The Bayonne Bridge: The Beautiful Arch

Resources for Teachers and Students
[Printable and Electronic Versions]

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NOTES:

- Key words indicated in **Bold** are defined in call-out boxes.
- Teacher-only text indicated with *Italics*.

OVERVIEW/OBJECTIVE:
Students will be able to understand and discuss the history of the Bayonne Bridge and use science and engineering basics to investigate bridge design and test an arch bridge model.

TARGET GRADE LEVEL:
Fourth grade instruction, adaptable to higher levels as desired in the subjects of Social Studies and Engineering.

FOCUS:
In Part I, students learn about history of the Bayonne Bridge including the many engineering challenges encountered during the project and the people who helped overcome those challenges. In Part II, students learn engineering concepts to understand how bridges stay up and use these concepts to complete activities on bridge design before applying these concepts to theorize how the Bayonne Bridge works.

MATERIALS:

- Part I: DVD of "The Bayonne Bridge Documentary"
- Part II: 2–4 heavy textbooks or 2 bricks per group; 2 pieces of "cereal box" cardboard or similar, 12 x 8 in; weights (anything small that can be stacked on the structure); red and blue marker, crayon or colored pencil for each student or group.

Contents

Teacher Materials | Part I: History of the Bayonne Bridge

Part I: History of the Bayonne Bridge

Materials: DVD of "The Bayonne Bridge Documentary"

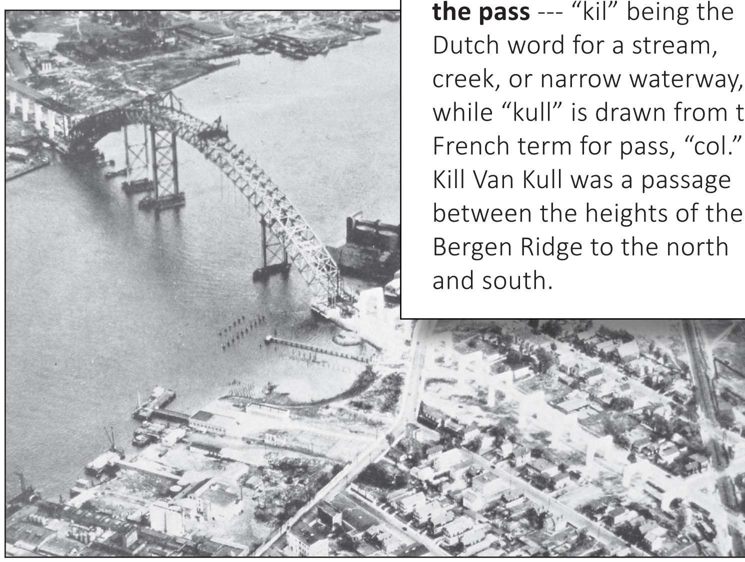
Objective: Students will be able to understand and discuss the history of the Bayonne Bridge. Students will read the background history and discussion questions (15 minutes, either as a class or independently), watch "The Bayonne Bridge Documentary," and answer discussion questions as they watch the film.

Background History

History of the Bayonne Bridge

The Bayonne Bridge was built in 1931, between Staten Island, NY and Bayonne, NJ. The bridge spans the "**Kill Van Kull**" which is an important waterway for ships traveling to the ports in Elizabeth, NJ and Newark, NJ.

Kill Van Kull: translates roughly to channel through the pass --- "kil" being the Dutch word for a stream, creek, or narrow waterway, while "kull" is drawn from the French term for pass, "col." Kill Van Kull was a passage between the heights of the Bergen Ridge to the north and south.

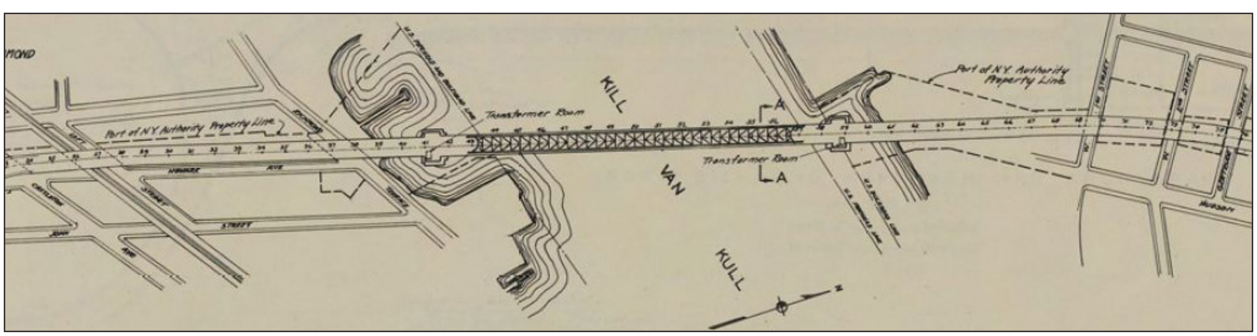


Aerial view of the Bayonne Bridge during construction.

The bridge was built by The Port Authority of NY & NJ, the agency in charge of managing the ports in the New Jersey-New York area. For the port system to work, ships need to move freely through the waterways to the **marine terminals**, while trucks travel easily over waterways on bridges.

Marine terminal: the piers, docks and warehouses where ships bring their cargo. In New Jersey, the Elizabeth and Newark Marine Terminals are accessed by way of the Kill Van Kull.

Chief Engineer at the Port Authority, Othmar Ammann (pronounced: ah-mon), teamed up with architect Cass Gilbert to design the bridge.



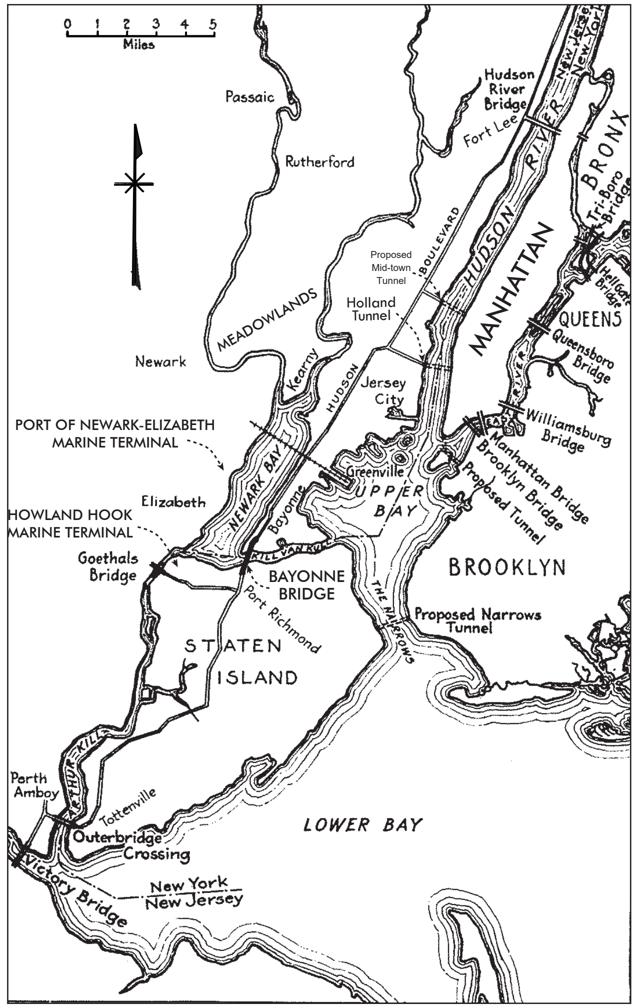
Overview plans for the Bayonne Bridge over Kill Van Kull showing that the bridge was not built at a right angle (90 degrees) to the shore, instead it was built on a slant or "skew" in order to line up better with existing roads.

Why was it built?

The Bayonne Bridge was built to move cars and trucks toward the new Holland Tunnel, the first tunnel designed for cars, under the Hudson River between New Jersey and Manhattan. Before the Bayonne Bridge, the entrance to the Holland Tunnel was difficult to get to because of swampy meadows and rivers that surround much of Jersey City.

The Bayonne Bridge was also built high enough so that ships traveling to the ports in Newark and Elizabeth could pass underneath. An arch was chosen because it was the most economical and beautiful way to span the water. When it was finished, it was the longest arch bridge in the world. The Bayonne Bridge met the needs of the Port Authority for the next 85 years.

Inside the Holland Tunnel during construction.



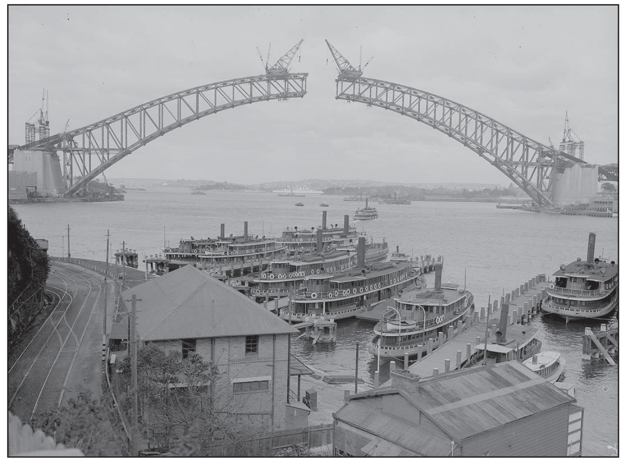
This map shows the bridges, tunnels, and proposed tunnels that were designed to link together the network of roadways between New York and New Jersey in 1931. While some of the proposed links were never constructed, the map illustrates the complex system that the Bayonne Bridge was and is a part of.

Arch Design

Othmar Ammann designed the Bayonne Bridge as the world's longest spanning arch bridge. At the same time, he was building the world's longest spanning suspension bridge, the George Washington Bridge, over the Hudson River. The Bayonne Bridge had a 1675-foot span and held the title of longest spanning arch bridge for 46 years. The Bayonne Bridge's "sister bridge," the Sydney Harbour Bridge in Australia, was also a steel arch though it was 25 feet shorter and opened the following year in 1932. In addition to its engineering achievements, the Bayonne Bridge was awarded the prize for Most Beautiful Steel Bridge in 1931 by the American Institute for Steel Construction.

"Raise the Roadway"

The world's shipping industry is changing in the 21st century. The Panama Canal, a man-made waterway in Central America connecting the Pacific and Atlantic Oceans, was expanded in 2016. The canal can now allow larger container ships to pass through. Some ships are almost 200 feet tall — taller than the Statue of Liberty from her torch to her toes — and can carry as many as 9,000 containers, each of which fits on a train car or the back of a truck. These large and tall ships are called "New Panamax Ships."



Sydney Harbour Bridge, Sydney Australia, during construction.

In order to stay competitive with other East Coast ports, the Port Authority started the "Raise the Roadway" project to allow the New Panamax Ships to be able to pass under the Bayonne Bridge. The roadway was raised from 151 to 215 feet above the average water level. While the project was under construction, the Kill Van Kull remained clear and shipping traffic continued to move freely below. The CMA CGM Theodore Roosevelt was one of the first New Panamax ships to pass under the Bayonne Bridge when it called on the Port of New York and New Jersey on September 7, 2017.

George Washington Bridge during construction, before the roadway was built.

Additional Background Historical Information

The Bayonne Bridge was designed by Othmar Ammann, a Swiss-American structural engineer. Ammann considered several types of bridges to span the Kill Van Kull before settling on the arch design. He worked in collaboration with architect Cass Gilbert who designed many famous buildings including the Woolworth Building and U.S. Customs Building in New York and the Supreme Court Building in Washington D.C. Gilbert drew preliminary sketches of a suspension bridge (roadway suspended from cables) over the waterway and designed ornate stone towers for the bridge.

A New Panamax Ship passes under the Bayonne Bridge in 2017 after the roadway was raised.

The cantilever design was not used because it required large amounts of steel and would be very expensive. The suspension design was considered, however, this type of bridge would have cost much more in the event that a rail line was added to the bridge (specialized bracing would need to be installed at an extra cost) and the tall towers to support the suspension cables would have risen dramatically higher than the surrounding low-lying industrial and residential neighborhoods. The arch style was finally chosen due to its cost, ability to accommodate a prospective rail line, and low-profile within the surrounding landscape.

The Verrazzano-Narrows Bridge.

While originally envisioned as a highly trafficked bridge and vital link to New York City, the Bayonne Bridge, along with the other bridges between Staten Island and New Jersey built during the 1920s and 1930s– the Outerbridge Crossing and Goethals Bridge—was not initially busy. Many factors were at play. The Great Depression had severely curtailed travel to beaches on Staten Island and fewer commuters were traveling to jobs in New York City. The Bayonne Bridge was also intended to complement a much-anticipated tunnel under the Verrazzano-Narrows between Staten Island and Brooklyn, but a bridge was built at that location in 1964 instead. Finally, though the Bayonne Bridge was intended to funnel cars and trucks toward the Holland Tunnel, the Pulaski Skyway would come to take on much of this traffic. The Pulaski Skyway was a free highway built by the NJ State Highway Department through Newark to the Holland Tunnel, a link which diverted vehicular traffic away from the Staten Island bridges. Additionally, though it was meant to supplant the ferry system, ferry service between Port Richmond and Bayonne did not drop off as anticipated, as the ferry company reduced rates to compete with the bridge. Ferry service continued to operate until 1962.

Container ship passes under the Bayonne Bridge, 1991.

The Bayonne Bridge effectively linked the two sides of Kill Van Kull without obstructing the waterway. The height of the roadway and the absence of support piers within the navigation channel allowed for vessels to pass under the structure safely. This traffic was and is vitally important to the financial health of the Port of New York and New Jersey. The maintenance of an open waterway between Newark Bay and the New York Bay via Kill Van Kull continues to be an important priority of the Port Authority.

The Bayonne Bridge Documentary (24 minutes)

- The Bayonne Bridge Documentary explores the conception, design, and construction of the Bayonne Bridge. The documentary also focuses on the history of The Port Authority of NY & NJ and the changing needs of the port which motivated the "Raise the Roadway" Navigational Clearance Project. Watch the documentary and answer the following questions.

The Bayonne Bridge Documentary Worksheet

Why did The Port Authority of NY & NJ decide to build the Bayonne Bridge?
- *The Bayonne Bridge was built to direct traffic toward to newly-constructed Holland Tunnel, while also managing the overall flow of goods, services, and people moving in, out, and around the Port of New York and New Jersey, thus helping to keep the port competitive. Its height and the method of construction used were designed to leave the waterway open for ships to travel through Kill Van Kull uninterrupted.*

What structures, landscape features, or design needs influenced Othmar Ammann before he designed the Bayonne Bridge?
- *Hell Gate Bridge --- Ammann helped to build this arch railroad bridge & the Bayonne Bridge incorporates some of its features,*
- *Surrounding neighborhoods & ferries --- Ammann took into account the nearby neighborhoods and path of the ferry in deciding where to build the bridge.*
- *The Port Authority's desire for railroad adaptability. The suspension bridge design would have been more expensive to adapt with a rail line.*

What is one thing you found interesting about the process of constructing the original bridge?
- *Open-ended question.*

What is the reason that the Port Authority needed to raise the height of the Bayonne Bridge's Roadway?
- *The Panama Canal has expanded its capacity and larger, taller ships known as "New Panamax" ships could pass through as of 2016. In order to accommodate these larger ships, the roadway of the Bayonne Bridge needed to be raised. This enabled the Port to remain competitive as the large ships could still access the marine terminals at Elizabeth and Newark.*

View from over Bayonne looking west at Bayonne Bridge, 1991.

Teacher Materials | Part II: Bridge Engineering

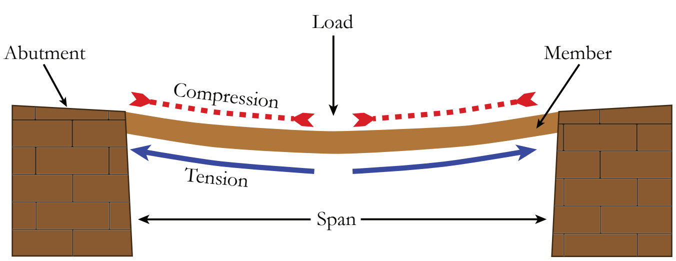
Part II: Bridge Engineering: How Does the Bayonne Bridge Work?

Objective: Understand the basics of how bridges work, conduct experiments related to arches, and analyze a diagram of the Bayonne Bridge.

Introduction: When the Bayonne Bridge was completed in 1931, it was the longest arch bridge in the world. The bridge's designer, Othmar Ammann, was a structural engineer, a person who designs bridges, buildings, and tunnels. He chose an arch design because it saved money, was beautiful, fit in with its surroundings, and could be adapted to add a rail line.

This section is focused on how the Bayonne Bridge works--how it spans such a long distance while keeping the waterway clear of support columns. To understand how the Bayonne Bridge works, we need some bridge basics.

We need to learn how a bridge supports its load--including its own weight and the weight of any people, cars, or other things it may carry. A bridge's load exerts forces including compression and tension on the material of the bridge itself and its supports (piers, abutments). Compression tends to squeeze components or "members" that make up the bridge, and tension, tends to stretch them.



Bridge Vocabulary:

Span the distance between two supports of a bridge.

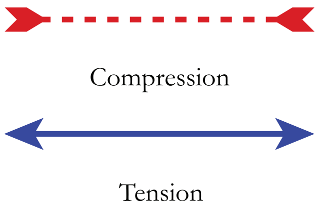
Load the weight that a bridge supports, including the bridge itself and anything crossing it. [*If you are carrying a 10-pound backpack, the load is your body supports is the backpack plus your weight*.]

Member an individual part of a bridge or other structure, such as a metal beam.

Compression the internal force that tends to make members shorter, squeezing them. [*When you squeeze a sponge you are applying compressive forces to it*.]

Tension the internal force that tends to make members longer, stretching them. [*When you stretch a rubber band, you are applying tension to it*.]

Abutment a structure that supports the end of a bridge; for arch bridges, this structure bears the forces imposed by the arch.

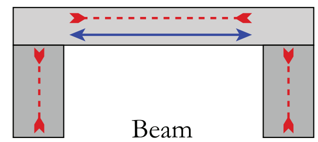


Main Types of Bridges

Understanding the forces that bridges need to contend with will help us to understand how each type of bridge works.

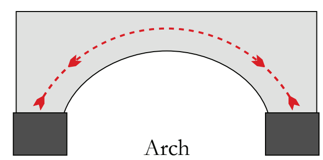
Beam Bridge - Composed of a deck or "beam" and abutments.

The forces acting on the beam bridge are compression at its surface (the roadway) and at the abutments, and tension where the bottom of the beam stretches under the weight of the load.



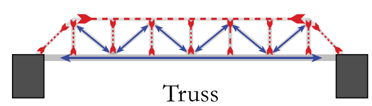
Arch Bridge - A bridge which transfers the load of the bridge downward and outward along the curve of the arch through compression.

Fixed abutments exert compressive forces which prevent the ends of the bridge from spreading. This bridge form has a strong structure and is good for longer spans.



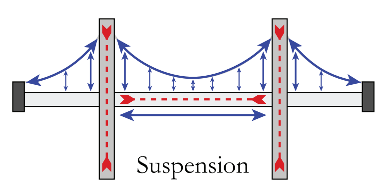
Truss Bridge - A bridge whose load-bearing structure is composed of trusses--triangular structures that distribute forces to create stability.

The use of trusses extend the reach of both the beam and the arch bridges by reinforcing and strengthening these bridge forms.



Suspension Bridge - A bridge where the roadway is supported by cables which run between towers.

The towers exert compressive forces on their foundations and the cables are under tension, suspending the roadway deck. This type of bridge is good for long spans.



Large bridges today incorporate several components of these basic forms, combining elements from each to create longer and stronger spans!

Real World Examples

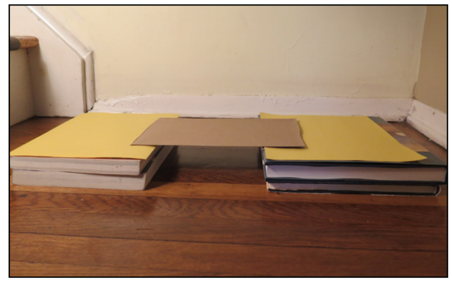
Left: Beam bridge spanning New Jersey Transit Tracks. Maple Street Bridge, Summit, New Jersey.

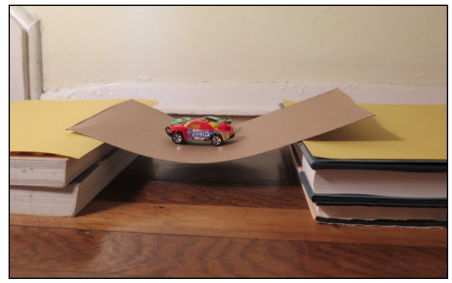
Right: Old Stone Bridge, Boonton, New Jersey.

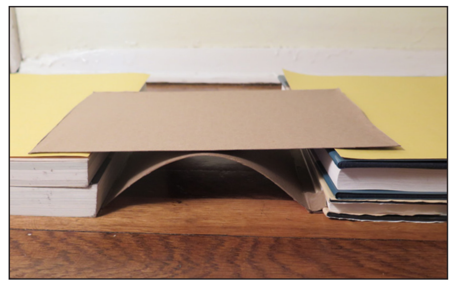
Left: Truss bridge spanning New Jersey Transit Tracks. Osborn Avenue Bridge, Westfield, New Jersey.

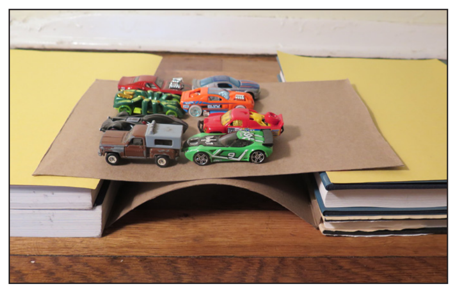
Right: Verrazzano-Narrows Bridge between Staten Island and Brooklyn, New York.

Activity: Cardboard Arch Bridge









Materials:
- 2-4 heavy textbooks or 2 bricks per group
- 2 pieces of “cereal box” cardboard or similar, 12 x 8 in.
- Weights (anything small that can be stacked on the structure)

Objective: Investigate and test bridge models to determine the factors contributing to stable design.

Step 1:
1. Place two stacks of textbooks 20 cm (about 8 inches) apart and place a piece of cardboard on top.
2. Gradually place weights in the center of the cardboard until it begins to sag in the middle.
3. Record the amount of weight the bridge held before it began to sag.
4. Experiment with a shorter span (distance between sides). Record how this changes your results.

Step 2:
1. Place an arch between the textbooks by carefully bending a piece of cardboard in the form of the arch. Make sure that it fits snugly.
2. Place a piece of cardboard on top of the arch, spanning the distance between the books.
3. Gradually place weights in the center of the cardboard until it begins to sag in the middle.
4. Record the amount of weight the bridge held.

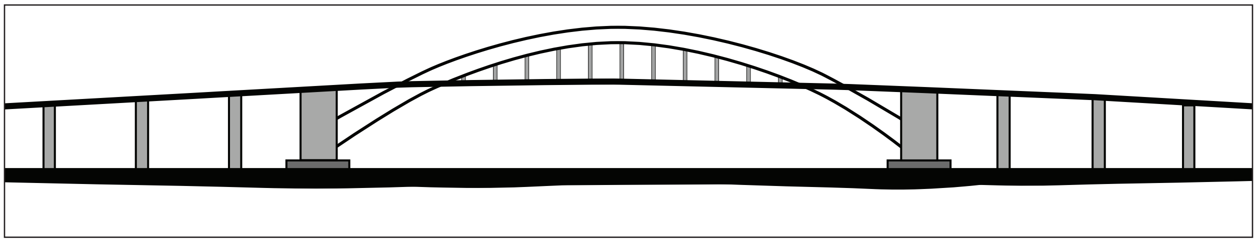
Observations

(1) What type of bridge did you build in Step 1? What type did you build in Step 2?
- *Students constructed a simple beam bridge in Step 1 and in Step 2, an arch bridge supporting a beam above.*

(2) What effect did adding the arch to the bridge have, if any?
- *The arch allowed the bridge to support more weight before buckling.*

(3) What other features could be added to the bridges to make it stronger?
- *Trusses could be added to roadway or the arch, piers could have been added under the beam*

(4) What happens when you change the span of the bridge (distance between the two sides)?
- *The beam bridge performs better for shorter spans.*



Activity: How the Bayonne Bridge Works!

Materials: Red and blue marker, crayon, or colored pencil

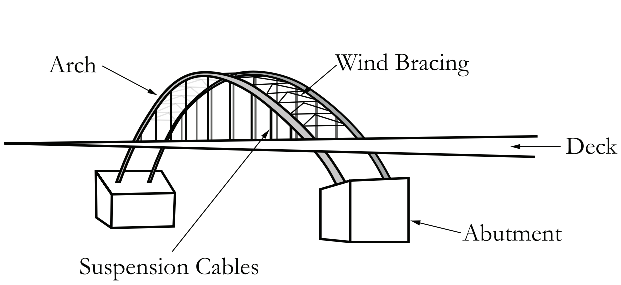
Objective: Determine the different types of bridges which are combined to form the Bayonne Bridge and identify some of the forces acting on the different parts of the bridge.

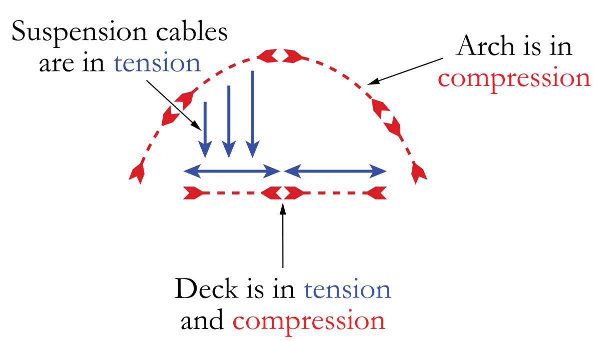
Step 1: Take a look at the photograph of the Bayonne Bridge and compare its structure with the Main Types of Bridges handout. What types of bridge is it? Does it combine more than one?

- *The Bayonne Bridge is an arch bridge, however, it uses trusses for stability within the arch and suspension cables to support the roadway deck. The approaches of the Bayonne Bridge are beam bridges.*

Step 2: Take a look at the simplified diagram of the Bayonne Bridge which excludes the details of the truss system. Using **red** for compression and **blue** for tension, draw where these forces are acting on different parts of the bridge and its approaches. Use the diagrams on the Main Types of Bridges handout to figure out where compression and tension are exerted on different bridge types.

- *The Bayonne Bridge combines several of these bridge types, including beam bridges as parts of the approaches, arch bridge design, and suspension cables to hold up the roadway itself. The deck also stops the arch from pushing outward, taking some pressure off the abutments.*





Student Materials | Part I: History of the Bayonne Bridge

Part I: History of the Bayonne Bridge

Objective: Students will be able to understand and discuss the history of the Bayonne Bridge. Read the background history and discussion questions, watch “The Bayonne Bridge Documentary,” and answer discussion questions as you watch the film.

Background History

History of the Bayonne Bridge

The Bayonne Bridge was built in 1931, between Staten Island, NY and Bayonne, NJ. The bridge spans the “**Kill Van Kull**” which is an important waterway for ships traveling to the ports in Elizabeth, NJ and Newark, NJ.

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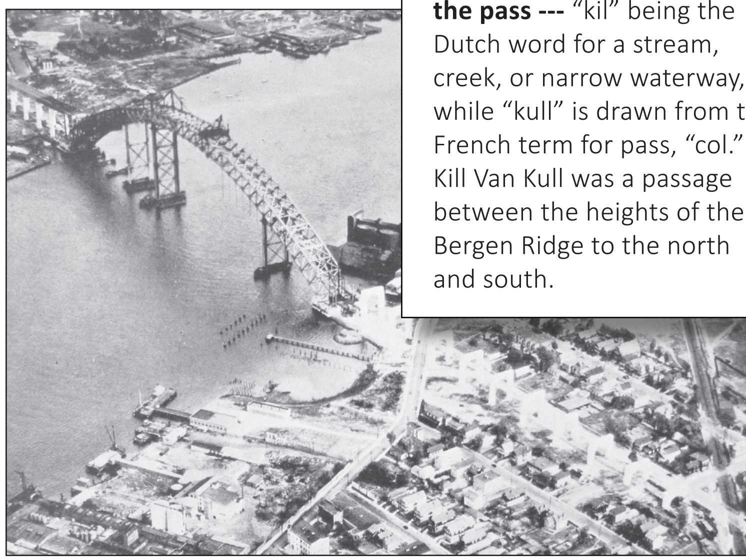

Aerial view of the Bayonne Bridge during construction.

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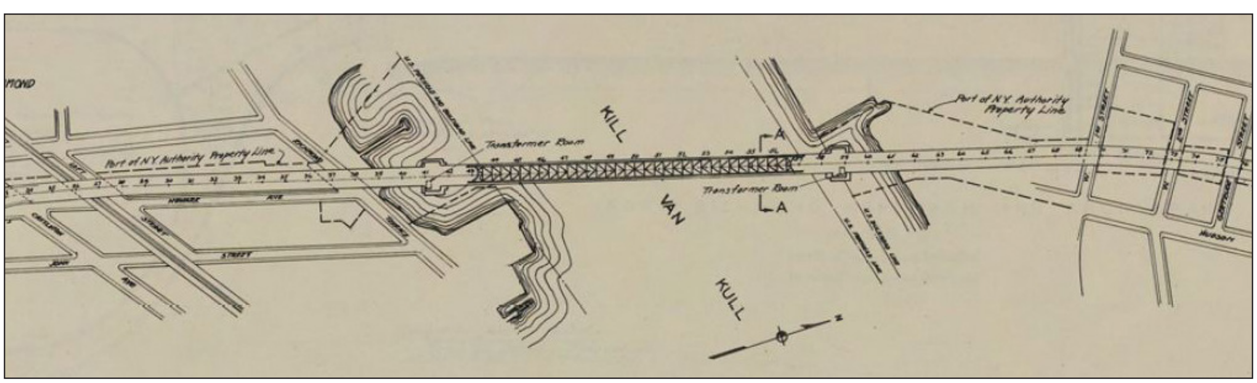

Overview plans for the Bayonne Bridge over Kill Van Kull showing that the bridge was not built at a right angle (90 degrees) to the shore, instead it was built on a slant or “skew” in order to line up better with existing roads.

Why was it built?

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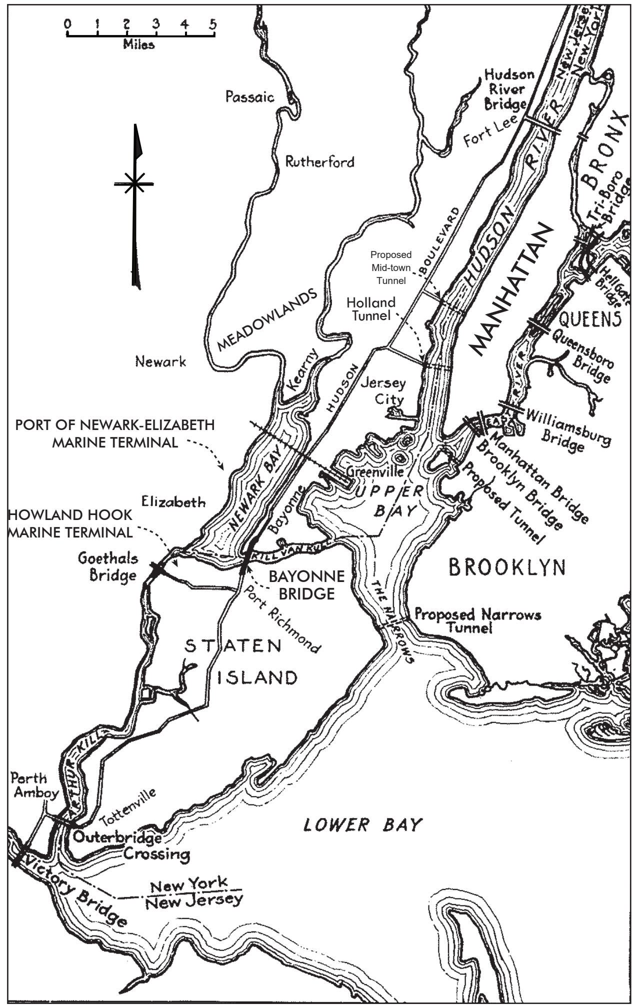
Inside the Holland Tunnel during construction.



This map shows the bridges, tunnels, and proposed tunnels that were designed to link together the network of roadways between New York and New Jersey in 1931. While some of the proposed links were never constructed, the map illustrates the complex system that the Bayonne Bridge was and is a part of.

Arch Design

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“Raise the Roadway”

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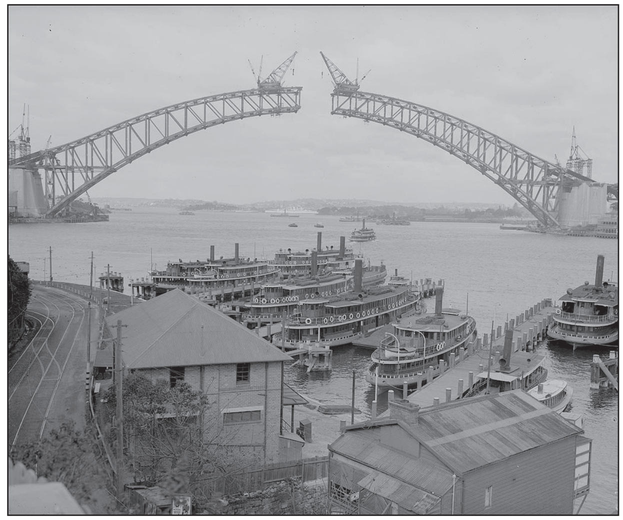


Sydney Harbour Bridge, Sydney Australia, during construction.

George Washington Bridge during construction, before the roadway was built.

A New Panamax Ship passes under the Bayonne Bridge in 2017 after the roadway was raised.

The Bayonne Bridge Documentary Worksheet

The Bayonne Bridge Documentary explores the conception, design, and construction of the Bayonne Bridge. The documentary also focuses on the history of The Port Authority and the changing needs of the port which motivated the "Raise the Roadway" Navigational Clearance Project. Watch the documentary and answer the following questions.

Why did the Port Authority decide to build the Bayonne Bridge?

What structures, landscape features, or design needs influenced Othmar Ammann before he designed the Bayonne Bridge?

What is one thing you found interesting about the process of constructing the original bridge?

What is the reason that the Port Authority needed to raise the height of the Bayonne Bridge's Roadway?

Student Materials | Part II: Bridge Engineering

Part II: Bridge Engineering: How Does the Bayonne Bridge Work?

Objective: Understand the basics of how bridges work, conduct experiments related to arches, and analyze a diagram of the Bayonne Bridge.

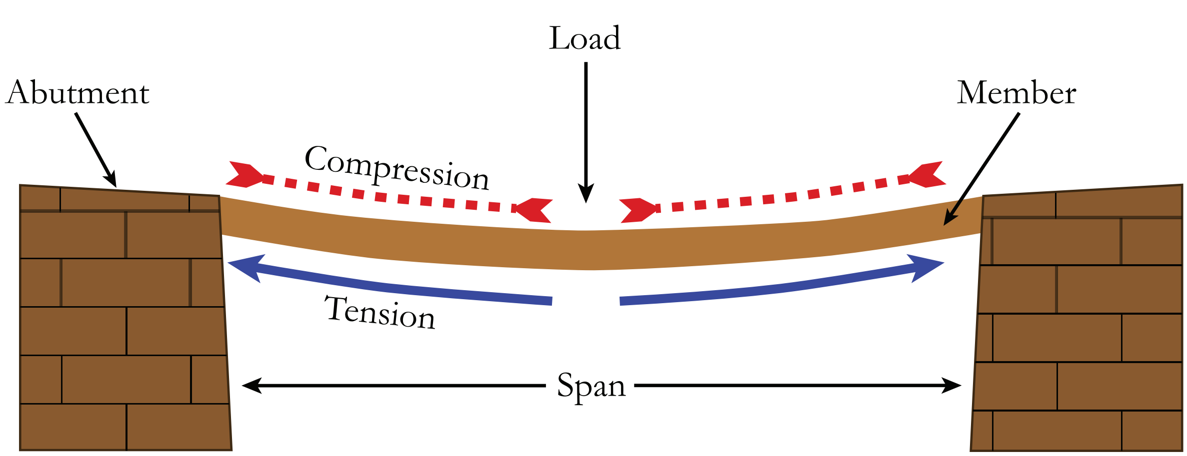
Introduction: When the Bayonne Bridge was completed in 1931, it was the longest arch bridge in the world. The bridge's designer, Othmar Ammann, was a structural engineer, a person who designs bridges, buildings, and tunnels. He chose an arch design because it saved money, was beautiful, fit in with its surroundings, and could be adapted to add a rail line.

This section is focused on how the Bayonne Bridge works--how it spans such a long distance while keeping the waterway clear of support columns. To understand how the Bayonne Bridge works, we need some bridge basics.

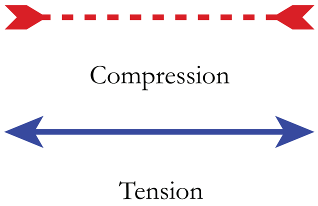
We need to learn how a bridge supports its load--including its own weight and the weight of any people, cars, or other things it may carry. A bridge's load exerts forces including compression and tension on the material of the bridge itself and its supports (piers, abutments). Compression tends to squeeze components or "members" that make up the bridge, and tension, tends to stretch them.

Bridge Vocabulary:

Span	the distance between two supports of a bridge.
Load	the weight that a bridge supports, including the bridge itself and anything crossing it.
Member	an individual part of a bridge or other structure, such as a metal beam.
Compression	the internal force that tends to make members shorter, squeezing them.
Tension	the internal force that tends to make members longer, stretching them.
Abutment	a structure that supports the end of a bridge; for arch bridges, this structure bears the forces imposed by the arch.



Part II: Student Materials

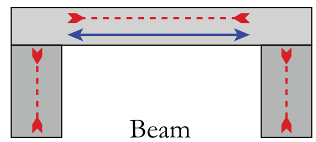


Main Types of Bridges

Understanding the forces that bridges need to contend with will help us to understand how each type of bridge works.

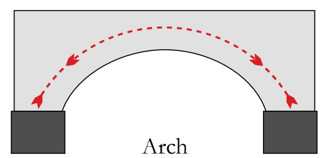
Beam Bridge - Composed of a deck or “beam” and abutments.

The forces acting on the beam bridge are compression at its surface (the roadway) and at the abutments, and tension where the bottom of the beam stretches under the weight of the load.



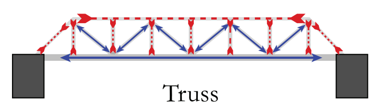
Arch Bridge - A bridge which transfers the load of the bridge downward and outward along the curve of the arch through compression.

Fixed abutments exert compressive forces which prevent the ends of the bridge from spreading. This bridge form has a strong structure and is good for longer spans.



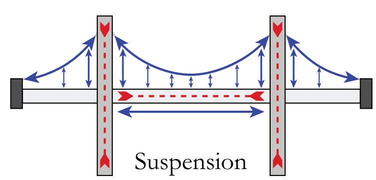
Truss Bridge - A bridge whose load-bearing structure is composed of trusses--triangular structures that distribute forces to create stability.

The use of trusses extend the reach of both the beam and the arch bridges by reinforcing and strengthening these bridge forms.



Suspension Bridge - A bridge where the roadway is supported by cables which run between towers.

The towers exert compressive forces on their foundations and the cables are under tension, suspending the roadway deck. This type of bridge is good for long spans.



Large bridges today incorporate several components of these basic forms, combining elements from each to create longer and stronger spans!

Real World Examples

Left: Beam bridge spanning New Jersey Transit Tracks. Maple Street Bridge, Summit, New Jersey.

Right: Old Stone Bridge, Boonton, New Jersey.

Left: Truss bridge spanning New Jersey Transit Tracks. Osborn Avenue Bridge, Westfield, New Jersey.

Right: Verrazzano-Narrows Bridge between Staten Island and Brooklyn, New York.

Name: ______________________________
Date: ______________________________

Activity: Cardboard Arch Bridge

Materials:
- 2-4 heavy textbooks or 2 bricks per group
- 2 pieces of “cereal box” cardboard, 12 x 8 in.
- Weights

Objective: Investigate and test bridge models to determine the factors contributing to stable design.

Step 1:
1. Place two stacks of textbooks 20 cm (about 8 inches) apart and place a piece of cardboard on top.
2. Gradually place weights in the center of the cardboard until it begins to sag in the middle.
3. Record the amount of weight the bridge held before it began to sag.
4. Experiment with a shorter span (distance between sides). Record how this changes your results.

Notes:

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Step 2:
1. Place an arch between the textbooks by carefully bending a piece of cardboard in the form of the arch. Make sure that it fits snugly.
2. Place a piece of cardboard on top of the arch, spanning the distance between the books.
3. Gradually place weights in the center of the cardboard until it begins to sag in the middle.
4. Record the amount of weight the bridge held.

Notes:

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Name: ____________________________
Date: ____________________________

Worksheet: Cardboard Arch Bridge

Observations

1. What type of bridge did you build in Step 1? What type did you build in Step 2?

Step 1: ____________________________

Step 2: ____________________________

2. What effect did adding the arch to the bridge have, if any?

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3. What other features could be added to the bridge to make it stronger?

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4. What happens when you changed the span of the beam bridge (distance between the two sides)?

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Name: ____________________________
Date: ____________________________

Activity: How the Bayonne Bridge Works!

Materials: Red and blue marker, crayon, or colored pencil

Objective: Determine the different types of bridges which are combined to form the Bayonne Bridge and identify some of the forces acting on the different parts of the bridge.

Step 1: Take a look at the photograph of the Bayonne Bridge and compare its structure with the Main Types of Bridges handout. What types of bridge is it? Does it combine more than one?

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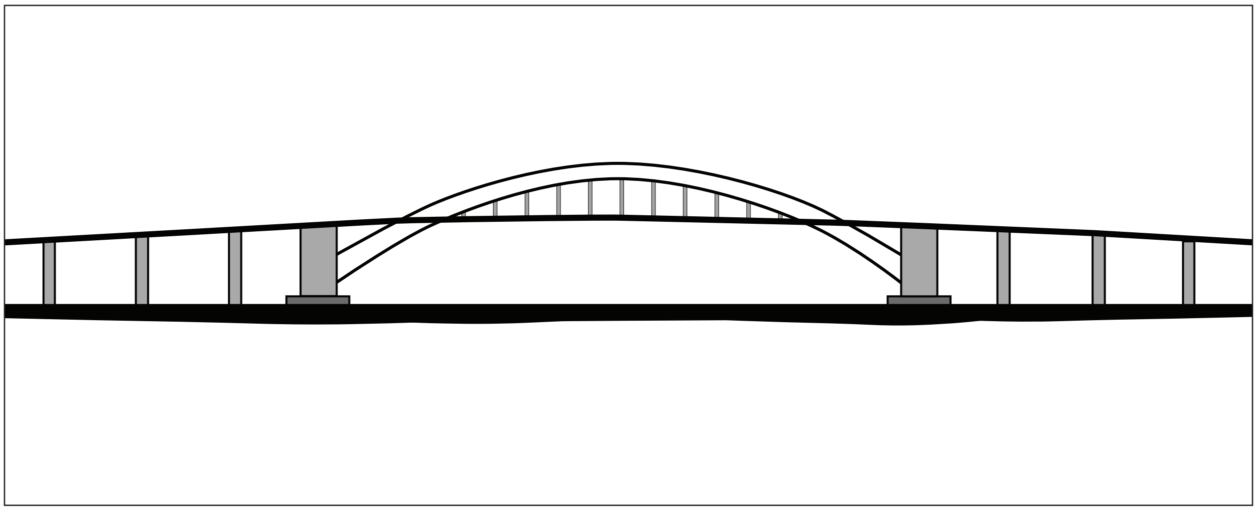
Name: ______________________________
Date: ______________________________

Activity: How the Bayonne Bridge Works!

Step 2: Take a look at the simplified diagram of the Bayonne Bridge which excludes the details of the truss system. Using **red** for compression and **blue** for tension, draw where these forces are acting on different parts of the bridge and its approaches. Use the diagrams on the Main Types of Bridges handout to see how these forces may act on the bridge.



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Additional Materials

CORE Standards
New York

This lesson meets the following Common Core and individual state core standards in Social Studies and Science.

New York (2016)
Fourth Grade Social Studies Core Standards
http://www.p12.nysed.gov/ciai/socst/documents/ss-framework-k-8a2.pdf

- 4.A.2- Recognize, use, and analyze different forms of evidence used to make meaning in social studies (including sources such as art and photographs, artifacts, oral histories, maps, and graphs).
- 4.A.6- Create an understanding of the past by using primary and secondary sources.
- 4.C.5- Describe historical developments in New York State with specific detail including time and place.

New York (2016)
Fourth Grade Science – Student Learning Standards
http://www.p12.nysed.gov/ciai/mst/pub/elecoresci.pdf

- T1.1 Describe objects, imaginary or real, that might be modeled or made differently and suggest ways in which the objects can be changed, fixed, or improved.
- T1.3 Generate ideas for possible solutions, individually and through group activity; apply age-appropriate mathematics and science skills; evaluate the ideas and determine the best solution; and explain reasons for the choices.
- T1.4 Plan and build, under supervision, a model of the solution, using familiar materials, processes, and hand tools.

CORE Standards
New Jersey

This lesson meets the following Common Core and individual state core standards in Social Studies and Science.

New Jersey (2014)
Fourth Grade Social Studies Core Standards
http://www.state.nj.us/education/cccs/2014/ss/

- SOC.K-4.6.1.4.B.2- Use physical and political maps to explain how the location and spatial relationship of places in New Jersey, the United States, and other areas, worldwide, have contributed to cultural diffusion and economic interdependence.
- SOC.K-4.6.1.4.B.4- Describe how landforms, climate and weather, and availability of resources have impacted where and how people live and work in different regions of New Jersey and the United States.
- SOC.K-4.6.1.4.B.7- Explain why some locations in New Jersey and the United States are more suited for settlement than others.

New Jersey (2014)
Fourth Grade Science –Student Learning Standards
Engineering Design
http://www.state.nj.us/education/cccs/2016/science/3-5-ETS1.pdf

- 3-5-ETS1-1.- Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time or cost.
- 3-5-ETS1-3.- Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. The performance expectations above were developed using the following elements from the NRC document A Framework for K- 12 Science Education.

Additional Resources

The following resources for teachers and educators include relevant information, ideas, and activities to explore and adapt as needed.

Online "Build-a-Bridge" Tutorials:
http://www.instructables.com/id/Toothpick-Bridge/
- Simple instructions, with images, for constructing your own truss bridge

http://www.exploratorium.edu/structures/
- A wide variety of activities related to bridges and other structures for all grade levels

http://www.education.com/science-fair/article/building-the-best-bridge/
- Simple instructions for bridge experiments using spaghetti and popsicle sticks

Online Arch Bridge Informational Video
https://nj.pbslearningmedia.org/resource/phy03.sci.phys.mfw.bbarch/arch-bridge/?#.Wo7O6YPwaUk
- Short video explaining how forces act on an arch and how an arch bridge supports weight

Online facts about the Bayonne Bridge
https://www.panynj.gov/bridges-tunnels/bayonne-bridge.html
- Official website of The Port Authority of NY & NJ with links on the bridge's history, images, and other information.

Online Bridge Facts/Activities
http://www.sciencekids.co.nz/sciencefacts/engineering/bridges.html
- Fun facts about the history of bridge building

http://www.historyofbridges.com/facts-about-bridges/
- Facts about bridge types, history, and model bridge building activities

Online Games/Challenges
http://www.pbs.org/wgbh/buildingbig/bridge/challenge/index.html
- Simple educational narrative games about building bridges for different communities

http://www.pbs.org/wgbh/nova/tech/build-bridge-p1.html
- More advanced educational narrative games about building bridges for different communities

YouTube Video (with additional bridge resources on the sidebar)
https://www.youtube.com/watch?v=ypfkMZFqSBA
- Animation of the construction of an arch bridge with deck above

WebQuests/Research Options
http://www.gwinnett.k12.ga.us/HarbinsES/Classes/burger/brigquest.htm#Task
- Virtual "Field Trip" to famous bridges around the world

Further Reading

Doig, Jameson W. *Empire on the Hudson: Entrepreneurial Vision and Political Power at the Port of New York Authority.* Columbia University Press, New York, New York, 2001.

Levy, Matthys and Richard Panchyk. *Engineering the City: How Infrastructure Works, Projects and Principles for Beginners.* Chicago Review Press, Chicago Illinois, 2000.

- Note: Grades 4+

Lewis, Anna. *Woman of Stone and Steel: Twenty-two Inspirational Architects, Engineers, and Landscape Designers.* Chicago Review Press, Chicago, Illinois, 2014.

- Note: Grades 6-8

Mysak, Joseph and Judith Schiffer. *Perpetual Motion: The Illustrated History of the Port of New York & New Jersey.* General Publishing Group, Inc., Santa Monica, California, 1997.

Rastorfer, Darl. *Bayonne Bridge: A Landmark by Land, Sea, and Air.* Port Authority of NY & NJ, 2007.

Reier, Sharon. *The Bridges of New York.* Quadrant Press, New York, New York, 1977 [2000 Reprint, Dover Publications, Mineola, New York.].

Richman, Steven M. *The Bridges of New Jersey: Portraits of Garden State Crossings.* Rutgers University Press, New Brunswick, New Jersey, 2005.

Salvadori, Mario, Saralinda Hooker, and Christopher Ragus. *The Art of Construction: Projects and Principles for Beginning Engineers & Architects (Ziggurat Book).* Chicago Review Press, Chicago, Illinois, 2000.

- Note: Grades 4+

Credits

Map found on pages S-3 and T-3 adapted from "Map of New York Harbor, Showing Location of Kill Van Kull Bridge" in *The Kill Van Kull Bridge between Bayonne, New Jersey and Port Richmond, New York*. Written by Henry W. Troelsch, Designing Engineer for the American Bridge Company, 1931, and published by the United States Steel Corporation. On file at the New York Public Library.

Images found in this Lesson Plan are used Courtesy of the following institutions:

The Library of Congress, Historic American Engineering Record Collections
The New York Public Library, Digital Collections
The Port Authority of New York and New Jersey Archives
The Royal Australian Historical Society

This Lesson Plan was created as one of several items required as mitigation for the Bayonne Bridge Navigational Clearance Program. The Bayonne Bridge, which spans the Kill Van Kull, is located in the City of Bayonne, Hudson County, New Jersey and Staten Island, Richmond County, New York. Owned and operated by The Port Authority of NY & NJ, the bridge has been determined eligible for listing in the National Register of Historic Places. The mitigation for its reconstruction (completed in 2019) was established by a Programmatic Agreement (PA) among the United States Coast Guard, New Jersey Department of Environmental Protection – Historic Preservation Office, New York State Office of Parks, Recreation and Historic Preservation, the Advisory Council on Historic Preservation, and The Port Authority of NY & NJ. The PA satisfies Section 106 of the National Historic Preservation Act of 1966, as amended. The Lesson Plan satisfies Stipulation 5 of the PA. The Lesson Plan has been created to provide students with an understanding of the history and basic structural design of the Bayonne Bridge. It was created in 2018 by RGA, Incorporated, cultural resource consultant, in consultation with The Port Authority NY & NJ, the New York State Education Department, and the State of New Jersey Department of Education.

January 31, 2020