Engineers Without Borders at
Practical Action "Small Is..."

2010/2/16-v1.2

# The Hexayurt In Haiti?

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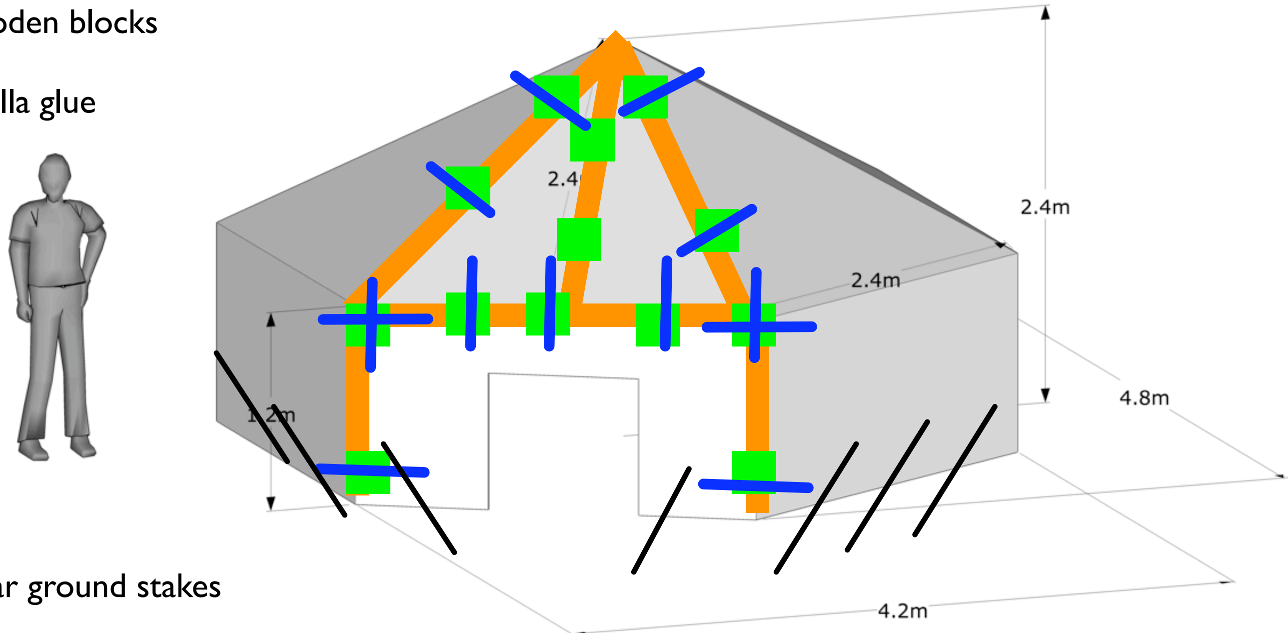
# Structural elements

steel strap

wooden blocks

gorilla glue




rebar ground stakes

# About this document

The Hexayurt Project is an open source volunteer effort to provide solutions for agencies providing shelter and other disaster relief and development services in crises.

This document outlines the basic elements of the Hexayurt Shelter in general, and one specific configuration suitable for use in Haiti.

It is provided as a reference document for agencies to analyze, and sole responsibility for use of the hexayurt in the field lies with the group building or providing them.

We are working with *Science for Humanity* to provide a fully credentialled set of engineering plans in the near future.

## Background

The hexayurt was invented by Vinay Gupta in 2002 in response to the *Sustainable Settlements* charrette hosted by the *Rocky Mountain Institute*. The charrette posited the need for long life, durable shelters which could be transported with refugee populations in the event of a return to their original land. The idea was to have a single shelter which was provided as emergency relief, but which could function in the medium term as development aid - helping people get back on their feet once they went home.

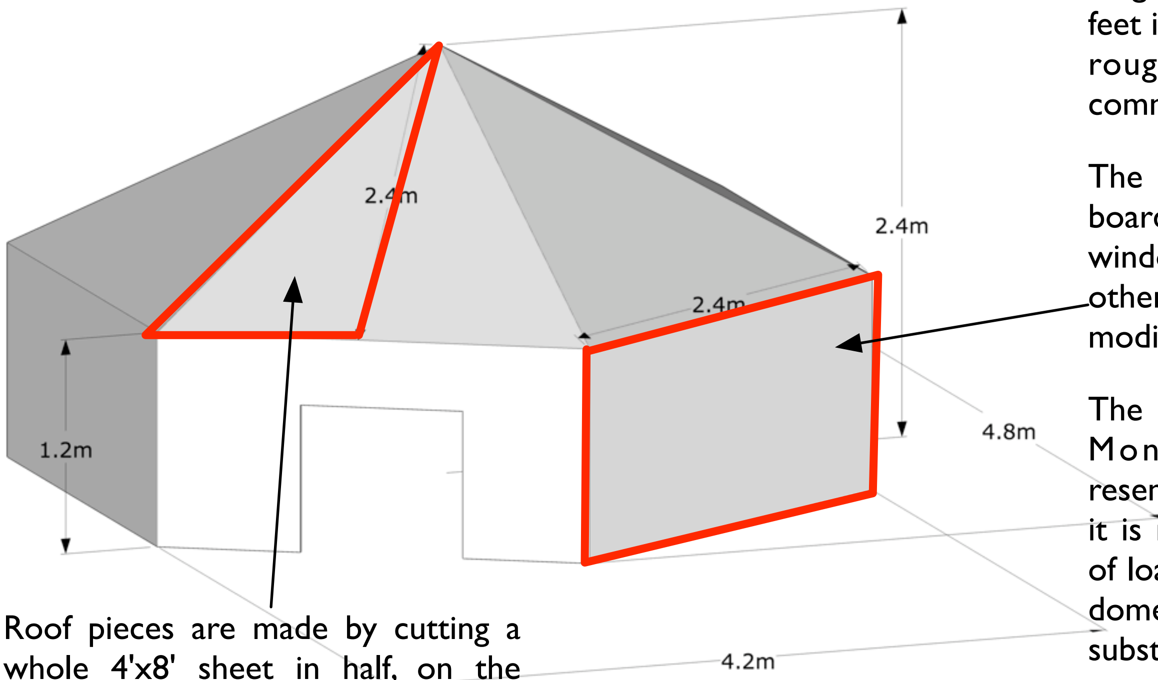
In particular, the limited lifespan of the tent in a disaster relief context requires new options. We hope you will find the hexayurt useful.

## Use Model

The hexayurt is not patented, and few if any of the materials produced by the Hexayurt Project are copyrighted. As far as possible we publish directly into the public domain to enable institutions to make full and free us of the resources we provide.

We expect the primary use of the hexayurt to be made in substantial disasters in areas close to industrial cities or ports. These areas make it possible to bring in bulk materials, like plywood. Local construction companies, or trained members of the general public would be expected to do nearly all the shelter construction work. Costs could be as low as $100 per tent-comparable shelter.

# Hexayurt basics




The simplest hexayurt is 8' tall, 16' long and 14' wide. It is 166 square feet in size, or 15 square meters. It is roughly comparable in size to common disaster relief tents.

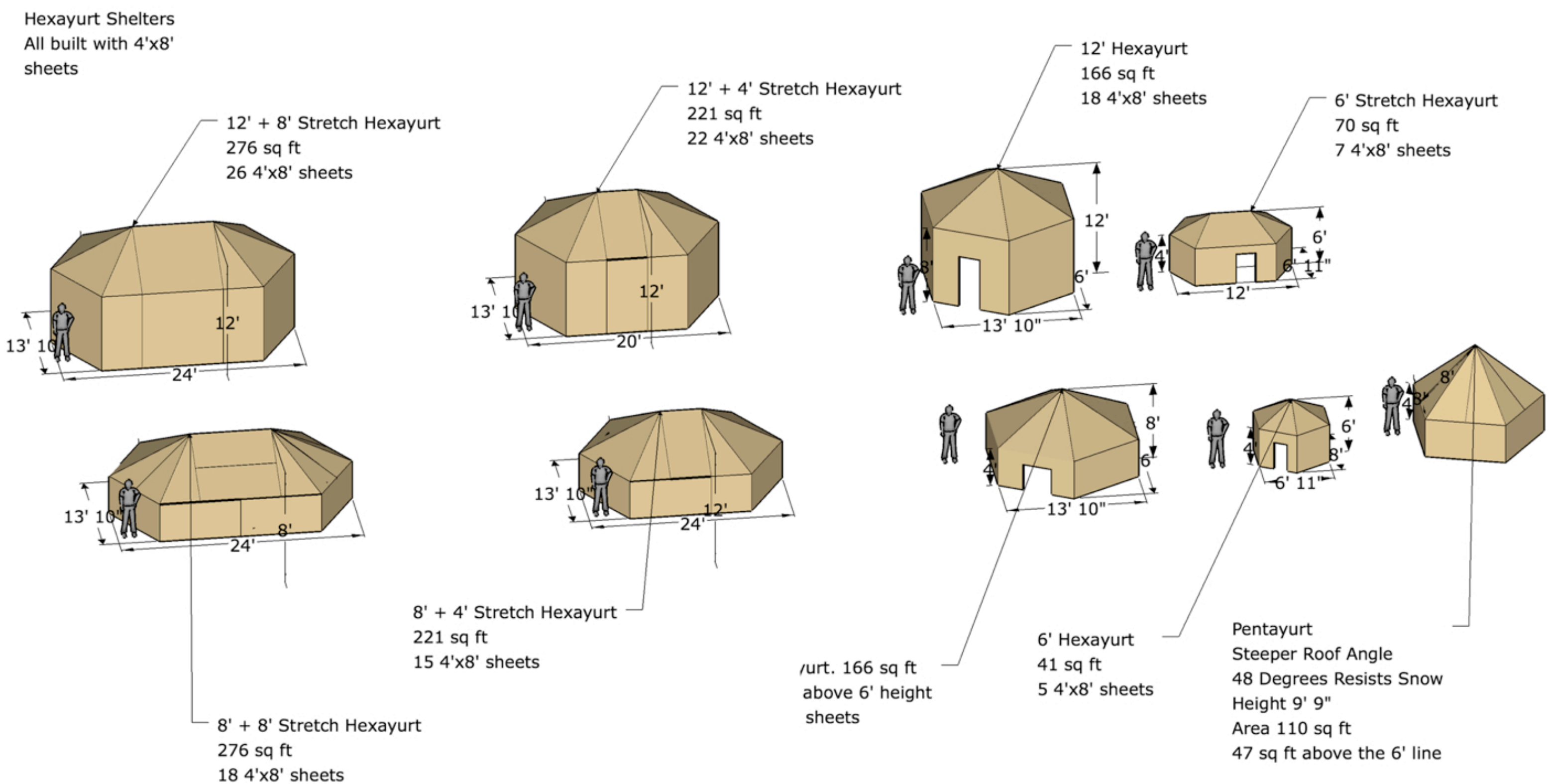
The walls are 4'x8' (1.2 x 2.4m) boards on their sides. Doors and windows can be cut to taste but otherwise the boards are not usually modified during construction.

The building functions much like a Mongolian yurt. Although it resembles a geodesic dome, in that it is made from panels, the handling of loads is much more yurt-like than dome-like. The building requires a substantial tension ring or equivalent structure, usually formed by the wall panels themselves.

Roof pieces are made by cutting a whole 4'x8' sheet in half, on the diagonal. This means no tools beyond a simple saw are required to manufacture hexayurts from common construction materials.

# Hexayurt sizes

All use whole sheets of materials and straight cuts to form the components of the hexayurt.

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# Deploying in Haiti?

At the time of writing, early February 2010, Haiti has around a million people who are either homeless or in disaster relief tents.

The rationale for using the hexayurt in Haiti is given in *Hexayurt Country*, on hexayurt.com, which outlines a strategy based on building homes which will last for longer than standard tents to give people more time to rebuild and get back on their feet economically. The short lifespan of the tent may create difficulties as the tents begin to fail, and the threat of a tropical storm destroying the deployed relief tents during the summer months is very real. However, the hexayurt has never been used in a real disaster. There is a lot we need to learn and know before it can be deployed.

**Defining Success**

There are four criteria for our work on the hexayurt in Haiti. They are:

1. Nobody should be harmed by it.
2. It should not draw resources from other areas of vital relief work.
3. It should not create a culture of "just try it and see what happens"
4. It should be open, honest and documented well enough to be replicable.

We have tried for years to get substantial field trials done on the hexayurt by a wide variety of agencies in several countries without previous success. The shelter is well reviewed, but operationalizing a new technology takes many years in an NGO context.

As a result, we are trying to learn as much as possible about the shelter's likely performance in Haiti as possible, to give the groups on the ground the best possible basis to make decisions on during this crisis.

We do not recommend that any given group uses the hexayurt, rather we make it available for them to try if it passes muster with their own engineering resources and practical, responsible experience.

This is extremely important to remember: ideally we would have years of field data from a few dozen test units in Haiti. We do not, so we are rapidly credentialling a unit for use.

This is where we need your help.

# Practical considerations in Haiti

**Ground conditions**
Haiti presents four specific challenges in shelter.

**Wind:** the risk of tropical storms leveling shelters is extremely severe.

**Wet and hot:** materials degrade very quickly in Haiti, and insects (termites) are extremely active.

**Materials supply chain:** just getting materials into the country may be a very substantial challenge.

**Local opinion:** we do not know how the shelter will be seen locally.

Hexayurts have been used in the USA for many years by desert camping enthusiasts, and work very well in hot, dry conditions.

**Picking a material: plywood**
We think that the most likely material for Haiti is plywood, OSB or a similar engineered wood product.

This is based on two factors: cost and strength. The polyiso insulation boards commonly used to make hexayurts in the US are vulnerable to wind and not suitable for long term use. Honeycomb panels are too expensive and are not available in large enough quantities. This leaves one of the myriad of wood products. We suspect that plywood will handle humidity better than OSB, but there are a wide variety of possible candidate materials out there, and this is an area we are actively seeking expert advice in.

**How do we do it?**
Wood is easy to fasten. Nailing a hexayurt together is inconvenient and nails pull out under load, so the natural fastener is deck screws.

Additionally, wood glue is incredibly strong and very cheap, and the hexayurt lends itself to glue reinforcement, although this does remove the option of taking hexayurts apart for transport.

Steel strapping combined with screws is cheap and easy support.

Finally, holding the building to the ground during storms is extremely challenging. If the ground conditions permit, rebar "candy-cane" stakes are probably the best bet, or ground screws if available.

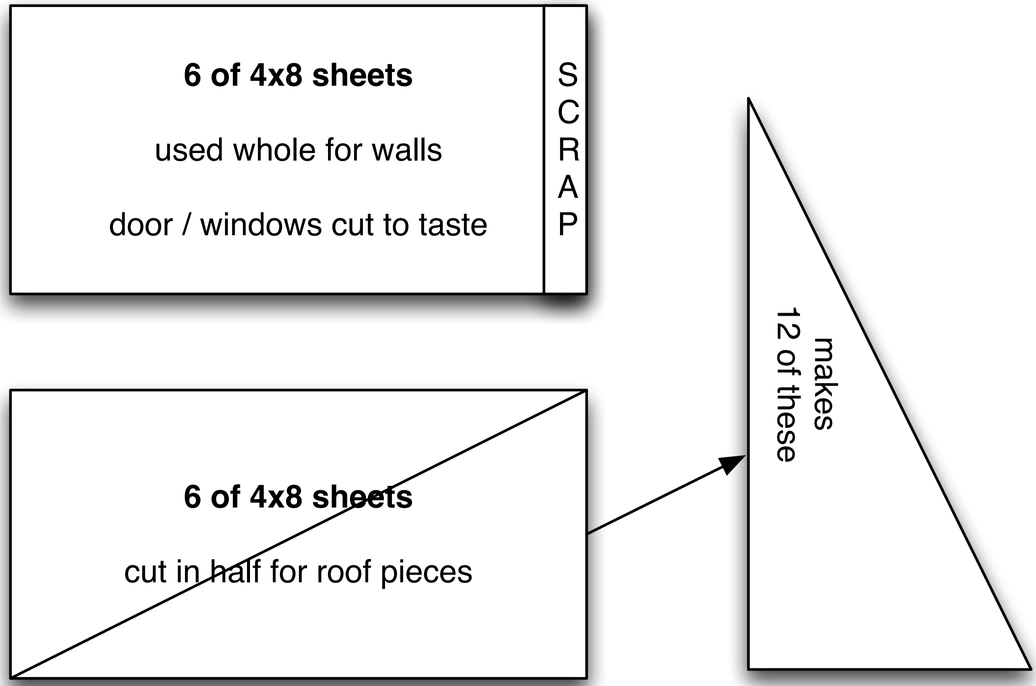
# Wall and roof boards

**12 boards total**, or more/less for the larger units.

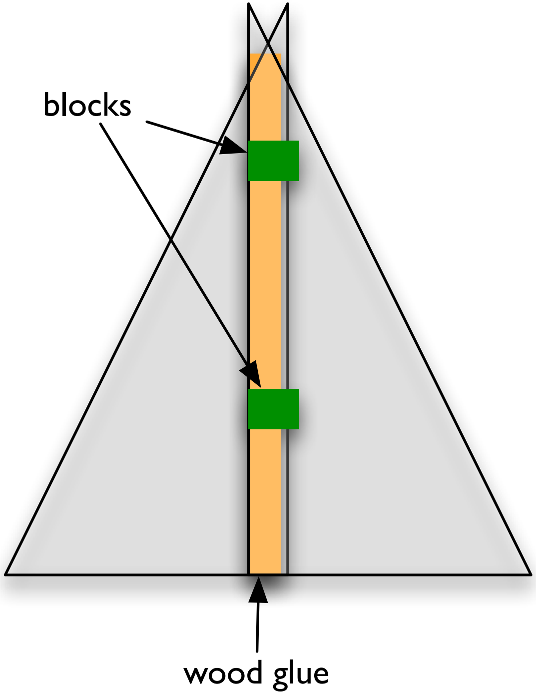
Six are cut in half, preferably with a table saw or hand held circular saw.

For a hexayurt with an overhang for better water properties, the wall boards must be trimmed - 6" must be cut so they wall falls inside the radius of the roof.

We'll look at how the roof is put together next.



# Roof construction - 1



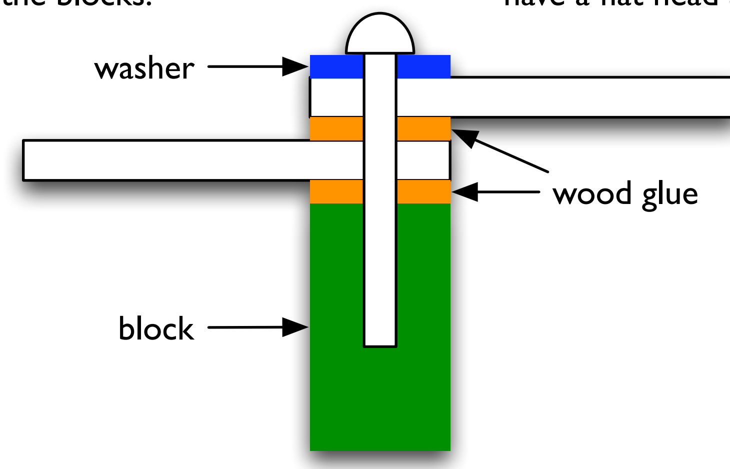

Roof pieces are placed over one another with a 2" overlap.

Wood glue is placed under the boards to produce a strong join.

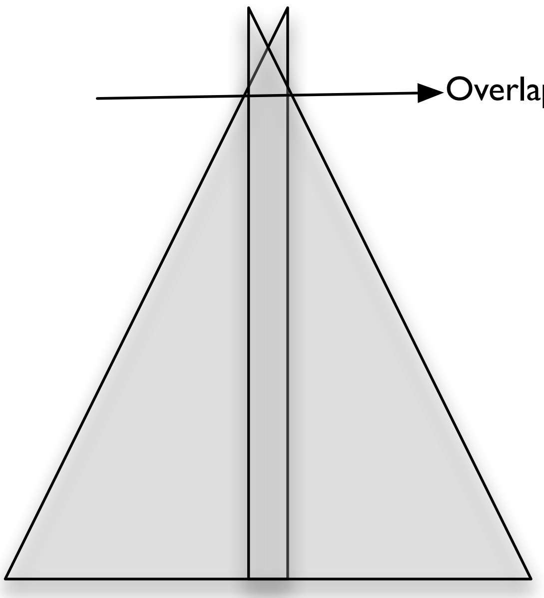
Two wooden blocks are placed below the boards, and screws fastened through both boards and into the blocks.

A washer is placed underneath the screws which go into each block to help prevent the head of the screw tearing through the plywood in a storm.

Each block should have two or three screws in it. The screws should **not** be countersunk screws, they should have a flat head against the washer.



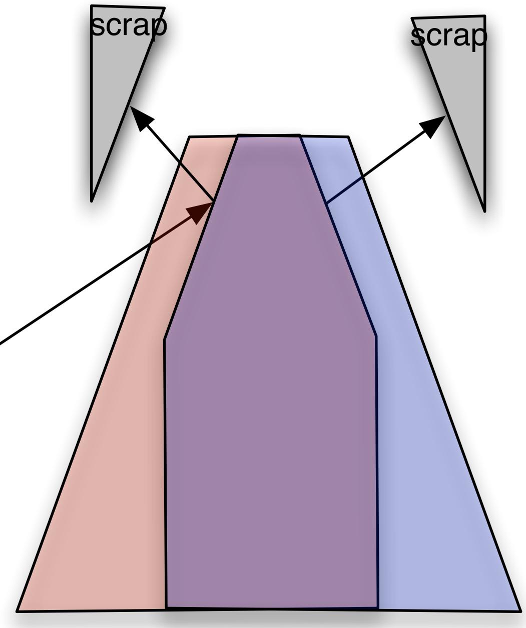
# Roof construction - 2




A small wedge is removed from each board to let the roof triangle beside it slot neatly into place when the roof cone is put together.

Without this cut the roof cone does not fit together properly in three dimensions.

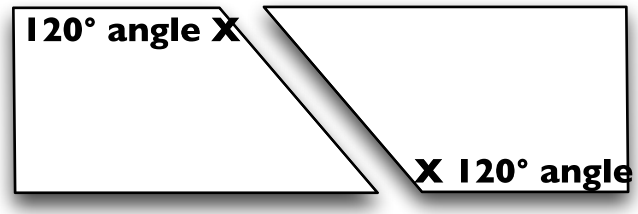
The wedge is about 0.5" x 1.5"

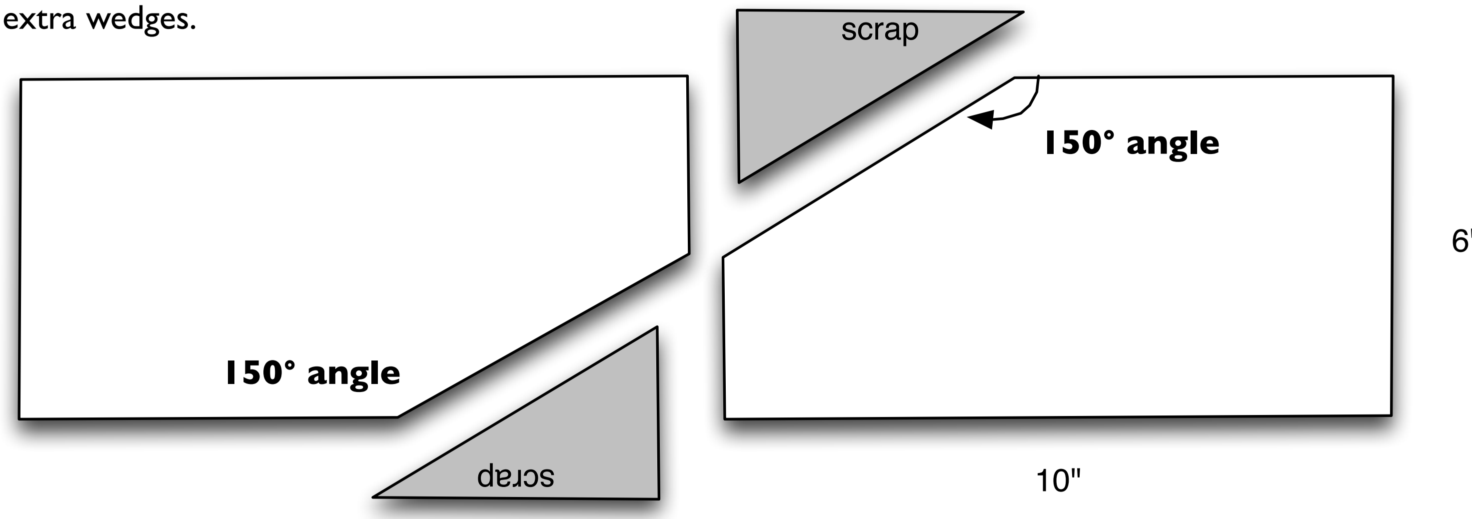


# 150° and 120° blocks

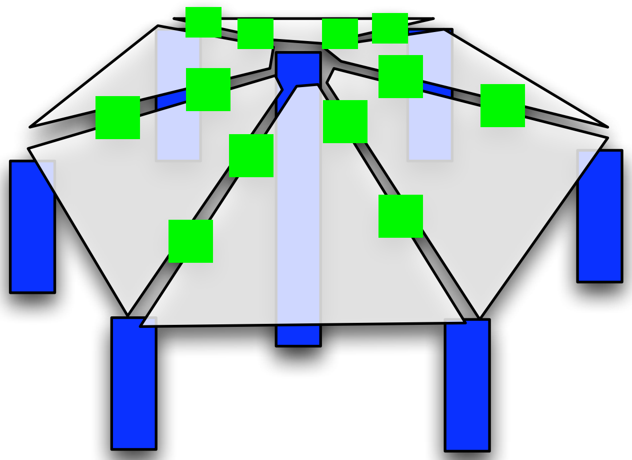
**12 blocks with a 150° angle and 30 blocks of 120°** are cut from 2"x6" or 2"x4" dimensional lumber, depending on the length of the screws being used.

The blocks are made with a single angled cut on a table saw or using a power saw, then trimmed, removing the extra wedges.



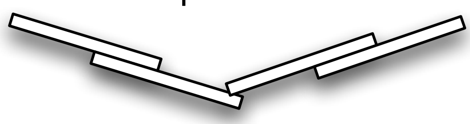
# Roof cone construction



**150° block joining roof pieces**

Six cinderblocks or posts are placed in a hexagon. They should be very precisely placed as they help keep the building positioned precisely as it is built. A center post, 4' taller than the other six posts, is used to rest the roof pieces on as they are assembled.

Roof pieces are placed one by one. Each board is lapped under the board beside it, like so. The blocks are placed against the inside, and screwed into place.



A foaming wood glue ("gorilla glue") is used to secure the board edges. Metal straps are placed over the blocks before they are screwed into place, as illustrated in a subsequent page.

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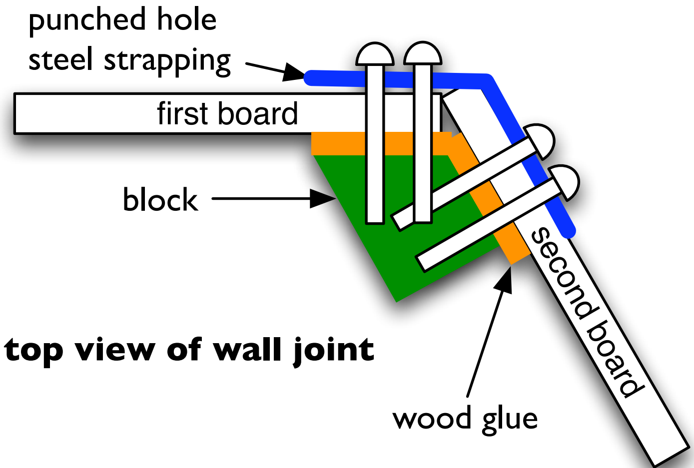
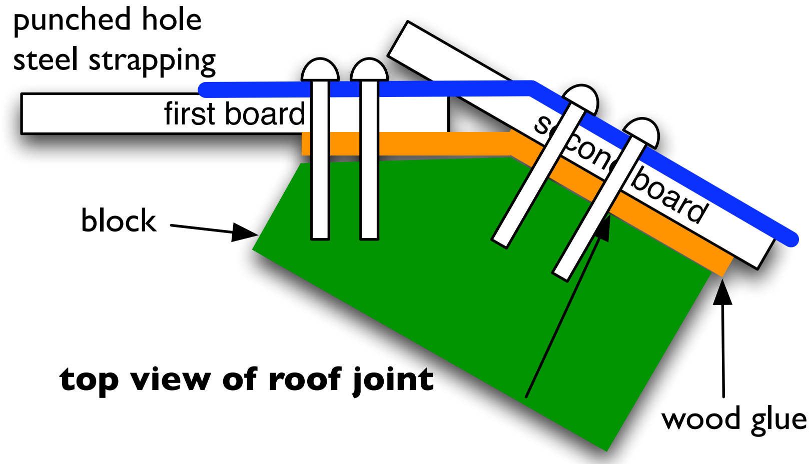
# Joining boards at angles




**top view of wall joint**




**top view of roof joint**

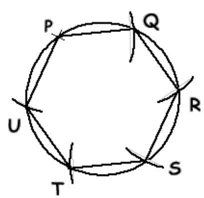
To join the wall pieces, a 120° block is used. The block is glued to the wall boards. The boards are put in place *slightly* asymmetrically to produce a more airtight seal. The first board is screwed slightly back from the corner of the block and then the second board is placed so that it is pressed tight against the board edge and screwed into place.

For these joins, the steel tape serves in place of the washers on the roof boards. Signode (and other firms) produce steel strapping, often used in packaging. It is center punched every inch or so. The screws are placed through these holes, then the strap pulled tight, then the rest of the screws placed. This makes the joint substantially stronger.

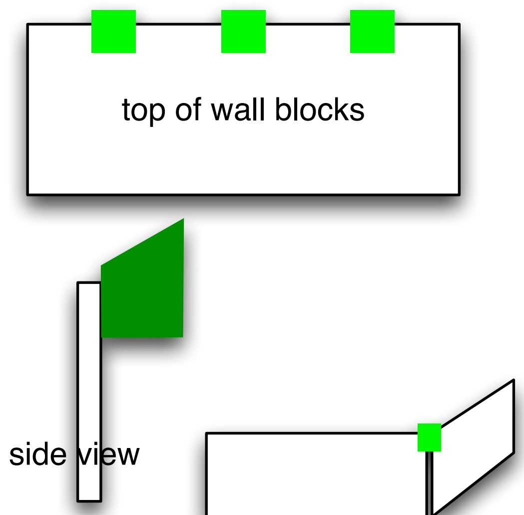
On the roof boards, a small hole must be cut in the second board for the steel strap to reach the screws cleanly. The second board extends substantially over the first board, to control water. Foaming wood glue is applied to both sides of the join, running the full length of the connection between the two roof pieces.

# Wall construction and roof joining

The wall is made very simply. A hexagon is quickly drawn on the ground using an 8' rope and a square-and-compass style construction. Peg one end of the rope where you want the center of the hexayurt. Then draw a circle on the ground with the other end, perhaps using a tent peg. Once the circle is drawn, mark one spot on the edge, put one end of the rope there, and mark where the other end of the rope crosses the circle. Now move the peg to that point, and mark the next crossing point. Continue all the way around to make the hexagon.




The wall boards are joined as shown on the previous place. Once they are all in place, three 120° blocks are screwed into place at the top of each wall. The blocks are evenly spaced at the quarter, half and three-quarter points along each wall.



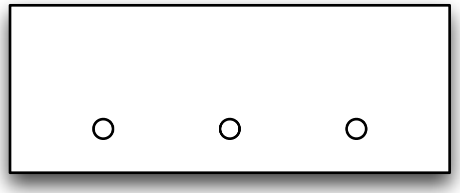

additional screws go into the top wall block once the roof is in place

The roof cone is lifted on to the walls. This process requires at least 18 people, but those people do not all need to be very strong. With 18 people, each person carries only 20 or 30 pounds (15kg) each. Three people stand on each side of the roof, and everybody lifts at the same time. The group will be easily able to carry the roof to the wall.

Once the roof is placed on the wall, it is secured in place with more screws and steel strapping as shown on the other pages. Additional screws go through the edge of the roof boards into the blocks which fasten the wall together at the top part of the wall.

# Tiedowns

The simplest approach to securing the building to the ground is the "candy-cane" rebar stake. Rebar is the metal used for reinforcing concrete, it is about 3/8" thick and quite strong and cheap. It is bent by placing a long pipe over one end, and then walking the other end of the pipe to lever the rebar into shape.

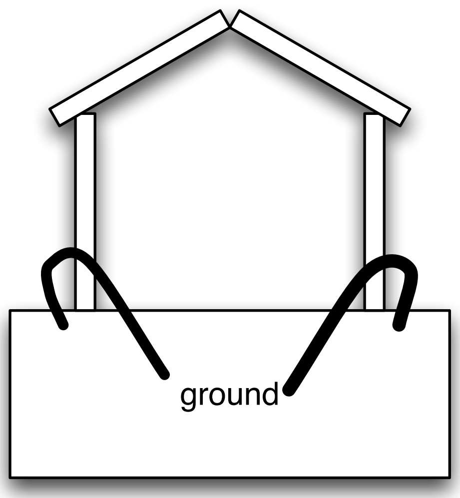


Small holes are drilled in each wall about 6" from the ground

The rebar tent stakes will only work in some kinds of soils. On very rocky ground, or even on concrete, they will be completely useless.

For those situations, ground screws, concrete footings or other standard construction techniques should be preferred.

The rebar is about 3' long after it is bent into shape



# The Research Agenda

Assuming that the hexayurt fits the operational needs of groups in Haiti, or in other disasters, there are three research questions we must answer.

1. Will the building stand up to wind, snow and other structural factors?

2. For a given material, how long will it last in the climate? What is the best material in terms of price/performance?

3. How will the building be connected to the ground?

Once these questions are answered, the building becomes an operational option, if

4. We have a sign off from an engineer that this look reasonable.

Initial work on costing this solution suggests that it will cost between $200 and $500 per unit, substantially more than the $100 per unit which buildings without these additional storm resistance properties cost.

Science for Humanity and the Hexayurt Project are actively soliciting help with structural engineering and all other aspects of building design and deployment.

Please contact Vinay Gupta, +44 7500 895 568 if you have resources to offer, or are interested in using the hexayurt in Haiti or elsewhere.

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Hexayurt Project

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