Physics: Building Bridges

Week 04/20/20

Reading:

- Annotate the article: How it Works: Engineering Bridges to Handle Stress
  - Underline important ideas
  - Circle important words
  - Put a "?" next to something you want to know more about

Activity:

- Engineer a paper bridge
  - Paper Bridge Challenge

Writing:

- Read the article Wildlife Crossings, from bridges to tunnels to overpasses
  - Answer the writing prompt at the end of the article.

Física: Construyendo Puentes

Semana 04/20/20

Lectura:

- Anote el artículo: How it Works: Engineering Bridges to Handle Stress
  - Subráye ideas importantes
  - Circúle palabras importantes
  - Ponga un "?" junto a algo sobre lo que desea saber más

Actividad:

- Construya un puente de papel
  - Paper Bridge Challenge

Escritura de la:

- Lea el artículo Wildlife Crossings, from bridges to tunnels to overpasses
  - Responda la pregunta al fin del artículo.

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How it Works: Engineering Bridges to Handle Stress

Mar. 17, 2017 Bridge Masters Bridge Design, Innovations

Bridges are generally thought of as static structures. The truth is that they actually act more like dynamic, living beings. They constantly change, responding to different loads, weather patterns, and other types of stress in order to function. In some cases, much like a person undergoing a trauma, bridges must "react" to extremely stressful events like accidents, explosions, fires, earthquakes, and hurricanes in order to survive.

In this article, we'll look at how different types of bridges are engineered to handle stress. We'll also examine some of the most common forces that put stress on bridges. These stressors can have a big impact on how bridges age, fall into decline, and potentially fail.

Understanding them can help engineers develop durable structures and inspectors and maintenance personnel make existing structures last longer.

The gravity dilemma

The most profound force affecting bridges is gravity, which is constantly pulling at them, trying to drag them down to earth. Gravity isn't such a big deal when it comes to buildings, including large ones like skyscrapers, because the ground below them is always pushing back.

That's not the case when it comes to bridges. Their decking spans open space. "Space" provides no support against gravity. Bigger bridges that span longer spaces are more vulnerable to gravity than shorter ones. Similarly, heavier structures are more likely to fall victim to gravity than lighter ones.

Bridge failures are a relatively rare occurrence. So, what is it that keeps them from tumbling down due to the force of gravity?

The answer is pretty much the same no matter the type of structure:

- Compression (a force that pushes or squeezes inward) is carefully balanced with tension (a force that stretches and pulls outward).
- This balancing happens by channeling the load (the total weight of the bridge structure) onto the abutments (the supports at either end of the bridge) and piers (the supports that run under the bridge along its length).

These forces are distributed in a variety of ways on different types of bridges:

Beam Bridge

A beam bridge has its deck (beam) in tension and compression. (The beam can be squeezed and stretched depending on conditions.) The abutments are in compression, which means they are always being squeezed.

Arch Bridge

An arch bridge supports loads by distributing compression across and down the arch. The structure is always pushing in on itself.

Suspension Bridge

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The towers (piers) of a suspension bridge are in compression and the deck hangs from cables that are in tension. The deck itself is in both tension and compression.

Cable-stayed bridge

A cable-stayed bridge is similar to a suspension bridge. However, the deck hangs directly from the piers on cables. The piers are in compression and the cables are in tension. The deck experiences both forces.

Truss bridge

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A truss bridge is a variation of a beam structure with enhanced reinforcements. The deck is in tension. The trusses handle both tension and comprehension, with the diagonal ones in tension and the vertical ones in compression.

An arch bridge supports loads by distributing compression across and down the arch. The structure is always pushing in on itself.

Cantilever bridge

A cantilever bridge is one of the simpler forms to understand. Basically, it addresses the forces of tension (pulling) above the bridge deck and those of compression (pushing) below.

Check out these bridges that manage forces in unique ways:

The Rolling Bridge, London

This sculptural structure is a type of bridge commonly referred to as a curling bridge. It's made up of eight triangular sections that are hinged together. The bridge is able to "uncurl" to allow pedestrians to cross it and "curl up" to let boats pass.

When the structure is in its "uncurled" state, it looks and functions much like a truss bridge. A system of hydraulic pistons is used to roll it into its closed, octagonal shape.

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By Loz Pycock [CC BY-SA 2.0], via Wikimedia Commons

The Gateshead Millennium Bridge, Newcastle

This innovative structure is often referred to as a “tilt” bridge. It uses an advanced hydraulic system to lift it out of the way when boats pass.

While this seems simple enough, this bridge must deal with unique tension and compression issues. It leverages features of suspension and cable-stayed designs that are pushed (and stretched) to extreme limits when the bridge is in motion. This structure adds a new dimension to standard bridge engineering.

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Bridge design is simple and complex at the same time. A bridge is constantly balancing compressive forces in certain locations with tensile ones in others so no overwhelming force, especially gravity, overcomes the structure at any time, leading to damage or collapse.

Stressors beyond gravity

The complicating factor is that compression and tension on a bridge are constantly shifting because of stressors like:

Changing loads

It would be easy to build bridges if the loads on them stayed static. The forces on them would never change. The reality is that the loads can vary dramatically and dynamically throughout the day and over time.

Bridges carry everything from trains, cars, trucks, and pedestrians to water lines and other utility infrastructure. The amount of traffic and utility volume shift throughout the day, causing significant variations in the live load, which can increase and decrease tensile and compressive forces across the structure.

Example: When a railroad travels over a bridge, the structure bends and flexes, then returns to its original relaxed state once the train passes by.

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Environmental forces

Bridges constantly react to Mother Nature. Environmental sources of stress include:

- **Tides, waves, and water back-ups**. Water is one of the most powerful forces on earth. Engineers often insert openings into bridge abutments to allow water to flow through rather than push against them.
- **Winds**. Large gusts of wind can cause bridges to sway and twist. Modern ones are lighter and more aerodynamic, allowing wind to pass through them, which prevents them from moving.
- **Earthquakes**. Seismic forces cause bridge sections to shake and crash into each other, which can make them crumble. Designers include dampers to absorb vibrations and bumpers to keep sections from banging into each other on bridges in active earthquake zones.
- Hurricanes and other major storms can have devastating effects on exposed areas of bridges. Construction teams often install protective equipment around vulnerable sections, such as utility infrastructure.
- **Ice, cold, and blizzards.** Cold weather and freezing conditions cause contraction on certain bridge elements. Thawing can have the opposite effect. The impacts of expansion and contraction have been exacerbated in today's more extreme climate conditions. Engineers account for this by incorporating more responsive and flexible components into bridges constructed in cold places.

Accidents and other unexpected events

Traffic and construction accidents, boats hitting abutments, and explosions can lead to significant bridge stress and sometimes, failure. Builders can leverage strong, fire-retardant materials and isolating elements to limit the impact extreme events have on the balance of forces affecting a bridge.

Conclusion

Some of the forces outlined above may cause immediate catastrophic damage to bridges or ultimate failure. These stressors also wear away at bridges over time, leading to long-term damage.

Much like living beings, bridges have ways of communicating that they're over-stressed. Inspectors, managers, and engineers must look for these signs. It can help them keep existing structures safe and provide them with the information they need to design even more durable and responsive structures in the future.

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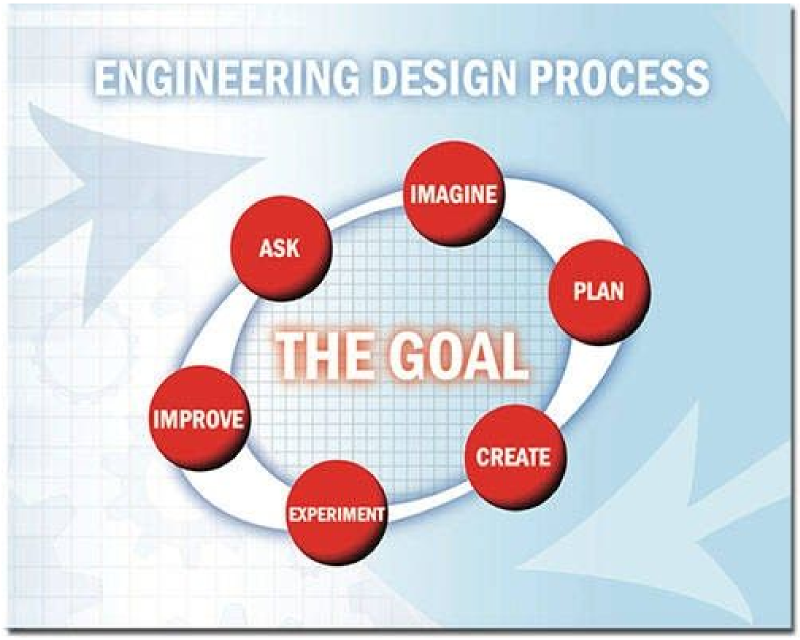
Building a Paper Bridge



After a large rainstorm, with much flooding, a new river has been created in the Amazon jungle. This new river has washed out a heavily driven road that many big trucks use, as well as cars and pedestrians. Many companies and people have started using the river as a means of transportation. The local government needs to build a bridge across this new river. This bridge must allow boats to go under it and trucks and cars to go over it at the same time. Using the design process created by NASA, build a prototype bridge that will support the weight of the vehicles and still allow boats to travel underneath safely. Using 2 pieces of paper only, create a prototype bridge. You may bend them, roll them, tear them, or fold them to create your bridge, but you may not use any other item to build it. The bridge must span 8" and have 5" clearance underneath. You might want to use two stacks of books placed 8" apart and 6" high. Once you have built your bridge, place pennies or other weights on the bridge. 1 penny represents 5 pedestrians, 5 pennies represent 1 car, and 60 pennies represent 1 truck. How many pedestrians, cars, and/or trucks can your bridge hold before it dips below 5" and boats crash into it? How many pedestrians, cars, and/or trucks can your bridge hold until it collapses?

Step 1 - Ask

What is the problem presented in this situation?

What are the constraints/requirements of the task in this situation?

Building a Paper Bridge

Step 2 - Imagine

Sketch 2 brainstorms of the bridge

Brainstorm 1	Brainstorm 2

Step 3 - Plan

Choose the best brainstorm. Why did you choose this design?

Step 4 - Create (Build your prototype bridge)

Step 5 - Experiment/Test (Test your prototype)

How many pedestrians/cars/trucks can the bridge support safely?

How many pedestrians/cars/trucks caused your bridge to break?

Building a Paper Bridge

Step 6 - Improve

Based on your data from Step 5, redesign your prototype.

What changes did you make?

Why did you make these changes?

Final Step - (Retest your improved prototype)

How many pedestrians/cars/trucks can the bridge support safely?

How many pedestrians/cars/trucks caused your bridge to break?

Was your improved prototype successful? Why?

newsela

Wildlife crossings, from bridges to tunnels to overpasses

By National Geographic Society, adapted by Newsela staff on 03.29.19

Word Count **843**

Level **1040L**

Image 1. Capuchin monkeys cross a "monkey bridge" above a road in Manuel Antonio, Costa Rica. Many different kinds of wildlife crossings, including bridges, tunnels and overpasses, help keep wildlife from getting hit by cars. Photo by: Katra Laidlaw/Kids Saving the Rainforest

Roadkill is a serious problem for drivers in the United States. In the U.S. alone, there are more than a million automobile accidents per year involving wildlife. They cost more than $8 billion in medical costs and vehicle repairs alone.

NATIONAL GEOGRAPHIC

If you care about the well-being of wildlife, the problem is even worse. According to some estimates, automobile collisions kill more than a million animals every day. For many species, it is the leading cause of death. Even worse, major roads can split up animal populations and destroy their habitats. Animals lose access to large areas of their habitats, which makes it much harder for many animals to find food and a mate.

Animal Crossings Becoming More Common

As people have become more aware of the danger to humans and animals, animal crossings are becoming more common. The crossings can come in many forms. The type depends on the species that need to cross and the geographic features of the land. The most common forms are bridges and overpasses, tunnels, viaducts and culverts. A culvert is a structure that allows water to flow under a road, railroad or trail from one side to the other side. Planners are increasingly including them when they design highways and road improvements. The crossings greatly reduce the number of collisions, provide a safe corridor for animals and reconnect animal habitats.

Wildlife bridges are usually covered in native vegetation. In the United Kingdom, people often call them "green bridges." The idea is to make the crossing look like a natural part of the landscape, so animals will cross there. The crossings often work best when fencing is placed on the side of the road to funnel wildlife toward the crossing.

The concept was first developed in France in the 1950s. It took off in the Netherlands, where more than 600 crossings have been constructed. They protect badgers, elk and other mammals. The Dutch built the world's longest animal crossing, the Natuurbrug Zanderij Crailoo, which spans more than a half mile. Wildlife crossings can also be found in Australia, Canada and other parts of the world. In the United States, the idea took a little longer to catch on. Wildlife bridges and tunnels began appearing here about 20 years ago.

Amphibian-Sized Village

One of the earliest U.S. crossings was in Davis, California. In 1995, the city built a 6 inch-wide tunnel, or "ecoduct," to allow frogs to pass under a road to a wetland on the other side. The town's postmaster decorated an area to make it look like an amphibian-sized village, and named it Toad Hollow. Despite this, the frogs did not use it.

The corridors in Banff National Park in Alberta, Canada, are far more successful. Between 1996 and 2016, six bridges and 38 underpasses were built for wildlife to cross the Trans-Canada Highway, which bisects the park. Park officials counted more than 150,000 crossings by mammals such as elk, moose, black bears, cougars and grizzly bears. Studies show that the corridors have specifically helped the grizzly bears find a mate. In addition, the park saw an 80 percent reduction in motor accidents involving wildlife. These statistics show the benefits that can come from a real effort to integrate conservation and highway construction.

Tunnels Adapted For Animals

In parts of Queensland, Australia, the koala population has declined at an alarming speed over the past few decades. Auto accidents were among the leading causes of koala deaths between 1997 and 2011, according to a government report. Between 2010 and 2013, the Queensland government built about a half dozen wildlife crossings. Several existing drainage tunnels under roadways were adapted for animals. The government added ledges, which were wide enough for small animals to cross without getting wet. One ecologist was surprised at how quickly the koalas adapted and began using the tunnels.

90 Percent Drop In Wildlife-Related Highway Accidents

In recent years, animal crossings have been built in the western United States. Since 2000, Arizona has constructed at least 20 corridors, each with funnel fencing. In a part of central Arizona where elk migrate, there was a 90 percent drop in wildlife-related highway accidents. In 2018, Washington state authorities were working on a wildlife bridge that spanned Interstate 90. The project consisted of multiple underpasses and at least two bridges to let wildlife pass between the northern and southern Cascade Mountain regions. Deer began using the bridge at one of the passes even before it was completed.

Some types of wildlife crossings, especially overpasses, can be expensive to build. But they are cost-effective over the long term. When state legislatures plan highways, ecologists and conservation experts advocate for wildlife crossings to be included.

Writing Prompt: Think of five animals in the area that you live that could use help crossing the roads safely. What type of structure would you build for them to help them cross the roads safely? Why did you choose these structures? What considerations need to be addressed when building these structures?