

# BRIDGE BASICS

National  
Building  
Museum

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## Instructions for Card Bridge Models

- Arch Bridge
- Beam Bridge
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- Truss Bridge

## Bridge Type Posters

- Arch Bridges
- Beam Bridges
- Cable-Stayed Bridges
- Suspension Bridges
- Truss Bridges

The *Bridge Basics Program Kit* has been produced in partnership with the Construction Industry Round Table (CIRT). For more information about CIRT, visit [www.cirt.org](http://www.cirt.org).



# Beam Bridges

**B**eam bridges are the oldest known bridges and tend to be the simplest to design and build. Roughly half of all bridges in the United States are beam bridges. They consist of vertical piers and horizontal beams. A beam bridge's strength depends on the strength of the roadway and can be increased by adding additional piers. While beam bridges can be quite long, the span, or distance between adjacent piers, is usually small.

## ■ Pros and Cons of Beam Bridges ■

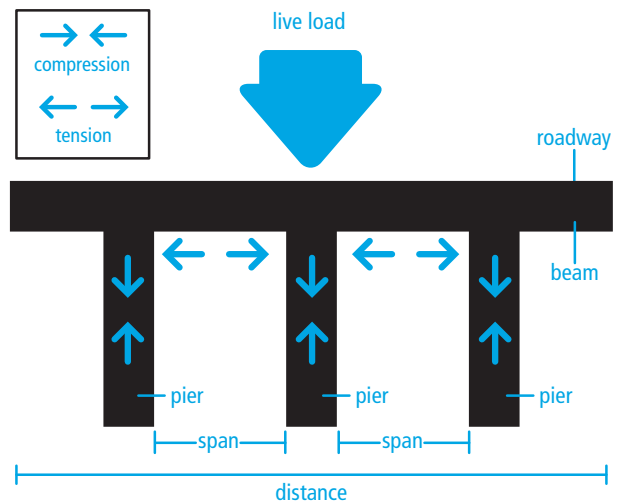
- **Pros:** Easy to build; inexpensive relative to other bridge types; used widely in urban and rural settings
- **Cons:** Limited span; large ships or heavy boat traffic cannot pass underneath; design generally not considered very interesting or eye-catching

## ■ ■ Compression and Tension ■ ■

- **Compression:** As live loads, such as cars and trucks, travel across the bridge, the force of compression acts on the top of the roadway and passes down into the piers.
- **Tension:** The force of tension acts on the underside of the roadway, which is pulled apart by the live loads pressing down on the top of the roadway.



Walter B. Jones Bridge, Hyde County, NC, completed 1981, courtesy North Carolina Department of Traffic



## BRIDGE BRAG

*It's the looooooongest bridge in the world, and it's a beam bridge! The Lake Pontchartrain Causeway in Louisiana is approximately 24 miles long, and its twin spans are supported by more than 9,000 pilings.*

# Arch Bridges

**A**rch bridges were built by the Romans and have been in use ever since. They are often chosen for their strength and appearance. It is the shape of the arch that gives the bridge its strength, which is reinforced by placing supports, or abutments, at its base. Arch bridges can be built from various materials, including wood, stone, concrete, and steel. The famous Italian artist Leonardo da Vinci once said, “An arch consists of two weaknesses, which, leaning on each other, become a strength.”

## ■ Pros and Cons of Arch Bridges ■

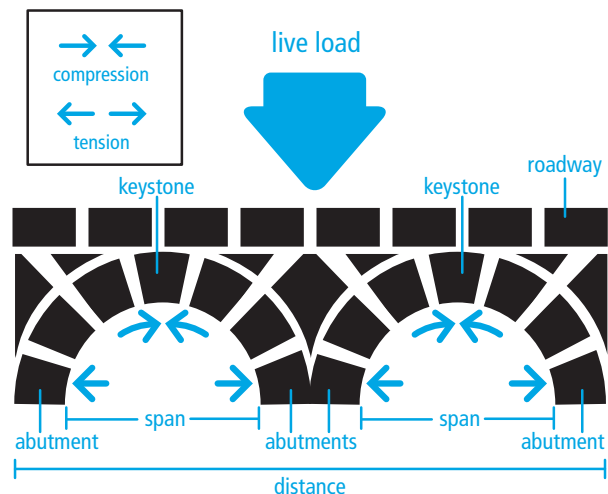
- **Pros:** Wide range of materials can be used; considered attractive; very strong
- **Cons:** Relatively expensive; typically, designs are limited to certain sites (e.g., where the ground can support the large forces at the base of the arch; where the span-to-depth ratio of the arch is proportional; or where an arch is visually appropriate)

## ■ ■ Compression and Tension ■ ■

- **Compression:** The force of compression is greatest at the top of the arch. The abutments press against the bottom of the arch, preventing the bases of the arch from being pushed outward.
- **Tension:** The force of tension is strongest at the bottom of the arch and pulls the sides outward. In general, the larger and shallower the arch, the greater the effects of tension and need for abutment support.



Antietam Aqueduct, Savage, MD, completed 1834, courtesy Lawrence Biemiller



## BRIDGE BRAG

Montgomery Meigs, the architect and engineer of the National Building Museum, also designed the complex Washington aqueduct system. It carries water from the Potomac River over the arched Cabin John Bridge in Maryland to two water processing plants in nearby Washington, D.C. When the bridge was completed in 1863, it was the longest masonry arch in the world. It held the record for 40 years. The main arch has a span of 220 feet, rising 57 feet above a creek.

# Truss Bridges

**W**ooden truss bridges were used as early as the 1500s, but the first metal one was completed in 1841. They are very strong and have been used for railroad bridges mainly because of the heavy loads that they can support. A truss, a rigid support structure that is made up of interlocking triangles, holds up the roadbed and is set between two piers. The triangle is used because it is the only shape that is inherently rigid.

## ■ Pros and Cons of Truss Bridges ■

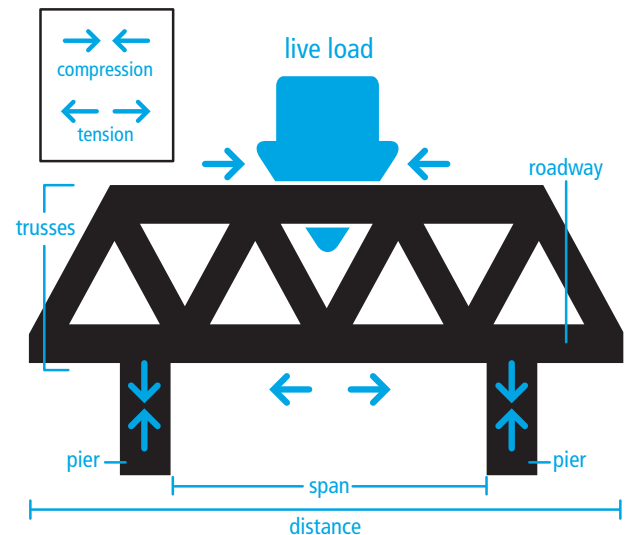
- **Pros:** Very strong; frequently used as a draw bridge or as an overpass for railroad trains
- **Cons:** Difficult to construct; high maintenance; difficult to widen if necessary; generally not considered attractive

## ■ ■ Compression and Tension ■ ■

- **Compression:** As traffic pushes down on the roadway, compression acts on the upper horizontal members of the truss structure.
- **Tension:** Tension acts on the bottom horizontal members of the truss structure. The forces of tension and compression are shared among the angled members.



George Street Bridge, Aurora, IN, completed 1887, courtesy Indiana Department of Transportation



## BRIDGE BRAG

*It's difficult to see the trusses on some of America's best-known truss bridges, the covered bridges that were common in the rural Northeast. The roofs were not constructed to protect people from severe weather, but to preserve the truss system itself. Wooden bridges without roofs would last 10 to 15 years, but covering the bridge extended its life to 70 or 80 years.*

# Suspension Bridges

**S**uspension bridges are strong and can span long distances. One early bridge was designed and built in 1801 in Pennsylvania. They are expensive because they take a long time to build and require a large amount of material. They are commonly found across harbors with a lot of boat traffic. The primary elements of a suspension bridge are a pair of main cables stretching over two towers and attached at each end to an anchor. Smaller cables attached to the main cables support the roadway.

## ■ Pros and Cons of Suspension Bridges ■

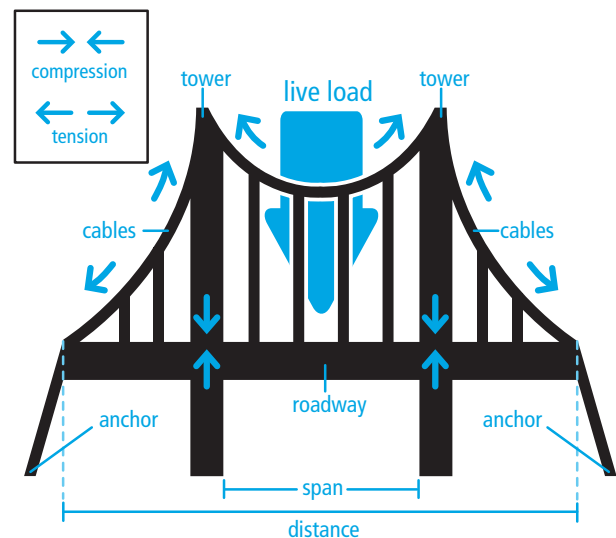
- **Pros:** Span distances up to 7,000 feet; considered attractive; allow large ships and heavy boat traffic to pass underneath
- **Cons:** Expensive (require a long time and a large amount of material to build)

## ■ ■ Compression and Tension ■ ■

- **Compression:** Traffic pushes down on the roadway, but because it is suspended from the cables, the weight is carried by the cables, which transfer the force of compression to the two towers.
- **Tension:** The force of tension is constantly acting on the cables, which are stretched because the roadway is suspended from them.



Golden Gate Bridge, San Francisco, CA, completed 1937, used with permission from The Golden Gate Bridge, Highway and Transportation District, San Francisco, CA, [www.goldengatebridge.org](http://www.goldengatebridge.org)



## BRIDGE BRAG

*The Tacoma Narrows suspension bridge in Washington State was known as “Galloping Gertie” because it rippled like a roller coaster. Completed in July 1940, the first heavy storm four months later caused the bridge to break and collapse from wind-induced vibrations. It was replaced by a stiffer bridge, which has proven to be satisfactory.*

# Cable-Stayed Bridges

The first modern cable-stayed bridge was completed in Sweden in 1956. Cable-stayed bridges were created as an economical way to span long distances. This bridge's design and success were made possible as new materials and construction techniques were developed. Cable-stayed bridges have one or more towers, each of which anchors a set of cables attached to the roadway.

## ■ Pros and Cons of Cable-Stayed Bridges ■

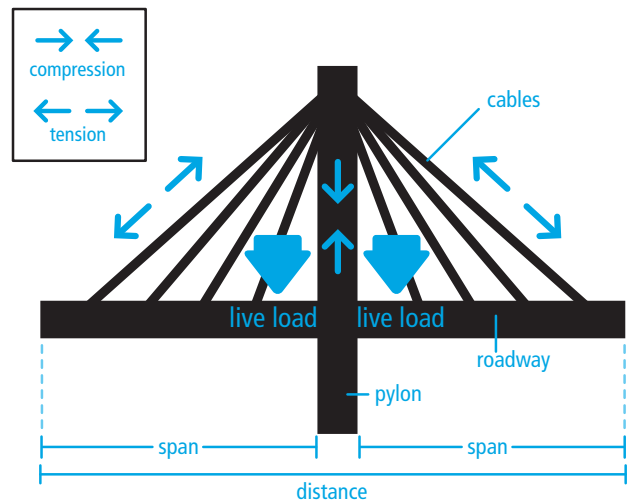
- **Pros:** Span medium distances (500–2,800 feet); less expensive and faster to build than suspension bridges; considered attractive
- **Cons:** Typically more expensive than other types of bridges, except suspension bridges

## ■ ■ Compression and Tension ■ ■

- **Compression:** As traffic pushes down on the roadway, the cables, to which the roadway is attached, transfer the load to the towers, putting them in compression.
- **Tension:** The force of tension is constantly acting on the cables, which are stretched because they are attached to the roadway.



Fred Hartman Bridge, Baytown/Laporte, TX, completed 1995, courtesy Kevin Stillman, Texas Department of Transportation



## BRIDGE BRAG

America's longest cable-stayed bridge, the Cooper River Bridge in Charleston, South Carolina, opened in summer 2005. It is approximately 2.5 miles long and 186 feet above the river. The central span between the two towers is 1,546 feet, and the towers themselves rise 575 feet above the water line.

# “Don’t Lose, Reuse” Supply Request Sheet

## Materials to Gather for the Engineering Bridges Lesson

Student’s Name: \_\_\_\_\_

### STUDENTS:

During your upcoming lessons, you will work in groups to create model bridges. Please bring items from home to use as part of your bridge.



- ☛ Paper towel or toilet paper rolls could be used as piers for a truss bridge.
- ☛ Oatmeal containers could be transformed into arches for a bridge.
- ☛ Narrow ribbons may become the cables on a suspension or cable-stayed bridge.
- ☛ Small boxes and egg cartons could be used to create pier, and cars for a bridge.
- ☛ Can you think of anything else?

*WARNING: Please avoid bringing milk cartons or containers that once held peanuts or peanut butter. Some people are highly allergic to these items.*

Using recycled materials to create bridges in this program helps to preserve the natural environment by promoting reuse of objects, rather than their disposal. Such activities prevent filling landfill sites and polluting our environment.

Other materials needed: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

**Please bring clean, recycled materials from home by:** \_\_\_\_\_ date

# Bridge Investigation Worksheet: Beam Bridges

**LOOK** at the beam bridge images on the poster.

**TEST** the strength of the beam bridge card model, using a stapler or another object of similar size.

**ANSWER** the questions below, using the images and model.

Over **WHICH** obstacles do you commonly find beam bridges?

check as many as are appropriate

- roads/highways
- canyons/valleys
- creeks/streams
- rivers
- bays

**WHAT** are two pros and cons of beam bridges?

Pros (positive aspects of the bridge)

1 \_\_\_\_\_

\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

Cons (negative aspects of the bridge)

1 \_\_\_\_\_

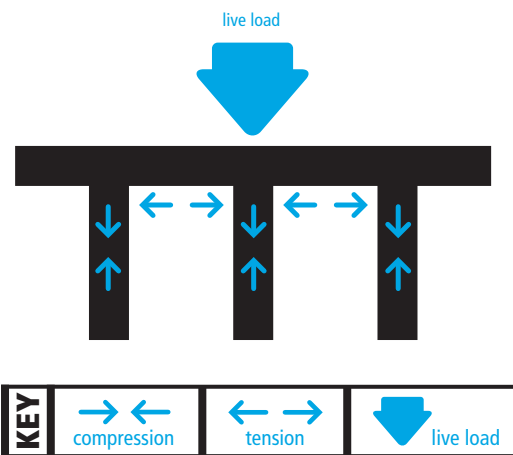
\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

**HOW** do beam bridges work?

Review the areas of compression and tension.



**WHY** do architects and engineers build beam bridges?

check as many as are appropriate

- easily span short distances
- span long distances
- sturdy
- easy to build
- engineering challenge
- cost effective
- allow large ships to pass underneath
- appearance



# Bridge Investigation Worksheet: Arch Bridges

**LOOK** at the arch bridge images on the poster.

**TEST** the strength of the arch bridge card model, using a stapler or another object of similar size.

**ANSWER** the questions below, using the images and model.

Over **WHICH** obstacles do you commonly find arch bridges?

check as many as are appropriate

- roads/highways
- canyons/valleys
- creeks/streams
- rivers
- bays

**WHAT** are two pros and cons of arch bridges?

Pros (positive aspects of the bridge)

1 \_\_\_\_\_

\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

Cons (negative aspects of the bridge)

1 \_\_\_\_\_

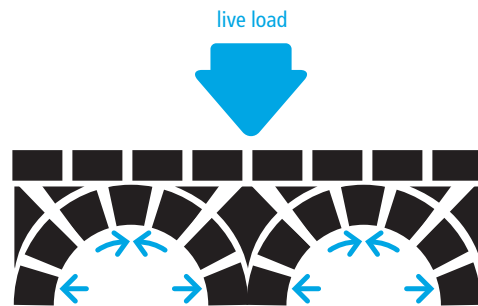
\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

**HOW** do arch bridges work?

Review the areas of compression and tension.



**WHY** do architects and engineers build arch bridges?

check as many as are appropriate

- easily span short distances
- span long distances
- sturdy
- easy to build
- engineering challenge
- cost effective
- allow large ships to pass underneath
- appearance

# Bridge Investigation Worksheet: Truss Bridges

**LOOK** at the truss bridge images on the poster.

**TEST** the strength of the truss bridge card model, using a stapler or another object of similar size.

**ANSWER** the questions below, using the images and model.

Over **WHICH** obstacles do you commonly find truss bridges?

check as many as are appropriate

- roads/highways
- canyons/valleys
- creeks/streams
- rivers
- bays

**WHAT** are two pros and cons of truss bridges?

Pros (positive aspects of the bridge)

1 \_\_\_\_\_

\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

Cons (negative aspects of the bridge)

1 \_\_\_\_\_

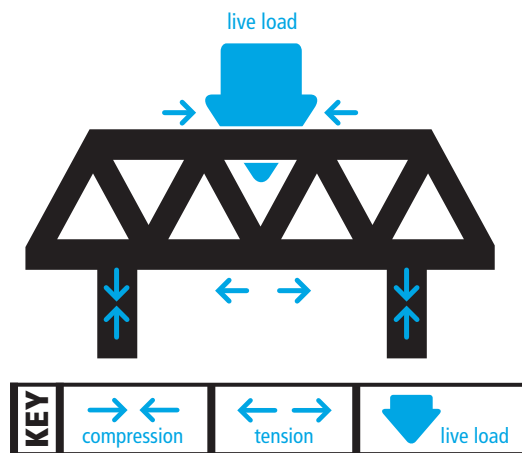
\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

**HOW** do truss bridges work?

Review the areas of compression and tension.



**WHY** do architects and engineers build truss bridges?

check as many as are appropriate

- easily span short distances
- span long distances
- sturdy
- easy to build
- engineering challenge
- cost effective
- allow large ships to pass underneath
- appearance

# Bridge Investigation Worksheet: Suspension Bridges

**LOOK** at the suspension bridge images on the poster.

**TEST** the strength of the suspension bridge card model, using a stapler or another object of similar size.

**ANSWER** the questions below, using the images and model.

Over **WHICH** obstacles do you commonly find suspension bridges?

check as many as are appropriate

- roads/highways
- canyons/valleys
- creeks/streams
- rivers
- bays

**WHAT** are two pros and cons of suspension bridges?

Pros (positive aspects of the bridge)

1 \_\_\_\_\_

\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

Cons (negative aspects of the bridge)

1 \_\_\_\_\_

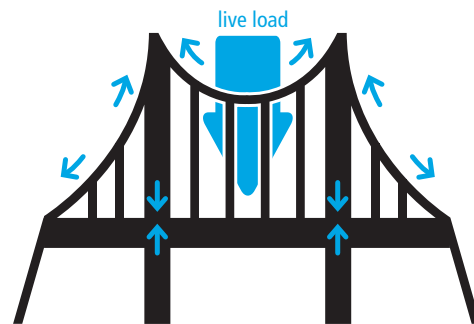
\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

**HOW** do suspension bridges work?

Review the areas of compression and tension.



**WHY** do architects and engineers build suspension bridges?

check as many as are appropriate

- easily span short distances
- span long distances
- sturdy
- easy to build
- engineering challenge
- cost effective
- allow large ships to pass underneath
- appearance

# Bridge Investigation Worksheet: Cable-Stayed Bridges

**LOOK** at the cable-stayed bridge images on the poster.

**TEST** the strength of the cable-stayed bridge card model using a stapler or similar size object.

**ANSWER** the questions below using the images and model.

Over **WHICH** obstacles do you commonly find cable-stayed bridges?

check as many as are appropriate

- roads/highways
- canyons/valleys
- creeks/streams
- rivers
- bays

**WHAT** are two pros and cons of cable-stayed bridges?

Pros (positive aspects of the bridge)

1 \_\_\_\_\_

\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

Cons (negative aspects of the bridge)

1 \_\_\_\_\_

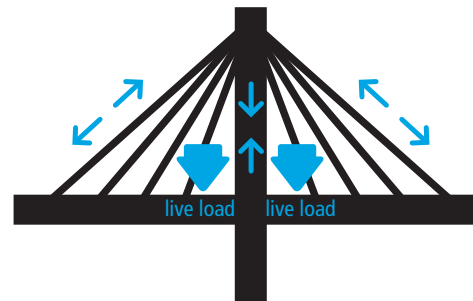
\_\_\_\_\_

2 \_\_\_\_\_

\_\_\_\_\_

**HOW** do cable-stayed bridges work?

Review the areas of compression and tension.



**WHY** do architects and engineers build cable-stayed bridges?

check as many as are appropriate

- easily span short distances
- span long distances
- sturdy
- easy to build
- engineering challenge
- cost effective
- allow large ships to pass underneath
- appearance

# Engineering Bridges Scenario 1

**AS ENGINEERS**, you must define the problem described at the right and determine which type of bridge best solves it, taking into account site location, forces, and appearance.

## ■ DIRECTIONS ■

1. Read the scenario described at the right.
2. Consider the questions below.
3. Sketch your bridge site and the bridge you have selected on the back of this page.
4. Show your drawing to the head engineer (teacher) for final approval.
5. Build a bridge model.

**A** truss bridge currently spans a deep river in a large city. There is heavy boat traffic under the bridge. Automobile traffic backs up on the bridge whenever it opens for boats to pass through. Traffic is especially heavy during rush hour, and commuters are angry about the constant delays. This is also an important site in the city, and the citizens want this bridge to be a symbol for them. What should the city do?



**WHAT** is the problem?

**WHERE** does the problem exist?

**WHO** thinks it is a problem?

**HOW** can the problem be solved?

**JUSTIFY YOUR SOLUTION.**

# Engineering Bridges Scenario 2

**AS ENGINEERS**, you must define the problem described at the right and determine which type of bridge best solves it, taking into account site location, forces, and appearance.

## ■ DIRECTIONS ■

1. Read the scenario described at the right.
2. Consider the questions below.
3. Sketch your bridge site and the bridge you have selected on the back of this page.
4. Show your drawing to the head engineer (teacher) for final approval.
5. Build a bridge model.

**A** beautiful creek runs through a park in a big city. The city is planning to build a highway that will cross the creek. The highway bridge will need to support heavy car and truck traffic. The creek is shallow and does not have boat traffic, although the local residents fish in it. The people who live near the creek are afraid that the bridge will be ugly and negatively impact the scenic beauty of the area. What should the city do?



**WHAT** is the problem?

**WHERE** does the problem exist?

**WHO** thinks it is a problem?

**HOW** can the problem be solved?

**JUSTIFY YOUR SOLUTION.**



# Engineering Bridges Scenario 3

**AS ENGINEERS**, you must define the problem described at the right and determine which type of bridge best solves it, taking into account site location, forces, and appearance.

## ■ DIRECTIONS ■

1. Read the scenario described at the right.
2. Consider the questions below.
3. Sketch your bridge site and the bridge you have selected on the back of this page.
4. Show your drawing to the head engineer (teacher) for final approval.
5. Build a bridge model.

**A** railroad is being built over a small rural river. There is limited boat traffic under the bridge. The trains are very heavy, and the existing wooden covered bridge will not be able to hold the weight of the trains. What should the county do?



**WHAT** is the problem?

**WHERE** does the problem exist?

**WHO** thinks it is a problem?

**HOW** can the problem be solved?

**JUSTIFY YOUR SOLUTION.**

# Engineering Bridges Scenario 4

**AS ENGINEERS**, you must define the problem described at the right and determine which type of bridge best solves it, taking into account site location, forces, and appearance.

## ■ DIRECTIONS ■

1. Read the scenario described at the right.
2. Consider the questions below.
3. Sketch your bridge site and the bridge you have selected on the back of this page.
4. Show your drawing to the head engineer (teacher) for final approval.
5. Build a bridge model.

**A** city with a large population is planning a bridge that will cross a river. The river is very deep and wide with a muddy bottom. The most favorable site for the bridge crosses a small island in the middle of the river. This land is currently unpopulated and is home to wild deer and shore birds. A local environmental group is protesting the bridge because of the negative impact of traffic and construction on the island. What should the city do?



**WHAT** is the problem?

**WHERE** does the problem exist?

**WHO** thinks it is a problem?

**HOW** can the problem be solved?

**JUSTIFY YOUR SOLUTION.**





# Engineering Bridges Scenario 5

**AS ENGINEERS**, you must define the problem described at the right and determine which type of bridge best solves it, taking into account site location, forces, and appearance.

## ■ DIRECTIONS ■

1. Read the scenario described at the right.
2. Consider the questions below.
3. Sketch your bridge site and the bridge you have selected on the back of this page.
4. Show your drawing to the head engineer (teacher) for final approval.
5. Build a bridge model.

**A** major city has a river running through it. The new business center needs to be connected to the historic district on the other side of the river. There are several existing arch and truss bridges along the river, and some have been landmarks for many years. What should the city do?



**WHAT** is the problem?

**WHO** thinks it is a problem?

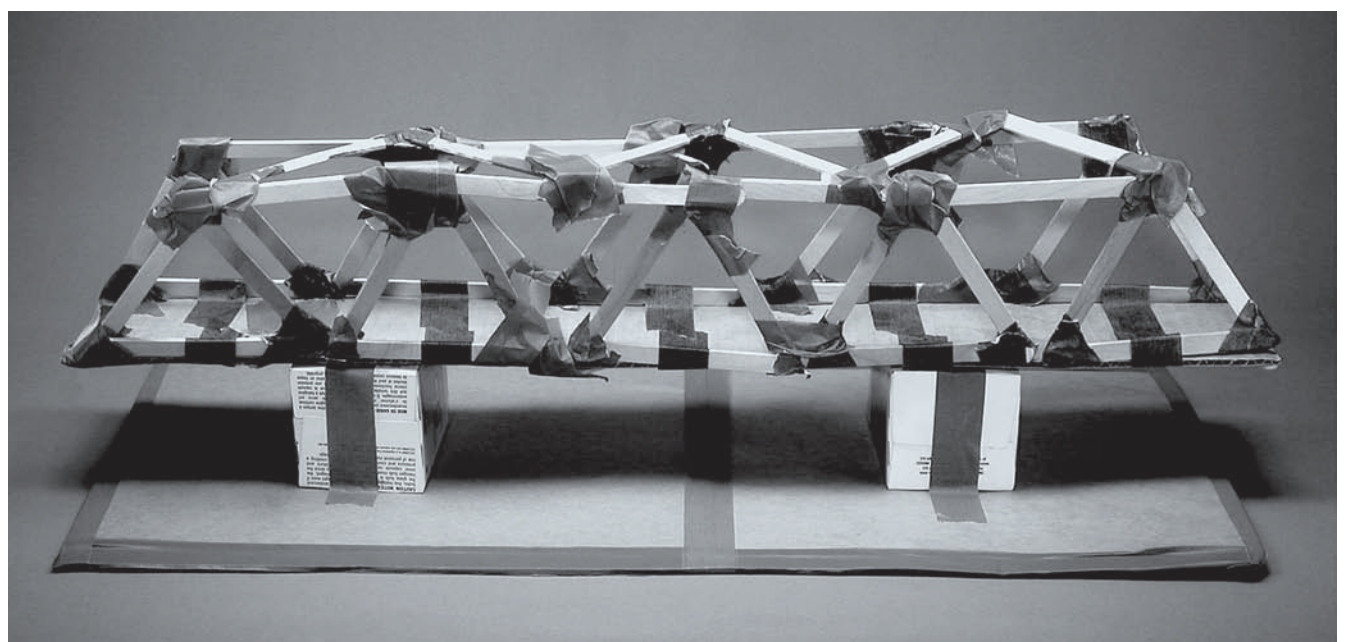
**WHERE** does the problem exist?

**HOW** can the problem be solved?

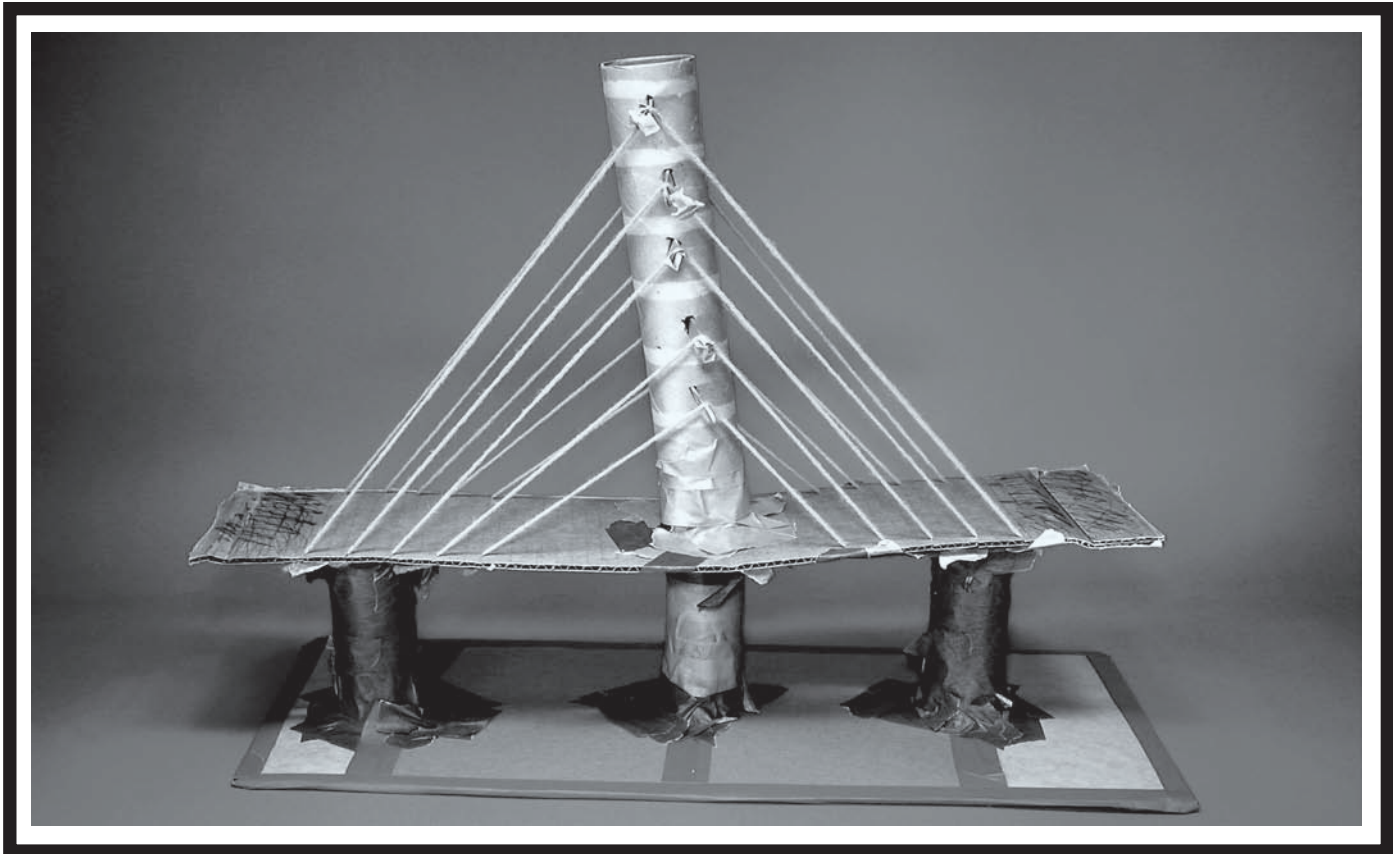
**JUSTIFY YOUR SOLUTION.**

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# Engineering Bridges Sample Images



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# Materials Testing Worksheet

This student worksheet accompanies Part I, Examine Strength of Materials, of the Testing Shapes and Materials for Strength lesson.

## Test each material for strength under compression and tension.

- **Compression:** Put the object in a vise. Record what happens to the material and as the vise is tightened rate its performance.
- **Tension:** Put one end of the object in a vise. Hold the other end of the object in your hand or with pliers and pull slowly. Measure how far the object can be pulled apart. Record what happens to the material and rate its performance.
- Record your observations in the chart below. Use the following scale to indicate how resistant each material is to the forces: V=very good, G=good, F=fair, P=poor

Materials		Observations / Measurement	Rating
Example: Sponge	COMPRESSION	Dented in/became compacted when compressed	G
	TENSION	Stretched then tore under tension / 2"	F
	COMPRESSION		
	TENSION		

Rating: V=very good, G=good, F=fair, P=poor

Materials		Observations / Measurement	Rating
	COMPRESSION		
	TENSION		
	COMPRESSION		
	TENSION		
	COMPRESSION		
	TENSION		
	COMPRESSION		
	TENSION		

# Pasta Bridge Building Evaluation Sheet

Student's Name: \_\_\_\_\_

Group Being Evaluated: \_\_\_\_\_

**Students: Evaluate your fellow classmates' bridges, according to the following criteria.**

## For Student's Use:

Scoring Range: "1" is the lowest score; "5" is the highest.

Used only the materials provided (circle one)	Yes	No			
Completed in 1 hour (circle one)	Yes	No			
Cleared a span of 11 inches (circle one)	Yes	No			
Total load supported (in grams and ounces)					
Attractiveness (circle one)	1	2	3	4	5
Innovative design (circle one)	1	2	3	4	5

## For Teacher's Use:

Effective group cooperation	1	2	3	4	5
Number of remaining points					

# The Long and Short of American Bridges Worksheet — I

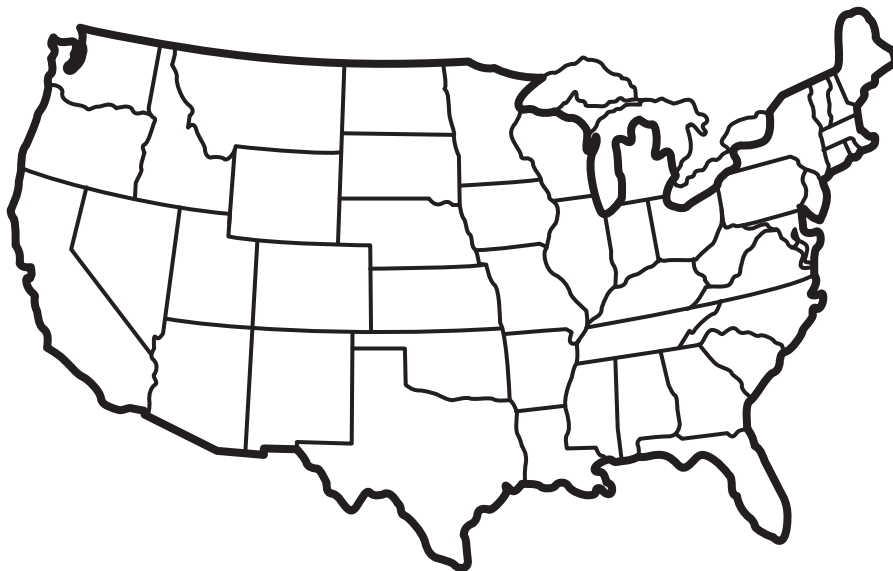
This student worksheet accompanies the *Unique American Bridges: A Research Project* lesson.

Student's Name: \_\_\_\_\_

The American landscape is dotted with unique bridges. Below are five examples of different bridges, some of which are considered engineering marvels. As you look over the information, notice the difference between the length and span of each bridge.

Name	Lake Pontchartrain Causeway	New River Gorge Bridge	Bollman Truss Bridge	Leonard P. Zakim Bunker Hill Bridge (Charles River Bridge)	Brooklyn Bridge
Location	Mandeville and Metairie, LA	Fayetteville, WV	Savage, MD	Boston, MA	New York, NY
Built	1969	1978	1869	2003	1883
Length	126,054 feet	3,030 feet	160 feet	1,457 feet	3,460 feet
Span	56 feet each	1,700 feet	80 feet	754 feet	1,595 feet
Type	beam	arch	truss	cable-stayed	suspension
Materials	steel, pre-stressed concrete	steel, concrete	wrought iron	steel, concrete	masonry, steel

On the map below, mark where each bridge is located. Next to each bridge, name the body of water it crosses.

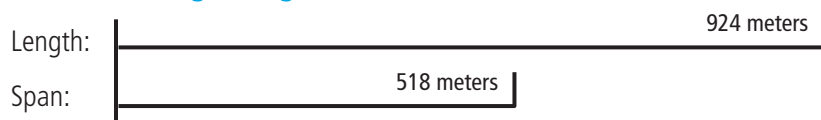


# The Long and Short of American Bridges Worksheet — 2

This student worksheet accompanies the *Unique American Bridges: A Research Project* lesson.



Convert feet to meters, rounding to the nearest whole; then, using a ruler, draw a bar graph showing both the length and span of each bridge. (If a bridge is longer than the graph, show this by drawing an arrow at the end of the bar to indicate a continuation beyond the page.)

## New River Gorge Bridge (EXAMPLE)





1 foot = 0.3 meters, 1 meter = 3.28 feet



## Lake Pontchartrain Causeway

Length:   
Span: 



## Bollman Truss Bridge

Length:   
Span: 

## Charles River Bridge

Length:   
Span: 

## Brooklyn Bridge

Length:   
Span: 







# Bridge Research Guide Worksheet

*This student worksheet accompanies the Unique American Bridges: A Research Project lesson.*

Student's Name: \_\_\_\_\_

Bridge: \_\_\_\_\_

**Use the questions below to guide your research on your bridge.**

1. Where is the bridge located? \_\_\_\_\_
2. What obstacle does the bridge cross? \_\_\_\_\_
3. When was the bridge built? \_\_\_\_\_
4. What materials were used to construct the bridge? \_\_\_\_\_
5. Which of the five basic bridge types best describes the bridge? \_\_\_\_\_
6. What types of traffic use the bridge? \_\_\_\_\_
7. What is the name of the engineer/architect (or engineering/architectural firm) who designed this bridge?  
\_\_\_\_\_

**Answer the following questions.**

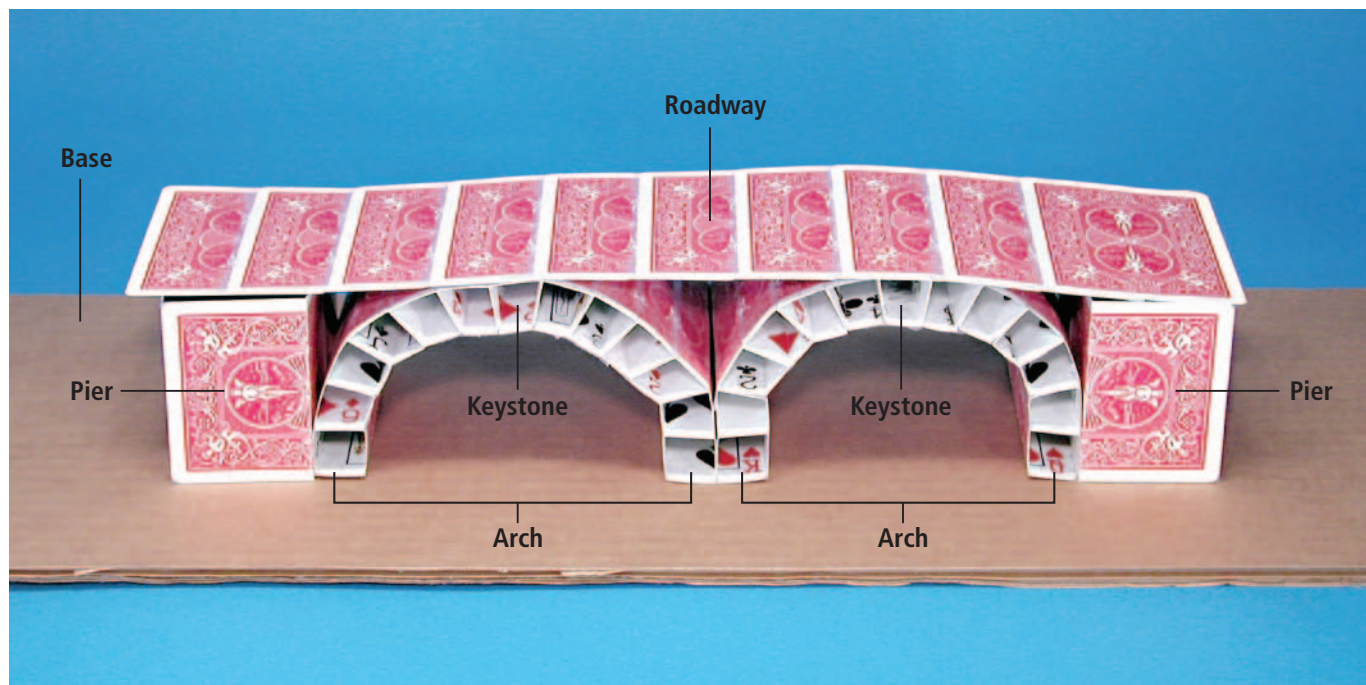
1. Why do you think the engineer built this type of bridge for this site?
2. What were the special challenges that the architects and engineers faced while designing this bridge?
3. How did they overcome those challenges?
4. Did you find any interesting stories or fun facts about this bridge?
5. Do you like the way the bridge looks? If so, then why? If not, then why not?



# Arch Bridge

1

**A**rch bridges were built by the Romans and have been in use ever since. They are often chosen for their strength and appearance.



## Instructions for Building an Arch Bridge

1. Divide team in half.
2. One half takes **Instruction Card 2** and the other takes **Instruction Card 3**.
3. After completing the individual bridge pieces, use **Instruction Card 4** and work together as a whole team to construct the arch bridge on the cardboard base.
4. When the bridge is constructed, cut the piece of copy paper into small rectangles. Use these smaller pieces and write the names of each bridge part on them. Refer to the labeled image of the bridge on the other side of this card for the names and locations of each part. Using tape, affix the labels to the appropriate locations on the finished arch bridge.

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## Needed Materials

- 1 deck of cards
- Scissors
- Cardboard base (6 x 18")
- Scotch tape
- Ruler
- Copy paper (1 piece) to create labels for bridge parts
- Object, such as a stapler, for testing bridge strength

# Arch Bridge

2

## Roadway Builders — Step 1

1. Get 10 cards.
2. Lay all 10 cards in a horizontal line on a flat surface overlapping each card at half-way point (Image 1).
3. Tape each overlap, turn over, and tape other side (Image 2).
4. The roadway is complete (Image 3). Set it aside and turn this card over for instructions to complete the piers.



Image 1: Cards overlapping at half-way point



Image 2: Roadway secured by taping overlaps on both sides

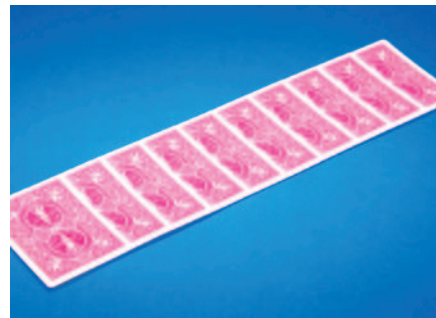


Image 3: Finished roadway

## Pier Builders — Step 2

1. Get 8 cards.
2. Lay back of 1 card down and fold card in half crosswise (Image 1). Repeat seven more times.
3. Open 2 cards, lay cards with insides facing each other, and tape bottom and top. Repeat three times.
4. Open and create a square (Image 2).
5. Tape 2 squares together (Image 3). Repeat for a total of 2 piers.
6. The piers are complete (Image 3). Set them aside and assist the arch builders (Instruction Card 3).



Image 1: Card folded in half crosswise



Image 2: Two folded cards taped together to form a square



Image 3: Two squares taped together to form a rectangular pier

## Arch Builders — Step 1

1. Get 26 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward the center crease (Image 1).
4. Repeat 25 more times for a total of 26 pieces.
5. Open, fold sides to create a rectangular shape, and tape closed (Image 2).
6. Repeat three more times for a total of 4 rectangular pieces.
7. With remaining 22 folded cards, open each card and trim approximately 1/8" from ONE of the long sides (Image 3).
8. Fold each card into shape of a trapezoid and tape closed (Image 4).
9. The arch pieces are complete. There should be 4 rectangular pieces and 22 trapezoidal pieces.

**TIP:** As members of the team finish other parts of the bridge, they will join the arch builders to help build the arch components.



Image 1: Card folded in four lengthwise



Image 2: Finished rectangular piece

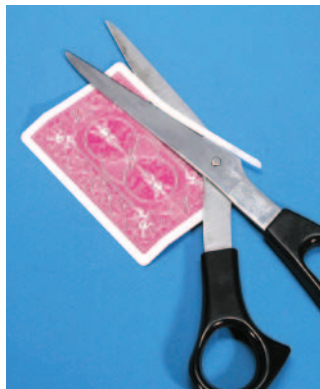


Image 3: One side trimmed to create trapezoidal piece



Image 4: Completed rectangular and trapezoidal pieces

## Arch Bridge Team Building Instructions — Step 1

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### Materials

- 1 roadway
- 2 piers
- 22 trapezoidal pieces
- 4 rectangular pieces
- 1 cardboard base
- Scotch tape
- Ruler
- Stapler

### Step 1 – Test a Basic Bridge

1. Place two piers on cardboard base about 8" apart (Image 1).
  2. Tape piers to base.
  3. Place roadway on top of these piers and lightly tape it to them (Image 2).
  4. Test strength of this basic bridge by setting stapler (or other object) on roadway.
- What do you notice about the bridge? Where are its weak points?  
How can you strengthen the bridge?

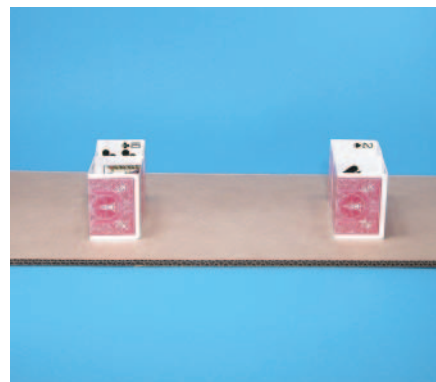


Image 1: Rectangular piers placed and taped on cardboard base

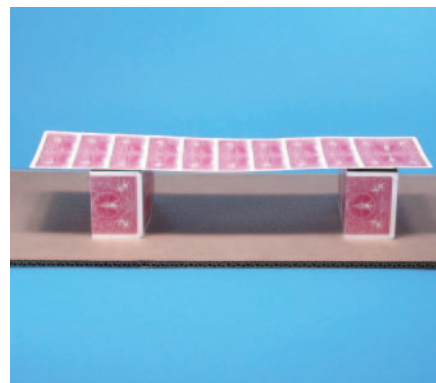


Image 2: Roadway placed across piers for test



## Team Building Instructions — Steps 2 & 3

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### Step 2 – Build an Arch Bridge

1. Gently remove tape that connects roadway to piers and piers to base.
2. Lift roadway off structure and set to side.
3. Begin arch construction by connecting 1 trapezoidal piece to 1 rectangular piece along their lengths (Image 1). (The rectangular piece is the base and should be on the bottom.)
4. Tape 4 more trapezoidal pieces to this stack until half arch is formed.
5. Repeat steps 3 and 4 three more times for a total of 4 half arches.
6. Complete each arch by standing 2 half arches up and placing another trapezoidal piece between them. This acts as the keystone (Image 2). Repeat this one more time for a total of 2 complete arches (Image 3).
7. Situate 2 arches in a row on center of base and place a pier at either end. Secure entire structure in place with tape.
8. To finish, place and tape roadway on top of arches and piers (Image 4).

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### Step 3 – Test the Bridge

1. Set stapler (or other object) on top of roadway.
  - What do you notice about this bridge? Is it stronger than the first bridge? Why or why not?



Image 1: Rectangular piece connected to a trapezoidal piece



Image 2: Trapezoidal pieces stacked until they form an arch

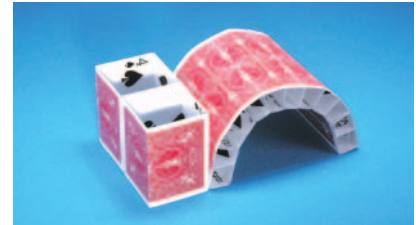


Image 3: Arches secured to the piers by taping

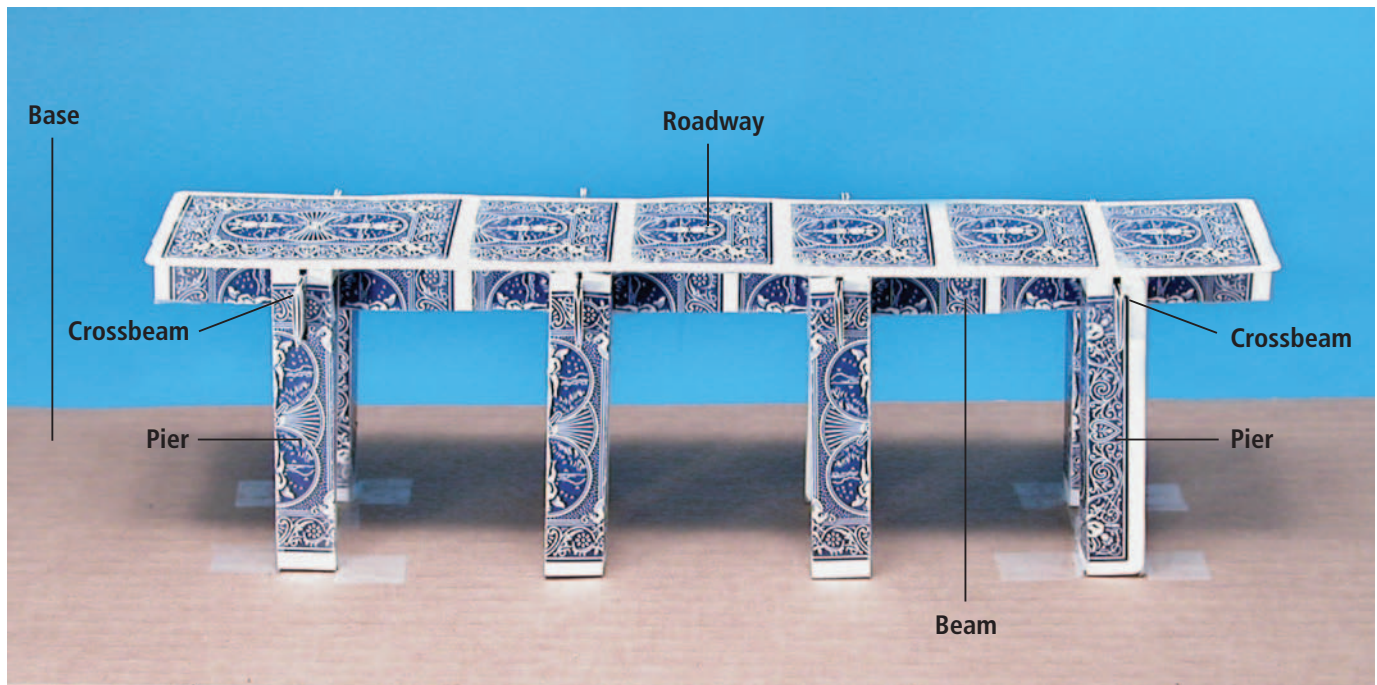


Image 4: Completed arch bridge

# Beam Bridge

1

**B**eam bridges consist of vertical piers and horizontal beams. Roughly half of all bridges in the United States are beam bridges, including the world's longest bridge, the 24-mile-long Lake Pontchartrain Causeway in Louisiana.



## Instructions for Building a Beam Bridge

1. Divide team in half.
2. One half takes **Instruction Card 2** and the other takes **Instruction Card 3**.
3. After completing the individual bridge pieces, use **Instruction Card 4** and work together as a whole team to construct the beam bridge on the cardboard base.
4. When the bridge is constructed, cut the piece of copy paper into small rectangles. Use these smaller pieces and write the names of each bridge part on them. Refer to the labeled image of the bridge on the other side of this card for the names and locations of each part. Using tape, affix the labels to the appropriate locations on the finished beam bridge.

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### Needed Materials

- 1 deck of cards
- Scissors
- Cardboard base (6 x 18")
- Scotch tape
- Ruler
- Copy paper (1 piece) to create labels for bridge parts
- Object, such as a stapler, for testing bridge strength

# Beam Bridge

2

## Roadway Builders — Step 1

1. Get 6 cards.
2. Lay all 6 cards in a horizontal line on a flat surface overlapping each card at half-way point (Image 1).
3. Tape each overlap, turn over, and tape other side (Image 2).
4. The roadway is complete (Image 3). Set it aside and turn this card over for instructions to complete the beams.

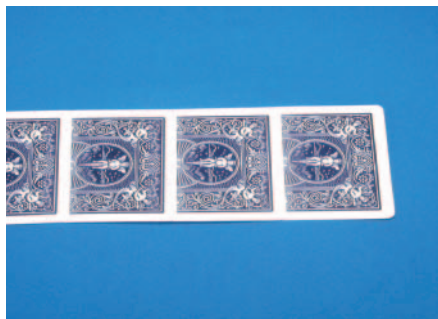


Image 1: Cards overlapping at half-way point

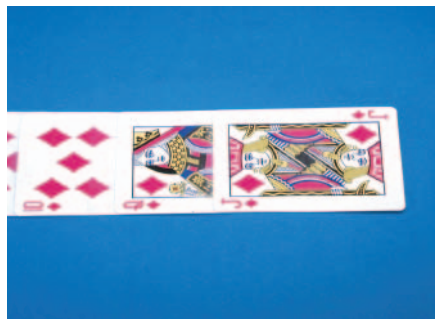


Image 2: Roadway secured by taping overlaps on both sides

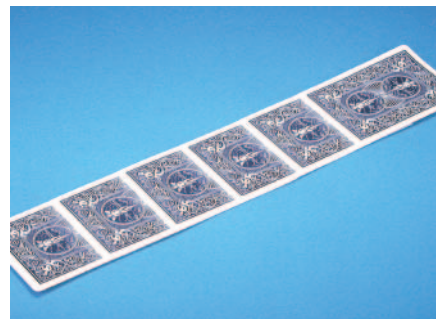


Image 3: Finished roadway

## Beam Builders — Step 2

1. Get 8 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card, turn it over, and fold long edges in toward center crease (Image 1).
4. Pinch two center rectangles together so card looks like the letter "T" (Image 2).
5. Repeat seven more times for a total of 8 beam pieces.
6. Use the 8 small beam pieces to create 2 long beams (Image 3):
  - Overlap 4 beam pieces and adjust them to same length as roadway.
  - Tape 4 beam pieces together to become 1 long beam.
  - Repeat two steps above to create another long beam.
  - When finished, there will be 2 long beams of equal length.



Image 1: Card folded in four lengthwise



Image 2: Small t-shaped beam piece



Image 3: Finished beam

# Beam Bridge

3

## Crossbeam Builders — Step 1

1. Get 4 cards.
2. Lay back of 1 card down and fold card in half lengthwise (Image 1).
3. Open card and fold long edges in toward center crease (Image 2).
4. Fold entire card in half again to create a long rectangle (Image 3).
5. Repeat three more times for a total of 4 crossbeams.
6. The crossbeams are complete. Set them aside and turn this card over for instructions to construct the piers.



Image 1: Card folded in half lengthwise



Image 2: Card folded in four lengthwise



Image 3: Finished crossbeam

## Pier Builders — Step 2

1. Get 8 cards.
2. Lay back of 1 card down and fold card in half lengthwise (Image 1).
3. Open card and fold long edges in toward center crease (Image 2).
4. Open card and form into a rectangular shape (Image 3).
5. Tape long edges of card together.
6. Repeat seven more times for a total of 8 piers.
7. Cut 2 v-shaped slits on opposite sides of the top of each pier (Image 3).



Image 1: Card folded in half lengthwise



Image 2: Card folded in four lengthwise

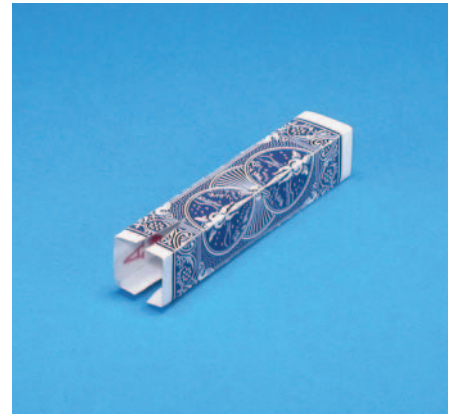


Image 3: Completed rectangular pier with slits

# Beam Bridge

4

## Beam Bridge Team Building Instructions — Step 1

### Materials

- 1 roadway
- 2 long beams
- 4 crossbeams
- 8 piers
- 1 cardboard base
- Scotch tape
- Scissors
- Ruler
- Stapler

### Step 1 – Test a Basic Bridge

1. Turn roadway upside-down and lightly tape 4 piers to underside of roadway (Image 1).
2. Turn roadway and piers right-side-up and stand on cardboard base (Image 2).
3. Tape piers to base.
4. Test strength of this basic bridge by setting stapler (or other object) on roadway.
  - What do you notice about the bridge? Where are its weak points? How can you strengthen the bridge?

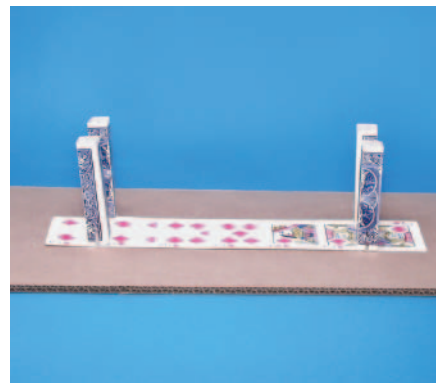


Image 1: Taped piers on underside of roadway

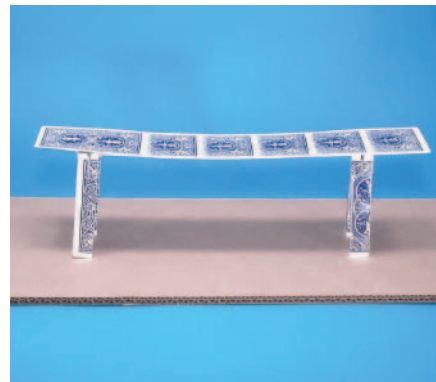


Image 2: Bridge secured to base with tape for test



## Team Building Instructions — Steps 2 & 3

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### Step 2 – Build a Beam Bridge

1. Gently remove tape that connects roadway to piers.
2. Lift roadway off structure and lay it upside-down.
3. Tape 2 long beams to underside of roadway so they parallel each other (Image 1).
4. Once in place, cut 4 v-shaped slits on each beam at the 1 1/2", 4 1/2", 7 1/2", and 10 1/2" points. Make sure slits on both beams line up with each other.
5. Slide 4 crossbeams into slits on beams (Image 2).
6. Turn over and place the roadway with its attached beams and crossbeams onto piers already taped to base. If piers need to be adjusted, remove taped piers and re-secure them in a better location (Image 3).
7. Test the bridge — set stapler (or other object) on top of roadway.
  - What do you notice about this bridge? Is it stronger than the first bridge? Why or why not? Where are the weak points? How could the bridge be strengthened?

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### Step 3 – Complete the Beam Bridge and Test

1. Slide 4 remaining piers onto outside edges of two interior crossbeams (Image 4).
2. Test bridge by placing a stapler on top of roadway.
  - Is the bridge stronger? Why or why not?



Image 1: Two long beams taped to underside of roadway



Image 2: Four crossbeams slid into slits on beams

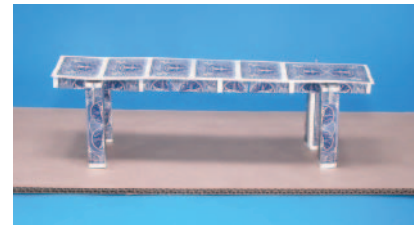


Image 3: Bridge with four beams and four piers

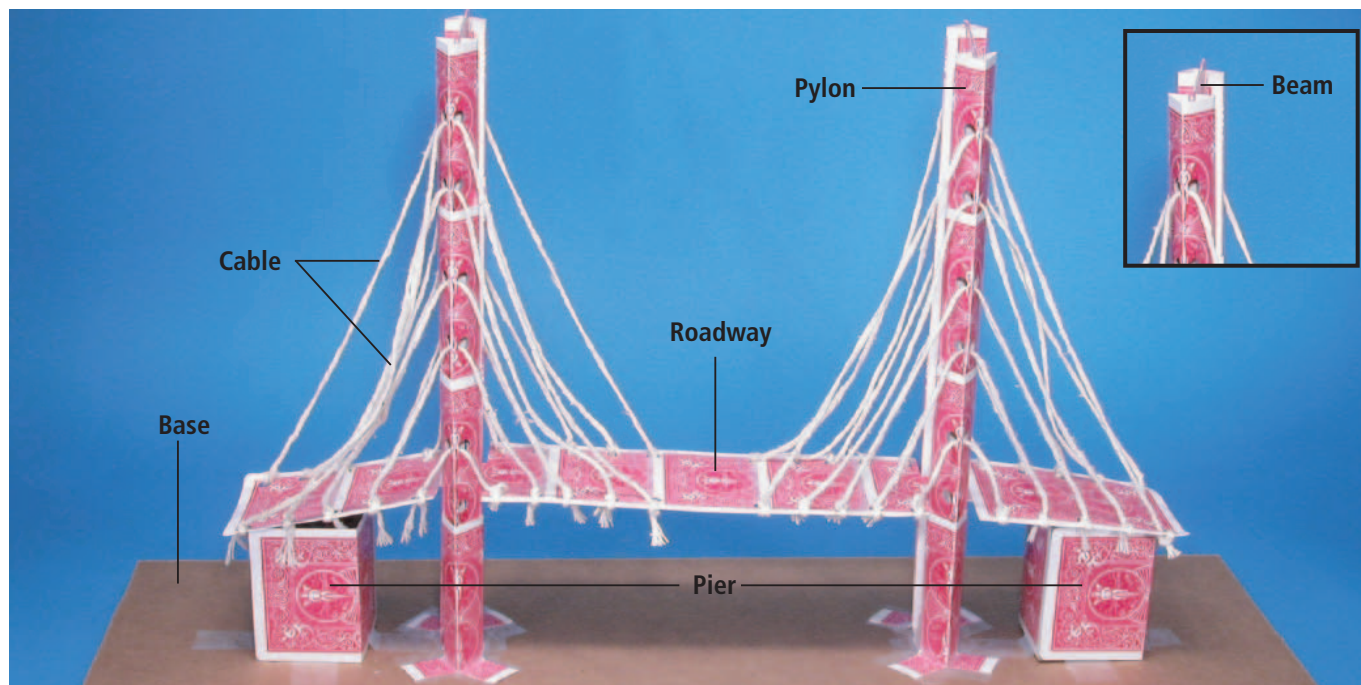


Image 4: Completed bridge with beams, crossbeams, and eight piers

# Cable-Stayed Bridge

1

**C**able-stayed bridges have one or more pylons, each of which anchors a set of cables attached to the roadway. These bridges were created as an economical way to span long distances.



## Instructions for Building a Cable-Stayed Bridge

1. Divide team in half.
2. One half takes **Instruction Card 2** and the other takes **Instruction Card 3**.
3. After completing the individual bridge pieces, use **Instruction Card 4** and work together as a whole team to construct the cable-stayed bridge on the cardboard base.
4. When the bridge is constructed, cut the piece of copy paper into small rectangles. Use these smaller pieces and write the names of each bridge part on them. Refer to the labeled image of the bridge on the other side of this card for the names and locations of each part. Using tape, affix the labels to the appropriate locations on the finished cable-stayed bridge.

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### Needed Materials

- 1 deck of cards
- Scissors
- Single-hole punch
- 26' of string
- Cardboard base (6 x 18")
- Scotch tape
- Ruler
- Copy paper (1 piece) to create labels for bridge parts
- Object, such as a stapler, for testing bridge strength

# Cable-Stayed Bridge

2

## Roadway Builders — Step 1

1. Get 8 cards.
2. Lay all 8 cards in a horizontal line on a flat surface overlapping each card at half-way point (Image 1).
3. Tape each overlap, turn over, and tape other side.
4. Measure along the roadway's long side and mark with a pencil at 3 1/2" and 12".
5. Cut out a 3/4 x 3/4" notch at each mark (Image 2).
6. Repeat steps 4 and 5 on other long side of roadway.
7. Punch five, evenly-spaced holes on both sides of notch near edge of roadway (Image 2).
8. Repeat step 7 with 3 remaining notches for a total of 20 holes on each side of roadway (Image 3).
9. The roadway is complete (Image 3). Set it aside and turn this card over for instructions to construct the beams and cables.

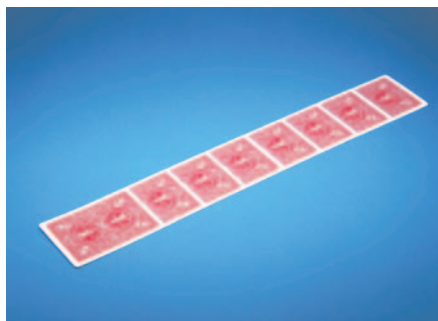


Image 1: Roadway consisting of eight cards overlapping at half-way points

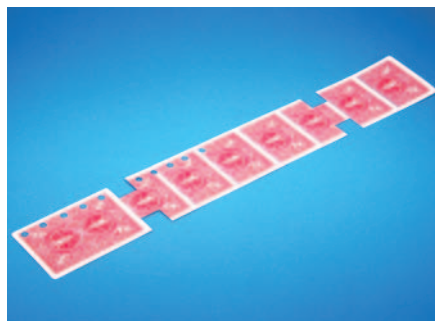


Image 2: Roadway with four notches and five holes punched to either side of notch



Image 3: Finished roadway with four notches and 40 holes

## Beam Builders — Step 2

1. Get 2 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward center crease (Image 1).
4. Fold entire card in half again to create a long rectangle (Image 2).
5. Secure with tape.
6. Repeat steps 2-5 to create another beam.

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## Cable Cutters — Step 3

1. Get 26' of string.
2. Cut 4 pieces of each length: 22", 18", 14", 13", 10" (Image 3).



Image 1: Card folded in four lengthwise



Image 2: Card folded into rectangular shape



Image 3: Four pieces of each length string required to complete cables

# Cable-Stayed Bridge

3

## Pier Builders — Step 1

1. Get 4 cards.
2. Lay back of 1 card down and fold card in half crosswise (Image 1). Repeat three more times.
3. Open 2 cards, lay cards with insides facing each other, and tape bottom and top (Image 2). Repeat for a total of 2 sets of taped cards.
4. Open each set of taped cards and form a square (Image 3). Repeat for a total of 2 square piers.
5. The piers are complete. Set them aside and turn this card over for instructions to construct the pylons.



Image 1: Card folded in half crosswise



Image 2: Two folded cards taped together to form a square



Image 3: Completed square pier

## Pylon Builders — Step 2

1. Get 16 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward center crease (Image 1).
4. Open card, fold in half lengthwise, and punch 2 holes 1" apart close to fold (Image 2).
5. Open card, overlap long edges to form a triangular shape, and tape closed (Image 3).
6. Repeat steps 2-5, 15 times for a total of 16 hole-punched triangular shapes.
7. Make a pylon by inserting 1/2" of one triangular piece into another. Continue stacking pieces to complete a pylon of 4 stacked pieces (Image 4).
8. Repeat step 7 three more times for a total of 4 pylons.
9. Create flaps at bottom of each pylon by cutting 1/2" slits in all 3 corners. Fold flaps back to enable pylons to stand on a flat surface (Image 3).

**TIP:** Be sure to take turns with the hole punches to avoid sore hands.



Image 1: Card folded in four lengthwise



Image 2: Folded card with two holes punched close to fold



Image 3: Completed triangular shape



Image 4: Completed tower using four triangular shapes

# Cable-Stayed Bridge

4

## Cable-Stayed Bridge Team Building Instructions — Step 1

### Materials

- 1 roadway
- 2 piers
- 4 pylons
- 2 beams
- 1 cardboard base
- 20 measured cables
- Scotch tape
- Scissors
- Ruler
- Stapler

### Step 1 – Test a Basic Bridge

1. Place 2 square piers on cardboard base about 8" apart (Image 1).
  2. Place roadway on top piers and lightly tape it to them (Image 2).
  3. Test strength of this basic bridge by setting stapler (or other object) on roadway.
- What do you notice about the bridge? Where are its weak points?  
How can you strengthen the bridge?

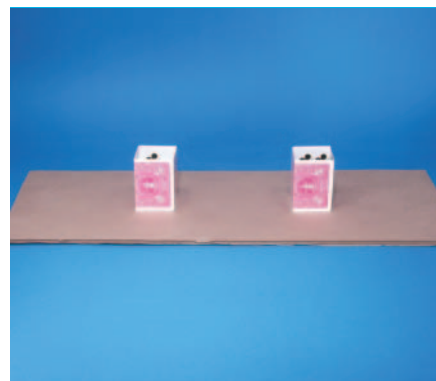


Image 1: Square piers placed on cardboard base 8" apart

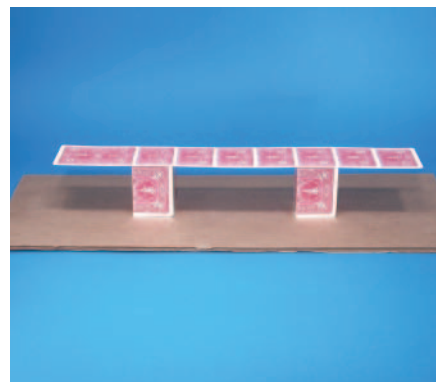


Image 2: Roadway placed across pier for test



## Team Building Instructions — Steps 2 & 3

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### Step 2 – Build a Cable-Stayed Bridge

1. Gently remove tape that connects roadway to piers.
2. Lift roadway off structure and set to side.
3. Place 2 pylons 8" apart (sides with holes should face out) and secure flaps at bottom to cardboard using tape (Image 1).
4. Lay roadway next to taped pylons lining up with notches and place other 2 pylons in open notches of roadway; secure flaps at bottom to cardboard base using tape.
5. Create 4 sets of cables by grouping one of each string length (22", 18", 14", 13", 10"). Each cable set will include 5 different string lengths.
6. Using 1 cable set and starting with shortest piece, thread each cable through a set of holes in 1 pylon, and tie each cable end to holes in roadway using a double knot. Each cable forms a triangle (Image 2). Make sure that roadway is level while tying.
7. Repeat step 6 with 3 remaining towers.
8. For added stability, cut a 1/2" v-shaped slit in the top of each tower, on side facing the roadway.
9. Place a beam in between each set of towers and secure with tape.
10. Place each pier 2" from pylons and tape to cardboard base (Image 3).

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### Step 3 – Test the Bridge

1. Set stapler (or other object) on top of roadway.
  - What do you notice about this bridge? Is it stronger than the first bridge? Why or why not?

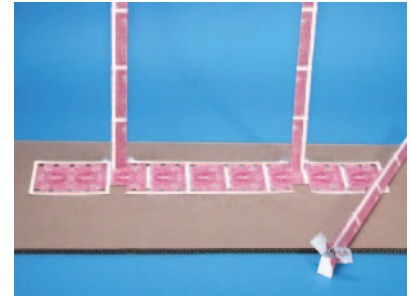


Image 1: Two towers placed 8" apart and secured with tape

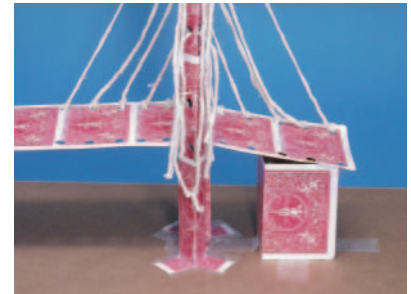


Image 2: Bridge cables connected with roadway level

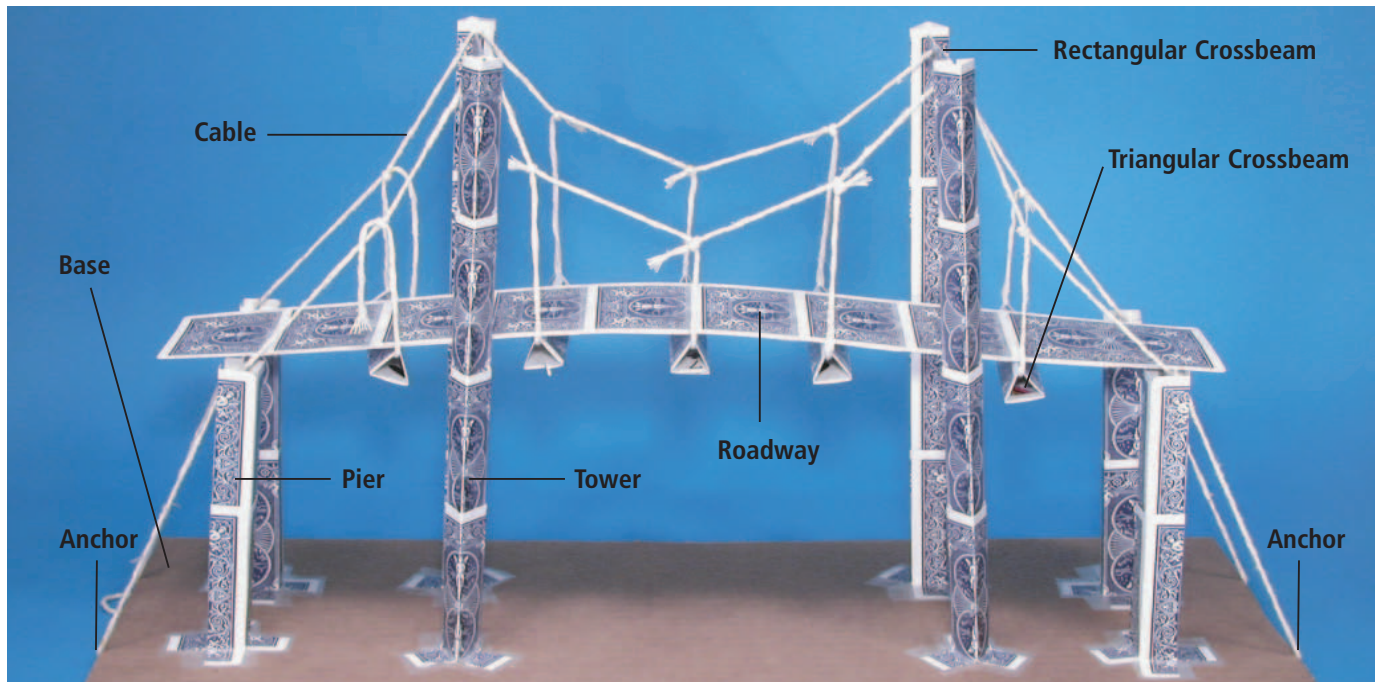


Image 3: Piers moved to outer ends of bridge and secured with tape after cables are tied

# Suspension Bridge

1

**S**uspension bridges are strong and can span long distances. They are commonly found across harbors with a lot of boat traffic. The primary elements of a suspension bridge are a pair of main cables stretching over two towers and attached at each end to an anchor. Smaller cables attached to the main cables support the roadway.



## Instructions for Building a Suspension Bridge

1. Divide team in half.
2. One half takes **Instruction Card 2** and the other takes **Instruction Card 3**.
3. After completing the individual bridge pieces, use **Instruction Card 4** and work together as a whole team to construct the suspension bridge on the cardboard base.
4. When the bridge is constructed, cut the piece of copy paper into small rectangles. Use these smaller pieces and write the names of each bridge part on them. Refer to the labeled image of the bridge on the other side of this card for the names and locations of each part. Using tape, affix the labels to the appropriate locations on the finished suspension bridge.

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### Needed Materials

- 1 deck of cards
- Scissors
- 16' string
- Cardboard base (6 x 18")
- Scotch tape
- Ruler
- Copy paper (1 piece) to create labels for bridge parts
- Object, such as a stapler, for testing bridge strength

# Suspension Bridge

2

## Roadway Builders — Step 1

1. Get 6 cards.
2. Lay all 6 cards in a horizontal line on a flat surface overlapping each card at half-way point (Image 1).
3. Tape each overlap, turn over, and tape other side (Image 2).
4. The roadway is complete (Image 3). Set it aside and turn this card over for instructions to complete the towers.

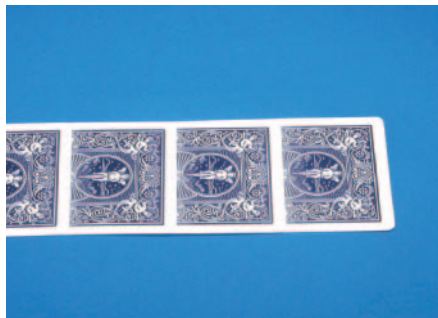


Image 1: Cards overlapping at half-way point

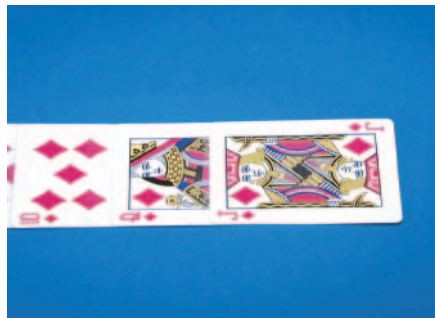


Image 2: Roadway secured by taping overlaps on both sides

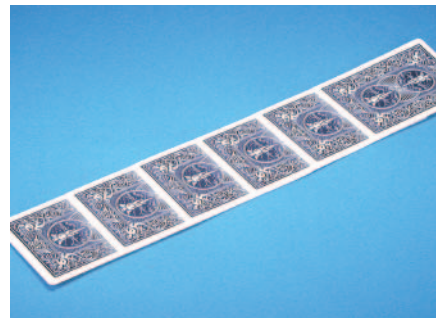


Image 3: Finished roadway

## Tower Builders — Step 2

1. Get 16 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward center crease (Image 1).
4. Open card, overlap long edges to form a triangular shape, and tape closed (Image 2).
5. Repeat steps 2–4, 15 times for a total of 16 triangular shapes.
6. Make a tower by inserting  $1/2$ " of 1 triangular piece into another. Continue stacking pieces to complete a tower of 4 stacked pieces (Image 3).
7. Repeat step 6 three more times for a total of 4 towers of equal length.
8. Create flaps at the bottom of each tower by cutting  $1/2$ " slits in all 3 corners. Fold flaps back to enable towers to stand on a flat surface (Image 3).



Image 1: Card folded in four lengthwise



Image 2: Completed triangular shape



Image 3: Completed tower

# Suspension Bridge

3

## Crossbeam Builders — Step 1 (Rectangular Crossbeams)

1. Get 4 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward center crease (Image 1).
4. Fold entire card in half again to create a long rectangle (Image 2).
5. Secure with tape.
6. Repeat steps 2–5 three times for a total of 4 rectangular crossbeams.

## Step 2 (Triangular Crossbeams)

1. Get 5 cards.
2. Like rectangular crossbeam, fold 1 card into four sections lengthwise.
3. Shape into a triangle and secure with tape (Image 3).
4. Repeat steps 2 and 3 four times for a total of 5 triangular crossbeams.
5. The crossbeams are complete (Image 3). Set them aside and turn this card over for instructions to complete the piers.



Image 1: Card folded in four lengthwise



Image 2: Card folded into the shape of rectangle



Image 3: Triangular shape

## Pier Builders — Step 3

1. Get 8 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward center crease (Image 1).
4. Open card and form into rectangular shape (Image 2).
5. Tape long edges of card together.
6. Repeat seven more times for a total of 8 pier pieces.
7. Insert bottom of 1 pier piece into top of another, overlapping 1/2" (Image 3). Repeat three more times for a total of 4 piers.
8. Create flaps at bottom of each pier by cutting 1/2" slits in all 4 corners. Fold flaps back to enable piers to stand on a flat surface (Image 3).



Image 1: Card folded in four lengthwise



Image 2: Completed rectangular shape

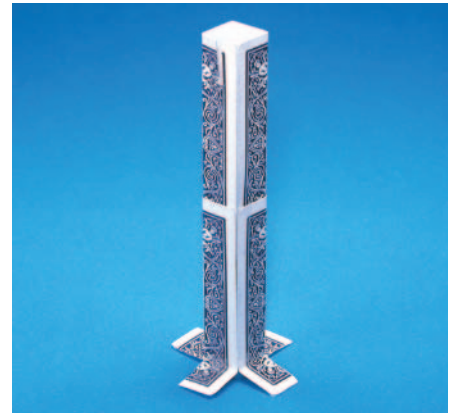


Image 3: Two rectangular pieces stacked to created pier

# Suspension Bridge

4

## Suspension Bridge Team Building Instructions — Step 1

### Materials

- 1 roadway
- 4 piers
- 4 towers
- 4 rectangular crossbeams
- 5 triangular crossbeams
- 1 cardboard base
- 2 48" long cables
- 5 18" long cables
- Scotch tape
- Scissors
- Ruler
- Stapler

### Step 1 – Test a Basic Bridge

1. Take 2 piers, and cut a v-shaped slit into one side of each.
2. Connect 2 piers with a rectangular crossbeam by inserting crossbeam into slit on each pier. Tape this structure together (Image 1).
3. Repeat steps 1 and 2 for a total of 2 pier structures.
4. Turn roadway upside down and lightly tape one of structures to each end of roadway (Image 2).
5. Turn basic bridge back over and stand it in center of the base and tape piers to base.
6. Test strength of this basic bridge by setting stapler (or other object) on roadway.
  - What do you notice about the bridge? Where are its weak points? How can you strengthen the bridge?



Image 1: Rectangular pier and crossbeam structure

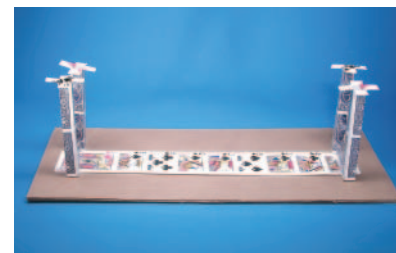


Image 2: Upside down roadway taped to top of piers



Image 3: Piers taped to base and roadway taped to piers for testing



## Team Building Instructions — Steps 2 & 3

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### Step 2 – Build a Suspension Bridge

1. Carefully remove tape holding roadway to piers and set roadway aside.
2. In between piers, center towers 9" apart from one another. Tape towers to base (Image 1).
3. Make a 1/2", v-shaped slit on one side of each facing tower, insert a rectangular crossbeam between each pair of towers, and secure with tape.
4. Make 2 slits towards ends of each rectangular crossbeam to allow main cables to rest.
5. Cut string to 48", tape one end of cable/string to underside of cardboard base, thread over pier and across top crossbeam to second tower crossbeam and back down second pier, and tape to underside of base (Image 2). Be certain to let cable droop between towers.
6. Repeat step 5 making sure that the cable's center droop is equal to first cable.
7. Cut 5, 18" lengths of string for cables connecting the main cables and roadway. Tie each 18" cable to long cables. Three cables should be evenly-spaced cable in middle section and one tied on each end section for a total of 5 smaller cables.
8. Thread the 5 cables through 5 triangular crossbeams and tie a double knot on the opposite side cable (Image 2). Be certain to make all five crossbeams level, and this may require tightening some cables by untying one side and tying it a little tighter.
9. Cut off extra length of string.
10. Insert roadway in between towers and on top of crossbeams and piers (Image 3).
11. Tape the roadway to rectangular piers at ends.

### Step 3 – Test the Bridge

1. Set stapler (or other object) on top of the roadway.
  - What do you notice about this bridge? Is it stronger than the first bridge? Why or why not?

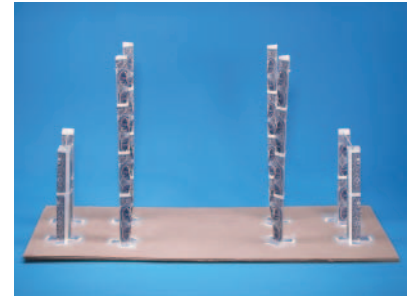


Image 1: Towers centered between piers and taped to base



Image 2: 5 triangular crossbeams suspended from 2 main cables by 5 shorter cables

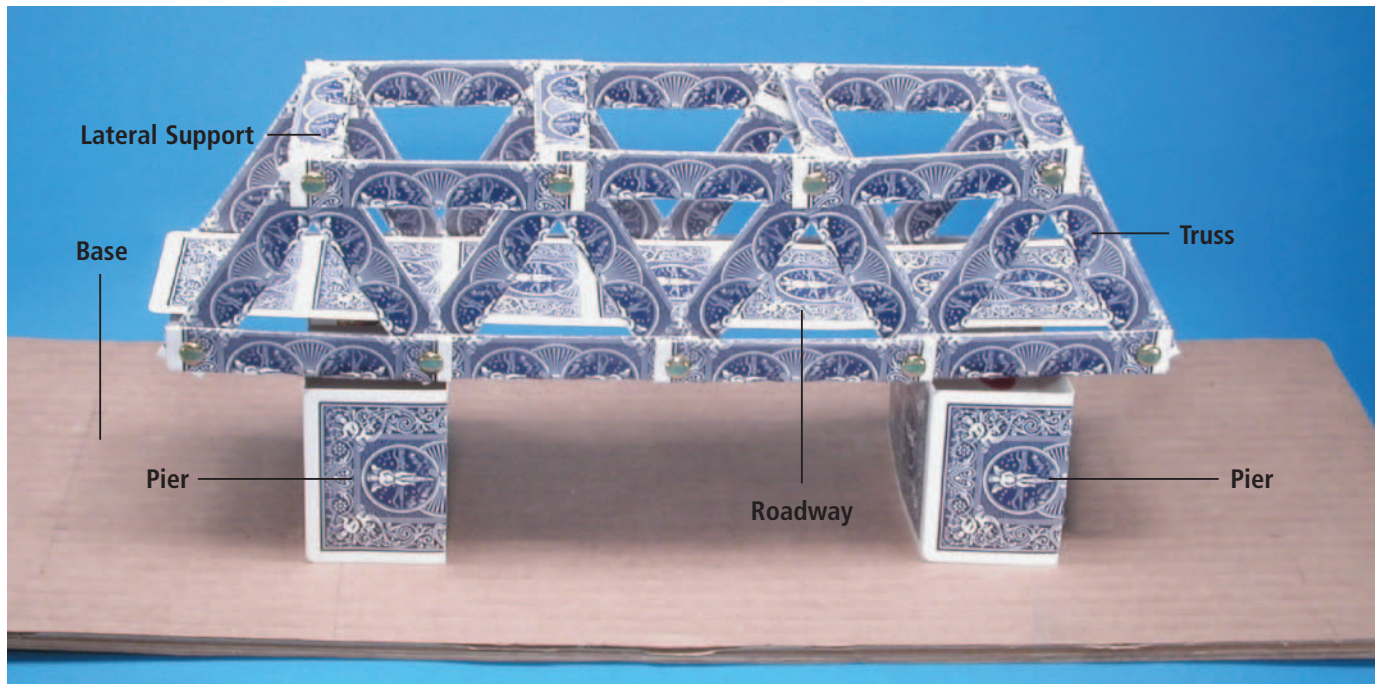


Image 3: Completed suspension bridge with level roadway

# Truss Bridge

1

**A** truss is a rigid support structure made of interlocking triangles. Since the triangle is the strongest shape, truss bridges are quite strong. Many railroad bridges utilize a truss system because of the heavy load that they can support.



## Instructions for Building a Truss Bridge

1. Divide team in half.
2. One half takes **Instruction Card 2** and the other takes **Instruction Card 3**.
3. After completing the individual bridge pieces, use **Instruction Card 4** and work together as a whole team to construct the truss bridge on the cardboard base.
4. When the bridge is constructed, cut the piece of copy paper into small rectangles. Use these smaller pieces and write the names of each bridge part on them. Refer to the labeled image of the bridge on the other side of this card for the names and locations of each part. Using tape, affix the labels to the appropriate locations on the finished truss bridge.

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### Needed Materials

- 1 deck of cards
- 18 brass fasteners
- 3 single-hole punches
- Scissors
- Cardboard base (6 x 18")
- Scotch tape
- Ruler
- Copy paper (1 piece) to create labels for bridge parts
- Object, such as a stapler, for testing bridge strength

# Truss Bridge

2

## Pier Builders — Step 1

1. Get 8 cards.
2. Lay back of 1 card down and fold card in half crosswise (Image 1). Repeat 7 more times.
3. Open 2 cards, lay cards with insides facing each other, and tape bottom and top. Repeat three times.
4. Open and create a square (Image 2).
5. Tape 2 squares together. Repeat for a total of 2 piers (Image 3).
6. The piers are complete (Image 3). Set them aside and turn this card over for instructions to complete the lateral supports.



Image 1: Card folded in half crosswise



Image 2: Two folded cards taped together to form a square



Image 3: Two squares taped together to form a rectangular pier

## Lateral Support Builders — Step 2

1. Get 9 cards.
2. Lay back of 1 card down and fold card in half lengthwise.
3. Open card and fold long edges in toward center crease (Image 1).
4. Fold entire card in half again to create a long rectangle (Image 2).
5. Make a fold 1/2" from each edge of the rectangle, leaving a 90° angle (Image 3).
6. Punch a hole in center of folded portion on both sides (Image 3).
7. Repeat eight more times for a total of 9 lateral supports.
8. When lateral supports are complete, set these aside and help the truss beam builders (Instruction Card 3).



Image 1: Card folded in four lengthwise



Image 2: Card folded into rectangular shape



Image 3: Finished card with hole-punched ends folded 1/2" from both edges

# Truss Bridge

3

## Roadway Builders — Step 1

1. Get 6 cards.
2. Lay all 6 cards in a horizontal line on a flat surface overlapping each card at half-way point (Image 1).
3. Tape each overlap, turn over, and tape other side (Image 2).
4. The roadway is complete (Image 3). Set it aside and turn this card over for instructions to complete the truss beams.

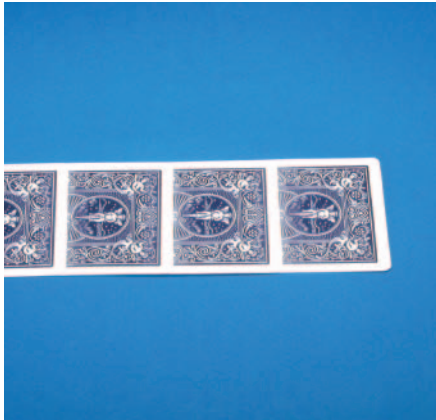


Image 1: Cards overlapping at half-way point

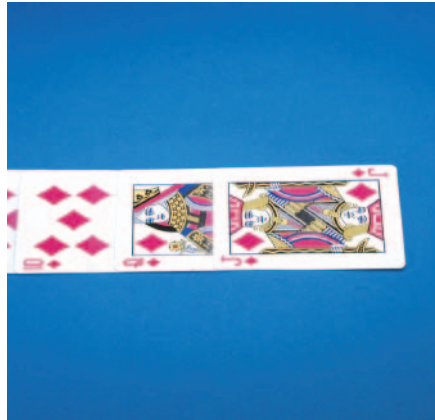


Image 2: Roadway secured by taping overlaps on both sides

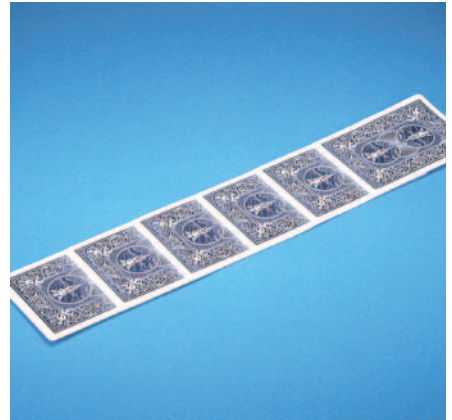


Image 3: Finished roadway

## Truss Beam Builders — Step 2

1. Get 30 cards.
2. Lay back of 1 card down and fold card in half lengthwise (Image 1).
3. Open card and fold long edges in toward center crease.
4. Fold entire card in half again to create a long rectangle (Image 2).
5. Punch holes in both ends of truss beam (Image 3).
6. Repeat 29 more times for a total of 30 truss beams.

**TIP:** Other teammates will help with this building portion. Be sure to take turns with the hole punches to avoid sore hands.



Image 1: Card folded in half lengthwise



Image 2: Card folded in four lengthwise to form a small rectangle



Image 3: Completed truss beam with both ends hole-punched

# Truss Bridge

4

## Truss Bridge Team Building Instructions — Step 1

### Materials

- 1 roadway
- 2 piers
- 30 truss beams
- 9 lateral supports
- 1 cardboard base
- Scotch tape
- 18 brass fasteners
- Ruler
- Stapler

### Step 1 – Test a Basic Bridge

1. Place 2 square piers on cardboard base about 5" apart (Image 1).
  2. Tape piers to base.
  3. Place the roadway on top of piers and lightly tape it to them (Image 2).
  4. Test the strength of this basic bridge by setting stapler (or other object) on roadway.
- What do you notice about the bridge? Where are its weak points?  
How can you strengthen the bridge?



Image 1: Rectangular piers placed on cardboard base



Image 2: Roadway placed across piers for test



## Team Building Instructions — Steps 2 & 3

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### Step 2 – Build a Truss Bridge

1. Gently remove tape that connects roadway to piers.
2. Lift roadway off structure and set to side.
3. Lay 15 truss beams on a flat surface to create 7 adjoining triangles (4 upright, 3 upside-down) (Image 1).
4. Line up the holes in truss beams and connect beams with brass fasteners.
5. Repeat steps 3 and 4 to create a second truss.
6. Using brass fasteners, connect both sets of trusses using lateral supports (5 folded pieces connect the bottom of trusses and 4 connect top) (Image 2).
7. Insert roadway into completed truss system and place entire system on piers (Image 3). If roadway is too wide, trim long edges with scissors.

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### Step 3 – Test the Bridge

1. Set stapler (or other object) on top of roadway.
  - What do you notice about this bridge? Is it stronger than the first bridge? Why or why not?

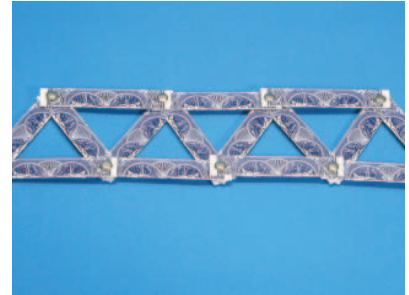


Image 1: One truss with seven adjoining triangles (4 upright, 3 upside down)



Image 2: Lateral support piece connected to truss

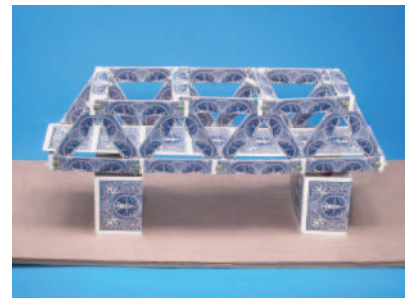


Image 3: Completed truss bridge

# Arch Bridges



Courtesy of FIGG



Courtesy of HNTB/Mark McCabe, 2005



Courtesy of Oregon Department of Transportation



Courtesy of Lawrence Biemiller

## Natchez Trace Parkway Arches

Engineer FIGG

Location: near Nashville, TN

Completed: 1994

Spans: 580 ft.

## Gateway Boulevard Bridge

Engineer HNTB Corporation

Location: Nashville, TN

Completed: 2004

Span: 545 ft.

## Rogue River Bridge

Engineer Conde McCullough

Location: Gold Beach, OR

Completed: 1932

Spans: 230 ft.

## Antietam Aqueduct

Engineer unknown

Location: Savage, MD

Completed: 1834

Spans: 40 ft.

# Beam Bridges



Courtesy of FIGG



Courtesy of National Park Service



Courtesy of FIGG



Courtesy of North Carolina Department of Traffic

## Hanging Lake Viaduct

Engineer FIGG

Location: Glenwood Canyon, CO

Completed: 1993

Spans: 300 ft.

## Seven Mile River Bridge

Engineer unknown

Location: Yellowstone, WY

Completed: 1932

Spans: ranging 16–34 ft.

## San Antonio “Y” Bridges

Engineer FIGG

Location: San Antonio, TX

Completed: 1989

Spans: 100 ft.

## Walter B. Jones Bridge

Engineer unknown

Location: Hyde County, NC

Completed: 1981

Spans: ranging 70–120 ft.

# Cable-Stayed Bridges



Courtesy of FIGG



Courtesy of Stan Williams/TxDOT



Courtesy of FIGG



Courtesy of Virginia Department of Transportation

## **Chesapeake and Delaware Canal Bridge**

Engineer FIGG

Location: St. Georges, DE

Completed: 1995

Span: 750 ft.

## **Fred Hartman Bridge**

Engineer DRC Consultants

Location: Baytown/Laporte, TX

Completed: 1995

Span: 1250 ft.

## **Sunshine Skyway Bridge**

Engineer FIGG

Location: Tampa/St. Petersburg, FL

Completed: 1987

Span: 1200 ft.

## **Varina-Enon Bridge**

Engineer FIGG

Location: near Richmond, VA

Completed: 1990

Span: 630 ft.

# Suspension Bridges



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Courtesy of Harris Photography

## Brooklyn Bridge

Engineer John A. Roebling

Location: Brooklyn, NY

Completed: 1883

Span: 1595 ft.

## Verrazano-Narrows Bridge

Engineer Othmar Ammann

Location: New York, NY

Completed: 1964

Span: 4260 ft.

## Golden Gate Bridge

Engineer Joseph B. Strauss

Location: San Francisco, CA

Completed: 1937

Span: 4200 ft.

## Royal Gorge Bridge

Engineer George F. Cole

Location: Canon City, CO

Completed: 1929

Span: 880 ft.

