Bridge Basics

Educator’s Resource Packet  ■  Grades Four–Eight

NATIONAL BUILDING MUSEUM
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To the Educator

Thank you for selecting the National Building Museum for your field trip. This resource packet is designed to supplement the Bridge Basics program and is intended to educate both teachers and students, grades four through eight.

The information and activities found in this packet should help you translate bridge building concepts for your students. The activities suggested in this booklet are designed for classroom use. They encourage young people to explore the complexity of choosing and building bridges and help them understand the engineering principles that underlie the structures that enable us to cross water, land, and roads.

This resource packet reflects the Museum’s mission to broaden public understanding of America’s built environment. The Museum hopes that the activities proposed here will be meaningful, yet fun, and that they will heighten your students’ awareness of their built environment—the parks where they play, the roads and bridges they travel, and the buildings they use.

Enjoy re-discovering your community with these activities. The Museum hopes that they will change the way you and your students view your surrounding environment.

National Building Museum Education Department
Whether it is a simple concrete highway overpass or a mile-long expanse of steel and suspended cable, bridges tie our everyday world together. Using bridge construction as a basis for understanding fundamental structural engineering concepts, students participating in the Bridge Basics program explore how technology and design, coupled with human and environmental resources, work in concert to meet the demands of a mobile society. They experiment with truss, beam, arch, suspension, and cable-stayed bridge models. Students work in teams to build model bridges that solve transportation problems while balancing issues of aesthetics, geography, materials, and cost.

Activities in this booklet are meant to complement the Bridge Basics program. They broaden its goals and objectives and reinforce national and local standards of learning met by the program.

**Skills Used**
- Identification
- Prediction
- Cooperative Learning
- Analysis
- Problem Solving
- Application of Knowledge
- Evaluation

**Goals**
After completing the Bridge Basics program and activities, students will:
- have an increased awareness of bridges and their importance to the built environment;
- understand the basic structural engineering concepts that underlie bridge design and construction; and
- understand the variety of factors that influence how bridges look.

**Objectives**
After completing the Bridge Basics program and activities, students will be able to:
- define the role of an engineer;
- identify and understand the forces of compression and tension and how these forces affect structures;
- identify live and dead loads and articulate how these weights affect structures;
- differentiate between architectural features of the National Building Museum such as columns, arches and trusses;
- list the factors to be examined before selecting and building a bridge;
- solve a problem by designing a bridge that is appropriate for a particular site;
- work cooperatively as a team; and
- evaluate bridges and determine the appropriateness of their design for their location.
Curricula Connections

The Bridge Basics program and educator resource packet activities meet local and national standards of learning. National standards are outlined below.

National Science Education Standards, National Research Council
Students will explore:
- properties of objects and materials;
- motions and forces; and
- science and technology in society.

Principles and Standards for School Mathematics, National Council of Teachers of Mathematics
Students will:
- use visualization, spatial reasoning, and geometric modeling to solve problems;
- formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them;
- develop and evaluate inferences and predictions that are based on data; and
- apply and adapt a variety of appropriate strategies to solve problems.

Standards for the English Language Arts, National Council of Teachers of English and the International Reading Association
Students will:
- employ a wide range of strategies as they use different writing process elements appropriately to communicate with different audiences for a variety of purposes; and
- conduct research on issues and interests by generating ideas and questions, and by posing problems; they gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

National Standards for Arts Education, Visual Arts Category, Consortium of National Arts Education Association
Students will:
- understand and apply media, techniques and processes;
- use knowledge of structures and functions; and
- choose and evaluate a range of subject matter, symbols, and ideas.

Standards for Technological Literacy, International Technology Education Association
Students will develop an understanding of:
- technology and society, including the effects of technology on the environment;
- design, including the attributes of design and engineering design; and
- the designed world, including the use of transportation and construction technologies.
Using This Booklet

Teachers: Use the following page labels to guide you through this booklet.

- **SHARE IT**
  - **Student Worksheet**
    - (Copy and distribute)

- **READ IT**
  - **Educator’s Notes**

- **POST IT**
  - **Facts for Students and Teachers**
    - (Copy and post)
Museum Orientation
Getting Ready

Before Visiting the Museum

Share this educator resource packet with each participating teacher.

Select chaperones. One adult must accompany every ten students. Please instruct chaperones that they are expected to actively assist students.

Arrange transportation and obtain permission slips.

Contact the Museum’s assistant school programs coordinator at 202.272.2448, x3450, if the number of students changes by five or more.

Review the map and directions to the National Building Museum and bring a copy with you.

If you would like to tour the building or an exhibition, allow for extra time after your two-hour program.

Prepare Your Students

Divide students into four even, compatible groups.

Make nametags—use template on page 8 to make it a fun activity.

Collect materials for bridge building—photocopy page 9 to send home with your students.

Use the activities in this packet to introduce basic bridge concepts to your students before attending the museum program.

Directions to the National Building Museum

The Museum is located between 4th & 5th and F & G Streets, NW. It is accessible by Metro and located immediately adjacent to the Judiciary Square Metro station (Red Line). Two-hour metered parking is available on all sides of the building. Buses may park in the G Street driveway, but drivers must remain with them. Please distribute this sheet to the drivers and remind them that the National Building Museum is NOT on the National Mall.

From Northern Virginia on I-395

Follow I-395 north into the District.
Take either 14th Street or 12th Street exit northbound.
Follow either 14th or 12th Street north to Constitution Avenue.
Turn right on Constitution Avenue.
Follow Constitution Avenue east to 6th Street, NW.
Turn left on 6th Street, NW.
After several blocks, turn right on F Street, NW.
Follow F Street east to 5th Street, NW.
Turn left on 5th Street, NW.
Turn right on G Street, NW.
Pull into the G Street driveway.

From Northern Virginia on I-66

Follow I-66 east into the District, crossing the Roosevelt Bridge.
I-66 becomes Constitution Avenue.
Follow directions above from Constitution Avenue.

From Maryland southbound on I-95/Baltimore-Washington Parkway (I-295)

Follow I-95 to Baltimore-Washington Parkway southbound.
Take Baltimore-Washington Parkway to Rt. 50 westbound into Washington, D.C.
Route 50 becomes New York Avenue.
Follow New York Avenue several miles, eventually passing the I-395 southbound exit to your left.
Shortly after the I-395 southbound exit, turn left on 5th Street, NW.
Take 5th Street to G Street and turn left.

From Maryland southbound on I-270

Take I-270 to I-495 (Belway) eastbound.
Take exit Route 355, Wisconsin Avenue southbound.
Follow Wisconsin Avenue into the District.
Turn left onto Massachusetts Avenue.
Take Massachusetts Avenue towards the Capitol, going through Dupont Circle.
Turn right onto 5th Street, NW.
Take 5th Street to G Street, and turn left.
Map to the National Building Museum

NATIONAL BUILDING MUSEUM
401 F Street NW Washington, DC 20001
Between 4th and 5th and F and G Streets at the Red Line Metro; Judiciary Square.
Wheelchair access at 4th and G Street entrances.

Telephone: 202.272.2448
Facsimile: 202.376.3564
Web site: www.NBM.org
Make a nametag before visiting the National Building Museum for *Bridge Basics*.

1. Write your first name clearly.

2. Cut out your nametag.

3. Color your nametag.

4. Attach your nametag to your shirt with tape or a safety pin.

**TEACHER TIP:** *Before coming to the Museum, divide your class into four compatible groups. During the museum program each group will be presented with a hypothetical problem, which it will have to solve by building the appropriate bridge.*
STUDENTS:

During your upcoming trip to the National Building Museum, you will work in groups to create bridges. To supplement supplies provided by the Museum, please bring items from home to use as part of your building.

Can paper towel or toilet paper rolls be the piers for a truss bridge?

Can your oatmeal container be transformed into arches for a bridge?

Can a ribbon become the cables on a suspension or cable-stayed bridge?

The National Building Museum suggests:

- Paper towel and toilet paper rolls
- Oatmeal containers
- Ribbon
- Gift boxes no larger than 9"x5"x5"

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:

- promotes creativity and individuality
- helps preserve the natural environment
- encourages young people to take ownership of their projects

We look forward to building with you at the National Building Museum, where young people and families can discover the world we build for ourselves!
While You’re Here

Upon Arrival

◆ A museum teacher will greet you inside the entrance to the Museum.
◆ Please have a total count of students and adults ready for the guard at the entrance.
◆ Security measures require the checking of adults’ bags.

Touring the Building and Exhibitions

Complimentary self-guided booklets on patterns, architecture, and engineering are available to guide you through the Museum’s grand, historic building. Call the assistant school programs coordinator at 202.272.2448, x3450, to order advance copies; one booklet is available per student. Exhibition tours are self-guided. Please allow additional time for these activities, as the Bridge Basics program does not include building or exhibition tours.

Lunches at the National Building Museum

Please note that there are no formal lunch facilities at the National Building Museum. Students may picnic on the west lawn outside of the Museum, or eat in the Museum’s Great Hall when space is available. However, please note that the Great Hall is frequently used for large events. When it is in use, students can eat outdoors or on their return trip to school.

During the museum visit, and especially during lunch, please ask your students and chaperones to observe the following guidelines:
◆ Dispose of trash properly. Please bring a garbage bag with you for this purpose. If you forget, ask your museum teacher for one.
◆ Stay with the group at all times. Forming a circle to the side of one of the large columns encourages the group to stick together.
◆ Keep away from the fountain, café tables (reserved for café patrons), and the information desk. TIP: Asking the students to stay on the carpet will help prevent them from falling into the fountain.
◆ Walk. Although children are often tempted to run and jump in the Great Hall, these actions are unsafe and not recommended. Climbing on the columns is not permitted.
◆ Talk and laugh, but please be considerate of other museum visitors who may be enjoying a tour, exhibition, or concert.
◆ Restrooms are located at the southeast and southwest corners of the Great Hall.

Visiting the Museum Shop

The National Building Museum shop offers a variety of items for children that range in price from 30 cents to $5.00 and up, including postcards, pencils, erasers, and puzzles. When visiting the Museum Shop, please keep these things in mind:
◆ Alert a shop staff member that a group of children will be visiting the shop.
◆ All children should be reminded to behave appropriately when visiting the shop.
◆ Students may visit the shop in groups of ten at a time. At least one adult must accompany and supervise each group of students.
◆ Arrangements can be made to purchase pre-packaged goody bags in amounts of $1.00 and up. Please call 202.272.7706 for more information.
Exploration of the world we build—from our homes, offices, and factories to our parks, roads, and cities—is the mission of the National Building Museum. It is the nation's only institution that comprehensively examines the what, who, how, and why of building in America. Architecture, urban planning, construction, landscape architecture, engineering, and design are the Museum's focus.

The Museum's exhibitions and education programs reveal the many connections between the way Americans build and live. Its innovative, hands-on programs for young people have won the D.C. Mayor's Arts Award for Outstanding Contribution to Arts Education as well as recognition from the National Endowment for the Arts. Created by an act of Congress in 1980, the Museum is a private, non-profit organization that opened its doors to the public in 1985.

The National Building Museum's historic home, a breathtaking building constructed in the 1880s, provides a stimulating setting for the Museum's school programs. They all begin with a visual observation and discussion of one of America's grandest interior spaces—the Great Hall—soaring 159 feet high and punctuated by 75-foot-tall Corinthian columns.

Visit our new and improved website at www.NBM.org.
◆ Learn about America's building heritage by browsing Building America, an online exhibition
◆ Explore different types of bridges through Bridging the Gap, an interactive design program that is part of the Building America online exhibition
◆ Register for youth programs and other Museum events
Facts about the historic home of the National Building Museum

Who designed the National Building Museum?
Montgomery C. Meigs (1816–1892), Quartermaster General in charge of provisions during the Civil War. He was a West Point-trained engineer. Meigs’ design was inspired by Italian Renaissance architecture.

When was it built, and how much did it cost?
1882–1887 and $886,614.04

What was the building used for before it was a museum?
Until 1926, it was occupied by the Pension Bureau, which provided pensions to veterans disabled during wartime. The building was later occupied by several other government agencies.

How big is it?
On the exterior, 400 feet by 200 feet, 75 feet to cornice level

What is it made out of?
15,500,000 bricks with brick and terra cotta ornaments

How long is the frieze on the building’s exterior, and who designed it?
1,200 feet long, 3 feet high, made of terra cotta
Designed by Bohemian-born sculptor Caspar Buberl (1834–1899)
Features a continuous parade of Union Civil War units

What are some interesting facts about the Great Hall inside the museum?
316 feet by 116 feet (a little larger than a football field)
159 feet—approximately 15 stories—at its highest point (The Statue of Liberty, without her base, could stand up straight if she were placed on top of the fountain.)
The Presidential seal has been in place since 1901, the only Presidential seal permanently affixed to a building other than the White House.
Presidential inaugural balls, from Grover Cleveland’s in 1885 to the present, have been held in the Great Hall.

What are the Corinthian columns made from, and how tall are they?
Among the tallest interior columns in the world—75 feet high, 8 feet in diameter, 25 feet in circumference
Each one is built out of 70,000 bricks and covered by plaster
Originally painted in 1895 to resemble marble. The present faux marble pattern was applied in 2000.

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The information in this section is designed to familiarize you with basic bridge information and the distinguishing characteristics of the five bridge types.

As people travel from place to place, they often cross bridges to reach their destination. Whether they are big or small, long or short, bridges are remarkable structures that enable people to cross water, land, and roads easily and efficiently. A bridge’s design is dependent upon many factors, including the:

- site and surrounding environment;
- bridge’s function;
- budget and building schedule;
- engineer’s or community’s aesthetic preferences; and
- community’s needs.
Beam 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; does not allow large ships or heavy boat traffic to 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.

Washington, D.C., Area Beam Bridges

Frederick Douglass Memorial Bridge
Anacostia River, Washington, D.C.

Benning Road Bridge
Anacostia River, Washington, D.C.

M Street Bridge
Rock Creek Parkway, Washington, D.C.

Chain Bridge
Potomac River, between Washington, D.C., and Virginia near Great Falls

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 over 9,000 pilings.
Arch 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 (for example, 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 outwards.

**Tension:** The force of tension is strongest at the bottom of the arch and pulls the sides outward. The larger and shallower the arch, the greater the effects of tension and need for abutment support.

Washington, D.C., Area Arch Bridges

- **Francis Scott Key Bridge**
  Potomac River between Washington, D.C., and Virginia

- **William Howard Taft Bridge**
  Rock Creek Parkway, Washington, D.C.

- **Cabin John Bridge**
  Cabin John Creek, Maryland

Roosevelt Lake Bridge, Phoenix, AZ; completed 1990

© 2004 National Building Museum
Truss Bridges

Wooden truss bridges were used as early as the 1700s, 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 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

**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.

Washington, D.C., Area Truss Bridges

**North Bethesda Trail Bridge**

I-495, Maryland

**Railroad Bridge**

Potomac River at 14th Street, between Washington, D.C., and Virginia

**New River Gorge Bridge**

New River, West Virginia

**Harry W. Nice Bridge**

Potomac River at Route 301 between Virginia and Maryland

**Bollman Truss Bridge**

Patuxant River, Savage, Maryland

BRIDGE BRAG

In the Washington, D.C., area, many truss bridges that are no longer used as railroad bridges have been converted into walking and biking trails, such as the ones along the Capital Crescent Trail from Georgetown in Washington, D.C., to Silver Spring, Maryland.
Suspension 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:** Spans distances up to 7,000 feet; considered attractive; allows large ships and heavy boat traffic to pass underneath

**Cons:** Expensive (requires 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.

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**Washington, D.C., Area Suspension Bridges**

**Chesapeake Bay Bridge**
Chesapeake Bay, Maryland
NOTE: This bridge uses a combination of suspension, truss, and beam bridge structures.

**BRIIDGE BRAG**
The Tacoma Narrows suspension bridge in Washington State was known as “Galloping Gertie” because it rippled like a roller coaster.
In 1940, the first heavy storm caused the bridge to break 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:** Spans medium distances (500–2,800 feet); less expensive and faster to build than a suspension bridge; 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.
In addition to creating name-tags and gathering materials (see pages 8—9), before your museum visit, use these activities to introduce your students to the basic concepts behind building bridges.

- **What is a Bridge?**
- **Understanding Forces at Work: Compression and Tension**
- **Testing Shapes and Materials for Strength**
Becoming aware of how bridges affect our lives will increase your students’ awareness of the built environment. They will begin to realize how much people rely on bridges to move about, and how bridges vary depending on their location. This activity, which introduces your students to the five basic bridge types, will prepare them for the more in-depth exploration of bridges during their field trip.

**What is a Bridge?**

**Materials**
- 5 pieces of poster board
- Glue or tape
- Internet access, magazines, calendars, brochures, books, or other printed materials that contain pictures of bridges (see pages 42–44 in the resource section)
- Copies of Bridge Essentials for Educators section in this resource packet, pages 14–18.

**Discussion and Analysis**

Ask your students to think about the last time they remember crossing a bridge. Where were they? How were they travelling—on foot, by car, bicycle, bus, or train? Ask them what their impressions were. Did they notice the bridge?

Ask your students to consider the definition of a bridge and what structures they consider to be bridges. Have them draw a sketch of what comes to mind when they think of a bridge. Usually when people think of bridges, they think of structures spanning water. Ask students to think about other obstacles bridges can span and brainstorm a list.

Refer to the Bridge Essentials for Educators sheets, pages 14–18, to introduce the five basic bridge types to your students. You may want to post these sheets in the classroom. Ask students if they know of any bridges in their local area, or famous bridges elsewhere. Can they identify what types of bridges they are?

**Action**

Break your class into five groups and assign each group a bridge type. Have each group collect photos of their type of bridge from the Internet, magazines, books, or other printed materials and create posters for display in the classroom. (Refer students to the books and Internet sites listed in the resources section of this packet.) The posters may contain additional information about the bridges, such as the distance or geographic feature they span, the materials used, date of construction, or interesting historical or anecdotal information.
Bridges, like all built structures, rely on unseen forces that hold them together and enable them to support additional weight, or loads. It can be difficult to visualize forces acting on an object or structure that appears to be at rest. This activity is designed to help students imagine these unseen forces and thereby better understand the mechanics of bridges.

Note: Each of the following short activities builds on the knowledge acquired in the previous one; therefore, it is recommended that you do the activities in the order presented.

**Materials**

A chair  
Soft kitchen sponges, at least 1 inch thick (1 per 2 students)  
Magic markers  
Rulers  
Hardcover books

**Part I**

**Forces**

**Discussion and Demonstration**

Explain that a force is a push or pull on an object. When an object is at rest (not moving), the forces acting on it are balanced.

Place a chair in the middle of the floor. Ask your students whether there are any forces acting on this chair. (Even without anyone pushing on the chair, there are forces acting on it. The force of gravity is pulling down on the chair, but it does not collapse because it supports its own weight.)

Have a student push the chair a short distance across the floor. Ask what force just acted on the chair. (A push unbalanced the forces on the chair and made it move.)

Next, have two students facing each other push on either side of the chair so that it does not move. Ask your students whether there are any forces acting on the chair. If so, why doesn’t it move? (Although two forces are acting on the chair, they are balanced, causing it to remain in place.)
Part II
Compression and Tension

Discussion and Demonstration

Explain to students that compression is the act of being pushed or pressed together. Have students place their hands with their palms together and elbows bent. Tell them to press their palms together. This pushing force is called compression.

Explain that tension is the act of being stretched or pulled. Have students place their hands in front of them, and clasp curled fingertips together. Tell them to pull on their hands. This pulling force is called tension.

Action: Force Search

Divide your class into two teams. Ask each team to search for building elements under tension and compression in your classroom or school. Give the class a time limit of 15 minutes to find five elements under tension, and ten elements under compression. One group member should be appointed to write down the information. When the time is up, compare the lists. Examples of elements under compression are walls, vertical sides of doors or window frames, columns or piers. Examples of elements under tension are cables or strings hanging from the ceiling with an object attached to it, such as a map, poster, or screen. Any arch or triangular structures is in both tension and compression.
Part III
How Do the Forces of Compression and Tension Act on Bridges?

Discussion and Demonstration

Pair students together and give each pair a large soft kitchen sponge. (New sponges work best for this activity because they are flexible.) Have the students draw a series of lines approximately 1/2 inch apart crosswise around the sponge. Next have the students take turns bending the sponge into a U-shape and observe what happens to the lines. The lines inside the U-shape get closer together, while the lines outside the U-shape spread farther apart. Ask where the sponge is in compression. (The inside of the U-shape.) Where is the sponge in tension? (The outside of the U-shape.) How could students balance out the forces of tension and compression acting on the bridge to make it stronger? (Some ideas include using a stiffer material for the beam, or adding supports, such as knitting needles or pencils, to the sponge.)

Part IV
Live Load and Dead Load

Discussion

Explain to students that bridges must be able to support two types of forces, called loads, or they will collapse. Dead load is the weight of the bridge itself, such as its columns, beams, nuts, bolts, trusses, cables, etc. Live load is the weight or force of temporary external elements acting on the bridge, such as people, vehicles, wind, etc. Ask students to come up with more examples of live load. Explain that environmental factors, such as temperature, earthquakes, and wind also constitute live loads acting on bridges. Hot and cold temperatures cause parts of the bridge to change shape and put pressure on other parts of the bridge; earthquakes push and pull horizontally on a structure as the ground beneath jerks back and forth; and wind blows on a structure pushing it horizontally.

Action: Load Search

Have students work individually to come up with a list of five examples of each dead load and live load in the classroom or the school building. When the allotted time is up, have students share their answers. Examples of dead load are walls, floors, ceilings, windows, and door frames. Examples of live load include desks, chairs, people, books, rain, and snow.

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Testing Shapes and Materials for Strength

In this activity students will examine different shapes and materials to determine their strength and why certain ones may be used when building bridges. Students will come to understand that the strength of a material does not depend only on the composition of the material itself; changing a material’s shape can also affect the way it resists forces. Likewise, a structure’s location or function in a bridge may determine the shape it takes.

Note: Each of the following short activities stands alone and can be done individually.

Part I
Materials Matter

Materials
Teacher discretion: materials may include string, rubber bands, styrofoam, sponges, marshmallows, brick, metal, copper wire, small blocks of wood

1 vise, 1 pair of pliers, and 1 ruler per group of students (note: A C-clamp can be used in place of a vise. C-clamps are readily available in hardware stores.)

Photocopy of Materials Testing Worksheet, page 28

Discussion

Explain to students that building materials withstand tension and compression to different degrees. Tell students that this activity will help them understand that because materials have unique properties, some are better suited for certain bridges or parts of a bridge than others. For example, arch structures experience high degrees of compression and must be built from materials that can bear such forces, such as bricks or concrete. Modern suspension bridges, on the other hand, rely on steel cables, which are extremely efficient at withstanding and transferring tension.

Action

Gather as many different kinds of materials as you can find, using the ones listed above as a guide. Divide the class into four groups and provide each with samples of the different materials, along with a vise, a pair of pliers, and the Materials Testing Worksheet. Have each group test each material for strength under tension and compression according to the following guidelines.

Compression test

Put the object in a vise. Note if the object changes shape or remains intact.

Tension test

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. Note if the object changes shape or remains intact. Measure how far the object can be pulled apart.

Have one member of each group be responsible for recording the group’s observations by filling in the chart in the Materials Testing Worksheet. When students have finished testing the materials, ask the groups to share their results. Were students surprised by the way some of the materials responded under tension and compression? Were there any unexpected results during the experiment?
Part II
The Strongest Shape

Materials (per student)

1 pair of scissors
3 4”x6” index cards
1 single-hole punch
11 small paper fasteners

Discussion

Explain to students that as trains became a popular way to transport goods in the late 1800’s, bridge engineers faced a new challenge: how to design a bridge that could support the massive weight of trains as well as their vibrations. Bridge builders conceived of a truss bridge, which is essentially a beam bridge supported by a series of triangular shapes called trusses. These shapes are rigid—they do not move when pushed—and they make a bridge extremely strong. Tell students that in this activity they are going to examine three shapes—a square, a triangle, and a rectangle—and determine what makes the triangle the most rigid.

Action

Instruct students to cut each index card into four 1-inch strips lengthwise. They will now have 12 strips, although they will only need ten. Next, have them punch a hole in each end of the ten strips. To make a triangle, have students attach three strips with the paper fasteners. Ask them to attach four strips to make a square. To make a rectangle, instruct students to cut one strip in half widthwise and punch a hole in the unpunched ends. Have them combine these shorter strips with two longer strips to make a rectangle. Now ask students to take the triangle, square, and rectangle and push down on the corners and sides of each shape.

What happens? (The square and rectangle should collapse, while the triangle keeps its shape.)

Why? (The triangle is made up of the least number of sides possible for a geometric shape, locking its three sides into place.)

Can students identify which parts of the triangle are in tension and which are in compression? (If pressure is applied to any of the corners, the two sides radiating from that point will be in compression, while the side opposite that point will be in tension. If pressure is applied to any of the sides, that side will be in tension, while the other two sides will be in compression.)

Can students add a longer strip to the square and rectangle so they don’t move? (Take notice of the shapes they have made inside the square and rectangle; they are triangles.)

Discussion

Based on the results of this experiment, which shape provides the most structural strength? (Triangle) Explain to students that truss bridges get their strength from triangles. Triangles can be arranged into many truss patterns, which can be located on the sides of the roadway, or beneath the base of the bridge. Refer to pictures of truss bridges for examples of different truss patterns. (See the Resources section of this packet for listings of Web sites and books that contain truss pictures.)
Part III
Pile It On—Strengthening
Shapes

Discussion
Explain to students that while a mate-
rial such as paper might not appear to
be able to support much load, it is
possible to greatly increase its strength
by manipulating its shape. This activ-
ity will encourage students to think
about the relationship between shape
and material, and how it may impact
bridge construction.

Action
Have students create a simple beam
bridge by standing two books, upright
like bookends, about six inches apart,
and placing a piece of paper horizon-
tally across them. Make another simple
beam bridge, but create an arch under
the beam by tucking the ends of
another sheet of paper downward
between the book covers. It may be
necessary to tape two sheets of paper
together in order to make the arch
high enough to touch the underside of
the beam bridge. Gently add paper
clips, one by one, to the middle of
both bridges. Have students keep
count of how many paper clips each
bridge can support. Which one holds
more load, the arch or beam bridge?
Why? (The arch, which helps to dis-
tribute weight, carries more weight.)

Now have students accordion-fold a
piece of paper lengthwise, put it
between two sheets of paper, and place
it over two bookends. Ask students to
predict which bridge will be strongest.
Test the bridges using the paper clips,
pennies, and keys. Did the students
predict correctly? (The triangles in
the third bridge make it the strongest
bridge.)

Ask students whether they can demon-
strate other ways to fold the paper to
span the two bookends. Have them
compare how much load each type of
bridge can hold.
Part IV
Standing Tall—Bridge Piers

Materials
Tape
Stack of 9"x12" construction paper
Paperback books (as weights)

Discussion and Demonstration
Explain to students that piers, or vertical beams, are an integral part of bridge structures because they help to support the structure. Referring to pictures of bridges, have students point out the piers. Tell students that in this activity they are going to examine different pier shapes and test them for strength. Demonstrate to the students how to create piers with paper and tape.

Square: Fold the paper in half (lengthwise). Open up the paper and fold each side of the same sheet into the center fold. Open up the paper and tape it into a square column.

Triangle: Fold the paper into three equal parts (lengthwise), like a letter except lengthwise. Open up the paper and tape it into a triangular column.

Cylinder: Roll the paper (lengthwise) into a cylinder with the ends slightly overlapping and tape together.

Activity
Have students work in groups of three. Provide each group with three pieces of construction paper, tape, and several books. Have each group construct the three different piers. Stand the piers on one end and pile books one at a time onto each pier. Make sure that the books are balanced. Which pier holds the most weight before collapsing? (The students should find that the cylinder holds the most books.)

Discussion
Explain that the cylinder is the strongest because it has no corners and, therefore, the weight pressing down on it (compression) is spread evenly. That is why cylinders are often used for the piers of bridges. Ask the students how they could strengthen the cylinders to support more books. (Filling them with sand or marbles will strengthen the cylinder because the stiffer the unit, the more weight it can support.)

If you did Part II with your students, have them consider why in this instance the cylinder was the strongest shape, while in the previous activity the triangle proved to be strongest. (Triangles are generally considered to be the strongest shape, but depending on their location and function, they are not always the most suitable for bearing weight.)
Test each material for strength under compression and tension.

**Compression:** Put the object in a vise. Record what happens to the material and 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.

<table>
<thead>
<tr>
<th>Material</th>
<th>Compression Observations</th>
<th>Compression Rating</th>
<th>Tension Observations/Measurement</th>
<th>Tension Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: Sponge</td>
<td>dented in/became compacted when compressed</td>
<td>G</td>
<td>stretched then tore under tension/2 inches</td>
<td>F</td>
</tr>
</tbody>
</table>

Materials Testing Worksheet
More Activities

Building on What You Have Learned

Use these activities to expand your museum experience.

- Pasta Passage
- Unique American Bridges: A Research Project
- Bridges Here, There, and Everywhere: Take a Closer Look
- Family Field Trips: Exploring Your Community
When designing bridges, engineers are often faced with such constraints as a limited budget, availability of materials, or schedule. It is not uncommon for bridge projects to cost more or take longer to complete than originally anticipated. This activity is designed to mimic real-life situations by encouraging students to work together as engineers to solve a problem and meet deadlines.

Note: This multi-part activity will require about two class periods to complete—the first period for preparations and the second period for building, testing, and judging the bridges.

### Materials

**Each group will need:**

- Uncooked pasta
- 1-inch bundle of spaghetti
- 1/2 cup rigatoni
- 1/2 cup bow pasta
- 2 sheets lasagna noodles
- 1 spool of thread
- 1 glue gun
- 3 glue sticks
- 50 points (use 10 3”x5” cards, each marked with the number “5”)
- Sketching paper
- 1 pencil
- Several bags of coins, nuts, bolts, or similar material (to be used as weights)

**The class will need:**

- Scale
- Measuring cups
- Pieces of fabric, at least 5 x 5 inches in size
- Pieces of string, at least 5 to 6 inches long, or twist ties
- Extra pasta, glue sticks, and spools of thread
- Copies of Pasta Bridge Building Scoring Sheet (page 32)

### Action

**Part I
Preparing to Build a Pasta Bridge**

In preparation for the activity, break your class into groups of four to five students and have each group collect about 100 coins. In class, have the groups divide the coins into four piles, wrap each pile in a piece of cloth, and tie it with a piece of string. Each group should end up with four such bags. **Teacher Tip:** Nuts or bolts work as well as coins.

Explain to students that these bags will be used as loads to test the strength of their bridges. Using a scale, have the groups weigh each bag and record its weight in both ounces and grams. Afterwards, ask students to put the weights aside. **Teacher Tip:** Record the weight by writing directly onto the fabric with a fabric pen.

Give groups samples of each type of pasta, a glue gun, glue stick, and spool of thread. Explain that before the students build a bridge out of pasta, they should spend time familiarizing themselves with the building materials. Give the groups about 30 minutes to explore the properties of the different kinds of pasta and become comfortable...
with the glue guns. You can point out that, for example, pasta snaps easily along its length, but standing vertically, it can support a lot more weight. Have students recall what they already know about bridges. Encourage them to think about ways to combine the materials to construct piers, a reinforced beam, and arch, truss, and suspension structures. At this point, tell students not to build a complete bridge, but rather to experiment with the materials. Have them consider how their final bridge will be constructed. Instruct students to draw a sketch of the bridge they will build.

If time permits, have each group gather its own set of materials to be used for building by dividing and measuring the pasta into the quantities as listed in the materials section.

**Part II**

**Building a Pasta Bridge and Contest Criteria**

Have each group briefly review its bridge design and sketch from Part I of this activity. Explain that they are going to build their bridge in one hour using a limited amount of materials, which they will need to use economically. Students can build any type of bridge they wish, but they must meet the following criteria.

### Bridge Building Criteria:

- Use only the materials provided
- Completed within one hour
- Clear a span of 11 inches (the length of a standard piece of paper)
- Support a minimum of four bags of weights
- Attractive

In addition, each group must adhere to a point system. Each group begins with 50 points with which to purchase additional materials from the instructor. Once a group's total number of points runs out, it must make do with the materials it has.

### Price List:

- 1-inch bundle of spaghetti = 10 points
- 1 glue stick = 10 points
- 1 spool of thread = 25 points
- 1/2 cup rigatoni = 5 points
- 1/2 cup bows = 5 points
- 1 sheet lasagna = 5 points

Once the bridges have been completed, place them over a span of 11 inches created by the ends of two tables, or two piles of books, and test how much load they can support. (NOTE: Each bridge must support at least four bags of weights to qualify to win the contest; the bridges should also be tested for the total amount of load they can support by adding additional bags of weights.)

### Discussion and Analysis

Using the Pasta Bridge Building Scoring Sheet on page 32, students will judge each bridge built by the other groups. The teacher will determine a winner based on three factors: bridge building criteria, group cooperation, and a group's number of remaining points. The group that meets the bridge building criteria, has worked well together, and has the highest number of points remaining will win.

Have the students analyze why and how the different bridges were successful, or not. Discuss changes that could improve each bridge.

### Taking it Further

Award prizes for other categories such as the strongest bridge, the most beautiful bridge, or the most innovative design.

(This exercise has been adapted from “Pasta Bridges,” an activity developed by CUBE, Center for Understanding the Built Environment.)
Name:

Group that is being evaluated:

Students: Evaluate your fellow classmates’ bridges according to the following criteria.

For Students:

Criteria Score (“1” is the lowest score, “5” is the highest)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses only the materials provided (circle one)</td>
<td>Yes</td>
</tr>
<tr>
<td>Completed in one hour (circle one)</td>
<td>Yes</td>
</tr>
<tr>
<td>Clears a span of 11 inches (circle one)</td>
<td>Yes</td>
</tr>
<tr>
<td>Total load supported (in grams and ounces)</td>
<td></td>
</tr>
<tr>
<td>Attractive (circle one)</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Innovative design (circle one)</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

For Teacher Use:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective group cooperation</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Number of remaining points</td>
<td></td>
</tr>
</tbody>
</table>
Now that your students have completed the *Bridge Basics* program, they have the basic knowledge enabling them to delve more deeply into the stories behind bridges—what makes them unique and how they were designed and constructed. This multi-disciplinary activity will engage your students’ reading, writing, research, and geography skills, as it encourages them first to compare bridge types and then to focus on one particular bridge.

**Materials**

- Internet access
- Atlas of the United States, books, articles, and reference materials about bridges
- Copies of *The Long and Short of American Bridges* worksheet (pages 34–35)
- Copies of *Bridge Research Guide* worksheet (page 36)
- Poster board (optional)

**Discussion**

Begin by asking students to recall what they learned during the *Bridge Basics* program. Ask the class to consider why bridges are made of different materials and what environmental challenges bridge engineers must overcome (e.g., earthquakes, strong winds, temperature changes). Factors such as limited budget, geography of the site, and concerns or preferences of the local community also merit discussion.

Review the definitions of *distance* (total length of a bridge) and *span* (the length between two supports of a bridge). Discuss which types of bridges have longer spans than others. Suspension and cable-stayed bridges span the longest distance, and beam bridges span the shortest distance. Truss and arch bridges span medium distances. Traditional arch bridges that are made from brick or stone span much shorter distances than newer versions made from metal.

**Action**

Distribute *The Long and Short of American Bridges* worksheet (pages 34–35) and allow time for students to complete it, either in class or as homework. Explain that they should first try to complete the worksheet on their own, but that they may access the Internet or an atlas if needed.

When students have completed the worksheet, divide the class into groups of 4–5 students. Assign each group to research one of the bridges from *The Long and Short of American Bridges* worksheet, using the *Bridge Research Guide* (page 36) to direct their work.

**Teacher Tip:** For suggested Internet sites and reference materials, see the Resources section of this packet.

Have the students synthesize their findings in a one-two page paper. A bibliography should be included.

**Taking it Further**

Each group may create an exhibition panel (out of poster board) that includes images, captions, and answers many of the questions on the *Bridge Research Guide* (page 36). Discuss the components of a good exhibition panel—title at the top in large text; images that feature different aspects of a bridge; introductory paragraph describing the purpose of the panel; short, concise captions next to each image. Use the posters to develop an exhibition and have the students act as museum docents presenting the information to their parents or other students at an “exhibition opening.” The bridges that the students built as part of the *Bridge Basics* program should be included in the exhibition.
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.

<table>
<thead>
<tr>
<th>Lake Pontchartrain Causeway</th>
<th>New River Gorge Bridge</th>
<th>Bollman Truss Bridge</th>
<th>Leonard P. Zakim Bunker Hill Bridge (Charles River Bridge)</th>
<th>Brooklyn Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Orleans, LA</td>
<td>Fayetteville, WV</td>
<td>Savage, MD</td>
<td>Boston, MA</td>
<td>New York, NY</td>
</tr>
<tr>
<td>Length: 124,700 feet</td>
<td>Length: 3,030 feet</td>
<td>Length: 160 feet</td>
<td>Length: 1,457 feet</td>
<td>Length: 3,460 feet</td>
</tr>
<tr>
<td>Spans: 56 feet each</td>
<td>Span: 1,700 feet</td>
<td>Span: 80 feet</td>
<td>Main span: 754 feet</td>
<td>Main Span: 1,595 feet</td>
</tr>
<tr>
<td>Type: beam</td>
<td>Type: arch</td>
<td>Type: truss</td>
<td>Type: cable-stayed</td>
<td>Type: suspension</td>
</tr>
<tr>
<td>concrete, steel</td>
<td>concrete</td>
<td>iron</td>
<td>steel</td>
<td>steel</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Length</th>
<th>924 meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span</td>
<td>518 meters</td>
</tr>
</tbody>
</table>

Bollman Truss

Brooklyn

<table>
<thead>
<tr>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>span</td>
</tr>
</tbody>
</table>

Charles River/Bunker Hill

<table>
<thead>
<tr>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>span</td>
</tr>
</tbody>
</table>

Lake Pontchartrain

<table>
<thead>
<tr>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>span</td>
</tr>
</tbody>
</table>

Analysis [answer these questions on another page.]

What is the difference between the length and span of a bridge? Do you think they are ever the same?

How does the bridge type relate to the distance it can span? How does the bridge type determine the total length it can cross?

What do you notice about the relationship between the age of the bridges and the technology and materials used to construct them?

Suspension bridges typically span longer distances than other types of bridges. Why do you think the New River Gorge Bridge, an arch bridge, spans a longer distance than the Brooklyn Bridge, a suspension bridge? Hint: Some things to consider might be the age of the bridge, technology, materials, and geographic site.
Use the questions below to guide your research on your bridge.

Where is the bridge located? 

What obstacle does the bridge cross? 

When was the bridge built? 

What materials were used to construct the bridge? 

Which of the five basic bridge types best describes the bridge? 

What types of traffic use the bridge? 

What is the name of the engineer or engineering firm who designed this bridge? 

On separate pages, re-write and answer the following questions.

Why do you think the engineer built this type of bridge for this site?

What were the special challenges that the architects and engineers faced while designing this bridge?

How did they overcome those challenges?

Did you find any interesting stories or fun facts about this bridge?

Do you like the way the bridge looks? Why or why not?
Catastrophic Bridges
Ask students to research factors that have caused bridges to fail. Were any of these bridges rebuilt? Some examples include: the Tacoma Narrows Bridge, Tacoma Narrows, Washington (collapsed 1940); the Quebec Bridge, St. Lawrence River, Quebec, Canada, (collapsed twice during construction, 1907 and 1916); the I-5 Arroyo Pasajero Twin Bridges, Coalinga, California (collapsed 1995).

Ornamental Bridges
Many bridges are decorated with ornamental sculptures. Examples in Washington, D.C., include: Lions, by Roland Perry, at the entrance to the William Howard Taft bridge on Connecticut Avenue at Calvert Street; Buffaloes, by Alexander Phimister Proctor that guard the four corners of the Q Street/Dumbarton Bridge; and artist Leo Friedlander’s equestrian sculptures that flank the east entrance to the Memorial Bridge crossing over the Potomac River.

Suggest that students add ornamental sculpture to the bridge models they created at the National Building Museum. Will they be inspired by human, animal, or plant motifs? Will they be stone, metal, or wood? Will they have a symbolic meaning? Where will they be located—at the entrances or along the sides? Sculptures can be made from clay, paper mache, paper, or nuts and bolts.

Engineering Experts
Invite a civil engineer to talk to the class about bridges and his/her job. Which courses did s/he take to prepare for a career in engineering? What tools do engineers use to design bridges and other structures?

Bridging the Future
Have students conduct research on future bridges. What kinds of materials will be used to build them? Will bridges take on new structural forms? Based on their research, have students use butcher paper and markers to show an example of a future bridge design. Santiago Calatrava, a well-known Spanish architect, has designed bridges that use new technology. Research his work on the Internet.
Families: Your children are learning about bridges in school and at the National Building Museum. Encourage them to explore bridges in their community and have them teach you about the basics of bridge building.

1 Discuss the Woodrow Wilson Bridge project with your child. Drive over the existing Woodrow Wilson Bridge (on I-95/I-495 crossing the Potomac River) and ask your child to look south to view the construction. Track the project through the Web site, www.wilsonbridge.com. Explore how the new bridge will affect people using it and living in its vicinity.

2 Walk, bike, or drive along the Rock Creek Parkway in Washington, D.C., and examine the different bridges you pass over and under. Ask your child to identify which types of bridges s/he sees. Have him/her point out the different structures that are holding up the bridges and explain how they work.

3 When you and your child drive around your community, notice the bridges that you use. What obstacles do they span? How old are they? What types of bridges are they? How do they help the flow of traffic? Are any of them historically or structurally significant?

4 Montgomery Meigs, the architect and engineer of the National Building Museum’s historic building, designed the Cabin John Bridge. Completed in 1863, it carries water from the Potomac River to Washington, D.C. With a span of 220 feet, it was the longest masonry arch in the world, a record held for 40 years. Drive under this awe-inspiring arch on the Cabin John Parkway in Maryland.

5 Learn more about engineering at the National Building Museum’s annual day-long family festivals, which allow young people to explore hands-on engineering and other building activities. Check the Museum’s Web site or call for more information.
Bridge Activities at the Museum

In addition to its school program Bridge Basics, the National Building Museum offers Bridging the Gap, both a hands-on demonstration cart and an online interactive that can deepen your students’ understanding of bridges.

Both the demonstration cart and online interactive introduce students to the environmental factors, function, cost, materials, and aesthetics that affect where, why, and how bridges are built. After students have learned about five basic bridge types, they apply their knowledge to solve a community’s transportation problem by selecting an appropriate new bridge.

The online interactive, which can be accessed through the Museum’s online exhibit Building America (see www.NBM.org), provides images and diagrams of several bridges, including a glossary of bridge-related terms.

Please contact the Museum’s Education Department if you are interested in scheduling a Bridging the Gap demonstration cart.

Figg Engineering Group generously provided the Museum financial support and technical assistance in developing the demonstration cart and online interactive.
Bridge Vocabulary

**Abutment**
A support for the end of a bridge.

**Anchorage**
A foundation structure that secures suspension bridge cables on land and allows them to bear the weight of the bridge.

**Arch**
A semicircular structure.

**Arch bridge**
A bridge in which the roadbed is laid across an arch or a series of them.

**Architect**
A professional who designs, plans, and coordinates the building of structures.

**Beam**
A rigid, usually horizontal, structural element.

**Beam bridge**
A bridge composed of a horizontal beam supported by vertical piers.

**Cable**
Formed from steel wire bound in strands; used in modern suspension and cable-stayed bridges.

**Cable-stayed bridge**
A bridge in which a portion of the roadway is supported by diagonal cables attached to a pylon.

**Compression**
The stress resulting from a pushing force on a structure; opposite of tension.

**Dead load**
The weight of any components in a structure; for example, the weight of the parts of a bridge.

**Distance**
The total length of the bridge.

**Engineer**
A professional who applies mathematical and scientific principles to the design of structures, equipment, and systems.

**Force**
A push or pull on an object; when an object is at rest (not moving), the forces acting on it are balanced.

**Keystone**
The slightly larger, wedge-shaped piece of stone or wood placed at the center of the arch to take pressure from both sides of the arch.

**Live load**
The weight of anything that is not a part of the structure, such as vehicles or pedestrians crossing a bridge; includes external environmental forces, such as wind or water.

**Pier**
A vertical column holding up a bridge or other structure.

**Pylon**
The vertical structural element from which cables radiate in a cable-stayed bridge.

**Roadway**
The part of the bridge traffic travels across.

**Span**
The distance between two supports of a bridge.

**Suspension bridge**
A bridge in which the roadway is hung from strung cables that pass over two towers.

**Structure**
An object constructed of a number of parts that are put together in a particular way.

**Tension**
The stress resulting from a pulling force on a structure; opposite of compression.

**Tower**
The vertical element in suspension bridges from which cables are hung.

**Truss**
A rigid support structure that is made up of interlocking triangles.

**Truss bridge**
A bridge in which the roadway is supported by rigid frames composed of short, straight pieces joined to form a series of triangles.
General Books

Focuses on the materials used in bridge building with excellent photographs of bridges around the world; good for research.

Contains the history of bridges, who builds them, how they work, and what happens when they don't work. Excellent photographs; good for research.

A celebration of the history and progress of American bridge building, transportation, and engineering.

A look at 40 famous bridges, including photographs (black & white) and detailed information about each bridge; good for research.

Offers an in-depth look at all the decisions that must be made while a bridge is being designed.

Pays tribute to the design and construction of the man-made wonders of the world, including bridges.

Fascinating history of the Brooklyn Bridge and the family who built it; includes historic photos and diagrams.

Through color photographs and explanatory text, shows how engineering and aesthetics can merge and create something both beautiful and useful.

Vivid descriptions of different types of bridges around the world and throughout history.

Comprehensive history of North American bridges, including almost 200 black-and-white photographs.

Storybooks

For the young reader; covers the major bridge types with color photographs of well-known bridges.

Colorful storybook that introduces the different kinds of bridges, from drawbridges to old covered bridges.

Illustrations of famous bridges with facts presented in storybook form.

Activity Books

Step-by-step instructions for drawing the world's most famous bridges, skyscrapers, castles and other structures.

Good suggestions for activities, basic descriptions of bridge types, and vocabulary.

Good suggestions for activities, diagrams of bridge types, and a brief history of bridge building.

Good suggestions for activities, simple explanations of how bridges are built, and excellent diagrams of bridge types.

The how-to of toothpick bridge building.
Web sites

At the publication of this resource packet, the following Web sites were all active.

How Bridges Work
www.howstuffworks.com/bridge.htm
Covers four basic bridge types, with excellent pictures of bridges. Provides links to many famous bridges.

Building Big: Bridges
www.pbs.org/wgbh/buildingbig/bridge
Excellent source of information about bridges, including basic bridge information, online forces lab, bridge challenge, and famous bridges databank.

Nova: Super Bridge
www.pbs.org/wgbh/nova/bridge
Test one’s engineering skills by matching the right bridge to the right location; includes teacher’s guide, additional resources, and complete program transcript.

Discovery School: Famous Bridges
Suggested lesson plans for classroom activities. Includes vocabulary and “worksheet maker.”

Bridge Building: Art and Science
www.brantacan.co.uk/bridges.htm
For the bridge enthusiast. Provides in-depth explanations of bridge types and many photos. Good for higher level research.

Bridge Pros: Learning Center
www.bridgepros.com/learning_center
Lists longest truss, arch, and suspension bridges. Also provides links to many exciting bridges around the world and to current bridge construction projects.

Structurae
www.structurae.de
International database of structures; provides technical data about hundreds of bridges around the world.

About Bridges
www.nireland.com/bridgeman/
Good general information about bridges; notable for its extensive bridge vocabulary.

The Civil Engineering Portal
www.icivilengineer.com
Comprehensive information about international bridges;bridges may searched by material, type, etc.

BridgeSite: Fun and Learning about Bridges
www.bridgesite.com/funand.htm
Links to many other websites related to bridges, for children as well as professionals.

Golden Gate Bridge
www.goldengate.org
A history of the Golden Gate Bridge and a virtual stroll across it.

London Bridge
www.towerbridge.org/uk
Discover London’s Tower Bridge—one of the world’s most famous bridges.

Brooklyn Bridge
www.brooklynjuniorleague.org/BRIDGE.htm
Read a short history of the Brooklyn Bridge with links to interesting photographs.

West Point Bridge Designer
bridgecontest.usma.edu
A software tool developed to help students learn about engineering, computer-aided design, and bridge structure; for middle to high school students.

Association for Bridge and Construction Design
www.abcdpittsburgh.org
Links to many fascinating sites about contemporary and historical bridges around the world.
Organizations

**Building Big**, 5 tapes, (each 60 minutes), 2000, WGBH Boston Video. PBS series hosted by David Macaulay. Explores the whens, whys, and hows of the world’s awe-inspiring structures, including bridges, skyscrapers, tunnels, domes, and dams.

**Big Cable Bridges (How Did They Do That?)**, 30 minutes, 1994, Figg Engineering Group, Tallahassee, Florida. Join youngsters Lee and Nikki on an educational adventure about how cable-stayed bridges are constructed.

**Bridges in History to the 20th Century**, 22 minutes, 1996, American Society of Civil Engineers (FilmComm Division), Glendale Heights, Illinois. Learn the principles of bridge design and construction and how bridges have engaged the ingenuity and imagination of human civilization since the beginning of time.


**American Society of Civil Engineers (ASCE)**
ASCE World Headquarters
1801 Alexander Bell Drive
Reston, Virginia 20191-4400
www.asce.org
Promotes the profession of civil engineering; includes Kids and Careers page, offering career guidance for young people interested in the field and links to engineering and bridge-related sites.

**Historic American Building Survey (HABS)**
U.S. Department of the Interior
1849 C Street, NW (2270)
Washington, D.C. 20240
www.cr.nps.gov/habsaer/habs/index.htm
Documents historic architecture—primarily houses and public buildings—of national or regional significance.

**The Historic Bridge Foundation**
P.O. Box 66245
Austin, Texas 78766
www.historicbridgefoundation.com/
Advocates for the preservation of cultural and engineering landmarks of the United States.

**Historic American Engineering Record (HAER)**
U.S. Department of the Interior
1849 C Street, NW
Room NC 300
Washington, D.C. 20240
www.cr.nps.gov/habsaer/haer/index.htm
Documents nationally and regionally significant engineering and industrial sites in the United States.
Other School Programs at the National Building Museum

Be a Builder
City by Design
Early American Architecture
Fuller’s Fantastic Geodesic Dome
Mathatecture
Patterns that Thump, Bump, and Jump

For more information, or to obtain a school programs brochure, contact school programs at school@nbm.org or 202.272.2448.

Other Youth Programs at the National Building Museum

Scout  Outreach  Family Programs  Festivals  Birthday Parties

For more information, contact scout and family programs at scout@nbm.org; family@nbm.org, or 202.272.2448.

Visit the Museum’s Web site at www.NBM.org
The National Building Museum, a nonprofit educational institution, was created by Congress in 1980 to celebrate American achievements in architecture, urban planning, construction, engineering, and design. It presents exhibitions and public programs, collects artifacts of the building process, and publishes books and a quarterly journal.

**MUSEUM HOURS**
Monday–Saturday
10:00 am–5:00 pm
Sunday, 11:00 am–5:00 pm

**ADMISSION**
Admission is free.

**LOCATION**
401 F Street NW, between 4th and 5th Streets at the Judiciary Square Metro Station (Red Line). Wheelchair access at 4th and G Street entrances.

**MUSEUM SHOP**
The Museum Shop, located on the ground floor, is Washington’s finest source of design and building-related books and gifts, including jewelry, home furnishings, toys, and games. Museum members and teachers receive a discount on all purchases.

**MEMBERSHIP**
Museum membership offers such privileges as invitations to exhibition openings and special events; discounts on Museum Shop purchases, programs, workshops, and tours; and subscriptions to Blueprints and the Museum Calendar of Events.