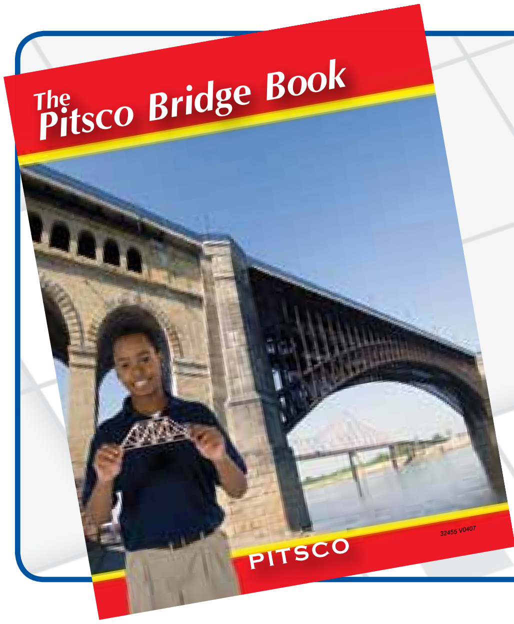

Pitsco Bridge Book Student Guide

User Guide

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Factors in Bridge Design

A number of factors must be taken into account when designing a bridge. An engineer must consider the following when designing a bridge:

- What is the span of the bridge? Span means the length of the bridge from one side (bank) of the river to the other.
- What will be the load on the bridge? Load means how much weight will be on the bridge.
- What type of load will the bridge have? Engineers consider two types of load: live load, which is the weight of the vehicles and people expected on the bridge, and dead load, which is the weight of the bridge itself.
- What environmental factors will affect the bridge? For example, will the bridge need to withstand strong winds, ice, snow, extreme cold, or heat?
- What is the budget allowance for the bridge?
- What are the soil characteristics of the banks?
- What are the soil characteristics of the bottom of the river if support columns are required in the bridge design?
- What is the time frame in which the bridge must be built?

After considering these and other factors, including the aesthetics (attractiveness) of the bridge, the engineer is ready to begin the design.

The number of design possibilities for a bridge is almost limitless. However, certain facts about the design of a bridge are necessary for the engineer to design a strong, durable bridge. Terms for bridges are shown below (Figure 1). Some of these basic facts and terms are described and discussed as follows.

The terms *load*, *compression*, and *tension* are the words commonly used in the design of a bridge. When the load is placed in the middle of a beam, it presses on top of the bridge, creating compression. The bottom of the bridge tries to pull apart, creating what engineers refer to as tension (Figure 2 on the next page).

Bridge Terms

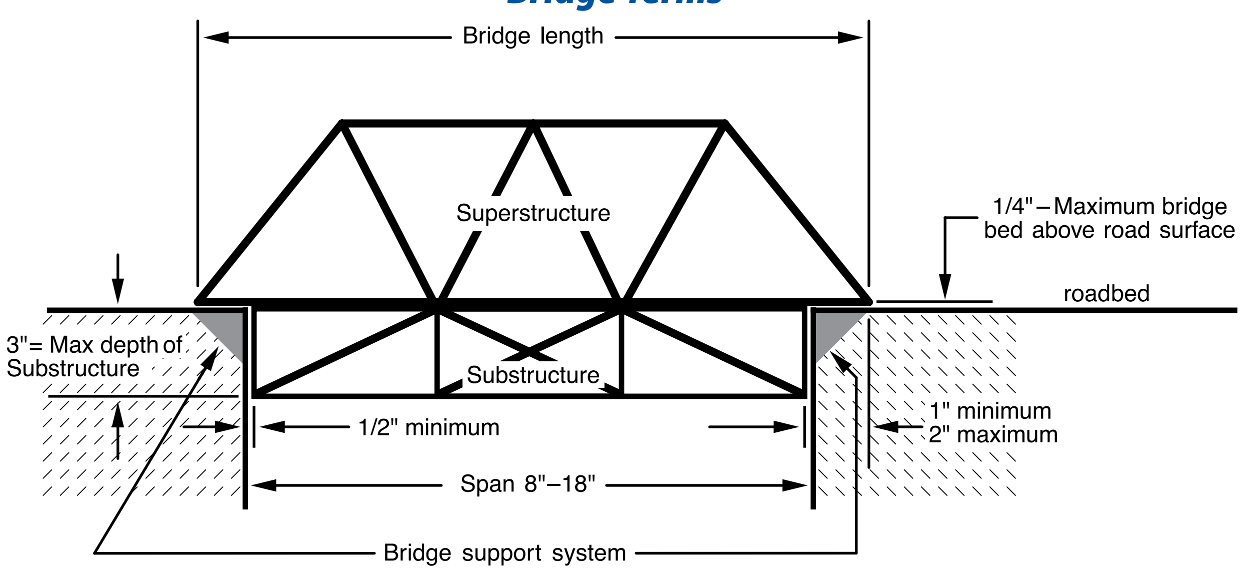


Figure 1 – The effect of racking

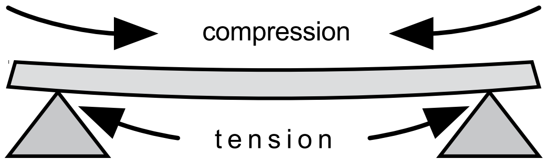


Figure 2

Racking is a kind of stress that distorts a square or rectangle, which causes it to become a parallelogram (Figure 3).

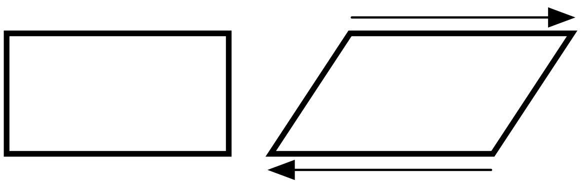


Figure 3 – The effect of racking

To strengthen a square or rectangle, a diagonal brace converts the rectangle into two triangles, making the figure much stronger (Figure 4). The brace serves to keep the length of the diagonal constant. This action minimizes the racking effect. When designing bridges, engineers often convert figures into triangles since triangles are the strongest possible figure.

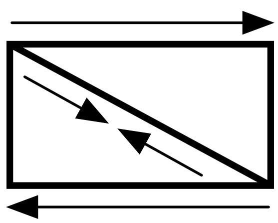


Figure 4

The bridge shown in Figure 5 is a variation of a simple beam with triangular bracing used in the truss design. A truss distributes the load across several parts, or members, of the bridge. If each member helps support the load, then the load is not concentrated on one member, which could fail under that much stress.

The King Post type of truss in Figure 6 transmits the load to all of the members so the roadway (beam) does not take all of the compression and tension. Additional vertical members further distribute the load.

Because a triangle is much stronger than a four-sided figure, designing the truss as shown in Figure 7 would further strengthen the bridge. This type of truss is often used for roofs.

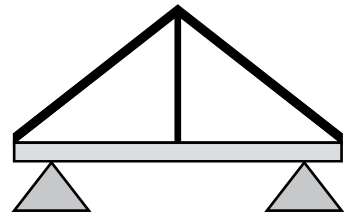


Figure 5 – A simple truss bridge (King Post type)

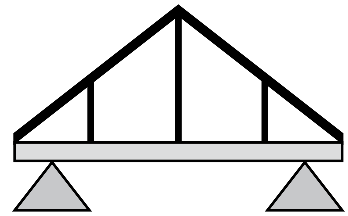


Figure 6 – Adding members to the truss strengthens it.

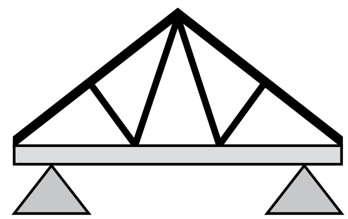


Figure 7 – The triangular position of the trusses increases strength and stiffness.

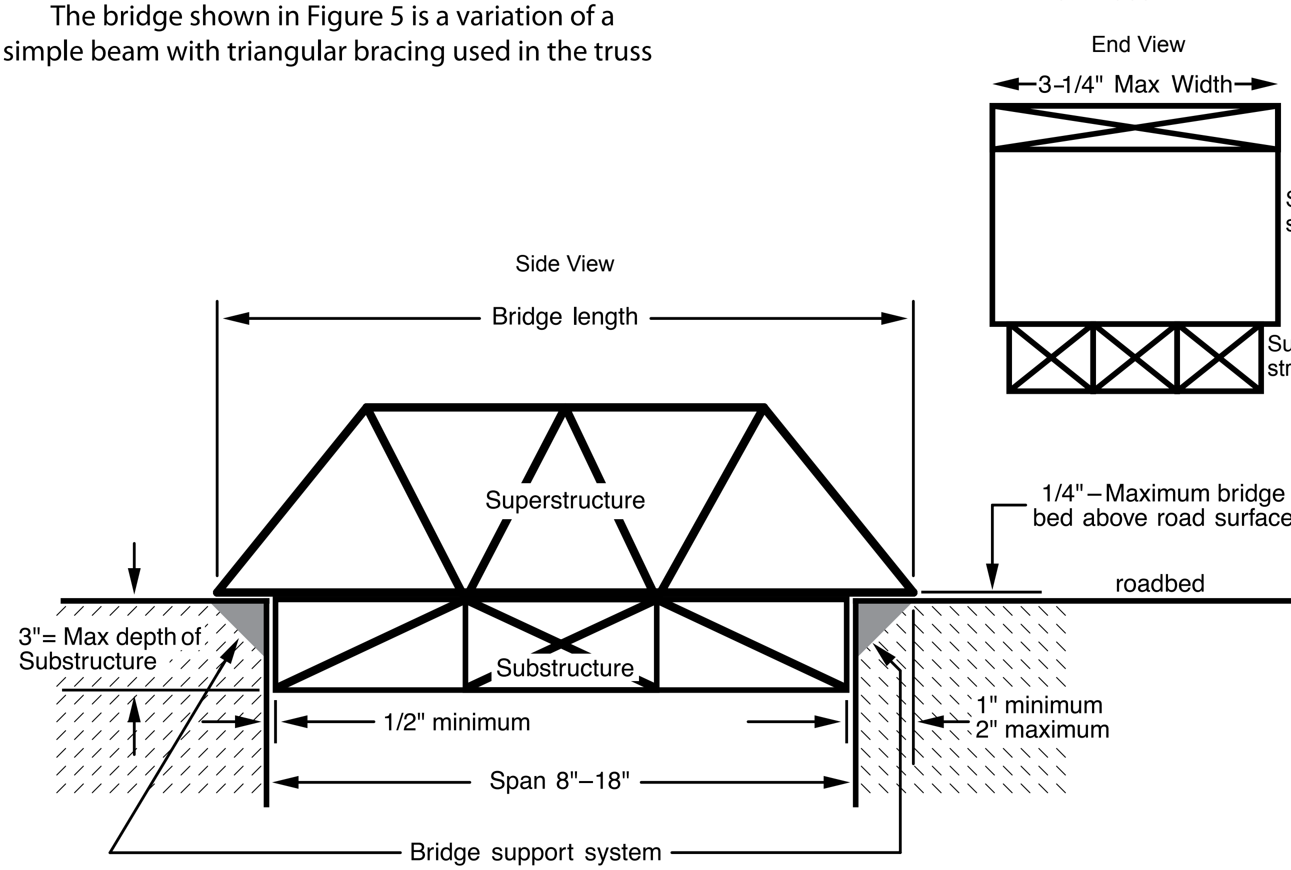


Figure 8 – Typical Model Bridge Terms and General Specifications

The truss structure above the roadway of a bridge is called the superstructure. The substructure is that portion of the bridge below the roadway of the truss bridge. To further strengthen the design of a bridge, an engineer can add a substructure.

Refer to Figure 8 on the previous page for these and other terms used in bridge design.

Designing Your Bridge

To effectively and successfully design a truss bridge, several of the basic methods used by engineers will be followed. Upon completion of the design, you will build a model of the truss bridge. The model enables the testing of the design to determine its soundness or efficiency.

Determine the efficiency of your model by the load (in grams) that your bridge holds. This will give you a failure mass. This failure mass can be divided by the mass of your bridge in grams. The formula looks like this:

Efficiency = Failure Mass (g)/Mass of Structure (g)

Note: If your load is measured in pounds, multiply the number of pounds by 454 grams to find the failure mass in grams.

The steps to be followed in designing, building, and testing your model truss bridge are:

Step 1: Complete truss design and sketch ideas.
Step 2: Complete a three-view sketch (top, side, and end) of the bridge you plan to build.
Step 2b: Drafting (optional)
Step 3: Build the model truss bridge you designed.
Step 4: Test the model truss bridge you designed.

Step 1: Truss Design & Sketch Ideas

Design sketches help the engineer to develop different ideas. Review the two truss design ideas provided at the right. In the remaining blank spaces on this page and the next, sketch trusses with superstructures and some with both superstructures and substructures.

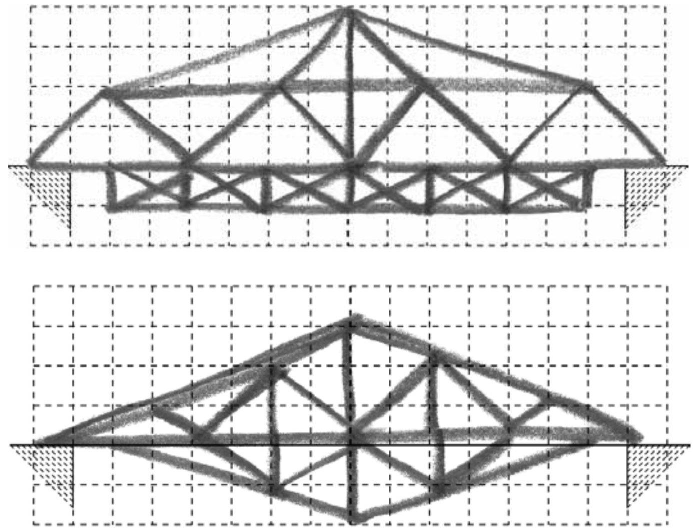
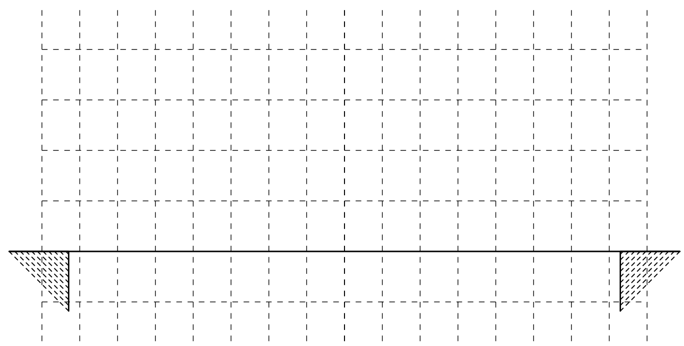
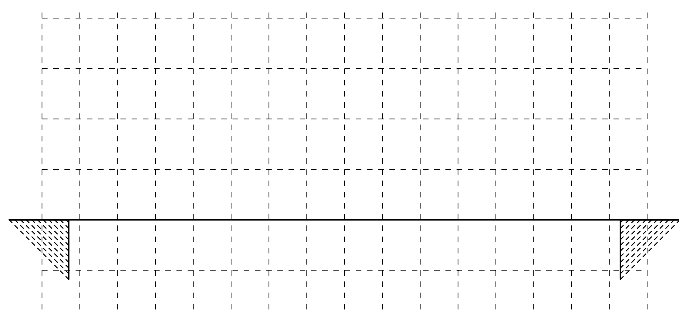
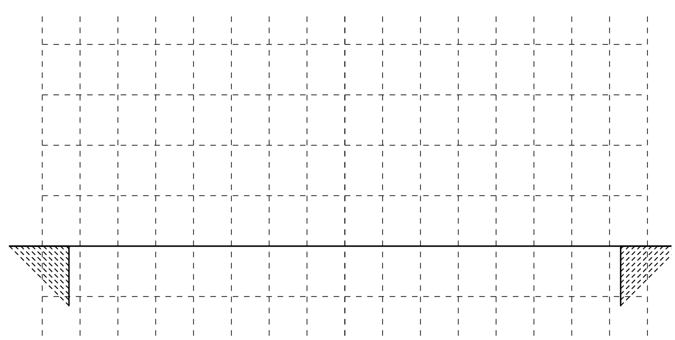
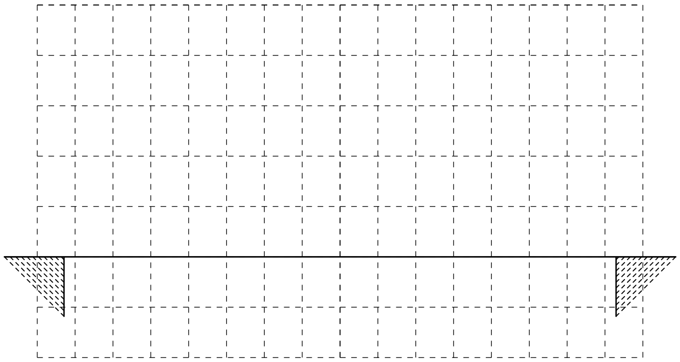


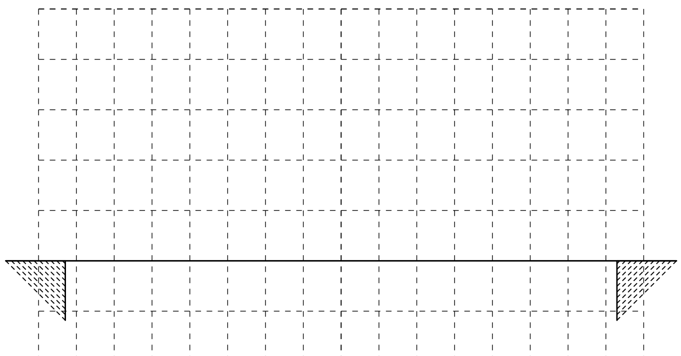
Figure 9 – Hand-drawn sketches of bridge designs on grid paper











Step 2: Complete a Three-View Sketch

Complete the top, side, and end view sketches of a model bridge you plan to build (Figure 10). Draw the views to full scale. If the bridge is to be made of balsa wood, each strip will be 1/8" wide. If it is to be constructed of basswood, each strip will be 3/32" wide.

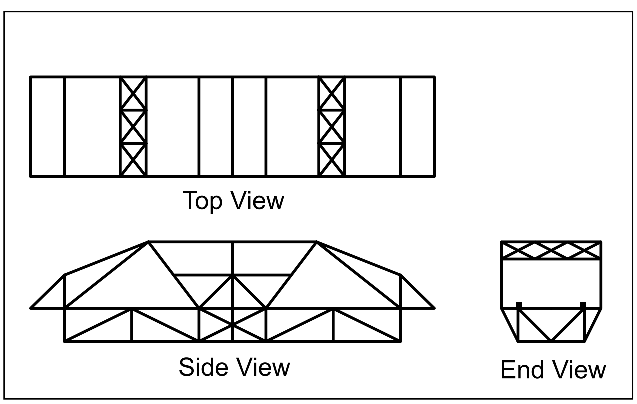


Figure 10 – Example of a completed three-view sketch

If building this bridge for a competition other than a classroom contest, be sure to follow the rules for the bridge competition in which you are competing. Links to the various competitions and organizations can be found in the resources section of this book.

Ask the instructor to provide the exact span for the bridge before beginning a three-view drawing. The span should be the same for all bridges built in the class if the models will be competing against each other.

The roadway surface inside the bridge must be open to allow a block of wood that is one inch thick and two inches wide to pass through the entire length of the roadway surface (roadway size may vary among different competitions) (Figure 11). The block will be used during the testing of the bridge.

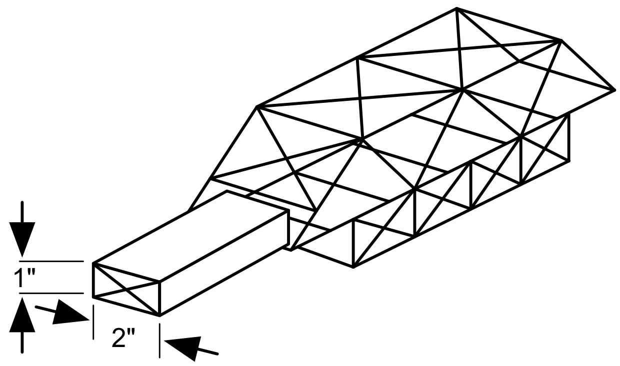


Figure 11 – Diagram showing placement of the test block into the bridge roadway

1. On the large grid sheet provided, sketch the side view of the bridge to full scale. The side view is the one you would see if you were in a boat in the river and the bridge was in front of you (Figure 12).

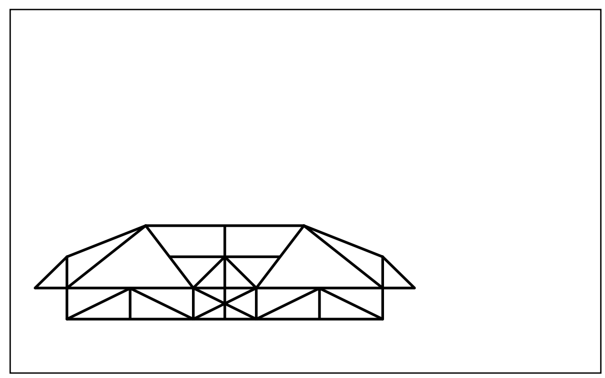


Figure 12 – Side view of the bridge drawn in bottom-left corner of grid sheet

2. Next, draw the top view to full scale (Figure 13). Align it directly above the side view. The top view is the view you would see if you were in an airplane looking down at the top of the bridge.

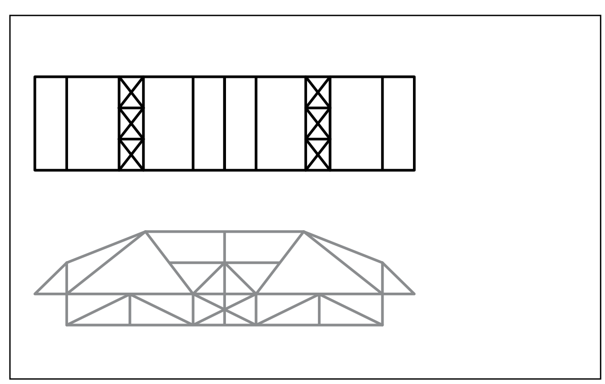


Figure 13 – Same view as Figure 12 but with the top view added directly above the side view.

3. Now, draw the end view (Figure 14). This is the view seen if you were in a car approaching the bridge.

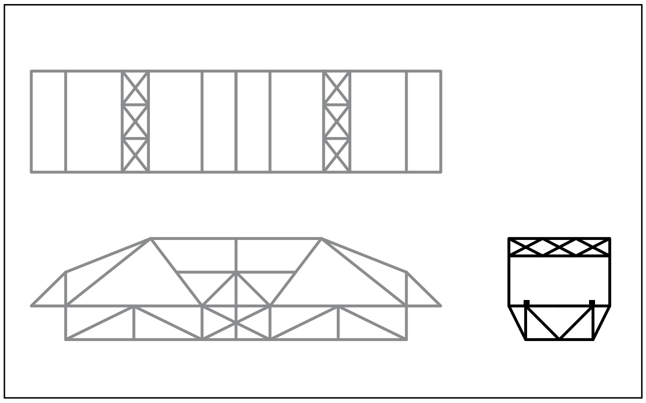


Figure 14 – Same as Figure 13 but with the end view added to the right of the side view

4. Use a ruler or scale to measure the length of the 1/8-inch material the model will require. Remember to include two sides, one top, one bottom, and the substructure (if used) when computing the total amount of material necessary.

Upon completing the three-view sketch, your teacher might ask you to complete a drawing of your bridge. Drawing technical information using international standards and symbols is called drafting. A drawing of the bridge you designed and sketched is called a civil engineering drawing, or it may be referred to as a mechanical drawing.

Figure 15 (on the next page) shows a bridge in three views and includes typical engineering standards of description and dimensioning.

Step 2b: Drafting

Your instructor may include a drafting requirement and will provide information and materials as needed.

Model Construction Methods

When making a wooden model of a bridge, joints are often the most critical aspects of making the model as strong as possible. Once a joint fails, the structural integrity of the entire bridge is weakened. This weakening starts a chain reaction that can cause the total failure of the structure.

Using the appropriate glue is also important in building a strong bridge. An aliphatic-type wood glue is recommended, such as Pitsco Colored Structures Glue. Its color enables quick identification of joints and the amount of glue used, which can be important in various competitions. Pitsco HD Bond II also works well.

While building, consider that glue doesn't work well on the end grain of wood. You make a stronger bridge if the joints are made with the side grain of the wood.

Increase wood joint strength by utilizing various joint types (Figure 16). A butt joint is easily broken; the notched joint can endure more stress. In addition to using better types of joints, making tight-fitting joints also enhances the joint strength. Contrary to what you might think, adding extra glue around a loose joint will do little to strengthen it.

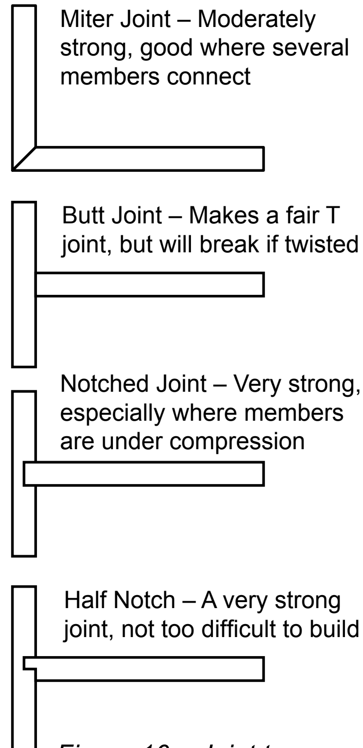


Figure 16 – Joint types

Braced joints, although difficult to make, provide the combined effect of the notched and half-notched joints (Figure 17). This provides an extremely strong joint.

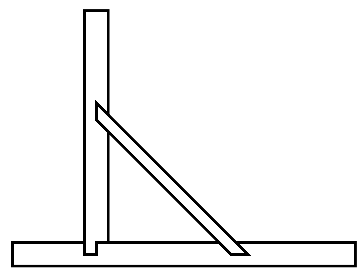


Figure 17 – Braced joint

A final suggestion before gluing joints is to scrape the wood where the joints will be glued, using a hobby knife. The natural oils from your hands touching the wood prevents the best possible bond to the glue. Scraping the joint surfaces helps remove dust and oil.

The following drawings describe construction tips that should assist you in building your model bridge. Review each tip carefully.

Set a diagonal brace between two parallel pieces. This technique helps prevent racking.

1. Lay the diagonal piece across (Figure 18). Mark with a pencil (Figure 19).

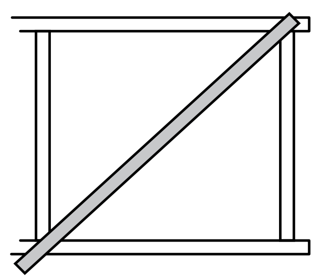


Figure 18

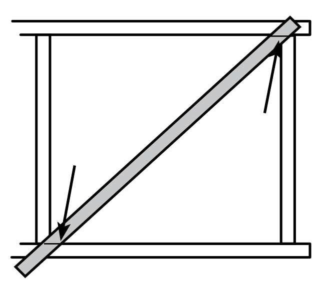


Figure 19

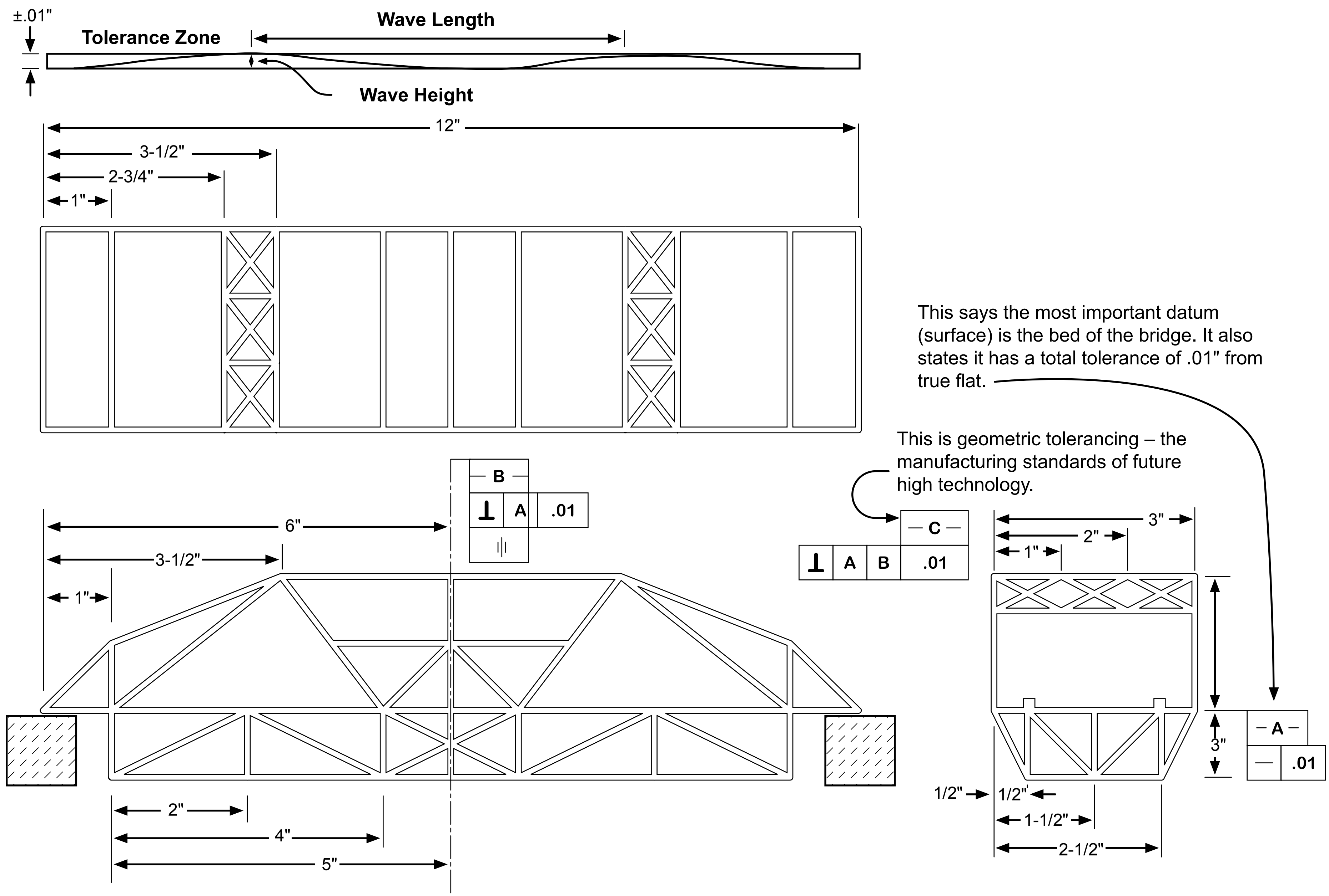


Figure 15

Designed by:	Scale:	Date:
Class:	Wood used:	Inspected by:

2. Cut off the tips of the ends so they fit into the corners (Figure 20 on the next page).
3. Glue the piece in place (Figure 21).

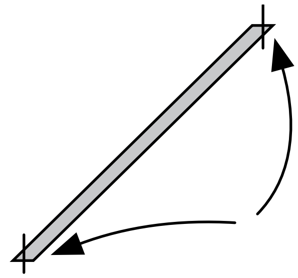


Figure 20

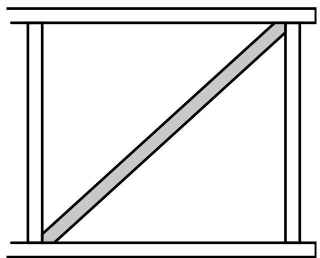


Figure 21

If you have trouble fitting a piece in a tight spot, try picking it up with a pair of tweezers instead of your fingers.

Use as many pins as needed to hold the wooden pieces in place. Cross two pins over a strip of wood to hold it in place (Figure 22).

Use foam board as a working base. It holds the pins better than cardboard.

A sharp knife gives cleaner, faster cuts than a saw. Cut on a protected surface and away from yourself. Alternatively, use the Pitsco Timber Cutter to cut the wood pieces. The Pitsco Lil' Termite Sander can be used to accurately sand the wood members to a tight fit.

Step 3: Constructing the Bridge

Check that you have the following items:

- Balsa wood or basswood strips
- Hobby knife or Pitsco Timber Cutter
- Structure-Building Pins or T-pins
- Three-view sketch or drawing (full scale)
- Waxed paper (12" x 18")
- Masking tape
- Pitsco Colored Structures Glue or HD Bond II
- Ruler or scale
- Foam board (minimum 12" x 18")
- Square
- Tweezer set (optional)
- Pitsco Construction Caddy II (optional)
- Pitsco Accu-Fixtures Set (optional)
- Pitsco Timber Tester (optional)
- Pitsco Lil' Termite Sander (optional)
- Small clamping devices such as Bridge Construction Clips or clothespins (optional)

1. Using masking tape, attach your full-scale, three-view sketch or drawing to a piece of foam board.
2. Cover the three-view drawing with the waxed paper, and tape it in place. If a Pitsco Construction Caddy II is available, slide the foam board into the slotted ends of the caddy.
3. Cut strips of wood to fit the outline of the bridge, which the three-view sketch provides. Use the hobby knife or the Pitsco Timber Cutter to cut the wood. To ensure a nice fit, cut the pieces a little long on the first cut and trim the ends to fit. Pin each piece into place (Figure 22).

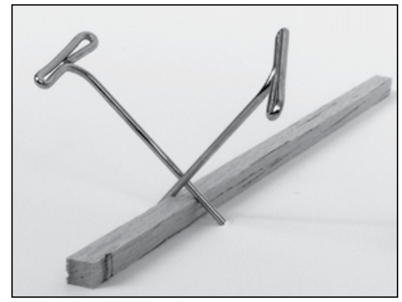


Figure 22 – Cross two pins over the wood to hold it in place.

4. Glue the pieces in place. Surfaces where strips connect should be coated with a thin film of glue. Use pins to hold the pieces flat (Figure 23).

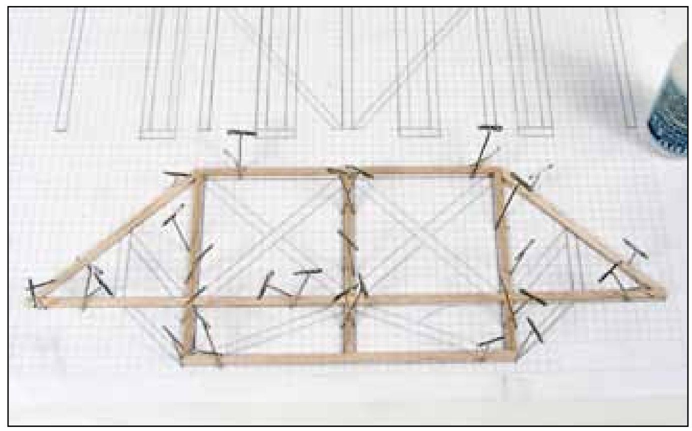


Figure 23 – Building the outline of the bridge side

5. After the outline has been glued into place, fill in the wood strips that make up the other members of the first side of the bridge. Make sure the joints are completely dry before moving the pins.
6. After the first side has dried, remove the pins and carefully lift the side off the waxed paper. Place the finished side on a flat surface.
7. Repeat Steps 1-6 to build the second side.
8. Cut and construct the cross braces that support the roadway of the bridge (Figure 24). Build each of them exactly the same length.

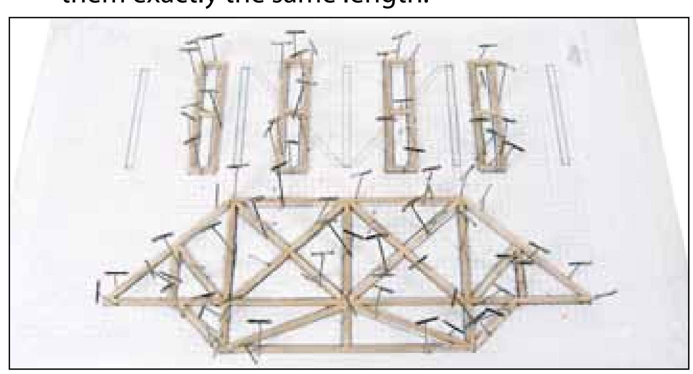


Figure 24 – Side of the bridge and roadway braces completed

9. Cut the cross braces that support the top of the bridge. Make each of them exactly the same length. **Note:** These instructions show the top braces attached first. Depending on the design, it might be best to attach the roadway cross braces first. Before starting Step 10, review the design and start with whichever set of braces will best stabilize the structure.
10. Pin one side of the bridge so it is perpendicular to the foam board – note the top is facedown. Glue the top braces to the side (Figure 25). Use a square to ensure the side is perpendicular to the cross brace members.

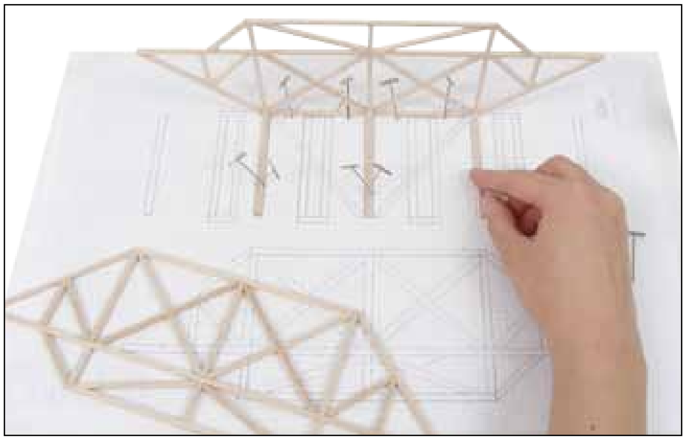


Figure 25 – Cross sections to go between bridge halves

11. Add glue to the other end of the braces and pin up the other side parallel to the first side. Make sure all the pieces fit together squarely and are not loose (Figure 26). Let this dry.

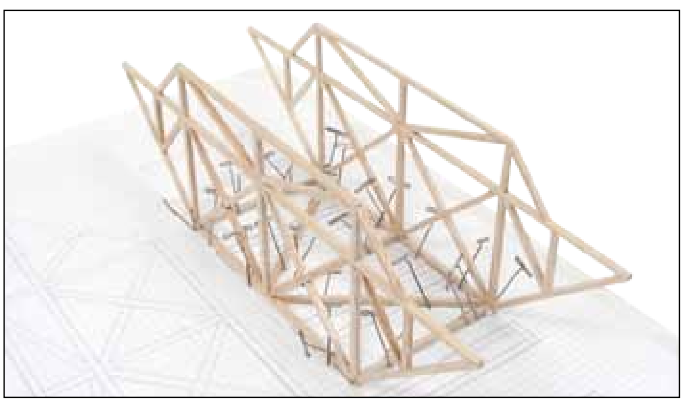


Figure 26 – Glue and pin up the second side in place.

12. Pull out the pins and carefully remove the bridge from the work surface. Turn over the bridge. If needed, pin the bottom of the bridge to hold it in place.
13. Apply glue to the sides where the roadway cross braces will be attached. Put the cross braces in place. If needed, you can clamp the braces in place with clips while they dry (Figure 27).

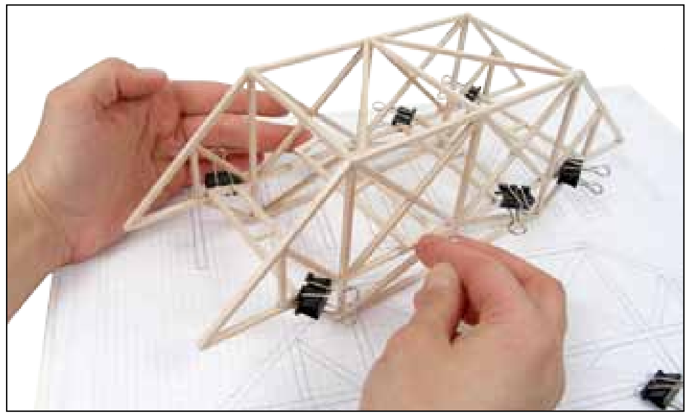


Figure 27 – Roadway cross braces glued in place

14. Remove the clamps, if used. Check all joints to ensure they are well glued and that all members are securely in place. The bridge you designed and engineered is now a model bridge (Figure 28).

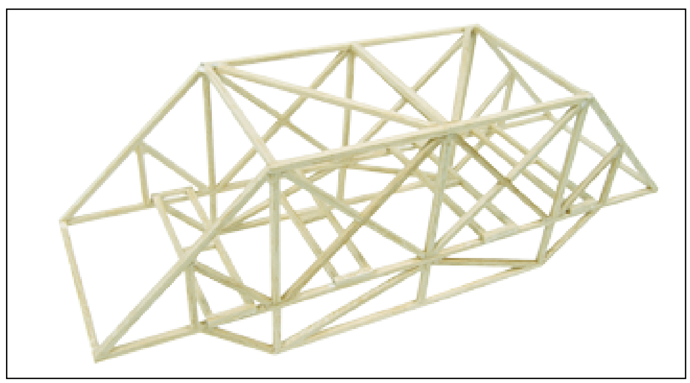


Figure 28 – A completed bridge

Step 4 Testing

Your instructor should first examine the completed bridge to make sure it meets all the specifications and to verify all its joints are glued correctly. Test your bridge according to the instructions for the type of tester used in your classroom.

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