

# Tutorial

To watch a Video Tutorial:

<https://www.youtube.com/watch?v=9w9fTC4eh3w>

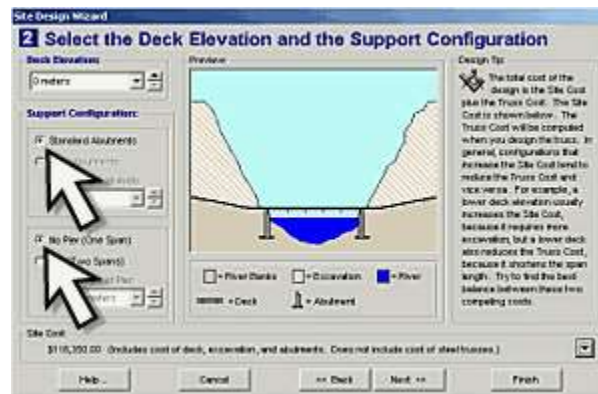
## 1. Getting Started

In this tutorial, we'll use the West Point Bridge Designer 2016 to design a steel truss bridge. You'll need to download the WPBD 2016 software and install it on your computer.



Click the Windows Start button and then All Programs. From the Programs menu, choose West Point Bridge Designer 2016. Read the Tip of the Day and click the Close button. On the Welcome screen, ensure that Create a New Bridge Design is selected and click OK. At this time, you'll see the Site Design Wizard.

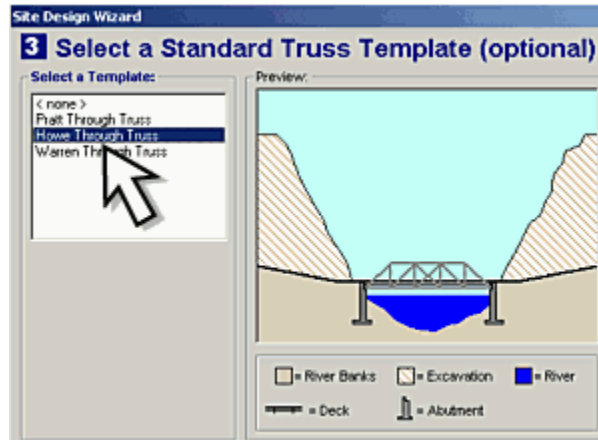
On the first screen of the Site Design Wizard (Step 1), take a moment to familiarize with the design requirement and the project site, then click the Next button.



In Step 2, we'll make some important decisions about how the bridge will be sited. To keep this tutorial simple, we'll choose the simplest possible site configuration. From the Deck Elevation list, choose 0 meters, which results in the shortest possible span length. Set the Support Configuration as Standard Abutments and No Pier. Note that the Site Cost is displayed near the bottom of the Wizard. This site configuration has a total cost includes the costs of the deck, abutments, and excavation—but not the steel truss (which you haven't designed yet). If you'd like to see how this number is calculated, just click the drop-down arrow on the right-hand side.

By the way, if you have any questions about the terminology used to describe the site configuration—abutments, deck, span, excavation, etc.—just click the Help button at the bottom of the Site Design Wizard.

Now click the Next button to proceed to Step 3.



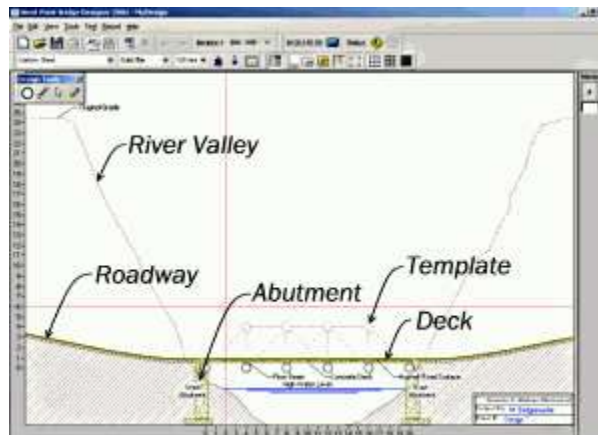
In Step 3, we will choose a Standard Truss Template to guide the creation of our structural model. Using a template is optional, but as a new or inexperienced WPBD user, you should take advantage of this tool. For our design, let's try the Howe Through Truss. Click this item in the Select a Template list and click Next.

In Step 4, enter your name in the Designed By box, and enter "Design 1" as the Project ID. (You can use the Project ID to uniquely identify each of the designs you create.)

Now click Finish to close the Site Design Wizard.

## 2. Creating the Structural Model

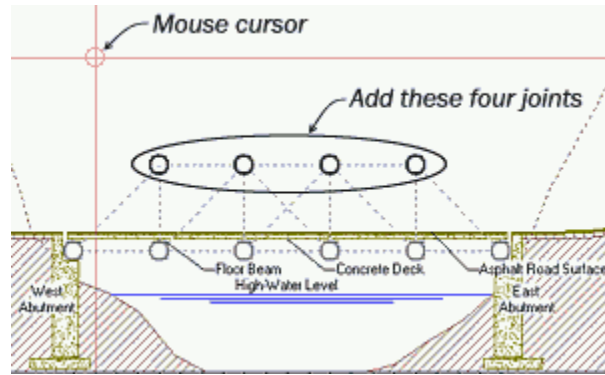
A structural model is a mathematical idealization of a real structure. The model is a tool to help us predict how the real structure will behave when it is loaded.



Before we begin the truss design, let's take a moment to familiarize with the Drawing Board—the screen area on which we will create, test, and optimize our structural model. Note that the screen already shows the river valley, roadway, abutments, and bridge deck, as well as our Howe Through Truss template, which is outlined in light gray dotted lines.

At the left and bottom edges of the Drawing Board are rulers, which show the dimensions of the project site in meters. Above the Drawing Board are several toolbars, and to the right is a list of the steel truss members in our structural model. The list is blank, of course, because we haven't created any members yet.

We'll begin the structural model by drawing joints—the points at which our truss members will be connected together.



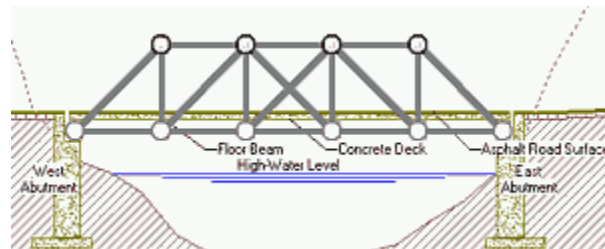
Note that six joints have already been created automatically. These six joints, which cannot be deleted or moved, represent the connecting points between the concrete bridge deck and the steel structure.

There are only four more joints to add. Their locations are indicated with dotted circles on the template. To draw these joints, move the mouse cursor (indicated by two perpendicular red lines) directly over each of the dotted circles and click the left mouse button. If you accidentally draw a joint in the wrong place, just click the Undo button on the WPBD toolbar.



Now we're ready to draw the steel structural members that will form our truss. From the Design Tools palette in the upper left-hand corner of the Drawing Board, select the Member tool. The mouse cursor will change to a pencil.

Members are drawn from joint to joint, and the dotted lines of the template show us which joints to use as the endpoints for each member.



To begin, move the cursor over any joint and press the left mouse button. While holding this button down, drag the mouse to an adjacent joint, using the template as a guide. When the cursor reaches the second joint, release the mouse button, and a dark gray member will be drawn between the two joints. Use this procedure to draw all 18 members that make up the Howe Through Truss.

Our structural model is complete! Though it might seem that all we've done is to draw a picture of a truss, we have actually completed a preliminary design of its engineering properties as well. You've probably already noticed that, on the lower toolbar, there are three drop-down lists, which currently read Carbon Steel, Solid Bar, and 120 mm.

These are the Member Properties lists.



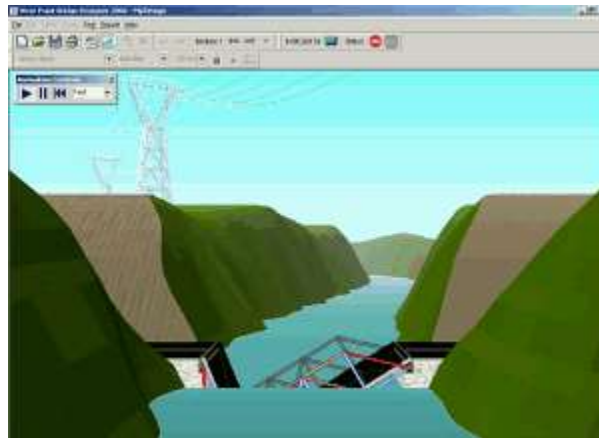
The three lists are used to define the material, cross-section, and size of structural members. The values displayed in these lists are automatically assigned to all newly created members. Thus all 18 members in our structural model are 120 millimeter solid bars made of carbon steel.

Are these members strong enough to carry the highway loads that our bridge will be subjected to? The only way to find out is to test our design.

### 3. Testing the Design



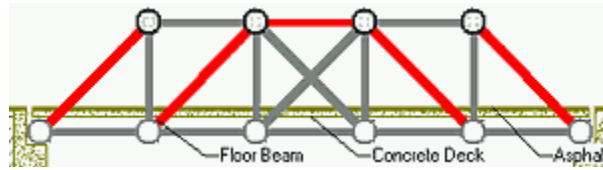
Now that our structural model is complete, we're ready to test our design to determine whether or not it can carry the traffic loads prescribed in the Design Specifications. To start the test, click the Load Test button on the toolbar.



As the load test begins, we see our bridge as it might look after it is built. The structure sags a bit, as it begins carrying its own weight. All that steel and concrete is heavy, but the trusses do their job well. Then along comes a truck—a 360 kilonewton vehicle representing the largest loading that this bridge is expected to experience in its lifetime. The truck moves out onto the bridge and...the structure collapses into the river. Ouch!

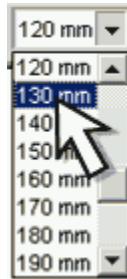
Our design has failed the load test—but don't worry. Engineering design is an iterative process. Some trial-and-error is always necessary to achieve a successful product. If at first you don't succeed, then go "back to the drawing board" and try again.

To return to the Drawing board and continue our design, just click the Drawing Board button. That's the one just to the left of the Load Test button (shown above).



Back on the Drawing Board, you'll notice that the appearance of the structural model has changed. Five of the 18 members are now highlighted in red—indicating that these members are not strong enough to carry the truck loading.

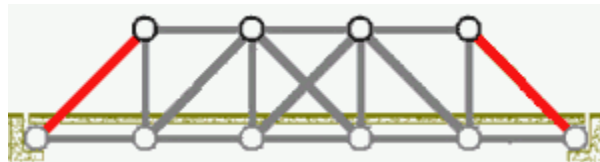
To make the bridge safe, we'll need to strengthen these members. To strengthen them, we'll need to make them larger. First, use the Select tool to select one of the failed members by clicking it with the mouse.



(Recognizing that you would probably need to edit your structural model, the West Point Bridge Designer has already chosen the Select tool for you. It's the arrow button on the Design Tools palette, as shown at right.)

The selected member will turn light blue. Once a member is selected, we can change any of its properties—material, cross-section, or size. The most effective way to strengthen a failed member is to increase its size. To make this change, click the drop-down arrow on the Member Size list (one of the Member Properties lists on the lower toolbar), and choose the next larger size—130 mm. Repeat the process for the remaining four failed members. Select each member, then choose 130 mm from the Member Size list.

We have attempted to repair the failed members in our structural model, but we won't know if the repairs are effective until we run the load test. So click the Load Test button and (ouch!) the bridge collapses again.



This time when we return to the Drawing Board, however, only the two diagonal members on the ends of the bridge are highlighted in red. Increase the size of these two members by first selecting each one, and then choosing 140 mm from the Member Size list.

Check this new design iteration by running the load test once more. The truck crosses the bridge without causing a collapse. Your bridge design is successful!

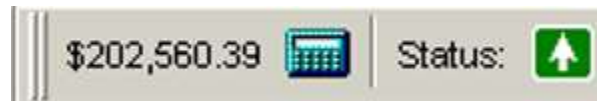


Before we return to the Drawing Board, take a moment to watch the Load Test Animation. Note that some of the structural members turn red, while others turn blue. This color coding illustrates the type of force in each member. Members that turn blue are experiencing tension—they are being stretched or elongated. Members that turn red are in compression—they are being squashed or shortened. The intensity of color indicates the magnitude of the member force. Thus the dark red diagonal members are being loaded very close to failure, while the light blue bottom chords are much stronger than they really need to be.

These observations are important, because they will help us to optimize our design.

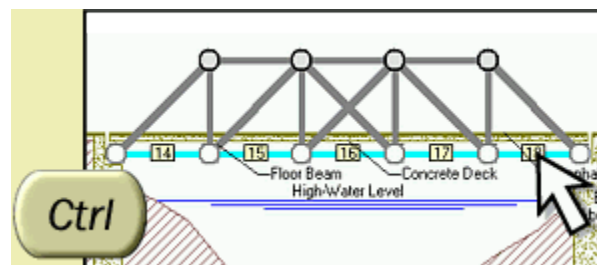
## 4. Optimizing the Design

Let's return to the Drawing Board and get started on the optimization process. Because our bridge didn't collapse, it is a successful design. But it is not an optimal design, because it is much more expensive than it really needs to be. Designing an inexpensive bridge is not as important as designing a safe bridge—but cost is still quite important. A bridge might never get built, if it costs more than your state or city can afford.



On the upper toolbar, notice that the cost of our design has already been calculated. To see how this number is computed, just click the Report Cost Calculations button (the little calculator) immediately to the right of the cost.

How can we reduce the cost of the bridge without compromising its safety? One way is to reduce the size of members that are stronger than they really need to be. Remember that, in the previous load test, all five bottom chord members were color-coded with a very light blue. The light color indicates that, for each of these members, the tension force was much less than the strength. As a result, all five of these members can be reduced in size without compromising the safety of the structure. In fact, you can reduce their size from 120 mm to 90 mm, and the bridge will still pass the load test.

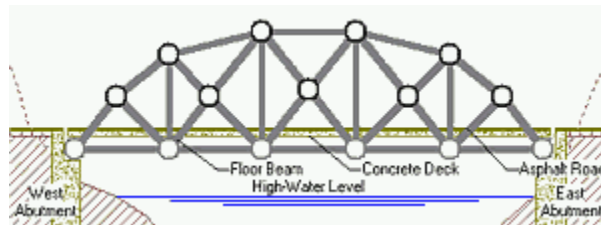


In making this modification to our structural model, let's take a little shortcut. Since we have to change the size of five members, let's use multiple selection to speed up the process. Hold down the Ctrl key on your keyboard, and then click all five bottom chord members. All will be selected simultaneously, as shown at right. Now choose 90 mm from the Member Size list, and all five members will be changed to this size.

Notice that the cost of our design has dropped. The structure still passes the load test, so the reduction in cost did not adversely affect the safety of the structure.

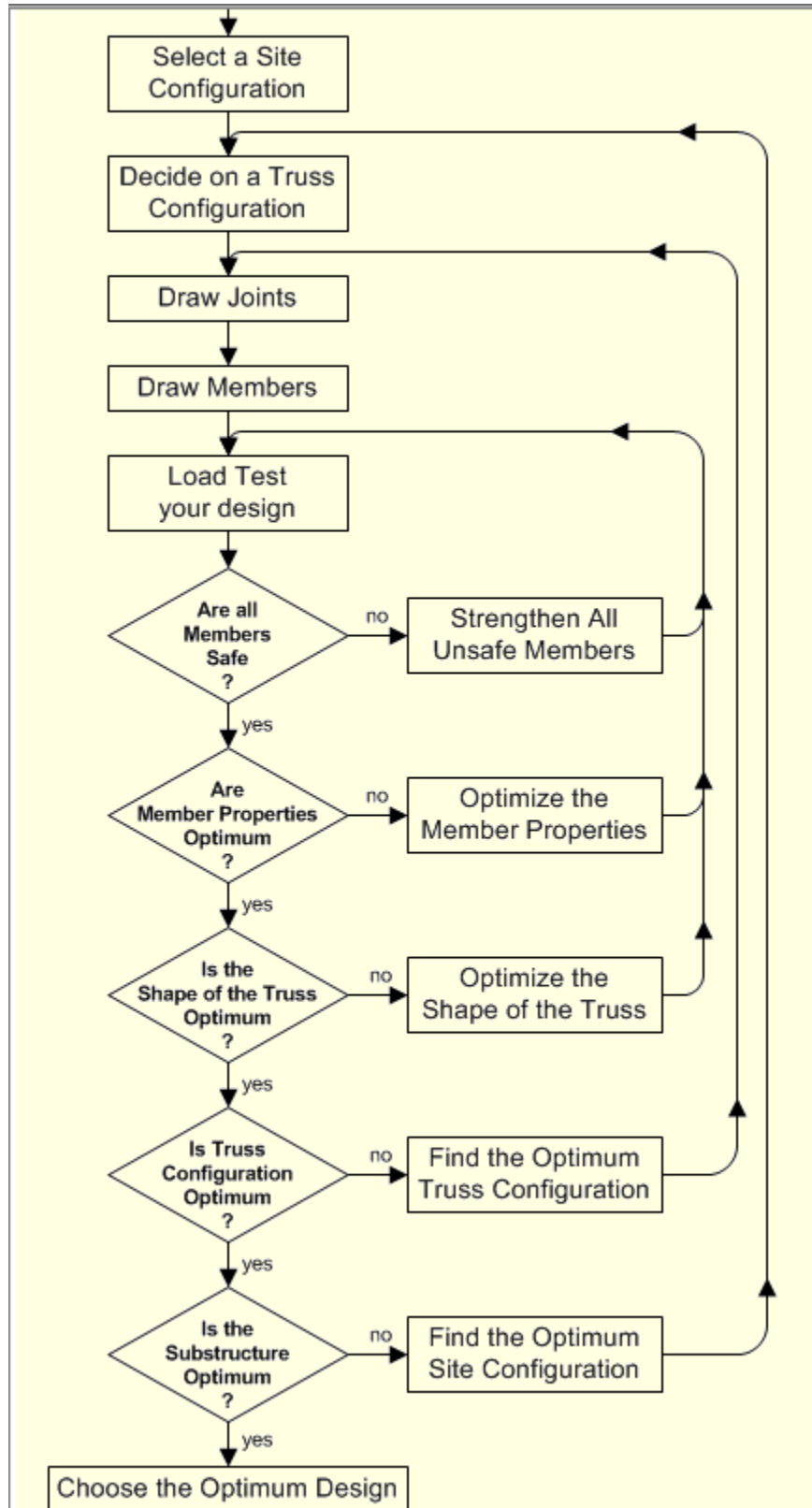
But we can still do a lot more to optimize this design. Many other members can safely be reduced in size. We might also find that we can save some money by using hollow tubes rather than solid bars or by using a different type of steel. Use the other two Member Properties lists to make these changes.

Remember that size is not the only member property you can change. You can also choose different cross-sections (hollow tubes vs. solid bars) and different materials (three different types of steel).



Optimizing member selections is not the only way to reduce the cost of a design. You can also change the shape of the truss by dragging joints with your mouse, and you can add or delete members. The drawing at right shows one possible configuration. There are literally millions of others. You might also try an entirely different site configuration. For detailed instructions on all of these optimization strategies—and much more useful information about bridges, engineering design, and the WPBD software—click the Help menu on the upper toolbar. Select How to Design a Bridge from the menu and carefully study each of the steps outlined in the flowchart. Pay particular attention to “Optimize the Member Properties,” “Optimize the Shape of the Truss” and “Find the Optimum Truss Configuration.” These articles contain a lot of helpful hints that will speed your search for a successful, low-cost bridge.

# Design Process Flow Chart





# Vocabulary

**Abutment:** a stone or concrete wall that supports one end of a bridge span. The abutment also acts as a retaining wall, holding back the earth embankments at the approaches to the bridge. An abutment is part of the substructure of a bridge.

**Anchorage:** a foundation structure to which the cables of a suspension bridge are connected. Because the cables support most of the weight of a suspension bridge, anchorages are generally very massive and often extend far below the surface of the earth. In the West Point Bridge Designer, anchorages are represented by pinned supports.

**Asphalt:** a mixture of gravel and bitumen, a by-product of the petroleum refining process. Asphalt is commonly used as a pavement and as a wearing surface for bridge decks.

**Compression:** an internal axial member force that tends to >>>shorten<<< a member.

**Concrete:** a mixture of portland cement, sand, gravel, and water. When concrete hardens, it forms a solid, rock-like substance that can be used to build many kinds of structures.

**Deck:** the floor of a bridge. It directly supports the vehicles and pedestrians that cross the bridge. Bridge decks are usually made of reinforced concrete.

**Chords:** the main horizontal load-carrying members of a truss. In a truss bridge, the top chords normally carry compression, while the bottom chords normally carry tension.

**Diagonals:** truss members that are oriented diagonally. Usually they connect the top and bottom chords together.

**Force:** a push or a pull. Weight is a common example of a force. Force is measured in pounds (in the U.S. system of measurement) or newtons (in the SI system). In the West Point Bridge Designer, all forces are reported in kilonewtons (kN).

**Joint:** a point at which the ends of two or more members are connected together. In a truss, a joint is assumed to act like a frictionless pin or hinge; it does not prevent the connected members from rotating with respect to each other.

**Loads:** forces applied to a structure. On a highway bridge, the loads include the weight of vehicles that cross the bridge, the weight of the bridge itself, and, in some cases, the weight of snow and ice on the structure, and the forces caused by high winds and earthquakes.

**Members:** the individual structural elements that make up a truss. Members are connected to each other at joints.

**Pier:** a part of a bridge substructure that provides intermediate support for a multi-span bridge.

**Span:** the span of a bridge is its length from support to support.

**Substructure:** the foundation of a bridge. It consists of the abutments and piers that support the bridge and transmit its weight to the earth below.

**Symmetrical:** the term "symmetrical" can apply to both a structure and its loading. In a symmetrical structure, the left-hand and right-hand sides of the structure are exact mirror images of each other. In a symmetrical loading, the loads applied on either side of the bridge centerline are identical.

**Tension:** an internal axial member force that tends to <<<lengthen>>> a member.