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SySTEM ALERT!

Tomorrow is almost here.

This beautiful bridge in Istanbul was never actually built, but it was imagined in the 16th century by Leonardo da Vinci. This artist rendition used with permission from www.uswitch.com/car-insurance/guides/bridges-never-built/.

The bridge that was lost for 500 years

In 1502, excitement was spreading among inventors and builders. The sultan of the great Ottoman Empire had just announced his desire for a bridge across the Golden Horn, a major waterway. One problem: nobody knew how to build such a long bridge.

One designer who responded to this opportunity was Leonardo da Vinci. Leonardo already had a reputation in Italy for his skill in engineering, science, mathematics, and painting. But his many accomplishments did not sway the sultan; the bridge design that Leonardo sent to him was rejected. The bridge remained unbuilt.

Leonardo's plan was forgotten about.

That is until 1952. Officials in present-day Turkey found Leonardo's letter describing the plan. A sketch was also found. This is interesting to history buffs, but engineers had a question: would the bridge have worked?

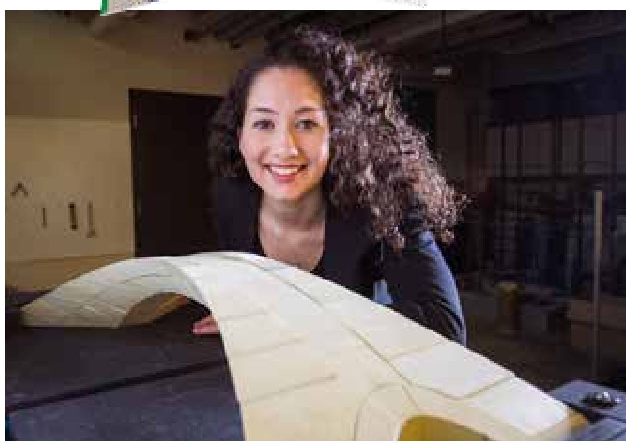
In 2019, MIT students Karly Bast and Michelle Xie decided to find out. They worked with professors to build a scale model of the bridge. Their model spanned about 32 inches. Compare that to the length of Leonardo's design – 919 feet. (If built, it would have been 10 times longer than typical bridges of its day.)

The MIT team 3-D printed 126 blocks for their construction. One fascinating aspect of Leonardo's bridge is that it requires no connecting pieces or mortar. Instead, the angled blocks rest together in such a way that the downward force of gravity actually compresses the blocks together.

"It's all held together by compression only," Bast explained. "We wanted to really show that the forces are all being transferred within the structure."

The result? The team tested their scale bridge and determined that Leonardo's design was sound! If it had been built, it would have been the world's longest bridge, tall enough for ships to pass under, and resistant to earthquakes.

Since the rediscovery of his design in the 1950s, some real-world bridges have been inspired by his design. These are much smaller pedestrian bridges built with wood and steel instead of stone blocks. ⚠



Karly Bast unveiled a scale model of a bridge designed by Leonardo da Vinci. The model she and her team members created proves that Leonardo knew his stuff! Image credit: Gretchen Ertl

TRUST THE TRUSS

The truss is a classic bridge design that reaches back to the Roman Empire. Travelers have trusted its strength. Engineers have admired its beauty and efficiency. Model bridge builders have appreciated its straightforward construction.

A truss is a rigid structure made of beams. The beams form separate shapes, and the shapes are arranged to support one another. You could say that a truss is more than the sum of its parts.

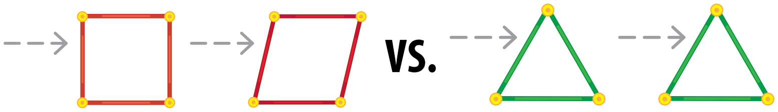
Trusses are used for more than just bridges. For example, houses with gabled roofs contain trusses in their internal support structure.

IS THE TRIANGLE THE STRONGEST SHAPE?

The secret of the truss is the triangle. Most truss bridges use triangular sections as support structures. Why is the triangle considered by many to be the strongest shape?

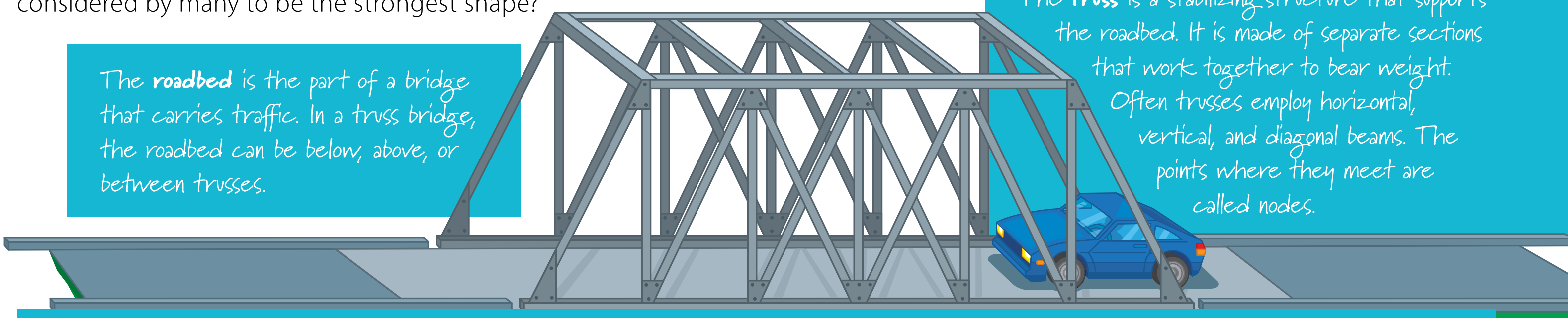
Under pressure, support structures can fail where lines come together. Imagine a square with a force pushing on it. Even if the material is strong, the angles can pivot. The shape can collapse.

Now imagine the same force pushing on an equilateral triangle. The lines brace one another and can't pivot at the angles. The shape holds together. Now imagine several triangles linked in a truss, supporting one another. You can understand why this structure is so strong. ⚠



The **roadbed** is the part of a bridge that carries traffic. In a truss bridge, the roadbed can be below, above, or between trusses.

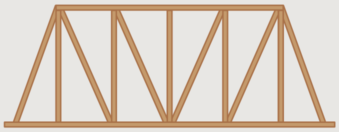
The **truss** is a stabilizing structure that supports the roadbed. It is made of separate sections that work together to bear weight. Often trusses employ horizontal, vertical, and diagonal beams. The points where they meet are called nodes.



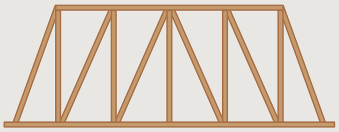
When a truss bridge supports a load (such as a vehicle passing over it), it must resist two forces: compression and tension. **Compression** pushes the material together. **Tension** pulls it apart. Both forces can destroy. Points where lines connect must be especially strong to resist them.

Truss bridge types

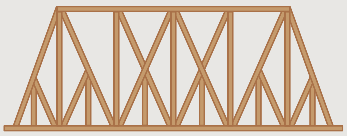
The three types of truss bridges shown here are only a few of the many effective trusses that have been discovered. And not all trusses are easily defined. How would you design your truss? ⚠



Howe truss: The diagonal supports slope toward the center of the truss. Vertical supports complete the triangular internal structure.



Pratt truss: The diagonal supports slope away from the center of the truss, with vertical supports creating a strong triangular structure. In some ways, it's the opposite of the Howe truss.



Baltimore truss: A twist on the Pratt truss — the diagonals are oriented similarly, but small supports create triangles within triangles for added strength. This is a very strong design.

SHADOWS OF THE BRIDGE

The Brooklyn Bridge links two parts of New York City: Brooklyn and Manhattan. The main deck is held up by suspension cables that connect to tall towers. It reaches more than 1,500 feet across the East River. Well over 100,000 people rely on it every day.

But, at one time, many doubted it would ever be reliable. When the plan for the bridge was announced in the late 1800s, it dwarfed all other suspension bridges. But civil engineer John Roebling designed it to be a hybrid; it included elements of both suspension bridges and cable-stayed bridges.

Disaster struck before construction even began. A ferryboat accident took John's life. But his dream did not die. Fortunately for the bridge, his son Washington had followed in his father's footsteps, becoming an engineer and bridge builder. He took over the project.

(continued on page 4)

Bridges have helped and inspired humans for thousands of years. All bridges start with a vision. With only craft sticks and glue, you can create a prototype of your vision.

When you have a handle on the basics, why not expand your creativity to new horizons with the Pitsco BridgePak? The set comes will all the materials you'll need to build sophisticated wooden models. You'll also receive a helpful resource book to spur your creativity. ⚠

A **suspension bridge** uses vertical cables to hold up the bridge deck.

A **cable-stayed bridge** holds the deck with diagonal cables that connect to towers.

(continued from page 3)

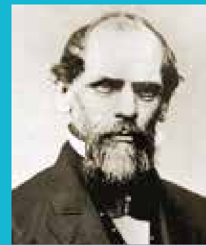
FAMILY OF THE BRIDGE

Earlier, Washington and his wife, Emily, had toured the continent of Europe to visit its suspension bridges. Their mission was to learn about their construction methods. So, when Washington took over the construction of the Brooklyn Bridge, he and Emily knew the risks.

One dangerous job was building the towers that were to rest deep in the riverbed. Workers dug through mud to reach the solid bedrock below. They worked in underwater chambers called caissons. Water was continually pumped out and air was pumped in. (See sidebar below.)

These conditions can lead to decompression sickness – also called the bends. Many workers fell very ill, including Washington. He could not leave his bed to visit the work site. Was his father's dream doomed at last? Once again, the bridge had another ally in the Roebling family: Emily.

Though she had no engineering degree, Emily had learned a great deal about bridges. She stepped in as a supervisor and inspector. She explained Washington's ideas to the assistant engineers. She even spoke with politicians and reporters. According to lore, Emily Roebling was the first person to walk across the completed bridge.



JOHN ROEBLING

WASHINGTON ROEBLING

EMILY ROEBLING

Civil engineers *design and build structures for the public. Airports, bridges, canals, and sewer systems are examples of civil engineering projects.*

DISCIPLES OF THE BRIDGE

The Brooklyn Bridge has gone down in history as a magnificent accomplishment. It took 14 years, 600 workers, and one dedicated family to bring it to life.

Over the years, it has inspired many engineers and artists. The poet Hart Crane toiled for years to write a poem he felt was worthy of the bridge. He praised its beauty and compared the steel cables to the strings of an angel's harp. David Steinman, an engineer and writer, was obsessed with the bridge. He remembered visiting it as a child:

"A boy grew up in the shadows of the bridge. He loved to walk over the span and to explore its marvels. He was awed by its vastness, by the majesty of the towers and by the power of the cables; and he was fascinated by all the details of the construction – the anchorages and the cables, the trussing and the beams, the slip-joint at mid-span, the machinery of the cable railway, the stone work of the towers, and the magic of the radiating stays."

The continued love many feel for the bridge is a great tribute to those who sacrificed to build it.

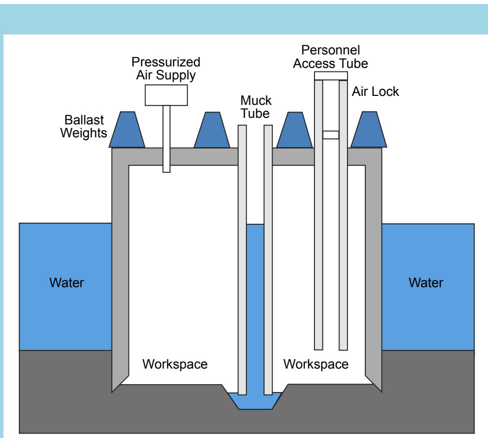


Image credit: YK Times

Caissons are watertight chambers used in underwater construction projects. These are useful during construction of bridges and dock structures. Typically, water is pumped out and pressurized air is pushed in, though designs vary.

The caissons used in the Brooklyn Bridge construction held up to 100 workers at a time. The workers would dig out the riverbed by hand. When digging was complete, the caissons were filled with concrete and served as the foundation.

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Student name: ________________________ **Class/hour**: ___________

SySTEM Alert! Quiz (Volume 9, Number 1)

1. Leonardo da Vinci's innovative bridge design is unique because it requires no _______.
   A. connecting pieces or mortar
   B. wood or stone
   C. deck or guardrail
   D. towers or caissons

2. A truss is _______.
   A. a rigid structure made of beams
   B. an underwater chamber
   C. a tool used to link blocks together
   D. the strongest shape known to engineering

3. The points where horizontal, vertical, and diagonal beams meet are called _______.
   A. fixtures
   B. hotspots
   C. apexes
   D. nodes

4. The part of the bridge that carries traffic is called _______.
   A. the suspension cable
   B. the foundation
   C. the caisson
   D. the roadbed

5. According to lore, who was the first person to walk across the Brooklyn Bridge?
   A. David Steinman
   B. Hart Crane
   C. Emily Roebling
   D. John Roebling

6. Why are triangles a strong shape to build with?
   A. The fewer sides a shape has, the more stable it is.
   B. The lines brace one another and can't pivot at the angles.
   C. The center of balance keeps it stable in space.
   D. A triangle's angles always add up to 180 degrees.

7. What is a caisson?
   A. a tool used to link blocks together
   B. the part of a bridge that carries traffic
   C. an airtight chamber used for underwater construction
   D. a type of bridge designed by Leonardo da Vinci

8. What force holds together the bridge that Leonardo da Vinci designed?
   A. tension
   B. static electricity
   C. compression
   D. chemical bonds

9. What material did the MIT team use to create the blocks for their bridge prototype?
   A. 3-D-printed plastic
   B. plaster of paris
   C. precision-cut marble
   D. aluminum

10. _______ pushes material together. _______ pulls it apart.
   A. Tension, Compression
   B. Compression, Tension
   C. Elasticity, Rigidity
   D. Rigidity, Elasticity

Bonus: Try to remember the last bridge you drove over. Without looking at it (or looking up a picture of it), describe it as fully as you can. What does it pass over? What is it made of? What structures support the roadbed?