What's In a Building?

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Engineers use lots of scientific knowledge to design buildings that are safe and strong. Here are some simple experiments that are all about basic structural engineering. As you do the activities, try to think about where these ideas might apply in the world around you; look for them in buildings and structures next time you are out with the girls.

1. Strong Paper (All Ages)

Buildings and structures need to be strong enough to support their own weight, and the weight of anything that goes in or on them (like freight trains on a railway bridge). That's why they are made out of strong materials like wood, steel, and concrete. But the type of materials is only part of the reason for a building's strength. Often, the shape of the material is also an important factor. This experiment shows that even ordinary paper can be surprisingly strong.

Divide the girls into small groups so that everyone can participate.

What you need (for each group):

- Four sheets of 8 ½ x 11 paper
- Masking tape
- Several small, thin books
- For the "More to Try" activities: two more sheets of paper, a kitchen cutting board, and a piece of corrugated cardboard approximately 30 cm x 10 cm.

What to do:

First, make four different shapes out of the paper.

1. Card: Fold one piece of paper in half lengthwise to make a V shape.
2. Triangle: Fold one piece crosswise into thirds, and tape the edges together.
3. Square: Cut one piece of paper in half lengthwise and tape the ends of both halves together. Fold each half in half again to make a square.
4. Circle: Bend one piece of paper into a circle. You might find it helpful to roll it around a large can. Tape the edges together (and remove the can).

Stand the V-shaped piece of paper on its edges and carefully place a small book on it. Can it hold the book? How many books can you stack on it before it collapses? Do the same thing with all four shapes. Which shape can hold the most books?

What is happening? The paper circle can hold a surprising number of books! A round tube is stronger than any other hollow shape, because the weight of the books is evenly distributed around it. In the other shapes, the corners are strong, and they support most of the weight. But those flat sides are weak, and with nothing to support them they collapse under a relatively small weight. The circle doesn't have corners or flat sides, so the

weight of the books is spread out over the entire paper. That means it can hold more weight.

More to try: Make a circle out of corrugated cardboard, taping the edges very securely so they don't come apart. Put it on the floor on one edge, and place a kitchen cutting board on top. Step carefully onto the board—make sure you keep your balance so you don't fall over. Does the cardboard circle support your weight? Can you get a friend to join you on the board?

You've already discovered that circular tubes are strong, but what makes corrugated cardboard strong enough to hold your weight? It is actually a "sandwich" of three sheets of paper: two flat pieces and one folded like an accordion between them. Accordion-folding adds strength to the paper and helps keep it from bending under a load. To test this, accordion-fold a sheet of ordinary paper, and support it at each end to make a bridge, with the folds running lengthwise from one support to the other. Soup cans, stacks of books, or inverted plastic cups make good bridge supports. How much weight do you think this bridge will hold? Test your theory by placing small objects (such as pencils, car keys, or small rocks) in the centre of the bridge one at a time. Start with the lightest items and then try heavier ones. Try the same test with a bridge made of flat, unfolded paper.

2. Tall Towers (Guides and Pathfinders)
As our population grows, more and more people are living and working in high-rise buildings. But it isn't easy to make a tall building that is also strong, and stable!

Divide the girls into teams of three or four. Each team should have the same amount of supplies. The amounts below are suggestions only. If you don't have a lot of time, give each team fewer materials.

Note: This is a challenging activity that takes patience, teamwork, and lots of problem solving. To adapt it for younger girls, use toothpicks and gumdrops instead of spaghetti and marshmallows. If the "tallest tower" goal is too frustrating, make the "most unusual" building, or the one with the most rooms.

What you need (for each team):

- Dry spaghetti (40-50 noodles)
- Mini marshmallows (60-70)

What to do: Build a tower out of spaghetti, using marshmallows to connect the noodles together. The object is to make the tallest tower you can, and the rules are simple:

- Your tower must be able to stand up by itself.
- Your tower does not have to be square.
- You can break noodles to make them shorter, or join them together to make them longer.
- Marshmallows do not have to be at the ends of the noodles; you can slide them along to any position you want.

- As with any real-life engineering project, you have a limited supply of building materials. Once you use them, lose them, break them, or eat them, they're gone.

Hints and tips: This is a challenging activity! Here are some suggestions for solving the most common problems. As much as possible, encourage the girls to figure these things out themselves. Give hints and nudges in the right direction, but let them think the problem through before you step in with a solution. Trial and error is part of engineering!

Since marshmallows are not rigid, the connections between noodles will flex quite a bit. Consequently, your tower will probably want to fall over right from the start, particularly if it is square or rectangular. To help your tower keep its proper shape, add diagonal braces or corner braces.

To make a corner brace, place an extra marshmallow on each noodle, a few centimetres from the corner where they join. Then stick the ends of a short piece of noodle into the extra marshmallows. Table legs are often braced this way.

Diagonal braces run corner-to-corner across a square or rectangle. Simply stick a long noodle diagonally into the marshmallows that are already holding the corners of your square together. However, if you used full-length noodles for vertical and horizontal pieces, you will find that your spaghetti isn't long enough for diagonal braces. Make the sides shorter, either by breaking the noodles or by sliding the marshmallows in from the ends. Then you can use full-length noodles for the longer diagonal braces.

Alternatively, you can join two noodles together in a line to make a longer piece. To prevent the long piece from bending at the joint, overlap the noodles by a few centimetres. Use two marshmallows to join them, one at each end of the overlapped section.

More to try: We don't want buildings that bend and sways all over the place, but some flexibility is a good thing. Engineers design modern office and apartment buildings to be flexible so that they don't break apart in earthquakes. The same thing goes for bridges and elevated roads or railways.

To test how earthquake-proof your tower is, build it on a light-weight card table or TV tray-table. Simulate an earthquake by bouncing the table up and down or shaking it from side to side. Start with fairly gentle movements, then get rougher. What happens? How long does your tower survive? How could you make it more resistant to earthquakes?

Many buildings don't survive earthquakes because they slip off their foundations. Make sure your tower is securely taped to the table!

(If you do this, let the girls know from the start that their towers will be destroyed; it will be too heartbreaking otherwise. Console them by letting them eat the marshmallows.)