Bridge Design Project

Using SolidWorks and SolidWorks Simulation to design, test and build structures

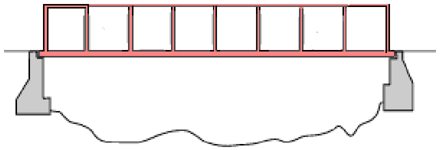
1 - Introduction

Prerequisites

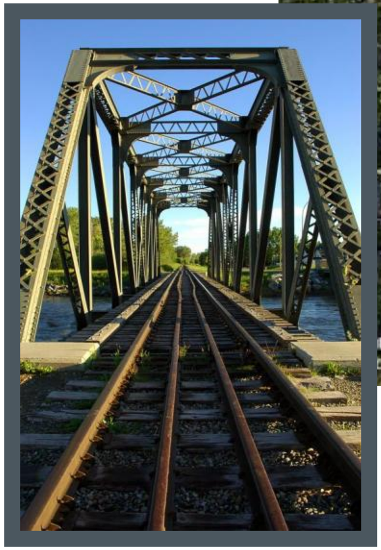
- Prerequisites for this project.
- SolidWorks files come in three basic types; parts, assemblies and drawing.

2 - Structure Design

What are Trusses?



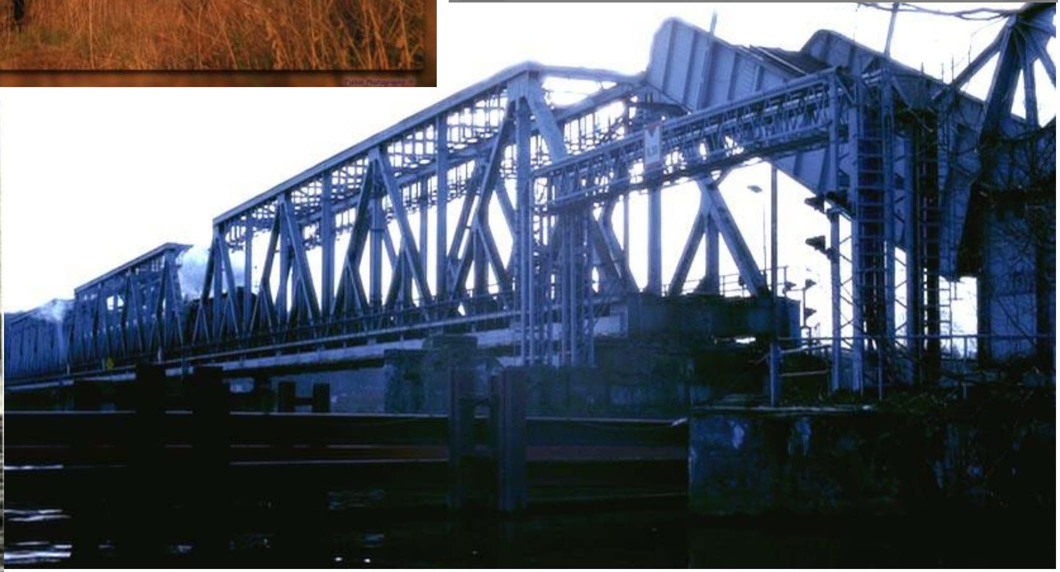
- Trusses are simple structures used as bridges for railroads, auto and foot traffic; capable of carrying large loads across spans. They consist of a road or rail surface, 2 walls and sometimes bracing between the walls.



SOLIDWORKS

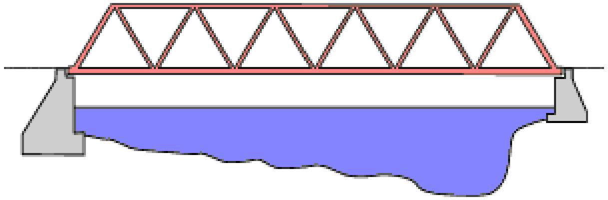
Longer Spans

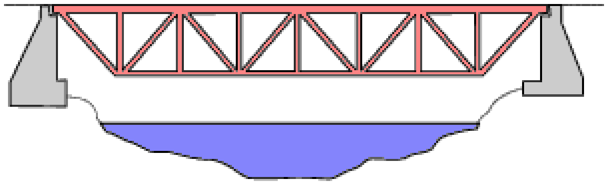
- For longer spans, the truss structure can be repeated several times.



Truss Types

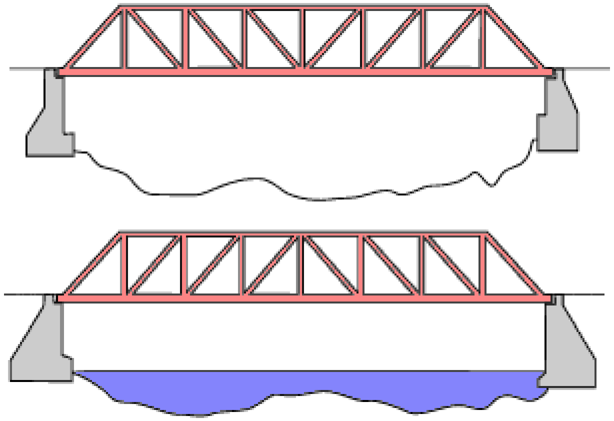
- The *Warren* truss, shown at right, is one of the simplest and most economical types. It can even be used upside down, in this case with added vertical members.





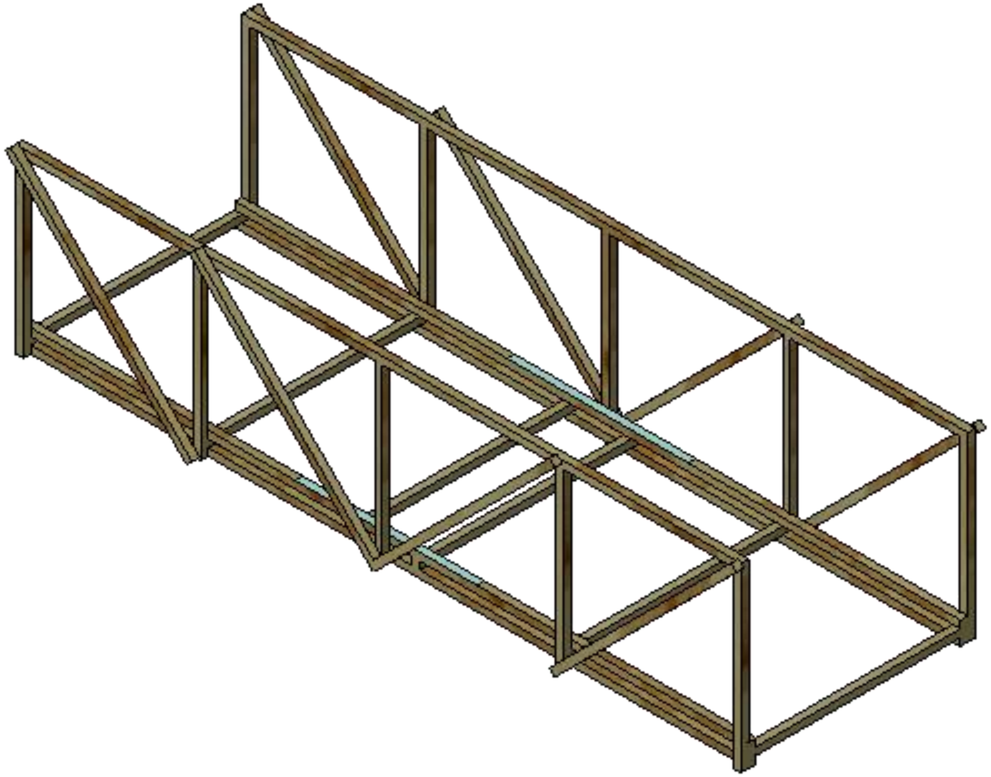
Truss Types (continued)

- The *Pratt* (above) and *Howe* (below) are other common types. We will look at a truss similar to the Pratt truss.



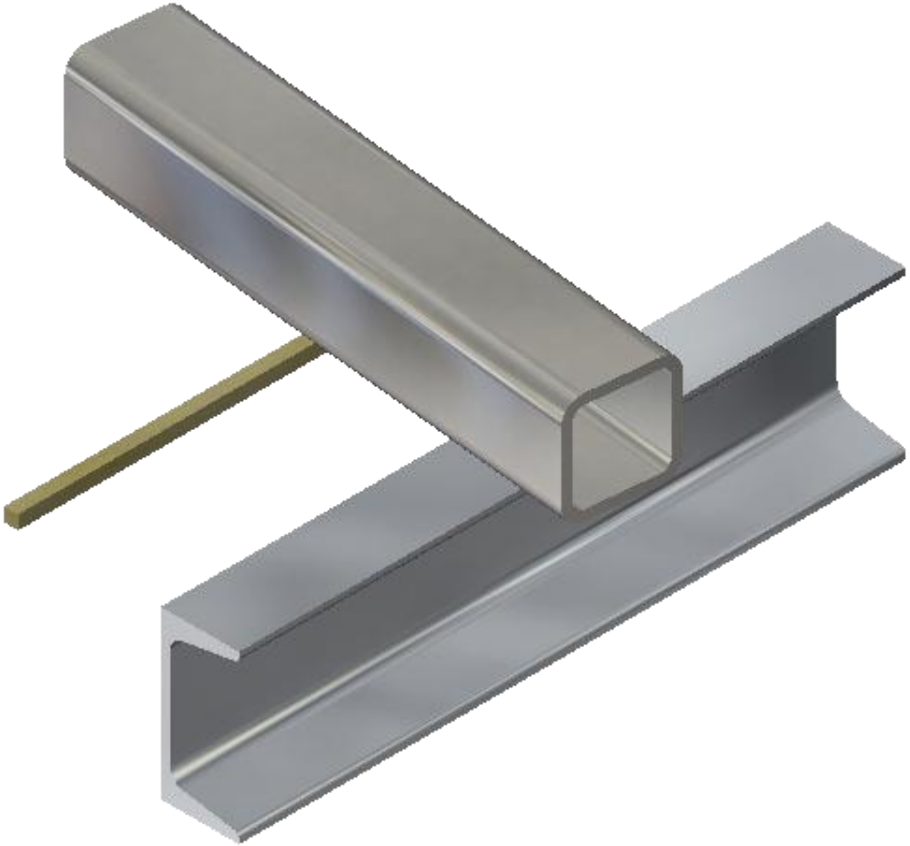
Truss Walls

- The side walls of the truss are much more than walls that keep the trains or cars from falling off the truss. They are used to absorb and direct the loads placed on the truss such as trains cars.



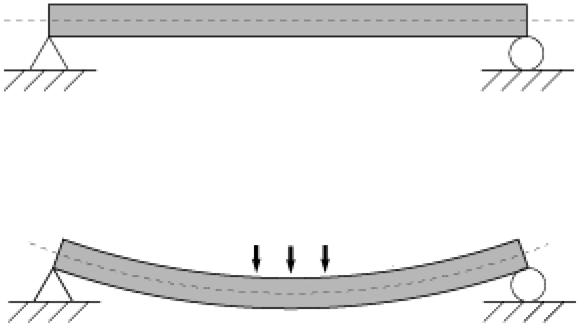
Beams

- Trusses are made up of beams that are held together by bolts, welds or rivets. A common example of a beam is a closet rod used to hang clothes.
- Beams have the same cross section.



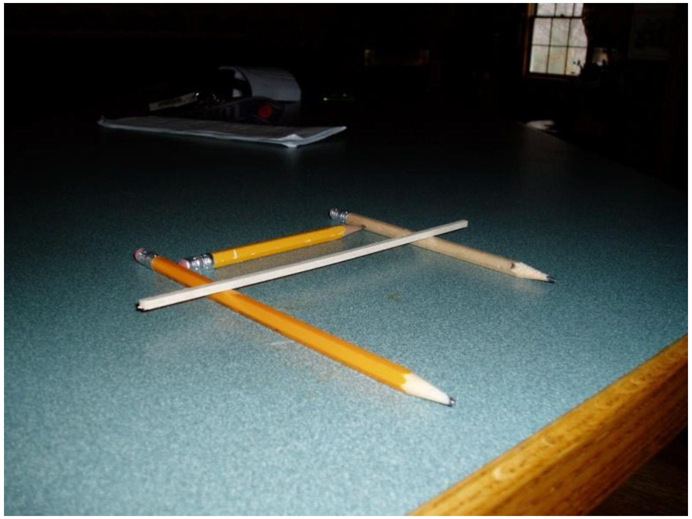
External Loads

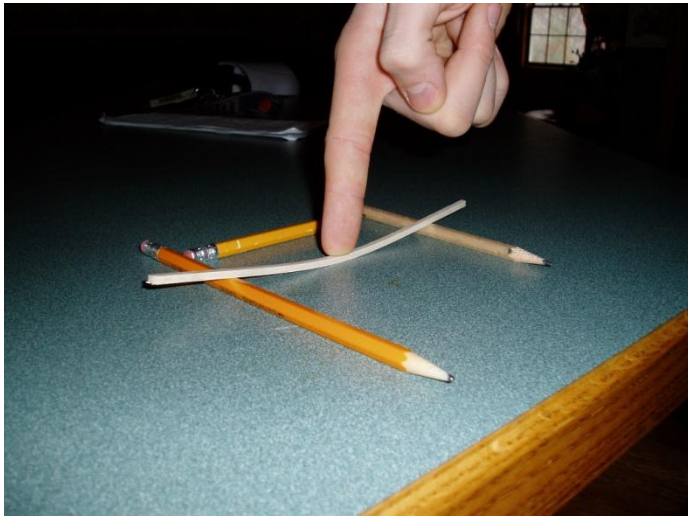
- External Loads are forces that are applied to the beam. A common load on a beam would be weight, such as a train car. Loads are usually applied over an area of the beam.



Bending and Deflection

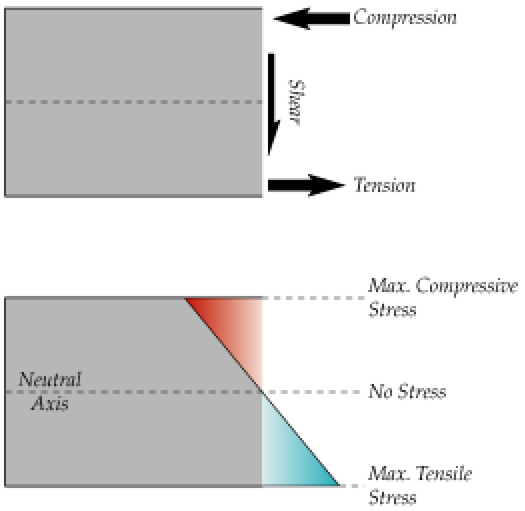
- Bending is caused by a load that is applied to a beam. The load causes the beam to bend and move in the direction of the load. The deflection is how far the beam moves from it's original position. The larger the load, the larger the deflection. The "worst case" deflection occurs when the load is at the center of the beam.





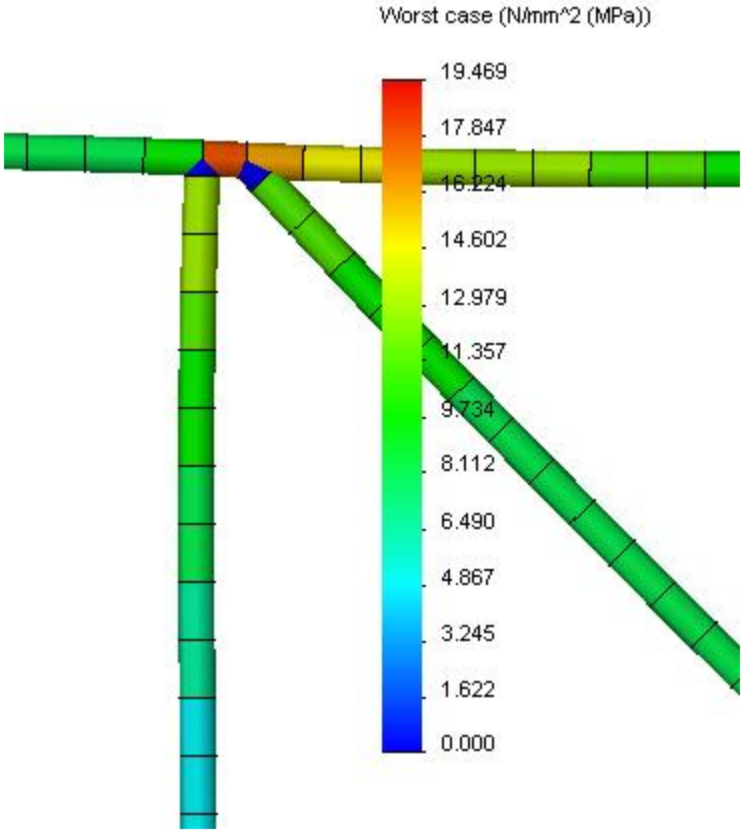
Tension and Compression

- While the beam is bending, things are happening within the beam. The top portion of the beam (the face the load is applied) *compresses* (pushing ends together) while the opposite face sees *tension* (pulling ends apart).



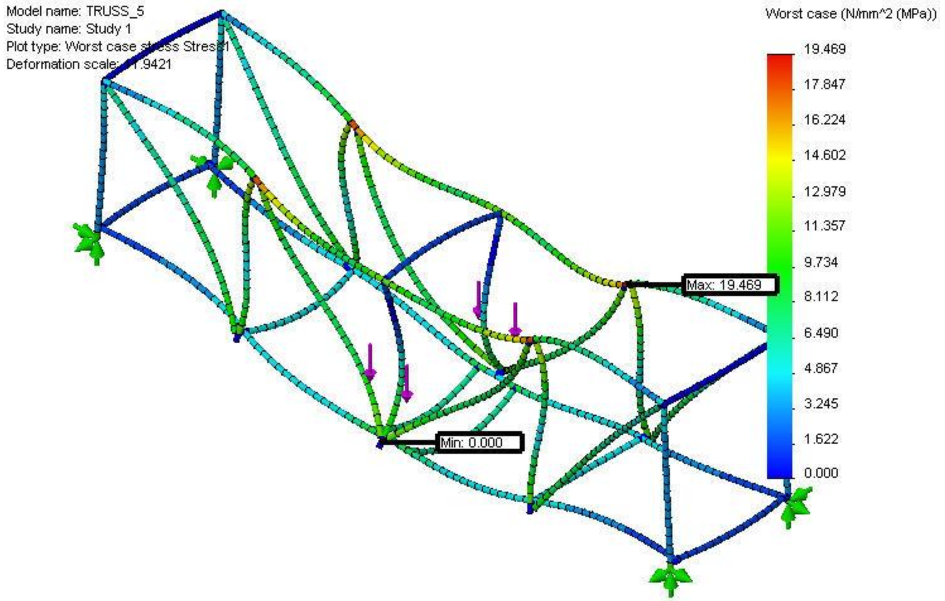
Stress

- Stress measures what happens inside the beam when forces are applied. It is defined as force divided by area, common units being Pascals (Pa), Megapascals (Mpa) or pounds per square inch (psi).
- Stress can cause the beam to break under high loads. Analysis provides maps that show areas of high and low stress.



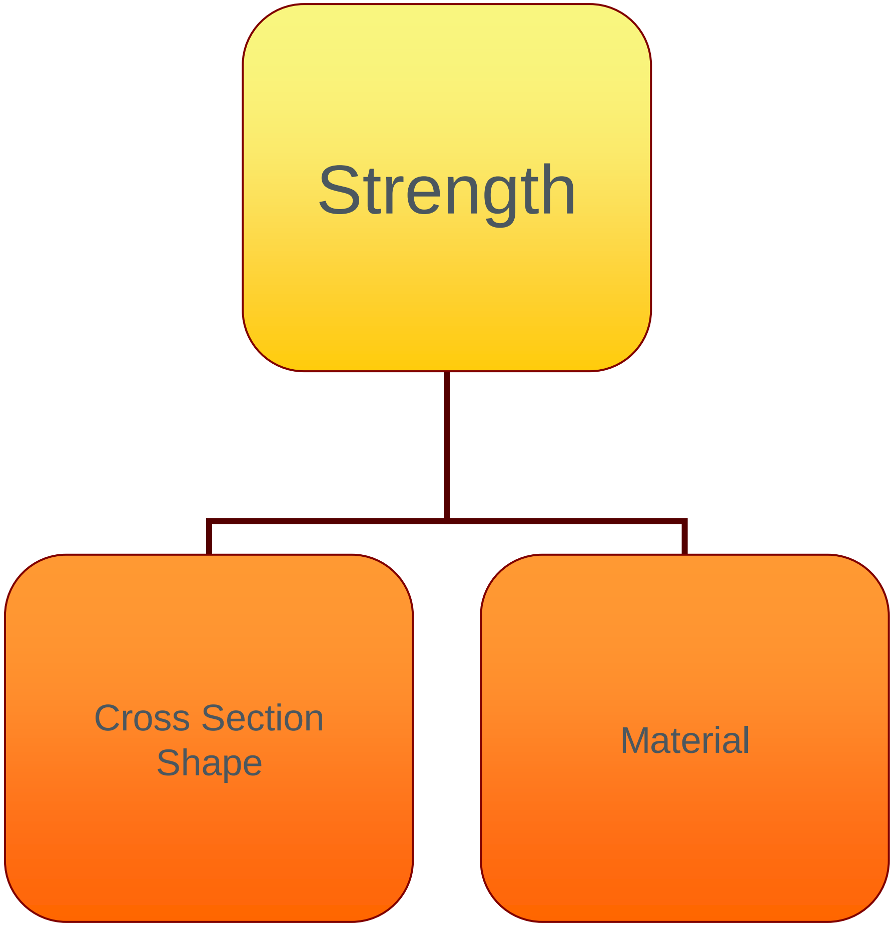
Yield Strength

- How much can the beam take before it breaks? We use the Yield Strength as the limit of the beam's strength based on stress.
- Actually it measures the point where a beam bends and remains in the bent shape.
- Both the material and beam section contribute to the strength.



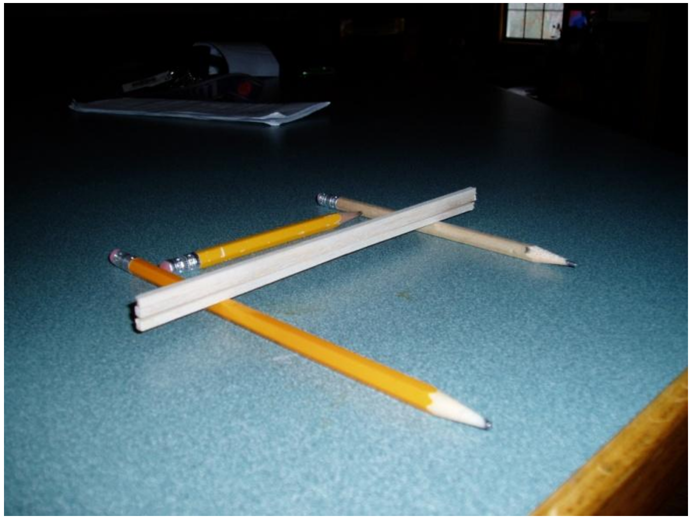
Strength of Beams

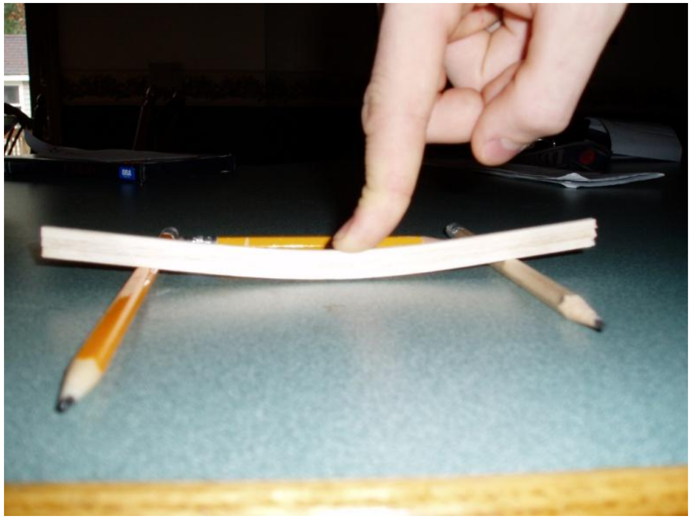
- The cross sectional shape influences the strength.
- Using a stronger material (steel rather than wood) makes the beam stronger.

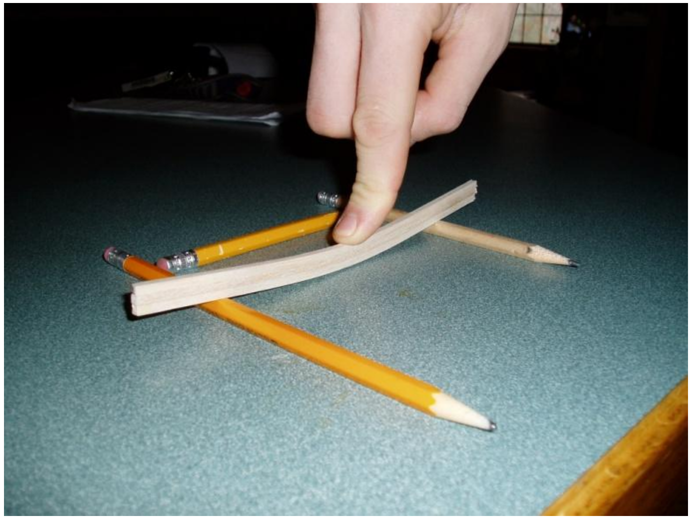


Cross Section Shape

- Stacking two or three beams as shown in the image makes the beam harder to bend and stronger against a load.

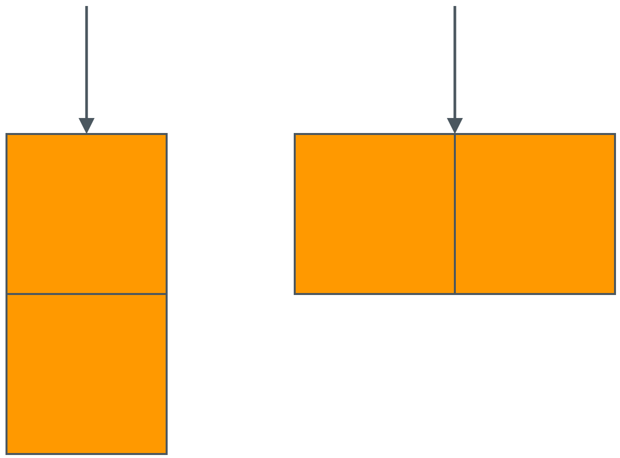






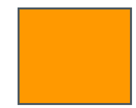
Section Depth

- The deeper the section (left) the stronger the material. Wider sections (right) help a little but not that much.
- The reason that deeper beams are stronger is the area moment of inertia. This is calculated using the width (b) and height (h) dimensions of the section.

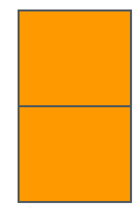


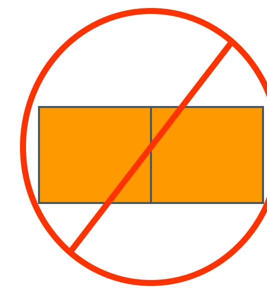
Area Moment of Inertia

- For a square section that measures 3.175mm (0.3175cm or 1/8”) on a side, the area moment of inertia is:
- 1 section = 8.47 base

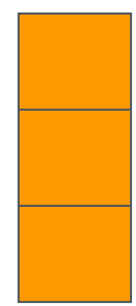


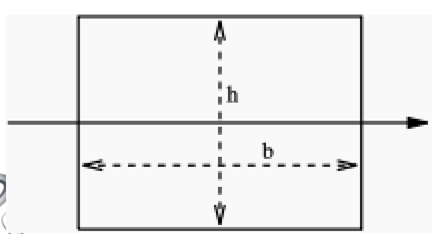
- 2 stacked = stronger 67.75 8X
- 2 side by side = stronger 16.94 2X





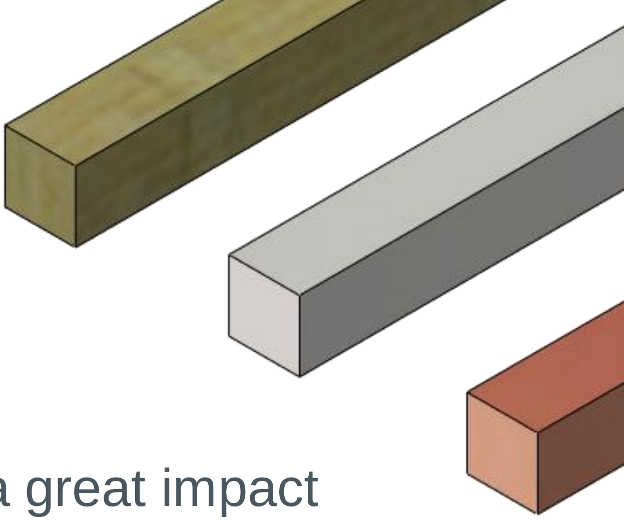
- 3 stacked = stronger 228.64 27X





$$I_0 = \frac{bh^3}{12}$$

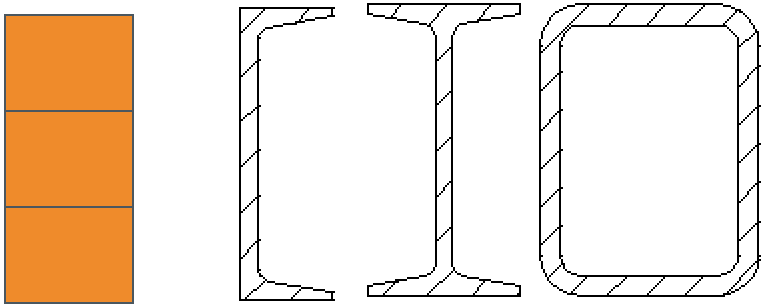
Materials



- The material used to create the beam has a great impact on it’s strength. Although there are many varieties of wood and alloys of metals, generally metal is stronger then wood.
- Note that wood, unlike metals, has a grain that makes it’s strength different in different directions.

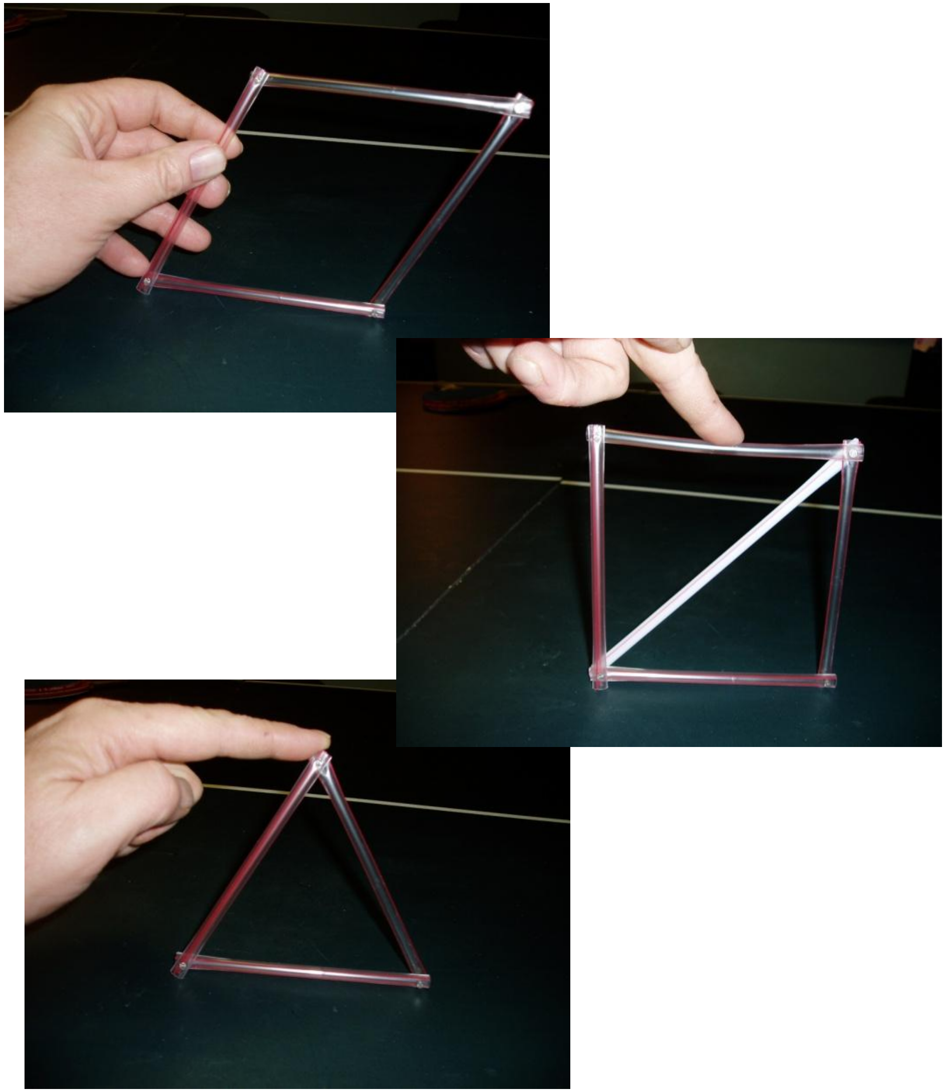
Steel Beams

- The deeper beam starts to look like the steel beams used in construction of trusses, and buildings, channels, I-beams and tubes.



Cross Bracing

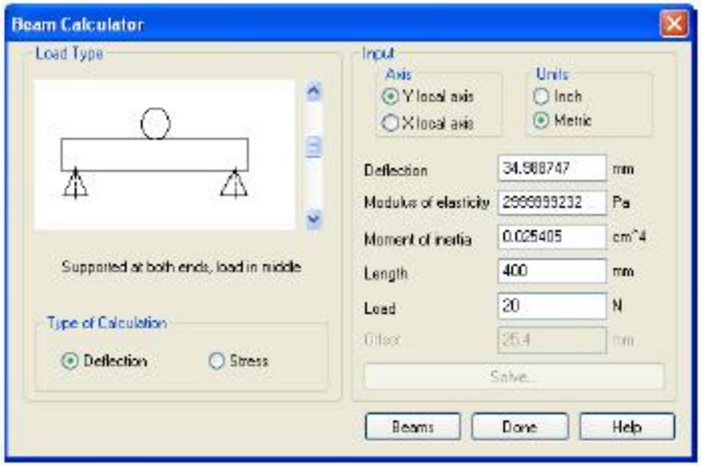
- Cross bracing stiffens the structure by preventing rotation at the joints.
- Using drinking straws pinned at the ends shows the difference that a brace can make.



3 – Using the Beam Calculator

Beam Calculator

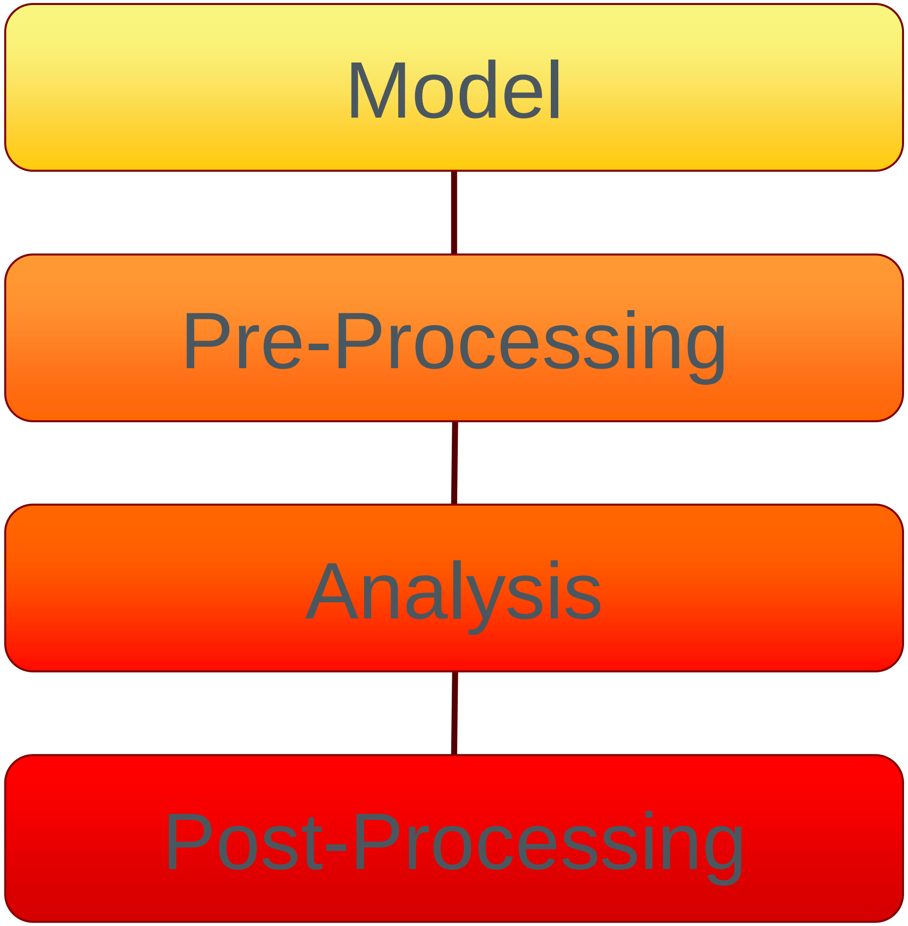
- The Beam Calculator can be used to get an estimate of the displacement. This can be used to make sure that the analysis is within expectations.



4 – Analyzing the Structure

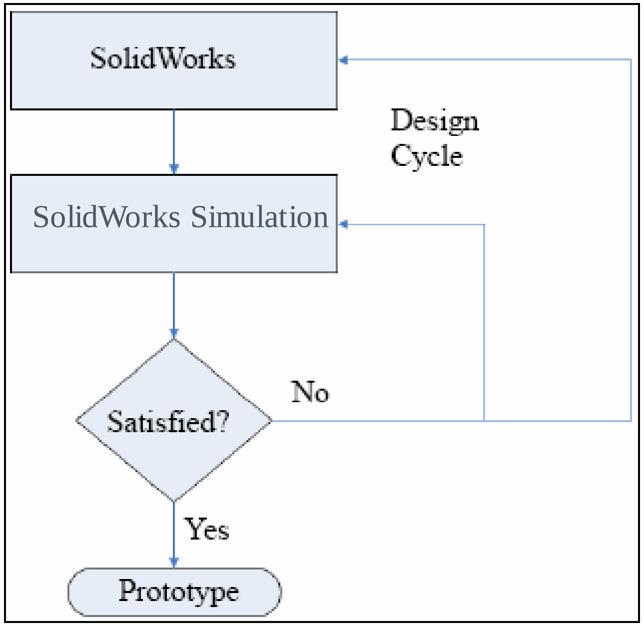
Analysis Stages

- A Structural Analysis has several stages that are followed in order.
- In SolidWorks:
  - Model is where the geometry is created.
- Using SolidWorks SimulationXpress:
  - Pre-Processing is used to add materials, fixtures and loads.
  - Analysis is where the input is “run” through the analyzer.
  - Post-Processing allows you to see the results.



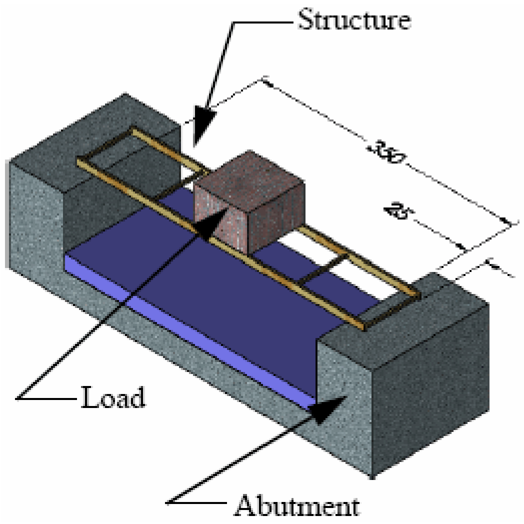
Design Cycle

- The Design Cycle is used to "iterate" changes by returning to the original design to change the model. The changes alter the results of the analysis.



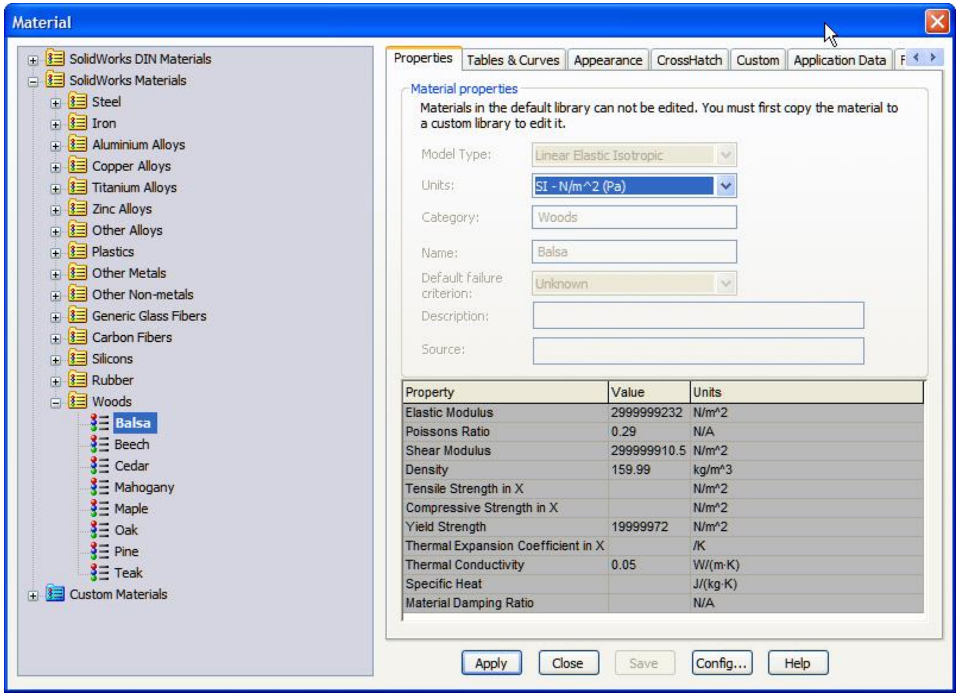
Fixtures and External Loads

- Fixtures prevent movement of portions of the structure.
- External Loads apply forces to the structure.



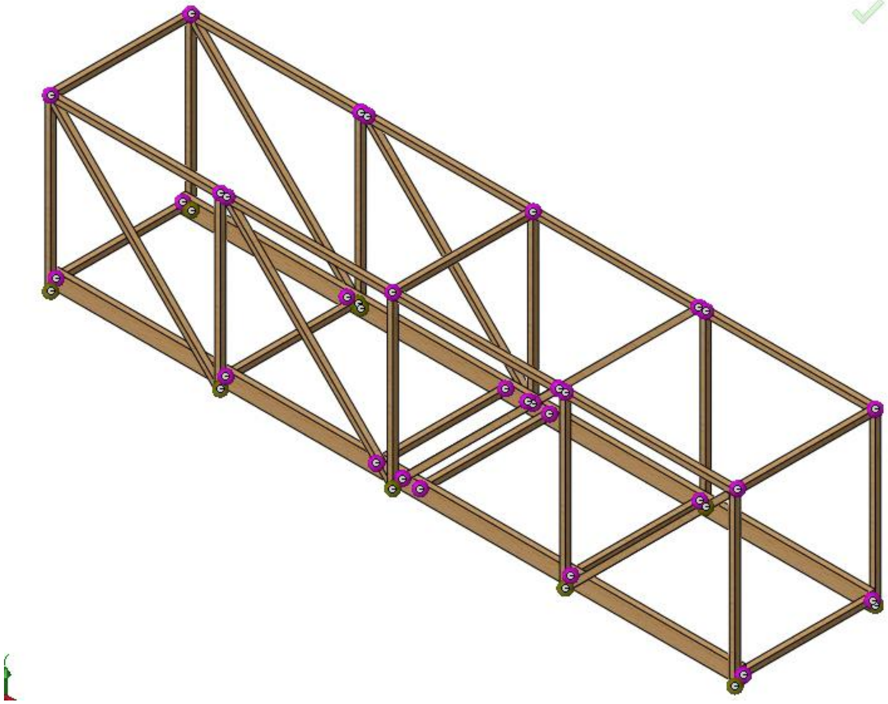
Material

- The material selected supplies data to the analysis in the form of numeric properties.



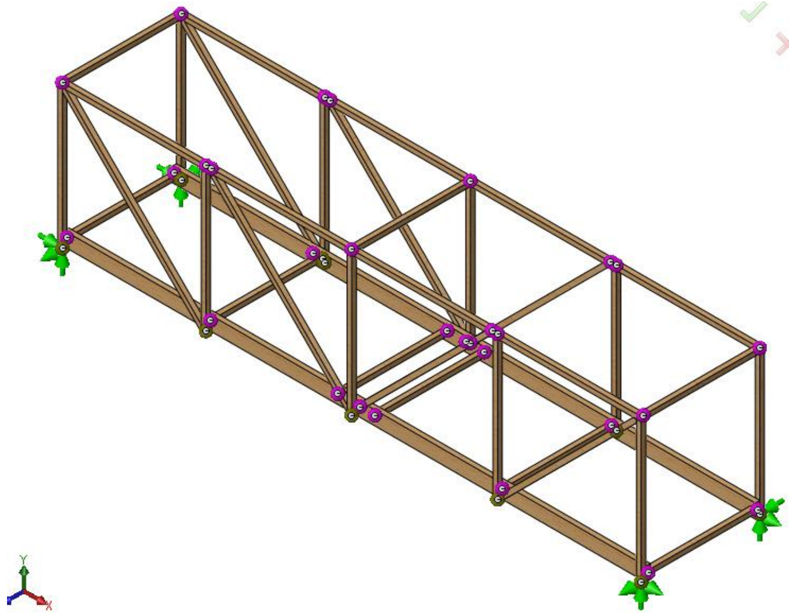
Joints

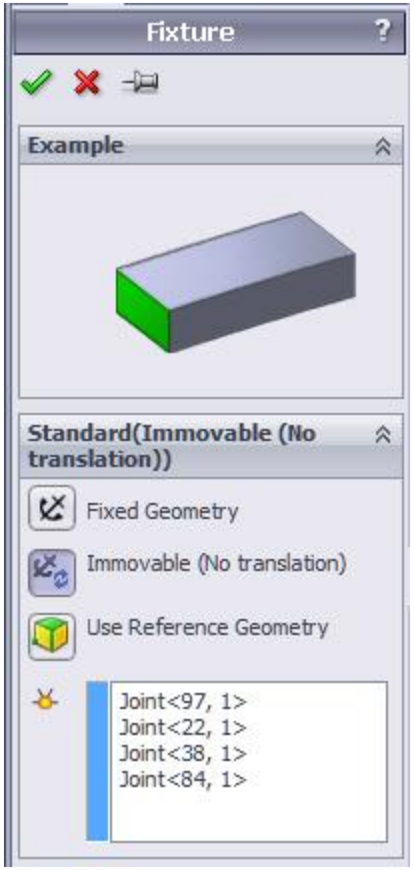
- Joints are automatically created at the intersections of the beam centerlines.



Fixtures

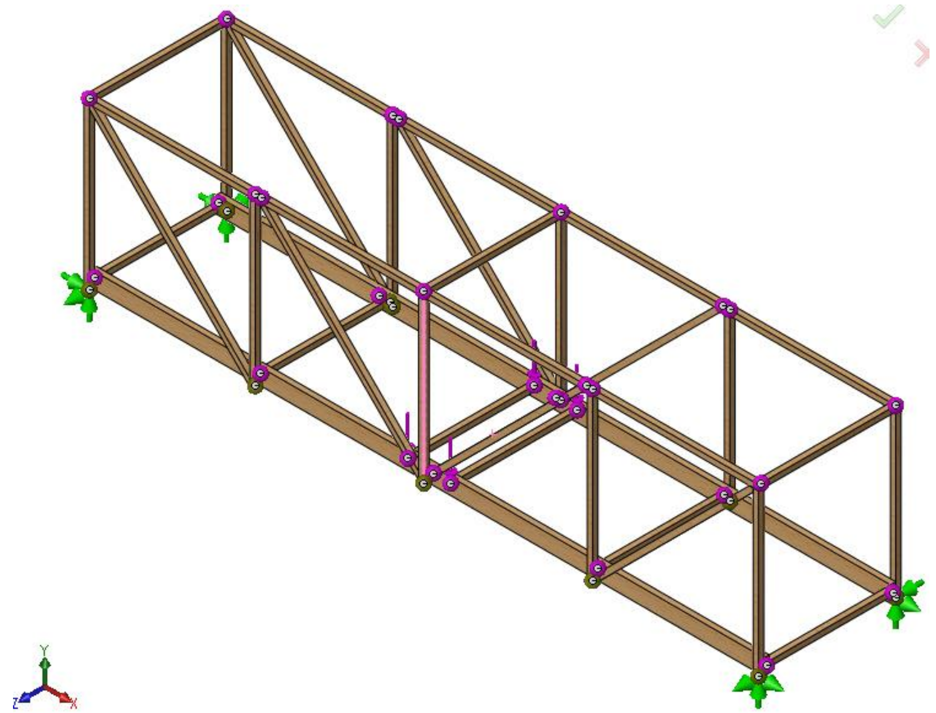
- The fixtures are applied by selecting joints in the model.

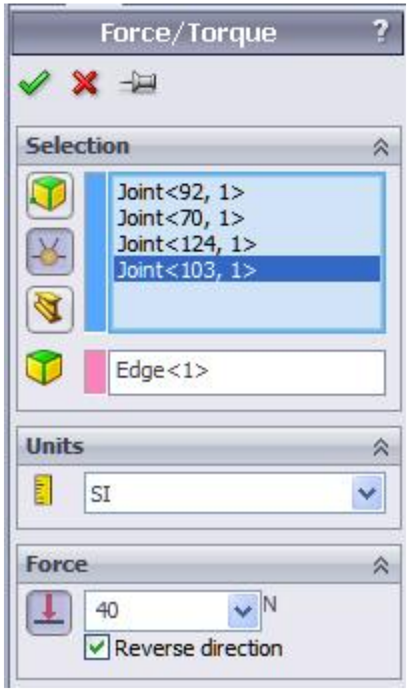




Loads

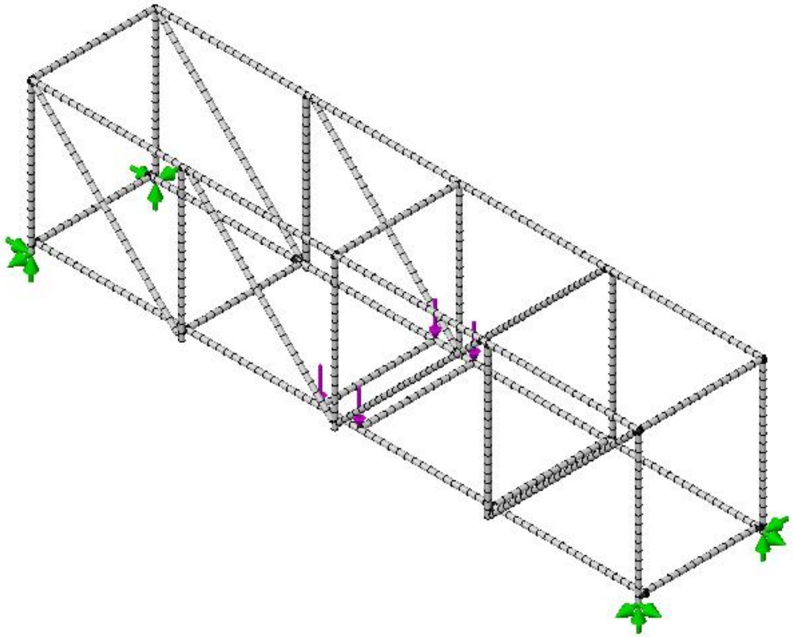
- The External Loads are applied by selecting joints in the model.

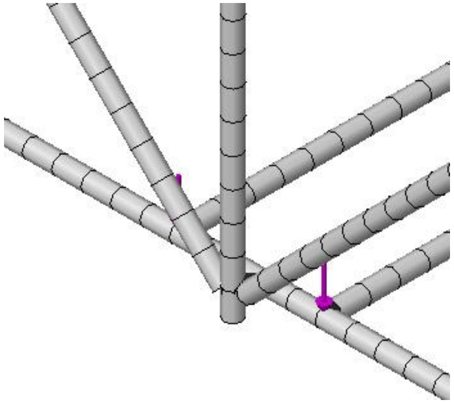




Mesh and Run

- Meshing creates beam elements and nodes that represent the model shape.

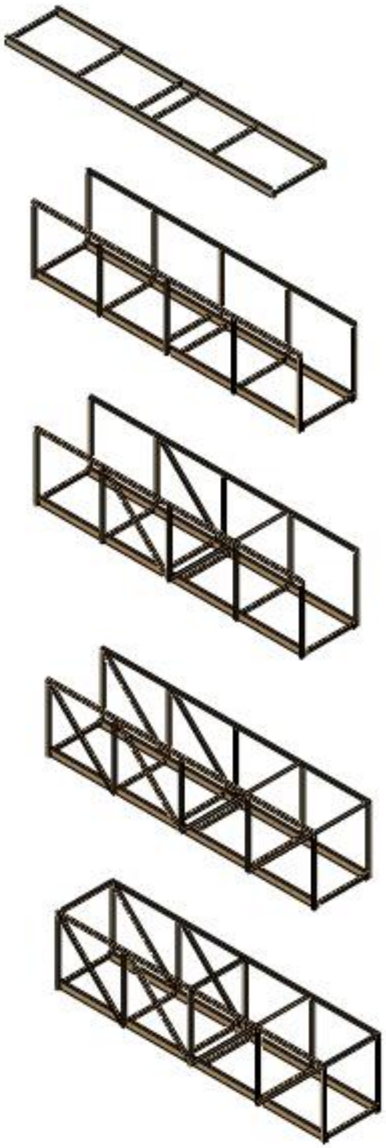




5 - Making Design Changes

Changes

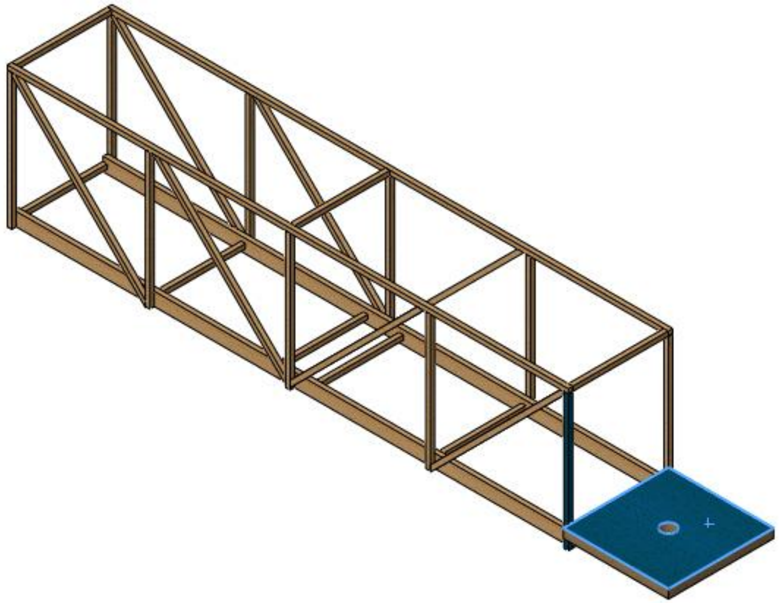
- Using different models, follow the changes in the model and the changes in capacity of the structure.



6 – Using an Assembly

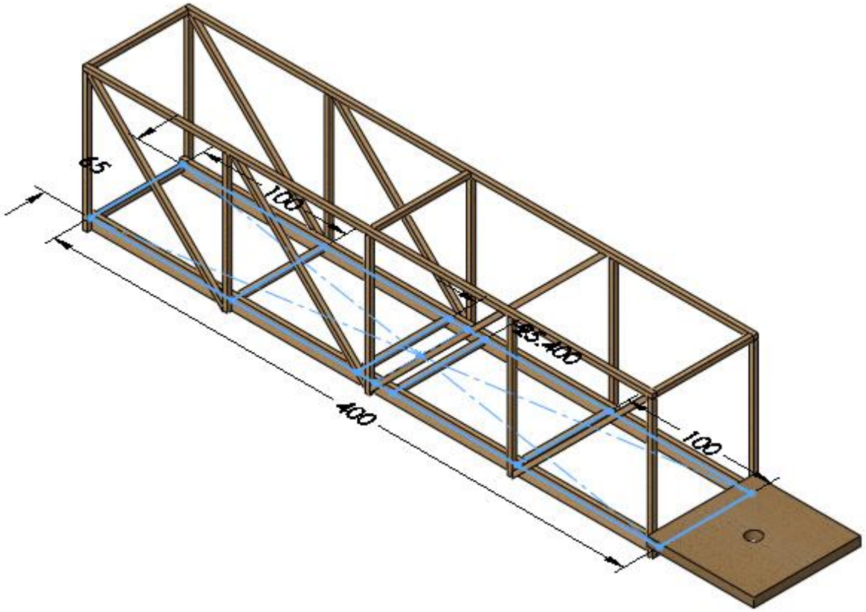
Collision Detection

- In an assembly, components can be checked for collision, interference or clash.



Changing Dimensions

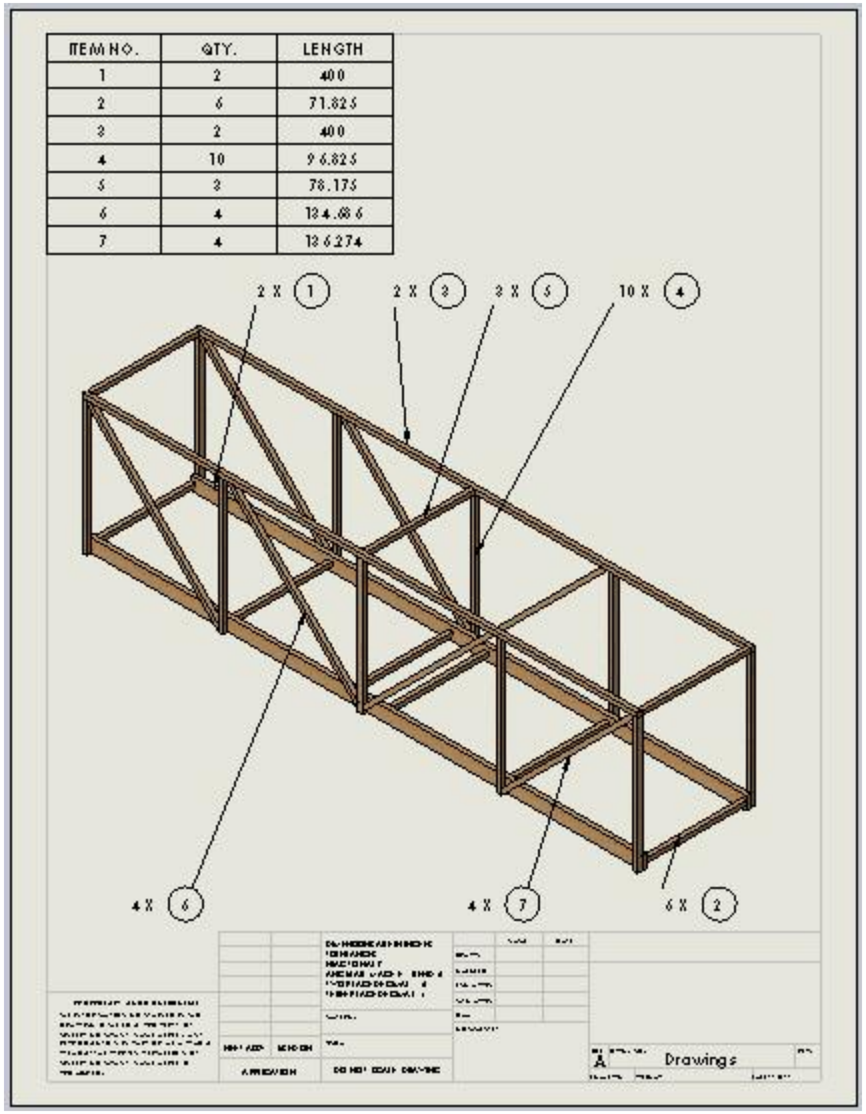
- The dimensions that define the shape of the model can also be used to change the size of the model.



7 – Making Drawings of the Structure

Drawings

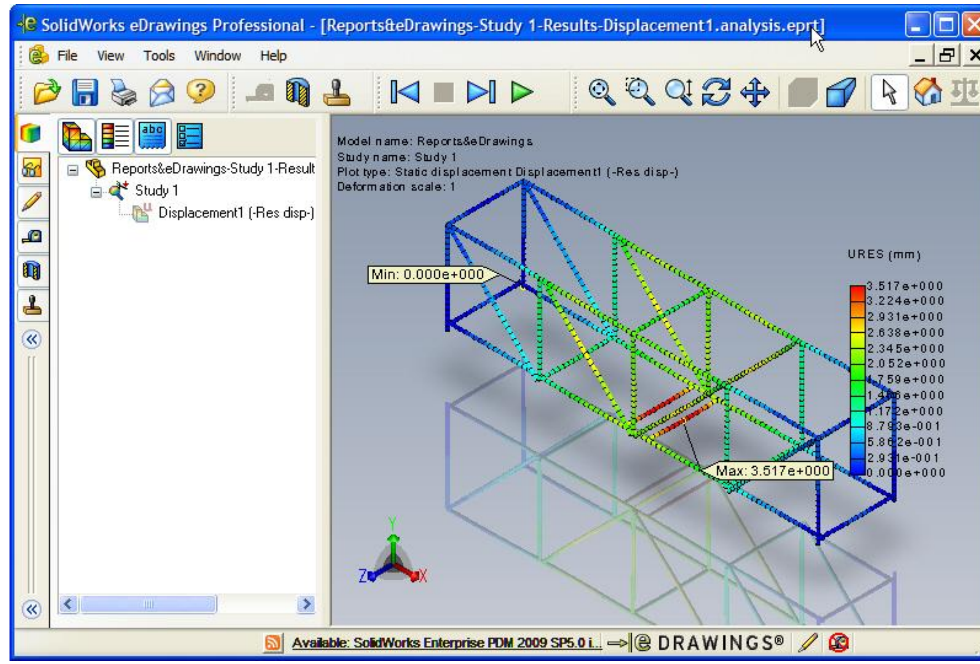
- The drawing includes a view of the model, a cut list and balloons.



8 – Reports and eDrawings

eDrawings

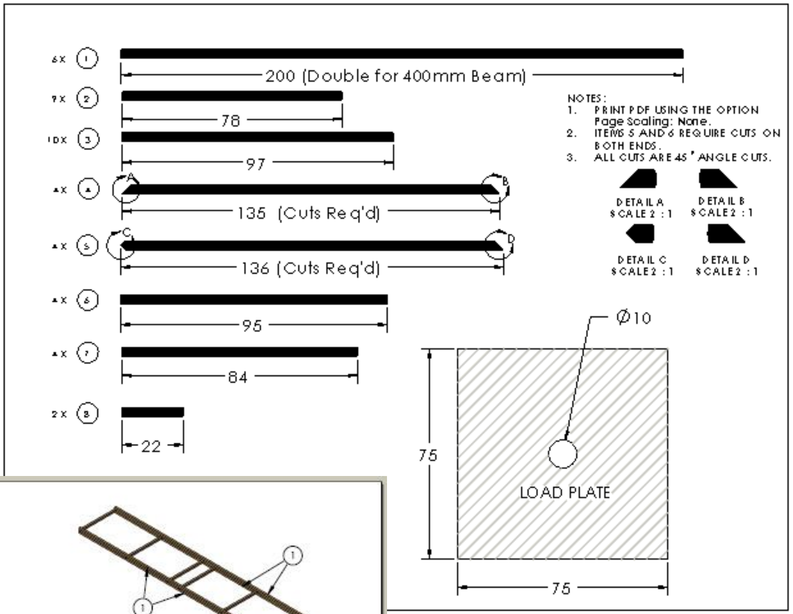
- HTML (web format) reports can be generated from the post-processor data.
- An eDrawing can be used to send information to other users.

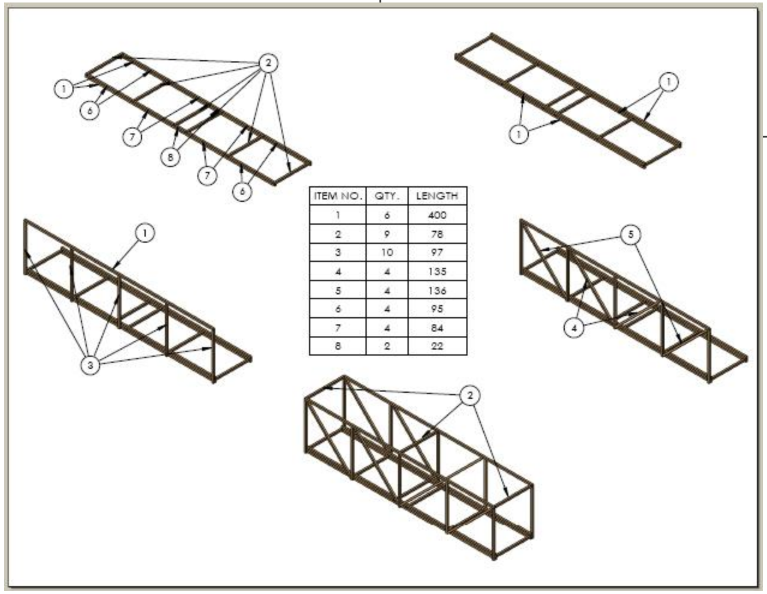


9 – Building and Testing the Structure

Construction Aids

- The PDF files *Measuring Chart* and *Construction Guide* can be used to make construction easier.





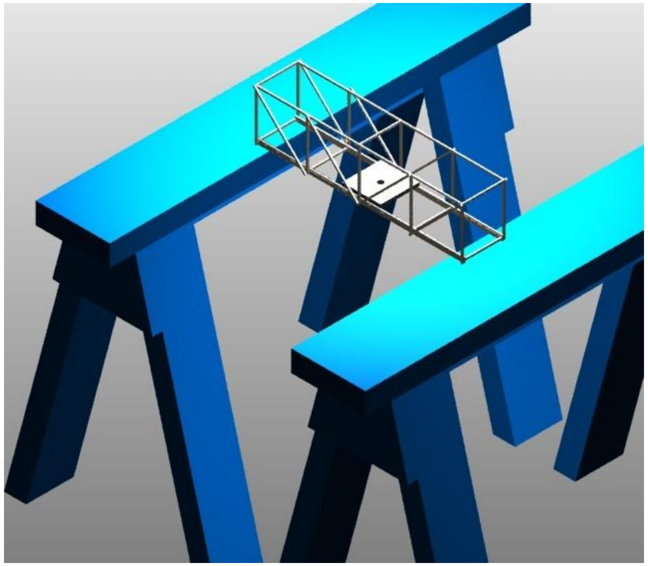
SOLIDWORKS

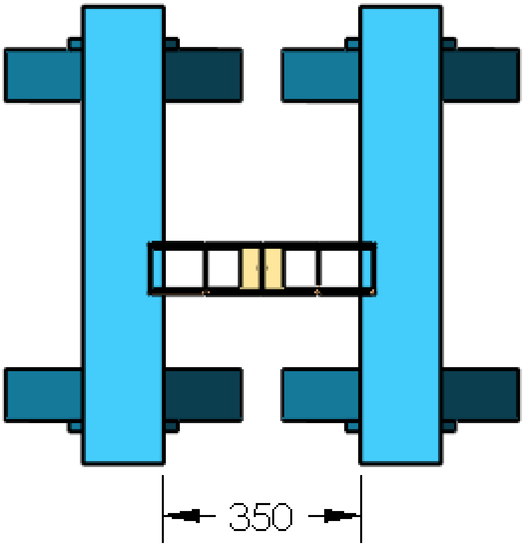
Building the Structure

- Distribute 1/8" x 1/8" x 24" balsa sticks, glue and cutters.
- Cut, glue and assemble structure per instructions.

Testing the Structure (setup)

1. Set up sawhorses or tables to represent the 350mm span.
2. Place the bridge and load plate across the sawhorses or tables.
3. Make sure to wear eye protection!





Testing the Structure (test weight)

4. Use a drawstring bag or bucket with wire attached.
5. Pass drawstring or wire through hole in load plate and pin in place.
6. Load bag or bucket with weighted objects until breakage occurs.