Bridge Comparison

Summary of Activity:

Activity Description: Participants will compare the strength of a beam bridge versus a suspension bridge.

STEAM Skills:

- Physics
- Construction Skills
- Engineering (if doing the adapted version)

Ideal Age Group: K-8

Ideal Learning Location: Individual in-person or online activity should be okay. For online offerings, make sure the participant has enough space to make the suspension bridge and furniture that can be taped on.

Used In: Summer 2021.

Materials and Supplies:

• 1 Dixie Cup (small paper cup)	• 20+ Marbles/Weights
• 4 Paper Clips	• 3 ft string
• 6 Regular Straws ○ Any color	• 1 Extra Large Straw (not thick)
• Space across even surfaces (see procedure)**	

General supplies needed: scissors, masking tape, ruler.

** Each participant will need a space to set up their bridge where there is room between two even surfaces for the weight to suspend. This could be between two desks, two chairs, etc.

Talking Points and Background:

Bridges!

Bridges work by balancing the forces of physics through a **superstructure** (girders, trusses, etc) that bears the weight of the bridge itself (dead load) and whatever it carries (live load), and a **substructure** (pillars, abutments, piers, and footings) that grounds the load into the earth beneath the bridge. A bridge needs to resist movement so it can provide a stable surface. Correct engineering and bridge construction can strike the perfect balance to keep a bridge standing.

Let's go over the 5 main types of bridges: **arch**, **beam**, **cable-stayed**, **suspension**, and **truss**. Have you seen any of these bridges in real life before?

1. Beam- The beam bridge was the first type of bridge ever built! It is also the cheapest to build. The beam bridge may only be supported by 2 abutments at either end of it. This becomes dangerous when you have a long beam bridge that carries a lot of live load. Adding supports in the middle (piers or stanchions) can help to stabilize a beam bridge. A beam bridge has forces of compression towards the centre and tension outwards towards the abutments.
    a. Ex: Yolo Causeway, California
2. Arch Bridge- This bridge dates back to over 3000 years ago! An arch bridge uses the forces of its load and gravity to keep itself up with the principle of compression. Temperature can destabilize fixed arch bridges (by expanding/contracting materials), so hinges can be added at each base and the centre to help the bridge adapt.
    a. Ex: Pont-Saint-Martin bridge, Italy (built by the Romans)
3. Truss- A truss bridge distributes its load across a series of small triangular sections fitted together. Vertical supports (wooden or steel) help hold up the bridge using tension, while the diagonal supports add stability via compression, directing the load toward the center of the bridge.
    a. Ex: Cottonwood River Pratt Truss Bridge, Kansas
4. Suspension- Suspension bridges are stabilized with vertical pillars or pylons connected by suspension cables. Attached to these main cables are smaller, vertical suspenders that hold up the bridge deck using tension, the main force that sustains suspension bridges. Only a couple places of a suspension bridge are connected to the ground beneath them, so they can sway in the wind or vibrate when heavy traffic is present!
    a. Ex: Golden Gate Bridge, California
5. Cable-Stayed- A cable-stayed bridge is a variation on the suspension bridge that connects the crossbeam or bridge deck directly to pillars or towers. There's no main cable, just a large number of vertical suspenders fastened to the top of the tower. These suspenders use tension to help keep the bridge deck stable and in place.
    a. Ex: Strömsund Bridge, Sweden

Many bridges are shaped in a **catenary curve** shape! The catenary curve is the strongest shape for an arch which supports only its own shape. Freely hanging cables naturally form a catenary curve.

The world's longest bridge is found in China, the Danyang-Kunshan Grand Bridge. It cost $8.5 billion to build and carries a high-speed railway more than 100 miles.

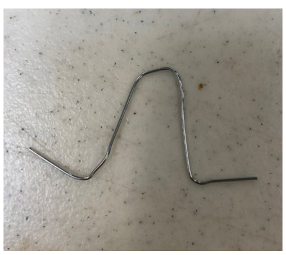
Now, let's compare a simple beam bridge with a suspension bridge.

PROCEDURE:

1. Cut off the bendy part of 6 straws.

2. Cut two 1 inch long pieces of straw with your remaining straw.
3. Tape 2 of your longer straws together at the top.
4. On the other end of the taped straws, tape your smaller piece between the longer pieces.

5. Repeat with 2 other long straws and 1 short straw. These are your 2 bridge towers.
6. Unbend a paperclip into an upside-down 'V' shape.



7. Poke the two ends through opposite ends of the cup, just under the rim, to make a bucket. Younger participants may need some assistance poking through the cup.

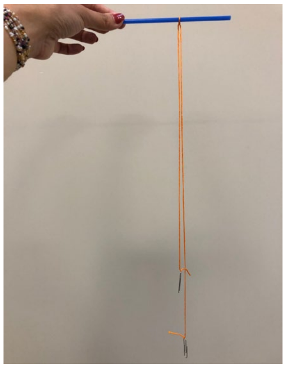
8. Slide another paperclip through the unbent paperclip.
9. Slide the paperclip through a long piece of straw. This is your bridge deck.

10. Tape your two towers on a level surface, like between 2 tables.
    a. The distance between should be enough to fit your bridge deck.
11. Place your bridge deck on top of the smaller pieces of straw.
    a. Make sure the bridge deck is only touching the straws; not the table!

Now you have a **beam bridge**; how many marbles/weights can the cup hold?

Time to convert your bridge into a suspension bridge!

1. With your remaining piece of long straw, tie the center of the string to the center of the straw.
2. Tie 1 paperclip on each end of the string.



3. Drape the string over the two towers & secure the paperclips to a surface to ensure the string stays taut.

Now you have a **suspension bridge**; how many marbles/weights can the cup hold?

Are there some that hold more weight than others? Why might that be (e.g. shorter straw, tighter string on the suspension, towers are closer, etc.)?

In this activity, the suspension bridge should be able to hold more coins than the beam bridge by around 150%. As coins were added to the suspension bridge, the cable (i.e., string) was under tension and reinforced the bridge deck straw, pulling it upwards (while compressing the towers) and allowing the bridge to hold more coins. When the suspension bridge eventually failed, the bridge deck straw likely bent into a V-shape like the beam bridge, but because it was attached by the thread, the straw could not fall and instead the cup may have slipped off of the straw.

Adaptations: Get the kids to modify the design even more so that the bridge can withstand more weight (may need to add another cup).

References or Other Links:

Activity Inspiration: https://www.sciencebuddies.org/stem-activities/bridge-building-designs#summary