# Table-top Composite Panel Fabrication Lab

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This module provided by MatEd, the National Resource Center for Materials Technology Education, www.materialseducation.org,

**Abstract**
The objective of this activity is to engage secondary education students in improving the mechanics of sandwich composites via construction and testing. Groups/teams are used to fabricate composite paper panels, and create both beams and signboards. The beams are tested for specific stiffness, while the team signboards are compared by popular votes. The activity can be done in an hour with common materials and tools.

**Module Objectives**: Students will be able to

- Fabricate a sandwich composite out of paper sheets.
- Quantitatively compare the mechanical properties (e.g. specific stiffness) of single sheet paper and sandwich composites in bending.
- Evaluate and apply recycling criteria to composites such as this one.

**MatEd Core Competencies Addressed:**

6A Apply Basic Concepts of Mechanics
7C Describe the General Nature of Composite Materials
7I Compare Mechanical Properties of Different Classes of Materials
8A Demonstrate the Planning and Execution of Materials Experiments
8F Perform Appropriate Tests on Polymers and Composites

**Type of Module / Mode of Presentation**: This activity describes in-class, demo and hands-on composite fabrication activities.

**Key Words / Key Phrases**: Composites, Sandwich composite, signboard, three-point bend, recycling

**Time required**: One hour.

**Pre-requisite knowledge:** None

**Target grade levels**: Secondary education

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**Equipment and supplies needed (per participant or team at 2+):**

Environment: Each student or team will need:

- Table-top space (about four square feet)

A list of materials at a 'common space' (to be used by all groups) follows:

- A paper crimper (we use 8.5" paper)
- A paper trimmer (used to pre-cut sheets before crimping)
- A box of pencils (three minimum for each 3-point bend specimens)
- Scissors (to trim the edges) – one for each group (e.g. 6)
- Transparent tape (to bind the edges) – one for each group (e.g. 6 rolls)
- A bend tester (e.g. 3 pencils and a 500 gm scale) or other creative scheme

A list of materials for each group (making a panel) follows:

- Sheets of paper (4 per sandwich panel) – it's paper: bring a ream
- A 'glue stick' for each panel/team – one for each group (e.g. 6)

**Curriculum Overview and Instructor Notes:**
Many students never participate in creating a 'manufactured' product. One method of creating a product is to use common materials and 'glue-up' a composite part. Composite manufacturing typically occurs in industrial settings, and perhaps isolated home projects (e.g. boat repair). The intent of this activity is to involve students, in their own class environment, with manufacturing composites and evaluating them.

Students participating in these activities early in their education have a better understanding of possible societal needs, opportunities and impacts. Students may watch television and see a part made, but with regard to Bloom's Taxonomy (1), this type of 'knowledge' and 'comprehension' are at the bottom of the hierarchy. This activity targets the upper part of Bloom's hierarchy, and the harder 'application' and 'evaluation' behaviors.

In a traditional composite fabrication laboratory approach, a movie may be shown that describes safety issues as well as fabrication techniques (e.g. safe handling of resins and fibers). Afterwards, a demonstration of a composite lay-up is common. For groups of students on tours, safety is an issue due to resin toxicity and off-gassing. Safety gear (PPE) is typically provided for participation in a composite fabrication facility, and procedural (safe practices) training is common.

This module addresses 'outreach' by taking casting out of the fabrication facility, and putting it into the hands of students. To that end, a suitable composite structure (reinforcement and resin) was selected for a hands-on classroom activity. Paper is a common education material, and 'glue-sticks' are commonly available.

**Activity Description:**
In preparation, the instructor should run through this activity before using it. The basic idea is to make a 'sandwich' composite. For completeness sake, you could refer to Wikipedia and review the basics of composites (2) and sandwich composites (3, 4). A common application of a sandwich composite would be as panels (sidewalls) on trucks or even simple signboards. Whereas truck panels are larger and made of different materials, we can use simple paper effectively and use them as signboards.

Note that a sheet of paper is flimsy, but a sandwich composite of paper is stiff (e.g. cardboard boxes)! Having examples of various cardboard material can be helpful to exemplify verbal descriptions of 'stiffness'. Deconstructing cardboard can reveal its parts (single sheets, corregation and glue). Hefting different materials can help explain the concept of 'specific' properties.

The instructor should view the details of the module procedure carefully, and perform the activity before having the students do the lab. There are aspects of the activity that can be challenging. For example, the 'crimped paper' strips are rather unwieldy and it can be tricky to get enough glue on the paper to hold the crimped strips in place.

Having made a sandwich panel, it is appropriate to test it. A simple three point bend test effectively demonstrates how much stiffer a material can be when modified into a composite. There is an associated increase in how much load a panel can sustain verses single sheets. And a discussion of ‘stiffness’ vs. ‘strength’ may be appropriate depending on the audience background.

Finally, a discussion on recycling is appropriate. This interaction can expose many social aspects of manufacturing materials. For example, compare a ‘paper sandwich’ panel to a ‘foam core’ panel (a common poster board).

Besides your own expertise at making and testing composites, the following items should be dealt with before embarking on the activity itself:

**Procedure:**
Preparation for the activity:

- Determine the workspace (tables for teams)
- Pre-cut strips and crimping if desired
- Plan the location of common tools (e.g. the paper trimmer, tape, scissors, etc.) as needed

This composite fabrication activity is comprised of an Introduction, then the Activity, and then a Debriefing.

**The Introduction** includes a discussion of composite fabrication. It is appropriate to use local industries and relevant products as examples (e.g. in our area we have a manufacturer of ‘RVs’: recreational vehicles). Perhaps you can show a product such as a foam poster board, or even a cardboard box. This provides a comparison to determine a ‘success criteria’. The ‘lay-up’ process should to be discussed in enough detail to meet the students' needs. Lastly, the actual lay-up process can be critical to success, so a demo may be appropriate.

Notes for evaluation: Before any work is started, have the students consider aspects of the finished product that may be important. For example, is the size, shape or texture (surface quality) important? Does the orientation of the core material matter? Is it important to be able to make it quickly? Is the panel stiffness important? Please demonstrate various bending stiffness properties of your example materials (e.g. paper, cardboard) so the students can witness. It is easy to set two pencils on a table, lay a piece of paper over them (they will drape: showing low bending stiffness). Setting a piece of cardboard on two pencils allows other objects to be supported: showing higher bending stiffness).

**In the Activity**, the students must plan their fabrication. Do they have the material they need (paper, core material, etc.). In general, the surface paper is cut (two sheets about 5x5”) and set in place. Then a sheet is slit into ¼” strips (but not completely; they hang on by a quarter inch to one end). Then this sheet (of ribbons) is ‘crimped’ using the appropriate tool (Figure 1), like the on by Fiskars™ (5). The activity can progress with students at various stages of preparation.

As students get ready to handle the crimped strips, the instructor (or aid) should monitor. One method of applying the strips is to first coat one panel surface sheet with glue (using the glue-stick). Make sure it is a ‘generous’ application of glue, because the strips must stick to this surface. Detach the strips from their common end, and stack them. Then lay them on the glued sheet in a spiral (Figure 3). Note that this ‘spiral’ geometry is simply a way to promote a more ‘omni-directional’ (same in all directions) set of properties.

After the crimped strips are in place (covering most of the bottom panel surface), apply a generous amount of glue to the other panel surface and stick it on. Rub the surface to ensure contact. To 'finish' the panel, it is possible to apply glue to any loose parts. Scissors can be used to trim sides and tape used to finish them.

Testing is done as shown in the demonstration (Figure 4 and 5). Have the students use two pencils as beam supports. Then use various objects to indicate how stiff their panels are.

**The Debriefing** is an important aspect of the module, and concentrates on the module objectives. For example, after the activity can student describe composites, their properties (and evaluation), their fabrication, and life cycles?

Aspects of the panel itself, such as quality, is important. At least two areas of process quality should be discussed. The quality of the surface may be important (e.g. size, texture) because of its intended use as a sign. Also, the quality of performance in bending stiffness of the panel is of interest (will the sign stay flat?).

The fabrication process can affect the final product quality. People have different skills, and the resulting panel quality may reflect it. A uniform core can result in better surface quality. Perhaps the students can use the panel as a poster or sign to help gage the quality of their panel.

Panel performance is important. It is possible to apply forensic engineering to discover why the beams performed (either better or worse). Is the core webbing of the panel uniform (and does this matter)? Is the orientation of the core at a particular angle to the surface (and does this matter)? Were some panels lighter than others (and is this important?).

Societal impacts (e.g. recycling) of using composites are of interest. Many composites (e.g. polymer matrix composites) are made of reinforcements that do not naturally (organically) break down or disintegrate. These materials are typically and simply buried though incineration is an option. Also, recycling 'streams' are set up to reuse some, but not all, types of polymers. Composites usually do not qualify because they are comprised of different polymers that can't be separated. However, the use of paper allows a discussion of 'green' composites and other products.

Evaluation of the objectives/competencies can be addressed using the attached assessment instruments (below, following the Bio).

**Variations of the activity:**
A significant factor in the final stiffness of the panel is the sandwich core dimensions. In this activity, the width of the strips (before crimping) would be the easiest variable to change. Other variables of interest might include the length of the strips, and the orientation of the strips. Finding a different 'tool' could allow for a change in the 'crimp' itself.

**Reflection Questions:**
The following is a list of questions that might be used in a Socratic scenario:

- What features of the panel are good (vs. poor) and which are really important?
- What aspects of making the panel were difficult or easy, and which could be improved?
- Is there a way to speed up the process (and what are the related issues)?

**Evaluation of the Activity:**
The 'application' aspect of fabrication composites is readily achievable during this activity. Students like to make things. The higher-level domain of 'evaluation' is dependent on many other aspects of the activity. If the students get done with enough time to have a good discussion, then aspects of quality can be addressed. It can be appropriate to have some 'poor' fabrications previously done, so that common defects such as shape can be referenced

**Evaluation of students: (questions, discussion or quiz items):**

1) 7C (comp): Explain what composites are, and how they are made; using your sandwich panel as an example.

2) 6A (mech): Explain how bending stiffness is measured and how you obtained your results.

3) 7I (prop): Compare your bending stiffness values with other examples (e.g. cardboard as a composite, paper as a quasi-homogenous material).

4) 8A (Exp), 8F (tests): Describe how you tested your material in bending. How could you improve the test?

**Instructor (user) evaluation questions:**

1. At what grade level was this activity used?
2. Did the activity succeed in facilitating the outcomes of interest?
3. Did the references and content suffice for your needs?

**Course evaluation questions: (to be filled out by the students)**

1. Did the activity help you better understand composites?
2. Did the instructor explain and facilitate the activity well?
3. Were you able to get your questions answered easily?
4. Did you have what you needed to make a composite panel?
5. Were you able to test your composite panel in bending?
6. Were you able to assess the quality of your panel?
7. What was the most interesting thing that you learned?

**References:**
1. Bloom B. S. *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain* New York: David McKay Co Inc. 1956.

2. Wikipedia on 'Composites', http://en.wikipedia.org/wiki/Composite_material
3. Wikipedia on 'Sandwich Composites', http://en.wikipedia.org/wiki/Sandwich_structured_composite

4. Composite Panel Organization information at www.sandwichpanels.org

5. Fiskars 'Paper Crimper' tool:
http://www2.fiskars.com/Products/Crafting/Embossing/Embossing-and-Texturing-Tools/Paper-Crimper

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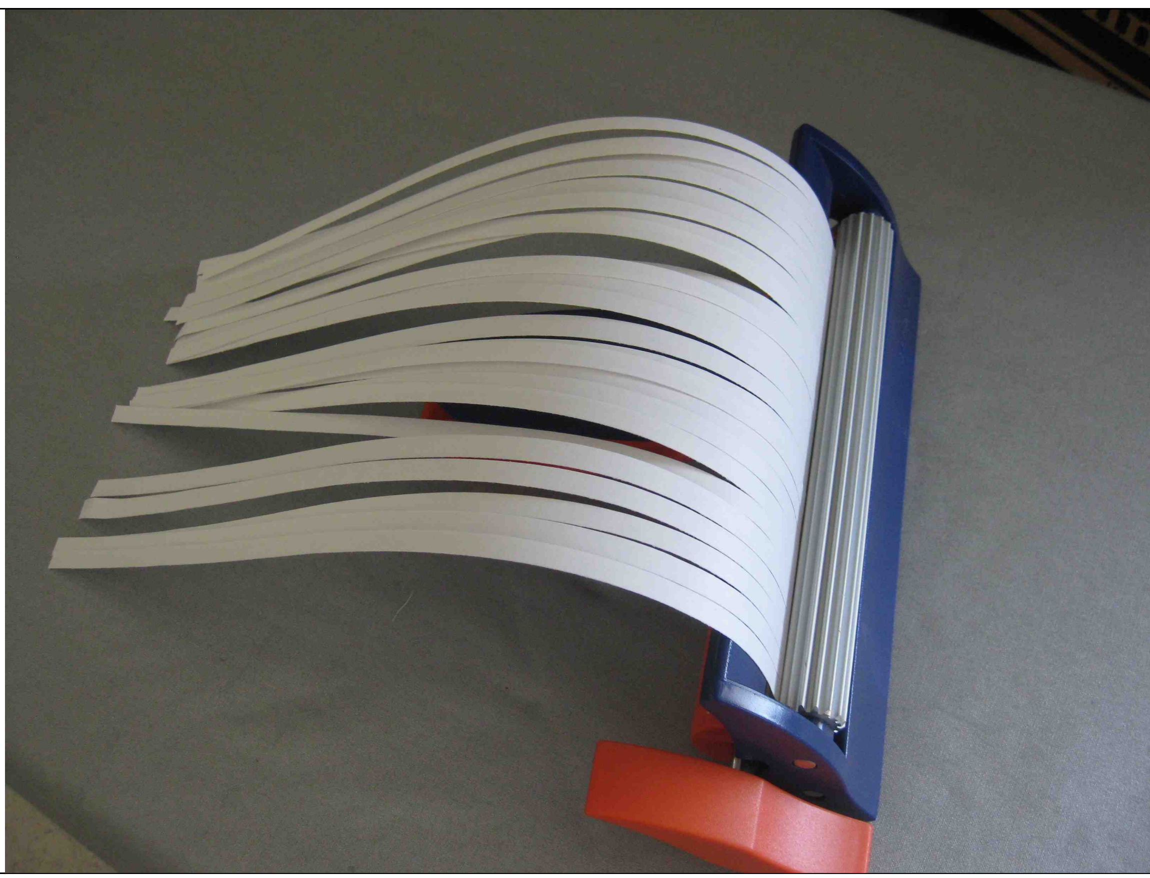

Figure 1: A sheet of paper strips inserted into a 'crimper' tool.

Figure 2:  Crimped paper strips are oriented in a spiral and glued to a panel surface sheet.

Figure 3: A completed sandwich composite (with a glue-stick shown in the background).

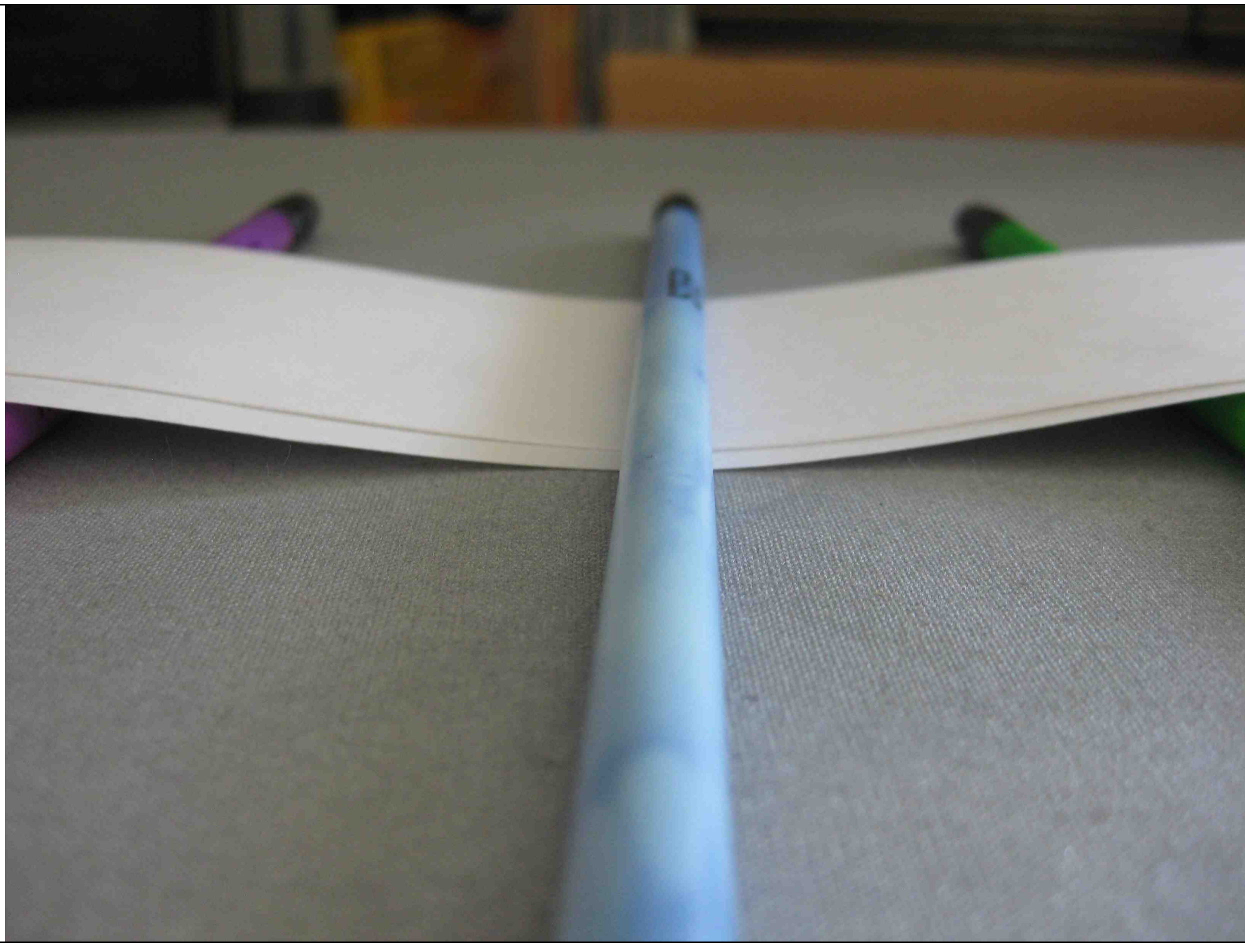

Figure 4:  Three point bend of sheets of paper (not supporting a pencil load of 5 grams).

Figure 5:  A sandwich panel in 3-point bend supporting a glue stick weighing 60 grams.