design of composite sandwich panels and why the panels are strong and lightweight. This experiment has two significant factors that influence strength and stiffness – the actual design and the materials of construction. Construction and testing of simple “bridges” from commonly available materials such as wood veneer (thin slices of wood), insulating foam and double sticky carpet tape. Students will construct composite sandwich panels of various geometries (wood and foam thickness). Other variations include type of double sticky tape or adhesive, orientation of the wood grain, type of foam, size of panels, and/or separation of supports. The panels are then weighed and tested by placing a container on bridge and adding pennies to see which geometry has the best strength to weight ratio. The different failure modes of the panels will be examined with respect to the panel geometry and constituent properties.

Pre-requisites: none

Key Words:

Composite, design, construction, testing

Grade Levels:

This activity is flexible enough to engage students from grade 4 though 12. Level can be adjusted by the amount of physics and theory introduced and the degree of analysis.

Time Required:

Time depends on number of variables (number of sandwich panels built and tested) included in the experiment . This can easily range from 1 to 3 hours.

MatEd Core competencies addressed:

- 0.B Prepare tests and analyze data
- 1.A Carry out measurements of dimensions and physical phenomena
- 7.C Describe the general nature of composites
- 7.J Demonstrate how materials properties are used in engineering design
- 8.A Demonstrate the planning and execution of materials experiments
- 8.F Perform appropriate tests of plastics and composites
- 11.A Describe structure and advantages of composite materials
- 11.B Explain basic processing processes for composites
- 16.A Explain effects of processing and manufacturing variations on material properties

Equipment and Supplies:

- Balance (scale) nominally 5kg capacity, 1 gram accuracy
- Loading device (container of pennies or other weights) - approximately 2 kgs (1000 pennies)
- Supports: 2 pieces of wood or pipe approximately 2 inches high or diameter, 3-4 inches wide.
- Wood veneer- strips approximately 2 inches wide and 24" long. Thickness variable but less than 0.1"

If wood veneer is not available, other thin materials can be substituted. The substitute materials should be stronger and stiffer than the foam. For example sheet metal, fiber reinforced plastics (aka fiberglass) or even glass fiber tape (reinforced strapping tape).

- Rigid foam- such as blue insulating foam board available at Home Depot, Lowes, etc. Styrofoam can also be used but can be difficult to adhere to. Foam should be same width and length as wood veneer strips. Thickness variable, between 0.5 and 2.0 inches

-1 roll Double sticky carpet tape approx 2" wide. Note stronger panels can be fabricated if appropriate glue is used in place of double sticky tape. However this increases time required since the glue must be allowed to dry (cure). 5 minute epoxy is often a good choice of glue. If glue is used, appropriate clamping or weighting of the panels improves the performance.

- 1 box cutter knife
- 1 ruler/T-Square/ right angle for cutting guide if foam and wood need to be cut.

Procedure

- 1) Cut foam and wood to same length and width, approx 24" X 2"
- 2) Apply double sticky carpet tape on to wood. Try to avoid touching the sticky part of the tape.
- 3) Remove any backing from double sticky tape (if present) and place on the foam. Apply firm even pressure over the whole surface
- 4) Repeat 2 &3 for other side of foam.
- 5) Weigh the sandwich panel, AKA Bridge
- 6) Place bridge on supports spaced 22" apart. Note it may be helpful to attach the supports to a board to stop them from moving during the test and to insure a repeatable span.

- 7) Place container on center of span and add pennies slowly until bridge breaks or deflects more than 1" downward. Weigh the container to determine load to failure. Calculate strength to weight ratio =load to failure/weight of sandwich panel.
- 8) This experiment can be repeated, without using the tape. Simply stack the wood and foam. This will be much weaker and deflect more than if the materials are stuck together.

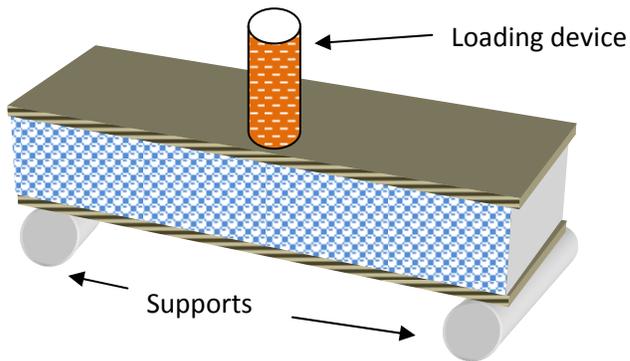


Figure 1. Sandwich panel on test fixture

Instructor Background

The design principle of a sandwich composite is similar to that of an I-beam, which is an efficient structural shape because as much as possible of the material is placed in the flanges situated farthest from the center of bending and neutral axis. In a sandwich structure, the faces resemble the flanges and the core acts as the web. The basic underlying concept of a sandwich panel is that face sheets carry the bending stresses and the cores carry the shear stresses. The faces act together to form an efficient stress couple or resisting moment, counteracting the external bending moment. The core resists shear and stabilize the faces against buckling or wrinkling. The selection of the adhesive that bonds the faces to the core is important as it must be strong enough to resist the shear and tensile stresses set up between them.

The strength of a beam in bending is a function of many factors including the properties of the materials used and the geometry of the beam. The material properties of main interest are the tensile strength, shear strength and elastic modulus. The geometrical parameters of greatest are the length of the beam (spacing of supports), the width and the height of the beam. For a composite or sandwich beam, the relative thickness of the layers and the shear strength of the bond between the layers are also important.¹⁻⁵

From elastic beam theory, the flexural stress, s in a beam is $s = MY/I$, where M is the moment, Y is distance from neutral axis (the centerline for a symmetric beam) and I is the 1st moment of inertia. For a rectangular cross section, $I = bh^3/12$, where b is the width and h is the height of the beam. In 3 point flexure, the moment, $M = FL/2$ where F is the force and L is the distance between supports. Increasing the moment of inertia, I , will decrease the flexural stress in the sandwich panel for a given moment, M which is dependent on the force (weight of the container of pennies). I increase's by h^3 , so a small increase in height

(thickness of foam) can significantly increase the strength and stiffness of the sandwich panel. **For the geometry shown in the figure, the top of the beam is placed in compression and the bottom in tension and the shear stress is uniform.**

Beams can fail in several different manners depending on the materials and geometry they are constructed with. There are four different modes of failure of sandwich composites when loaded in bending. The structure will fail at the mode that occurs at the lowest load. The most common failure modes are buckling of the compressive skin, shear failure of the core, tension failure of tension skin and/or delamination between the skins and the core. Changing the geometry can affect mode of failure. For example decreasing the skin thickness, may change the mode from core shear to skin tension.¹

This experiment has two significant factors that influence strength and stiffness – the actual design and the materials of construction. Since I believe the goal of this experiment is to teach the students both these factors influence strength, I would add something to the experiment that forces them to explore both design and materials. For materials, they could orient the wood in two directions or they could use two different types of foam or two different kinds of adhesive. For design, they could change the beam height.

References and resources

- 1) Bitzer, T.N, Honeycomb Technology: Materials, design, manufacturing, applications and testing , Chapman & Hall, ©1997.
- 2) <http://composite.about.com/library/docs/mil-hdbk-23/bl1-2.htm>
- 3) http://en.wikipedia.org/wiki/Sandwich_Panel
- 4) http://www.diabgroup.com/europe/literature/e_pdf_files/man_pdf/sandwich_hb.pdf
- 5) http://www.hexcel.com/NR/rdonlyres/80127A98-7DF2-4D06-A7B3-7EFF685966D2/0/7586_HexWeb_Sand_Design.pdf

Evaluation packet:

Student evaluation questions (discussion or quiz):

1. How would the weight of a sandwich panel compare to the weight of a solid piece of facesheet the same thickness as the sandwich panel?
2. Why do the facesheets need to be attached to the foam core?
3. How did the sandwich panel fail under load?
4. How would you change the design of the sandwich panel to make it stronger?
5. How would you change the design of the sandwich panel to make it lighter?
6. Why is the strength to weight ratio an important material property for airplanes?

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?

3. Did the lab work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material on composite sandwich panels sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the lab generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the students)

1. Was the lab clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?