Lessons 6 and 7 Foam Bridge Experiment- Forces and Stresses Lab

1. Background

All industrial and building materials undergo forces that they must withstand to function as designed. Concrete is strong under compressive forces, but not tension. Therefore reinforcing bars are added to improve the performance of concrete under tension.

Applying a force until the concrete fails and using our knowledge about compressive forces can be used to determine the strength of concrete.

This lesson will prepare the students for the experimental measurement of the strength of our concrete cylinders.

Force: a push or a pull. $force = mass \times acceleration, in\ Newtons$ or $Pounds$

Load: The overall force to which a structure is subjected in supporting a force

Compressive Force: Forces that press together

Tensile Force: Forces that pull apart

Stress: *Force per unit area.* (Stress is not directly applicable to this lesson, better to bring this up when it is. When you first talk about your cylinders may be a better time.

$$Stress = \frac{force}{area}, in\ units\ of\ \frac{newtons}{m^2}\ or\ \frac{pounds}{in^2}(psi)$$

This lesson will show the students the difference between compression and tension, how they affect the strength of concrete and some of its applications.

2. Performance Objectives

The students will apply concepts of tension and compression to the design of a model bridge.

The students will be able calculate the stress factor of different loads on different shapes

The students will analyze the elements of an ideal bridge.

3. Standards

NY S Integrated: 5.2
US Science: 2.2
US Technology: 5.7

4. Resources

http://www.teachersdomain.org/resources/phy03/sci/phys/mfw/lp_tension/index.html

Supplies for Foam Bridge Activity: See list in Teacher Notes at the end of this Lesson

5. Vocabulary

Compression	Tension
Force	Stress
Newton	Failure

6. Instructional Plan

1. Introduction(5 min)

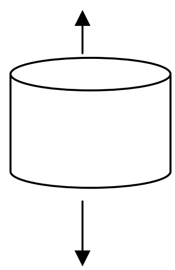
a) Have students stand up and bend over at the waist, keeping their knees straight. "Feel your back stretch, and feel the folds in your belly? Which is in tension? (back) and which is in compression?(belly)

b) Ask for two student volunteers. Have the students hold on to opposites sides of the rope (or a slinky). Have each student tug on their end of the rope (tug of war-like) to simulate tension. Have the students then push the ends together to simulate compression. (Optional)

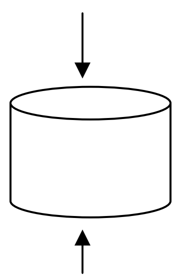
c) **What is a force?**
(Answer: a push of a pull, **force** is anything that can cause a massive body to accelerate)

d) Have students define tension and compression (draw on the board to show students better):

Tension: a pull



Compression: a push



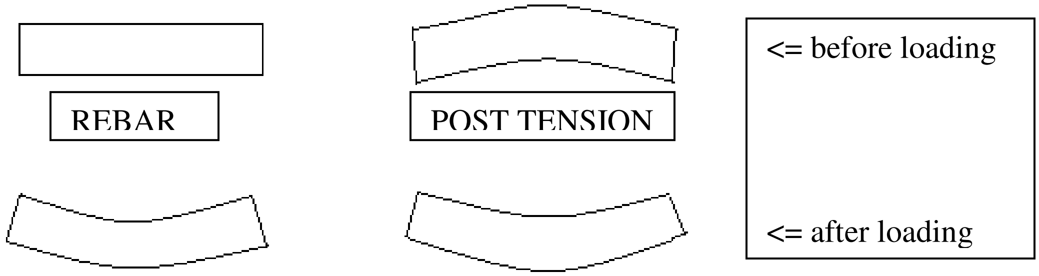
e) **What are the units for force**? (SI Units are Newtons; English Units are pounds. We will be using pounds for this activity.)

2. Activity: Imitation Bridge Deck(30 min)

Directions and explanation for this Activity are included at the end of this lesson.

Be sure to record the load data for the decks on the board for all students to see.

The diagram below may be helpful for the discussion that follows.



3. Discussion of Ideal Bridge (10 min)

Focus the students on the data regarding the loads that the different decks held. Ask the students with the decks that held the most to explain their designs. Recap critical concepts.

Lesson could end at this point. The next class could begin with a review of the bridge designs.

"What makes an ideal bridge?" (continued)

Allow students 2-3 minutes to discuss in pairs what would make an "ideal" bridge. List the responses on the board. Combine a number of students' answers to develop a set of composite characteristics.

Ask the following questions

a) **"What other materials are strong in tension?"**
Ans: Steel, list others

b) **"What other materials are strong in compression?"**
Ans: Concrete, list others

c) **"How will we test our concrete cylinders? (In tension or compression.) And why are we testing it that way?"**
Ans: We test concrete in compression because it is strongest in compression. It is never used solely in tension.

d) Show the elephant video. (This is a link off of a teacher website, but it cannot be saved)
http://www.teachersdomain.org/resources/phy03/sci/phys/mfw/bbarch/index.htm

*On the right hand side of the screen, under Multimedia Resources Used in This Lesson, it is **"Arch Bridge."** You don't have to be registered, just select a "test drive" when prompted.*

e) Why do we care about tension and compression?

i. Explain that "engineers need to know how much weight their concrete can hold before they can build a bridge or building."

ii. Instead of building a bridge and testing how many cars can go across it, then making it stronger next time, they mix a test cylinder using the type of concrete they plan to use, just like what you did.

iii. Then they crush these cylinders using a hydraulic press to see how much force it takes to crush them.

4. Discussion of Stress

Does the strength of the cylinder equal the strength of the bridge? No, not really. To compare, engineers divide the force by the cross-sectional area to calculate ***Stress***.

a. Stress = force/unit area

b. Example – show 2 shoes, one with a large flat heel (or a sneaker) and another with a small, spiky heel. If I stand in each shoe, will the force I put on the floor be different? (no, it will be the same because I weigh the same in both shoes). Will the stress be different? (yes, since the cross sectional area of the spike heel is so much smaller, the stress will be much greater with this shoe – that's why ladies can poke holes in soft floors with their heels!)

c. Units: In English units: psi (pounds per square inch)
In SI units: N/m^2
NOTE: We only use psi in this activity

5. Stress Calculations (This should be done as a class on the board/overhead)

1. Hand out the "Stress Calculations" worksheet and fill it out as a class.
2. Emphasize to the students that stress is only a function of area and force (not of depth of an object, the 3rd dimension doesn't matter.)
3. Hand out "Stress Homework" sheet for homework.
4.

6. Assign the "Stress Homework" due next class. Tell the students that this will help them understand the crushing of the cylinders that they made, and the test at the end.

7. Closure/Conclusion Questions:

a) What is the difference between stress and force?
b) What have we learned about stress?
c) How does stress apply to our daily lives?

Imitation Bridge Deck Activity

Purpose

In order to understand how force affects concrete, we must first understand that force affects objects differently. In an actual concrete deck there are parts of the concrete under tension and parts under compression. As you know concrete does not withstand high forces of tension. Therefore reinforcement must be added. Your job in this activity is to come up with a way to allow your deck to withstand a larger force.

Equipment

1) Activity Sheet
2) Foam deck
3) Dowels
4) String
5) Tape

Procedure

1. Before you begin the actual construction, sketch some ideas for your deck in the space provided.
2. Next put your idea into action. With the materials provided build your deck.
3. Once you have your final design built , it will be tested to see how much of a load it can bear. Bring your deck to the designated testing area.
4. When you are instructed to test, you will hang a bucket on the deck and fill that bucket with sand until the deck fails.
5. Once there is failure, weigh the bucket to see how much force it was able to withstand.

NOTE: In this class we will say that failure is when your foam deck breaks. However in the real design and testing stage for engineers we say failure has many stages and each one is documented.

SKETCHES:

Total weight of bucket and sand: ________________________________lbs

NAMES OF GROUP MEMBERS:_____________________________________

Teachers Notes for Activity

Supply List: Each group will need the following:

1) Foam Pieces (12” long x ~2.5” wide)
2) Dowels 12” long 3/16” diameter
3) String 16” long
4) Two piece dowel ~1.5” long to apply the tension to the string
5) Bucket
6) Small Cup
7) Large amount of sand.

Design Options: The amount of design that you let the students do is up to you. Before the students begin their designs, make sure they know:

1. Compression
2. Tension
3. Where and what the deck of a bridge is – the part that you drive across
4. Foam is acting as the concrete. It is not sufficient to hold a significant load.
    a. Snap a piece of foam with little effort and explain that this is why you need to add reinforcement.
5. How one object can have different parts in compression and tension. Draw the rectangle representing the deck and show its deflection, as seen in the instruction plan. Don’t just tell them this, see if they can correlate this to when they bent over to touch their toes in the beginning of this lesson.
6. Also at the end during the loading, they can test to complete failure, or when the foam snaps. However they should know that when beams are tested by engineers, they are still tested to when they crush, but each pahse of failure is documented. In concrete you are able to see the onset of cracks and their progression. This is similar to noting when their foam begins to bend.

During the design and construction phases, students can place the reinforcement either taped to the outside or they can create a ‘gouge’ in the bottom and place the dowel or string in that. This would be more similar to the actual cases where reinforcement is placed in the lower half of the deck.

To load the deck you need to:

a. Set up the deck between two level planes with approximately two inches on each side, leaving about eight inches clear in the middle.
b. Next place a small flat object in the center (a small black Lego plate works well). This allows the load to be distributed along that distance, instead of a point load where the bucket is hung.
c. Then place the bucket so that it is in the center of the foam and the ‘load distributor’ and hanging freely below.
d. Begin to add sand to the bucket. Remember that sand is loaded until the foam breaks. Therefore one of the students in the group should keep their hands near/around the bucket so that when the deck fails, the student can catch the bucket and the sand stays in the bucket.
e. Last, weigh the bucket and record on the activity sheet.

During the conclusion of this activity compare the weights of each group and the respective designs and their effects. This is an important discussion.

***Post-Tensioning** – this allows for a larger load to be placed over the deck. This works best in a 'gouge' or inset in the deck. Use the small dowels to hold and tighten the string to apply the tensile force. See the illustration in the instruction plan. It will still fail the same way as the dowel, but could hold a larger load. A similar case is the trailer flat bed semi truck. If you look at one without a load on it, it bows up because of the axial tension on the bed.

Name____

Stress Calculations Worksheet

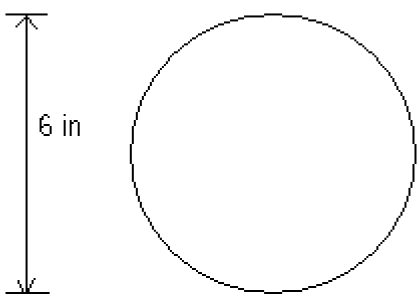
1) How do you calculate the area of a circle? _________________________

2) How do you calculate the area of a square? _______________________

3) How do you calculate the area of a triangle? _______________________

4) Calculate the area and stress of the following shape:

Assume that there is a 20 pound load pushing on the shape.



Area _______________________________

Stress_______________________________

Stress Calculations (TEACHER)

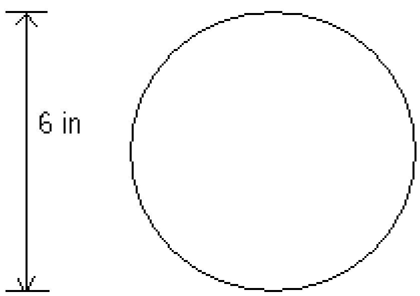
1) How do you calculate the area of a circle? **$\pi \times r^2$**

2) How do you calculate the area of a square? **Length x width**

3) How do you calculate the area of a triangle? **(base x height) / 2**

4) Calculate the area and stress of the following shape:

Assume that there is a 20 pound load pushing on the shape.



Area __ $28.27\ in^2$ ________________________

Stress__ 0.7074 psi ______________________

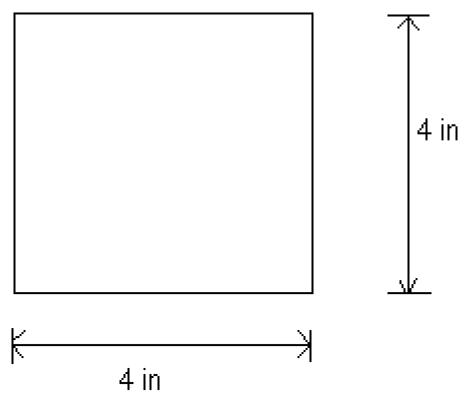
Name____

Stress Homework Sheet

Directions:

Calculate the area and stress for the following shapes. Assume there is a 20 pound compression force applied to the shapes. Show all work and include units on your answer.

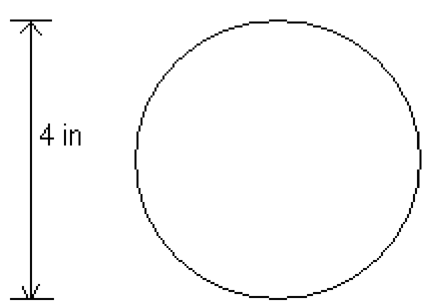
1.)



Area ____________________________________

Stress ___________________________________

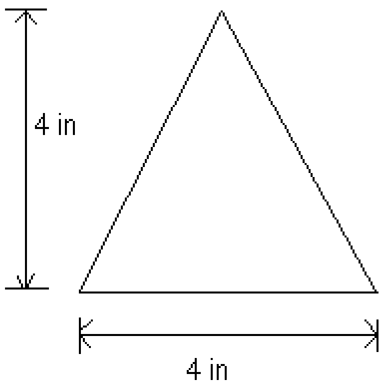
2.)



Area ____________________________________

Stress ____________________________________

3.)

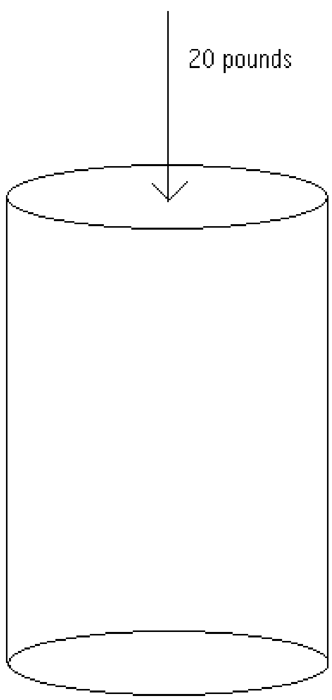


Area ___________________________________

Stress __________________________________

Directions:

Calculate the stress of the following object. The circle has a 4 inch diameter and the compression force applied to the cylinder is 20 pounds. Show all work and include units.



Area ___________________________________

Stress __________________________________

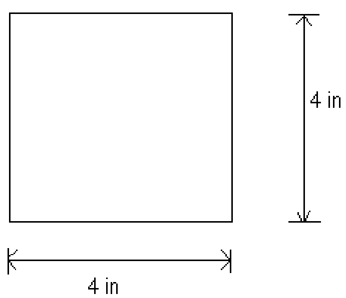
Name____

Homework- Stress (TEACHER)

Directions:

Calculate the area and stress for the following shapes. Assume there is a 20 pound compression force applied to the shapes. Show all work and include units on your answer.

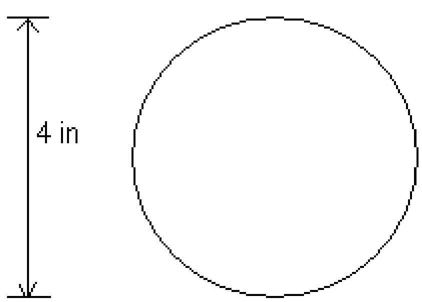
1.)



Area ______16 in^2____________

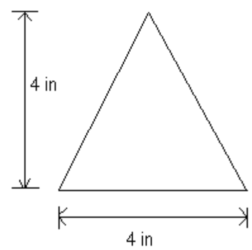
Stress ____1.25 psi_________

2.)



Area _____12.57 in^2_______________
Stress _____1.59 psi_______________

3.)

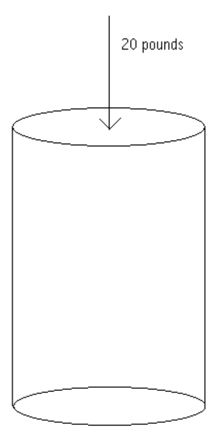


Area _____8 in^2_____________

Stress ____2.5 psi___________

Directions:

Calculate the stress of the following object. The circle has a 4 inch diameter and the compression force applied to the cylinder is 20 pounds. Show all work and include units.



Area _______16 in^2______________________
Stress ______1.25 psi______________________