# Lesson 3 Using the Beam Calculator

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

- Start SolidWorks;
- Add-in the SolidWorks Simulation software;
- Open an existing SolidWorks part;
- Understand a simply supported beam;
- Assign a material;
- Calculate section properties;
- Use the measure tool;
- Use the beam calculator to calculate a displacement.

# **Using Beam Calculations**

Before you perform any kind of an analysis, it is a good idea to have some idea on what results to expect. Although you will not know how much weight the structure can withstand, you can make an educated guess on one or more of the results that you will get. This is where beam calculations, simple formulas for beams, can be used. Below are some of the beam calculations available.



**Note:** Hand-calculated type beam calculations typically include formulas and look like this.



### **Order of Magnitude**

Will the displacement (see "Displacement" on page 11) be close to 1mm? 10mm? The difference is **10** times greater than the previous one and are increasing by what is called an **Order of Magnitude**. An initial calculation can give you an idea of the order or magnitude of the results. This will help you determine whether the analysis has been done correctly.

### Questions

- 1. What is the next value after 1mm and 10mm using an increasing order of magnitude?\_\_\_\_\_
- 2. What values are missing in this set? 5mm, \_\_\_\_\_, 500mm

# Starting SolidWorks and Opening a Part

1 Start the SolidWorks application. From the Start menu, click Programs, SolidWorks, SolidWorks.

# Adding in SolidWorks Simulation

SolidWorks Simulation software is included with **SolidWorks Education Edition**. To use it, it must be activated using **Tools, Add-Ins**. Click both **Active Add-ins** and **Start Up** for SolidWorks Simulation and SolidWorks Toolbox and click  $\checkmark$ .

2 Add-in selections.

Click Tools, Add-ins and make sure that Active Add-ins and Start Up for both SolidWorks Simulation and SolidWorks Toolbox are checked.

Click 🖌.

**Note:** If the SolidWorks Simulation software is not added in the project cannot be completed.



# 3 Open the part file.

Click Open 彦.

From the **Open** window, browse to the Bridge Design Project\Student\ Lesson 3 folder.

Select TRUSS\_1.sldprt and click **Open**.



### **The Model Geometry**

This model is made up of a series of *beams* that are placed against each other. The beams represent balsa wood sticks. In your project, the beams are combined by gluing them together. In a real structure, the beams would be welded or bolted together.



# Simplifying the Analysis

The model appears as two parallel beams connected by smaller beams in several places. If we take just half of the model (just the large beam) and apply 1/2 the loads, we should get some idea of what the values will be in the real analysis.



# The Simply Supported Beam

This type of beam calculation is often referred to as a "simply supported beam" where the contact points are not completely fixed and a load is applied. There are two key definitions you will need to know; fixtures and external loads.

### **Fixtures**

Fixtures are used to limit movement of certain points in the model. These are usually points of contact. They are also called constraints or restraints.

### **External Loads**

External loads or forces can be used to add **Force** or **Gravity** loads to the structure. Adding a force requires a location on the structure, a value (in Newtons) and a direction.

### **Theoretical Model**

This is the theoretical model (right) of the beam supported by the pencils in the previous lesson.



### Why are Simply Supported Beams Important?

Although the theoretical model may seem very simple, it has far reaching effects. There are examples of the simply supported beam in use in many places.

### Structures

Wood and steel frame spans for homes and buildings are designed using simply supported beams.



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### Trebuchet

The trebuchet arm rotates on an axis between the frames. The axle is a simply supported beam.

### Mountainboard

If you were standing in the middle of a mountainboard, you would be the external load and the wheels would be the fixtures. The structure can be approximated with a simply supported beam.

**Note:** This example is a "simplified analysis" that takes 3 dimensional problem and simplify it to 2 dimensional problems. A full simulation would still be needed.

# **Conservative Assumptions**

Engineers often use "conservative assumptions" to make the analysis worse than reality for the structure. Doing this adds an extra level safety to the design and makes it stronger than it has to be. Here are some assumptions that will be made:

- 1. Using the ends of the structure is worse than using the actual points of contact.
- 2. Using a single external load at the center is worse than two external loads near the center.







### **Required Data for the Beam Calculation**

There are several pieces of data that are required to use this beam calculation. They include:

| Data                  | Where to Find It?   | What is it?           |
|-----------------------|---------------------|-----------------------|
| Modulus of Elasticity | Material Properties | Stiffness by material |
| Moment of Inertia     | Section Properties  | Resistance to bending |
| Length                | Geometry            | Length to cross span  |
| Load                  | (given)             | External load         |

### Common Units

Common metric units are used in this project. Some of the common units used in the SI and IPS (inch, pounds, seconds) units systems are:

| Data                  | SI Units        | IPS Units |
|-----------------------|-----------------|-----------|
| Modulus of Elasticity | Pa, MPa,        | psi       |
| Moment of Inertia     | mm^4, cm^4, m^4 | in^4      |
| Length                | mm, cm, m       | in, ft    |
| Load                  | N, kN           | lb        |

**Note:** We will use the **SI** unit system in this analysis. The SI system of units is also known as the International System of Units. It uses metric units such as meters., millimeters and Newtons.



Search on international system of units for more information.

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# Collect the Data

The required data will be collected using several different tools in upcoming steps. You will calculate the missing values in the chart below.

**Note:** As an initial guess, we will assume that the total weight load on the full structure is **40N**. We will use half of that, 40N/2 = 20N, for the beam calculation.

| Data                                     | Value | Units        |
|--|-------|--------------|
| Modulus of Elasticity<br>(pressure)      | ????  | Pa (Pascals) |
| Moment of Inertia (length <sup>4</sup> ) | ????  | cm^4         |
| Length                                   | ????  | mm           |
| Load (force)                             | 20    | N (Newtons)  |

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# **Assign a Material**

The first step is to assign a **Material** to the beams of the model. We want to make the structure out of balsa wood.

4 Material.

Right-click the Material feature and select **Edit Material**. Expand the SolidWorks Materials and Woods folders on the left and click Balsa.

Under Units, select SI - N/m<sup>2</sup> (Pa).

Click **Apply** then click **Close**.

TRUSS\_1 (Default<As Machined>
 Sensors
 Annotations
 Equations
 Equations
 Front Plane
 Top Plane
 Right Plane
 Origin
 Roadway

| 📒 SolidWorks DIN Materials | Properties    | Tables & Curve                     | Appear        | ance Cros           | sHatch    | Custom       | Application Dal  | a F  |
|----------------------------|---------------|------------------------------------|---------------|---------------------|-----------|--------------|------------------|------|
| 📒 SolidWorks Materials     | Material      | properties                         |               |                     |           |              |                  |      |
| 🛨 🔠 Steel                  | Materia       | propercies<br>als in the default   | library cap   | not be edite        | d Your    | oust first i | ropy the materi: | alto |
| ∓ 🚼 Iron                   | a custo       | om library to edit                 | it.           | not be calle        | a, roan   | naseriise    |                  |      |
|                            |               | _                                  |               |                     |           |              |                  |      |
|                            | Model         | Type:                              | ear Elastic I | Isotropic           | Y         |              |                  |      |
| 🕂 🔢 Titanium Alloys        | Units:        | SI                                 | - N/m^2 (Pa   | a)                  | *         |              |                  |      |
| + III Zinc Alloys          |               |                                    | 1             |                     |           | 1            |                  |      |
| + B Other Alloys           | Catego        | ory: w                             | oods          |                     |           |              |                  |      |
| 🗄 🔢 Plastics               | Name:         | Ba                                 | Balsa         |                     |           | 1            |                  |      |
| 🕀 🔢 Other Metals           | Defaul        | t failure                          | beau          |                     | 1.5       |              |                  |      |
| 🕀 🔢 Other Non-metals       | criterio      | in:                                | KHOWH         |                     |           |              |                  |      |
| 😟 🔠 Generic Glass Fibers   | Descrip       | otion:                             |               |                     |           |              |                  |      |
| 🗄 🔠 Carbon Fibers          | in the second | -                                  |               |                     |           |              |                  |      |
| 😟 🔢 Silicons               | Source        |                                    |               |                     |           |              |                  |      |
| 🕀 🔢 Rubber                 | Durante       |                                    | l.            | /=l=                | 11-3-     |              |                  |      |
| 🚊 🔠 Woods                  | Floatic Ma    | alı dı və                          | V             | /alue               | DIAL      |              |                  |      |
| Balsa                      | Elastic IVIL  | Elastic Modulus                    |               | :9999999202<br>1 29 | 2 IN/IT/2 |              |                  |      |
| Beech                      | Shear Mo      | Poissons Ratio<br>Shear Modulus    |               | 999999910 5         | 5 N/m^2   |              |                  |      |
| <b>§</b> Ξ Cedar           | Density       | Density                            |               | 59.99               | ka/m^3    |              |                  |      |
| <b>§</b> ∃ Mahogany        | Tensile St    | trength in X                       |               |                     | N/m^2     |              |                  |      |
| <b>§</b> Ξ Maple           | Compress      | Compressive Strength in X          |               |                     | N/m^2     |              |                  |      |
| i∃⊒ Oak                    | Yield Stre    | Yield Strength                     |               | 9999972             | N/m^2     |              |                  |      |
| E Pine                     | Thermal E     | Thermal Expansion Coefficient in X |               |                     | K         |              |                  |      |
| Teak                       | Thermal C     | Thermal Conductivity               |               | ).05                | WW(m·K)   |              |                  |      |
| E Custom Materials         | Specific H    | Specific Heat                      |               |                     | J/(kg·K)  |              |                  |      |
|                            | Material D    | amping Ratio                       |               |                     | N/A       |              |                  |      |
|                            |               |                                    |               |                     |           |              |                  |      |

**Note:** The material used, **Balsa**, is chosen to make the analysis useful to those who will actually design, construct and test the structure. Balsa wood is a common material for student building projects.

The value of the Elastic Modulus or Modulus of Elasticity = 299999232 N/m^2.

\*You will learn more about materials, construction and testing in later lessons.

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# **Section Properties**

The section properties are based on the cross section of the beam.

### 5 Zoom to area.

Click **View**, **Modify**, **Zoom To Area** and drag a window, upper left to lower right, around the corner of the structure as shown.



- **Note:** Press the **Esc** key to turn off the zoom tool.
  - 6 Face selection.

Select the face as shown.



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#### 7 Section properties.

Click **Tools, Section Properties**. Click **Options** and **Use custom settings**. Select **Centimeters** and **6** decimal places as shown.

Click **OK** and **Recalculate**.

Moments of inertia of the area, at the centroid: (centimeters ^ 4) Lxx = 0.025405. Click **Close**.

| Mass/Section Property Options  | 🕅 Section Properties  |
|--|---|
| Units  | Print Copy Close Options Recalculate Output coordinate system: default V  |
| Use document settings     Use custom settings     Length: Decimal places:     Centimeters      6   | Selected items:   |
| Mass:  | Show output coordinate system in corner of window Section properties of the selected face of TRUSS_1  |
| Per unit volume:<br>millimeters^3  Material Properties   | Area = 0.302419 centimeters^2<br>Centroid relative to output coordinate system origin: ( centimeters )<br>X = 20.000000<br>Y = 0.000000<br>Z = 3.750000   |
| Density:     0.00015999 g/mm^3       Accuracy level       Operault mass/section property precision | Moments of inertia of the area, at the centroid: (centimeters $^4$ )         Lxx = 0.025405       Lxy = 0.000000         Lyx = 0.000000       Lyy = 0.002540         Lyx = 0.000000       Lyy = 0.002540         Lxx = 0.000000       Lzy = 0.000000         Lzx = 0.000000       Lzy = 0.002864         Delay present of inertia of the area at the centroid = 0.025405 centimeters 0.4  |
| Maximum property precision (Slower)  | Angle between principal axes and part axes = -0.000000 degrees<br>Principal moments of inertia of the area, at the centroid: (centimeters $^4$ )<br>Ix = 0.002540   |
|  | Iy = 0.022864         Moments of inertia of the area, at the output coordinate system: (centimeters ^ 4 )         LXX = 4.278168       LXY = 0.000000         LYX = 0.000000       LYZ = 22.681406         LYX = 0.000000       LYZ = -0.000000         LZX = 22.681406       LZY = -0.000000         LZX = 22.681406       LZY = -0.000000         LZX = 22.681406       LZY = -0.000000 |

8 Zoom.

Click View, Modify, Zoom To Fit or click the f key to return to the full view.

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# **Using Measure**

Measure can be used to measure distances or angles using model geometry.

#### 9 Measure.

Click **Tools, Measure**. Select an edge of the beam as shown. The length of the beam is displayed.

Length: 400mm.



| Measure - TRU55_1     | X |
|-----------------------|---|
| ძშ • ლო ႃᢅ×₂ ၞ∔ • 🔊 • | Â |
| Edge<1>               |   |
| Length: 400mm         | _ |
| Lengun: 400mm         |   |
|                       |   |

### 10 Close.

Click the "x" in the upper right hand corner of the dialog to close it.

# Beam Calculator

The beam calculator uses the input to determine the largest displacement of the beam. Retrieve the data from the chart "Collect the Data" on page 23.

**Note:** This dialog uses *deflection* but we will be referring to it as *displacement* throughout the manual.

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### 12 Settings.

Clear any values in the **Deflection** field (the **Solve** button will not be available until that field is cleared). Use the scroll bars to access **Supported at both ends**, **load in middle**. Click **Y local axis**, **Metric** and **Deflection**.

### 13 Type in values.

Type or copy and paste the values listed below into the dialog:

| Data                                     | Value      | Units        |
|--|------------|--------------|
| Modulus of Elasticity<br>(pressure)      | 2999999232 | Pa (Pascals) |
| Moment of Inertia (length <sup>4</sup> ) | 0.025405   | cm^4         |
| Length                                   | 400        | mm           |
| Load (force)                             | 20         | N (Newtons)  |

Click **Solve**. The displacement is about **35mm** at the load (center of the beam). Click **Done**.

| Beam Calculator                         |                                  |  |            |
|---|----------------------------------|--|------------|
| Load Type                               | Axis                             | Units                                    |            |
|   | ⊙ Y local axis<br>○ X local axis | <ul> <li>Inch</li> <li>Metric</li> </ul> |            |
|   | Deflection                       | 34.988747                                | mm         |
|   | Modulus of elasticity            | 2999999232                               | Pa         |
| Supported at both ends, load in middle  | Moment of inertia<br>Length      | 400                                      | cm 4<br>mm |
| <ul> <li>Type of Calculation</li> </ul> | Load                             | 20                                       | N          |
| Deflection     O Stress                 | Offset                           | 25.4<br>Solve                            | ] mm.      |
|   | Beams                            | Done                                     | Help       |

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**Note:** The **Solve** button will not be available until the **Deflection** field is cleared.

### Questions

- 1. Is this displacement more or less than an inch?\_\_\_\_\_
- 2. Convert the displacement inches: 35mm/25.4 = \_\_\_\_\_ in

# 14 Close the part.

Click **File**, **Close** to close the part.

At the Save changes to TRUSS\_1? message, click Don't Save.