BRIDGE UP!
ENGINEERING

LESSON 9 – GRADES 9-12

LESSON 9 – GRADES 9-12: Geometry in Engineering

Big Idea
Bridge design focuses on several basic geometric structures.

Essential Questions
What fundamental shapes drive bridge design?

Why do engineers use these shapes?

Background Information
Bridges have been around since the first tree fell across a stream. Design has evolved over time as new designs and materials have been developed.

Minnesota has more than 20,000 bridges. According to the Minnesota Department of Transportation, for a structured to be considered a bridge by the State of Minnesota, it must have a span of 10 feet or more.

The Wisconsin Department of Transportation says it generally defines a bridge as any structure spanning 20 feet or more that carries motor vehicle traffic.

Wisconsin has about 13,600 bridges spanning state and local roadways. Of these, about 4,900 are along the state highway system (numbered state and federal highways) and are the responsibility of the Wisconsin Department of Transportation.

The Minnesota Department of Transportation says that, as structures, bridges can be classified in several different ways: by use, span type, or construction material. The types of use can include pedestrian, bicycle, vehicular (automobiles and trucks), railroad, or a combination. Over time, the load capacity of a bridge has increased with the increase of use and types of vehicles that cross bridges.

Standards & Benchmarks

Minnesota Science Standards
9.1.2.1 Addressing Human Need
Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Benchmark 9.1.2.1.1 Refinement of Designs
Understand that engineering designs and products are often continually checked and critiqued for alternatives, risks, costs and benefits, so that subsequent designs are refined and improved.

Benchmark 9.1.2.1.3 Considerations in Devices
Explain and give examples of how, in the design of a device, engineers consider how it is to be manufactured, operated, maintained, replaced and disposed of.

9.1.2.2 Practice of Engineering
Engineering design is an analytical and creative process of devising a solution to meet a need or solve a specific problem.

Benchmark 9.1.2.2.1 Constraints on Designs
Identify a problem and the associated constraints on possible design solutions.

Standard 9.1.3.1 Systems
Natural and designed systems are made up of components that act within a system and interact with other systems.

Benchmark 9.1.3.1.1 System Relationships
Describe a system, including specifications of boundaries and subsystems, relationships to other systems, and identification of inputs and expected outputs.

9.1.3.2 Culture
Men and women throughout the history of all cultures, including Minnesota American Indian tribes and communities, have been involved in scientific inquiry and engineering design.

Benchmark 9.1.3.2.2 Careers
Analyze possible careers in science and engineering in terms of education requirements, working practices and rewards.

9.1.3.3 Society
Science and engineering operate in the context of society and both influence and are influenced by this context.

Benchmark 9.1.3.3.1 Role of Values and Constraints
Describe how values and constraints affect science and engineering.

9.3.4.1 Benefits vs Risks
People consider potential benefits, costs and risks to make decisions on how they interact with natural systems.

Benchmark 9.3.4.1.1 Natural Hazards
Analyze the benefits, costs, risks and tradeoffs associated with natural hazards, including the selection of land use and engineering mitigation.

9P.2.3.1 Waves & Sound
Sound waves are generated from mechanical oscillations of objects and travel through a medium.

Benchmark 9P.2.3.1.1 Oscillatory Systems
Analyze the frequency, period and amplitude of an oscillatory system.

Connections with Multimedia Program
Bridge Up! Geometry in Engineering

Activity Description
The teacher provides initial introduction to the topic by brainstorming what students know about local bridges. Review those bridges and basic bridge designs. Use Multimedia program and pictures of local bridges to highlight shapes in engineering. Students then are assigned bridge designs to research in small groups. Jigsaw follows to build comparisons and differences between bridge designs and uses.

Vocabulary

Arch – A curved symmetrical structure spanning an opening and typically supporting the weight of a bridge, roof or wall.

Support – A thing that bears the weight of something or keeps it upright.

Keystone – A central stone at the summit of an arch, locking the whole together.

Structural failure – Point at which a structure no longer supports the load applied to it.

Arch bridge – A bridge made from one or more arches and abutments.

Truss bridge – This bridge type has a superstructure composed of elements connected to form triangles.

Suspension bridge – A bridge made of a platform that is held up by wires or ropes strung from the tops of piers.

Hybrid – A structural component comprised of more than one material.

Materials

- Bridge Up! Media links
- Access to pictures of local bridge structures that illustrate specific geometric shapes (**http://www.dot.state.mn.us/historicbridges/**)
- Video links to bridge failures (see under Other Resources)

Procedure

Teacher Led Brainstorming (15-30 Minutes)

- How do bridges affect your life?
- What are the cultural impacts of a new bridge?
- Why does bridge design matter?

Building Background Knowledge (2 periods)

- Students are provided data sources (articles, drawings/pictures of old and new, Google search, opinion pieces, technical stories, environmental impact studies).
- Jigsaw to share data findings.
- Groups present poster and share question of interest/importance.

Bridge Design (1 period)
Basic bridge designs

- Give each person in a group an example of different bridge design (arch, truss, suspension, hybrid designs).
- Jigsaw how designs are alike, unlike each other.
- Discuss how designs overlap and are used in several examples.
- Students determine what they think will be important – What do they need to know to build a bridge?

Bridge designs that fail

- Share clips showing failure (Tacoma Narrows, 35W).
- General tension/compression discussion here.

Extensions

Try testing multiple sizes/configurations of a truss bridge, but exclude other bridge types. Give everyone exactly the same amount of material and have them design different shapes of bridges to see the effect shape has beyond material.

Other Resources

Design Software
Johns Hopkins Truss Builder
http://pages.jh.edu/~virtlab/bridge/truss.htm

West Point Bridge Designer
https://bridgecontest.org/resources/download/

Bridge Fails
Tacoma Narrows
http://youtu.be/j-zczJXSxnw

Silver Bridge
http://youtu.be/dGQfUWvP0II

Bridge Construction Methods
Incremental launch
http://youtu.be/S3Kf9e6JgF4

Alconetar Bridge construction
http://youtu.be/o4eM0qoUhaE

Megastructure – Denmark to Sweden Bridge
http://youtu.be/X8_VQbOh7go

Concrete arch bridge in St. Paul, Minn. Photo credit: Minnesota Department of Transportation

Truss bridge in Waterford Township (Dakota County, MN) Photo credit: Minnesota Department of Transportation

Suspension bridge in Minneapolis, Minn. Photo credit: Minnesota Department of Transportation