16 foot tall Tensegrity Ball

by **alejandroerickson** on July 21, 2012

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Intro: 16 foot tall Tensegrity Ball

I made this giant tensegrity for GeoBurst at the Vancouver Island Mini MakerFaire 2012 .

GeoBurst creates ZEST for MATHEMATICS by doing hands-on mathematical activities with kids. Check out our website and see what this emerging not-for-profit is up to !

I believe in the intrinsic value of mathematics, and most especially geometry and symmetry. Learning to appreciate math for what it is will reduce our aversion to it when we actually need to use some.

Learning objective: Students will learn about two of the 5 platonic solids, the icosahedron and the dodecahedron. They are both visible in this structure because their dual relationship is highlighted here. The tensegrity ball is neither the icosahedron nor the dodecahedron, yet it is also both. Students will also learn about the principle of tensegrity, and this activity can be partnered with the building of a smaller tensegrity such as the ones on GeoBurst . Students will also learn about knots.

Learning Keywords: 3D geometry, Icosahedron, dodecahedron, platonic solids, dual solids, tensegrity, symmetry (and symmetry groups), triangles, pentagons, engineering, structures, building materials, knots... etc :)

A little background: I first built a small model last year after seeing George Hart's post on Make . I also had these 1/2-1 inch diameter 8-foot bamboo poles, lying around for a project like this, but the giant tensegrity ball idea went into limbo because I didn't know how to reliably attach the ropes to the ends of the poles. You can't just notch bamboo, because it will split to pieces, and I didn't want to buy fasteners for 60 ends of poles.

The answer lay in knots, and this is what my instructable is about. Good, non-slipping, easy and fast knots. Tying the knots for this project took nearly 35 man hours, for which I had help from three friends. Veronika Irvine, Eric Davies, and Charles Campbell. The rest of the time was spent rolling the ball around at the park!

Let us start with a video of the end result.

Step 1: Materials and build summary

Materials (sorry for confusing imperial and metric units so much):

- 1/2" to 1" thick bamboo poles, 8 feet long, 30 of them
- At most 100 meters of paracord
- At most 500 feet of 3/8" thick yellow polyrope
- Duct tape (better than tarp tape I used)

Tools:

- propane torch
- efficient rope cutting knives
- respirator
- time and patience

(some images above from wikipedia.org)

Each pole and 11 foot piece of poly rope are paired up and attached at the ends. The poly rope pulls inwards, toward the middle of the pole, so the paracord is used to prevent the attachment points from slipping.

Warning: Knot lingo is approaching. If you don't know these names, just skim over them and I'll explain later.

At each end of each pole, a piece of paracord is tied on with a rolling hitch and a jug knot, and the poly rope ends are tied to the handles of these jug knots, with half hitches.

The Rolling Hitch tightens when you put a load on it that is parallel to the pole. This prevents the whole knot from sliding toward the middle.

The Jug Knot is used for carrying jugs because it provides a nice little handle. We use then handle to tie the poly rope into. This knot takes a long time to initially adjust, so I am debating whether I recommend using it, but it does work very well once it is on.

Go to http://geoburst.ca/craft_articles/random_canvas_details.html to see how I made the print on the wall in the picture.

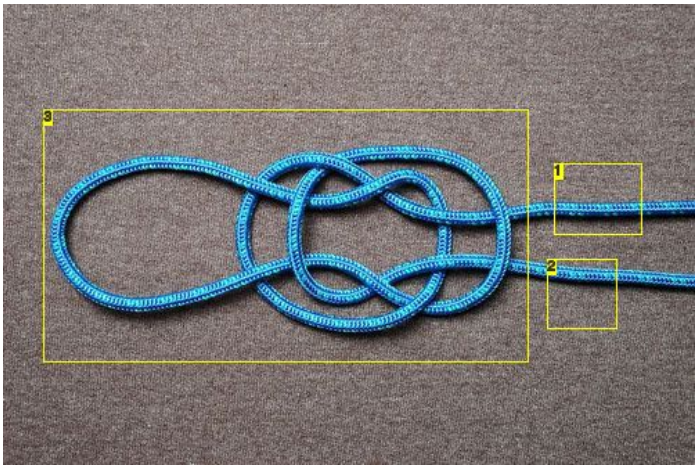
Image Notes
1. this is randomly generated artwork. Check out how I made it at http://geoburst.ca/craft_articles/random_canvas_details.html

Step 2: Tie a SINGLE jug knot

Cut a 110cm length of **paracord** and seal the ends of it with the **torch** . Tie a jug knot following the instructions below, leaving only about 5cm on one end, and the rest on the other.

I'll borrow from wikipedia , since there are great instructions there.

> The knot is begun by making a bight in a piece of rope and folding the bight back on itself to make two separated loops that are mirror images of each other. Lay one loop on top of the other so that they overlap slightly and create a cat's eye shaped hole above a triangular shaped hole between the two loops. Make a bird's beak with your index and thumb and weave them down through the loop, up through the cat's eye and down through the bottom loop, bunching the coils of rope against your fingers. Pinch the section of rope that was the bottom of the triangle and flip the coils over the pinched section. The flip may take a little practice, but the pinched section should become a short bight hanging off a circular shaped knot.



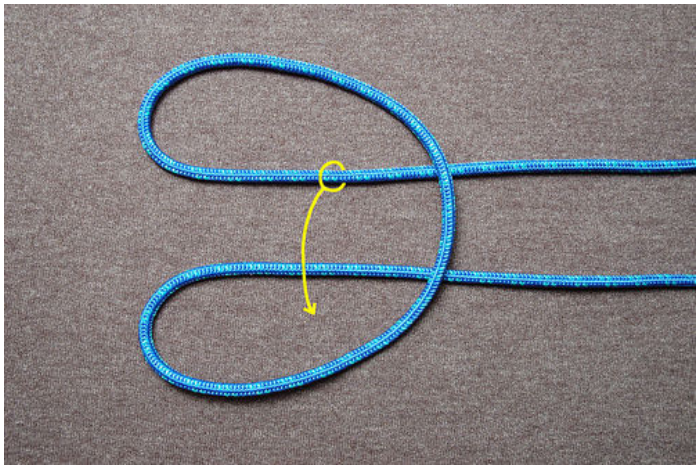
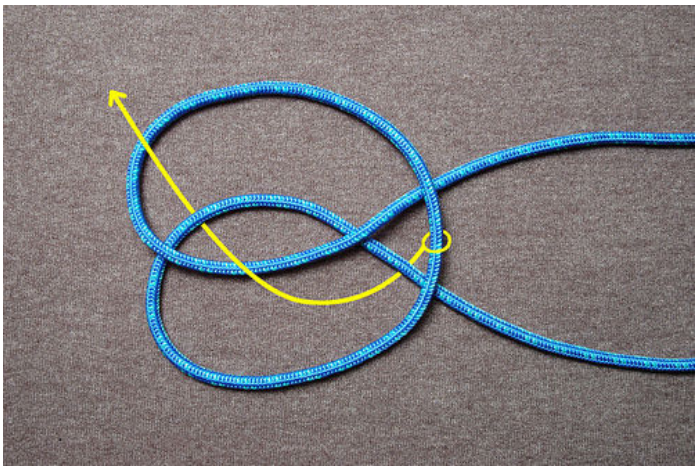
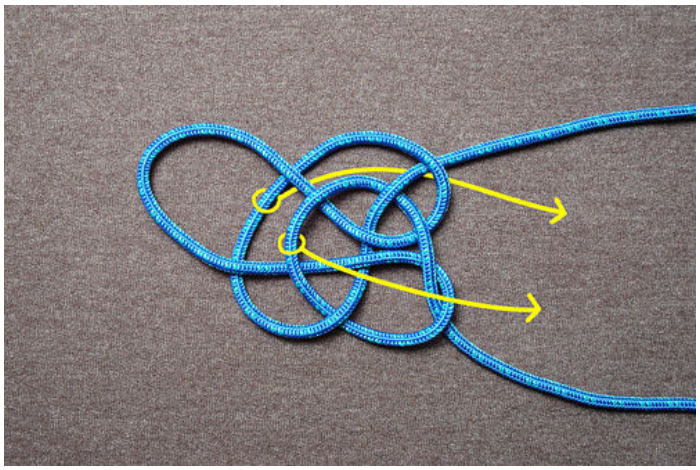


Image Notes
1. Make one end short. About 5cm.
2. You'll tie your rolling hitch on this end after dressing the jug knot on the bamboo pole.
3. This is actually the final step!

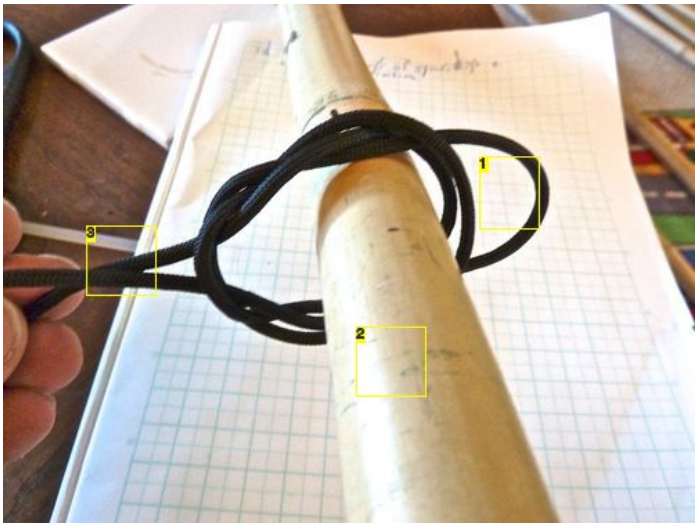




Step 3: "Dress" the jug knot on the pole

"Dressing" a knot means "making it all pretty, neat and nice". Keep a finger in the loop while you tighten the knot around the pole. The loop should stick out 2-3 cm from the pole, the jug knot should otherwise be tightly tied 8-10cm from the end of the pole. There should be a 5cm short end, as well as a long end.

Tie the 5cm end to the long end behind the jug knot with a surgeons knot (or sheet bend?). I have not perfected this part, because I know that a surgeon's knot can "capsize", but it does seem to be working so far.



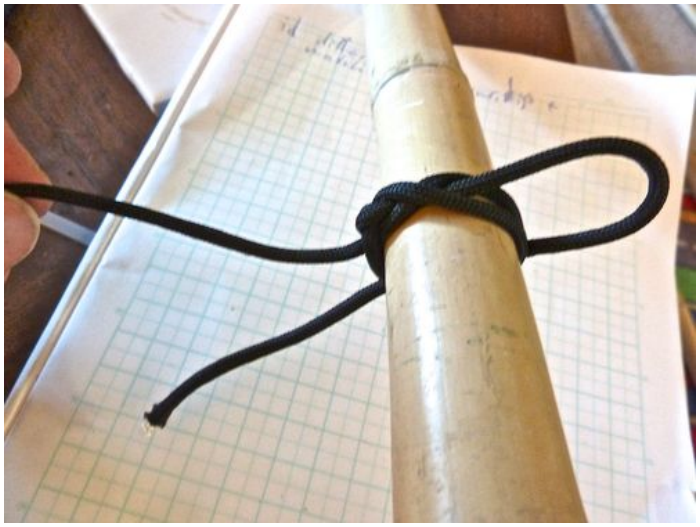


Image Notes
1. keep a finger or two in here.
2. 8-10cm from end of pole.
3. one of these will be about 5cm when jug knot is dressed. tie a knot here when dressed.

Step 4: Tie the rolling hitch

The rolling hitch is tied **between the jug knot and the end of the bamboo** to prevent the jug knot from getting pulled to the middle of the pole.

Once again, best to pull knot tying instructions from a wikipedia .

1. Start with a turn around the object. Bring the working end towards the direction of pull and between the standing part and the object.
2. Make another wrap around the object, completing a round turn. The wraps of the round turn should progress towards the desired direction of pull. Bring the working end out over the standing part away from the direction of pull.
3. Complete with a half hitch, moving around the object in the opposite direction as the first turns, as for a cow hitch.
4. Dress by snugging the hitch around the object before applying load.

Tie the rolling hitch as close to the jug knot as possible, in such a way that the loaded piece between the two knots is parallel to the pole (ie comes straight off the rolling hitch and into the jug knot).

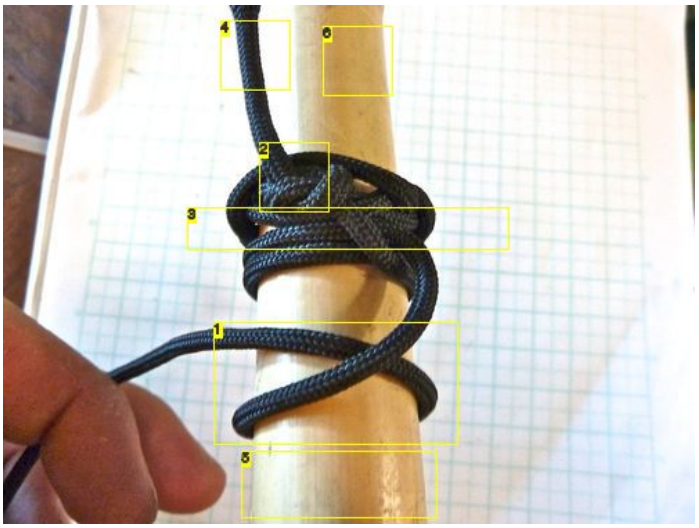


Image Notes
1. rolling hitch. direction of load is up, toward middle of pole, in this picture.
2. surgeons knot at back of jug knot to secure.
3. properly dressed (tightened) jug knot
4. short end of paracord
5. short end of bamboo
6. toward middle of bamboo

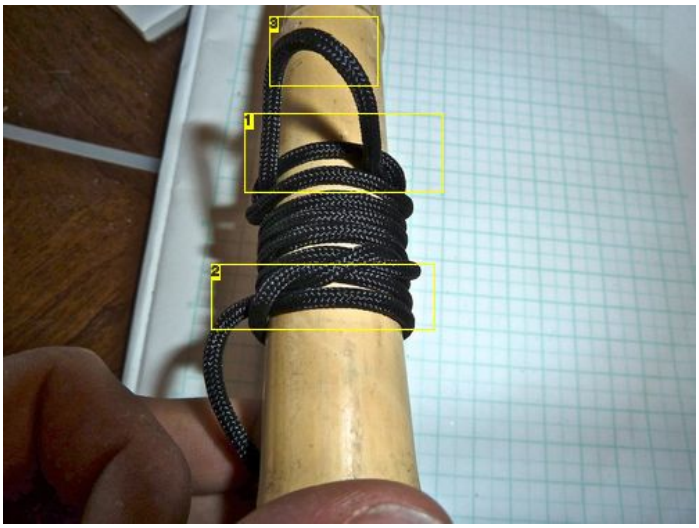


Image Notes
1. dressed jug knot
2. tie extra half hitches with the remaining paracord.
3. tighten everything, and pull the jug knot's loop toward middle of stick to test rolling hitch.

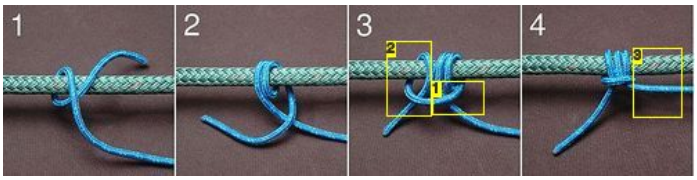


Image Notes
1. notice this change in direction.
2. this half hitch ties off the end. keep doing more of these with the rest of the paracord.
3. your jug knot will be here, as close as possible to the rolling hitch.

Step 5: Cover rolling hitch with duct tape

We will be tying yellow poly rope over the rolling hitch, so to avoid unravelling or fraying this knot, we should protect it. What better way to do so than wrap it in duct tape!

Duct tape is what I would have used if I had found any, but instead I used tarp tape. It is a distant second.

Important: Before taping the second rolling hitch on a pole, make sure your jug knot loops are sticking out on the same side of the pole.

Image Notes
1. tarp tape, or duct tape.

Step 6: Debug steps 2-5 for 1 or 2 knots... and repeat.

Once you've got an end or two done, It's time to start the assembly line. If you are doing this with friends, get each person to do as much of one single thing as possible.

The numbers below include any knots we've already done.

- Cut 60 lengths of paracord 110cm long. Speed up by folding a 110cm length over on itself as the rope comes quickly off a well secured spool.
- Melt the ends of them using a torch. Wear a respirator.
- Tie 60 jug knots and lay them out on a table.
- Repeat steps 3-5 for each jug knot.

Image Notes
1. jug knots. Just pile em up neatly.

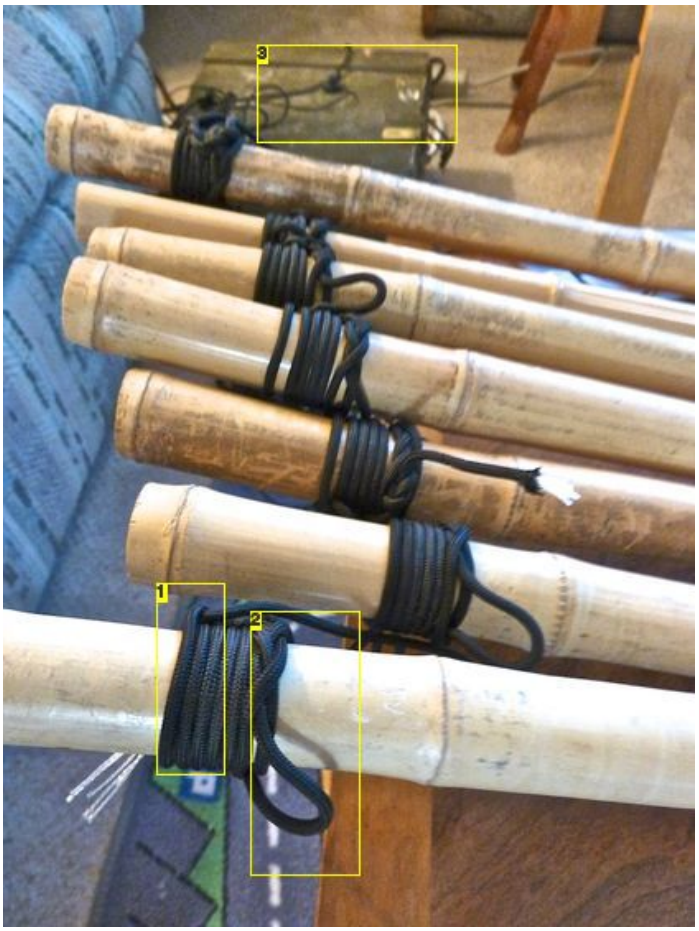


Image Notes
1. rolling hitch
2. jug knot
3. not actual ammunition, just an old box I have

Step 7: Prepare, tie, and mark the polyropes

Overview:
We prepare 30 lengths of polypropylene rope, and pair each of them up with a pole, permanently fastening one end to a jug knot loop. Finally, we mark off the rope with a thick permanent marker in four places.

Do this with 10 lengths of rope and poles first, and test it. Then do the other 20.

1. Cut polyrope into 11 foot lengths. Use a spool and double the rope over to save time. Melt the ends with a torch, and use a respirator.
2. Secure a rope to one end of a pole with two half hitches and tighten. You will not need to undo this knot later. Repeat this for all poles.
3. Mark the rope at 3 foot intervals, starting with the knot you just made (in case it gets loose). Make thick marks all the way around the rope. Repeat this for all poles.

If you are just doing your first 10, you should test part of the structure to make sure you have enough length to tie the knots. It can depend on the thickness of your poles, ropes, etc.

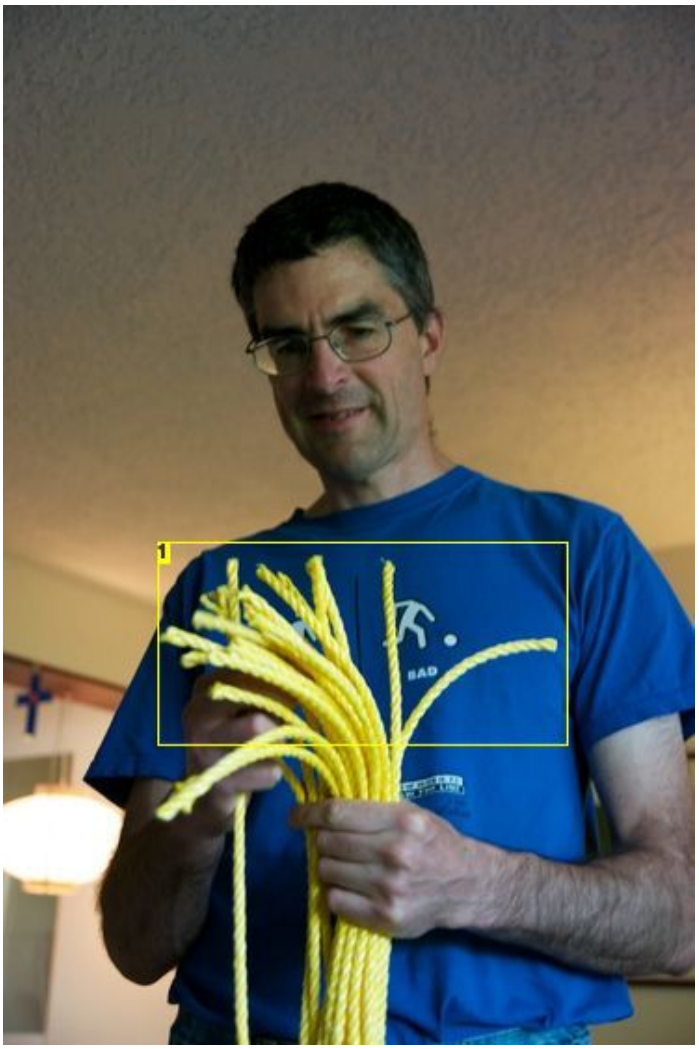


Image Notes
1. melt the ends! Much rope has been wasted because of bad ends.

Image Notes
1. thick mark every 36 inches

Step 8: Learn to tie poles together

Each poly rope has its own pole. We'll fasten it to the ends of two other poles, and then bring it back to the other jug knot loop of its pole. The two other poles tied into it come from opposite directions, and the poly rope stays on one side of its own pole.

Tie the clove hitches:

1. Make an figure 8 in the rope, with one of the black marks on top of the middle.
2. Fold the knot and bring the loops of the 8 together, underneath the mark.
3. Slip the end of another pole into the loops, up the point just before the jug knot.
4. Turn the new pole so that the jug knot loop is on the same side as the mark on the clove hitch.
5. Dress (tighten) the clove hitch, keeping the mark in the middle.
6. Repeat this for another pole, at another one of the middle marks on the poly rope.

Now bring the end of the poly rope through the jug knot loop and pull tight. The **poly rope should stay on one side of its pole** , and not wrap around it at all. Tie it off with a simple **slip knot** (don't tie an overhand knot first, you'll have a heck of time getting it undone after it has been loaded).

The key here is to use knots that are secure, fast, and easy to untie. I have tried several different ones, and this setup is by far the most successful. As you are building later, you'll often tie one pole into a polyrope, and leave it open to wait for the next pole, before finishing with the slip knot.

Image Notes
1. black mark over the middle of the 8. fold loops back and together.

Image Notes
1. pole end goes in here.

Image Notes
1. tie clove hitch near jug knot. mark on the same side as jug knot's loop. dress it with the mark in the middle

Image Notes
1. permanently fastened
2. poly rope does not wrap around pole.
3. clove hitch at fist middle mark

4. clove hitch at second middle mark. pole comes in from opposite direction, but still above the pole we are tying into.

Image Notes
1. tighten as much as possible by hand.

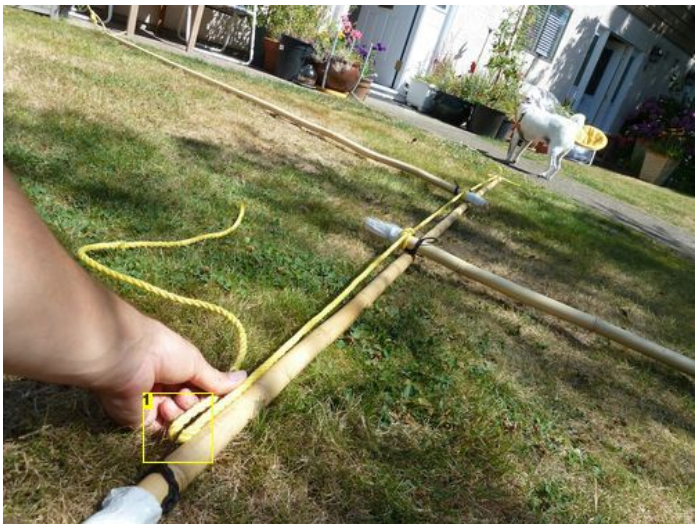


Image Notes
1. finish with a simple slip knot.

Step 9: Test structure

Make part of the Tensegrity Ball before going back to finish step 7. This is also a good primer on how to build a Tensegrity Ball, big or small.

The key is regularity. The tensegrity ball consists of pentagons and triangles. You'll want to keep notions like "left over right", or vice versa, in your head. Learn to recognize the look of each pole.

The test structure has one pentagon, surrounded by 5 triangles. Build this as a small dome, with the **ropes and jug knot loops above the poles.**

- pentagons all go in the same direction. I follow the poles around in clockwise or counter clockwise order, and say "left over right" or "right over left", as the case may be.
- triangles go in the opposite direction of pentagons.
- poly ropes must not wrap around their poles.

Assemble the test structure in whatever order works best for you. When you are done, secure the ropes of the outer poles (with slip knots) even though they only have one pole tied into them.

When ready, push the outer poles inwards, bracing them on the ground perhaps, and push the pentagon upwards. You are testing to see whether you

- Had long enough poly ropes to tie it together at all,
- have a dome with approximately the right curvature, and fairly tight poly ropes (esp the ones around the pentagon).

When you are satisfied and have made any necessary modifications, go back and complete Step 7.

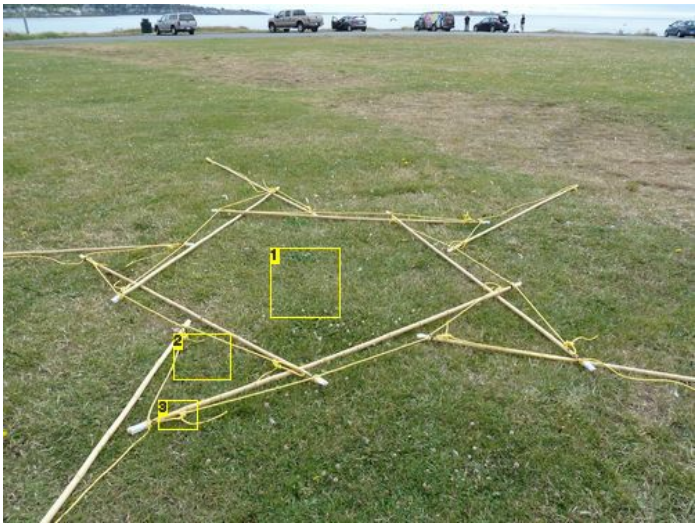


Image Notes
1. middle pentagon. each pole goes over one neighbour , and under the next, in clockwise direction. This will consistent throughout your Tensegrity Ball.
2. one of the 5 triangles around a pentagon. Opposite "direction" as the pentagon.
3. big funny looking knot is a bowline. I don't recommend it here.

Image Notes
1. I would say this was looser than your should be when testing. It should have some spring to it when curved like this. The final ball has diameter about 16', if you can imagine how curved it should be when finished.
2. this is actually me.

Step 10: Plan assembly

You'll need a space approximately 2-3 times the diameter of the ball to build it, so that you can roll it over; ie perhaps 40 feet by 40 feet. I built this thing alone for the intro video, but for the method I describe here, I had one helper.

Build most of the ball flat, with **the inside up** . That is, jug knots and clove hitch marks are all next to the ground, underneath the poles. Poly ropes also go underneath the poles, and ends of poles never go over the poles they are tied into.

The (mostly) flat part, uses up 25 of the poles. The last 5 form a pentagon at the top. You can roll the structure around as needed.

Here is a video where I assemble the Giant Tensegrity Ball using this method at Vancouver Island Mini MakerFaire. Refer to the video in step 1 too.

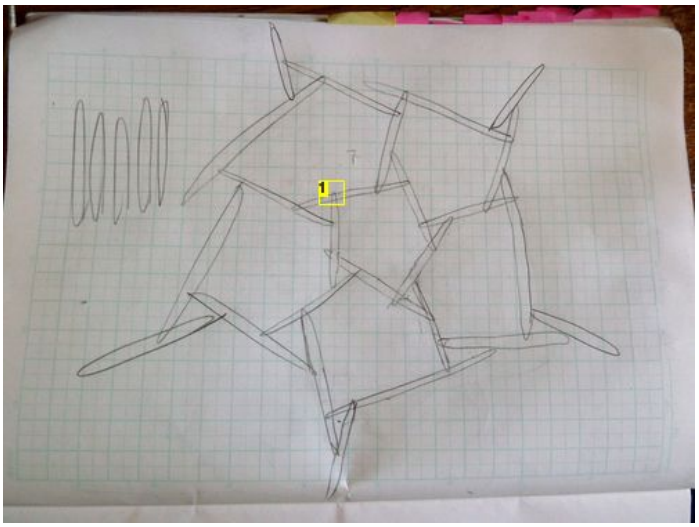


Image Notes
1. pole ends under pole middles.

Step 11: Take your Tensegrity Ball for a walk!

You didn't build this thing so you could keep it to yourself... so take it out and show it off! Block traffic! Attach sails, or floats!

Enjoy Mathematics , and learn more about my not-for-profit, math education enrichment initiative, called GeoBurst .

Image Notes

1. If there is any wind, tie it to something if you have to leave it unattended.

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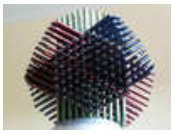

"Mad Chopstick Burr" 10 x Madder (video) by alejandroerickson

Tensegrity Tensecoration Decoration (video) by alejandroerickson

Rope and Sound Interactive Tensegrity Sculpture by dan

Desktop Tensegrity Tower by Data643

Red Vinyl Frabjous (Photos) by emattrose

Comments

4 comments **Add Comment**

meanpc says: Aug 17, 2012. 4:02 PM **REPLY**

I love the grand scale of your ball - looks like a modern art sculpture.

wilgubeast says: Aug 17, 2012. 2:44 PM **REPLY**

awesome awesome awesome. PM me about GeoBurst, please.

arasbm says: Aug 17, 2012. 2:10 PM **REPLY**

This is just awesome Alejandro! Its amazing how much people can be attracted to *big* things. Really cool project, looking forward to see more instructables from you.

jessyratfink says: Aug 16, 2012. 9:06 PM **REPLY**

That's amazing - love the way it looks!