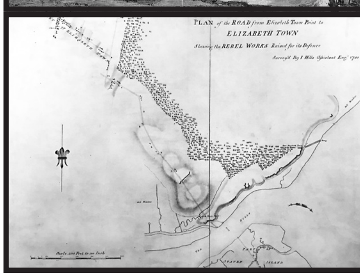


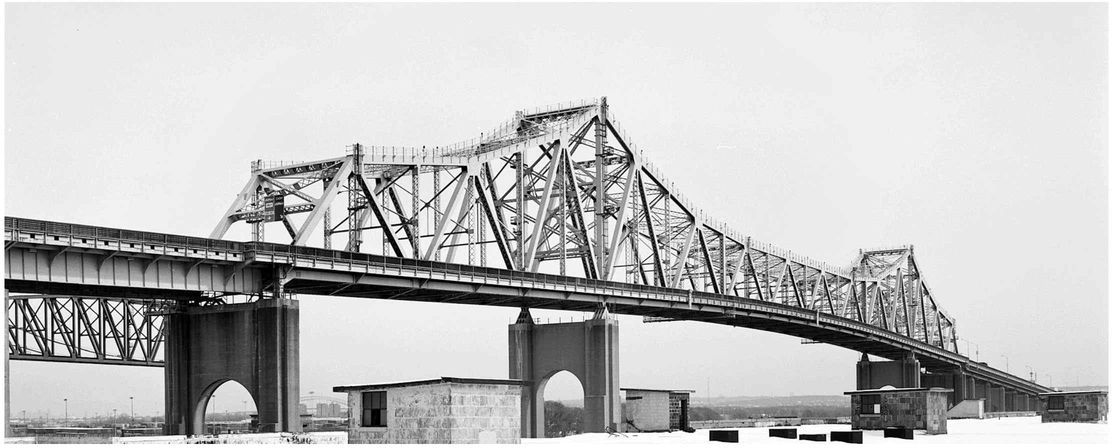
The Goethals Bridge
Resources for Teachers

[Printable and Electronic Versions]

This Lesson Plan was created as one of several items required as mitigation for the Goethals Bridge Replacement Project. The Goethals Bridge is located in the City of Elizabeth, Union County, NJ and Staten Island, Richmond County, NY. Owned and managed by the Port Authority of New York and New Jersey, the bridge has been determined eligible for the National Register of Historic Places. The mitigation was established by a Memorandum of Agreement (MOA) 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, and the Port Authority of New York and New Jersey. The MOA satisfies Section 106 of the National Historic Preservation Act; the lesson plan satisfies Stipulation 5C of the MOA. The lesson plan has been created to provide students with an understanding of the history and basic structural design of the Goethals Bridge. It was created by RGA, Incorporated, cultural resource consultant, 2016.

The Goethals Bridge
Resources for Teachers

Goethals Bridge as it exists today (Joseph Elliott 2014)



Introduction:

When we build bridges we meet a need to connect people and places while often creating complex and beautiful structures. In this lesson, students will see how a structure like the Goethals Bridge promoted the economies of Staten Island and New Jersey while helping to lay the foundations for the modern Port of New York and New Jersey. They will then learn about the bridge, its design, and how it works.

Target Grade Level:

Fourth grade instruction, adaptable to higher levels as desired in the subjects of History, Geography, Civics, and Science.

Overview/Objective:

In Part I, students use their knowledge of New Jersey and New York geography and history, critical thinking skills, and map reading skills to understand why and where the Goethals Bridge was built. In Part II, students use math and science concepts to build and test bridge models and learn how the Goethals Bridge works.

Focus:

Discussion of the geography of New York Harbor, the history of the Goethals Bridge, its importance to the states of New York and New Jersey when first proposed, and why replacing it remains vital to the region today. How do simple beam and truss bridges work? Why is a more complex bridge like the Goethals, a steel truss cantilever bridge, appropriate for the location?

Note: Directives for students are found througout the text**.**

Computer Rendering of the Replacement for the Goethals Bridge projected to open in 2018 (Courtesy of PANYNJ)

Part I: Culture, Geography, & the Goethals Bridge

Goethals Bridge, 1927 (Courtesy of PANYNJ)

Materials:

1. 1924 Map of North New Jersey/Port of New York (included below)
2. Present Day Map of North New Jersey/Port of New York and New Jersey (included below)

Goal:

In this section we will draw on the student's knowledge of New Jersey and New York geography, map reading skills, and creative thinking to discuss what factors influence where and why bridges are constructed.

Why We Build Bridges – Why We Built the Goethals Bridge

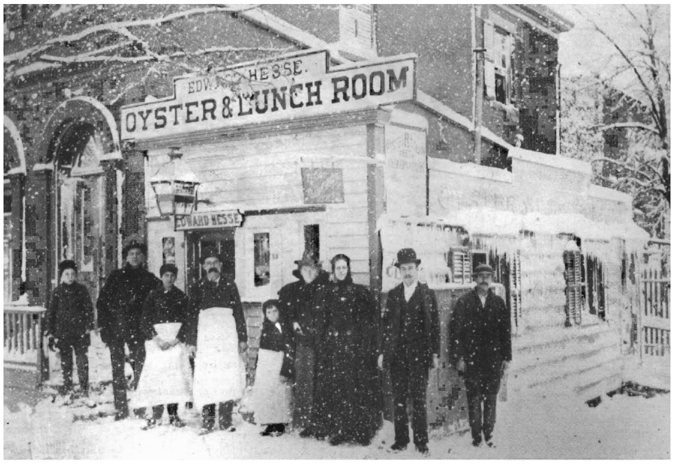
We build bridges to connect people, places and goods from one side of a divide (river, bay, valley, for example) to another. The Goethals Bridge was built in order to improve the movement of goods and people in and around the Port of New York and New Jersey. The Goethals Bridge was the first bridge completed by the Port Authority of New York and New Jersey (Port Authority), a new organization formed just three years before to manage the Port. The Goethals Bridge opened on the same day in 1928 as its sister bridge, the Outerbridge Crossing. These bridges were important for two reasons:

1. They promoted economic growth and commerce for the Port of NY and NJ region by connecting port facilities and communities with efficient ground transportation.
2. They gave the public confidence in the Port Authority, a brand new and extremely important organization which had not yet been tested.

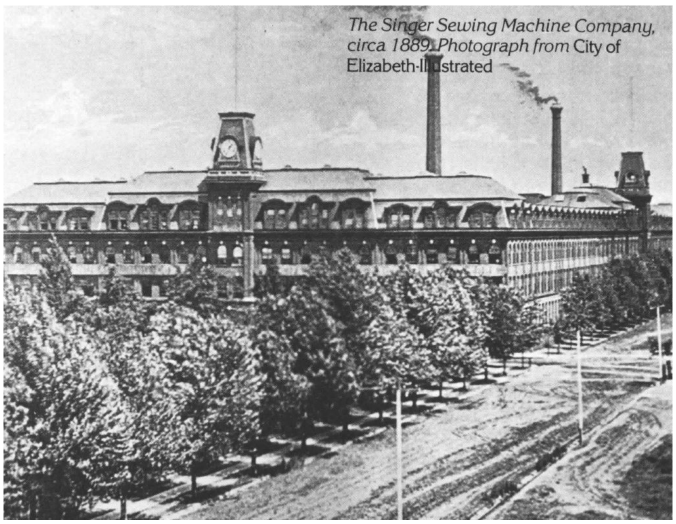
The Port Authority would go on to pursue many more ambitious projects, including the Bayonne and George Washington bridges.

"Kill" (see following page):

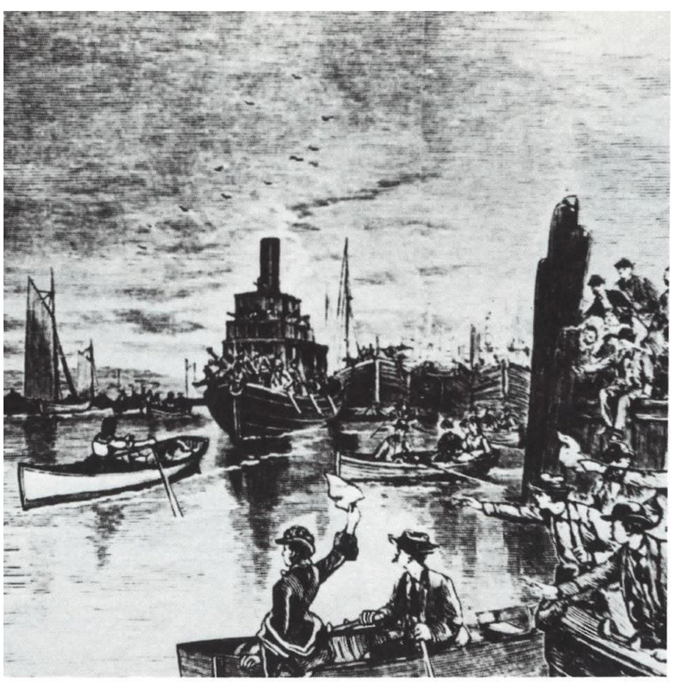
Kill is the Dutch word for "creek." The Dutch were the first settlers of New York City and the names of some of the waterways in the area incorporate Dutch words.



Oyster House, Staten Island, 1898 (Courtesy of the Staten Island Historical Society as seen in MacKenzie, 1996)



Singer Sewing Machine Factory, 1889 (Photograph from City of Elizabeth Illustrated as seen in Aquilana et al., 1982)



Race across Arthur Kill, 1890s (Courtesy of Elizabeth Public Library as seen in Aquilana et al., 1982)

The Goethals Bridge spans Arthur Kill, a major shipping channel between New Jersey and Staten Island, New York. The span of the bridge is 1,152 feet (about 351 meters or 1/5 of a mile) and its design is called a "steel truss cantilever" bridge. When it was built, it had four lanes for traffic (two in each direction) and a 5-foot wide lane for walkers on each side of the bridge.

Before the Goethals Bridge was built, travel between New Jersey and Staten Island was difficult, but vitally important to the economic and cultural life of the both places.

Staten Island's economy was varied and relied on transportation to neighboring off-island communities. The island, also known as "Richmond County" before it became part of New Yok City, had a variety of industries. Beginning in the seventeenth century these included farming, shipbuilding, and oyster planting. These industries were soon followed by the manufacturing of paper, plaster and paint, as well as dyeing and printing.

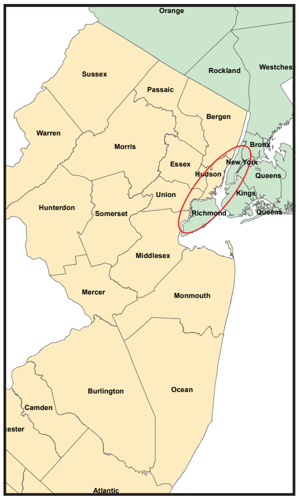
On the western shore of Arthur Kill is New Jersey. Here farms and pastures gave way to industrial development with the advent of the railroad in the mid-nineteenth century. Paper mills, machine shops, iron-casting factories, and later, oil refineries located here. Major companies included Singer Sewing Machine Company and Standard Oil. Railroads offered direct access to inland cities while seaports and ferries linked New Jersey to Manhattan, Staten Island, and other markets by water. Towns and cities, such as Bayonne, Elizabeth, and Jersey City grew rapidly at this time to meet the housing and other needs of workers.

The industries on Staten Island and New Jersey provided thousands of jobs, becoming one of the great manufacturing – and transportation – centers of world. But the people working in these places did more than just work. They had co-workers, family and friends on both sides of Authur Kill. A barrier to be sure, but the waterway also provided opportunities for leisure and recreation: a canoe race, for example in the late 19th century between women from New Jersey and Staten Island working at the Singer factory was met with much friendly competition (New Jersey won).

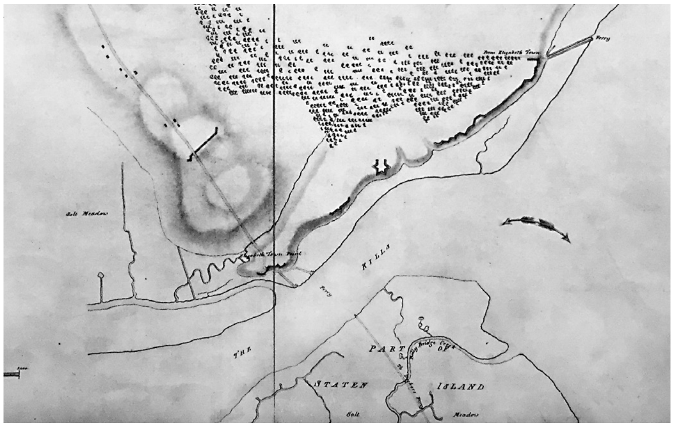
Keiber Farm in Westerleigh, Staten Island, 1900 (Courtesy of the Westerleigh Improvement Society as seen in Roberts, 2012)

What did the Port of New York and New Jersey look like before the Goethals Bridge?

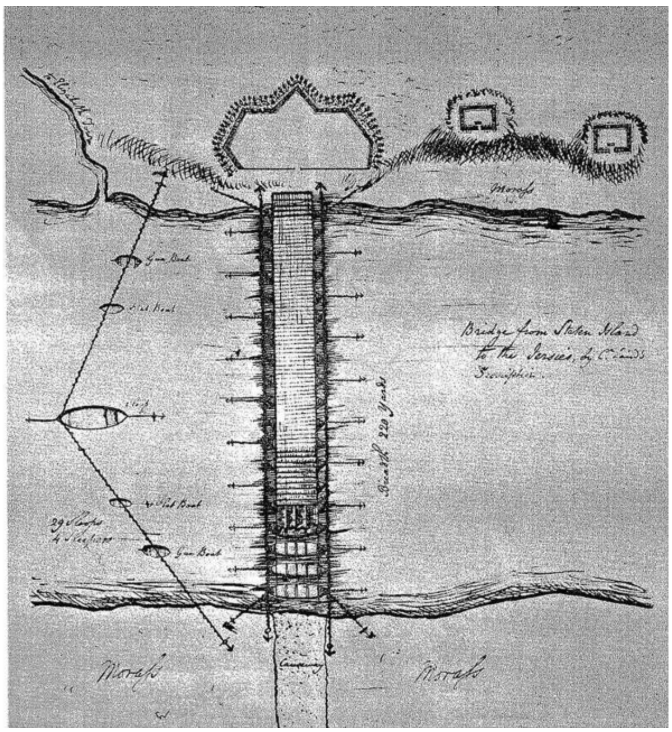
This 1924 map of the Port of New York and New Jersey below was drawn before highway bridges connected the five boroughs of New York City to New Jersey. Look closely and find Staten Island (also labeled "Richmond"), Elizabeth, Newark, Jersey City, Bayonne, Manhattan, and Brooklyn. Find examples of roads and railroads. Ferry routes, not shown on map, were the primary means of crossing the waterways before the bridges were built.



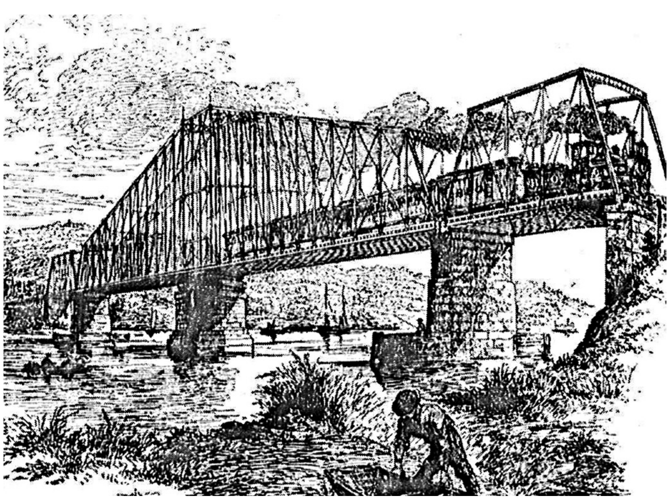
1924 "Rand McNally Standard Map of New York - Philadelphia District", including the Port of New York (Courtesy of David Rumsey Historical Map Collection)



Map excerpt showing a ferry between Elizabeth and Staten Island in 1780 (Hills 1780)



Revolutionary War Era (1781) map of Elizabethtown, showing a temporary "pontoon" bridge over the Arthur Kill near where the Goethals Bridge now stands. The text reads "Bridge from Staten Island to the Jersies" (Courtesy of Clements Library, University of Michigan)



Baltimore & Ohio Railroad Bridge over Arthur Kill, built 1890. The location of this railroad bridge was close to where the Goethals Bridge would eventually be built. (Reier 1977)

Group Discussion: Modes of Transportation

How did people and goods cross Arthur Kill and other waterways before highway bridges like the Goethals Bridge were built? Split up into groups, and each group will need to think of at least two examples of how people could have crossed the water to create social and economic connections before bridges. After you have brainstormed ways to cross the kill, discuss the Modes of Transportation provided below.

Boats

Ferries began crossing Arthur Kill as early as 1671. Ferries transported people and goods between New Jersey and Staten Island. A short time later, ferries were also established across Kill Van Kull connecting Staten Island and Bayonne, New Jersey. Ferry service began operating on a regular basis in the mid-eighteenth century when commerce and travel demands warranted the service (Bayles 1887: 678).

Temporary Bridges

During the Revolutionary War, British forces constructed a "pontoon" over Arthur Kill, between Elizabeth and Howland Hook (the northwest tip of Staten Island). This floating bridge, made of movable barges, was destroyed after the war.

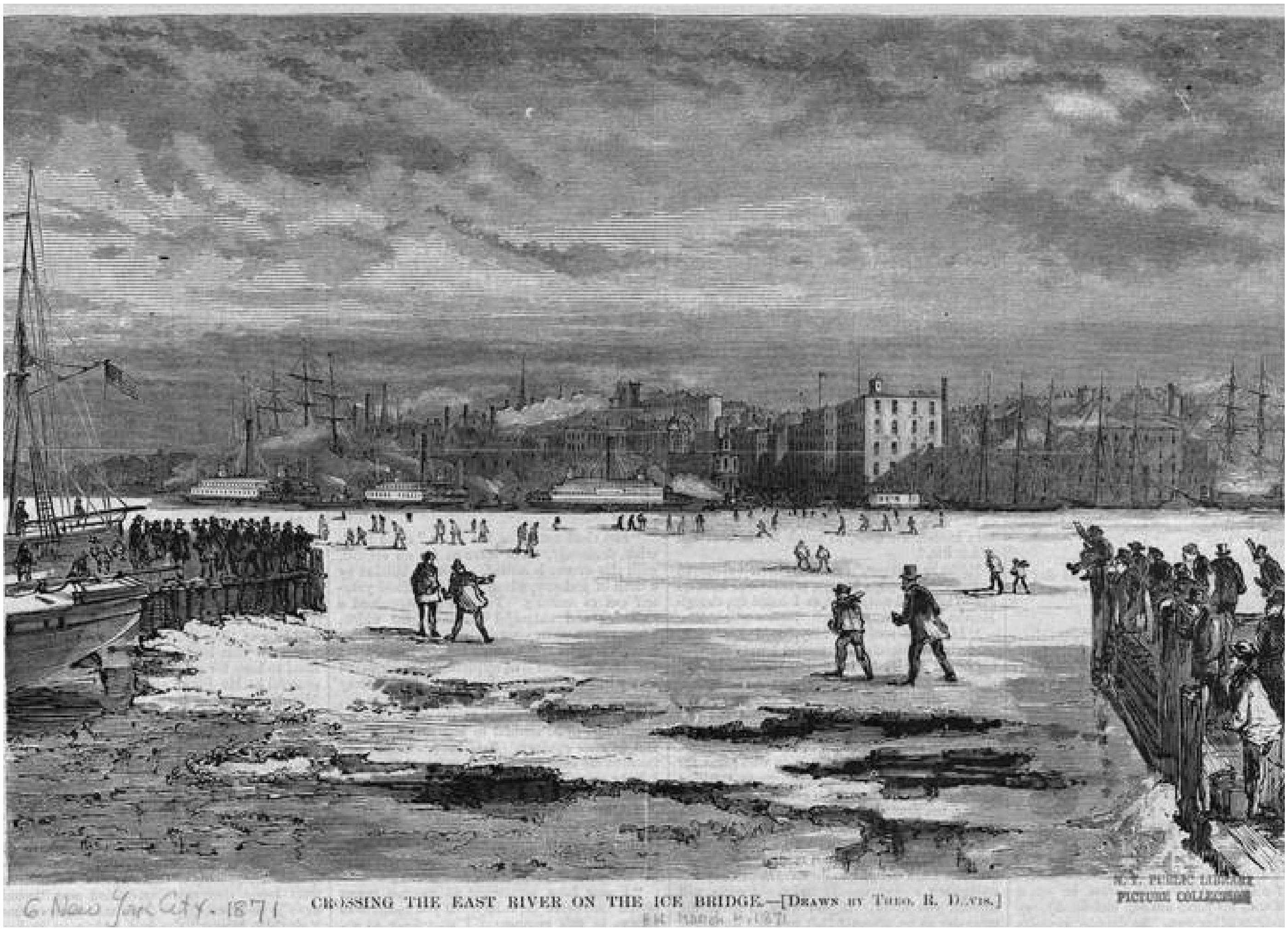
Walking on Ice!

Arthur Kill and other waterways around the Port of New York were subject to periodic freezing with ice thick enough to travel across. The winter of 1779-1780, during the Revolutionary War, was brutally cold. The Authur Kill froze over. General George Washington, stationed in Morristown, took advantage of the freeze. He ordered General John Sullivan with up to 3,000 troops and 300 sleds over Arthur Kill to stage a surprise attack on Staten Island, then a loyalist stronghold. While the attack failed (the British saw them coming), the troops looted the local civilians, only to be ordered by General Washington to give everything back. The British also mounted several attacks on rebel forces in New Jersey using the frozen kill (Sullivan 2012).

In the nineteenth century, several cold winters caused ice flowing down the Hudson River to clog and back up the adjoining rivers. The Hudson River was passable on foot for four days in February of 1875. The East River would freeze more frequently creating "ice bridges" which were popular topics in the newspapers (New York Times 1911).

Railroad Bridges (for cargo only)

Early railroad bridges such as the Baltimore and Ohio Bridge, built in 1890, connected New Jersey and Staten Island, between Elizabeth and northwest Staten Island. Can you find this railroad on the 1924 map? Several other railroad bridges crossed the Newark Bay, connecting Newark and other cities with Jersey City, Hoboken, and Bayonne.



Ice Bridge over the East River, excerpt from March 1871 *Harper's Weekly* magazine

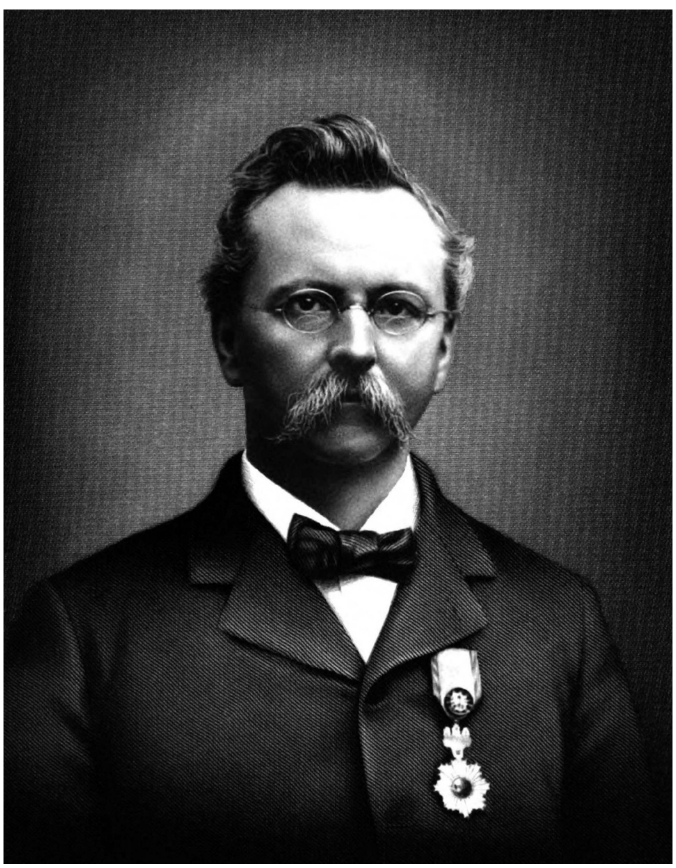
Personal Connections

Even though business and trade may have been the main reason why people traveled across the water, social connections drove many people to make the journey. A desire to meet with friends and relatives, and visiting tourism destinations motivated inviduals, families and communities to envision an easily-accessible road bridge between Staten Island and New Jersey.

Read the following excerpt from an oral history from Andrew White, a former resident of Linden, New Jersey. He lived there before the Goethals Bridge was built. Write down one way you think the Goethals Bridge may have changed everyday life for him or for the people on Staten Island.

> Andrew White: "I guess [my parents met] through Lithuanian circles. There was a Lithuanian Church in Elizabeth, St. Peter and Paul… then there were a lot of Lithuanian, Polish, and other ethnic people… We are such a mixed nation today; we don't have the neighborhoods we used to have of the ethnic groups…My mother told me they used to go to the beaches on Staten Island…They were nice beaches then, believe it or not. They had amusements, boardwalks, and restaurants, and my mother said they used to go there a lot. They would take, before Goethals Bridge was constructed, a small ferry from Elizabethport and then a trolley across the island. It took about an hour or so to get there, maybe longer, crowded with people from Jersey, but she said they had a lot of fun. South Beach, I think, was one, and New Dorf might have been another one."

Circa 1920 photograph showing the crowded maritime conditions within the Port of NY and NJ (Doig 2001)



John A. L. Waddell, a highly respected bridge engineer of the late nineteenth century was chosen to design the Goethals Bridge and the Outerbridge Crossing (Waddell and Harrington 1905)

Where Was The Goethals Built?

Discussion:

The important ferry and railroad routes, as well as the established network of roads in both Elizabeth and Staten Island, set the groundwork for where the Goethals Bridge would be constructed. By the early 1900s, the region between New York and New Jersey was a bustling center of economic, social and political interest. The Port of NY and NJ, however, was in chaos. Its waterways and roads were congested and disorganized.

A major reason that the port was in such chaos was that the highways, railroads, canals and other transportation systems operated under multiple authorities. The result was an ongoing argument between New York and New Jersey over the boundaries, access rights, fees, and ultimate control of the enormous trade flowing into and out of the port.

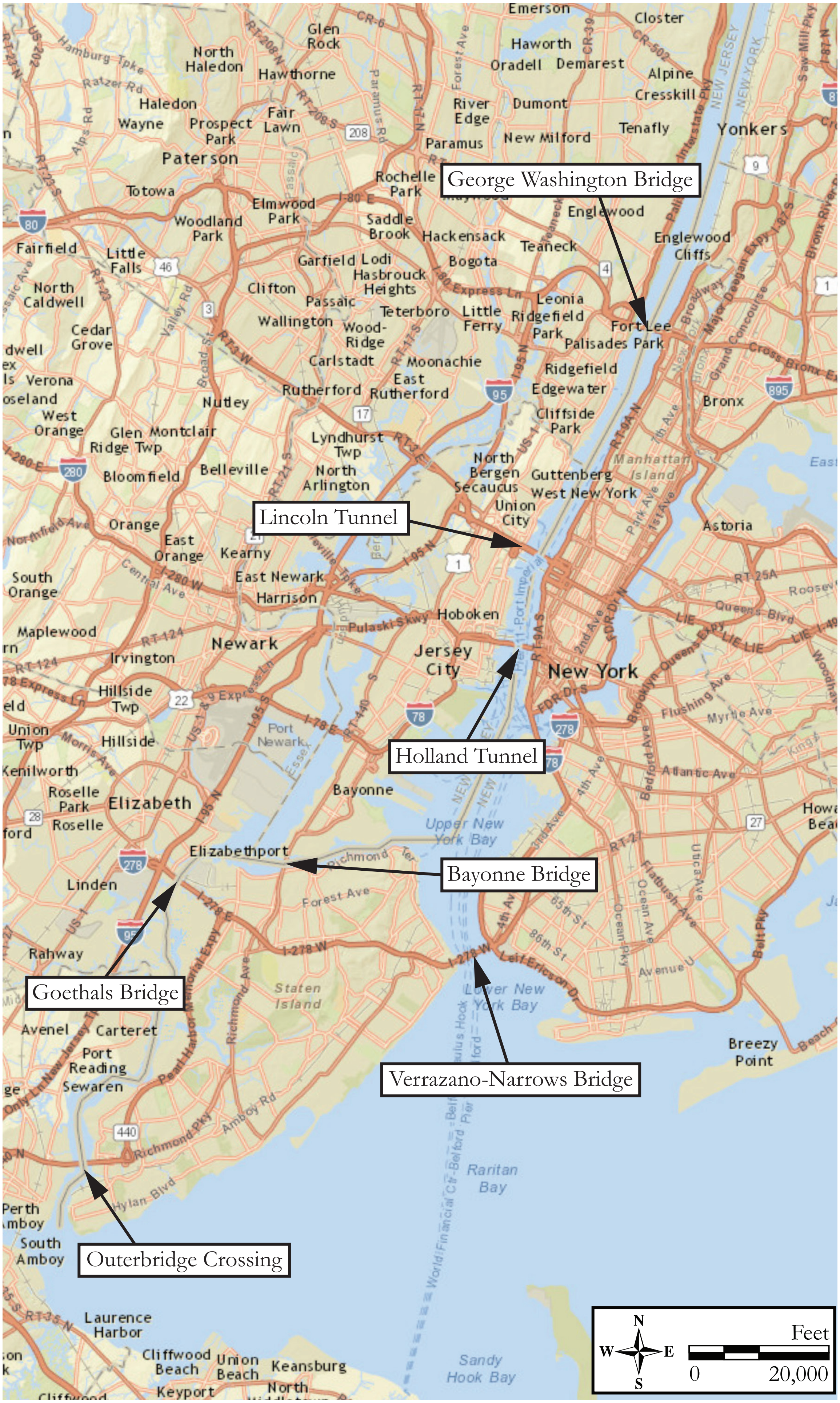
To find a solution to this problem both states came together to form a commission to study the issue. The result was the formation in 1921 of the The Port of New York Authority. It is now known as the Port Authority of New York and New Jersey [PANYNJ], but often called simply the "Port Authority."

To facilitate transportation and reduce congestion, one of the first plans that the Port Authority devised was to build four bridges.

- Goethals Bridge between Elizabeth, New Jersey and Staten Island, New York
- Outerbridge Crossing Bridge between Perth Amboy, New Jersey and Staten Island, New York
- Bayonne Bridge between Bayonne, New Jersey and Staten Island, New York
- George Washington Bridge between Fort Lee, New Jersey and Manhattan Island, New York.

The Port Authority decided to begin its bridge-building campaign with the Goethals Bridge and the Outerbridge Crossing. It reasoned these bridges would have the highest probability of success, and it needed to prove that the new organization was effective in management, design and construction before taking on bigger projects. A necessary part of the project's success was financing through the selling of bonds, a way of borrowing money to pay for the bridge. The Port Authority encouraged the public to buy bonds by hiring John A. L. Waddell to design and build the new bridges. Waddell was a famous and successful bridge engineer and the Port Authority was able to use his reputation to get support from the public.

Present day map showing some of bridges and tunnels operated by the Port Authority of New York and New Jersey as well as the Verrazano-Narrows Bridge, operated by the Metropolitan Transportation Authority (ESRI 2016).



Group Discussion:

Imagine that it is 1925 and the newly-established Port Authority has asked for public input on where it should build a highway and pedestrian bridge between New Jersey and Staten Island. The Port Authority has asked you for your input.

1. What factors do think would be important in choosing the location of the bridge?

2. Take another look at the 1924 map. What location would you select for a bridge to connect these states? Select a location and discuss why.

Some Practical Factors to Consider:

- Narrowness of the crossing; Proximity of large cities (Elizabeth, Perth Amboy, Bayonne, Jersey City, Brooklyn, Manhattan); Access to port facilities; Locations of waterways; Closeness of already-developed areas; Locations of established communities; Tourism to beaches on the south shore of Staten Island and in New Jersey.
- The original engineers had to consider geological conditions and traffic patterns. These are not apparent on the map, but are important to think about!
- The original design of the bridge included alternate options, including a tunnel under Arthur Kill and a bridge that would utilize the existing Baltimore & Ohio Railroad Bridge.

3. Compare the 1924 and the present day maps provided above. Look at where the Port Authority of New York and New Jersey decided to build its four bridges. How do these locations compare with the location that you chose?

Part I: Summary

The bridges built by the Port Authority helped form a "necklace" of highways that traversed the ports of New York and New Jersey (also called the New York Harbor). They encouraged economic growth by connecting the port facilities, shortening truck deliveries, connecting population centers, and fostering new connections between cultural communities. The first bridge to open was the Goethals Bridge followed closely by its sister structure, the Outerbridge Crossing. Both bridges opened on the same day in 1928; the Goethals Bridge in the morning and the Outerbridge Crossing in the afternoon. The location of the Goethals Bridge was chosen in 1926 after many design drafts took into account traffic needs, geological conditions, and shipping interests.

Part II of this lesson discusses the Goethals Bridge itself. It will describe the reasoning behind the engineers' choice of a steel "cantilever through truss" design for the bridge and how the structural design of Goethals Bridge works.

How Does the Goethals Bridge Work?

Materials:

1. Blocks
2. Strips of poster-board of varying lengths
3. Weights: pennies, toy cars, or other small objects
4. Bag & Book
5. Tape

Goal:

In this section, you will learn the basics of how bridges work, analyze a diagram of the Goethals Bridge, and learn how it works by experimenting with a simple cantilever. You will also build model bridges to test the stability of two different types of bridges.

What Type of Bridge is the Goethals?

After the location for the Goethals Bridge was chosen and John A.L. Waddell was recruited, a design was proposed for the bridge. Several designs would have worked for this span (1,152 feet); however, it was important to the Port Authority to build a bridge that met two central requirements: it needed to be high enough to allow large shipping vessels to pass underneath both during and after construction and it needed to be built quickly and efficiently to prove the abilities of the Port Authority to complete other important projects within reasonable timelines. The engineers chose a "cantilevered design." This type of bridge was very expensive because of the large amount of steel required. Its sturdy appearance, however, and more importantly the ability to keep Authur Kill open to shipping vessels passing underneath during construction was a necessary trade-off.

Goethals Bridge under construction, 1926 (Courtesy of PANYNJ)

Bridge Vocabulary

The Goethals Bridge is a steel cantilever through truss bridge that builds on the technology of simpler bridges. First you will review how simpler beam and truss bridges work and think how they carry the weight of their loads. You will then learn about how cantilever bridges work.

Abutment: A structure at each end of a bridge on which the superstructure rests.

Deck: The part of the superstructure on which vehicles ride or people walk.

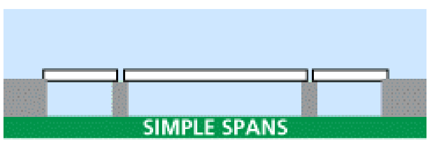
Pier: A structure between abutments on multi-span bridges that supports the superstructure above.

Span: That part of the superstructure between two supports (piers, abutments, cantilever arms) of a bridge. More than one span is a "multi-span" bridge.

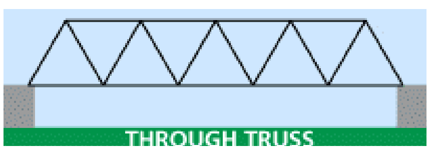
Substructure: The structure forming the foundation of the bridge, including piers or abutments.

Superstructure (or **Beam**): The part of the bridge that rests on the piers or abutment.

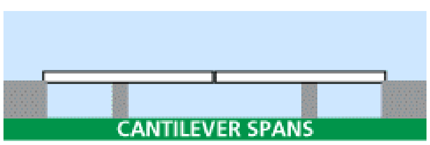
Some Examples of Bridge Designs



Beam Bridge: This is a common bridge type with a horizontal superstructure supported on each end by substructure foundations or piers. The beam supports the load or weight of the span by transferring the force to the piers or abutments below.

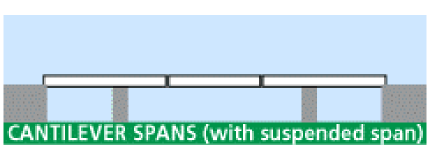


Truss Bridge: Lengths of steel or wood connect to form triangles that are called trusses. A truss bridge superstructure consists of an assembly of triangular units which support the deck, and is generally much stronger than a beam. A "through truss" is one that allows the traffic to travel through the superstructure, rather than on top of it.

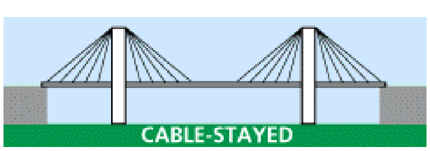


Cantilever Arm Bridge: A cantilever arm is a horizontal beam supported at one end. This type of bridge usually has a superstructure of two outer cantilever arms which meet in the middle. Using a cantilever arm instead of a simple beam allows bridge builders to create longer spans across wider obstacles.

Cantilever Through Truss Bridge: The Goethals Bridge has a suspended span and also uses trusses to stabilize the bridges structure, which the traffic passes through as it crosses the bridge. A diagram of a similar bridge which clearly shows the span is found in the pages below.



Note: Many cantilever bridges, like the Goethals Bridge, have a third span suspended in the center between the two cantilever arms.



Cable-Stayed Bridge: The diagonal cables in a cable-stayed bridge hold up the span below and are connected to high towers. This is the type of bridge that is replacing the Goethals Bridge.

(Bridge Diagrams Courtesy of Bruce Cridlebauch of PHHBridges.com)

Experiments

Bridge Stability Experiment: Beam and Truss Bridges

Teacher's Note:
See Appendix A for
Discussion of Experiments

Now that you have reviewed the basic types of bridges, you will experiment with the factors which influence the loads they carry in real life.

Beam Bridge: Beam bridges can be very simple, connecting two points, such as a balance beam or a log over a stream. Using blocks as supports (substructure), strips of poster-board or index cards for the deck of the superstructure, books for the abutments, and a lightweight load such as pennies, test the stability of a simple beam bridge.

Penny beam bridge example (Courtesy of RGA, Inc. 2016)

1. How many pennies can you balance on your beam bridge before it collapses?
2. What factors affect how many pennies can be supported by the bridge?
3. Is there a length of beam which simply cannot support any pennies (i.e. when it collapses under its own weight)?
4. Can a pier be used to support the span?

Truss Bridge: Now fold a long strip of poster-board into an accordion shape, with approximately 1-inch folds, creating "trusses" (see image at left).

Tape this assembly of trusses on top of a strip of flat poster-board, taping each end of the truss to the board. Tape a second poster-board "beam" on top of the truss assembly.

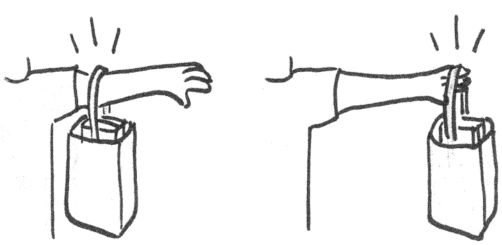
Experiment again with the ability of the bridge to support different weights, and with different distances between supports.

Paper Truss Bridge Example, showing the strength of the truss as compared to the beam bridge above (Courtesy of RGA, Inc. 2016)

Cantilever Bridge Experiment

The Goethals Bridge uses three elements to create stability: the strength and rigidity of steel, the stability of the triangle truss shape, and the balancing force of the cantilever arms. Let's see how a cantilever arm works.

Simple Cantilever: A cantilever is a beam supported on one end. This might be a diving board or a horizontal pole holding a flag ---or your own arm!



Simple Cantilever Example, showing the support/pier, the counterweight, and the cantilever arm (Images by RGA, Inc. based on PBS.org Mini-Cantilever Activity)

1. Put a heavy book in a bag. Do you think you can support the weight with one arm?
2. Place the bag on your arm, near your shoulder, then stick your arm out horizontally. Is it easy or hard to hold up the bag?
3. Now try and hold the bag in your hand with your arm straight out. Is it easier or harder to support the bag?
4. Draw a Diagram of your cantilever. Label the support/pier, the counterweight, and the cantilever arm.

Goethals Cantilever Through Truss Bridge:

Below is a diagram of the Goethals Bridge drawn in 1928. In addition to the bridge, the diagram shows the roadway approaches on the east and west sides. The Goethals design incorporates beams, trusses, and cantilever arms to support the loads it carries. The Goethals Bridge has a suspended span in the center. The span is difficult to see because of the bridge's design, which created a smooth line along the arches of the upper beams. In reality it works like the second diagram (showing the Grace Memorial Bridge, a similar structure in Charleston, South Carolina) with the suspended span (in blue) supported by the cantilever arms.

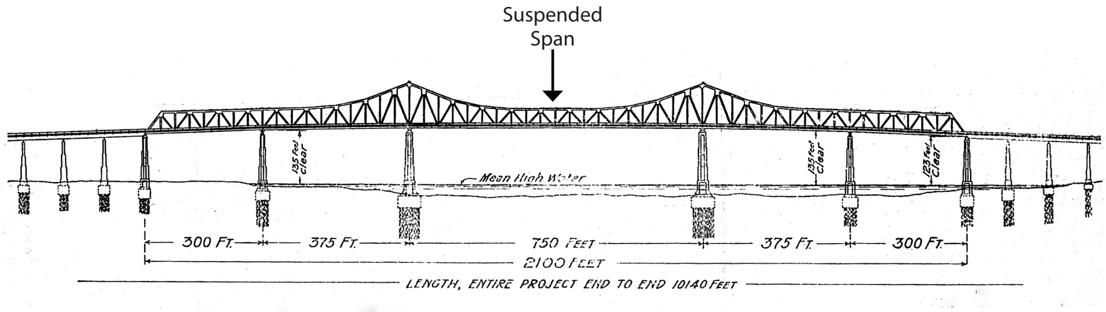


Diagram of the Goethals Bridge from the pamphlet distributed at the Bridge's Opening (Courtesy of the PANYNJ)

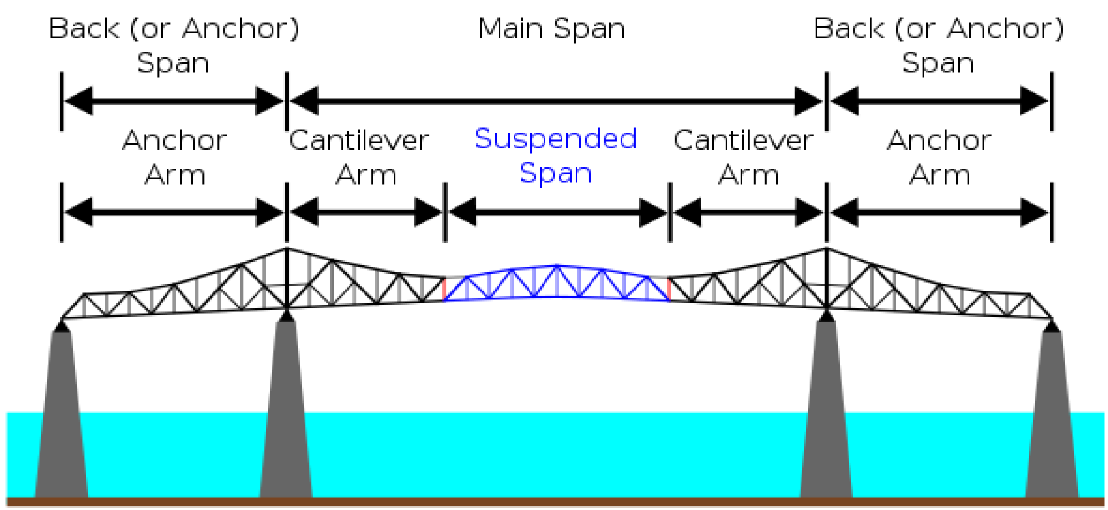


Diagram of the John P. Grace Memorial Bridge demonstrating a cantilever truss bridge (Wikicommons, PennySpender1983)

How it works!

The cantilever bridge utilizes the stiffness of the superstructure material (the Goethals Bridge uses steel) and the ability to balance the superstructure from supports or piers to span the Authur Kill. In the case of the Goethals Bridge, the superstructure is composed of two "anchor arms," two central cantilever arms, which begin at opposite sides of the Author Kill. In the center, directly over the water, is the suspended span, placed between the central cantilever arms (it is shown in blue in the diagram of the Grace Memorial Bridge above). These central cantilever arms, which hold the suspended span in between, are connected to the anchor arms. The anchor arms are in turn anchored to piers. The tension caused by the weight of the suspended or center span is counterbalanced by the anchor arms, which are anchored to the piers, enabling the arms to support the suspended span in between.

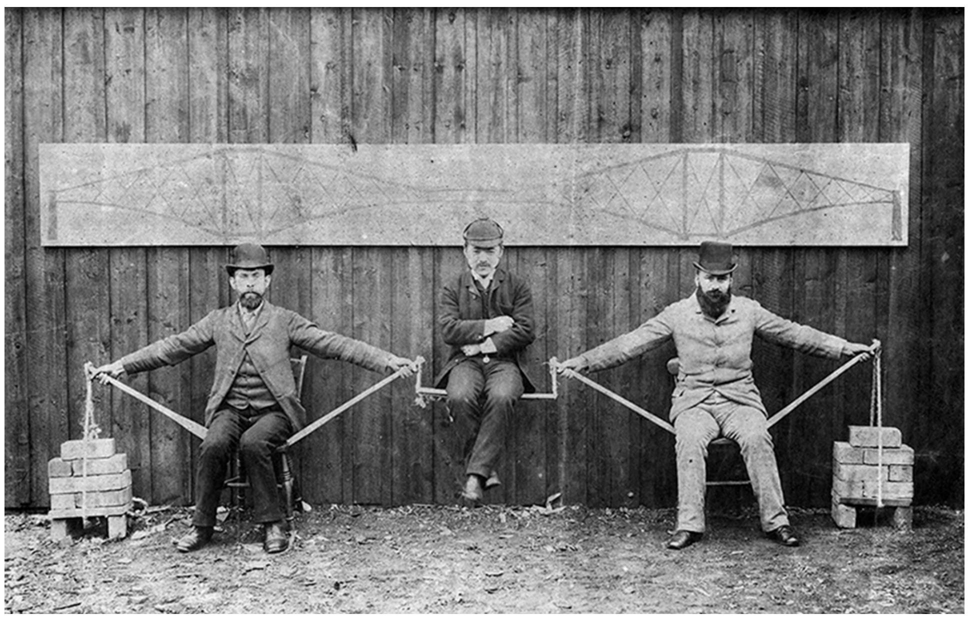
The design allowed for a wide shipping channel between the central piers while the suspended span, at the highest point above the water, enabled large ships to pass beneath. Construction began at each end of the bridge, thus enabling the channel to remain open throughout construction.

OPTIONAL: 1887 Cantilever Bridge Demonstration Discussion

To understand how all these forces work together, take a look at a cantilever bridge on a human-scale. In the image below, English engineers Sir John Fowler and Sir Benjamin Baker and Japanese engineer Kaichi Watanbe model how the Firth of Forth Bridge works. This cantilever truss bridge was built in Scotland and is somewhat different from the Goethals in appearance, but it uses the same principles. This demonstration was undertaken by the bridge engineers in 1887 to show that the design was safe. Note: this experiment should not be tried in the classroom or at home.

What you see below are the two outer men sitting on chairs with their arms extended. The two bats that each man holds are butted up against their chairs. These men are the "supports" or piers of the bridge, as seen in the image behind them. The "suspended" or center span (flat piece of wood under the man in the center) is hanging from the inner end of the bats. At the same time, the brick supports represent weights to balance the load that the central man exerts on the cantilever arms. The men's arms supporting the suspended span are the "central cantilever arms" and their arms supporting the brick weights are the "anchor arms." When a load is put on the suspended span by a person sitting on it, the men's arms and the anchorage ropes come into tension.

Benjamin Baker demonstrating the safety of the Firth of Forth Bridge in Scotland (Baker 1887)



In 2014, a class at the Università IUAV di Venezia re-enacted the 1884 Human Cantilever and demonstrated the principle of the Firth of Forth Bridge. A video of this can be seen at: https://www.youtube.com/watch?v=jBdmAyyUnHs. This is a two-minute video, but if you only want to show the most important part, the construction of the human cantilever bridge demonstration can be found between the minute markers: 1:15-1:50.

Still image from 2014 Human Cantilever video (Courtesy Università IUAV di Venezia)

Part II Summary:

The network of bridges and tunnels throughout the Port of New York and New Jersey was begun with the opening of the Goethals Bridge and was not complete until 1964, when the Verrazano Narrows Bridge was built. The Goethals Bridge and the Outerbridge Crossing laid the groundwork for further community and economic development on Staten Island and northern New Jersey. Due to the Port Authority's success in quickly and efficiently building the Goethals Bridge, the public gained confidence in the Port Authority. This confidence buoyed the Port Authority to embark on other bridge projects such as the Bayonne Bridge, and the monumental task of constructing the George Washington Bridge.

Today, almost 90 years later, the Port of New York and New Jersey remains as busy as ever. Modern large-capacity container shipping, big-rig truck transport, interconnected highway networks, tunnels and bridges knit the Port of New York and New Jersey together and help bring prosperity to the region. The original Goethals Bridge has served its purpose well, but it no longer meets the demands of today. The time has come for a new span. The Port Authority is replacing the current structure with a new "cable-stayed design" dual span suspension bridge. This type of bridge suspends the road deck from thin steel cables tied directly to tall piers. The design uses less steel than the old design and fewer riveted connections.

The Goethals Bridge Replacement is projected to open in 2018. This new bridge will have two separate spans, each with three 12-foot wide lanes, replacing the smaller 10-foot wide lanes of the existing Goethals Bridge. Each span will also have shoulders allowing for disabled vehicles to pull over, and 10-foot wide sidewalks/bikeways. Between the two spans, an area is available for the potential construction of a public transit rail line. The new bridge will have a similar height above the water as the existing bridge, 138 feet. The new bridge will double the potential number of vehicles crossing the span, ease congestion, and speed cargo traffic throughout the Port of New York and New Jersey well into the twenty-first century.

Computer rendering of the new bridge which will replace the Goethals, projected to be opened in 2018, 90 years after the original Goethals Bridge was opened (Courtesy of PANYNJ)

CORE Standards:

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

New York:

Fourth Grade Social Studies Core Standards

- 4.A.7 - Create an understanding of the past by using primary and secondary sources.
- 4.C.4 - Recognize the relationship among geography, economics, and history in Social Studies.
- 4.C.5 - Describe historical developments in New York State with specific detail including time and place.

New Jersey:

Fourth Grade Social Studies Core Standards

- 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.b - Places are jointly characterized by their physical and human properties.
- SOC.K-4.6.1.4.B.d - Regions form and change as a result of unique physical/ecological conditions, economies, and cultures.

Common Core:

- CCSS.Math.Practice.MP1 - Make sense of problems and persevere in solving them.
- CCSS.Math.Practice.MP7 - Look for and make use of structure.

Fourth Grade Science Core Standards

- SCI.3-4.5.1.4.A.1 - Demonstrate understanding of the interrelationships among fundamental concepts in the physical, life, and Earth systems sciences.
- SCI.3-4.5.1.4.A.b - Connections developed between fundamental concepts are used to explain, interpret, build, and refine explanations, models, and theories.
- SCI.3-4.5.1.4.A.3 - Use scientific facts, measurements, observations, and patterns in nature to build and critique scientific arguments.
- SCI.3-4.5.1.4.B.1 - Design and follow simple plans using systematic observations to explore questions and predictions.
- SCI.3-4.5.1.4.C.a - Scientific understanding changes over time as new evidence and updated arguments emerge.

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/Popsicle-Stick-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 facts about the Goethals Bridge

http://www.panynj.gov/bridges-tunnels/goethals-bridge.html

- Official website of the Port Authority of New York and New Jersey 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

BrainPop Video and Activity-Bridges (requires a subscription)

http://www.brainpop.com/technology/scienceandindustry/

Online Games/Challenges

http://www.hoodamath.com/games/buildthebridge.html

- Users build structures to allow a train to cross a gorge. No explanation of mechanisms.

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)

http://www.youtube.com/watch?v=QheSSHUbPeE

- Video demonstration on building a popsicle truss bridge

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

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- Note: Grades 4+

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- Note: Grades 4+

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1897 *History of Union County, New Jersey*. East Jersey History Company, Newark, New Jersey. Pp. 219-231.

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Sharon Reier
2000 *The Bridges of New York*, 1977 (Reprint), Mineola, NY: Dover Publications.

Sullivan, Robert
2012 *My American Revolution: Crossing the Delaware and I-78*. Farrar, Straus and Giroux, New York. Pp.207-209.

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1905 *The Principal Professional Papers of Dr. J. A. L. Waddell, Civil Engineer.* V.H. Hewes, New York.

Appendix A: Teacher Discussion of Experiments

Bridge Stability Experiment: Beam and Truss Bridges

Beam Bridge:
The distance between the blocks/supports is the key factor. This activity is intended to show that beam bridges are most useful for very short spans, as the wider the span the weaker the bridge. In the real world, they rarely span more than 250 feet.

Truss Bridge:
A truss bridge uses the stability created by the straight, connected elements of the triangular trusses to redistribute the stresses created by the load (in this case the weight of the paper bridge and the pennies on top of it). The truss bridge will therefore be stronger than the beam bridge and be able to bear more weight.

Simple Cantilever:
It will be easier for the students to support the bag closer to their shoulders. As cantilevers are supported at one end, the shoulder and body are the support in this example. Near the unsupported end, the cantilever (arm) will tend to bend to support the weight of both the structure itself (arm) and the load (bag with book). Cantilevers can support the greatest amount of weight near their fixed point.