DOCUMENT RESUME

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ABSTRACT

In this activity, students learn about composite materials, tension as a force, and how they act on structural components through the design and testing of a strip of plastic chair webbing. This activity requires a 60-minute time period for completion. (Author/NB)

Activity: **Stop The Stretching**

GRADE LEVELS: 6-8

SUMMARY:

Students will learn about composite materials, tension as a force and how they act on structural components through the design and testing a strip of plastic chair webbing.

LEVEL OF DIFFICULTY [1 = Least Difficult: 5 = Most Difficult]

5-most difficult

TIME REQUIRED

(30 min) class period demo/initial computer graphing

1 (30 min) class period design

½ - 1 (30 min) class testing and follow-up

COST

Materials to build one tensile test station: $6

Student materials: $3 per class

STANDARDS:

5.3 Explain how the forces of tension, compression, shear, bending, and torsion affect the performance of bridges and towers.

2.1 Identify materials used to accomplish a design task based on a specific property (i.e. weight, strength, hardness, flexibility).

2.2 Demonstrate methods of representing solutions to a design problem (ex. sketched, prototypes).

2.3 Describe and explain the purpose of a given prototype

WHAT WILL THE STUDENTS LEARN?

Students will learn about tension as a force and how it acts on structural components through a hands-on group design problem. They will also learn about composite materials and how they can be made for increased strength.

BACKGROUND INFORMATION:

- Set up only two test stations. This will focus all students attention on the testing, and they will learn how to improve their designs after watching the results of other teams' tests

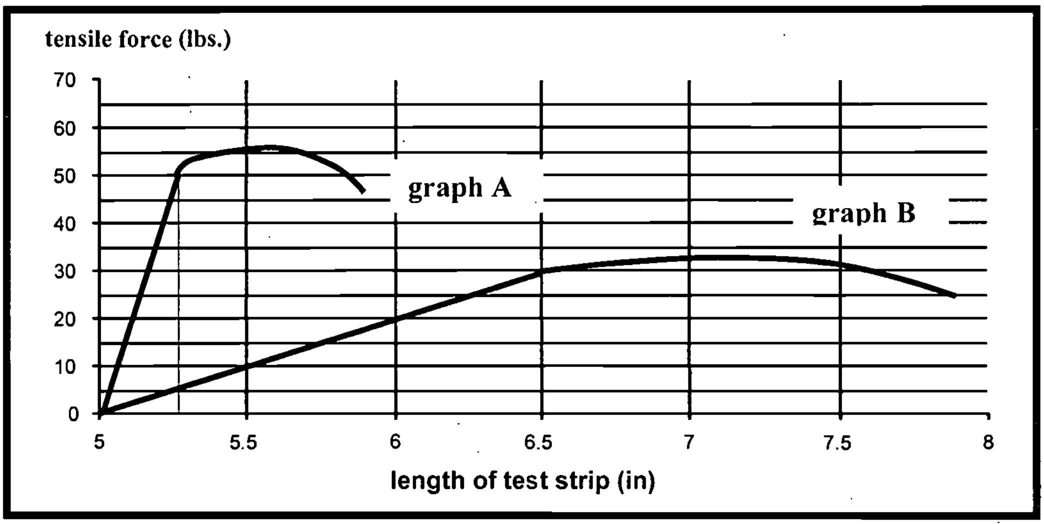
- Before the class tests their own chair webbing designs, you should demonstrate to students the process of running a test. Run the first test on a single 4 mil thick plastic strip (2" X 18") and have a student record the data on the board. Have the whole class graph these results on the grid provided in their packets. By doing the plain plastic test first, students will be able to really see the improved stiffness and strength of their composite material designs.

Teacher / Background Notes:

Structural elements subjected to tension (pulling forces) will stretch and "neck down" before they break. The actual amount of elongation (stretching) depends on the load, but it also depends on the original length of the material; the longer the piece of material, the more it will stretch when subjected to a given load (so it is important for all students to mark off the 5" initial length). Have students watch for the necking on their plastic samples that are loaded in tension; they will observe that the middle of the material gets skinnier and thinner. All materials in tension, even steel, will stretch and neck down, before they fail (break). When a high enough load is placed on a structural member in tension, the ultimate tensile strength of the material is exceeded and it fails.

Direct students to find these real-life examples of structural elements in tension: cables (wire ropes) used to hold up bridges, antennas and small towers, and also used in hoists and cranes; telephone lines hanging between poles; wires used to hang or support signs, and hold up sailboat masts; ropes used with pulleys to lift heavy loads (block and tackle), or used in rope ladders, playground equipment and boat rigging.

The **stiffness of a material** is a measure of its rigidity or flexibility; the greater a material's stiffness, the less it will deform (compress, stretch, bend) when a certain load is placed on it. **In this lab, students are trying to develop not only a stronger material, but also one that has a much greater stiffness.** Their graphs will tell them if they are successful. The steeper the slope of the linear (straight-line) part of their graph, the higher the material's stiffness (see graph below). A steep slope indicates a very rigid material – the amount of stretch increases slowly as the load increases – this is the goal for designing the chair webbing. Notice that material "A" only stretches 1/4" when loaded to 50 lb. A curve with a less steep, flatter slope (graph B) indicates a more flexible or stretchy material – the amount of stretch increases quite a lot as the load is applied. Notice that material "B" stretches 1 1/2" with only a 30 lb. load applied.



Composite materials are quite common today. A composite material is one that is created by bonding two or more materials together to create a material that is stiffer, stronger, lighter or has some other improved property (less thermal conductivity, higher electrical resistance, etc.). Maybe it would be interesting for your students to do a net search to find different composite materials, find how they're made, what they're used for and what are their improved properties. Students might investigate the following: reinforced concrete, insulation and other building materials; materials used to make skis, snowboards, racing bicycles, tennis rackets, fishing poles and golf clubs; materials used to make spacecraft, airplane and automotive bodies. Specific materials that they might look into include: glass fiber-reinforced resins (fiberglass), carbon-graphite composites, ceramic composites, plastic laminates and plastic-metal laminates, and there are many others.

MATERIALS:

To build 1 test station:

At least a 14' section of link chain (make sure the links fit around a 3/8" bolt)

An approximately 8" section of link chain

3/8" x 6" round head bolt threaded enter length

3/8" hex nuts

Duct tape

5-gallon pail with strong handle (school floor wax buckets)

Small, pea stones (uniform size) or sand - enough to fill both the 5-gallon pails (sand is messier)

Ruler

Small coffee can (16 oz.)

For One Sample (each team will need 4 Sample sets):

1 strip of plastic sheet, 4 mils thick X 3 in wide X 18 in long

(1 mil = 1/1000 in.) – A roll of plastic sheeting can be purchased from Home Depot - don't use trash bags

5' of masking tape

5' of thread

Tools for Sample Construction:

rulers

scissors

marker

PREPARATION:

Obtain Materials & Photocopy Worksheets

Constructing the Tensile Test Stations and problem statement

DIRECTIONS:

See Problem Statement Worksheet

INVESTIGATING QUESTIONS:

What is tension?

What effect does it have on structures and structural elements?

Give real life examples of tension and actual examples of structural elements that are loaded in tension.

What are composite materials and how are they made?

Find real life examples of composite materials and identify the special properties possessed by them.

REFERENCES:

(none)

SAMPLE RUBRIC PARAMETERS:

Maximum load carried

Minimum amount of stretching (deflection)

Minimum amount of material used

STOP THE STRETCHING!

DESIGNING AND TESTING COMPOSITE MATERIALS TO BE STRONG AND STIFF IN TENSION

by Douglas Prime and Lacey Prouty
Tufts University, Center for Engineering Educational Outreach
and Brad George
Hale Middle School, Nashoba Regional School District

Constructing the Tensile Test Stations

Materials (to build 1 test station)

- At least a 14' section of link chain
- An approximately 8" section of link chain
- 3/8" x 6" round head bolt threaded enter length
- 3/8" hex nuts
- Duct tape
- 5 gallon pail with strong handle (school floor wax buckets)
- Small, pea stones (uniform size) or sand - enough to fill both the 5-gallon pails (sand is messier)
- Ruler
- Small coffee can (16 oz.)

Assembly

1) To make the top holder, loop the chain around something sturdy on the ceiling and cut it so the two ends will be hanging at a comfortable level off the floor (see Figure 1).
   Slide a bolt through one of the bottom links of the chain and Thread the nut to the end; this will clamp the chain in place.

Thread another nut onto the bolt allowing at least a 3" space between the nuts already on the bolt. Slide the other chain link on the bolt and secure it with another nut.

Wrap duct tape around the exposed threaded part of the bolt so it will not cut into the plastic strips being tested.

2) The bottom holder is made the same way, except you only need an 8" length of chain which you will put through the handle of the bucket (see Figure 1). One trick to help reduce the bucket sliding is to ensure an odd number of links in the bottom chain.

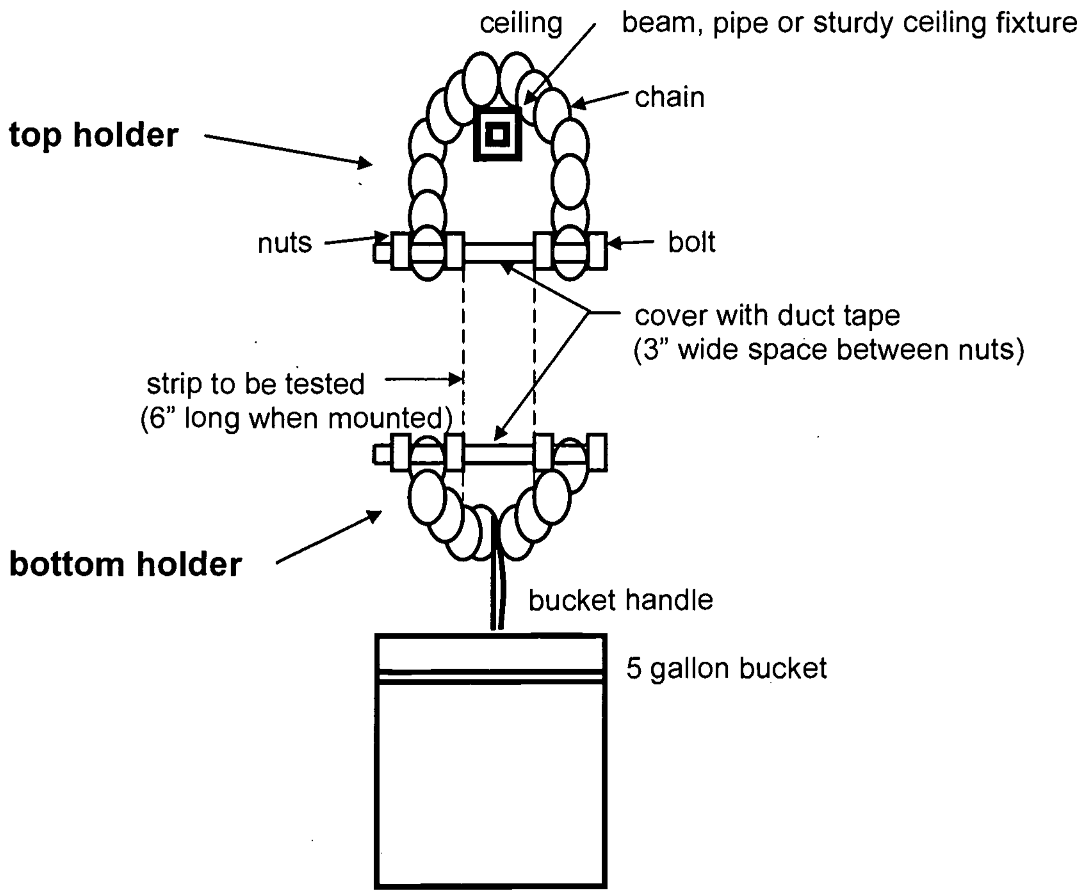


Figure 1: Assembly of Tensile Testing Station

IMPORTANT NOTES ON RUNNING THE LAB:

- Set up only one or two test station. This will focus all students' attention on materials testing and they will learn how to improve their second designs after watching the results of other teams' tests.
- Demonstrating testing of a sample test strip of unmodified plastic sheeting so that students will understand the testing methods as well as having a standard for comparison of their composite design. Run the First Test on a single 4 mil thick plastic strip (2" x 18") and have a student record the data on the board. Have the whole class graph these results on the grid provided in their packets. By doing the plain plastic test, students will be able to really see the improved stiffness and strength of their composite material designs.
- Ensuring uniform testing is very important given the importance of relatively small measurement differences. It is important to make sure that duct tape does not overlap the 5" testing length. In addition, it may be necessary for the teacher (or at least one consistent student) to take measurements of the elongation of all strips so that the data gathered can be compared.
- Something should be placed to catch the bucket after each test strip breaks, depending upon the bucket's height.
- All students should wear safety glasses and keep their feet away from the area where the bucket will land.

STOP THE STRETCHING!

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by Douglas Prime and Lacey Prouty
Tufts University, Center for Engineering Educational Outreach
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Hale Middle School, Nashoba Regional School District

Problem Statement

Because of the increasing cost of making plastic chair webbing (plastic strips), your company needs to find a new way to make lawn chairs. An idea was introduced to make strips out of plastic sheets, and develop a new product line. However the plastic alone is not strong enough in **tension,** and it stretches way too much to be used to make lawn chairs. Your team has been assigned to design and test a new **composite material** to use for chair webbing. A composite material is one that is made from one or more other materials bonded together. Your goal is to design a 3" wide strip of chair webbing made from thin plastic, masking tape, string, and hot glue. Your chair webbing must be designed to hold the greatest **load** possible in tension, with the smallest amount of **elongation** (stretch). Your team will develop and test two designs for chair webbing. Each design must be made only from the materials provided. The chair webbing test strips that you design and make, must be 3" wide and 18" long.

Materials **(needed for each team to make 1 test strip for 1 design. Each team will need 4 sets of materials. Two for testing and two to keep for their records)**

- 1 strip of plastic sheet, 4 mils thick X 3" wide X 18" long
  (1 mil = 1/1000 in.) – A roll of plastic sheeting -don't use trash bags
- 5' of masking tape
- 5' of thread

Tools

- rulers
- scissors
- marker

Procedure

1) Your team must spend ten minutes brainstorming and making sketches of possible ways to design the chair webbing, before you will be allowed to get materials.

2) Select the two designs that you believe to be the best, and make 2 sample strips of each chair web design – one to test and one to keep for your records.

3) Record the weight of the bottom bolt chain and bucket. This is the initial Load that will be placed on your test strip.

4) Place your team's test strip in the testing device as shown: Tape a strip into the test fixture (see Figure 1). For each end, you will fold 3" of the strip over the bolt, and then place a 4" piece of duct tape vertically across the seam. Place another 5" piece of duct tape horizontally across the seam and fold it over to the other side of the test strip (it is important to tape in both directions to prevent the seam from breaking).

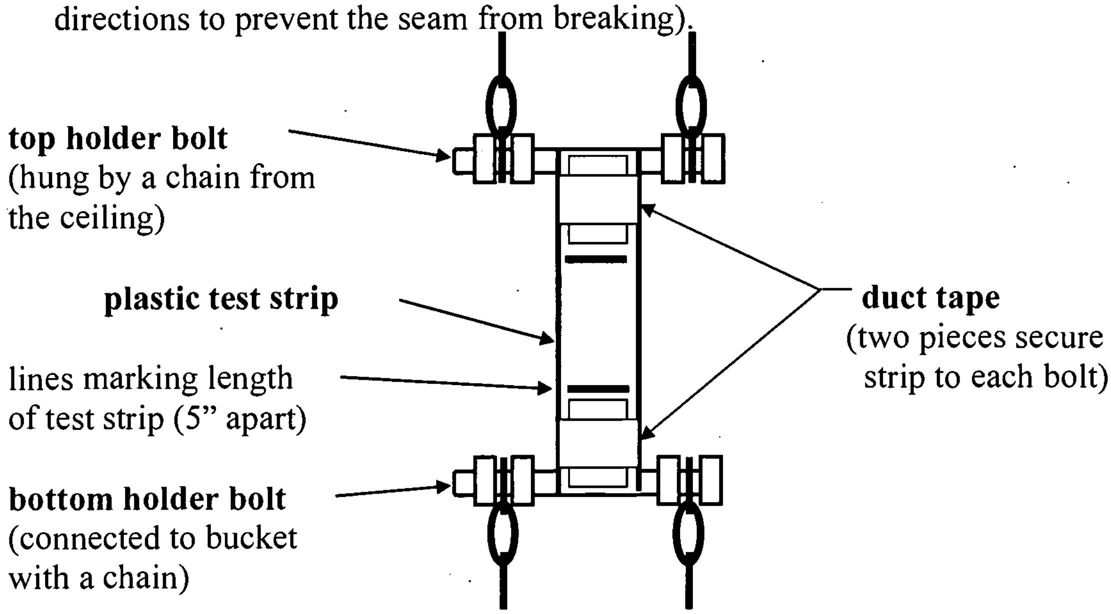

Figure 1: Mounting a Test Strip in the Test Fixture

5) With a marker, draw two lines on your test strip (see Figure 1) that are 5" apart (the lines must not be on the duct tape) . These lines mark the initial length of your test strip. The ends of the strip that are covered with duct tape don't count as part of the test length because the duct tape adds strength to the material.

6) Fill a small coffee can with peastones (or sand) and record the weight.

7) Pour two cans of peastones (or sand) into the pail and record the new length of the test strip in the table provided.

8) Repeat this procedure until the test strip breaks. Keep increasing the weight in the bucket two cans at a time, and recording the new length.
Make a tensile load (lbs) v. length (in.) graph for your test strip.

Repeat this test with your other design, and graph the results on the same graph as design #1

FAIRLY FUNDAMENTAL FACTS
ABOUT FORCES & STRUCTURES

by Douglas Prime
Tufts University
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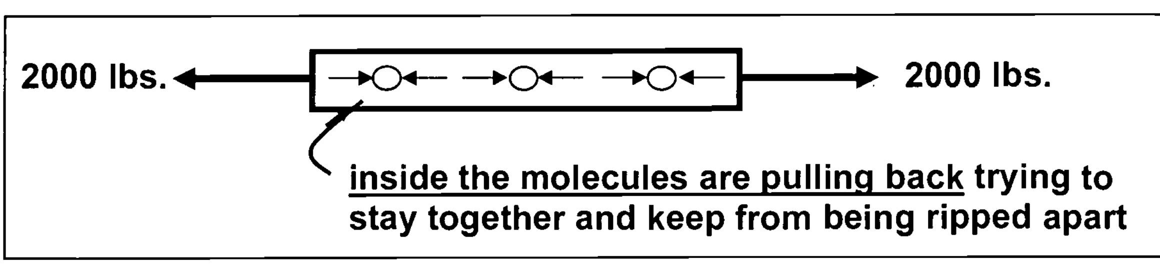
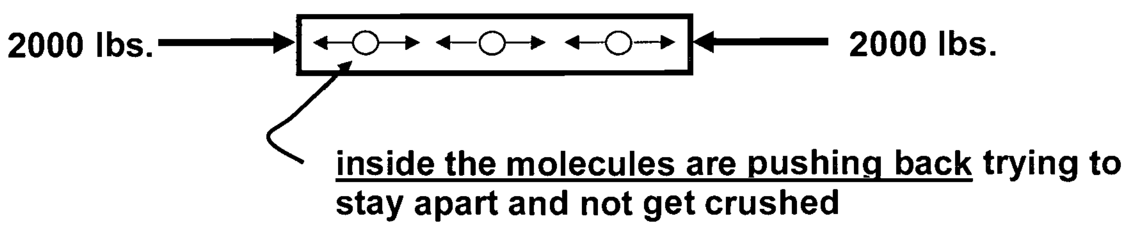
Everyone knows from experience that a **force** is a pushing or a pulling action which moves, or tries to move, an object. Engineers design **structures**, such as buildings, dams, planes and bicycle frames, to hold up weight and withstand forces that are placed on them. An engineer's job is to first determine the **loads** or external forces that are acting on a structure. Whenever external forces are applied to a structure, **internal stresses** (internal forces) develop inside the materials that resist the outside forces and fight to hold the structure together. Once an engineer knows what loads will be acting on a structure, they have to calculate the resulting internal stresses, and design each **structural member** (piece of the structure) so it is strong enough to carry the loads without breaking (or even coming close to breaking).

<u>The 5 types of loads that can act on a structure are tension, compression, shear, bending and torsion</u>

3) <u>tension</u>: **two pulling forces, directly opposing each other, that stretch out an object and try to pull it apart (ex. pulling on a rope, a car towing another car with a chain – the rope and the chain are in tension or are "being subjected to a tensile load")**

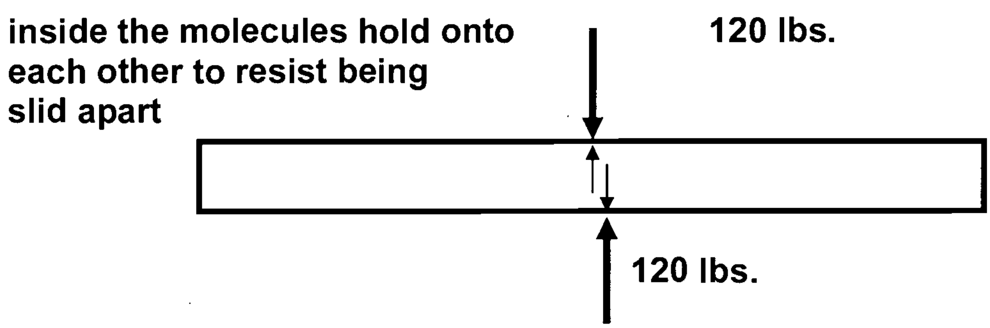


4) compression: **two pushing forces, directly opposing each other, which squeeze an object and try to squash it (ex. standing on a soda can, squeezing a piece of wood in a vise – both the can and the wood are in compression or are "being subjected to a compressive load")**

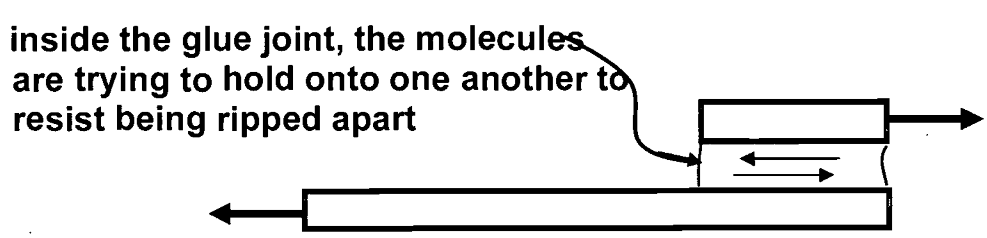


5) shear: **two pushing or pulling forces, acting close together but not directly opposing each other – a shearing load cuts or rips an object by** sliding its molecules apart sideways

ex. pruning shears cutting through a branch
paper cutter cutting paper
(the branch and the paper are "subjected to a shear loading")

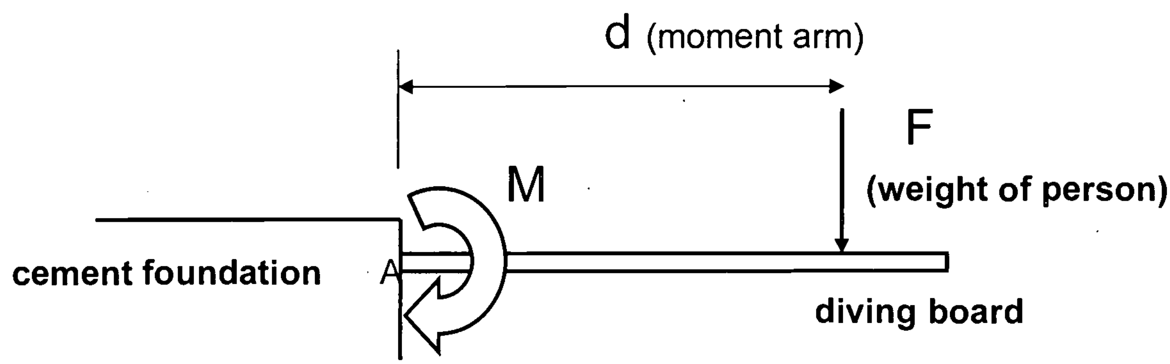


ex. pulling on two pieces of wood that have been glued together
(the glue joint is "being subjected to a shear loading")



A Moment of A Force

Before you can understand the last two types of loads, you need to understand the idea of a moment of a force. **A moment is a "turning force" caused by a force acting on an object at some distance from a fixed point. Consider the diving board shown below. The heavier the person, and the farther he walks out on the board, the greater the "turning force" which acts on the cement foundation.**



the force (F) produces a moment or "turning force" (M) that tries to rotate the diving board around a fixed point (A) – in this case the moment bends the diving board

The stronger the force, and the greater the distance at which it acts, the larger the moment or "turning force" which it produces.

A moment or "turning force" (M) is calculated by multiplying a force (F) by its moment arm (d) – the moment arm is the distance at which the force is applied, taken from the fixed point:

$$M = F \bullet d$$

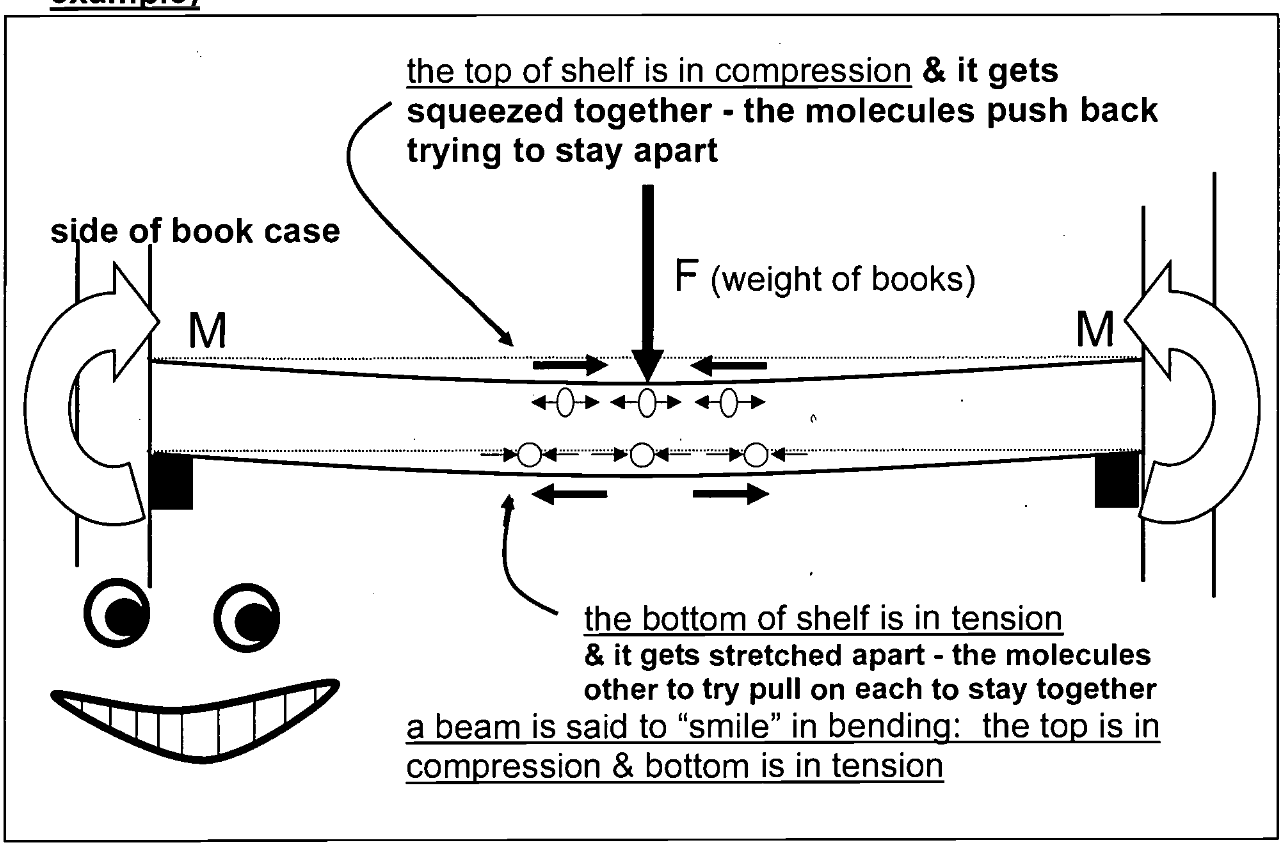
(as long as the force acting on the object is perpendicular to the object)

If you have a force measured in Newtons multiplied by a distance in meters, then your units for the moment are N-m, read "Newton-

meters". If your force is measured in pounds and you multiply it by a distance given in inches, then your units will be lb-in., read "pound-inches". <u>The units for moments can be any force unit multiplied by any distance unit</u>.

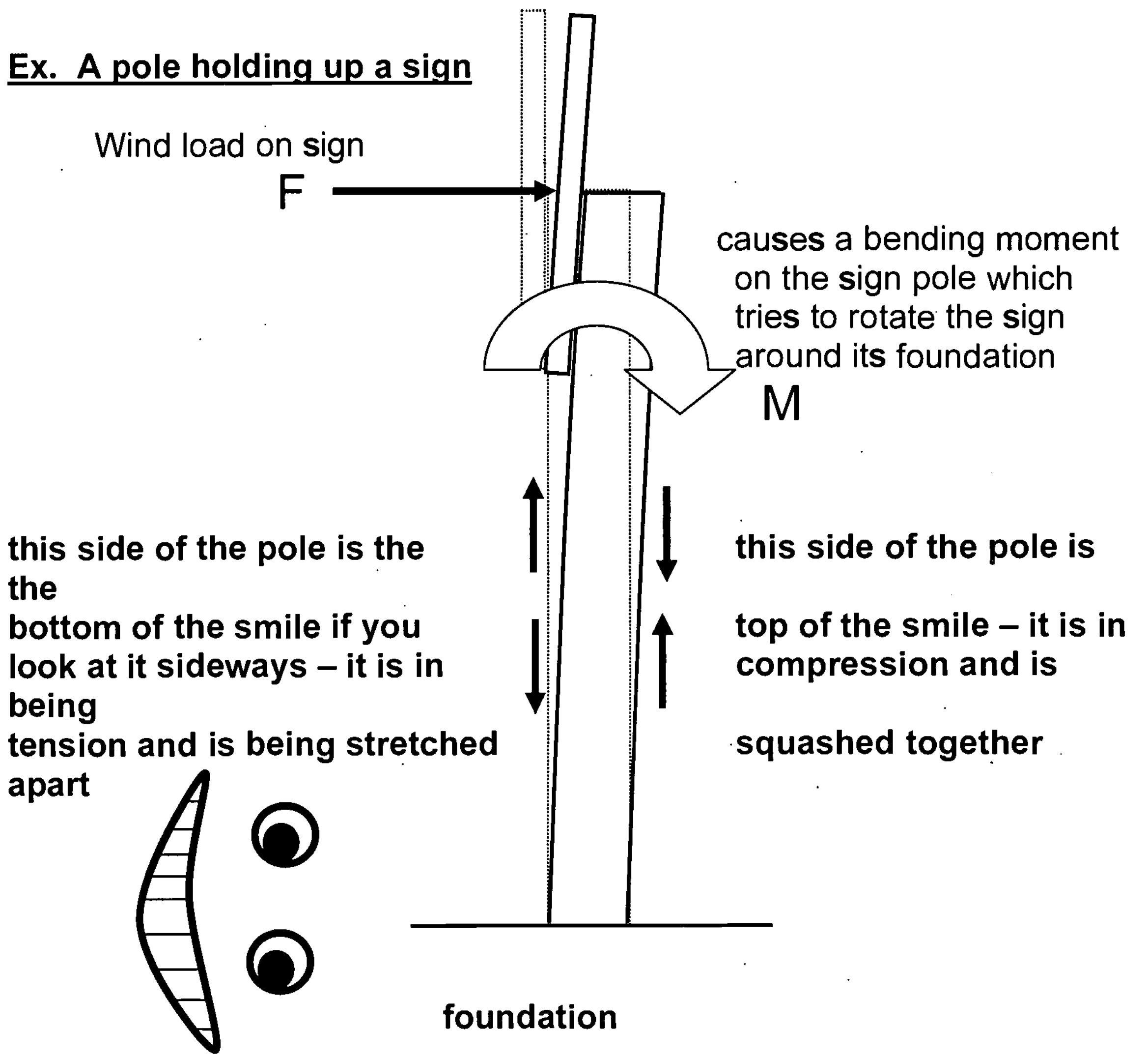
6) <u>bending</u>: **created when a moment or "turning force" is applied to a structural member (or piece of material) making it** deflect or sag (bend), moving it sideways away from its original position **- a moment which causes bending is called a** bending moment – bending actually produces tension and compression **inside a beam or a pole, causing it to "smile" – the molecules on the top of the smile get squeezed together, while the molecules on the bottom of the smile get stretched out** – a beam or pole in bending will fail in tension **(break on the side that is being pulled apart)**

ex. <u>a shelf in a book case (& the diving board from previous example)</u>



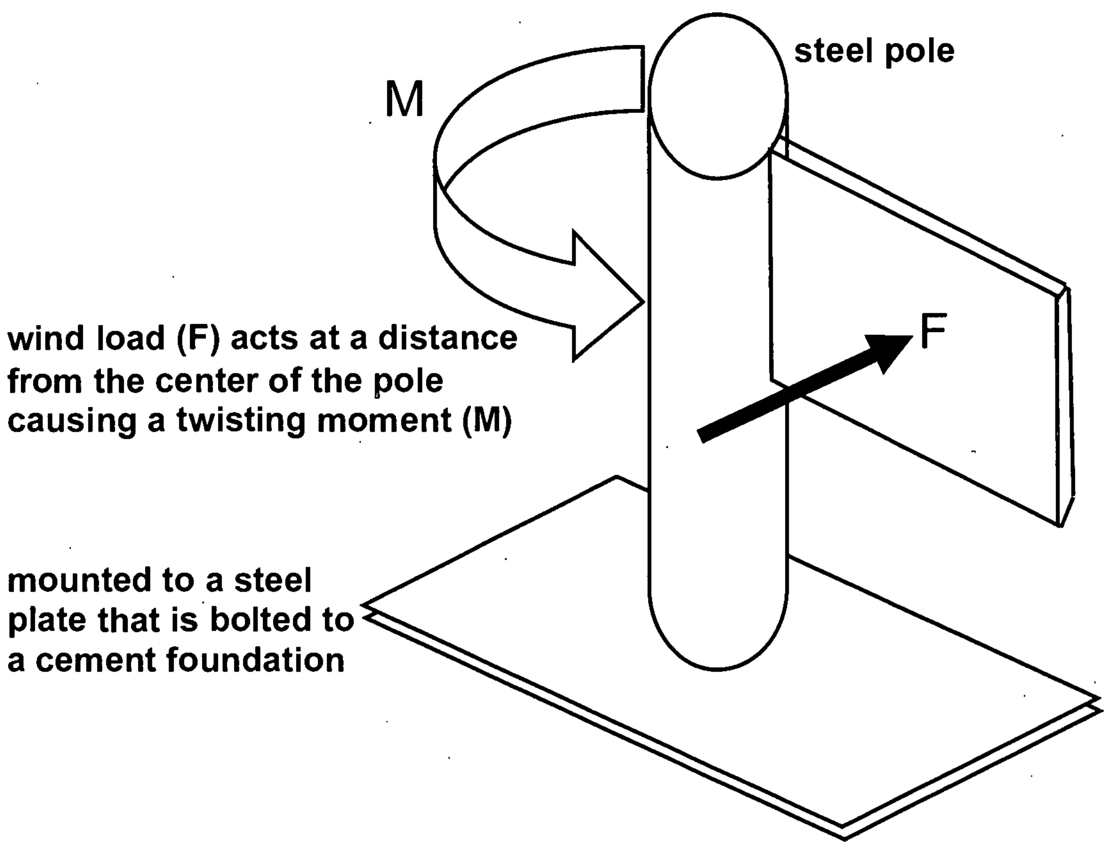
<u>Glue stick experiment to show tension and compression created by bending.</u> **Take a glue stick used in a glue gun and use a ruler to mark four straight 4" lines which run down the length of the stick – the lines should be spaced 90 degrees apart: one on the top, one on the bottom, and one on each side of the glue stick. Hold the glue stick between a finger and your thumb, and apply a force to the middle. Notice how the lengths and shapes of the lines change. <u>What happens to the line on the top of the glue stick (side where your finger pushes)? What happens to the line on the bottom? What happens to the lines on the two sides of the glue stick?</u>**

<u>Ex. A pole holding up a sign</u>



7) <u>torsion (twisting):</u> **created when a moment or "turning force" is applied to a structural member (or piece of material)** making it deflect at an angle (twist) **- a moment which causes twisting is called a** twisting or torsional moment – torsion actually produces shear stresses inside the material - a beam in torsion will fail in shear **(the twisting action causes the molecules to be slid apart sideways)**

<u>ex. a pole with a sign hanging off one side</u>



<u>Glue stick experiment to show torsion.</u> **Again take a glue stick used in a glue gun and use a ruler to mark a series of straight lines along its length, similar to the experiment above. Hold one end of the glue stick, and get a partner to twist the other end as hard as possible. <u>What happens to the lines on the glue stick</u>? Imagine that each vertical line represents a line of glue molecules** – notice how they have been slid sideways out of position by the twisting moment – this is the sign of shear forces acting inside the material.

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