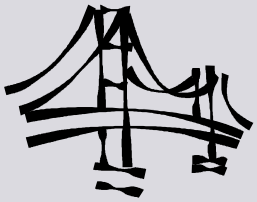
BRIDGE DESIGN PROJECT

An Engineering Experience with structural principles and budgeting



Engineers:

ENGINEERING PROCESS

Problem Statement: Your engineering team has been asked to build a new bridge for a small island off the coast of Denmark. A lot of heavy vehicles need to reach this island to deliver supplies, so the bridge must hold as much weight as possible. The main concern for this small island town is that it is on a budget. They need the strongest bridge for the lowest amount of money as possible. Build a small scale bridge to prove to the town that they should choose your design. The team with the strongest bridge compared to the budget spent on construction (the ratio of weight the bridge holds to kroner spent) will be chosen as the head engineers.

Design Rules:
Divide yourselves into groups of four. After researching bridge design, you will design and build a bridge to meet the following criteria:
· It must span a 75 cm gap
· It must be 15 cm wide
· It must be able to support as much weight as possible at the center.
· A toy car must not fall through the roadway surface of the bridge

Note: You must pick what type of bridge you are designing and sketch that bridge. Working as a group, be sure to pay particular attention to sketching your bridge, as this is an important aspect of the engineering process.

STRESSES AND STRAINS

The bridge you design will be subject to the force of the weight on it. This force is known as "stress" on the bridge, and causes the material of the bridge to experience a "strain." A good bridge distributes the weight to more stable sections, such as firmly planted towers or supports that are in the ground. This section contains explanations of the different forces that occur when a load is placed on a bridge, and some tips to avoid problems when designing and building the bridge. The next section contains five different bridge types, and the way the designs allow for the spreading of forces to make a stable method for holding weight.

Compression and Tension

Depending on the way your bridge is designed, certain portions will be affected by forces known as COMPRESSION and TENSION. Compression is a force that pushes an object in on itself, and tension is a force that stretches an object out. The right-hand diagrams for each bridge type show which parts of the bridge are subject to which forces. Tension forces are shown by the green arrows and compression forces are shown by red arrows. Some materials are stronger in one form of stress than they are in the other.

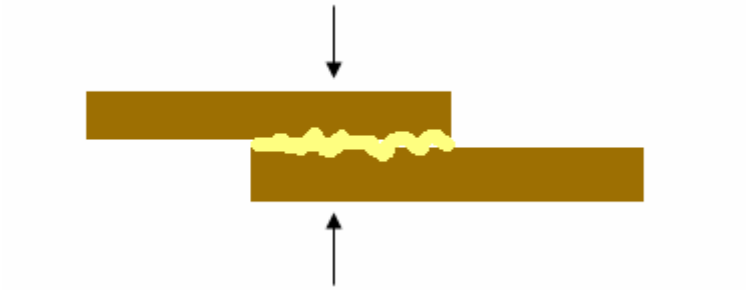
What materials in your list of parts would be good at withstanding compression? Is a piece of string or a piece of spaghetti better at withstanding tension? Consider questions like these when you choose which materials to make each part of your bridge.

Shear Forces

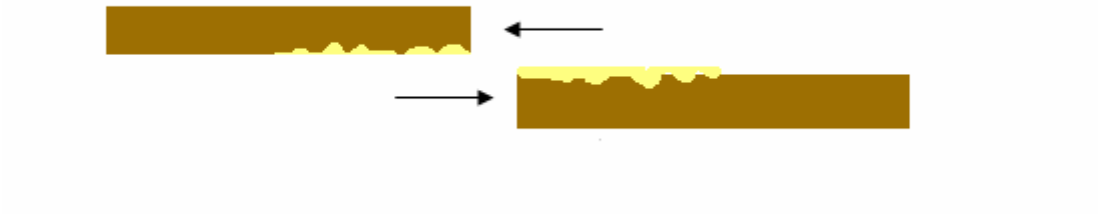
The span of your bridge is longer than any one building material you can purchase. You must attach pieces to one another in some manner. This process introduces a possible weakness into your bridge where the materials are connected.

Suppose you attach two pieces of wood with glue to make a longer piece of wood.

Now look at some ways forces can be applied to the joined pieces. If the joined part experiences a compressive force, nothing will happen.



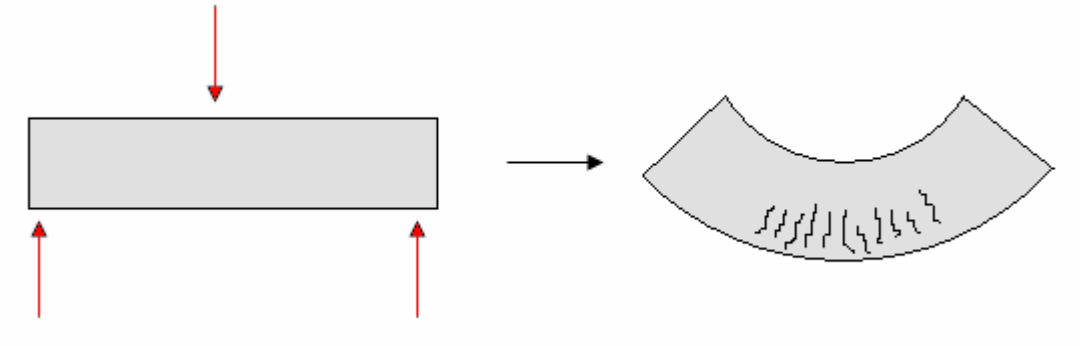
However, if a horizontal force is applied, the joint may fall apart. This force is known as “shear.”



You must consider which direction the weight applied to the bridge will affect the material, and design a bridge that minimizes weak points where the weight can cause the bridge to break.

Bending

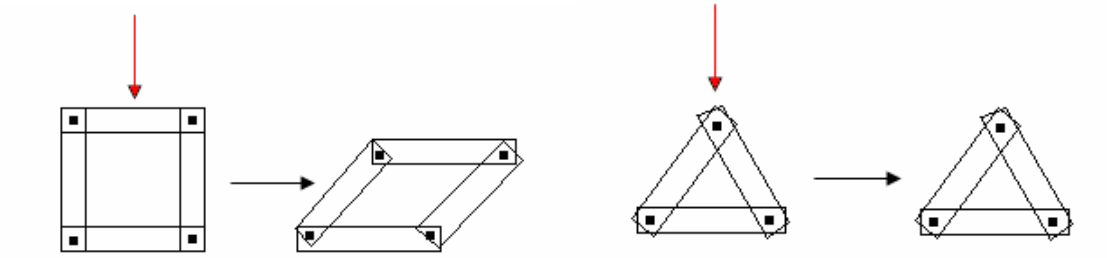
When a long unsupported beam is subjected to weight at one point, it bends. This occurs because the upper half of the beam is being compressed, while the lower half of the beam is under tension. This force is a problem because many solid materials fail under tension. This stress can be lessened by decreasing the distance from the load to the nearest support structure, thus distributing the force of the weight to other segments of the bridge.



Construction tips

Two very strong shapes in architecture are the circle and the triangle. If possible, try and incorporate these shapes into your design. For example, a support that reaches from the bridge to the ground might be made of a rolled up piece of paper. You might also consider the truss bridge, which takes its strength from the triangle.

Take a look at what happens when forces are applied to a square rather than a triangle:



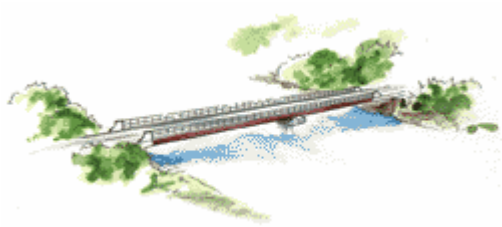
If the force is applied to the top of the square, it can deform. The triangle does not have this property, as the sides distribute the weight evenly to the base.

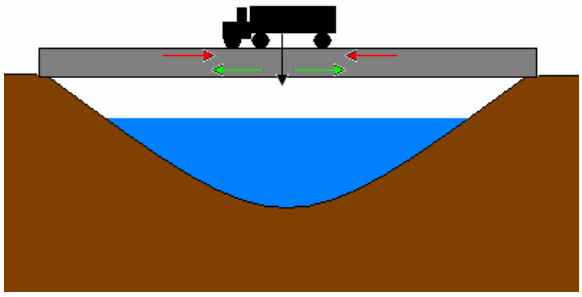
You should consider the properties each material has when deciding which type of bridge to build. Does the bridge require materials that are strong in compression? Shear? Tension? Which are the best materials to use for each purpose?

BRIDGE TYPES

Girder Bridge

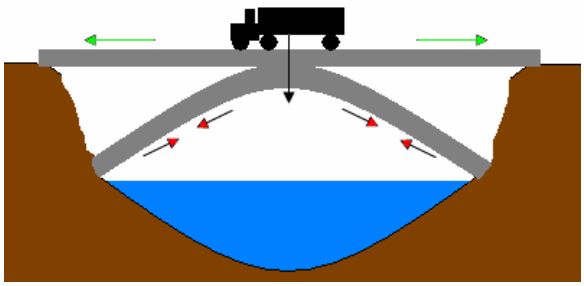
A girder bridge is a very simple type of bridge and can be built with any long, straight material. The problem with this bridge type is that there is no method to distribute the load and the bridge integrity is entirely dependent on the bending strength of the material. In the figure at right, the top portion of the bridge is compressed (shown by red arrows), and the bottom portion is tensioned (shown by green arrows). The bridge wants to bend down toward the water in the middle. Although easy and inexpensive to construct, this type of bridge cannot support a large amount of weight or span very far.





Arch

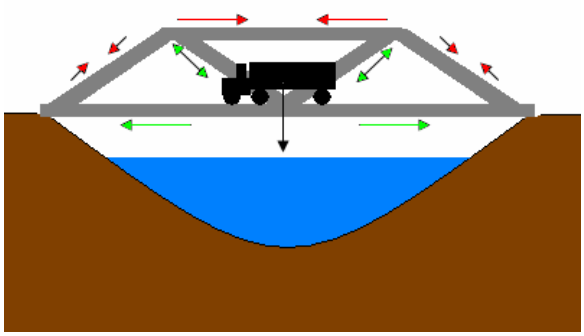
Arch bridges rely on the natural strength of the arch shape to distribute the load of a bridge. Arches are generally located across spans with deep bottoms, because the load can be transferred to the sides of the gap. Arch bridges are made from materials that are strong in compression because the entire arch experiences compression even when no load is on the bridge.



BRIDGE TYPES (CONT.)

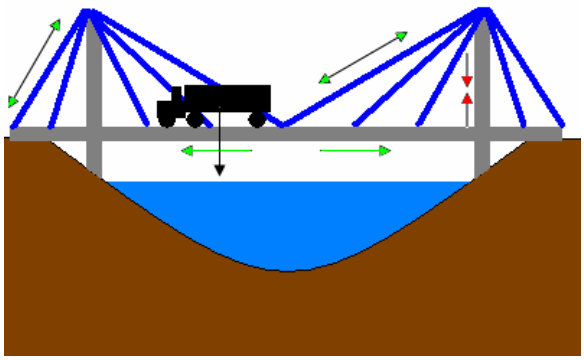
Truss

The truss bridge draws upon the strength of triangles. It uses many small sections which individually experience only small loads. At any point in the bridge, about half of the material is experiencing a compressive force, and half is experiencing tension. While this is also true for the girder bridge, here each force is experienced by a separate section, rather than the same piece of material. As a result, the intense bending force seen in the girder bridge is not present in the truss bridge. The truss bridge is also rather efficient to build.



Cable-Stayed

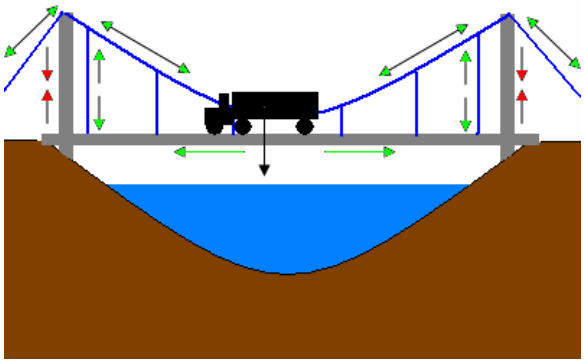
The cable-stayed bridge introduces cables as a support structure. Cables are different from other materials used in bridge construction because they can only experience tension (not compression or shear). The main difference between this type of bridge and the previous three is that the majority of the load is placed on the vertical supports. The cables, and especially the vertical supports, must be strong enough to handle a significant load.



BRIDGE TYPES (CONT.)

Suspension

The suspension bridge is very similar to the cable-stayed bridge. The main difference is the addition of a main cable which causes the flat surface of the bridge to be pulled upward, rather than upward and outward. The other cables are attached to the main cable rather than the support columns. This bridge design is most effective for very long spans where a large amount of weight must be supported.



Our bridge type will be _____.

Left-hand bridge pictures courtesy of
http://www.matsuo-bridge.co.jp/english/bridges/index.shtm
For information on the stresses on different bridge types, visit
http://www.pbs.org/wgbh/buildingbig/bridge/basics.html

AVAILABLE RESOURCES

Material:	Price per unit (in Kr):
1 hot glue stick & use of hot glue gun	1000
1 bottle of glue	750
1 A4 sheet of heavy paper	200
1 A4 sheet of printer paper	125
1 cm of cellophane tape	2
1 cm of masking tape	4
1 cm of duct tape	6
1 cm^2 of foam core board	10
1 popsicle stick	20
1 straw	10
1 cm of string	1
1 paper clip	5
Pasta (spaghetti)	1
Pasta (fettucine)	3

IDEAS AND SKETCHES

On this page make some simple sketches and write down ideas for your bridge design.
This is part of preliminary planning.

GROUP MATERIALS LIST

Group Number _____

The Group Materials List should contain the quantity and cost of all parts purchased for the construction of the bridge, even if they were not used in the final bridge.

QTY	Item	Cost

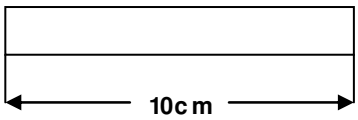
Total amount of money spent: _____

Amount of weight your bridge supported: _____

Ratio of weight to money spent (g/kr): _____

TECHNICAL DRAWING TIPS

- Writing in the information boxes should be in all capital letters
- "View:" Enter the perspective of the drawing here. Common perspectives are front," "back," and "right side." These labels allow the viewer to know what part of the item they are viewing.
- "Scale:" This box tells the viewer of the drawing how big the actual structure is. A scale of 1:2 means that the drawing is half the size of the actual object (for every 1 unit in the drawing, it would actually be 2 units).
- “Sheet:” This box shows the current page number.
- Dimensions: All parts of the drawing should have dimensions. This allows for an accurate interpretation of the drawing.
  Example:



NOTES:

DESIGNED BY:

DATE:

VIEW:

SHEET:

SCALE:

TITLE: