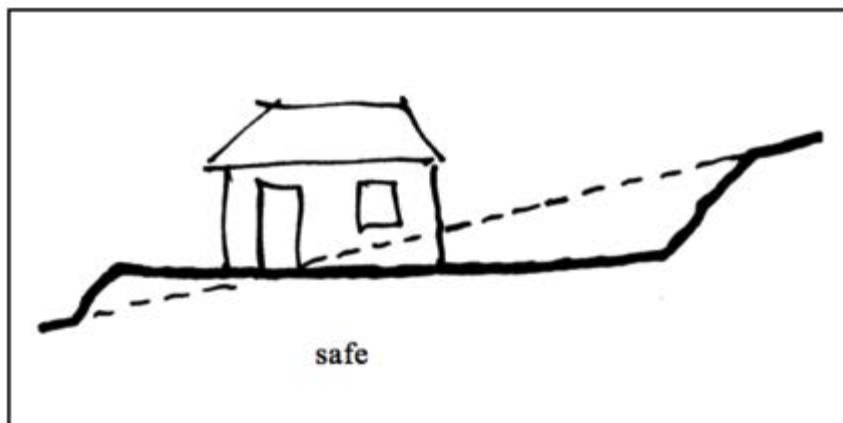


## Guidelines to build an earthbag roundhouse in Naya Gaon, Nepal

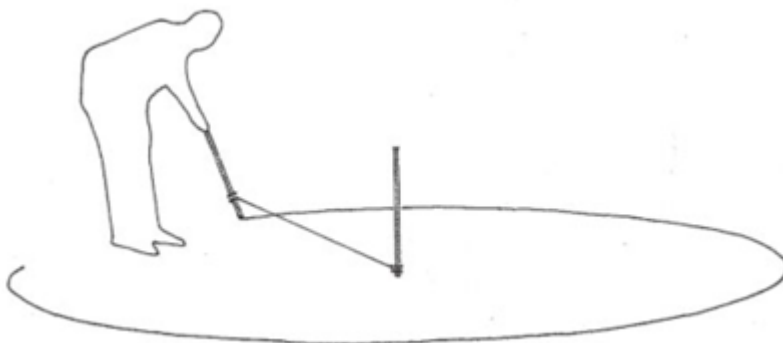
### **1. Site selection**

For the first house, select as far as possible a flat space that should be at least 10m large. We await many people coming to visit and participate in the construction therefore a larger place is to be preferred. If the site is on a slope, make sure that the backside wall is far enough from the slope.



### **2. Form: Roundhouse**

Round houses have the best static and are safest in an earthquake. Old Newari houses were built round exactly for this reason. We propose an outer diameter of 6m. Use a rope to demarcate the circle for the foundation:



#### **2.1 Form: Rectangular House**

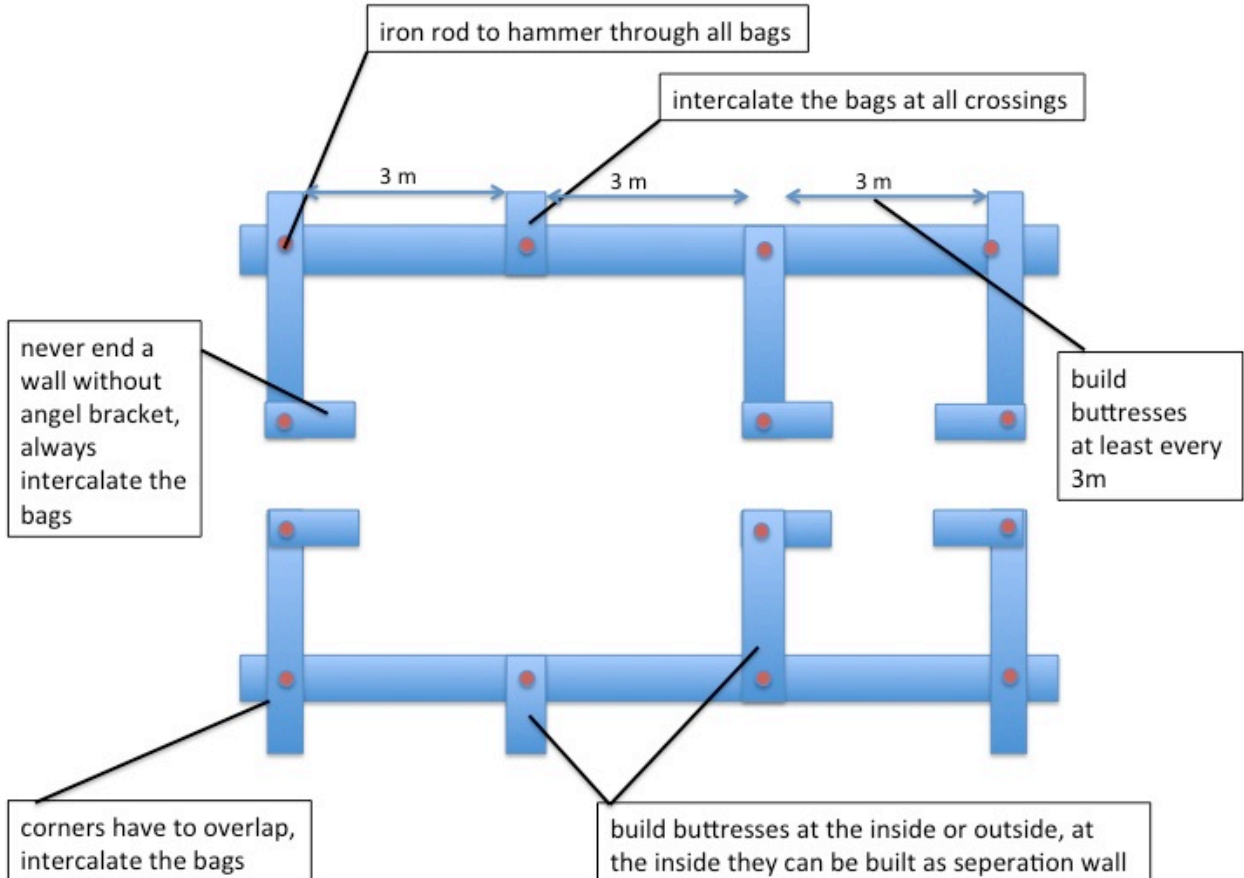
If for any reason you cannot be convinced to build a round house, please let you convince to building a house with a square shape and not a rectangular. If, however, you decide for a rectangular shape, you have imperatively to add every 3-meter a buttress. Never build a straight wall for more than 4 m without a buttress (see chapter 3 how to build and intercalate a buttress). If you build with square or round shape the corner have to be build as buttress and the walls have look out at each edge (see chapter x on corners).

### 3. Foundation

Dig the foundation trench 50 cm wide and 30 – 40 cm deep. Ramp the soil in the foundation trench. If the soil is hard and not sandy a depth of 25 cm is sufficient. Take of the grasses, roots and organic top soil layer in the middle of the circle which will be floor of the house.



Round or rectangular foundation: Dig the foundation also for each buttress, for the corner-buttresses and the angle-brackets at the door openings. In a rectangular shape, put two doors vis-à-vis in case of emergency.

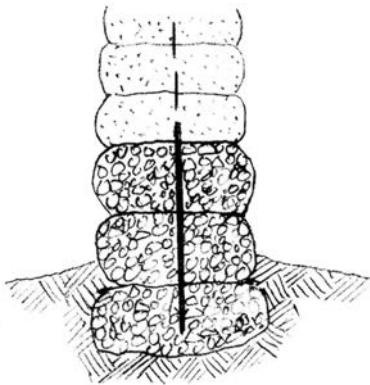


#### 4. Filling of the foundation

Try to get gravel stones of 20 to 50 mm (should be possible to get with a tip lorry, take one lorry load which should be enough for 3 – 5 house foundations). Fill the gravel in the 45cm x 90cm PP bags and place three layers in the foundation trench. You will need 25 bags per layer. Each layer should be tamped/rammed a bit so that a fairly equal and flat surface will occur.

Hammer through every meter a 6 – 8 mm and 50 cm long iron rod through the three layers but not into the soil. 10 cm of the rods should look out.

The first 1,5 layers of gravel bags should be in the soil, while the second 1,5 layers gravel bags are above soils and serve as plinth that protects the base against erosion from rain (see image):



*Foundation of 1 to 2 bags , depending on soil quality, add than 1,5 to 2 bags with gravel as plinth which makes at total of 3 gravel bags half under the soil and half above to protect against eroding rain water. Place only then the clay-soil filled bags. Place the iron rod like in the image through all three bags but not into the soil.*

If you cannot obtain gravel, use small stones from crushed buildings. You can also mix gravel and small stones. Makes sure no clay is mixed with the stones otherwise water would be soaked into the wall that would keep always wet and not stable!

If you have no gravel you might also put the stones directly into the trench without the bags. However, the gravel bags have the advantage to make a floating foundation that make the house more resistant in the case of earthquakes.

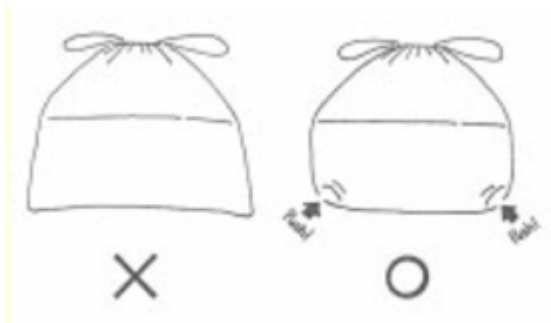
#### 5. Filling the bags with clay soil

Dig the clay soil from the surrounding land, use the soil of the foundation trenches, reuse clay from crumbled clay buildings. Mix the clay soil and if to dry add some water. If you compress the soil-mixture in your hand, no water should drip out and the form of the fingers should keep imprinted into the clay. If you then press the mixture between finger and thumb, the mixture should break apart.

Hold the PP bag open with a large funnel like in the image below:

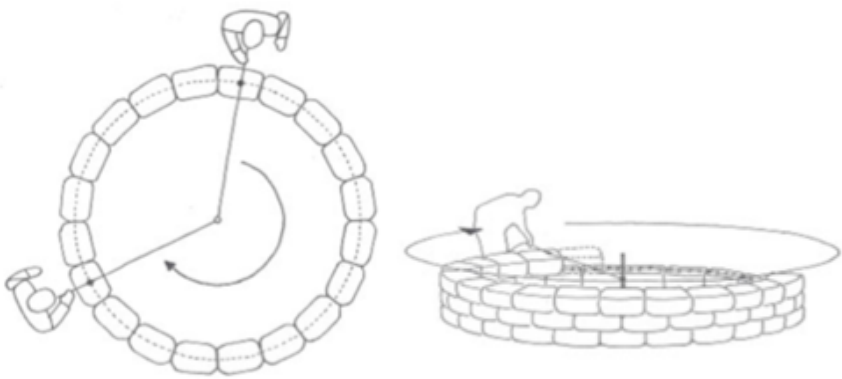


Before filling, pull in the corners of the bag so that there are no pointed corners:



### 6. Placing the bags

Place the bags and make sure that they are tightly lined. To make sure that you build a perfect cylindrical wall use a rope from the middle of the circle and verify for each bag. The rope should always be perfectly horizontal. Use a 2m20 long pole in the middle to lift the rotating point of the rope for every new layer.



### 7. Interconnection of PP bags

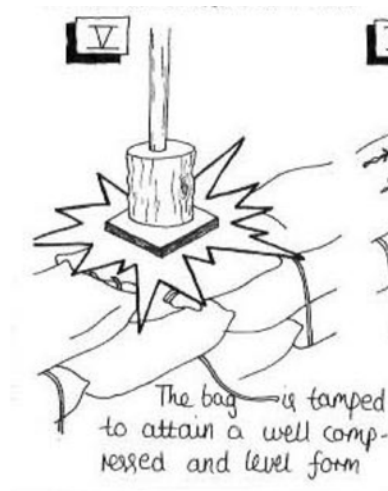
Prepare plenty of 15 to 20 cm long bamboo sticks (app. 8 to 10mm diameter). Sharp both ends of the sticks. Hammer four of these sticks into each filled bag so that half of the stick looks out. Put the bags of the next layer onto the stick so that they go through the bag into the bag filling. The bamboo sticks replace the barbed wire that is often used in earthbag building but is less resistant and more expensive.

Beside the bamboo rods between each layer of bags, hammer every 2 m a 6 to 8 mm iron rod with a length of 50 cm to interconnect several layers of earthbags. Once the clay-soil in the bags cure and become hard, the flexible bamboo sticks and the iron rods allow a very strong and at the same time flexible interconnection of the layers.

The interconnection sticks and rods will not only fix the bags in its position but allow a high flexibility of the wall during an earthquake. In fact during strong shocks, the earthbags can slightly move and get back in their position. The wall cannot break but adsorbs the shocks transferred from the soil (in addition to the shock adsorption of the floating foundation).

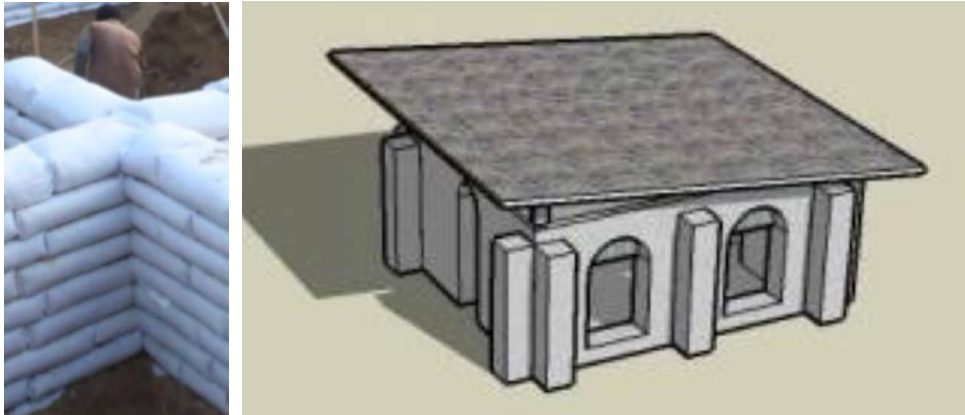
### 8. Compressing/Tamping the clay-soil in the bags

The stability of the earthbag wall highly depends how good the clay-soil is compressed. Tamp the earthbags with a 5 to 8 kg heavy, flat tool (see picture) solid and level after each course is complete. Tamp the high points first. Then evenly tamp the entire wall several times as you continually move the tamper. Once the bags become solidly compacted, you will remark that the sound of tamping will change. There is, however, no need to tamp the bags excessively, just tamp until they're solid. Two minutes per bag should be plenty.



**9. Buttress**

Round buildings with diameter below 10 m have a very resistant and strong static and do not need buttresses. Square and rectangular building are much weaker from a static point of view and need imperatively the inclusion of buttresses. For straight earthbag walls you have to include a buttress every three meters and should reach the ring beam. Lay and slot the perpendicular earthbags of the buttress into the wall as seen in the following picture:



*Remark that the picture on the right hand side is only used as an illustration for the position of the buttresses. In regions with danger of earthquakes they have imperatively to reach the ring beam and be connected with the ring beam.*

**10. Corners**

If you build rectangular, the corners where the outside walls meet have to be build like buttresses that means the walls have to got through the perpendicular wall. The earthbags of the meeting walls have to be intercalated.



**11. Door opening**

The door opening is a weak point of the house and has to be built with care. The door opening should not be larger than 80cm and has to go from the threshold to the ring beam. Finish the door opening at both sides with a 90° angle made of intercalated earthbags (see foundation plan). If possible make a wooden frame. Install a doorframe with a height of 1m60 to 1m80 which leaves enough height to place a window above the door.

**12. Window**

Once the farmer are more experienced with this building technique, an arched window at the opposite of the door becomes possible but now before the rainy season we should not lose time with too many details that are difficult to execute and may hamper the stability of the house. Place a window or aeration flap above the door and fix it to the ring beam.

If you decide to add windows especially in rectangular constructions, the horizontal distance between the door and a window or between windows has to be at least 1 m. They should always be higher than large and the upper side of the window frame should be fixed to the ring beam.

**13. Height of the wall**

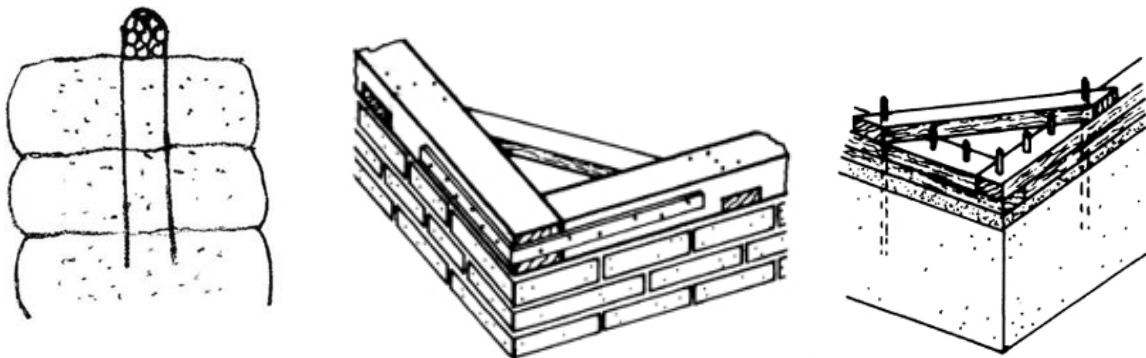
The above soil final height of the wall should be 2 m. Don't build it too low to permit air circulation inside the house.

**14. Ring Beam**

The ring beam is the most important single detail to improve the earthquake resistance of the house. For the rectangular house, use strong bamboo rods of at least 12 cm diameter. Let them cross at each corner and fix with ropes. Improve the strength of the connection with triangular corner enforcement (see picture) and fix with ropes. Fix the ring beam every 1 m with U formed iron bars to the wall (at least 50 cm into the wall layers).

For a round house, finish the wall with a circular ring beam made from 8 to 10 thin bamboo poles (about 2-4 cm diameter each), fix them with ropes tightly together. Thicker bamboo would not bend but many thin bamboo bend nicely and fixed together are sufficiently strong. Don't use fresh bamboo they are not strong enough, best are rods, which are 3 to 4 years old.

Fix the ring beam every 1 m with U formed iron bars to the wall (at least 50 cm into the wall layers)



*The U formed iron bars go around the bamboo poles ring beam and should reach through the 3 top earthbag layers. Interconnect the bamboo ring beam at the corners with ropes.*

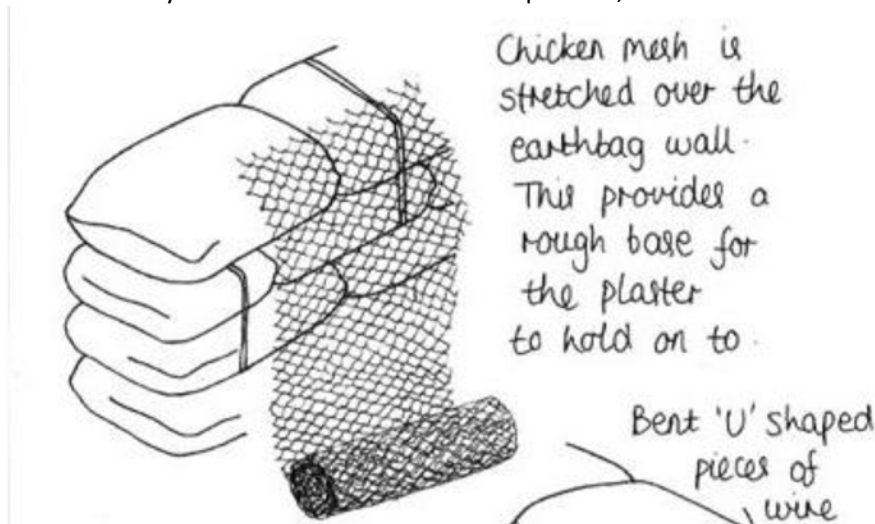
### 15. Roof

Fix perpendicular bamboo poles to the ring beam; fix them also to the wall. They will hold the corrugated roof with the corrugated tin sheets to be recovered from crumbled houses. Give the roof at 10° inclination to the West (side from which most rain comes and at least 90° away from the door). Make the roof stick out at least 70 cm to each side to protect the walls against rain. Dig a drain for rainwater to recover. A straw roof would be much more insulating and beautiful, it could replace the tin roof whenever the time and material constraints allow it.

### 16. Finishing

You do not need to plaster the house now as this can be done later after the end of the rainy season. Once the inner and the outer side of the walls are covered with clay plaster and possibly with a white lime coating, the houses are very beautiful while the bags are protected from UV. The house looks like a normal clay house, it is just more resistant in the case of an earthquake. The lifetime of the house will be as long as any other well maintained clay house and well above 100 years.

The PP bags used for the earthbags are degraded by UV light. There is no material in the proposed construction that will be a waste and left as toxic legacy to future generation. However, to protect the PP earthbags from degradation, you should do the outside finishing within 6 months. As the clay for plaster will have difficulties to hold on the plastic of the bags, you need either to hammer small bamboo sticks from the outside into the bags. You could also install a metal mesh (as it is used for chicken barns) and throw the clay on the mesh. If that is too expensive, the bamboo sticks will also do.



Please further consult the following web pages for step by step instructions:

<http://earthbagbuilding.com/articles/stepbystep.htm>

<http://earthbagbuilding.com/articles.htm>

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