Let’s build bridges!

Overview

The real test of scientific learning and thinking is in finding solutions to real problems and the ability to explore, learn, and apply different concepts in situations with constraints. One such example is the case of making bridges. Bridges have been crucial to growth of human civilization and continue to play an important role in development in human society. Yet we also regularly hear the news of failure of bridges and accidents caused by these. Understanding the factors that give structural strength to a bridge is a very empowering scientific knowledge for any student as an individual and as a citizen of the society. In this Learning Unit, students will explore bridge design by thinking like real engineers and designers. First they will observe different types of bridges through photos, and identify material used, shapes, size and their purpose. Next they will build and test paper bridges while discovering which shape offers strength and better support. And lastly, they will undertake a thought exercise which allows them to think all possible design considerations while building a bridge.

Type of Learning Unit: Classroom/Field

Minimum time required: 5 sessions of 40 minutes each

Links to Curriculum: This Learning Unit incorporates concepts from Chapter on Forces, and concepts of geometrical shapes. In addition, students thinking may connect them to diverse topic such as properties of materials, environmental science, etc.

Materials required: A4 paper sheets, lightweight container (small plastic dish or paper box), *Kabuli Chana* or marbles, paper clips, glue, clay, thread.

Learning objectives: After doing this unit, students would be able to:

- Analyze real-world bridge images and identify materials and structural features
- Construct paper bridges using different shapes
- Predict and test the strength of paper bridges
- Compare the structure and strength of various paper bridges
- Reflect on various bridge designs and their uses, and the factors that influence bridge designing

Introduction

Bridges are amazing structures that help us cross rivers, valleys, and even other roads. You might have heard of the famous Howrah Bridge in Kolkata or the new *Atal Setu* in Mumbai, which is (currently) the longest sea bridge in India! Have you ever heard of the *Chenab* Rail Bridge in *Jammu* and *Kashmir*, or the living bridges of Meghalaya? Are they natural or human-made? Bridges, both in India and around the world, are known for their size, beauty, and history. They connect people and places, making travel faster. In this unit, we will explore some simple bridges and learn why they are considered great examples of engineering. You may have also heard news of many bridges breaking these days. Why do you think bridges break? Let us start understanding bridges step by step.

Q1. Have you seen bridges around you? Where you have seen bridges, and what was the purpose of the bridge? Share with your classmates.

> Bridges can be made over roads (flyovers, footover bridges), water bodies, railway tracks, etc. It can be made for light vehicles, heavy vehicles, people, animals etc.

Q2. Have you heard about any bridge breaking/collapsing? From which point did it break? What was the cause?

> Bridge collapses can occur due to design flaws, material failures, overloading, or poor maintenance. Natural disasters like earthquakes or floods, construction errors, and collisions (e.g., with ships) also contribute. Environmental factors such as erosion or fatigue from repeated friction and stress can weaken structures over time. Accidents or rare acts of sabotage may also play a role.

Q3. Draw the bridges you have seen in your life. What geometrical shapes do they include?

> In general there can be discussion on "Is a flyover the same as a bridge?" A flyover is like a bridge because it's built to go over roads or junctions to keep traffic moving smoothly. Both use similar ideas and design principles to stay strong and safe, so a flyover is a kind of bridge.
> If students are comfortable, they can draw the bridges on the board also.

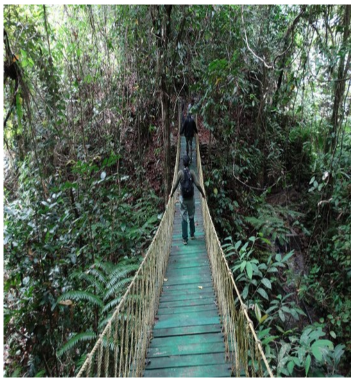
Task 1: Looking at some actual bridges: Photographs of some real bridges are given here.


(a)


(b)


(c)

(d)



(e)

(f)

(g)

(h)

(i)

Figure 1: *Various examples of bridge*

> The teacher can display images of bridges on a screen or projector. The teacher can search for additional similar images online to share with the class. Students can engage in discussions about the bridges shown in the images.

Have you seen any bridges with similar structure? Where? In each of these bridges, the flat part of the bridge is common, on which humans, animal and vehicles pass through. In addition, certain structures, parts are made to support the flat part of the bridge.

Q4. Can you guess the materials required in building or constructing support structures in each of these bridges?

(a) ____________________ (b) ____________________ (c) ____________________

(d) ____________________ (e) ____________________ (f) ____________________

(g) ____________________ (h) ____________________ (i) ____________________

> (a) – Steel, (b) – Steel, (c) – Steel, (d) – Stone and cement, (e) – Wood and rope, (f) – Steel, stone, cement,

(g) – Wood, (h) – Aerial roots, (i) – Fallen tree

Q5. (a) In which of the above cases, support is given to the flat part from below? Which materials are used for these support structures?

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(b) In which cases support is given from above? What materials are used for the support structures?

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Q6. What geometrical shapes you can identify in each of the bridges?

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Q7. Is there any passage of vehicles/people under the bridge? Does it affect the overall design of the bridge?

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Task 2: Making a paper bridge

Make groups of 3-4 students. We want to build a simple model of a bridge using paper as a material. Take two compass boxes/ books /blocks with equal height as two end supports. Take two unwrinkled A4 paper sheets.

Sheet 1: Can be used creatively, by folding, cutting, or gluing/taping as needed, to construct and reinforce the flat part of the bridge. The length of this structure should compulsorily be 17 cm only.

Sheet 2: Use a part of it as the flat road surface of the bridge. This flat paper will rest on the structure you created with sheet 1. You may use glue or tape to combine sheet 1 and 2.

The bridge created with those 2 sheets should rest on the end supports one centimeter on each side as shown in the figure 2. Do not use glue, tape, or staples to attach the bridge to the end supports. You are also not allowed to support the bridge from the middle.

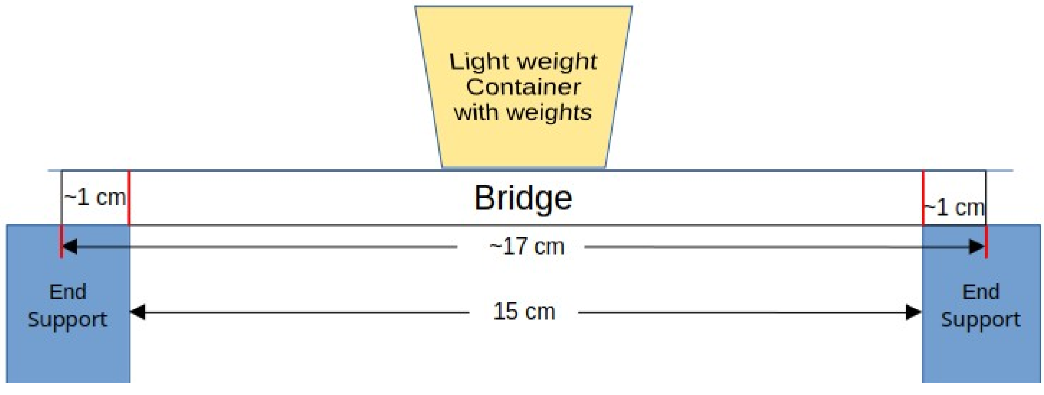

Figure 2: *Setup to test the Bridge*

Rules while making the bridge:

1) The two end supports (pillars) supporting the bridge must be placed 15 cm apart.

2) while you are allowed to cut or glue/tape to combine sheet 1 and 2, you are not allowed to use glue, tape, or staples to attach the paper bridge to the end supports (pillars) at either end.

Design a bridge capable of supporting a greater amount of weight while adhering to these rules. Some suggestive shapes for support structures using second paper are given below. You should also come up with at least one new design.

i. Plain paper with no folds and no wrinkles
ii. Rolling the paper from both ends as an arch
iii. Folding the paper such that a triangular cross section can be seen
iv. Folding paper in zigzag form
v. Folding the paper to have a U-cross section
vi. Forming cuboidal structure by folding paper
vii. Making supporting pipes by rolling both long edges of the paper

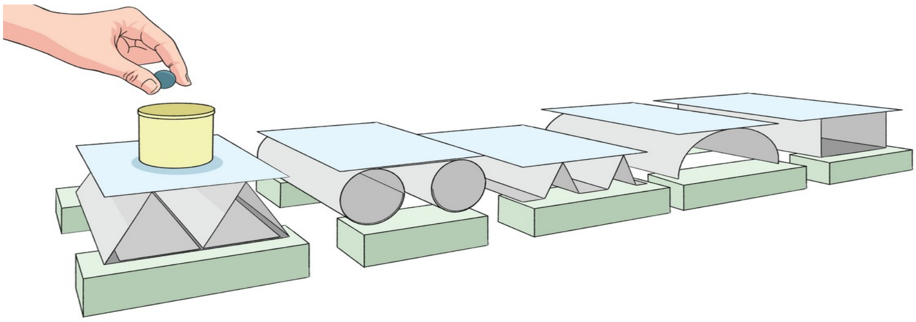

Figure 3: Suggestive p*aper structures for bridges*

4) The maximum weight that can be supported by the bridge (also known as load bearing capacity of the bridge) can now be tested by putting a lightweight container (plastic dish or paper box) in the middle of the bridge and adding small weights like *chanas*/coins/marbles to it one by one. (You don't need to calculate the total weight; simply count the number of objects placed on the bridge, as each object has approximately the same weight. For example, the bridge's capacity can be expressed as the number of objects it holds, such as 10 marbles or 5 small blocks.)

Q8. Describe the shape/structure of your bridge, and **predict** how much weight the bridge can support?

Once you make your predictions, start adding weight to the lightweight container to test your bridges.

Rules while testing the bridge

1) You cannot place the paper cup and weights on the end support or pillar; You have to place the lightweight container only in the middle of the bridge.
2) Use the same lightweight container consistently for testing all the bridges.
3) Make sure you use the same type and size of paper for all your tests.

Note: Any paper bridge that does not adhere to the specified design constraints given earlier cannot be tested for strength or performance.

Q9. Explain significance of point 3.

When you put too much weight in the container, the middle of the bridge will start lowering towards the ground. You can keep adding weight until the bridge collapses OR the shape gets permanently deformed, The weight at this stage can be considered just over the maximum capacity of the bridge.

Guide students to add items slowly and observe changes (e.g., slight bending, deformation, or collapse).

The rules ensure that every student’s bridge is made with the same materials (two A4 sheets), comparable quantity of material, and methods (cutting and gluing/taping allowed but no additional materials). If a bridge uses extra paper, tape, or other materials, it’s not a fair test because those additions could make it stronger or weaker than intended. Only bridges following the rules can be compared fairly to see how design affects strength.

Deformation is any change in the shape or structure of the paper bridge caused by the weight placed on it. This includes permanent bending, stretching, or twisting without necessarily breaking. Some deformations may hold weight and some may yield.

Collapse is when the paper bridge completely loses its structure and can no longer support the weight, often resulting in failure like falling apart or flattening.

The teacher can make the following table on the blackboard to get a comparison of the structure and load bearing capacities of the bridges made by different groups (As many rows as number of groups):

	Shape/Structure of bridge structure	**Predict how much weight the bridge can support**	**How much weight did the bridge support?**
1	Plain Paper (no folds)		
2	Zig-zag		
3	…….		
4	……..		

Q10. How does the paper bridge changes with increasing loads, and what is its maximum capacity?

Students should discuss that a single item doesn’t bend the bridge because the paper’s design (e.g., folds, arches, or supports) can handle small loads. As more weight is added, the paper’s structure is stressed, leading to deformation or failure. Encourage recording the maximum load to compare designs.

Q11. When we add weight to the container, their total (resultant) weight (force) acts on the paper. What is the direction of this force? Are there any other forces acting on the paper?

Q12. Which type of structure(s) is (are) not able to take much load?

The strength of a bridge depends on its design and how the two A4 sheets are used. Folding sheet into shapes like arches or triangles distributes weight better than a flat sheet. Gluing parts to create supports (e.g., rolled tubes or folded beams) adds strength. Strong designs prevent bending or collapsing under weight.

Q13. How does the design affect the strength of the bridge? What do you think happens?

Task 3: Bridge design considerations

Design brief: Imagine you are an engineer, and you have been given the following design brief: Two towns are separated by a sea-water creek, 500 meters wide at points A and B. Across this creek we need to build a bridge that will support the weight of about 40 trucks (live load) at a time. The creek is affected by the ocean tides. At high tide, the depth of water in the creek is around 6 meters.

Figure 4: *Aerial view of Towns A and B separated by a river*

At the most basic level, bridges serve as paths for transport. But in some sense they also are the links between two communities or cultures (for example, the 2 towns mentioned in the design brief). The design of the bridge is influenced by a number of factors. Use the given example to discuss the kind of factors an engineer may need to think about before designing a bridge. This will give a better understanding of any design problem.

Q14. What factors would you consider while building this bridge? Some factors are listed below. List at least 10 more.

i) Stability of bridge during strong water flow
ii) Materials that will bear the weight of the bridge
iii) Cost of construction

In a Design thinking process, problem identification is an important step. Students may bring up the

following factors:
(1) It should be able to withstand tidal water movement.
(2) It should be resistant to corrosion by sea (salty) water.
(3) Depth of the creek should be considered.
(4) Daily traffic should be considered.
(5) Size of the vehicles should be considered.
(6) Wind directions.
(7) Rainwater drainage.
(8) Structures and strengths, choosing of material
But then, the teacher can prompt them for these too:

- Type of soil over which the pillars of the bridge will be constructed
- Precautions against natural disasters
- Location of the bridge
- Safety and security (for eg: lights at night)
- Accessibility
- Resource efficiency
- Easy maintenance/Repair-ability
- Landscape design
- Aesthetics (symmetry, simplicity, elegant, composition, colour, texture)
- Economic feasibility / costs
- Environmental effects
- Social and cultural benefits offered
- Context: bridges should complement their context. This means considering the geography,
- Topography, rural or urban setting, socio-cultural aspects, any existing structures, visibility of the bridge etc.
- "Views" from the bridge- Bridges can be viewed or can serve as viewing platforms.
- Noise barriers to curb noise pollution
- Lighting on the road
- Extra lanes for cycling, walking etc.
- Skilled labors in construction
- Accident prevention instruments like convex mirrors
- Disaster detectors

Q15. What kind of environmental harm can happen due to construction of a bridge?

Students can discuss range of environmental impacts caused by bridge construction, such as habitat destruction, water pollution from construction waste, and disruption of local ecosystems, including aquatic life. Encourage them to think about both immediate effects, like deforestation or soil erosion, and long-term consequences, such as altered water flow or increased carbon emissions from construction activities.

Q16. What all you can do to make the construction of this bridge less harmful for the environment?

Encourage students to think about sustainable practices, such as using eco-friendly materials, minimizing land disturbance, or implementing erosion control measures. Encourage creative solutions like incorporating wildlife corridors or replanting native vegetation to restore habitats. Ensure students provide specific examples to demonstrate their understanding of environmental harm and mitigation strategies.

Task 4 (Possible extension) : Using a different material - Threads

Now that we have looked at ‘paper’ as a material to build bridges and tested various designs, let us try to make use of thread to design stronger bridges. Can you think of ways to do it?

You can do this activity in groups. You can use cardboard/chart paper and threads to design a bridge such that the load is taken up by the thread, giving more strength to the bridge. You also need to ensure that the pillars supporting the entire structure have a firm support themselves. Here is an example:

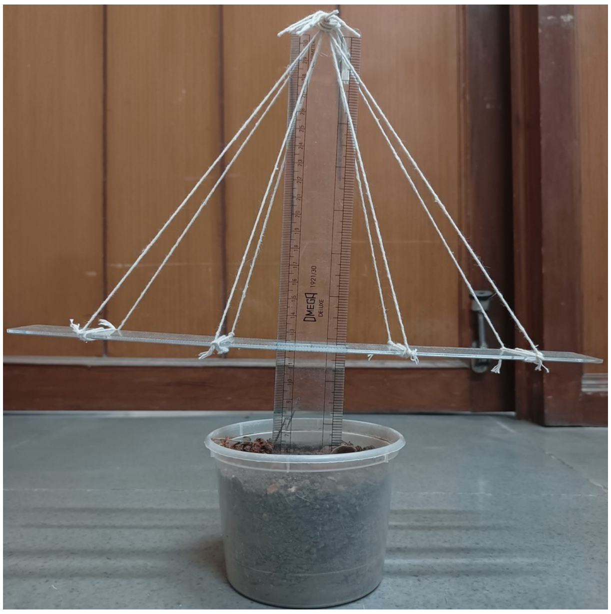

Figure 5 : *Making a bridge using threads*

Q17. Can you describe this picture? What are the materials used? How does the structure help in load bearing?

As you can see, here we have used plastic scale to make the skeleton of the bridge. You can instead use multiple layers of paper or cardboard to make it and then tie threads (you might have to punch holes or cut small slits in the cardboard for the threads to stay and not slide away) to it to help bear the load.

Q18. Is there some particular pattern in which you tie threads?

Feel free to design your own bridge, but make sure that threads are doing the weight lifting and not there just for aesthetics.

Q19. How will you test if the threads you used are actually the ones bearing weight?

> The bridge’s design determines how it handles the weight on it. Folding the bridge sheet into an arch spreads weight to the ends, while a truss with triangles stays rigid. More about it explained in the next section. Cutting strips to create supports or gluing folded sections increases stability. A flat, unfolded sheet sags easily, but a well-designed bridge with folds or supports holds more weight without collapsing.

Effect of triangular shape on strength of the bridge

If students are curious, teacher can have a brief demonstration and discussion on how the same material such as paper can take different load in different shapes. Teacher can start with a simple demonstration using a ruler:

Take the scale and hold it in two different orientations as shown.

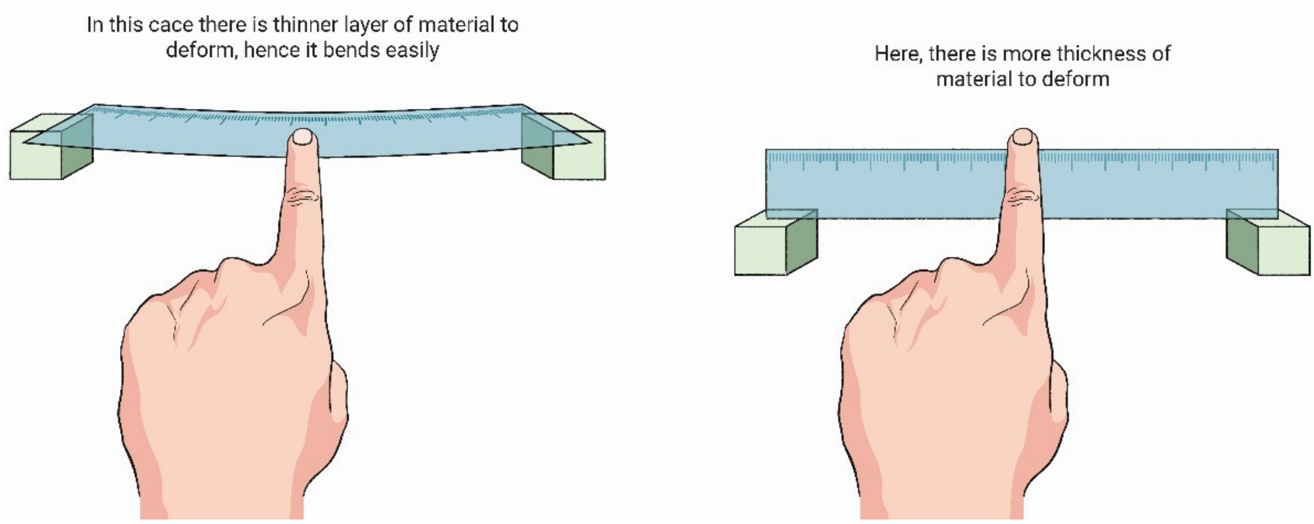

Figure T1 : *Force acting on different orientations of the scale, a model*

Ask students in which case, the scale bends with less force? In which case, force acts on higher thickness of material of the scale?

In the second case, when the force is applied along the side of the scale, there is more thickness of the material to resist the force.

Further, teacher can demonstrate an activity with 5 scales and pieces of molding clay. Take a cuboidal block of soft clay and put a scale on it in vertical orientation. As you press the scale onto clay, the clay will break into two parts.

Now take 2 scales and keep them in a triangular arrangement. Make 2 similar cuboidal blocks of soft clay (at least 1 cm thick) and fix the triangular arrangement on these two blocks. Now, press the top of the triangle with your finger.

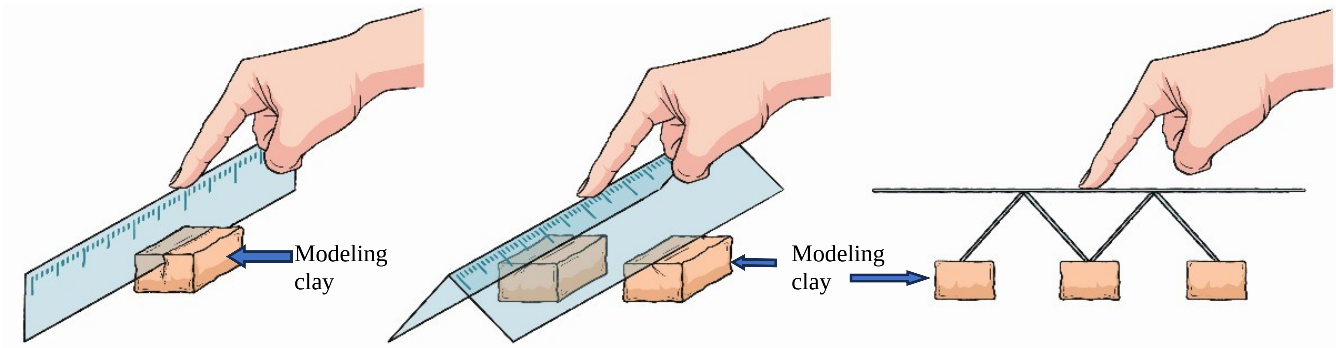

Figure T2: *Force acting on scales arranged in a triangular arrangement*

Students will observe that if they press the top hard enough, i.e. with enough load/force, clay/support objects at the side are pushed away from the scale. This demonstrates that the force of the load is transferred downwards as well as sideways in truss (triangular arrangement) bridges, giving it more stability.

Now take 4 identical scales and make 3 similar cuboidal blocks of soft clay (all having identical height of more than 1 cm). Arrange the scales in 2 such triangular arrangements adjacent to each other (M shape) kept on 3 blocks of clay. Put another scale on top of it and press on it with same force as you pushed in previous 1 triangular arrangement. Now students would be able to apply more force, and they'll notice that clay will deform much less. Also the clay in middle block will deform less than the side clay blocks. From this students may observe that force by middle scales on clay seems to be lower than the side two scales even though student applied force in the middle.

Support structures to horizontal surface of any bridge are made to transfer its load to supporting pillars. In good bridge design, the load on horizontal surface should be transferred to the supporting pillars and the ground below in such as way that there is minimum bending in any of these parts.

The same phenomena can be observed in paper bridge, when paper is arranged in zig-zag (or triangular forms), without any wrinkles. It is also important to notice that how skill-fully those folds are made, and the folds should be made at uniform distances. For example in the case of the triangular zig-zag bridge, does the number of notches have a role to play in the strength of the paper bridge? Would it also depend on how sharply the folds (edges) are made.

Figure T3 shows how one can successively fold a A4 sheet of paper into half 3 times, to give lines/folds at a uniform distance. Then the sheet can be re-folded to make a bridge with 4 triangular folds. Use the same technique to make paper bridges with more number of triangular folds (8 folds, 16 folds...etc.)

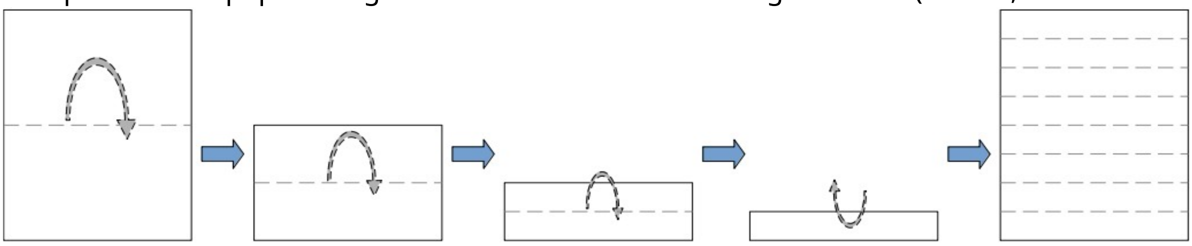

Figure T3: *Procedure to fold paper to make bridge with triangles or rectangles*

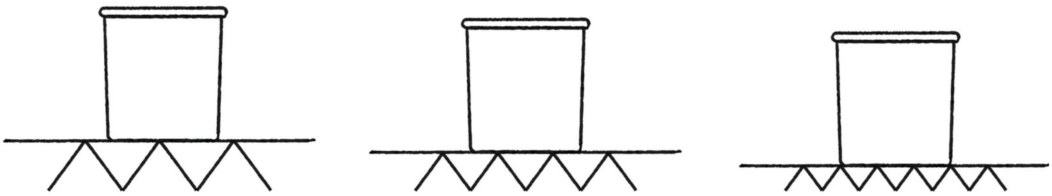

Figure T4: *A Paper bridge with different number of folds*

Students may also note that such triangular and rectangular truss geometries are also used in packing materials for sturdy yet lightweight packaging. Students can try to find such packaging materials and study their designs and strengths.

Suggested Readings

1. Zhong, B., Liu, X., & Li, X. (2024). Effects of reverse engineering pedagogy on students' learning performance in STEM education: The bridge-design project as an example. *Heliyon, 10*(2), Article e24278. https://doi.org/10.1016/j.heliyon.2024.e24278

2. Goode, J. S., Friedrichsen, J., Mach, N., Valenti, C., Lander, D., Carlson, D. W., & Zarske, M. S. (2024,

September 11). Bridge design: Load determination and member sizing. *TeachEngineering*. https://www.teachengineering.org/lessons/view/cub_brid_lesson02

Image Sources

Figure 1: Photographs of Various Real Bridges

(a): ExportersIndia. (n.d.). *Foot over bridges, structure type: Prefabricated* [Product photograph]. https://www.exportersindia.com/product-detail/structural-steel-fabricated-foot-over-bridges-4126495.htm Retrieved October 3, 2025,

(b): Doodles43. (n.d.). *Golden Gate Bridge San Francisco* [Photograph]. Pixabay. https://pixabay.com/photos/golden-gate-bridge-san-francisco-1549662/ Retrieved October 3, 2025, from

(c), (e), (g): Muralidhar, A. (n.d.). *Bridge photographs (c, e, g)* [Personal photographs].

(d): alex1965. (n.d.). *Stone Bridge Verona* [Photograph]. Pixabay. https://pixabay.com/photos/stone-bridge-verona-italy-3067953/ Retrieved October 3, 2025, from

(f): ANI. (2024, June 21). *Indian Railway conducts a trial run on the newly constructed world's highest railway bridge—Chenab Rail Bridge* [Photograph]. The Hindu. https://www.thehindu.com/news/national/railways-conducts-trial-run-on-worlds-highest-arch-rail-bridge-in-j-k/article68314011.ece

(h): Ganesh Mohan T. (n.d.). *Umshiang Double-Decker Root Bridge 01* [Photograph]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Umshiang_Double-Decker_Root_Bridge_01.jpg Retrieved October 3, 2025, from https://creativecommons.org/licenses/by-sa/4.0/

(i): Pinterest. (n.d.). *Natural tree bridge over stream* [Photograph]. https://i.pinimg.com/originals/d8/16/2c/d8162c3debb12949ef18761342008de8.jpg Retrieved October 3, 2025

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