**How Strong is Your Chocolate?**

**Introduction:** Materials such as metals (aluminum, iron, copper, etc.), ceramics (porcelain, silicon carbide, etc.) and polymers(milk jugs made of polyethylene) are tested by scientists and engineers to reveal the material’s mechanical properties. One type of mechanical testing is strength testing. Strength is a measurement of the maximum stress that a material can withstand. Many of the materials that we see every day are subjected to a variety of stresses and must be designed to provide a certain measure of strength.

The atomic structure of a material is a major factor that influences the strength of a material and involves the elements in the material –the way they are bonded to each other and the way the atoms are arranged to make different structures. However, two materials that share all of the same atomic traits can still have different strengths if their microstructure is altered due to processing. The chocolate bars in this lab are an excellent example of how microstructure can be altered due to processing. The chocolate in all of the bars has the same elemental make-up and atomic traits. However, the microstructures differ due to things that have been added to the chocolate, such as almonds or crisped rice.

**Lab Description:** In this lab, different types of chocolate bars will be tested to examine the influence of different microstructures on the strength of the chocolate bar. The flexural strength of the chocolate bars will be measured using a conventional 3-point bending test set-up (see Figure 1). For this test set-up, chocolate bars are placed on two supports (making two points of contact), and a force is applied to the center of the bar (making the 3rd point of contact in a 3-point bending test).



**Figure 1**. Test set-up for a 3-point bending test

**Keywords:** Mechanical properties, stress, 3-point bending test, microstructure

**Materials List:**

· protective mat (aluminum foil, saran wrap, etc.)

· tape or stapler

· plastic cup with twine attached

· mass balance

· pennies

· milk chocolate bar, milk chocolate bar with almonds, and milk chocolate bar with crisped rice

**Safety Precautions:** This lab does not require any safety apparel. However, standard lab rules and procedures (only using the equipment as indicated in the instructions) should be followed.

**Instructions:**

1. Measure and record on your data sheet the following information about the bar:

a. Type (milk chocolate, almond, crisped rice, etc.)

b. Width of the bar (mm), *w*

c. Thickness of the bar (mm), *t*

2. For each type of chocolate bar, make a prediction of how many pennies you think the chocolate bar can hold.

3. Position two desks so that the chocolate bar can span across the space between the desks. Approximately ½ inch of the chocolate bar should be touching each desk.

4. Measure and record (in mm) on your data sheet the length of the chocolate bar that is not supported by the desks. This is called the length of the support span, *L*.

5. Place the twine with the cup attached across the middle of the chocolate bar so that the cup hangs freely below the chocolate bar as shown in Figure 2.



6. Place the protective mat on the floor to catch the chocolate when it falls.

7. Create a paper funnel by rolling a piece of paper and either stapling or taping it.

8. Using the funnel, start placing the pennies into the cup, one at a time. The pennies should be funneled in at a steady pace, ensuring that each penny lands in the cup before the next penny enters the cup (a pace of two to three pennies per second is good). Try funneling the pennies in a way that they do not fall a large distance when they enter the cup.

9. Continue placing pennies into the cup at a steady rate until the chocolate bar fractures. Be sure to note any deflections or bending of the chocolate bar during the loading process.

**NOTE:** If it is difficult to see the bar start to deflect, place the ruler across the desk just to the side of the chocolate bar to help indicate when the bar starts to deflect from a horizontal line.

10. Record the number of pennies in the cup at the time of fracture.

11. Look at the fracture surface and record any observations.

12. Find the mass (in grams) of the cup, string, and the pennies in the cup at fracture using a mass balance. The force, *P*, applied to the chocolate bar can then be calculated as follows:

*P*= (weight of cup, twine, and pennies)\*(acceleration due to gravity = 9.81m/s2)

If you do not have access to a mass balance, use the following weights to approximate the mass:

a. Weight of one penny –2.35 grams

b. Weight of the cup and twine –25 grams

The force, *P*, applied to the chocolate bar can then be calculated as follows:

*P*= ((weight of penny)\*(# of pennies) + weight of cup and twine)\*(gravity = 9.81m/s2)

13. Use the force, *P*, found in step to calculate the flexural strength of the chocolate bar. The formula for calculating flexural strength is:

σ = 1.5*PL/ wt*2

where σ is the flexural strength (*MPa*), *P* is the applied force (*N*), *L* is the length of the support span (mm), *w* is the width of the bar (mm), and *t* is the thickness of the bar (mm).

14. Repeat steps 1-12 for each chocolate bar to be tested.

15. Complete the questions below.

**Clean Up:** Eat the chocolate!

QUESTIONS:

1. Did you notice any changes in the chocolate bars during the loading process? Were these changes the same for all of the chocolate bars or different?

2. Which type of chocolate had the highest flexural strength? The lowest flexural strength?

3. Why do you think the bars had different strength values?

4. Which bar had the highest standard deviation for the number of pennies?