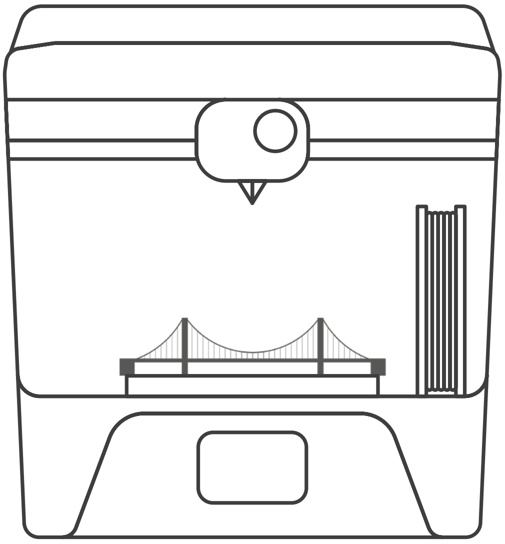
Make a Suspension Bridge

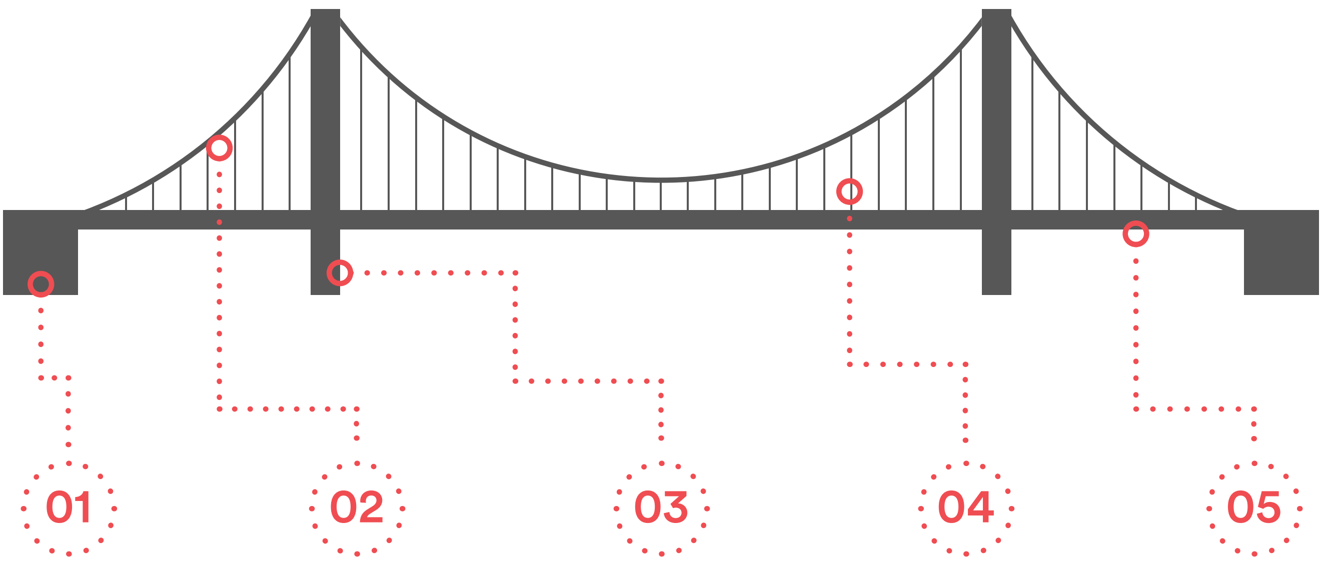


PrintLab

About Suspension Bridges

Hello!

In this project, you will be designing and 3D printing a model of a bridge! Bridges are structures that carry a road or path over obstacles such as rivers and railways. This project focuses on a specific type of bridge called suspension bridges, which can span extremely long distances. The aim of creating the model is to help you understand how suspension bridges work, together with the forces that act upon them. First of all, take a look at the below diagram, which shows the key components of a suspension bridge. You may also wish to research suspension bridges on the internet to get an overview of their appearance.



01 – Anchorages
Anchorages are the connection point for the cables, keeping them tight. They must have a large mass and are usually constructed from concrete or rock.

02 – Main Cables
The main cables are made up of hundreds of wires bundled together! They stretch from one anchorage to the other and are the components that the deck 'hangs' from.

03 – Towers
The main purpose of the towers are to support the main cables and transfer load down to the ground. Generally the design consists of 2 piers and bracing between them.

04 – Suspension Cables
Generally made of steel, the suspension cables are strong and flexible and connect the main cable to the deck.

05 – Deck
The deck consists of the road/path and the structure beneath it, which usually includes large girders and cross-beams to strengthen the deck.

Model Overview

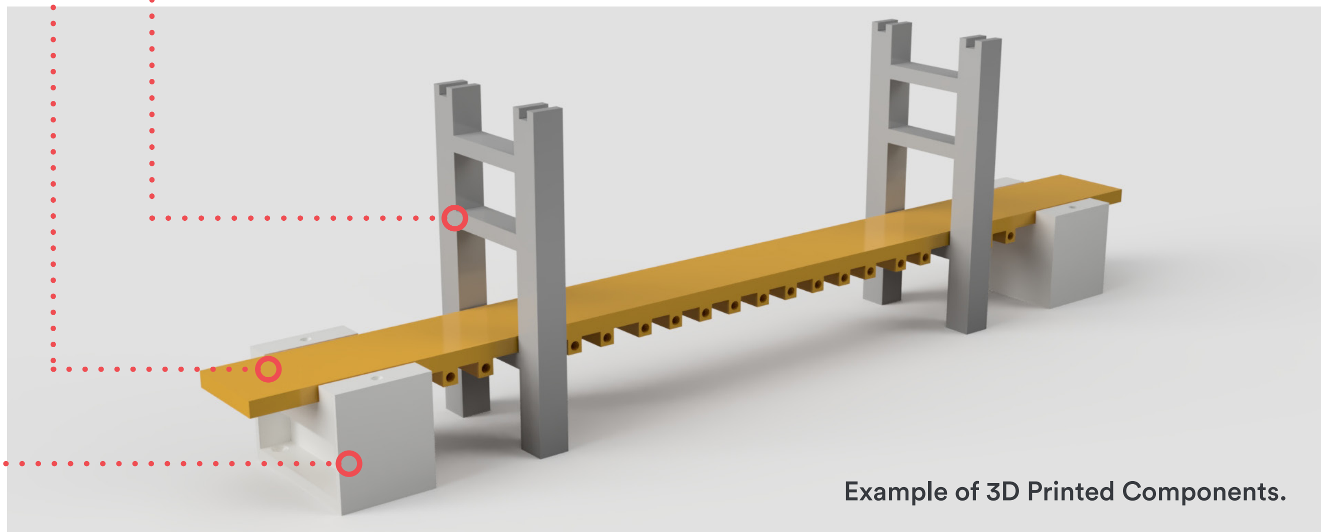
01 You must design and 3D print 2 anchorages. These components must be designed in a way that allows the main cables to attach to them.

02 The main cables will be represented by cotton string that is roughly 1-2mm in diameter. They will span across the towers and attach to the anchorages on either end of the model.

03 You must design and 3D print 2 towers. The towers must be braced sufficiently and allow the roadway to pass through them.

04 The suspension cables will be represented by thin thread, which will be tied to the main cables.

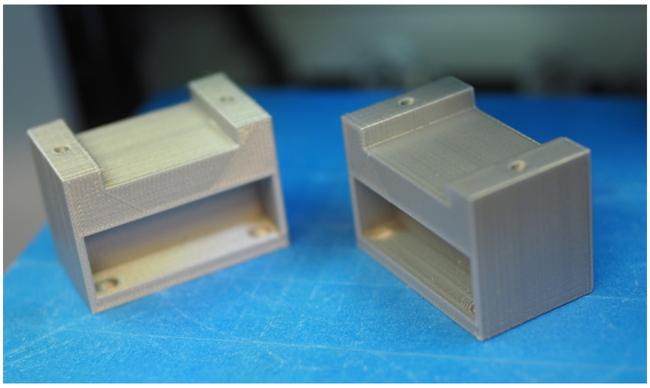
05 An STL file of the deck will be provided for you to 3D print. The deck consists of 3 sections, connected by a set of 3D printed pins.

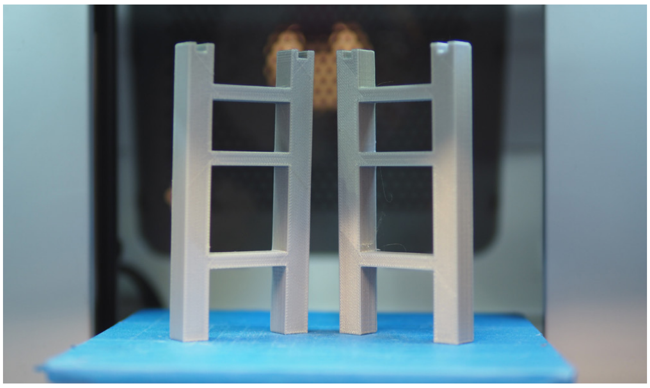


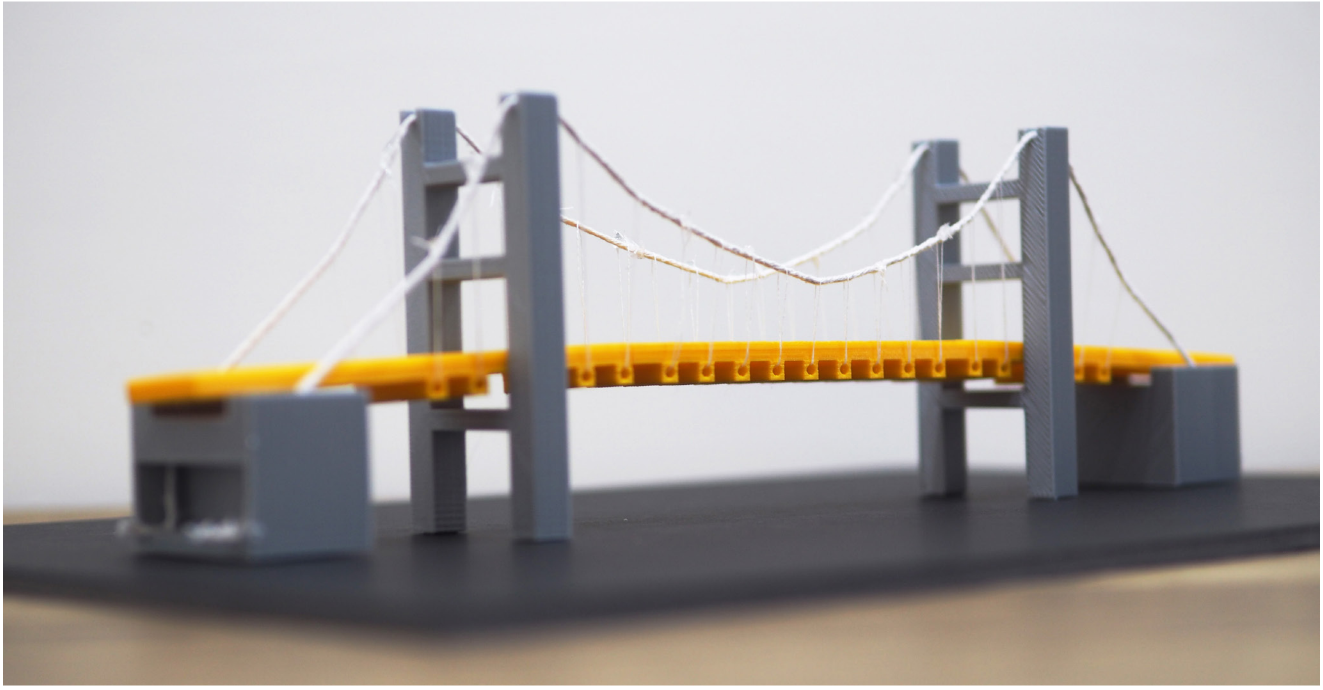
Example of 3D Printed Components.

Model Example

Before you begin designing, take a look at the example designs below. You may use these as inspiration to create your own unique versions.





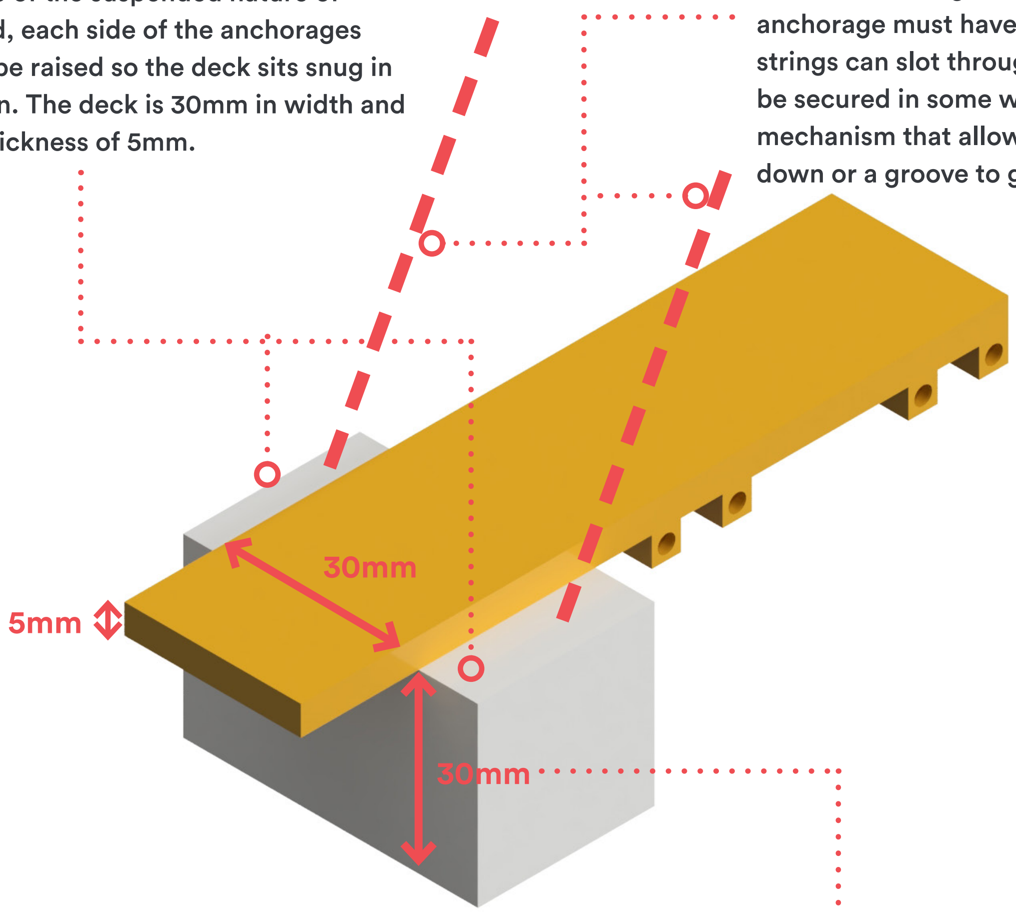


Design the Anchorages

This page explains the criteria and constraints for the anchorages. Look through the information and move on to design the anchorages in CAD software.

Because of the suspended nature of the road, each side of the anchorages should be raised so the deck sits snug in between. The deck is 30mm in width and has a thickness of 5mm.

Refer to the images on page 3. Your anchorage must have holes where cotton strings can slot through at an angle and be secured in some way. This may be a mechanism that allows you to tie the string down or a groove to glue down the string.



The maximum size allowed for each anchorage is 55×35×50mm (w x l x h). You will require 2 identical anchorages for the model.

The deck should rest on the anchorage. The bottom of the deck will sit 30mm from the ground. Bear this in mind when designing the anchorage.

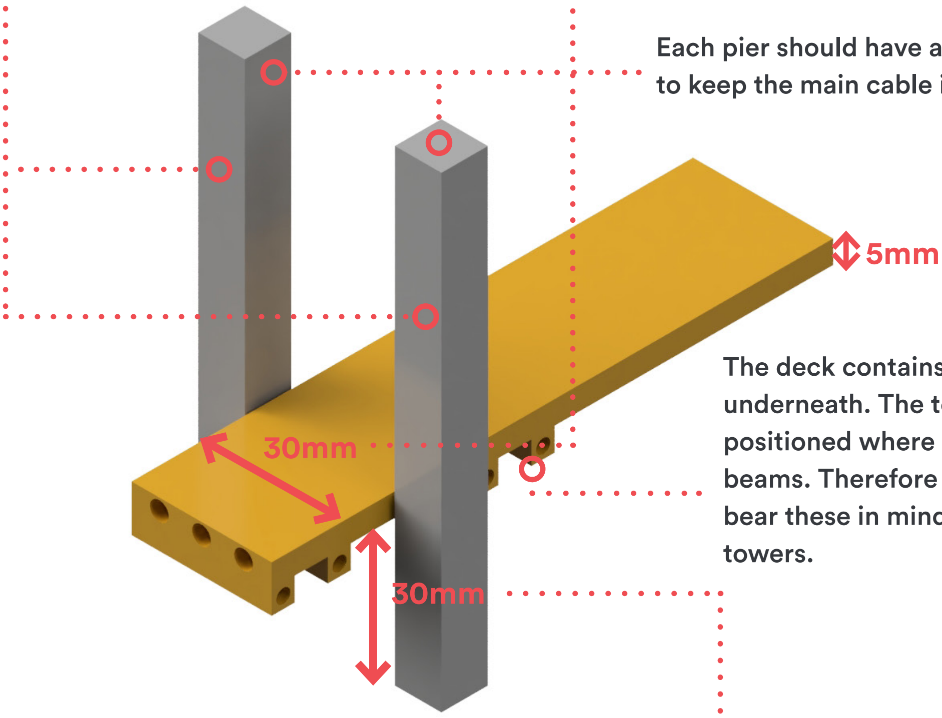
Design the Towers

This page explains the criteria and constraints for the towers. Look through the information and move on to design the towers in CAD software.

Refer to the images on page 3 for guidance. Your towers should consist of 2 tall piers, which have beams/bracing to connect them together.

The 2 piers must allow for the deck to pass between them. The deck is 30mm in length. Bear this in mind when determining the distance between your piers.

Each pier should have a groove at the top to keep the main cable in place.



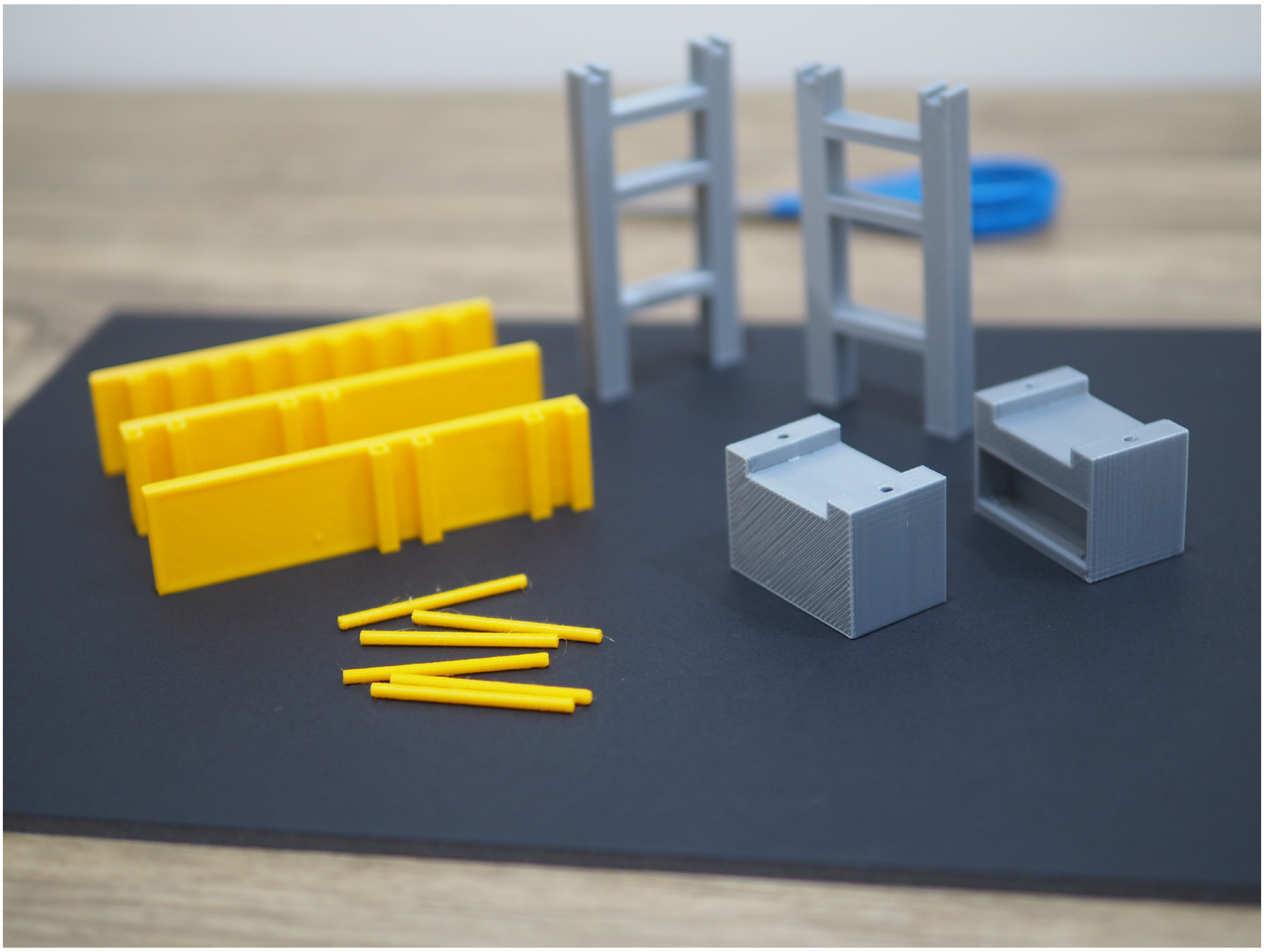
The deck contains cross-beams underneath. The towers will be positioned where there are no cross-beams. Therefore you do not need to bear these in mind when designing the towers.

The maximum size allowed for each tower is 60×15×105mm (w x l x h). You will require 2 identical towers for the model.

The deck should rest on a beam, which spans across the 2 piers. The bottom of the deck will sit 30mm from the ground. Bear this in mind when designing the beam across the piers.

3D Print your Components

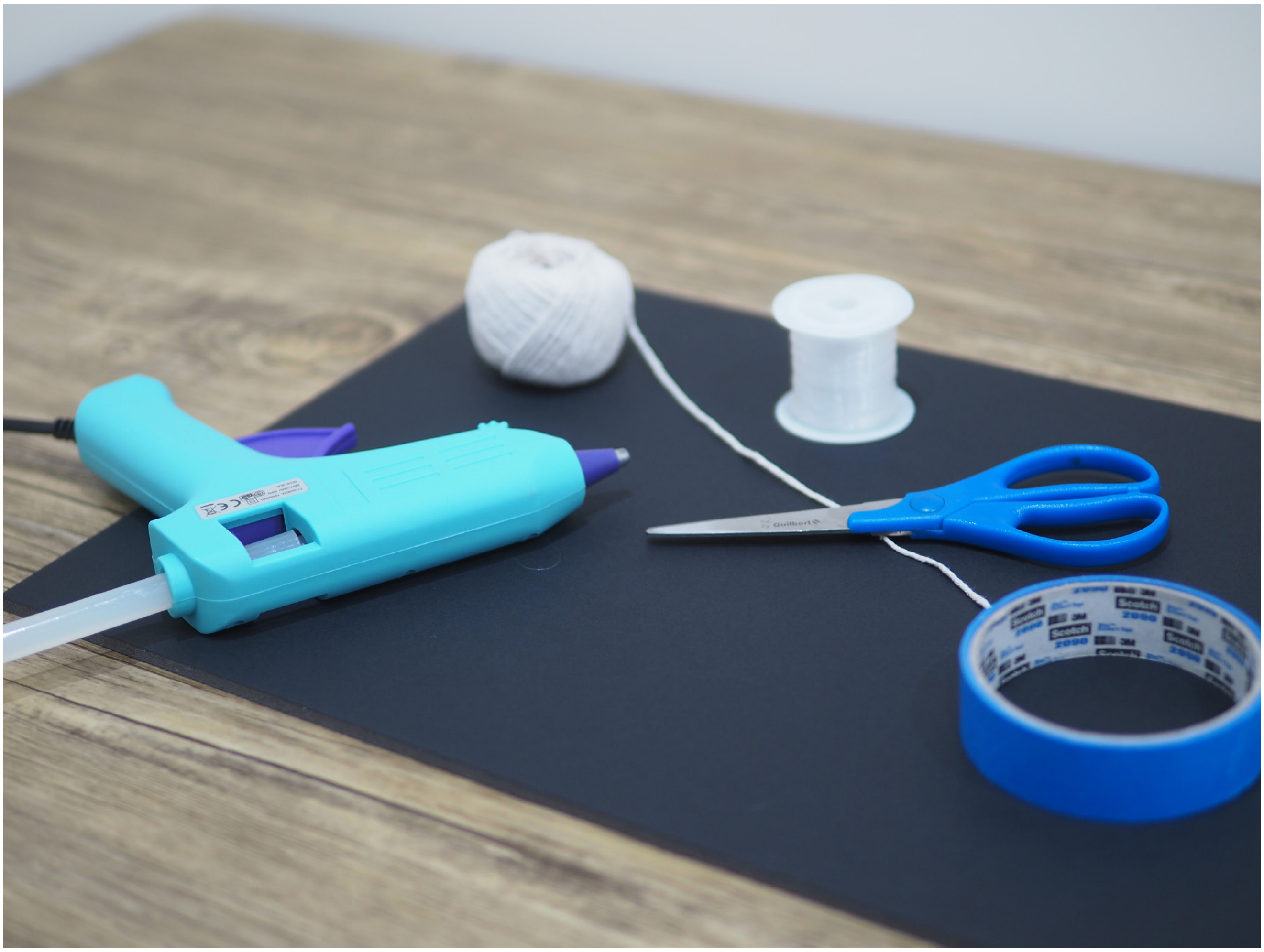
Once you have completed the designs for the anchorages and towers, export the STL's and prepare them for 3D printing in slicing software. Remember to 3D print the deck and pins, which are available in the project materials. We advise you to print the deck pins solid (100% infill) to ensure they have adequate strength to hold the deck components together. The below image shows all the 3D printed components required to build your model.



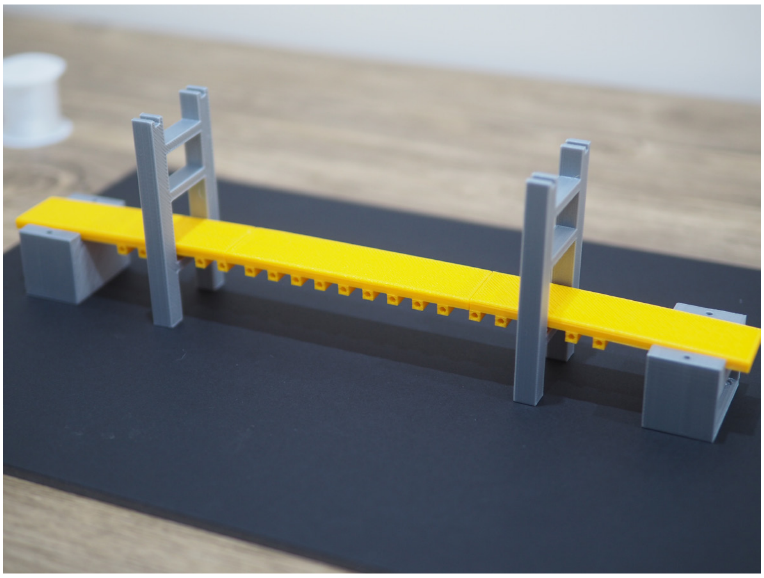
Model Equipment

In addition to the 3D printed components, you will require the following materials to build your model:

- 1 x base platform (roughly A3 size) e.g. foam board
- 1 x hot glue gun
- 1 x ball of cotton string
- 1 x reel of thread e.g. knitting thread
- 1 x roll of masking tape



Model Assembly

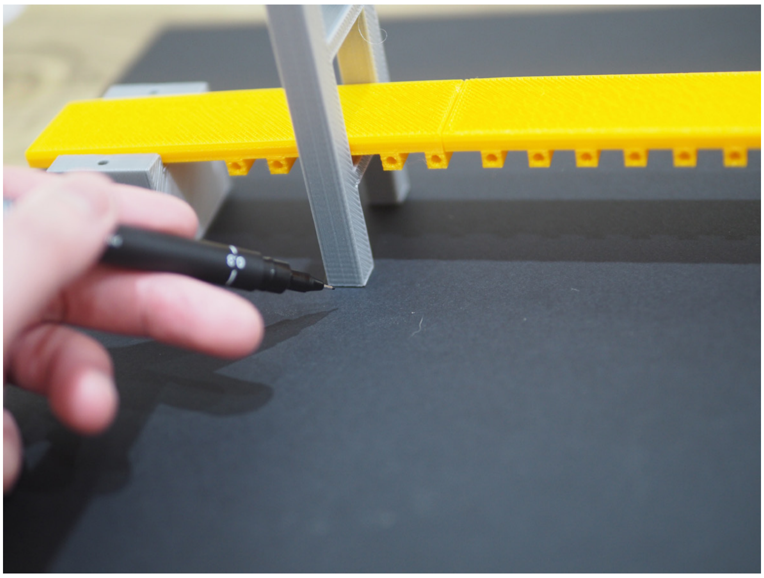


1.

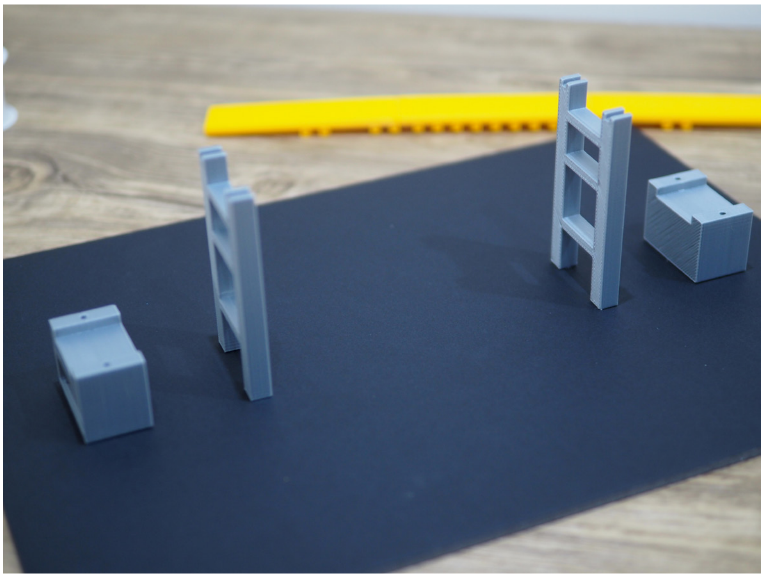
Use the deck pins to connect the 3 deck pieces together. Then place your 3D printed components onto your base as shown here. The anchorages should sit 1-2cm from the edge of the deck on either end. There is a gap in the deck, where there are no cross-beams. The towers should sit in the centre of this space.

2.

You will be using glue to fix the anchorages and towers to the base. Use a pen/pencil and draw around the base of the components. The marks will be used as a reference point when gluing the components down.



Model Assembly

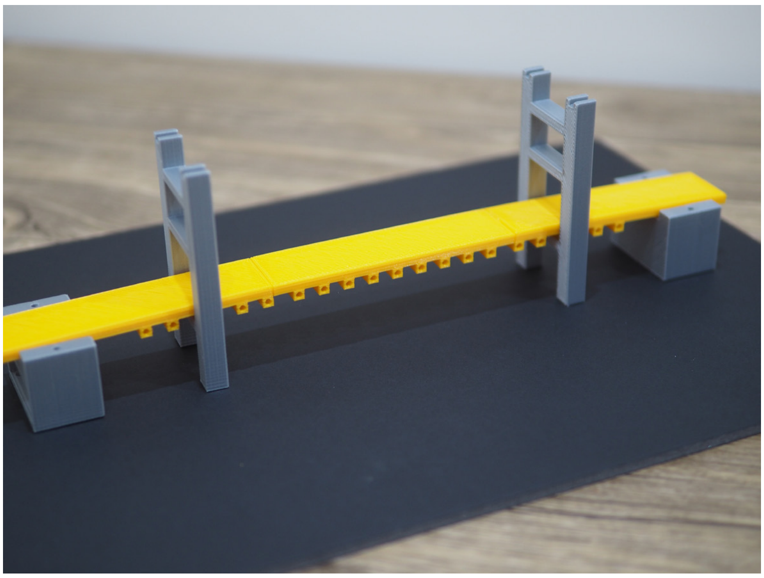


3.

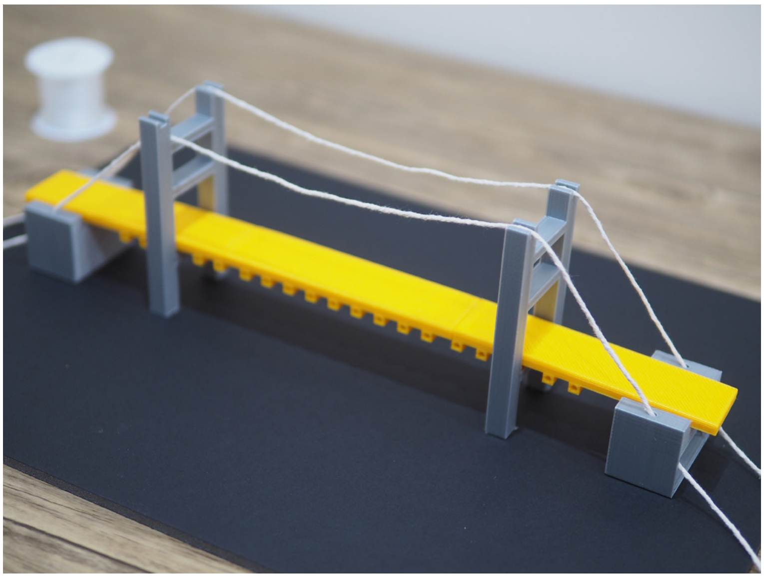
Use a hot glue gun to fix the anchorages and towers to the base platform. Align them with the reference points you previously drew.

4.

Slide the deck into the model and position it so there is an equal amount of overhang on each end. The deck should be resting on the anchorages and the beams of the towers.



Model Assembly

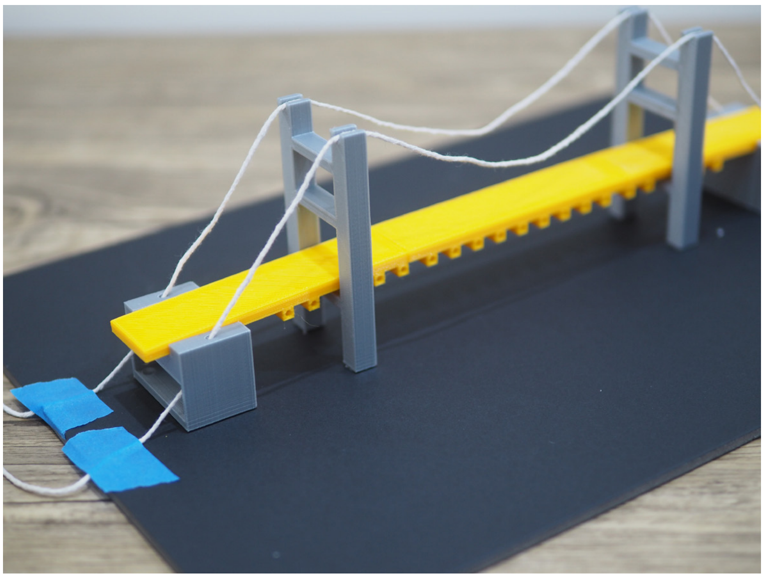


5.

Cut 2 lengths of cotton string (approx 40cm). Slot them through the anchorages at either end - they should also rest in the grooves on top of the towers as shown in this image.

6.

Use masking tape to fix the cotton strings down to the platform at one end. Push the cotton string down in the middle of the model so they form a nice curve as shown in this image. Tape the other end of the cotton strings down to the platform. Once everything is taped in position, you should be able to push down on the string in the middle and feel some tension.



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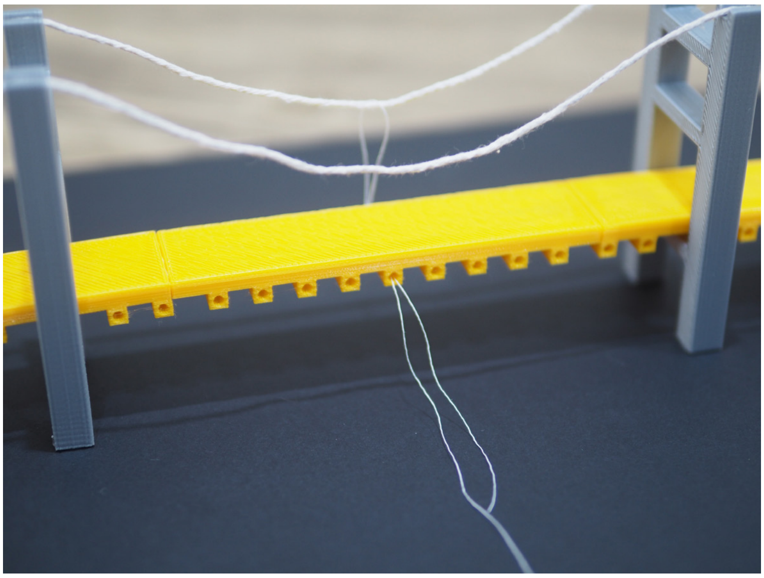
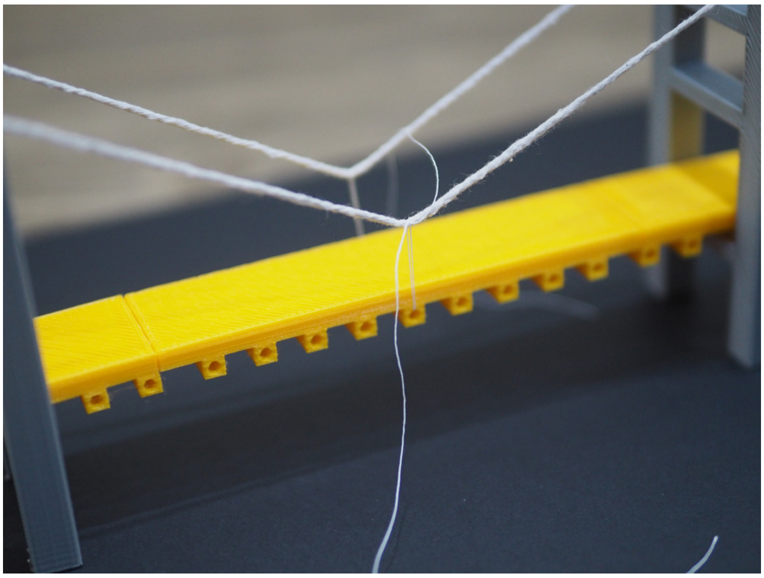


7.

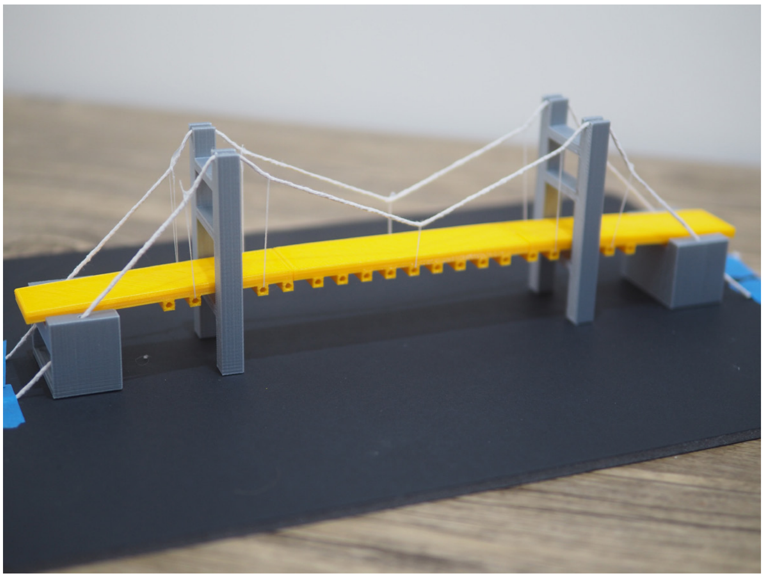
Cut a length of thin thread (approx 30cm). Look for the central beam in the deck and place the thread through the hole. Wrap the thread over the cotton string and back through the same hole.

8.

Wrap both ends of the thread over the other cotton string and tie a knot. Pull the knot tight until you feel the deck lift ever so slightly. At this point, you can either turn the knot into a double knot to secure it or alternatively, place a drop of glue onto the single knot. With the knot secured, trim the loose ends of the thread to make it nice and tidy.



Model Assembly

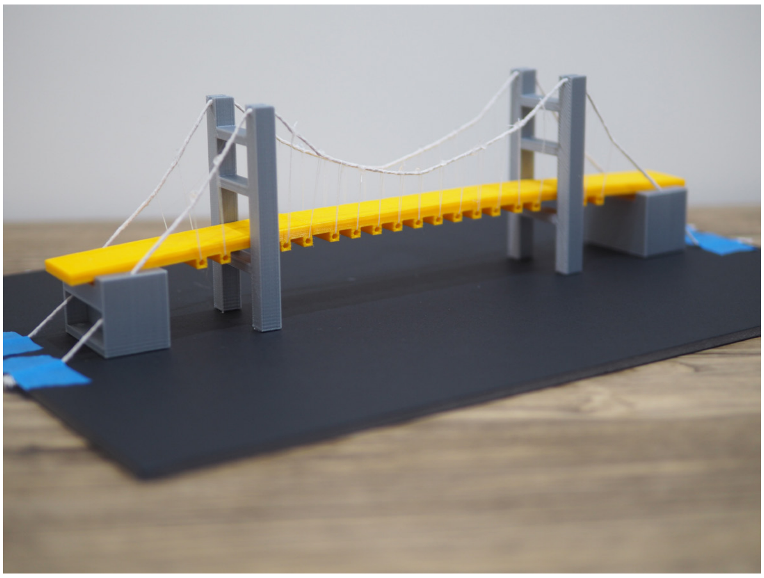


9.

Continue adding more suspension cables. We advise that you move on to add the cables either side of the towers next.

10.

Once all threads have been attached, your model should look similar to this image. If you don't have time, it is not necessary to add strings to every cross-beam in the deck. However, ensure you have an even amount on each side of the model.



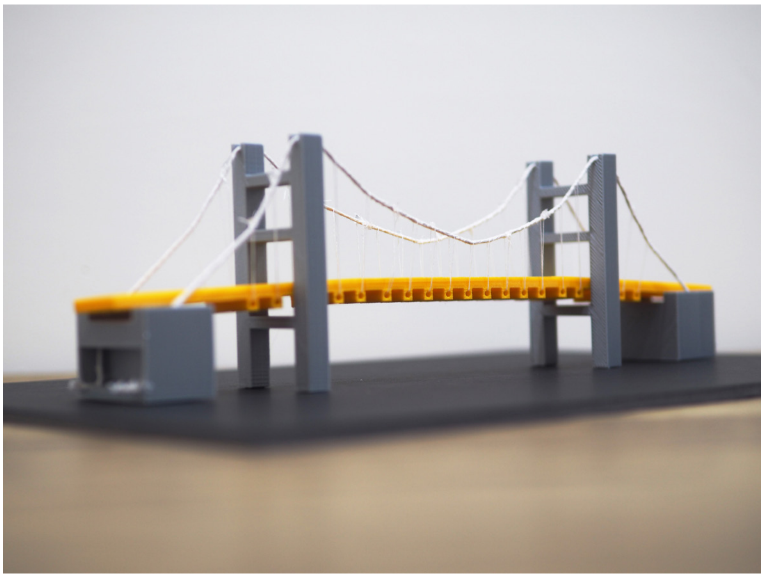
Model Assembly

11.

The final step is to secure the cotton strings to the anchorages. The method to do this will depend on how you designed the anchorages. In this example, the ends of the string were inserted into grooves and glue was used to secure the string in place. Play around with the tension you leave in the string before you secure them. The deck should be slightly 'suspended' and not just rest on the tower beam and anchorages.

12.

Your final model should look similar to this image. In the next section, you'll be investigating the various forces that may act upon it.

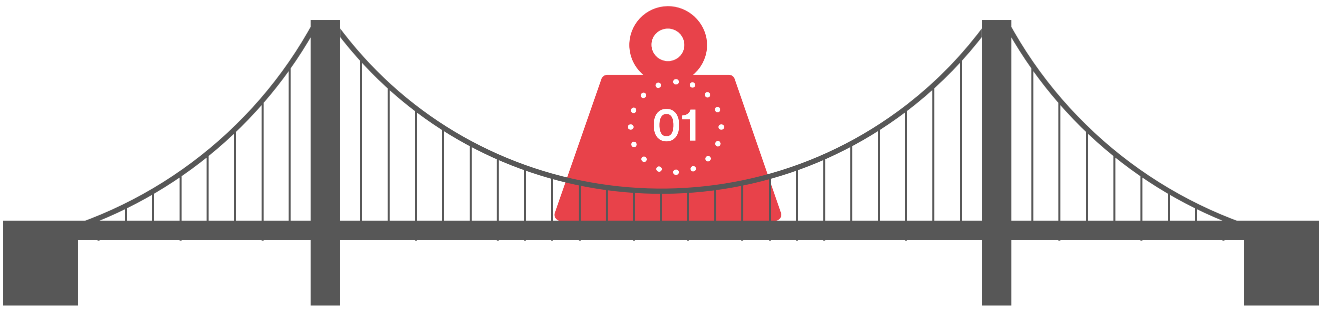


Analysis: Tension & Compression

Tension and compression are 2 key forces that act on all suspension bridges. Tension refers to the force that attempts to pull a material apart. Imagine a game of tug of war - when both sides pull, the rope becomes under tension. Compression is a 'pressing' force. Imagine pushing down on a spring - this puts the spring under compression.

In the case of suspension bridges, there are generally 2 main loads that act on the bridge, which result in tension and compression in the various components. 'Dead' load refers to the weight of the bridge itself. 'Live' loads refer to the weight of people, vehicles and other objects that temporarily exert force on the bridge.

Experiment 1.



Place a small weight on the deck of your suspension bridge model. Remember that you model is not made from steel cables like real suspension bridges so don't overload it. Once the weight is placed on the deck, go through each component and note down whether you think it is in tension or compression.

Analysis: Torsion & Shear

Torsion and shear are another 2 forces that act upon suspension bridges. Torsion is a 'twisting' force and can be potentially dangerous to a suspension bridge structure if the design is not thought through. An example of torsion is when high wind causes suspension bridges to rotate and twist like a rolling wave.

Shear is a force that occurs when 2 fastened structures are pushed or pulled in opposite directions. In the case of a suspension bridge, shear can occur when the main cables are pulling the compressed tower sideways. Considering shear when designing suspension bridges will ensure the towers are not 'ripped' apart.

Experiment 2 & 3.

2. Blow on your suspension bridge model as if it was a gust of wind on a real bridge. Take note of which components move and how. Discuss ways in which you could improve your model to reduce the effects of torsion.

3. Press down on the main cable next to a tower. Take note of how the tower is fixed in a position but is forced in a sideways direction. When the tension in the main cable is correct, the main force acting on the tower is compression downwards. However, shifts in live loads and technical errors can cause a shear effect. Discuss ways in which you could improve your model to reduce the effects of shear.