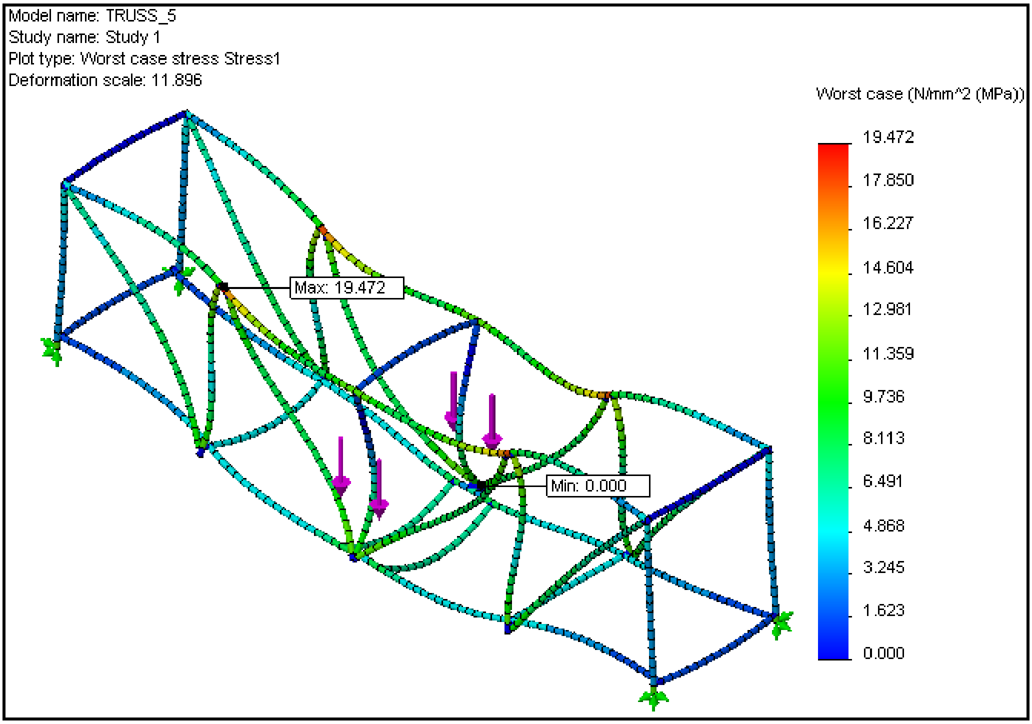
Engineering Design and Technology Series

Bridge Design Project with SolidWorks® Software



Dassault Systèmes SolidWorks Corporation
300 Baker Avenue
Concord, Massachusetts 01742 USA
Phone: +1-800-693-9000

Outside the U.S.: +1-978-371-5011
Fax: +1-978-371-7303
Email: info@solidworks.com
Web: http://www.solidworks.com/education

Document Number: PME0518-ENG

Table of Contents

Lesson 2
Structure Design

When you complete this lesson, you will be able to:

- Define a structure;
- Describe several types of trusses;
- Understand what beams are;
- Understand what factors provide strength in a beam;
- Calculate a moment of inertia;
- Understand the importance of triangular bracing in a structure.

What is a Structure?

Structures are frames commonly used bridges for railroads, automobile and foot traffic. Examples of these structures can be seen across the country and the world.

Structure Designs

Structure designs are meant to be simple structures that are efficient, meaning that they are easy to build and accomplish their goals with the minimum amount of materials. There are many different structure designs, the differences are based on the load that the structure is required to support and the span that it must cross. The structure design may be repeated over several spans in the same bridge.

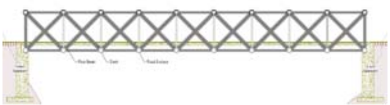
Trusses

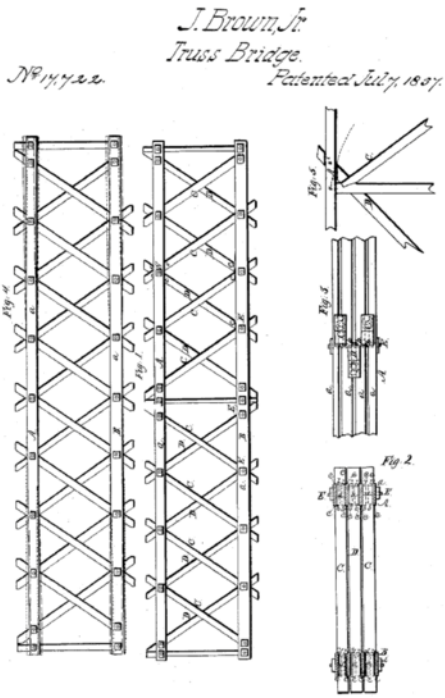
Trusses are specific types of structures commonly used a railroad bridges. They usually consist of a road or rail surface (deck), two walls and sometimes bracing on the top. You will be analyzing a truss design.

Search on **truss** for more information.

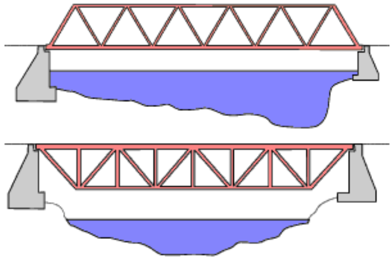
Brown Truss

The **Brown Truss** (patent shown here) was used in the design of covered bridges. This truss is a “box” truss (named for it’s boxy shape) that was so efficient that it could be constructed using only the (diagonal) cross bracing beams to support it.



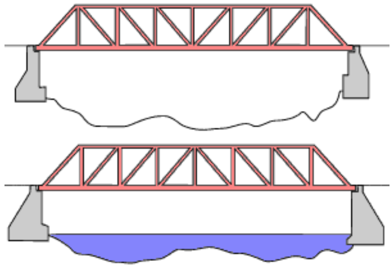


Warren Truss



The **Warren Truss** is another simple and economical type. It can be reversed and used with or without the vertical bracing depending the on the load it needs to carry.

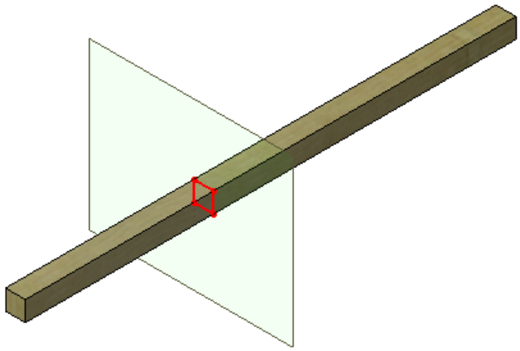
Pratt and Howe Trusses



The Pratt Truss and Howe Truss are very similar. Like the reversed Warren Truss shown above, the both have vertical and cross bracing. The difference is the direction of the cross bracing.

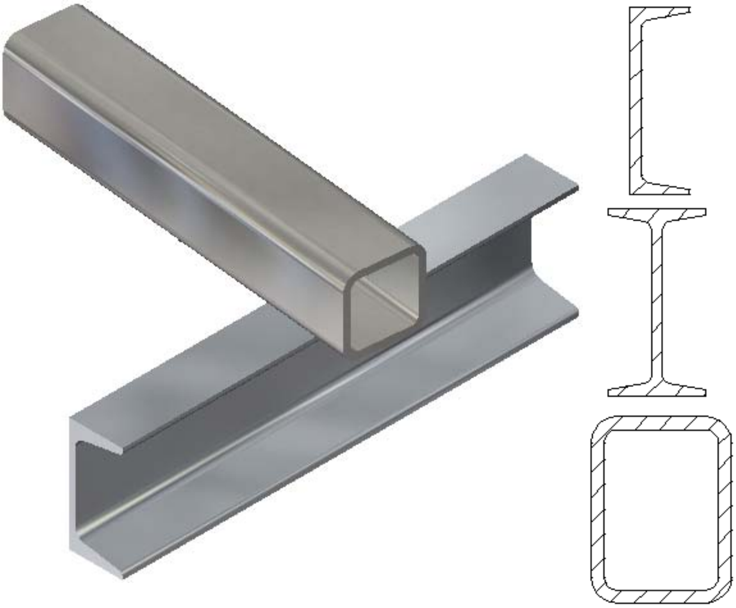
Beams

A **Beam** is an object that has the same cross section along it's whole length. In this case, the cross section is square. Structures like trusses are composed of beams.



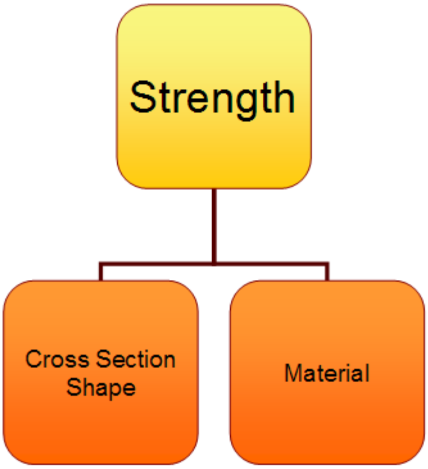
Steel Beams

Steel beams use standard shapes like channels, I-beams and tubes.



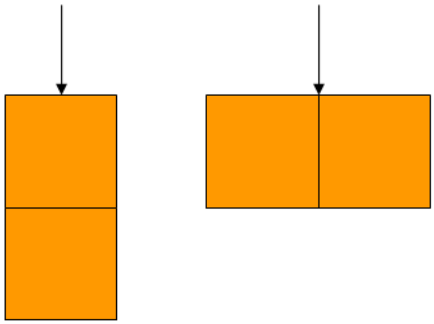
Strength

The strength of a beam depends on two factors, the **Cross Section Shape** and the **Material**.



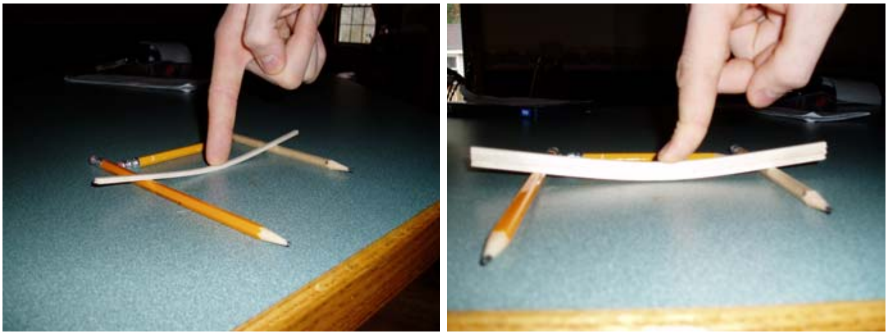
Cross Section Shape

Stacking two square beams creates a "deeper" section. The deeper the section (left) the stronger the beam. Wider sections (right) help a little but not that much.



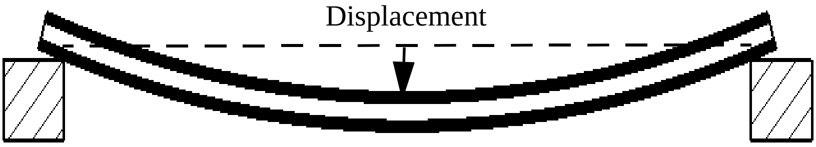
Try it!

Notice the difference in resistance between 1 balsa wood beam and 3 stacked beams when you try to press down. Use pencils for support and distance.

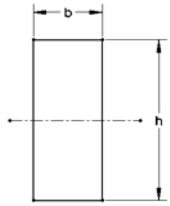


Displacement

One of the results that we will be searching for in the structural analysis is the largest **Displacement**. It is the distance that the beam moved from the start when it an *external force* was applied to it. The displacement will help us determine the capacity of the structure.



Area Moment of Inertia



The reason that deeper beams are stronger is because of the **Area Moment of Inertia**. This is a formula calculated using the width (b) and height (h) dimensions of the cross section. It is a measure of the strength of the beam section alone, not the material.

The Area Moment of Inertia is used in calculations as resistance of a beam to bending. The higher the value, the more resistance against bending.

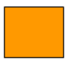
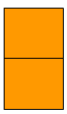
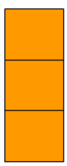
Calculating the Area Moment of Inertia

Using the formula below, you can calculate this value for several arrangements to square cross sections.

$$AreaMomentofInertia = \frac{b \times h^3}{12}$$

Try some calculations

Try some calculations using the formula above and the values shown in the table below. The values are based on the cross section of a balsa wood beam, **3.175mm** (1/8”) square.

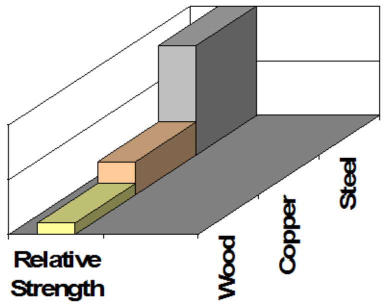
Number of square sections	Arrangement of square sections	b	h	Area Moment of Inertia
1		3.175mm	3.175mm	__________
2 Stacked		3.175mm	2 X 3.175mm	__________
2 Side by Side		2 X 3.175mm	3.175mm	__________
3 Stacked		3.175mm	3 X 3.175mm	__________

Questions

1. Which arrangement has the largest value? ______________
2. Is the 2 side by side as strong as the 2 stacked arrangement?________
3. Which arrangement is the weakest?______________?

Material

The material that the beam is made of is another critical factor in the strength of the beam. Take three materials as an example: Wood, Copper and Steel. The relative strength of each is shown in a chart at right. In general, steel is stronger than copper which is in turn stronger than wood. Keep in mind that there are a wide range of values within every material type and there are several types of *Material Properties* such as *Young's modulus* and *Poisson's ratio* that are used to define a material.



Note: Metals are manufactured products and due to the way they are created, they have equal strength in each direction. Materials like this are called *isotropic* materials.

Search on **material properties** for more information.

Wood as a Material

Wood is especially difficult material to predict because it has a grain within it. The grain causes the strength to be different in each direction and it is not really an isotropic material. The porosity of Balsa wood makes it very susceptible to moisture which can cause large variations in the property values.

The values that we are using are estimates. If you choose to build and test a structure your results will be relative but the values may vary.

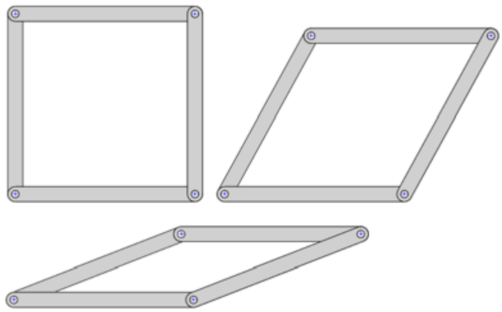
Truss Walls

The side walls of a truss are much more than just a fence to prevent objects from falling off. The walls usually contain bracing in the vertical and diagonal directions. When a truss contains both vertical and diagonal bracing, it is generally more stable.

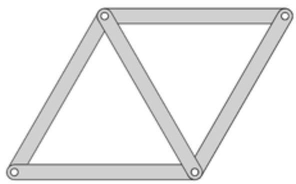
Triangles

Many structures, especially truss designs, contain triangles. Why are triangles so important? One reason is for stability. Stability is achieved by using cross braces to form triangles. Triangular shapes create stability in the truss.

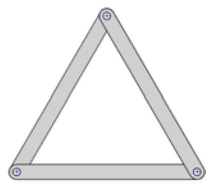
Consider a collection of members connected in a square shape by bolts or pins. Holding the bottom still, push on the top or side. It can form a square but can also be easily pushed into a flattened parallelogram.



Adding a 5th member diagonally makes a big difference. The shape is now locked in that position. The addition has broken the parallelogram into two triangles.



Using the same members and fasteners, create a triangle. This time fewer members are used but stability is achieved.



Try it!

You can simulate this process using something as flexible as a drinking straw. Use small pins to connect them together.