Teacher Created Resources®

STEM

Hands-On Challenges

Grade 2

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Engineering Design Process

—a series of steps used by engineers in order to solve a problem—

Define the Problem

- What is the problem?
- Define the constraints.

Imagine

- How can you approach the problem?
- Discuss ideas and possible solutions.
- Use your imagination.

Plan

- Sketch your idea to solve the problem.
- List materials and steps to create your solution.

Create

- Follow your plan.
- Build your solution.

Test

- Try it out!
- Record results.

Analyze & Evaluate

- Evaluate your results.
- What works or needs changes?

Improve

- Make it better.

Share & Reflect

- Share your results—what did you learn?
- Compare your solution to others.
- What would you like to try next?

Build a Beam Bridge

Objectives

Students will learn about the forces of compression and tension through a hands-on activity. Students will then work in pairs to complete bridges using only paper, and will test to see how much weight each bridge can hold. They will improve each design, complete a second bridge, test again, and then compare their two bridges.

STEM Focus

Physical Science: Pushes and pulls can have different strengths and directions.

Engineering Design: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs

Science and Engineering Practices: Carry out investigations, analyze and interpret data, use mathematics and computational thinking, construct explanations, engage in argument from evidence.

Crosscutting Concepts: Structure and function; cause and effect

Setup

For Mini Challenge

- Students will need large index cards.

For Main Challenge

- Make copies of *Building a Beam Bridge* and *Reflections—Building a Beam Bridge* for each student.
- Collect index cards, paper clips, cups, weights, and tape for each student or group.
- Set up abutments (platforms) for students to build bridges on. The abutments should be roughly 3 inches high and 5 inches apart. Some ideas for abutments include stacked books or building blocks, upside-down cups, or boxes with weights. If the abutments are not heavy enough, tape them to the work area so they will not move.
- Collect small items for weights to test the strength of the bridges. Pennies work well, but any heavy, small objects of consistent weight will do, such as nuts or bolts or decorative glass pebbles.

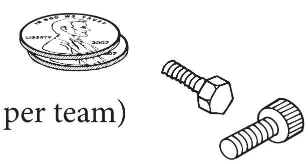
Materials

Mini Challenge

- large index cards (5" × 8") or sheets of cardstock cut in half (5.5" × 8")

Main Challenge

- *Beam Bridge Information* (page 27)
- *Building a Beam Bridge* (pages 28–29)
- *Reflections—Building a Beam Bridge* (page 30)
- materials for abutments (See Setup.)
- paper clips (5 per team)
- paper or plastic cups
- pennies, bolts, or other weights (See Setup.)
- rulers
- scissors
- tape (6" per team)



Time Frame

The Introduction and Mini Challenge can be completed in one class session of about 20 minutes.

The Main Challenge can be completed in 45 minutes to an hour.

Follow up with the Writing Reflection as time allows.

Vocabulary

abutment	failure
beam	force
compression	tension

Build a Beam Bridge

Introduction

1. Introduce the bridge challenges with the following discussion questions:
   —Have you ever walked or driven over or under a bridge?
   —Can you describe it?
   —Why do we build bridges?
   —What materials have you seen used to build bridges?
2. Tell students they will be building bridges out of nothing but paper!

Mini Challenge

1. Have students put the palms of their hands together in a "praying" position and push their hands together.

   Explain that this type of **force** (strength or energy) is called *compression*.

   Compression is a pushing force.

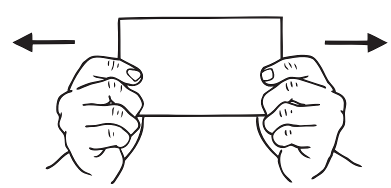
2. Then have them lock their fingers together (*see illustration*) and pull their hands away from each other in opposite directions.

   Explain that this type of force is called *tension*.

   Tension is a pulling force.

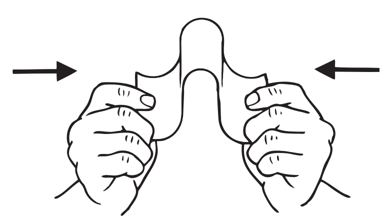
3. Give each student an index card. Have them hold the ends and try to pull the ends away from each other. Ask them to describe what happens. (*Not much! They should not be able to move or break the paper.*)

   Explain that paper is strong in tension, which is a pulling force. That is why they couldn't pull it apart.



4. Now have them try to push the ends of the paper toward each other. Ask them to describe what happens. (*The paper bends.*)

   Explain that the piece of paper is weak in compression, which is a pushing force.

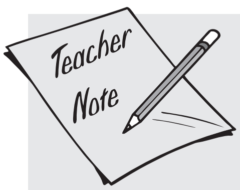


Build a Beam Bridge

Mini Challenge *(cont.)*

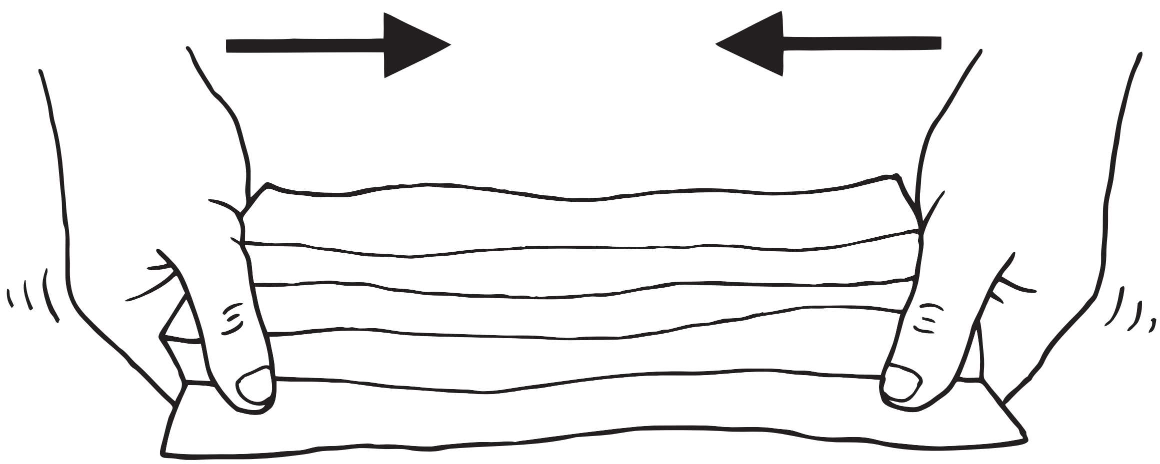
5. Give students several more index cards. Challenge them to fold or roll the paper in ways that will increase its compressive strength so that it's harder to bend.

6. Encourage students to try different types and sizes of folds, and then test each one by pushing the ends of the paper toward each other.

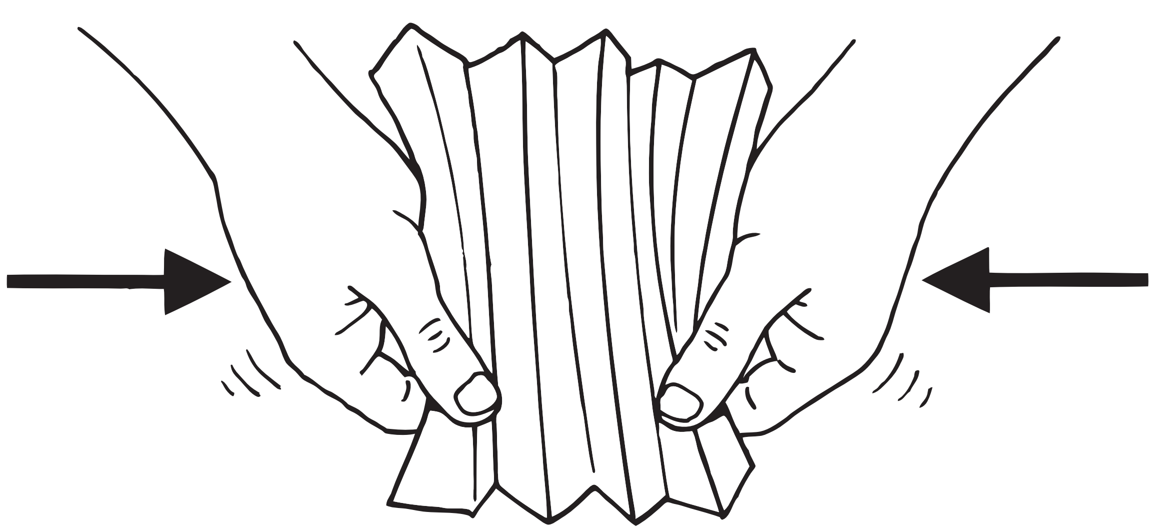


Students should find that folding the paper into an accordion (like corrugated cardboard) will create a lot of compressive strength in one direction, as will rolling it into a tight tube. If they do not make these discoveries on their own, you may want to show them how to fan-fold the paper.

Strong in compression when pushed in this direction.



Weak in compression when pushed in this direction.

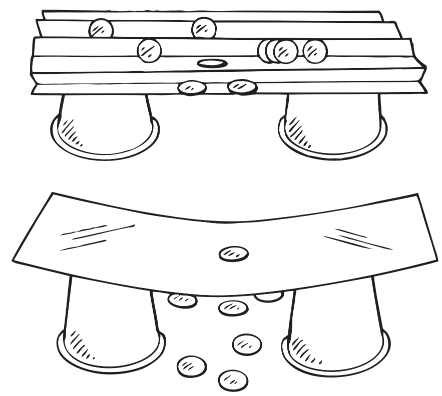


Build a Beam Bridge

Main Challenge

Define the Problem

1. Demonstrate a simple bridge for students. Show them one of the abutment setups you created. Tell students that the two platforms are called abutments. **Abutments**, or platforms, hold up a bridge at either end. They will build their bridge on top of the abutments.
2. Lay a card on top of the abutments. Tell students that the part of the bridge that goes across the abutments is called the **beam**.
3. Show students the weights and ask, "How many weights do you think my bridge beam will hold?"
4. Slowly and carefully add one weight at a time while students count the weights. Continue adding weights until the bridge fails.



✏ On the board or chart paper, record the number of weights your bridge held just before it failed.

5. Challenge students to use what they learned about forces to build a bridge that holds more weight than yours did. Have students choose a partner (or assign partners), and give each pair of students a copy of *Beam Bridge Information* (page 27).
6. As a class, read through the information about tension and compression on a bridge beam.
   —Ask students what their beams will be made of. (*paper*)
   —Ask students to share some ideas about how to make their paper bridge beams stronger than your unaltered paper beam.
7. Tell students that in engineering, the rules are called *constraints*. The constraints tell what the engineers can and can not do. With students, review the constraints for the project on the *Beam Bridge Information* sheet.
8. Explain to students that when something breaks, engineers call that a **failure**. Make sure students know this is different from "failing" in school! During design and testing, failure is an expected part of the engineering process.

Engineers use failures to see what went wrong and to improve their designs so that when they build the real thing, it won't fail. Let students know that when their bridges fail, they can learn from what went wrong and try again.

✏ With students, decide on a definition of *failure* for their bridges and have them write it on their information sheets. For example, "The bridge touches the ground," or "The bridge comes off one or both of the abutments."

Build a Beam Bridge

Main Challenge *(cont.)*

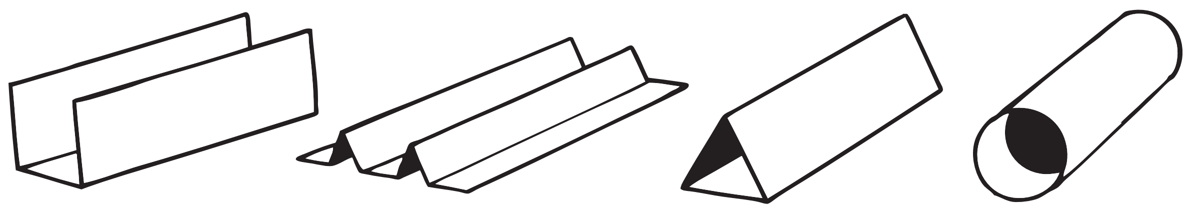
Imagine • Plan • Create

1. Direct students to sketch the first bridge they plan to build and predict how many weights they think it will hold.

✏ Sketch the bridge on the *Building a Beam Bridge* recording sheet.

2. Once the plans are finalized, pass out cards, scissors, and paper clips and provide time for students to build their bridges. Each student or group may also use six inches of tape if needed.

3. As students are working, circulate to observe and prompt with questions as needed. For example, you might ask:
   —What did you do to your paper to make it stronger?
   —If you put too much weight on this bridge, where do you think it will fail?



Test & Improve

1. Have students add weights in the center of each bridge, one weight at a time. If the bridge holds a lot of weights, they can transfer the weights to a paper cup, place it in the middle of the bridge, and keep adding weights to the cup.

2. Students should keep adding weights until the bridge fails.

✏ On their *Building a Beam Bridge* recording sheets, students should record the number of weights **Bridge 1** held just before it failed.

3. Once a bridge fails, ask students the following questions to get them thinking, and then give them time to make improvements and test again.
   —Where exactly is the bridge failing?
   —How can you strengthen the beam at that point?

4. Groups will sketch their new bridge design, predict how many weights it will hold, and build it.

✏ Have students update their recording sheets for **Bridge 2.**

5. Have students use the same procedure to test their new bridge.

✏ Students should record the number of weights the new bridge held on the recording sheet.

Build a Beam Bridge

Main Challenge *(cont.)*

Analyze & Evaluate

1. Have each group share their bridges with the class and report on how many weights each bridge held.
2. Ask them to describe how they built the bridges and how they came to their design decisions.
3. Ask groups to explain the improvements they made and analyze whether the improvements worked or not.
4. Encourage students to cite evidence for their answers, such as "Our first bridge only held 10 weights, but our second bridge held 35 weights, so our second bridge was stronger because it held more weight."

Writing Reflection

✏ Have each student complete the *Reflections—Building a Beam Bridge* writing reflection individually.

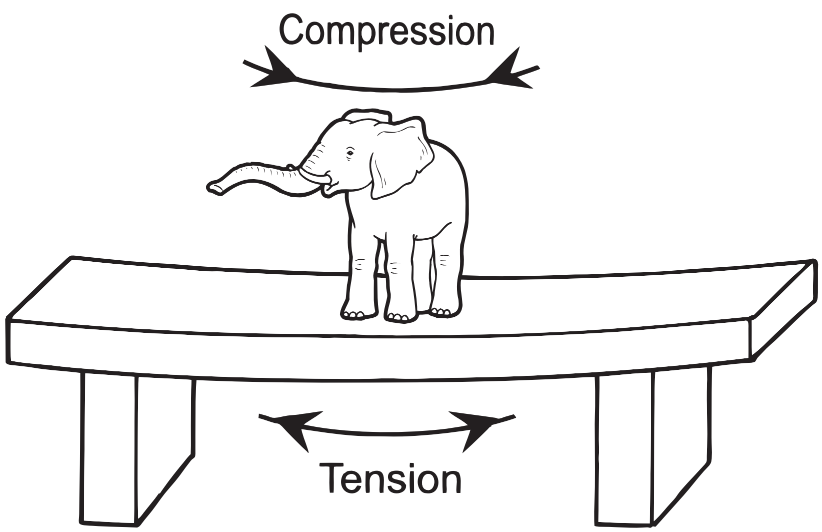
Extensions

- Have students create rivers or roads to go under their bridges.
- Place the abutments farther apart. Give students more tape so they can attach cards to each other to make longer bridges.
- Challenge students to build bridges out of other materials, such as craft sticks, straws, or uncooked spaghetti.

Beam Bridge Information

The **beam** of a bridge is the part that goes across the abutments. The beam must be strong enough to hold the weight of people, cars, or trains that go across it. It must be strong in both **compression** and **tension**.

Here is what happens when you put weight on the middle of a bridge.



The top of the beam is being pushed together toward the middle by *compression*.

The bottom of the beam is being pulled apart by *tension*.

If either or both of these forces are strong enough, the bridge will fail.

Use this information to design and build a paper bridge beam. Try to build your beam strong enough that it will hold a lot of weight!

Challenge Constraints

- ☐ You can use up to 10 cards.
- ☐ You can fold, roll, or cut the cards any way you like.
- ☐ You can use only six inches of tape and five paper clips to hold the cards. You may cut the tape into pieces.
- ☐ You may not attach the cards to the abutments.
- ☐ You may place the weights directly onto your bridge, or you may put them in a paper cup. You must place the weights as close to the middle of your bridge as possible.
- ☐ Once your bridge fails, improve your design and build and test another bridge!

▶ For this project, *failure* is defined as ______________________________

____

____

Name ______________________________ Date ____________________

Building a Beam Bridge

Directions: Use these recording sheets to plan your bridges, then test and record your data.

Bridge 1

1. Sketch the plan for your team's first bridge in the frame below.

2. What will you do with the paper to make it stronger?

3. **Hypothesis:** We think this bridge will hold __________ weights.

4. Our first bridge held __________ weights before it failed.

Name ______________________ Date ______________

Building a Beam Bridge

Bridge 2

1. Sketch the plan for your team's second, improved bridge.

2. What changes did you make to your first design?

____

____

____

____

3. How many weights do you think it will hold? __________

4. Our second bridge held __________ weights before it failed.

5. Was your second bridge more successful than your first? **YES** **NO**

   Why do you think that happened? ______________________________

   ____

   What is your evidence? ______________________________

   ____

Name ______________________ Date ______________

Reflections—Building a Beam Bridge

1. What was the challenge?

____

____

2. How many weights did **Bridge 1** hold? [____ weights]

3. How and where did **Bridge 1** fail?

____

____

4. How did you improve **Bridge 1**?

____

____

5. How many weights did **Bridge 2** hold? [____ weights]

6. Which bridge was more successful? **Bridge 1** **Bridge 2**

   What is your evidence? ____

____

7. What do you think went well? ____

____

8. What would you do differently next time? ____

____

____