

# Ecoshell 1

**Second Edition  
with Addendum**

David B South  
Edited by Freda Parker  
Illustrated by Merrisa Ramirez



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Edited by Freda Parker

David B. South is president of Monolithic, Inc. and chairman of the Domes For The World Foundation (DFTW).

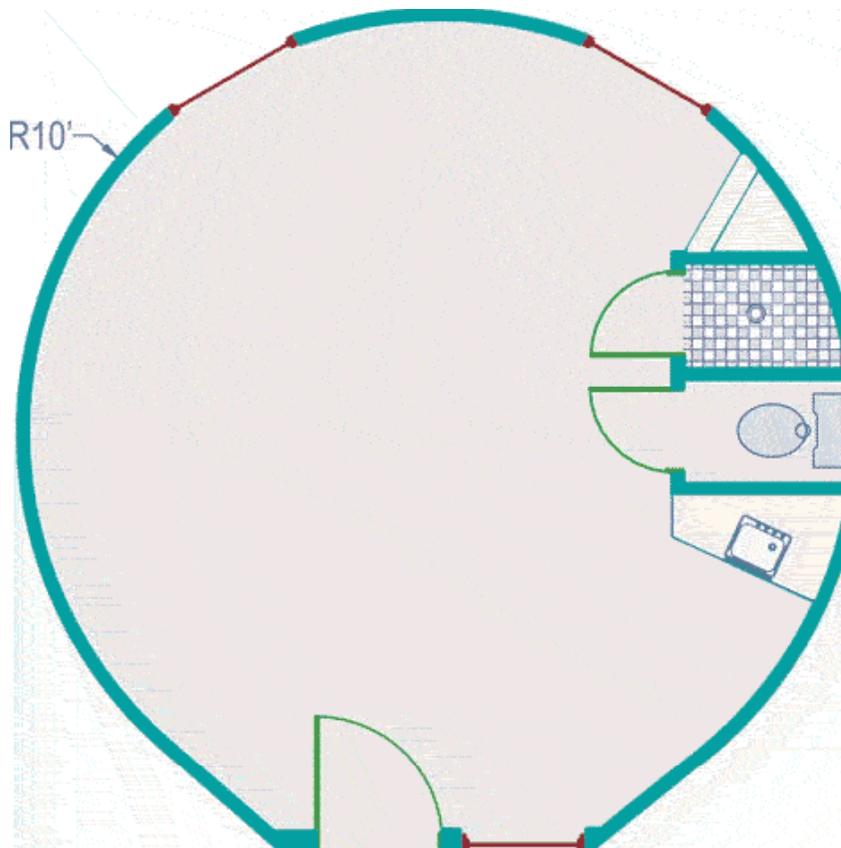
Monolithic, Inc. is a family of companies with a mutual goal: to improve the lives of people worldwide through the introduction and construction of Monolithic Domes and Monolithic EcoShells, for personal and public use. DFTW is the newest member of that family.

Established in 2006, DFTW has been registered as a nonprofit 501(c)(3) with federal tax status.

Domes For The World Mission Statement: DFTW will initiate and coordinate efforts to alleviate housing shortages in struggling cultures and impoverished lands. We will seek grants and donations to fund important projects worldwide. We will train local crews in our construction methods and technology.

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The UniShell is an EcoShell I with a diameter of 20 feet and a living area of 314 square feet, suitable for family habitation in developing nations.

# EcoShell 1

David B South

Many countries beyond the United States can benefit from the construction and use of EcoShells.

Monolithic created this step-by-step manual and illustrated it with cartoon-like drawings so that all workers -- regardless of what their native language may be -- can learn and use these instructions to complete an EcoShell I.

An EcoShell's construction process is a modern adaptation of the building of the Pantheon and thousands of other domes, erected over the centuries. The ancients built them by piling mounds of earth or by creating large, false works of timber in the shape of a dome. They then covered these forms with brick, stone or a monolithic layer of concrete. Once the covering settled or set, they removed the forms.

Monolithic has substituted an inflatable Airform for the earth work or false work. To construct an EcoShell, concrete and rebar are placed on the outside of the Airform. (This differs from the construction of a Monolithic Dome; it calls for rebar and concrete on the inside of the Airform.)

EcoShells built for habitation in developing areas with desert-like or tropical climates are not insulated; nor do they usually need to be. But they may need roof coatings. Nevertheless, EcoShells make super-strong dwellings, impervious to fire, tornadoes, hurricanes, earthquakes, and termites. They can be built by native labor for a fraction of the cost of any comparable structure.

We estimated that a single Airform can be used to build more than a hundred buildings, thus making the cost of forming negligible. Because the EcoShell is a thin shell, its actual volume of concrete is very small -- far less than that used in conventional buildings (see table).

The EcoShell is perfect for any type of building that doesn't require insulation. (Note: In climates requiring insulation, the uninsulated EcoShell should not be substituted for an insulated Monolithic Dome.)

So, in economically developed nations, particularly those with temperate or cold climates, it's ideal for garages, small warehouses, sheds, storage, grain storage, etc. -- but not housing.

However, in developing countries with equatorial climates, EcoShells can provide suitable, practical and affordable housing.

The EcoShell's construction method has also been used to build bridges over small rivers and streams. We here at Monolithic think that its applications are virtually unlimited and that, in the future, more ideas for this construction procedure will be generated and implemented.

## Monolithic EcoShells Solve World Housing Problems

The United Nations has determined that an average family habitation in developing areas needs to be about 28 square meters or 302 square feet.

One EcoShell design, the UniShell, fits that bill perfectly. The UniShell has a diameter of 20 feet and a living area of approximately 314 square feet.

Its construction, including the floor and dome shell, requires less than eight yards of reinforced concrete -- or 64 sacks of cement for a cost of about \$320. The price of the aggregate will vary from place to place, but assuming that it's about \$10 per yard, that adds another \$80. The 1,250 pounds of rebar will cost about \$375. So the total cost of the materials for a UniShell home, that will last for generations, is about \$800.

(Cost does not include labor, windows, doors, exterior coating, interior finishing.)

In countries such as the Union of South Africa, India, Pakistan, Korea, Mexico, Ghana, Philippines, Honduras and others, the need for low-cost housing is staggering. Housing shortages range from 500,00 to 1,000,000 in each.

So the need for structures is obvious, and the solution is the UniShell. Unfortunately, there is a missing part to that equation: money.

For that reason, in 2006 we established Domes For The World (DFTW), a nonprofit organization determined to promote practical, affordable and safe housing in developing nations. To that end, DFTW actively seeks grants, contributions and funding.

## Monolithic's Promise

We want to support you in your construction goals. Our website [www.monolithic.com](http://www.monolithic.com) is a carefully maintained source of information, that can answer many questions about the nature and construction of Monolithic Domes, Monolithic Crenospheres and Monolithic EcoShells.

But you are also welcome to contact us with your questions and concerns.

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## EcoShell Versus Conventional Concrete Buildings

Type	Size	Floor Area	Interior Volume	Surface Area	Concrete Needed	Rebar Needed
Dome	20' d x 11' h	314 ft <sup>2</sup>	2,408 ft <sup>3</sup>	690 ft <sup>2</sup>	8 yd <sup>3</sup>	1,250 lbs
Square	18' x 18' x 8'	324 ft <sup>2</sup>	2,592 ft <sup>3</sup>	900 ft <sup>2</sup>	22.7 yd <sup>3</sup>	4,900 lbs
	Difference	-10 ft <sup>2</sup>	-182 ft <sup>3</sup>	-210 ft <sup>2</sup>	-14.7 yd <sup>3</sup>	-3,650 lbs
Dome	30' d x 13' h	707 ft <sup>2</sup>	5,744 ft <sup>3</sup>	1,238 ft <sup>2</sup>	24.1 yd <sup>3</sup>	2,500 lbs
Square	24' x 30' x 8'	720 ft <sup>2</sup>	5,760 ft <sup>3</sup>	1,584 ft <sup>2</sup>	42.7 yd <sup>3</sup>	9,200 lbs
	Difference	-13 ft <sup>2</sup>	-16 ft <sup>3</sup>	-346 ft <sup>2</sup>	-18.6 yd <sup>3</sup>	-6,700 lbs
Dome	40' d x 16' h	1,257 ft <sup>2</sup>	12,197 ft <sup>3</sup>	2,060 ft <sup>2</sup>	30 yd <sup>3</sup>	4,200 lbs
Square	24' x 52' x 8'	1,248 ft <sup>2</sup>	9,984 ft <sup>3</sup>	2,464 ft <sup>2</sup>	68.8 yd <sup>3</sup>	13,300 lbs
	Difference	9 ft <sup>2</sup>	2,213 ft <sup>3</sup>	-404 ft <sup>2</sup>	-38.8 yd <sup>3</sup>	-9,100 lbs

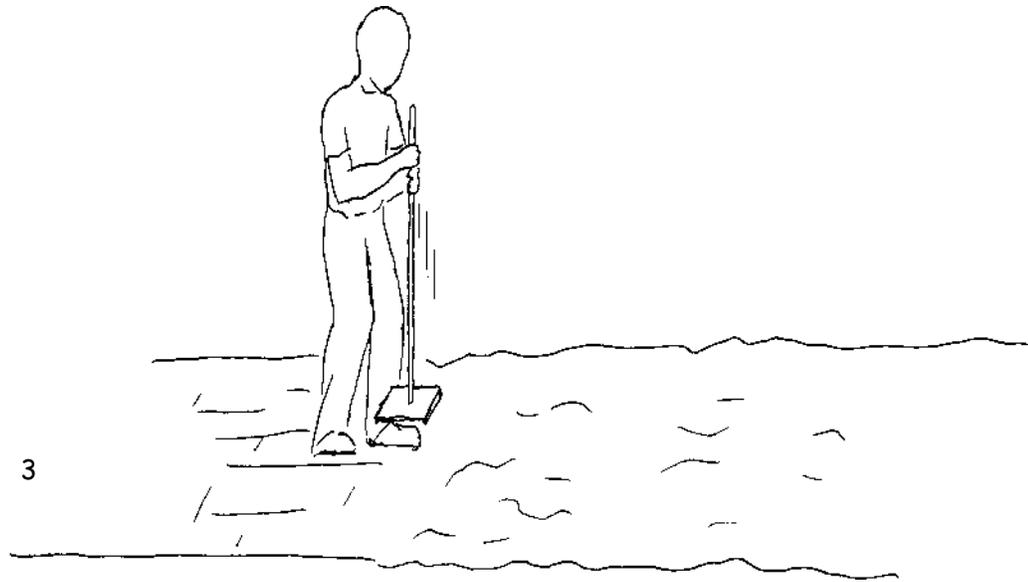
Conventional buildings require 200% to 300% more concrete, 300% to 400% more reinforcing bar and double the labor of comparably sized EcoShells. Ironically, EcoShells are far stronger and better able to withstand natural disasters.



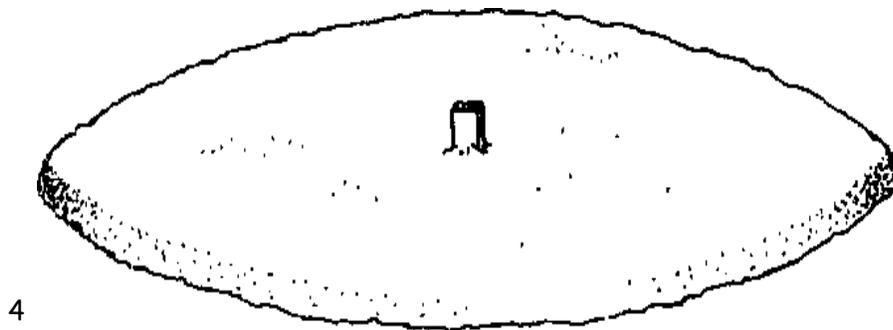
Clear all obstructions, debris and organic material, such as trees, bushes and grass, off the ground on which the EcoShell will be built.



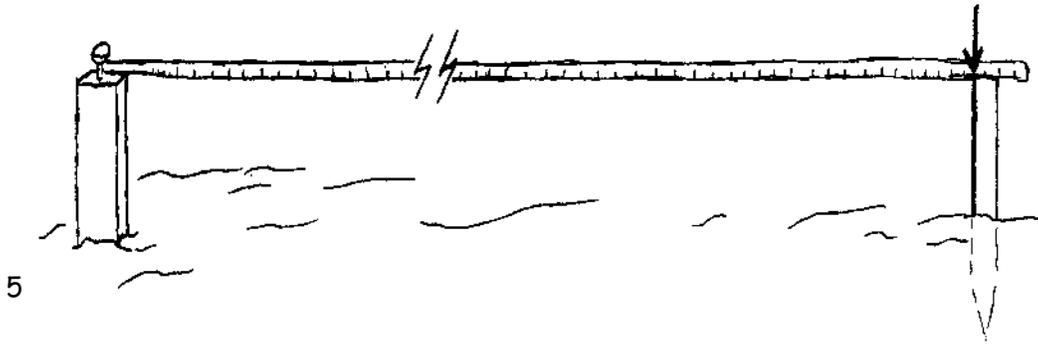
Then level the ground.



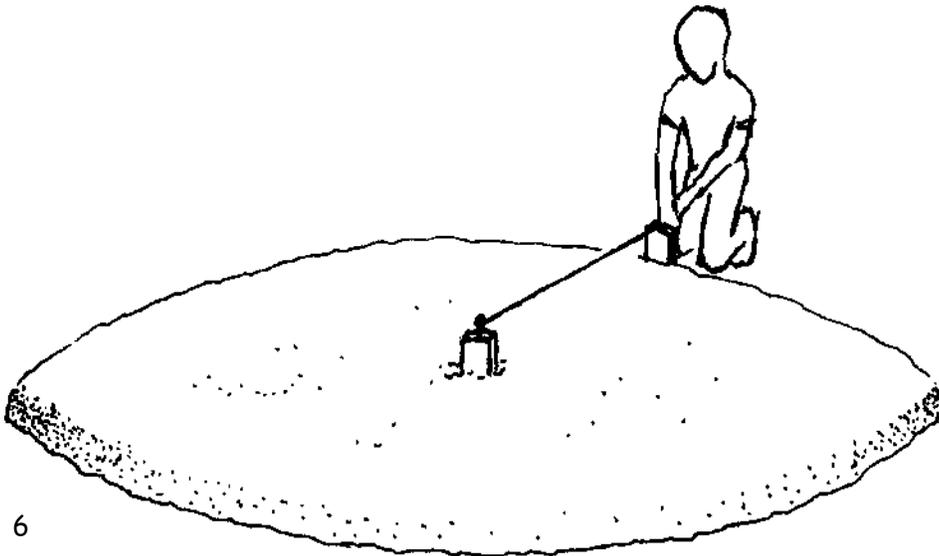
Tamp the ground with a hand tamp or mechanical equipment until it has an even, all-over firmness.



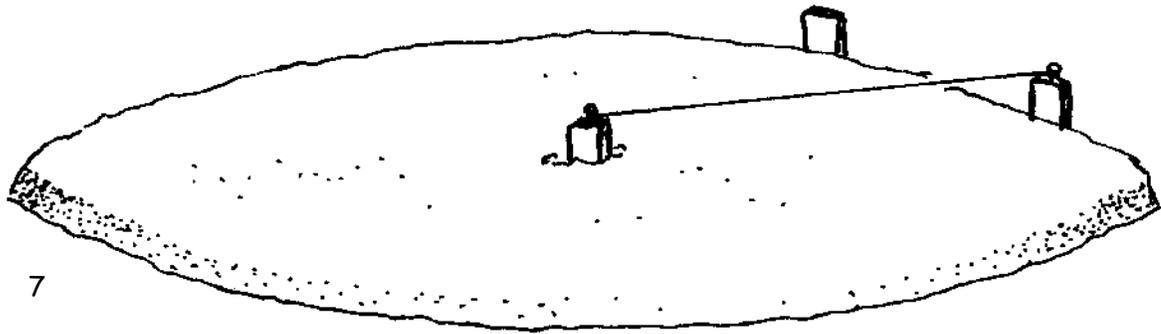
Set a stake into the center of the site that the EcoShell will occupy. This center stake will act as a guide for marking the perimeter.



Set a nail into the middle of the center stake. Using a tape or pole, measure the distance from the center stake to points on the perimeter where the forming stakes will be placed.

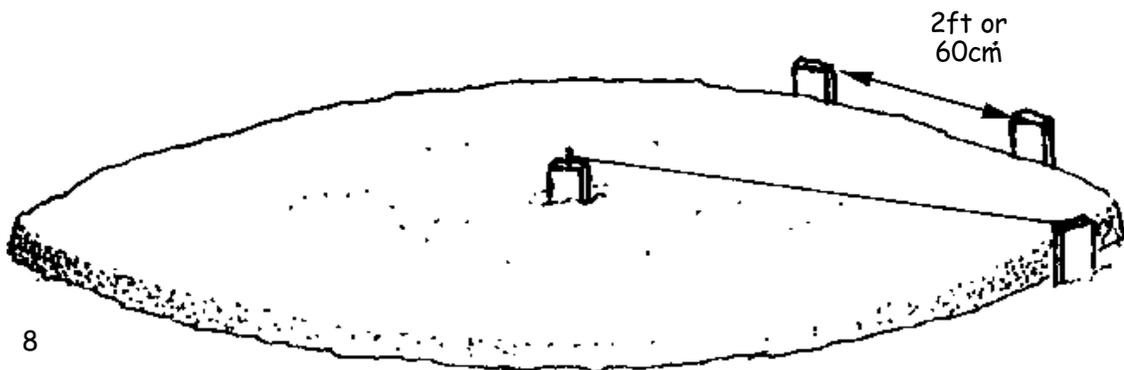


Drive the forming stakes into the ground. All forming stakes should be at the same distance from the center so that a circle is formed. Be sure to allow for the thickness of the forming stakes.



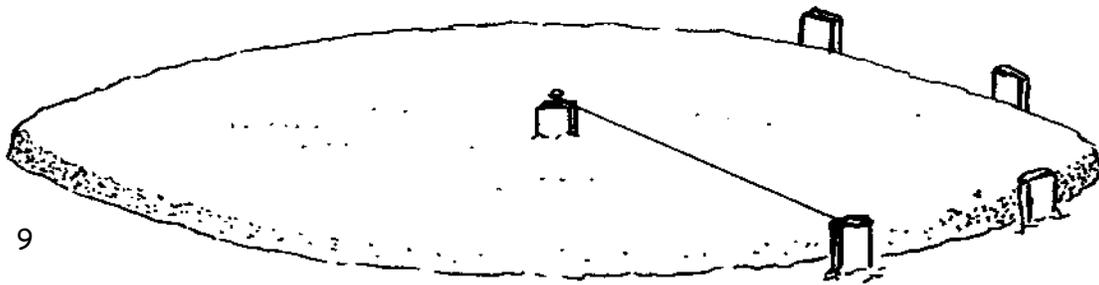
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Space the forming stakes about 2 feet apart around the perimeter. That perimeter, created by the forming stakes, outlines the site for the foundation/floor slab edge of the EcoShell.

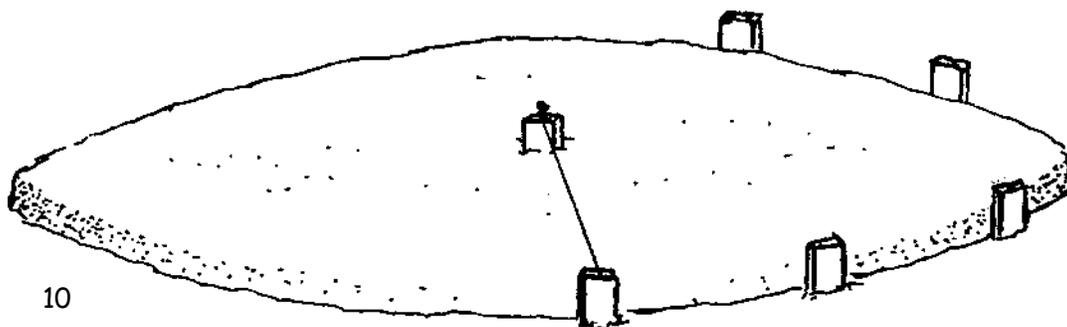


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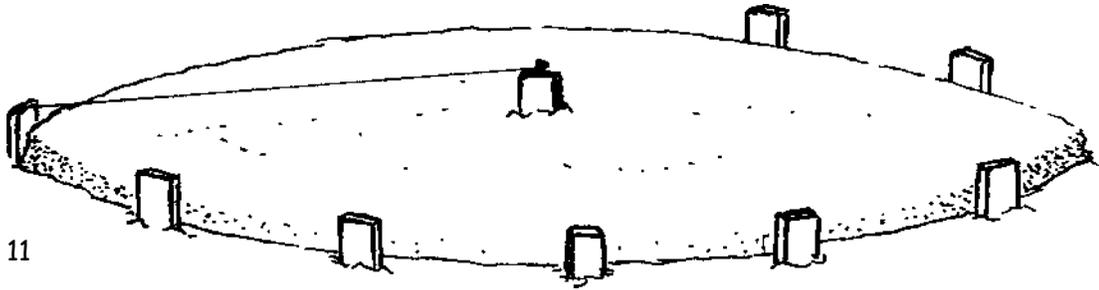
Drive the forming stakes deep enough so that they will hold under the concrete's pressure even after the footing trench is dug around the perimeter.



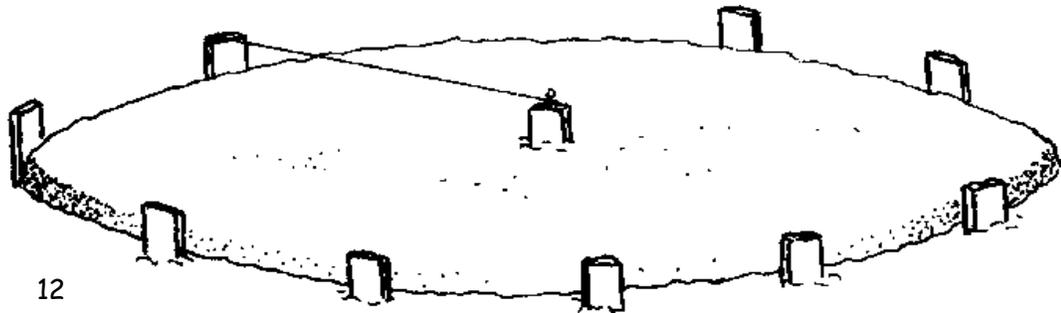
Remember that the forming stakes must all be at the same distance from the center stake plus the thickness of the forming boards. Center stake and forming stakes should all be at the same level.



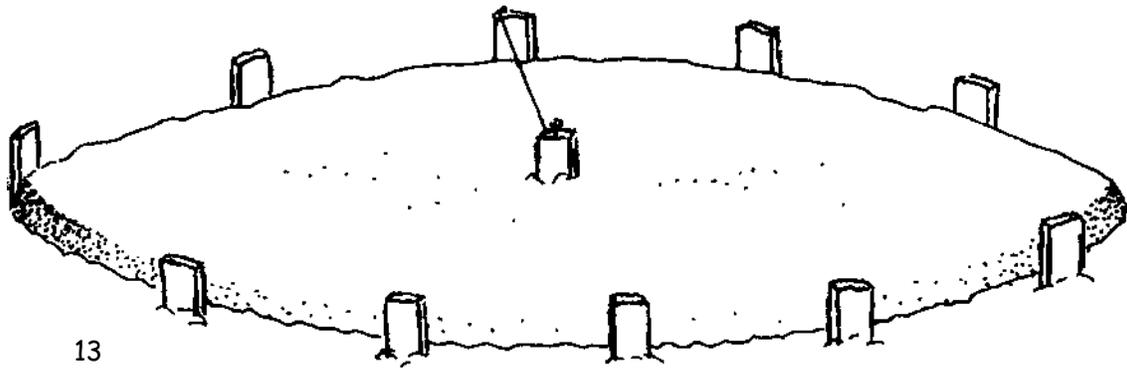
Check level and distance for each stake. Instead of trying to drive the forming stakes all to the same depth, mark the set stakes and cut them at the level you need.



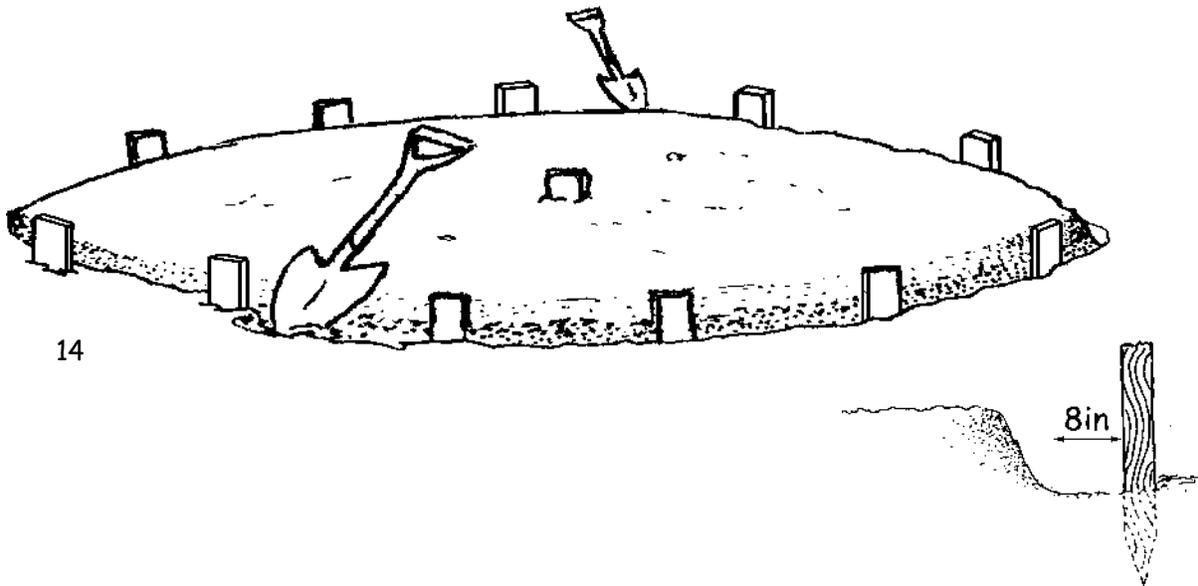
The forming stakes will contain the floor/footing. While they do not have to be perfect, it helps to have them all as level as possible.



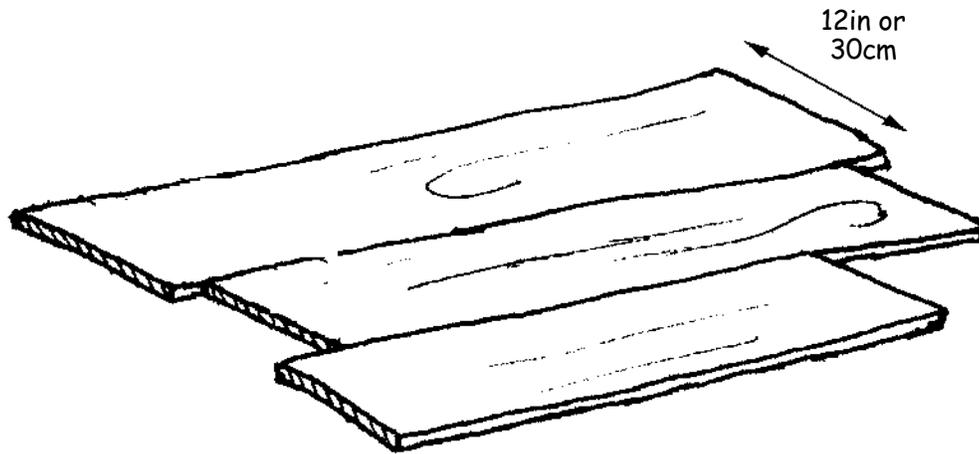
The floor will hold the Airform down as it is inflated. When inflated, the Airform for an EcoShell with a 20-foot (6m) diameter may have an uplift of 15,000 pounds (7,000 kgs).



These instructions are for a small to moderate size EcoShell. Larger EcoShells may require deeper and wider footings. After the forming stakes are driven in and leveled, they should get a final diameter check.

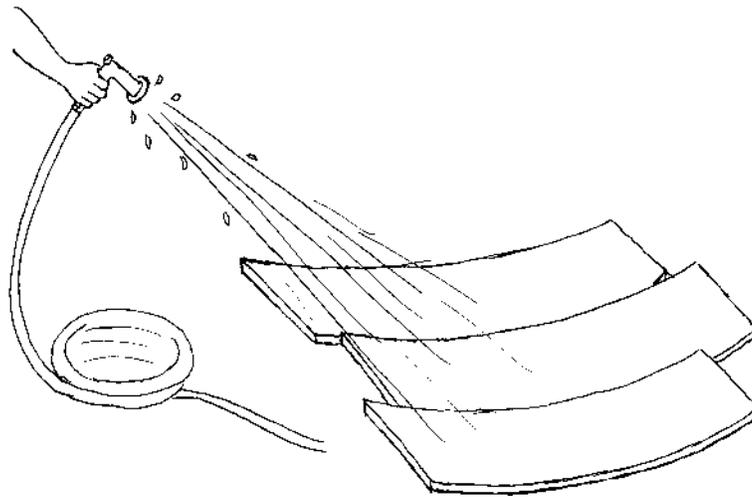


Dig a footing trench approximately 8" x 8" (20 cm x 20 cm) on the inside of the forming stakes.



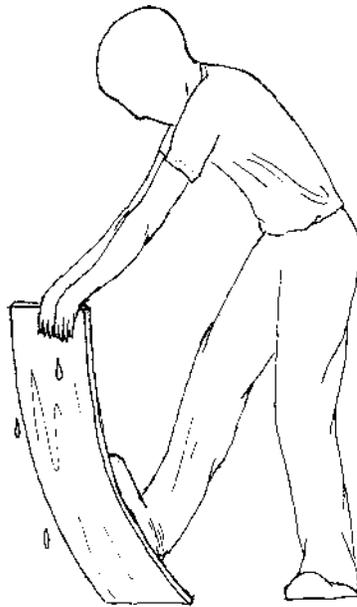
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Forming material is needed. Usually this is plywood cut into 12" (30 cm) widths. But many other products, such as heavy sheet metal, plastic panels, siding, etc., will also work.



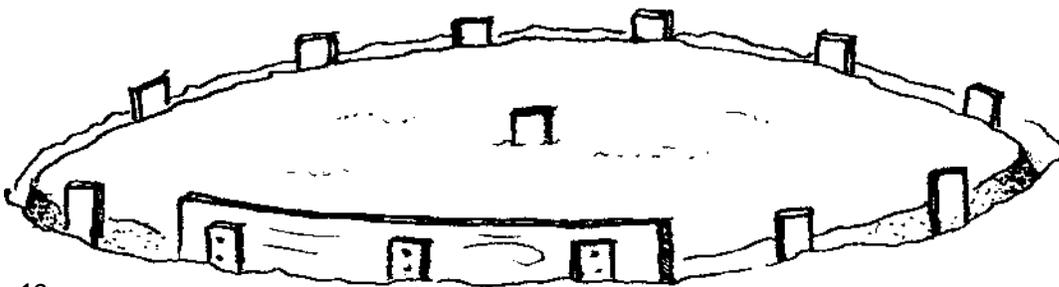
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Wet the plywood. Wetting allows you to bend the plywood into the shape you need. If plywood is not available, multiple layers of a pliable material may be used.

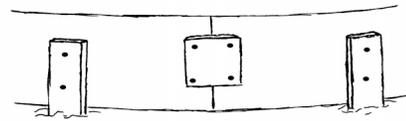


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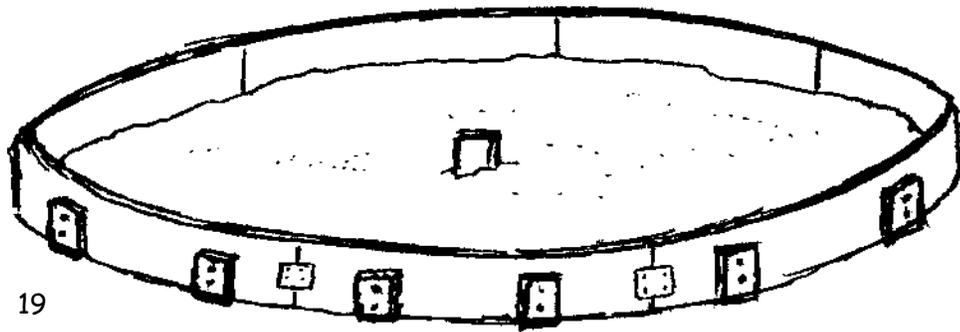
Manually bend the plywood. Before bending, the plywood may need to be soaked for a day or two. Usually, 1/2" (10 to 12 mm) plywood works best.



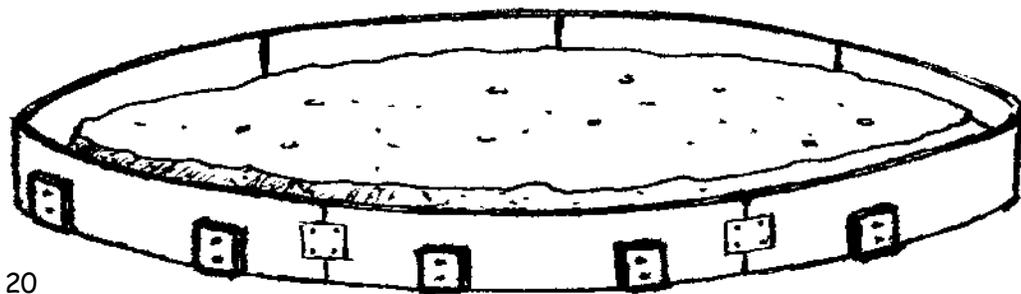
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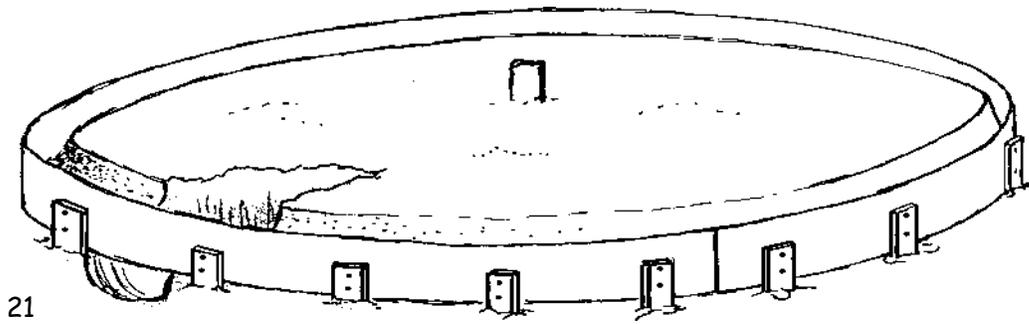
Place the formed boards inside the forming stakes and fasten them to the stakes, preferably with screws, but nails or staples can also be used. Fasten together the ends of the forming boards so that they will not move when concrete is poured inside.



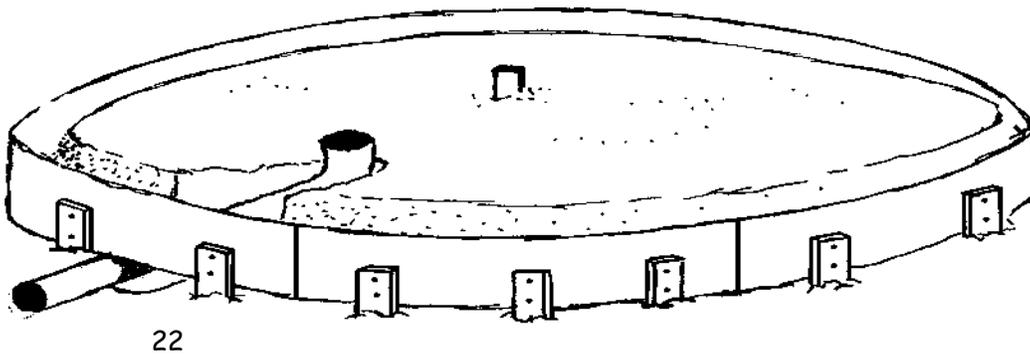
With plywood all the way around, the footing perimeter looks like this.



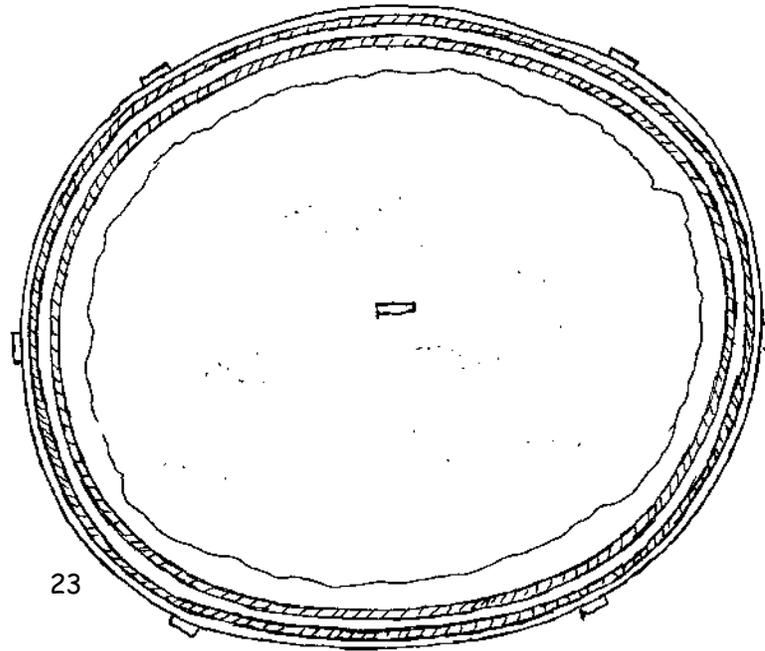
Check for proper trench diameter and be sure the floor is level. Keep in mind that changes/corrections are hard to make once reinforcing rebar is placed.



For plumbing, sewer or electrical installations, dig a trench under the plywood perimeter to the spot where the utility will be placed.

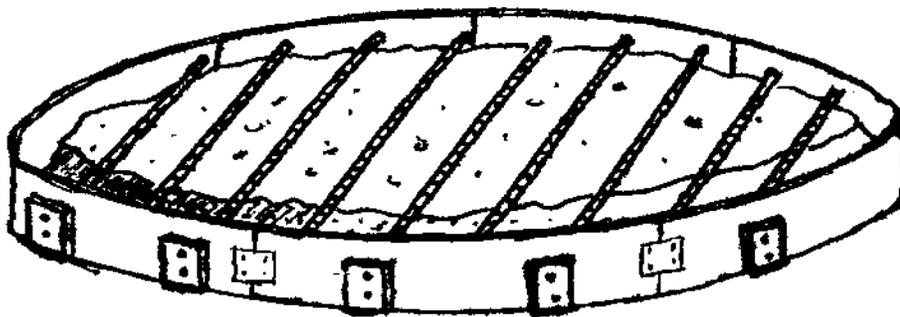


Slide pipe into the trench and up to its proper position.

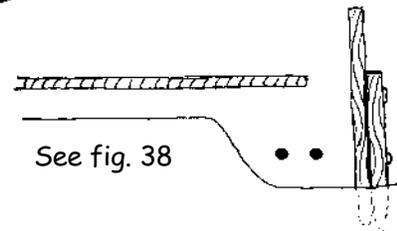


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Place two continuous rebars 1/2" (12mm) in diameter into the trench.  
Rebars may be spliced with a 12" (30 cm) overlap.

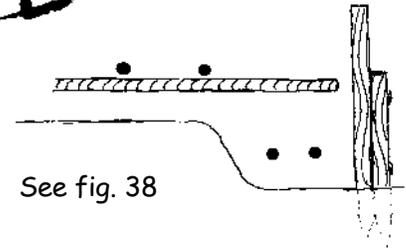
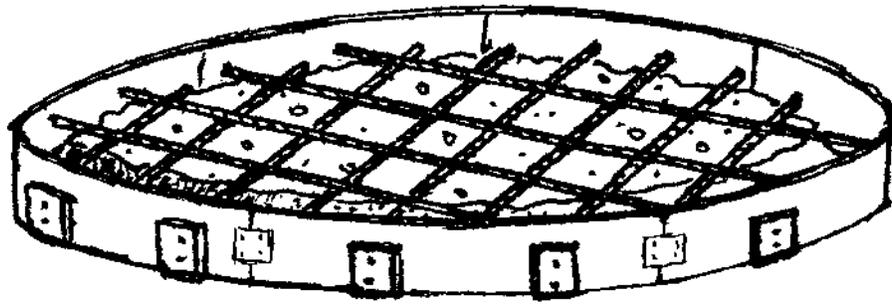


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See fig. 38

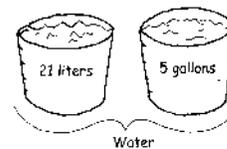
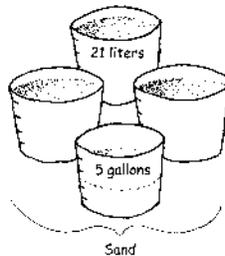
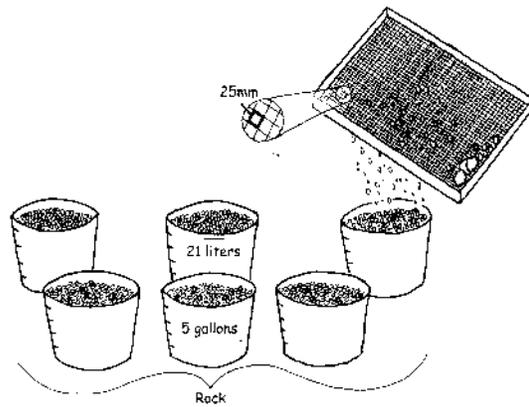
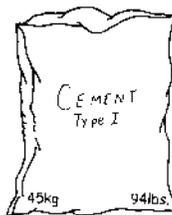
Use bricks to hold perimeter rebar (ring beam tendons) 3" off the dirt  
and at least 2" in from the formed edge. Then place the floor rebar.



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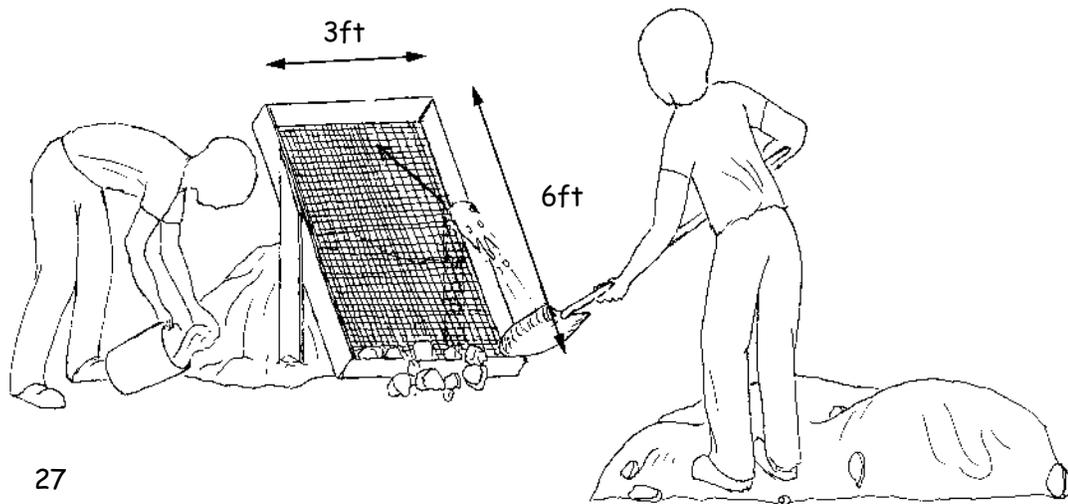
Place floor rebar in the middle of the slab. A cross pattern of #3 (3/8" or 10 cm) rebar 15" (35 cm) on center is adequate for most floors. Stop rebar about 2" (5cm) from edge.

Mix: 1 bag cement  
 6 buckets of rock  
 4 buckets of sand  
 2 buckets of water  
 -----  
 1 batch of cement



26

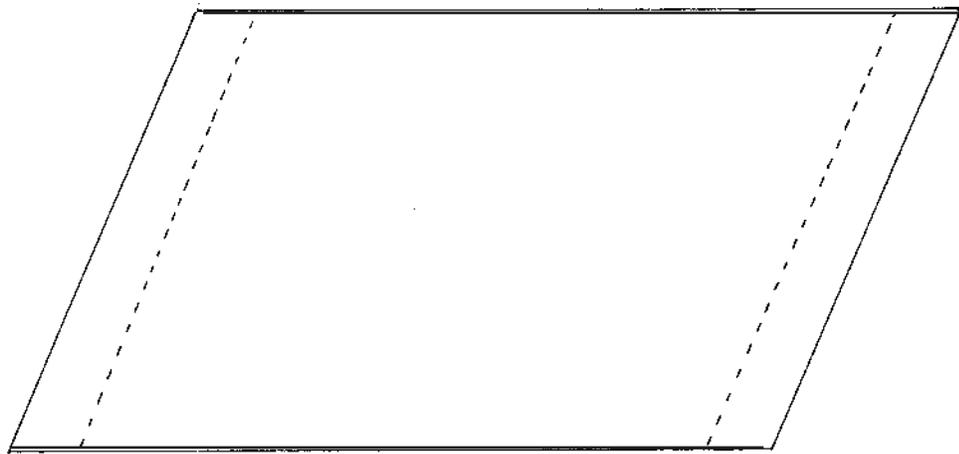
Materials for the footing mix: Cement Type I or II, several 5 gallon (21 liters) buckets, a sifting screen with 25 mm holes



Sift the dirt by throwing the unsifted dirt at the top of the screen. As the dirt falls to the bottom, the proper mix size will fall through.

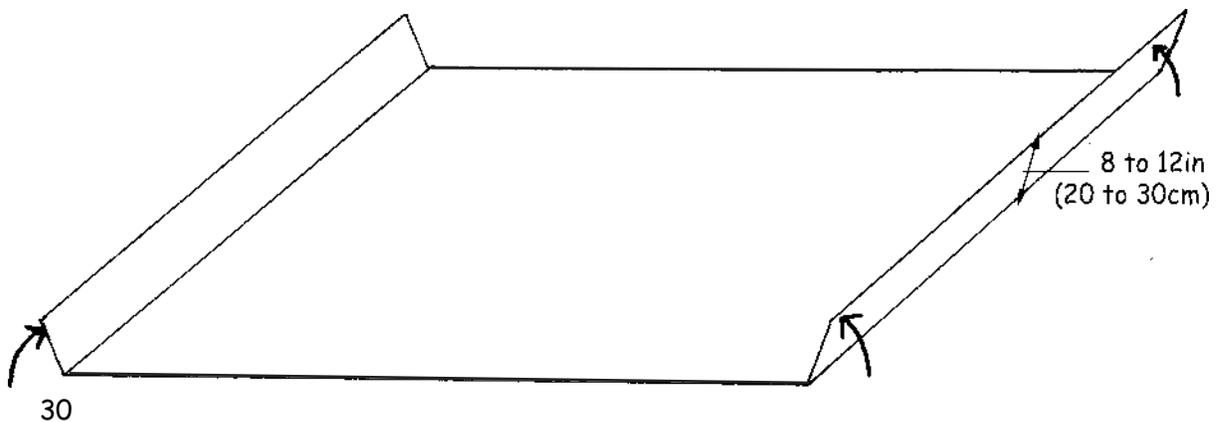


Mix the concrete in a wheelbarrow or a mixing box.

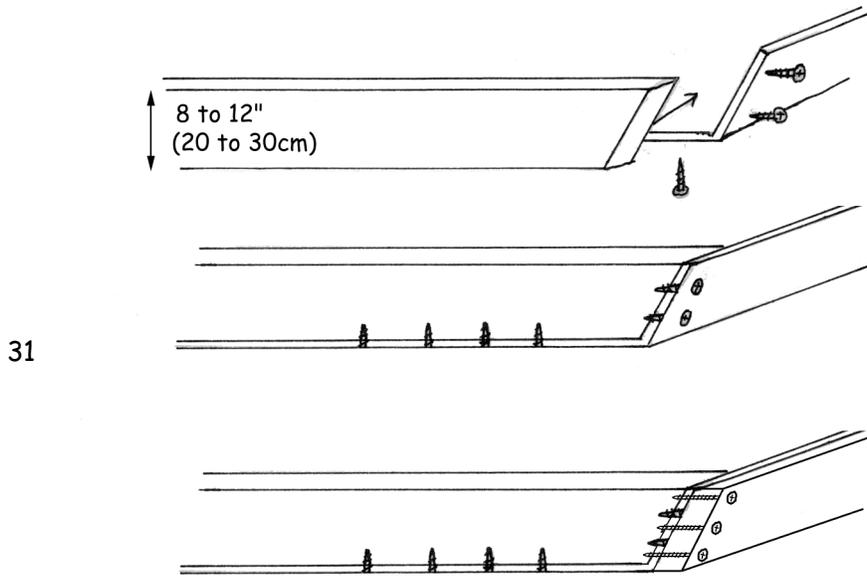


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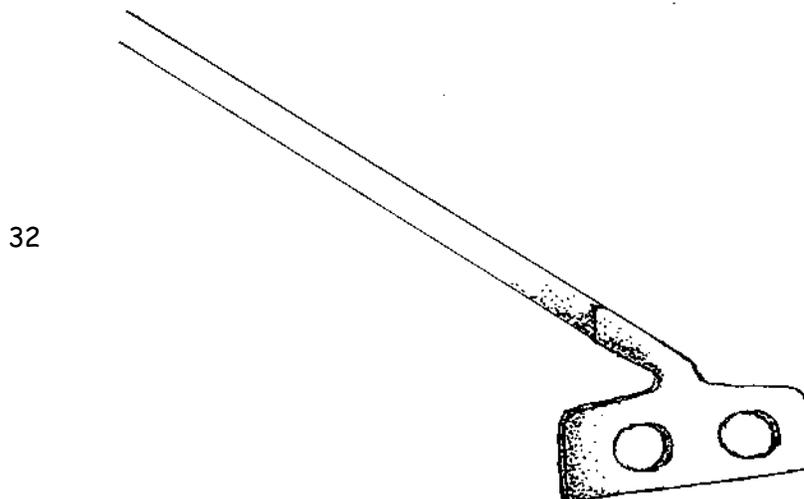
Mixing boxes are made with sheet metal floors enclosed in wood frames. The sheet metal can be anything, but 22-gauge galvanized steel is recommended.



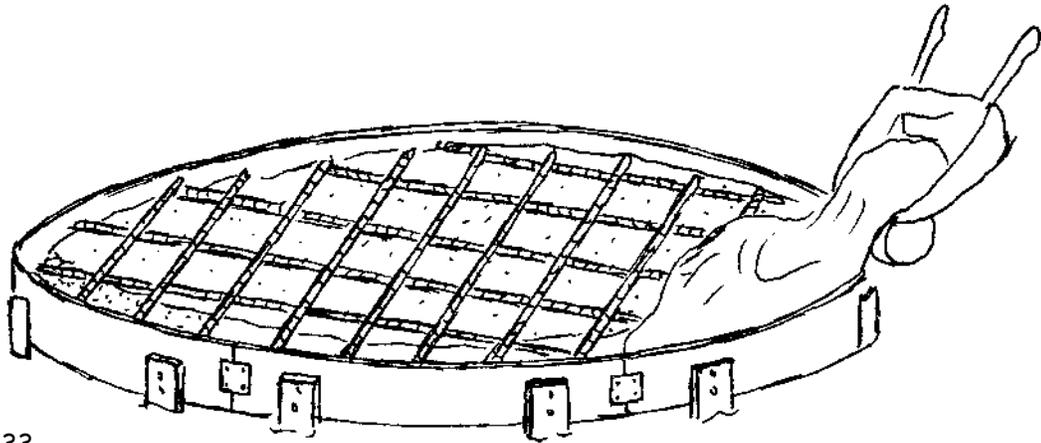
For 2 people, sheet metal measuring 36" x 72" (1m x 2m) is adequate. Factory bends can often be made at time of purchase. If not, the sheet metal can be field bent.



Fasten sheet metal to wood frames with screws or ring shank nails. To minimize leakage, place screws close together. First batch of concrete that's mixed will stop leakage.

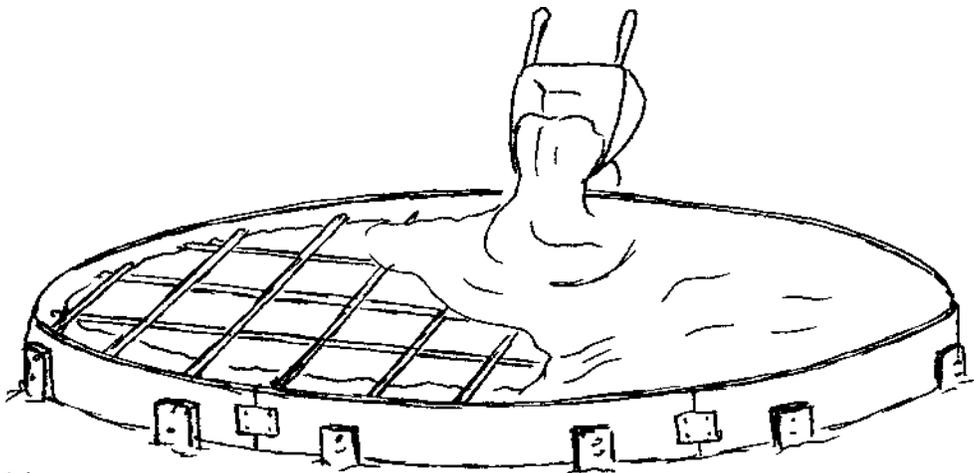


Mix concrete using a hoe. Any hoe will work, but the best hoes for mixing concrete are large and have double holes that provide twice the mixing action.



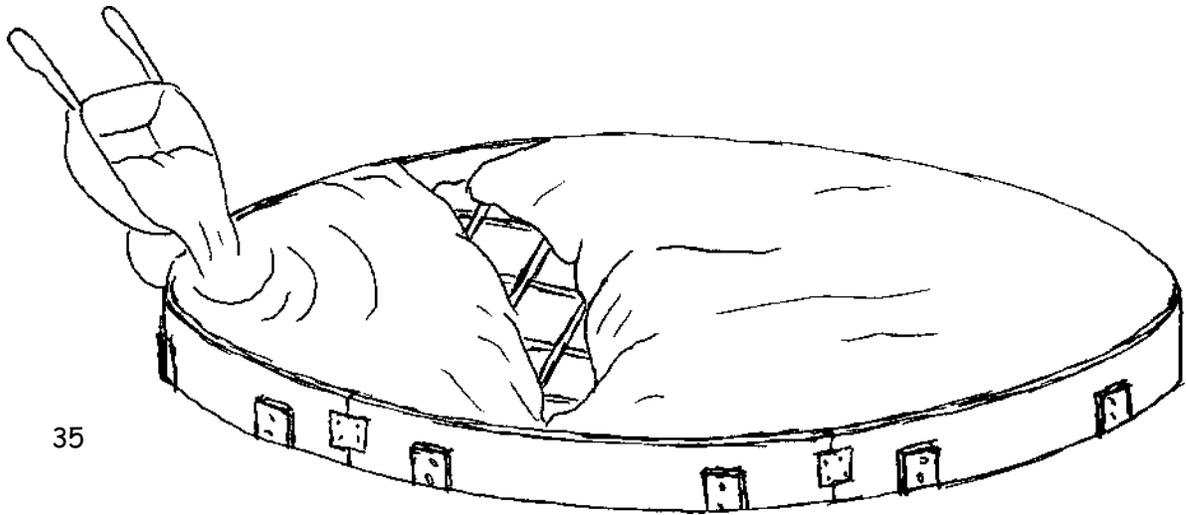
33

Mix concrete for the floor, by hand if you like. Concrete should be placed fast enough to prevent cold joints. Keep putting fresh concrete against older concrete all the way around.

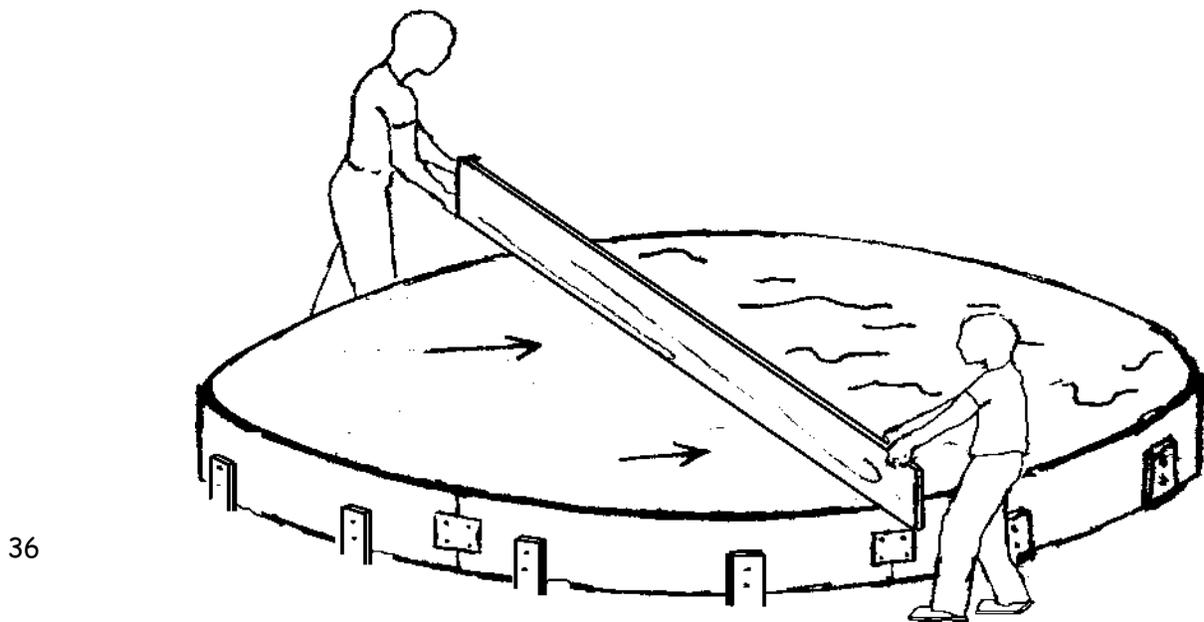


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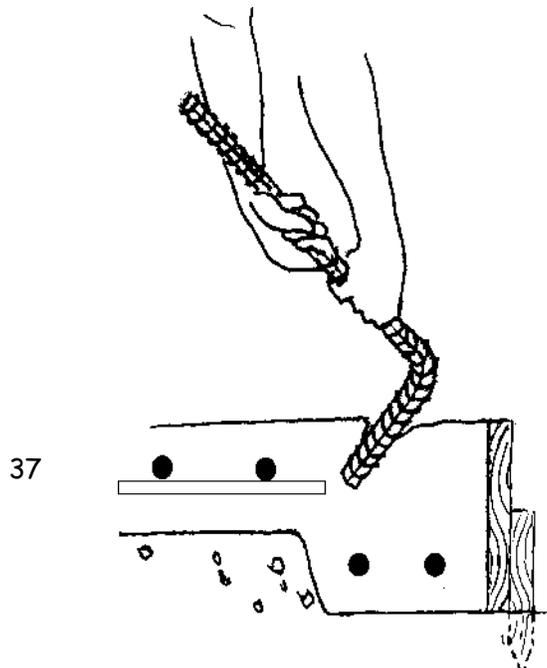
Use care in pouring the concrete so that rebar stays in the middle of the slab. Check to make sure that the placing of the concrete does not knock the forms out of alignment.



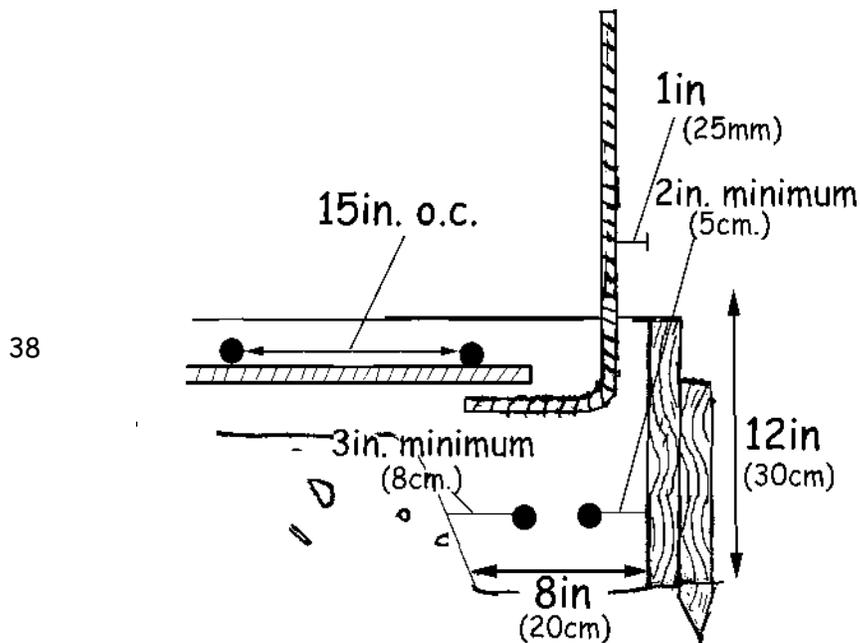
Place concrete. If placing of all of the concrete cannot be done in 15 minutes, start the concrete placing on one side and continue placing by moving across to opposite side.



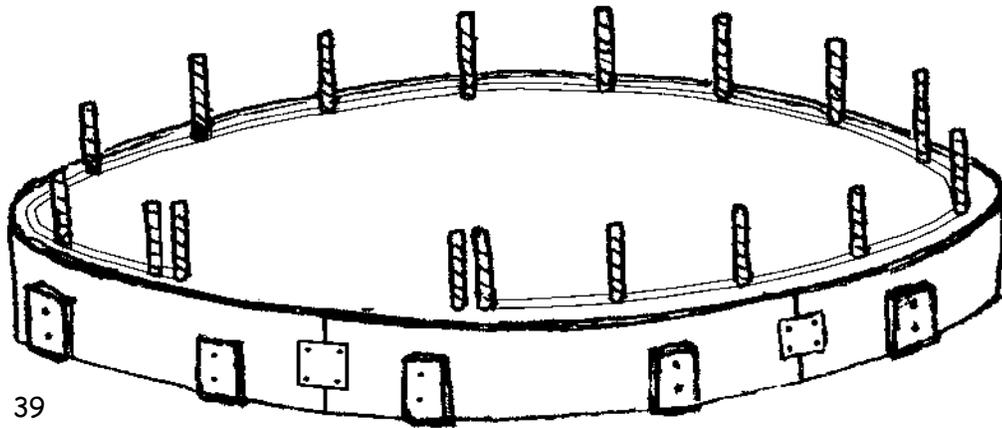
Level the concrete with a screed board as it's being poured. Excess can be moved ahead or removed. As concrete hardens, it can be troweled to a finer finish.



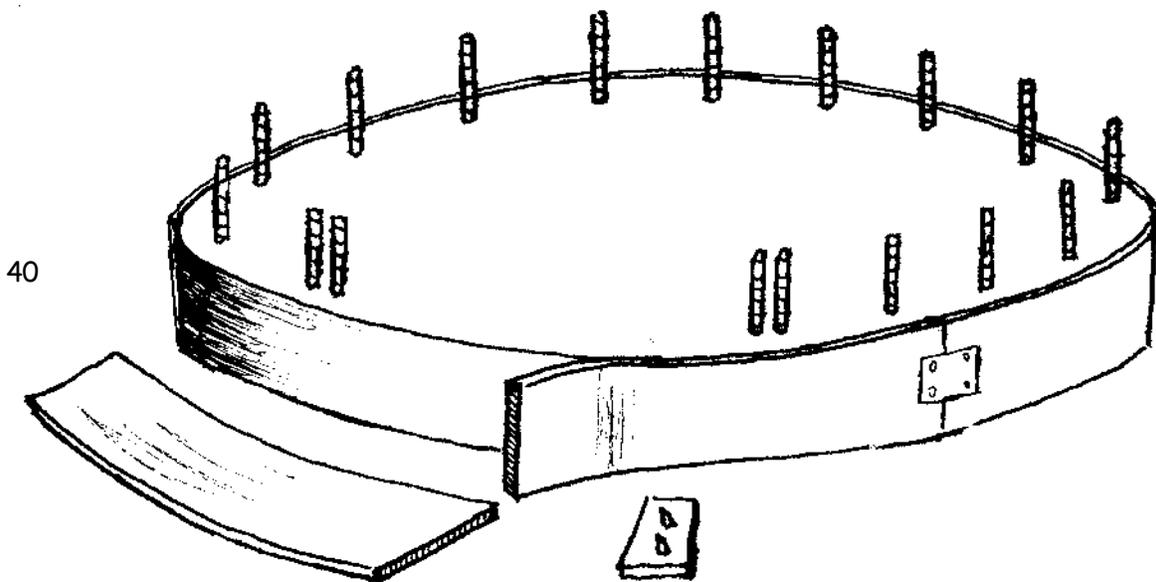
Important: Before the concrete floor/footing sets up, the uprights must be placed. Uprights are #3 rebar (3/8" or 10 mm). Place the short leg into the floor about 1" from the edge and turn it, as much as possible, toward the center.



Placement shown is for an EcoShell with a 10' to 20' diameter. Larger structures may require different engineering. Always check for accuracy.

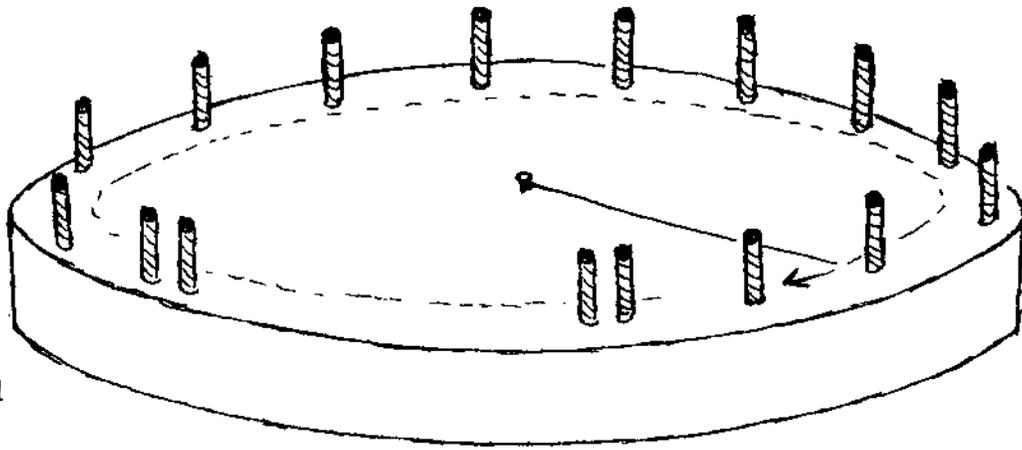


Place two uprights on each side of a doorway, but do not place any uprights within the doorway. Dig a small trench approximately 1" (25 mm) wide and 3/4" to 1" deep into the fresh concrete between the uprights, except for doorways. For larger structures, this trench should be 2" wide and 1" deep.



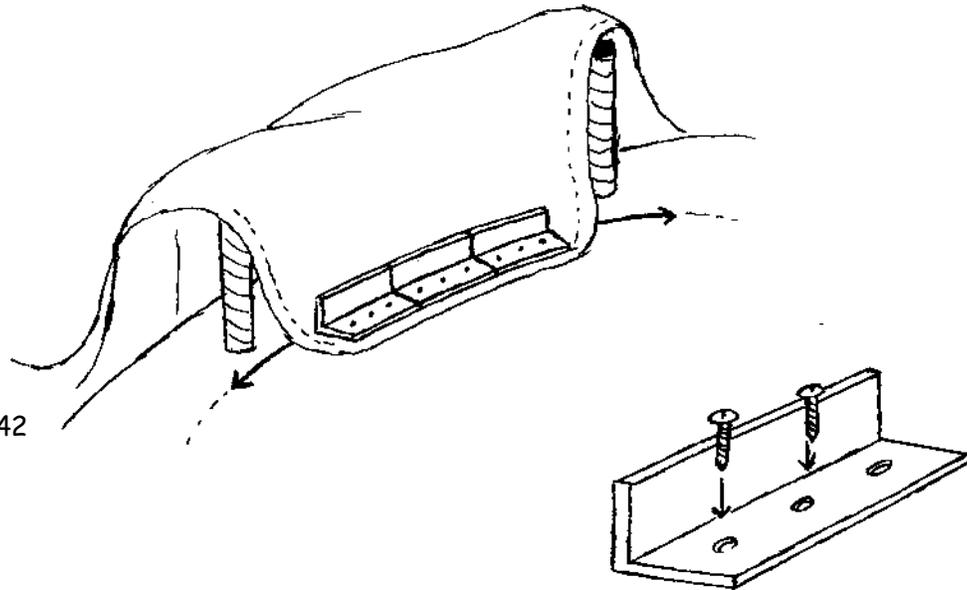
Remove the form boards once the concrete sets -- usually the next day. Provide a safe and clean job site by cleaning and stacking the form boards for future use.

41

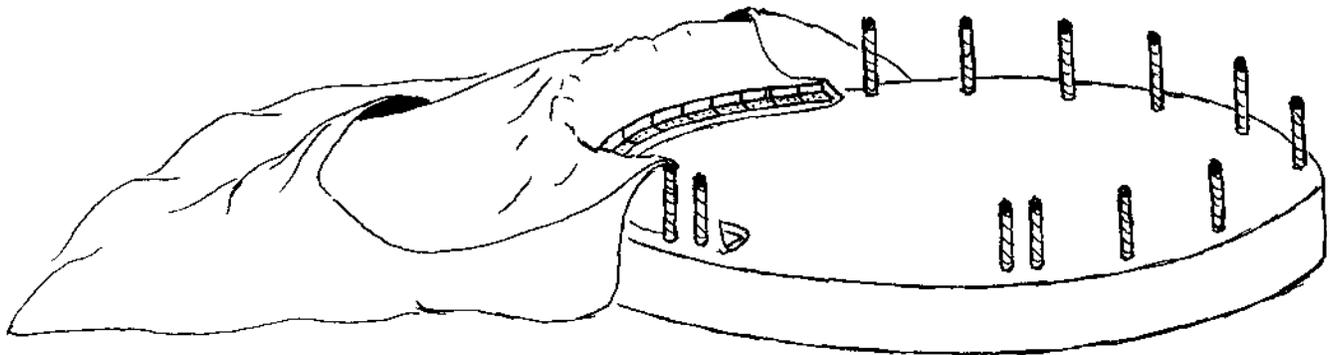


Mark a guideline 1" (25 mm) from the uprights. Guideline indicates where the edge of the EcoShell's Airform will be.

42

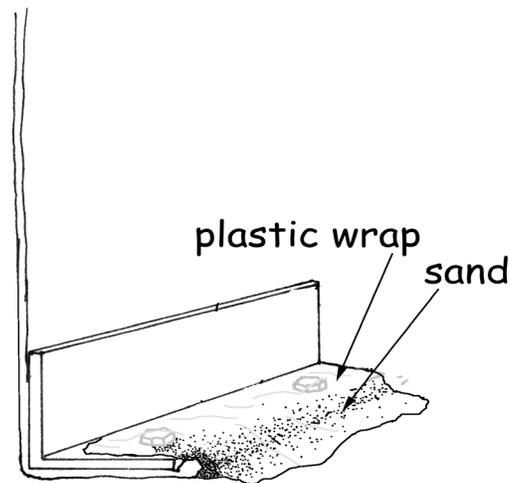
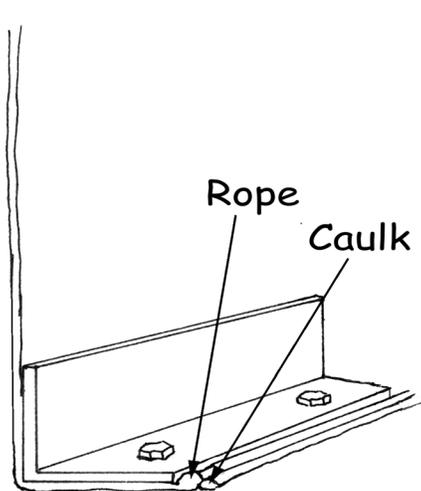


Place Airform as shown. Use 1, 2 or 3 concrete anchors as needed. Anchors can be screws (Tapcons) or a wedge foot anchor. It must be removable.



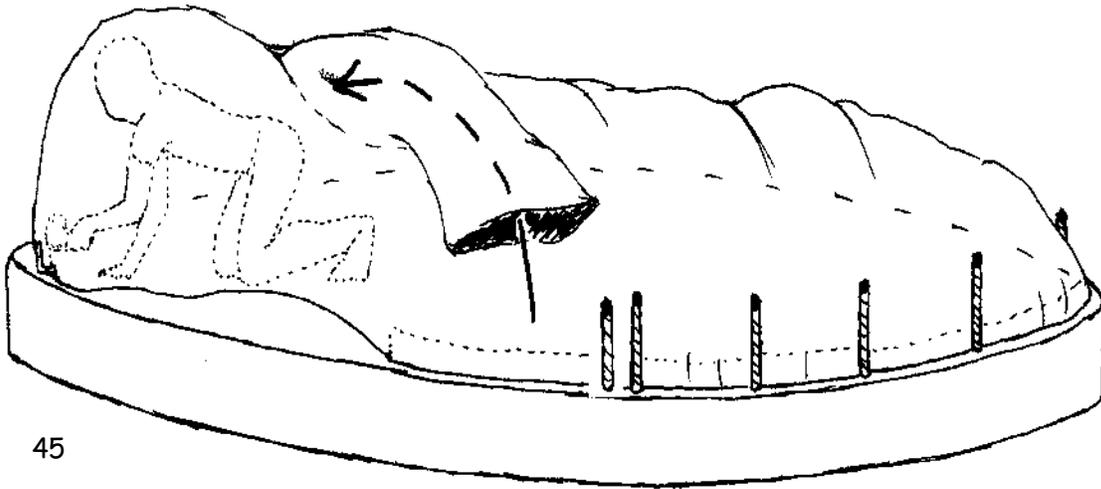
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Continue placing clamp angles along the guideline. Carefully stretch the fabric along the guideline, distributing the fabric evenly all around. If not stretched evenly, there may not be enough to go all the way around.



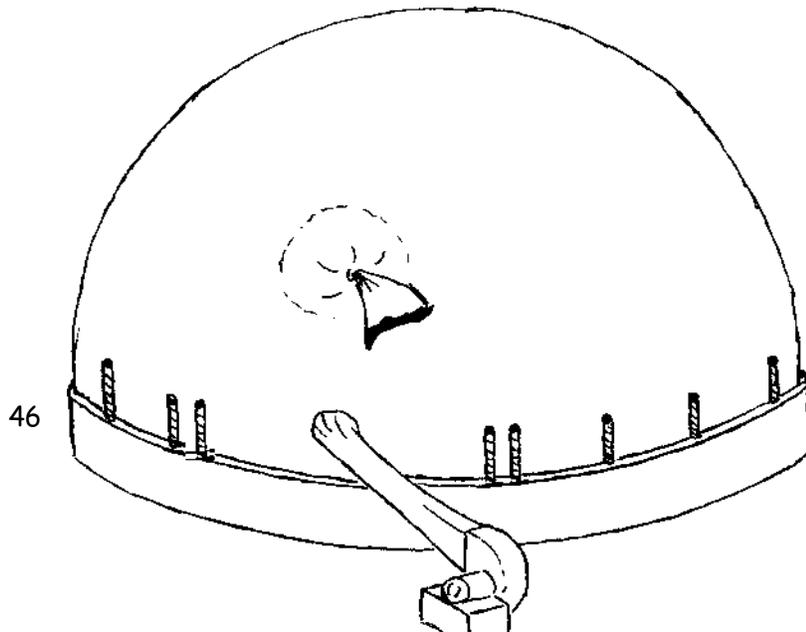
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After all clamp angles are in place, the joints must be sealed. Clean the joints and seal them with caulking or with plastic wrap and sand. See last page for drawing of Clamp Angle.



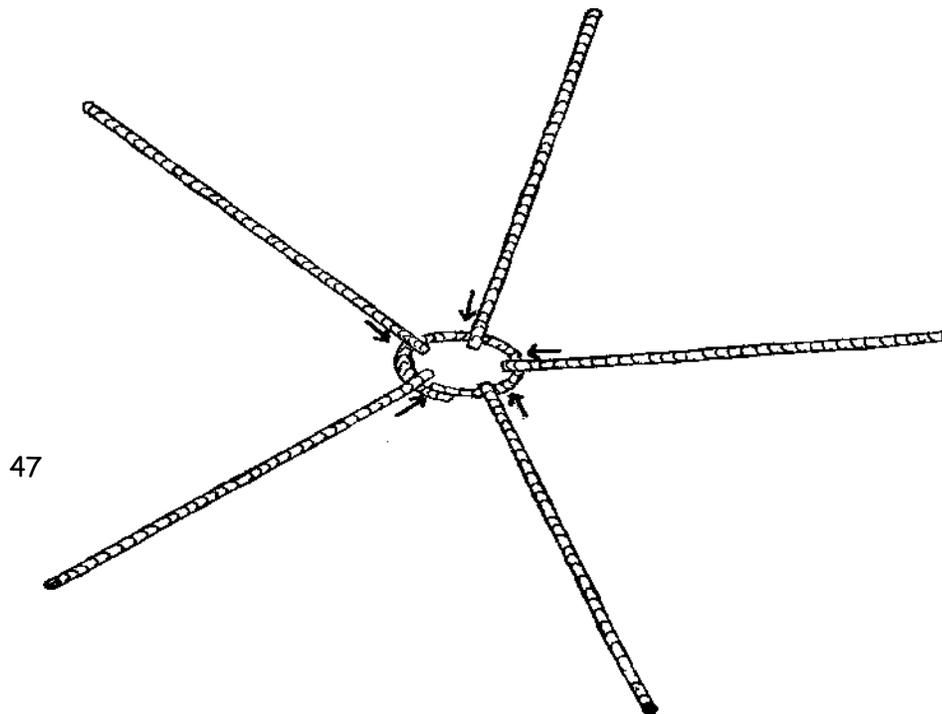
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As placement continues, workers placing the clamp angles will wind up inside of the Airform. Workers can crawl out through the provided sleeve. A saw horse or other bracing device used to hold the fabric off the workers is helpful.



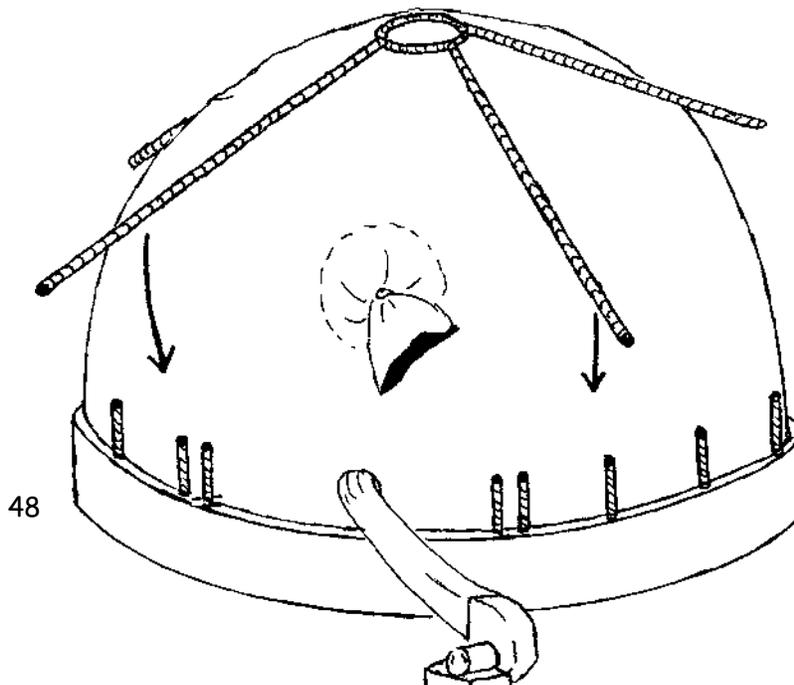
46

After all workers have exited, roll up and tie off the sleeve, making the Airform as air tight as possible. As placement of clamp angles progresses, ventilate under the Airform by starting the inflators. This is especially useful if a large fan is used only for this phase. The EcoShell Inflator must be used to properly inflate the EcoShell's Airform for construction.



47

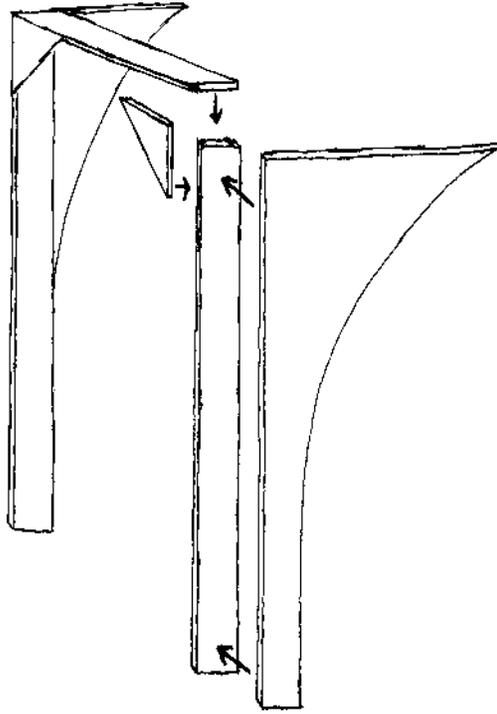
Start the rebar hanging with a few rebar tightly bent around a center ring 1.5' to 2' (45 to 60 cm) in diameter. Place the ring in the center of the Airform's top and, on the outside of the Airform, hang the starter rebar from the center ring to the perimeter.



48

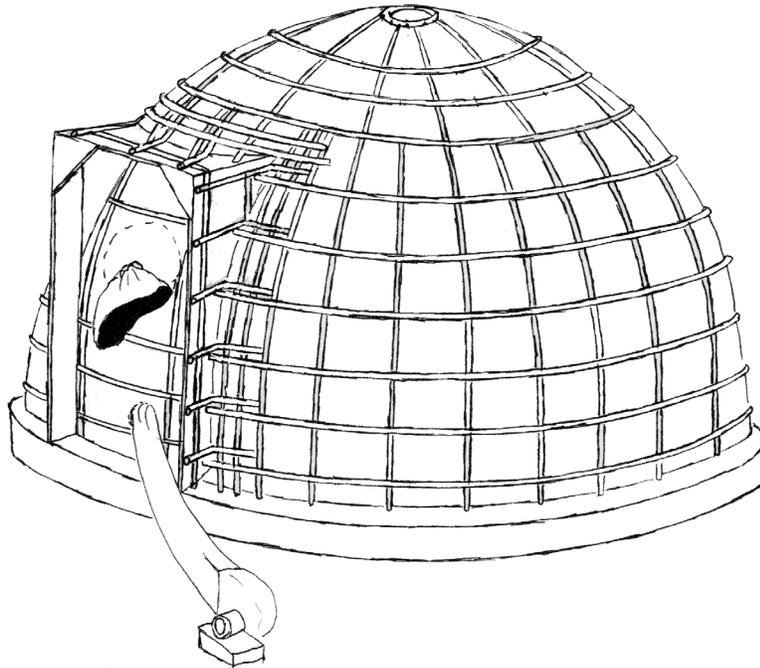
Tie the starter rebar to the uprights as shown, creating an even layout. Depending on the size of the dome, the layout will vary. Maintain a maximum spacing of 10" (25 cm) each way. Vertical rebar should lay against the Airform.

49



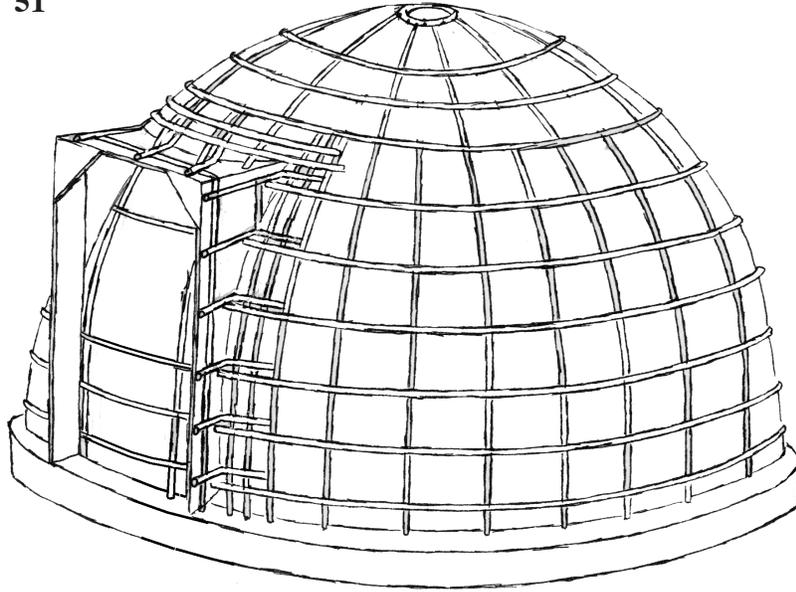
From plywood or boards, cut pieces that will make up the augmentations. Scribe them to fit the Airform. Then lean them against the Airform and fasten them to the rebar.

50



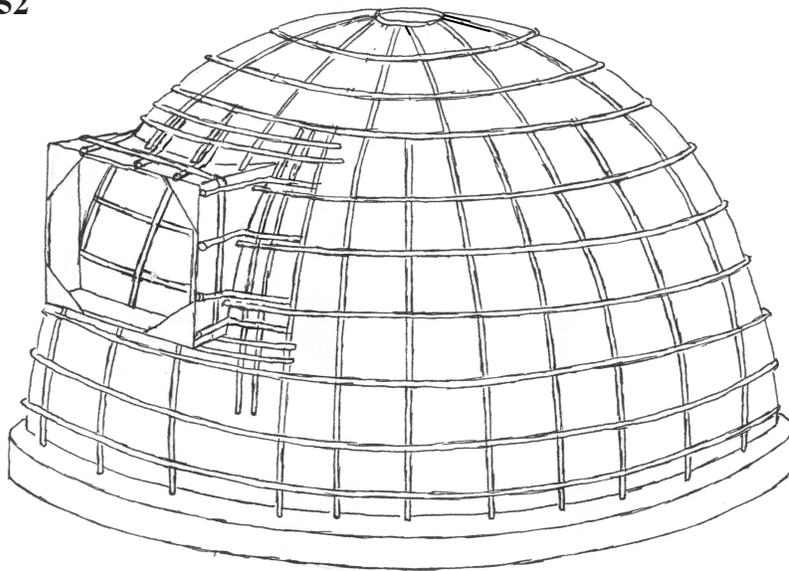
Position vertical rebars 10" (25 cm) apart. Place horizontal rebars over the outside of the vertical rebars. Attach horizontals to verticals.

51



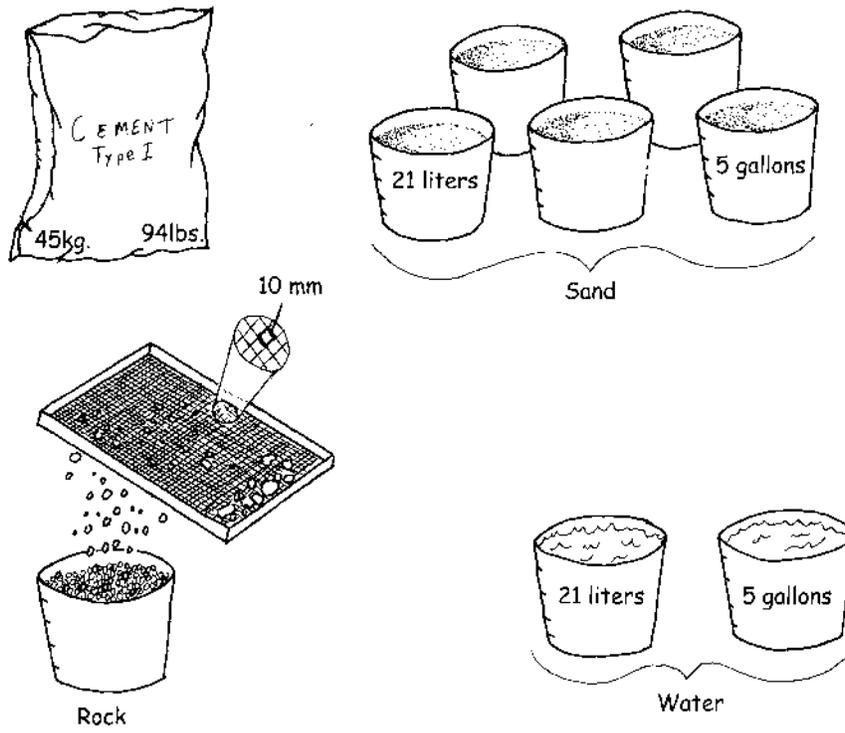
Place rebar around the augmentations and tie it to the shell rebar.  
Leave existing shell rebar in place; it can be cut out later.

52



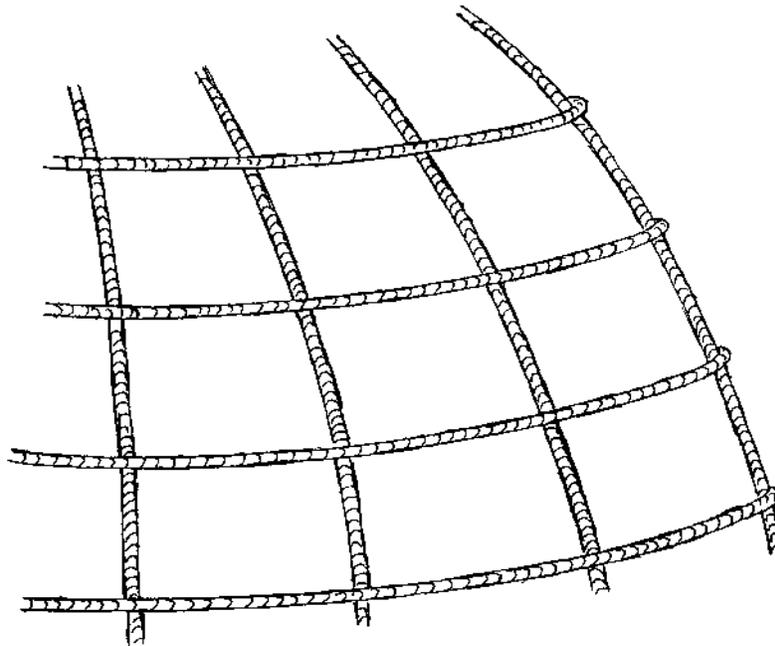
Place two or more extra rebars on top of and on the sides of the opening in the shell.

53



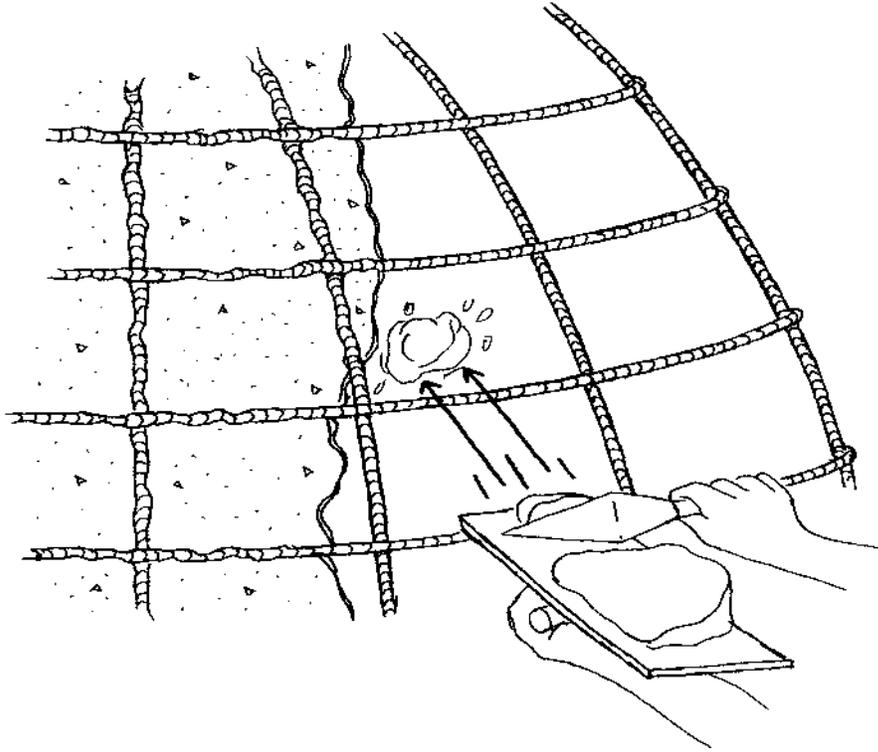
Shotcrete mix is stronger than the floor mix. It's designed as 4000 psi (280 kg/cm<sup>3</sup>) concrete. If sand contains coarse material, add another pail of sand and omit the rock. Add nylon fibers and Kel-Crete to the mix.

54



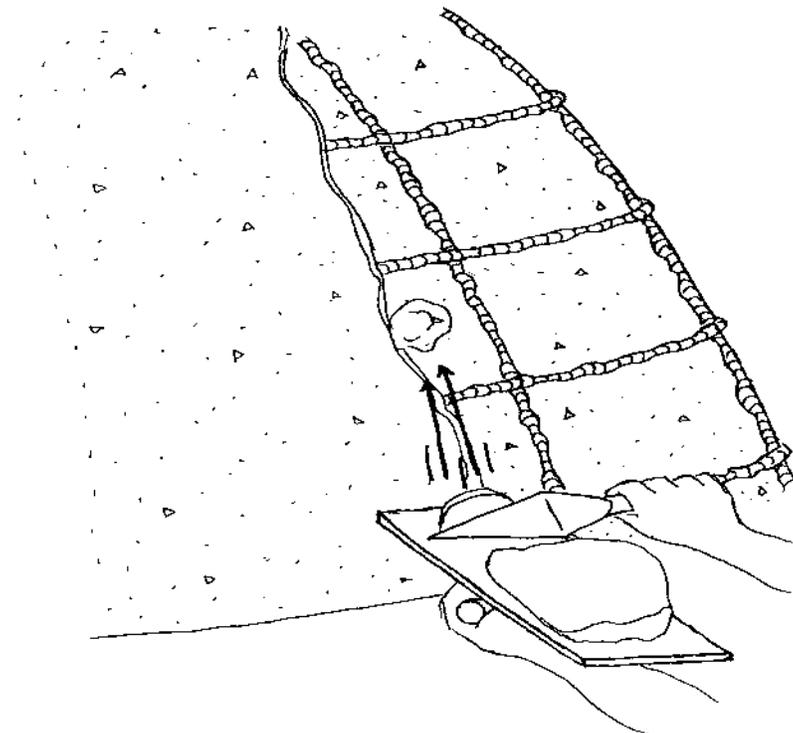
Make final inspection. Rebar should lay on the Airform with horizontal bars on the outside. Maximum spacing between rebar is 10" (25 cm) each way.

55



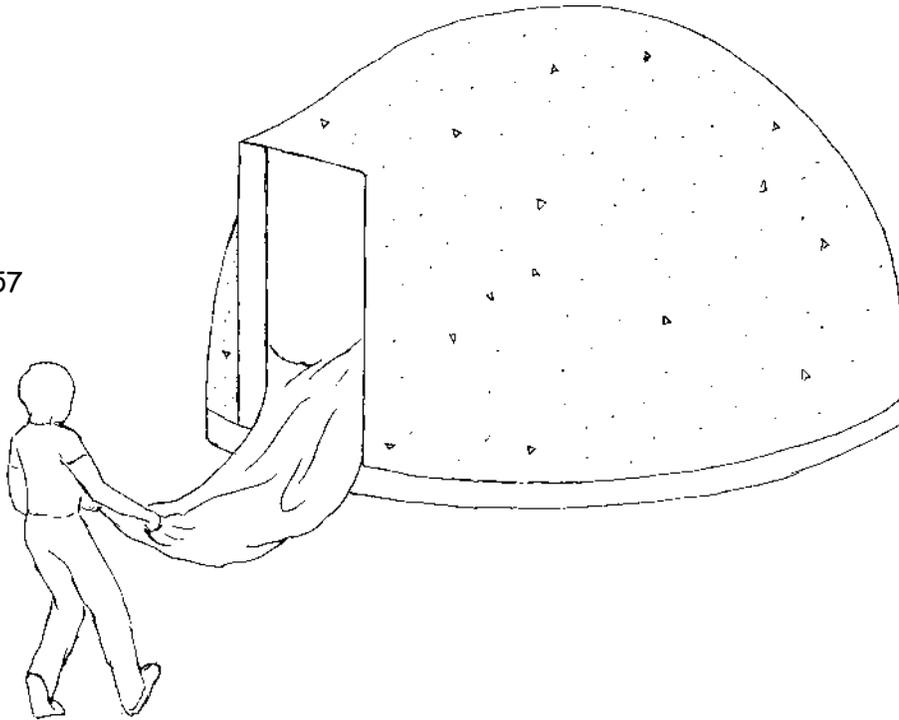
Apply first layer of concrete. Concrete can be hand applied by troweling or flipping it on, using a small mason trowel. It also can be applied with a Shotcrete pump. Be sure to place only what will stick.

56



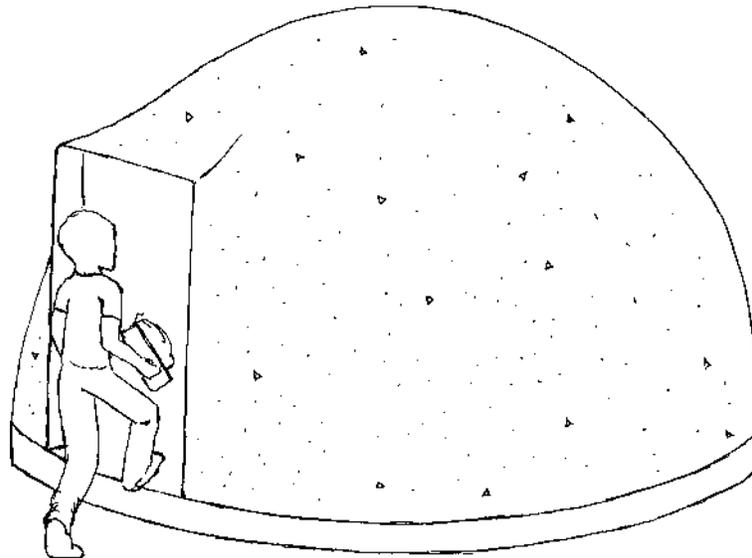
Note: A layer of concrete should be hard to the touch before applying a new layer of concrete over it. Be sure first layer is hard before applying second and second is hard before applying third. Keep concrete moist between coats.

57

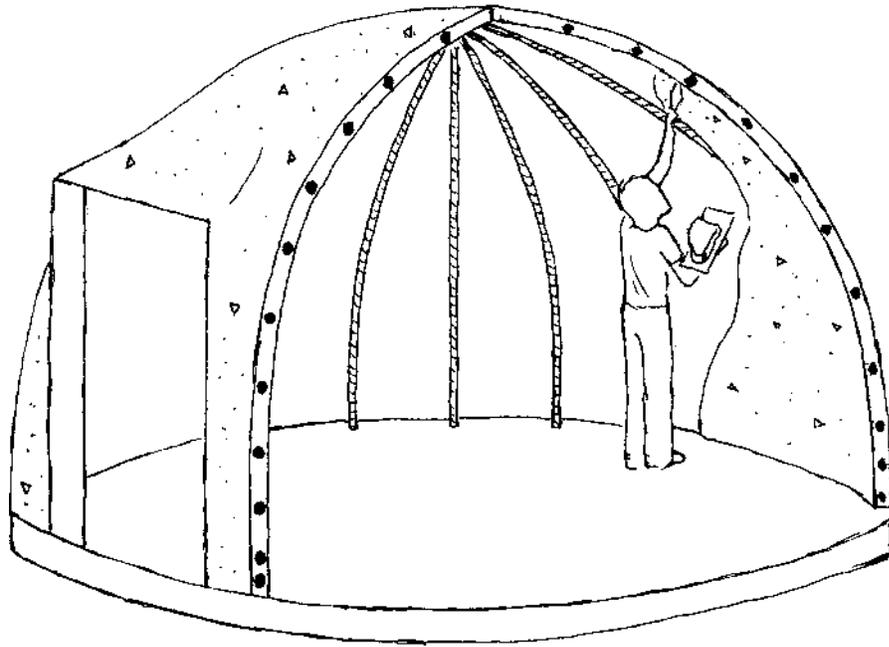


Remove the Airform after the exterior concrete has cured -- usually about 24 hours after the final concrete coat has been applied. But in cold weather, curing may take a few days.

58

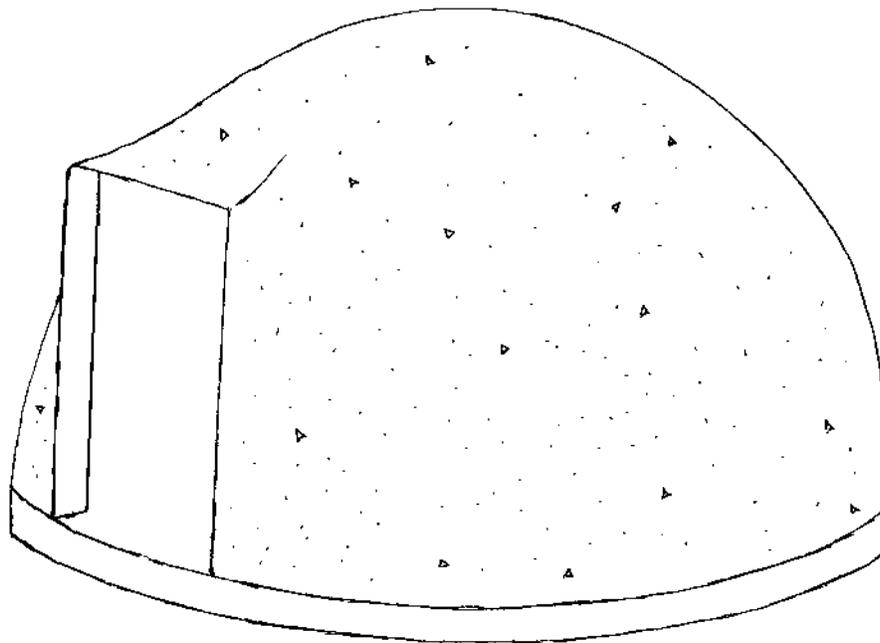


Clean the exposed rebar inside of the dome and place a 1/2" layer of concrete over it. Concrete can be troweled or sprayed onto the dome's interior.



59

Interior plaster may require two coats. If the interior will not be subjected to water, lime can be added to those inner coats to make the troweling easier.



60

EcoShell is now structurally complete. Its exterior should be coated with an elastomeric coating to help with solar reflectance and to protect against possible leaks from hairline cracks.

# Fabric Mixer

The Monolithic Fabric Mixer is simplicity itself -- fast and easy to use.

Here's how it's used: A cubic foot or less of concrete ingredients are put into the center of this fabric. The fabric is then agitated from side to side by two people. The completed concrete can then be transported to its point of use.

Here's the mix design we suggest for use with the Monolithic Fabric Mixer when building a concrete EcoShell: one container of cement, four containers of sand and water as needed. Start with one liter of cement, four liters of sand and one liter of water. Adjust the water to the conditions. Adjust the sand, if needed, by adding some 3/8 minus pea rock.



# Basalt Addendum

Over the years we have become aware of another reinforcing made of basalt. Basalt is another name for volcanic. It is a fiber pulled from the basalt basically as fiberglass fiber is pulled from a mixture of rock. The basalt fibers are then put into a rebar like pattern by using an epoxy to form the rebar. Basalt has some really good features. First and foremost it doesn't rust. Because it doesn't rust, it doesn't need nearly as much concrete covering it up to protect it from rusting.

The basalt rebar is a little more than twice as strong as steel rebar and weighs about one fifth as much. Again, this has some huge ramifications in building EcoShell I buildings. If the rebar is basalt we don't have to worry about leakage of rain water getting into the reinforcing, rusting it and exploding the concrete.

We have been buying basalt in coils. In the EcoShells we are now using a four millimeter basalt or if you wish you can use a six millimeter basalt. My preference is the four millimeter as it coils tighter and ships easier. You simply have to put the rebar a little closer together as you build the dome. My recommendation is if you are using the four millimeter bar is to put it six inches on center in both directions. If you are using the six millimeter you put it one foot on center both directions.

If you use the basalt rebar and if you have quality control on building the structures you can use a total thickness of one and a half to two inches.

It is always smart to coat the outside of the EcoShell buildings. The best coating we have found to date is silicone but other water proof coatings can be used. The huge advantage by using basalt rebar, is if over time the coating should start to leak water into the rebar, the building will just be bothered by unsightly spots where the leak occurs. But it will not have any structural problems.

There is another product that we have been experimenting with (Note: the word experimenting): that is basalt roving. We have found that just the roving is not enough. We need the roving woven into a small rope and we can use the rope as the primary reinforcement. It is important that the correct size of the rope is used and that some experience included. At present we are doing much more testing on the basalt and most especially the basalt roving wound into a rope.

It is fascinating and fun to contemplate the millions of houses we can build using the combination of concrete and basalt.

