CANTILEVER BRIDGE

OBJECTIVE:

You will understand how the forces of compression and tension work in a cantilever, and will construct a model of a cantilever bridge.

INTRODUCTION:

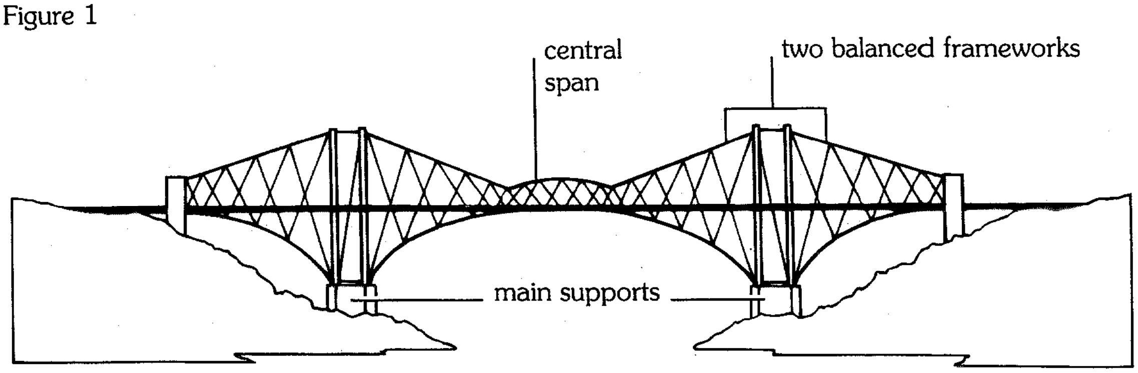
A cantilever is essentially a beam supported at only one end. In most beams used in architecture (see 4.01), the beam is supported at both ends and the force of the beam's weight acting downward causes the beam to bend in the middle, so that the top of the beam is under compression (squeezed) and the bottom is in tension (stretched). In a cantilever, on the other hand, because it is supported at only one end, the top of the beam is under tension, while the underside is under compression. A cantilever bridge most commonly consists of two cantilever frameworks balanced around two piers or supports and joined by a simple span in the center (see figure 1).

Simple cantilever bridges, usually constructed of wood with stone foundations, date back several hundred years in India and the Far East. Steel cantilever bridges were introduced in Europe and the United States in the mid-nineteenth century.

Like bridges constructed of free-standing arches (see 4.02), cantilever bridges are able to withstand large loads. A key advantage of the cantilever bridge is that no special supporting structures (called falsework) are required while the bridge is under construction. In conventional stone-built arch bridges, supports such as wooden or metal scaffolding are required during the building of the bridge.

Nowadays, many arch bridges are made of steel or reinforced concrete and during construction rely on the cantilever principle. The sides of the arch are self-supporting, and once the two halves are joined together, the bridge becomes load bearing and is able to carry traffic. The steel arch Sydney Harbour Bridge in Australia, built in 1932 and 1,650 feet across, was constructed in this way. True cantilever bridges include the Quebec Railway Bridge in Canada, the Firth of Forth Railway Bridge in Scotland, and the Transbay in San Francisco.

Figure 1



TIME NEEDED:

1 hour

MATERIALS:

- cardboard box, at least 10 in. x 8 in. x 4 in. (e.g., laundry detergent box)
- 6 pieces of heavy cardboard of the following sizes:
  - 16 in. x 12 in.
  - 15 in. x 3 in.
  - two 7 in. x 3 in.
  - two 3 1/2 in. x 3 in.
- glue
- masking tape
- X-acto® knife
- 10 25g (1-oz.) weights
- 10 50g (2-oz.) weights
- 2 12-in. lengths of string
- 2 paper clips

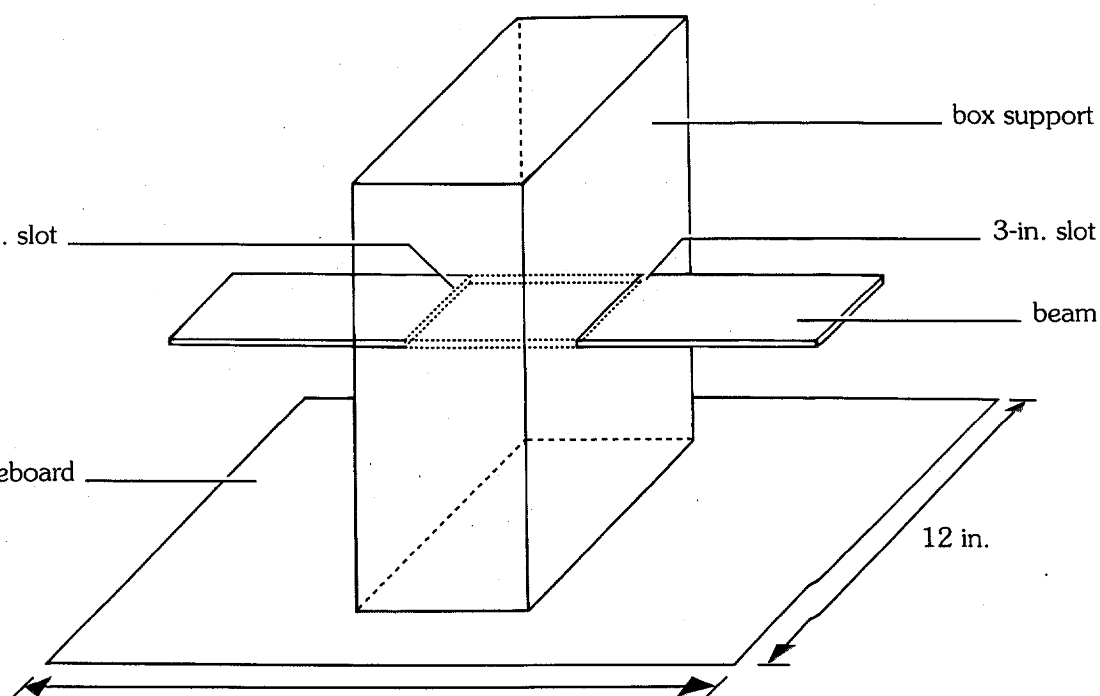
Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful when cutting holes in the cardboard box.

PROCEDURE:

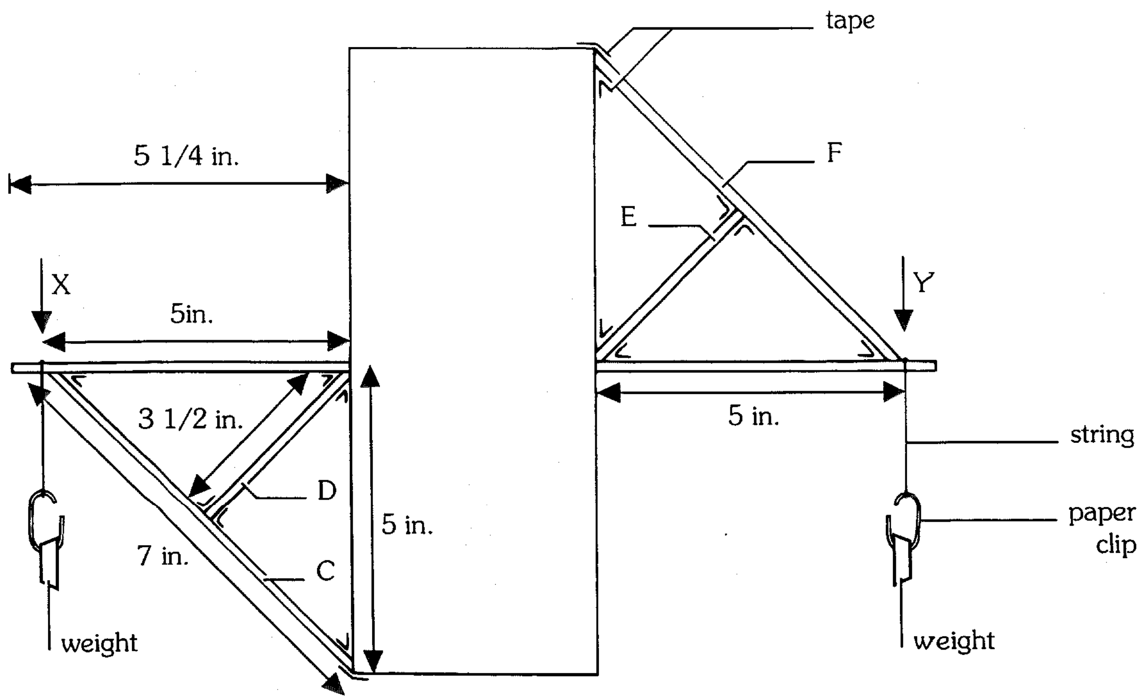
1. Make a 3-in. horizontal cut in the center of each side of the box.
2. Glue the base of the box to the center of the largest sheet of cardboard.
3. Place the 15-in. piece of cardboard through both slots in the sides of the box to form the beam of the bridge (see figure 2).

Figure 2



4. Use 3-in. lengths of tape to secure the large and small cardboard pieces to the beam to form supports C, D, E, and F as shown in figure 3.
5. Tie loops of string loosely over the ends of the beam at points X and Y, and tape the string in place. Attach paper clips to the string for hanging the weights (see figure 3).
6. To test the effectiveness of the supports, hold the base steady and place a 25g weight at point X and at point Y on the beam. Repeat this, adding 25g weights each time to both sides, until one side of the beam collapses or becomes badly deformed. Record the load (total grams) at which this occurs.
7. Continue adding weights to the other side until this too collapses or becomes badly deformed. Record this load.

Figure 3



ANALYSIS:

1. Which side of the beam, X or Y, is able to support the larger load?
2. When the beam is supporting loads at X and Y, which side of the beam is stretched? Which side is compressed? Which supports (C, D, E, or F) are stretched and which are compressed?
3. Do some research. What are the technical names for a) compressed framework supports and b) stretched framework supports?
4. What are the advantages of a cantilever bridge? What are the disadvantages?
5. Other than in bridges, where are cantilever structures commonly used?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES