Bridges

Lesson Type: Engineering/Building
Target Grade: Elementary School
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Semester: Fall 2012

Brief Overview/Challenge

The goal of this project is to design and build a bridge based on the principles of tension, stress, load bearing distribution, and geometry. The bridges will be judged by the amount of weight they can hold before deformation or buckling is observed.

Teaching Goals

- Understand how different types of bridges operate (beam, cable, suspension)
- Understand how bridge construction (load bearing distribution, symmetry, geometry) affects strength

Agenda

- **Introduction** (10-15 min)
  - Introduce bridges as the topic of the day
  - “What makes a bridge good?” (see below)
  - Ask students for famous bridges they’ve seen, how they think they work
  - Present the different types of real-world bridges and how they operate (see below)
  - Introduce the challenge (write rules on board)
    - With a strip of cardboard as the base, use the given materials to build a bridge that can support the most weight
    - Free-standing, must be able to be moved to front of class for testing
    - Must span a chair’s width for testing
    - Weights will be placed at the center of the bridge
    - Work in groups of 3-4
    - Present the materials available for building
      - Cardboard base (1/group)
      - Popsicle sticks (50/group)

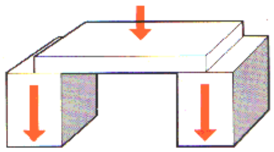
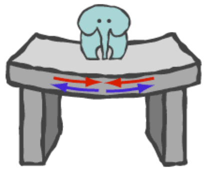
        - Paper (2/group)
        - Paper clips (20/group)
        - String (1/group)
        - Tape (1/group)
        - Scissors (1/group)
- **Build** (40 min)
    - Split the class into groups of 3-4
    - Distribute packages of materials
    - Build!
- **Test** (10-15 min)
    - Group by group, have students come up to the front to test their designs
    - One end of the bridge should lay on one chair, the other end on another chair
    - Weights will be added at the center on top of the cardboard strip by the mentors. An empty water bottle can be filled with increasing amounts of water as the weight to see how many “stages” the bridge can withstand (make sure to close the bottle each time to avoid spills!)
    - Record the amount of weight added (on board) when first signs of deformation observed (let deformation be any unintentional change in the structure)
    - Test the students’ designs
- **Recap** (10-15 min)
    - Ask the winning group how they designed their bridge
    - Review what went well (triangular/strut bases, even load distribution, symmetry) and what did not go well

Materials

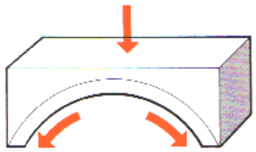
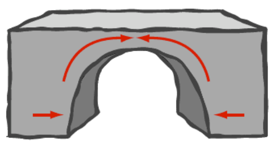
Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Cardboard Base	1 /group of 3-4		
Popsicle sticks or toothpicks	50/group of 3-4	$5/box	
String/twine/fishing line (depending on availability)	1 roll/group of 3-4	$2/roll	
Paper	2 pieces/group of 3-4		
Paper Clips	20/group of 3-4	$2/box	
Empty water bottle, Water	Can be supplied by mentors		
Tape	1 roll/group of 3-4	$2/roll	
Scissors	1 /group of 3-4		

Types of Bridges and How They Work

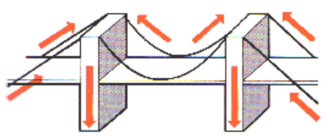
- Beam Bridge
  - Plank/bridge is supported by two bases. Under load, the top portion of the bridge compresses while the bottom portion stretches

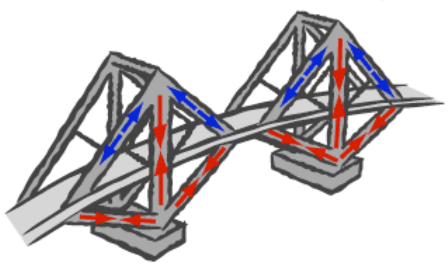

- Arch Bridge
  - Spreads the load outwards, from the top of the arch to the bases


- Suspension Bridge
  - Cables under tension concentrate the load on the vertical tower; forces must be balanced on both sides (i.e. Golden Gate Bridge)



- Truss Bridge
  - Constructed from an assembly of triangles (i.e. Bay Bridge)




What Makes a Bridge Good? / Tips for Building

- Even weight distribution
  - Want weight to be borne by the entire structure, don't want stress concentrated at a single point. Stress = Force/Area → By increasing the load bearing area, the stress at each point is reduced.
  - Want weight to be transmitted from the center of the bridge outward towards the base (contact points with the table/chair)
- Trusses (triangular units)
  - Direct weight (stress) toward the corners of the triangle.

    - Triangles are strong bases because its geometry is fixed/locked in place: triangles cannot be squished/deformed without changing the length of the sides.
    - Demonstration of how squares can elongate/stretch to become diamonds, but triangles do not have this flexibility
- Avoid buckling
    - Buckling can be reduced by building bridges that are longer than the length they need to span
- Avoid long, straight beams
    - Poor ability to distribution the stress and strain; more likely to snap at a weak point/buckle
- Lateral bracing
    - Support in multiple directions prevents the bridge from twisting, and better locks the desired structure in place to avoid deformation
- Units
    - Build the bridge from smaller repeating units, adds stability and allows for symmetry
- Symmetry
    - Allows for even load distribution
    - Bridges must maintain good strength at every point (if there is a single weak spot, the bridge will buckle)
- Reinforced joints
    - i.e. In the formation of a triangle, this can be achieved by taping the two faces of the popsicle sticks together (rolling the tape so it is two sided) and then wrapping tape around the joint.

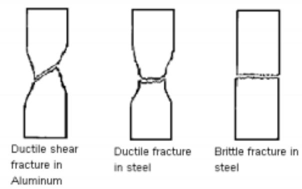
Background for Mentors

Bridge building involves many concepts surrounding a material’s strength, and stress, strain, and deformation properties.

- Plastic (Permanent) Deformation
    - A materials strength is determined by its intermolecular bonds, microstructure, and interactions between different phases of a composite material.
    - Plastic Deformation is observed when the load applied exceeds the critical stress value.

Stress = □□□□□□□□□

    - This is why we want to increase the load distribution area; it decreases the stress placed on the material
    - The type of fracture is dependent on the ductility of the material.



    - The initial deformation observed is elastic and its effects can be reversed upon the removal of the load. However, at higher stress levels, the deformation becomes plastic and irreversible.
- Buckling
    - Buckling is dependent on the aspect ratio (ratio of length to width)
    - The more slender a sample is, the more likely it is to buckle.
    - Buckling begans at...
      $P_{critical} = \frac{\pi^2 EI}{(KL)^2}$
      where E is Young's Modulus, I is the area moment of inertia, L is the length of the sample, and K is a constant based on how the sample is being supported.
    - Buckling can be reduced by choosing stiffer materials, decreasing the length of a sample, or by increasing the area moment of inertia. This is why we build a bridge longer than the area it needs to span (to increase the area moment of inertia),

References

- http://www.pbs.org/wgbh/buildingbig/bridge/basics.html
- library.thinkquest.org/J002223/types/types.html
- http://www.apeg.bc.ca/services/branches/documents/pr/Bridge_Engineering_Principles.pdf
- http://www.eod.gvsu.edu/~oostdykj/techniques.html
- http://www.garrettsbridges.com/building/25-bridge-building-tips/

Summary Materials List

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