

Grade 3 Structures: Bridge Bonanza!

Students learn about strong and stable structures by building three different kinds of bridges and testing their load limits. The take-home message is that triangles are strong and stable shapes.

Time: All of these activities take 1.5 – 2.0 hours

Class Organization: Students work in pairs (can also work in groups of three) and they need two desks with a gap between them to make a bridge span.

Materials:

Mini marshmallows (can't reuse)

Toothpicks (can't reuse)

Small zip bags

Straws

Clear tape (some used to prep supplies, plus one roll for each pair of students)

Embroidery floss or thin string

Pennies (or other small objects that can be added one at a time to test load-bearing limit of bridges)

Plastic cups, string/ribbon, large paper clips

Pictures/slideshow on a USB stick

Optional: large marshmallows and spaghetti strands or skewers for demo cubes and pyramids (or appropriate building toy)

Preparation:

1. Have pictures on a USB stick (a PowerPoint slideshow is convenient).
2. Make sure you have enough copies of the bridge worksheet – one per student.
3. Put mini marshmallows and toothpicks into small zip bags for Introductory Activity and Building Bridges #1 (one bag per pair of students). Separate bags for each activity are good so that the students have only what they need at any given time. Stale marshmallows work better than fresh – just expose them to air for a few hours or even overnight.
4. For Building Bridges #2, make suspension bridge piers and tie string/floss onto suspension bridge decks ahead of time – these are both too finicky for Grade 3 students. Put suspension bridge materials in small zip bags (one bag per pair). The straw piers and decks can be reused – decks need to be replaced when they get weak/creased in the middle.
5. Make cups to hang from bridges to test strength – one per pair of students.
6. Put pennies (or other small, reasonably heavy objects like metal washers) into zip bags (one bag per pair). I use pennies, but they are hard to come by if you don't have a collection already. 80-100 pennies per pair of students is ideal because the suspension bridges can be quite strong. Students can share pennies and take turns testing their suspension bridges if there aren't enough pennies – it's only one bridge out of four that might necessitate sharing.

Introduction

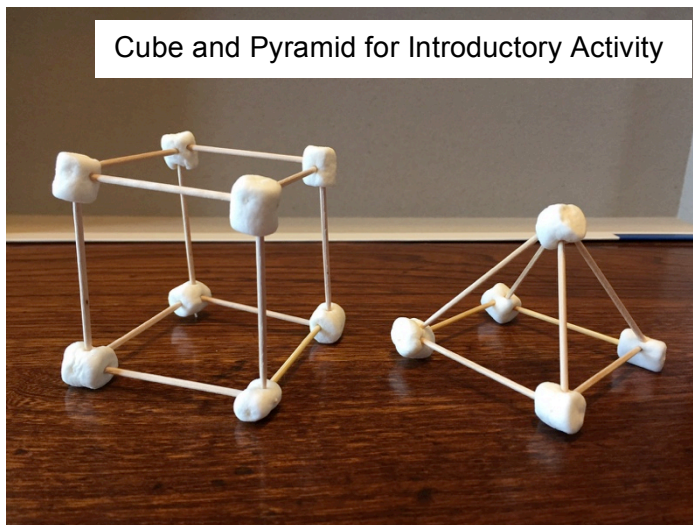
Begin by asking the students if they know what shapes give structures strength and stability. Unless you're coming in at the very beginning of the unit, the students will probably say **domes** and **triangles**. Those are both strong, stable shapes. These activities explore **triangles** (shape) by building different kinds of **bridges** (structure).

You can show some pictures on the SmartBoard of different structures that incorporate triangles: pyramids in Egypt, the Eiffel Tower (overall shape is triangular, plus lots of triangles in the metal structure), bicycle (triangles in frame), playground climber (the picture I use has triangles making up a dome shape – mention both stable shapes), house roof during construction (introduce the term **truss**).

Introductory Activity – Squares versus Triangles

Hand out small bags with mini marshmallows and toothpicks (about 15 marshmallows and 25 toothpicks per pair). Now is a good time to emphasize that eating your science experiments is a bad idea. (I also mention that the marshmallows are stale, the bags have been reused and aren't clean, and they are being given only enough supplies to build their structures.)

Each student builds either a cube or a pyramid using mini marshmallows and toothpicks, i.e. for each pair, one cube and one pyramid (square base or triangular base is fine; see picture below). You can build some as a demo – you could even build large demo structures using regular sized marshmallows and spaghetti strands or skewers. You will probably have to tape multiple strands together if using spaghetti because single strands aren't strong enough. Building toys like Tinkertoy, K'Nex or Magneatos also work.



Tip: It's helpful to tell the students that the toothpicks should be inserted *all the way through* the mini marshmallows. If they just barely insert the toothpicks, their structures will fall apart too easily. Tell them that they should be able to feel/see the tip of the toothpick poking through the marshmallow.

Instruct the students to place their palms gently on top of their cubes and pyramids and move them in a circular motion to feel

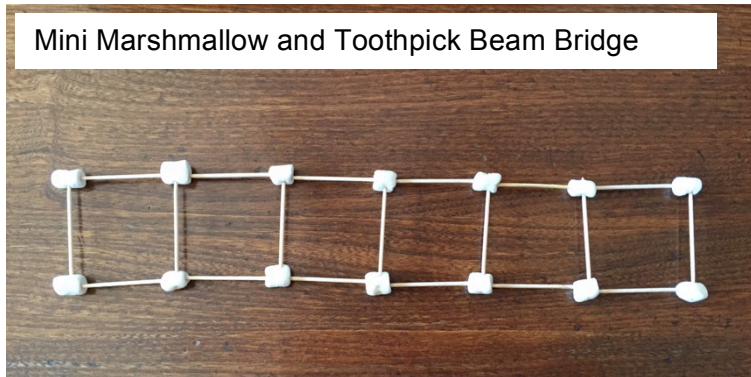
the difference in stability. The cube, with square sides, is quite wobbly. The pyramid, with triangular sides, is quite stable.

Bonus: You can also demonstrate how adding triangles to the cube, i.e. diagonal pieces to make the hypotenuse on the faces, adds a great deal of stability. This only works if you have "sticks" that are long enough – if you have used spaghetti strands or skewers for your demo structures, build your cube with shorter strands/skewers so that the full-length strands/skewers are long enough to span the hypotenuse.

Building Bridges #1 – Beam Bridge versus Truss Bridge

Begin with a short introduction about beam bridges, including a picture on the SmartBoard. Mention the absence of triangles in the structure. Good bridge terms to introduce at this stage are **span** and **deck**.

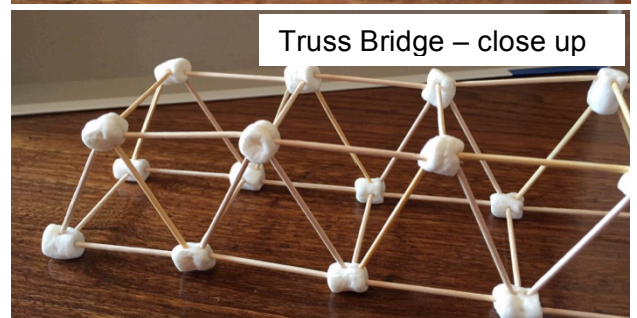
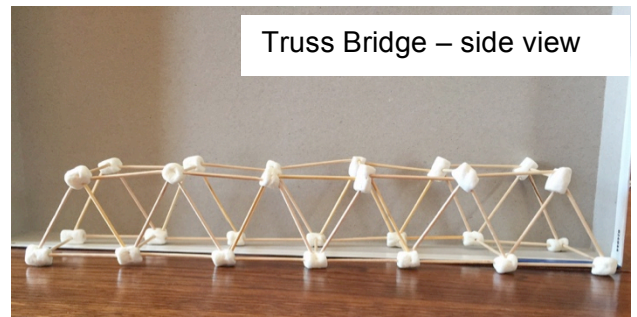
Hand out the small zip bags with enough mini marshmallows and toothpicks for the beam bridge and the truss bridge (about 30 marshmallows and 62 toothpicks), the cups to hold the pennies, and the bags of pennies. The students start by building a beam bridge – looks like a ladder, with 7 marshmallows on each side and 7 rungs (see picture below). Show them how to place their beam bridges to span a gap between two desks – the terminal “squares” of the bridge, or two rungs at each end, should be resting on the desks to give enough support. The first question the students answer is: *Can the beam bridge support its own weight?* (see attached worksheet). Most of the marshmallow/toothpick beam bridges sag under their own weight and some will fall apart completely. (That’s OK – it’s usually because they haven’t inserted the toothpicks far enough. You can help them fix their bridge.)



For the bridges that don’t completely fall apart, the students then test how many pennies they support. Show them how to hang the cup from the *middle* “rung” of their beam bridge. One student adds pennies to the cup one at a time until the bridge collapses. The other student is waiting to catch the cup before it crashes to the floor – but NOT supporting the cup. They record the number of pennies their beam bridge supported before collapse in their worksheets.

Introduce truss bridges with a new picture on the SmartBoard – I use two pictures to show that the trusses (triangles!) can be above or below the deck of the bridge. The students then *rebuild their beam bridges* and add more mini marshmallows and toothpicks to make a truss bridge (see picture). The truss bridge gets tested the same way as the beam bridge – same questions on worksheet. The students will see that the truss bridges are MUCH stronger than the beam bridges – relate this back to the addition of **triangles** to the structure of the truss bridge.

Note: At some point early in the beam bridge building, you can introduce the terms **dead load** and **live load**. Loads create forces on structures. Dead load includes all the permanent parts of the structure – relate that to



Testing Truss Bridge



the worksheet question “*Can the bridge support its own weight?*”. Live load includes all the removable, changeable parts of a structure such as vehicles, people, trains, furniture, wind etc.

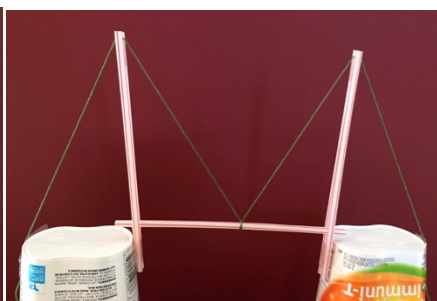
(http://www.pbs.org/wgbh/buildingbig/educator/act_mini_load.html)

Building Bridges #2 – Beam Bridge versus Suspension Bridge

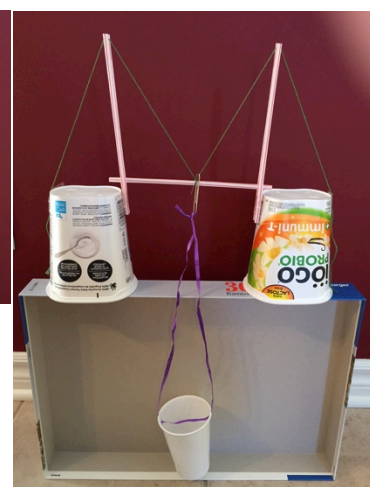
Introduce suspension bridges with a new picture on the SmartBoard – the Golden Gate Bridge is a great example and lots of students recognize it. You can repeat/reinforce the terms **deck** and **span**, and add the term **pier** (sometimes also obvious in the truss bridge pictures). Also mention that many suspension bridges include trusses below the deck, including the Golden Gate Bridge.

Hand out the small zip bags with the materials for the suspension bridge construction. Detailed instructions for making the piers (do this ahead of time for the students) and tying the string/floss onto the straw that serves as the bridge deck are here: http://www.pbs.org/wgbh/buildingbig/educator/act_suspension_ho.html. I also give the students a straw without attached string/floss; this is their straw beam bridge. They need something to compare the suspension bridge to that’s made of the same materials. I usually take a couple minutes to introduce the idea of a fair comparison in science (i.e. appropriate controls). Since the building materials have changed, it’s not really fair to compare a straw suspension bridge to a marshmallow/toothpick beam or truss bridge.

Demonstrate how to tape the piers to the sides of two desks across the bridge span and show them how to insert the straw, how to slide the string/floss into the space between the pier straws at the top of the piers and how to tape the ends of the string/floss to the desk tops (see pictures below for a guideline). They start with a plain straw (no string/floss) to make a straw beam bridge then they use the straw with the string/floss to make a suspension bridge. They test each bridge the same way as the marshmallow/toothpick bridges, hanging the cup from the middle of the straw (questions on worksheet).



Straw Suspension Bridge Construction and Testing



The straw beam bridge can support much more load than the marshmallow/toothpick beam bridge – you can relate this to choice of construction material in the “real world”, i.e. wood vs. steel vs. concrete with rebar. The suspension bridge can support quite a lot of load (relatively speaking) – you can relate this to suspension bridges in the “real world”, which are among the strongest. Be sure to point out the triangle shapes in the suspension bridge, formed by the strings between the deck, the piers, and the desks. Reinforce that triangle are strong and stable shapes.

Bonus: If you have time, you can show a video of the Tacoma Narrows Bridge collapse in 1940. It’s an example of what can happen when bridges aren’t engineered correctly. Bridges (and other structures) still collapse today but they tend to be sudden collapses. The Tacoma Narrows Bridge collapse took a long time and the drama was captured on film. I use the following video (about 6 minutes long):

<https://www.youtube.com/watch?v=j-zczJXSxw>.

Background information about this bridge and its collapse can be found here:

http://encyclopedia.kids.net.au/page/ta/Tacoma_Narrows_Bridge.

Links for Background and Activity Information

Good general info about bridges: <http://www.pbs.org/wgbh/buildingbig/bridge/index.html>

Companion Educators’ Guide: <http://www.pbs.org/wgbh/buildingbig/educator/index.html>

Building Bridges Activity #1 Inspiration:

https://cyfar.org/sites/default/files/cyfar_research_docs/Sweet%20Bridge.pdf

Building Bridges Activity #2 Inspiration/Procedure:

http://www.pbs.org/wgbh/buildingbig/educator/act_suspension_ho.html

(Note: I find that wrapping the end of the string/floss around paper clips is not necessary – it works just fine to tape the string/floss directly to the desk.)

Wikimedia Commons Links for Bridge Workshops pictures

Roof truss:

https://commons.wikimedia.org/wiki/File:Defense.gov_photo_essay_100713-A-51700-167.jpg

By English: Sgt. Nicholas Olson [Public domain], via Wikimedia Commons

Pyramids of Gizeh: https://commons.wikimedia.org/wiki/File%3AAll_Gizah_Pyramids-2.jpg

By Ricardo Liberato ([1]) [CC BY-SA 2.0 (<https://creativecommons.org/licenses/by-sa/2.0>)], via Wikimedia Commons

Eiffel Tower:

https://commons.wikimedia.org/wiki/Tour_Eiffel#/media/File:Tour_Eiffel_Wikimedia_Commons.jpg

By Benh LIEU SONG - Own work, CC BY-SA 3.0,

<https://commons.wikimedia.org/w/index.php?curid=6926930>

Eiffel Tower (close-up):

https://commons.wikimedia.org/wiki/File:Tour_Eiffel_01.JPG

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Bicycle:

<https://commons.wikimedia.org/wiki/File:Cykel.JPG>

Picture of a black Mustang bicycle originally created and uploaded to Danish Wikipedia by [da:Bruger:Gajda-13](#), This file is licensed under the [Creative Commons Attribution-Share Alike 3.0 Unported](#) license.

Playground climber:

<https://commons.wikimedia.org/wiki/File:Climberdome.JPG>

By GreenGlass1972 (Own work) [Public domain], via Wikimedia Commons

Beam Bridge:

https://commons.wikimedia.org/wiki/File%3AGerber_beam_Bridge%2CKuma_village%2CJapan.jpg

By Katorisi (Own work) [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0>)], via Wikimedia Commons

Truss Bridge (trusses on top of beam):

https://commons.wikimedia.org/wiki/File:Illecillewaet_River_Bridge.jpg

Illecillewaet River Bridge, Revelstoke, BC. Photo by Alan Silvester ([mascdman](#)). {{cc-by-sa-2.0-ca}}

Truss Bridge (trusses underneath beam):

https://commons.wikimedia.org/wiki/File%3AKingston-Rhinecliff_Bridge2.JPG

By David Hermeyer and Sam [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0>) or GFDL (<http://www.gnu.org/copyleft/fdl.html>)], via Wikimedia Commons

Suspension Bridge:

<https://commons.wikimedia.org/wiki/File%3AGoldenGateBridge-001.jpg>

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