EARTHBAG TECHNOLOGY - SIMPLE, SAFE AND SUSTAINABLE

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ABSTRACT

Earthbag technology is an inexpensive, simple and sustainable method for *building* structures. Having evolved from military bunker construction and flood control methods, Earthbag buildings are notable for their ability to endure fire, flood, wind, *earthquake* and vermin, and are used in *disaster*-prone zones all over the world. In *Nepal*, 55 Earthbag buildings survived a 7.8 magnitude earthquake with no structural damage. Because Earthbag technology makes minimal use of cement, concrete, steel and timber-and the fuel needed to transport them-the technique is easy on the *environmen*t, and doesn't deplete scarce natural resources. Earthbag technology also requires less expertise than more traditional building methods, and only the simplest of tools.

I. INTRODUCTION

Earthbag technology is a wall system, with structures composed primarily of ordinary soil found at the construction site. The soil is stuffed inside polypropylene bags, which are then staggered like masonry and solidly tamped.
Barbed wire is used between the layers of bags and serves as mortar. For seismically active zones, reinforcements like buttresses, vertical rebars and bond beams are recommended. The classical foundation used in Earthbag construction is a rubble trench foundation. The roof design can be of any preference, as long as it is lightweight.

Earthbag Construction, Makwanpur, Nepal

Completed Earthbag House, Gorkha, Built by Good Earth Nepal

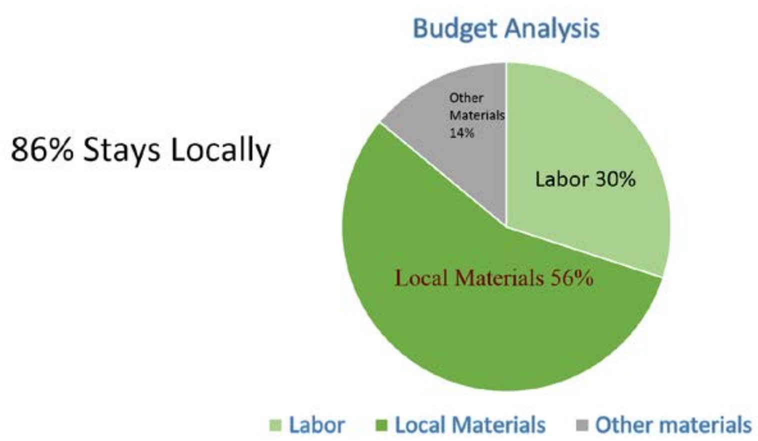
Earthbag construction minimizes the need for skilled labor, and does not require any special tools or machinery. An Earthbag building can easily be built by a group of unskilled workers, under the supervision of a construction manager.
Earthbags are used in retaining walls and for erosion and flood control, as well as under highways.
Though relatively "new", the basic principles behind Earthbag technology have been around for centuries. Some call Earthbag technology "Rammed Earth in a Bag" or "Reinforced Rammed Earth".

Kagbeni Rammed Earth Monastery, built 1429

II. EARTHBAG TECHNOLOGY

Earthbag building offers many advantages over existing technologies:

- *Safety*- Earthbag technology has now been tried and tested in Nepal. More traditional building techniques were also tested, and tragically failed
- *Ease of Construction*- Earthbag technology is easily learned by rural villagers
- *Reduced Use of Materials*- Earthbag structures require a minimal amount of cement, concrete, wood and steel
- *Reduced Use of Fuel and Transportation*- Use of local materials, and fewer materials, means less need for transport and lower fuel costs
- *Less Pollution*- Building with soil means fewer factories and smoke stacks, fewer pollution-belching trucks for transporting the load, and less depletion of Nepal's forests and natural resources
- *Cost-Effective*- Building with Earthbags is inexpensive. For example, a typical Earthbag house might cost 900 NPR per square foot, versus 2500 NPR for concrete block construction.



The main material of an Earthbag structure is ordinary soil, obtainable at the worksite. Most soils are adequate and precise ratio is not necessary, but there must be enough clay and moisture to bind the aggregate together. The soil can be easily tested without any equipment, using a drop test or a roll test. The most common mix is:

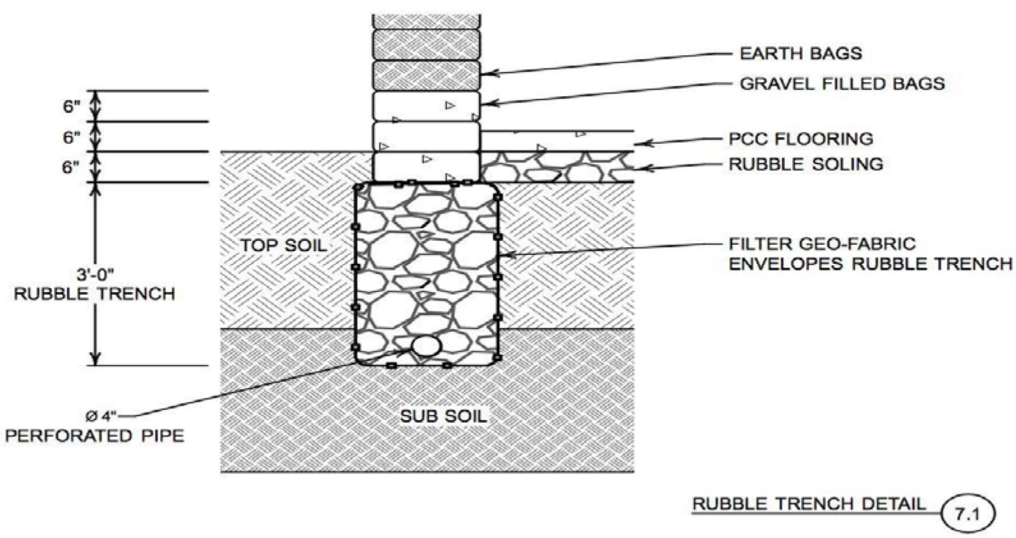
25-%-30% Clay
70%-75% Sandy soil
10% Moisture

Earthbag construction is durable, and if the polypropylene bags are plastered properly the construction can last for hundreds of years. A study by the U.S. Federal Highway Administration found that the half-life of polypropylene fabrics in benign environments could be 500 years or more. The bags themselves have a tensile strength even higher than steel, and can resist circumferential forces generated from the weight above.

Rolls of polypropylene fabrics

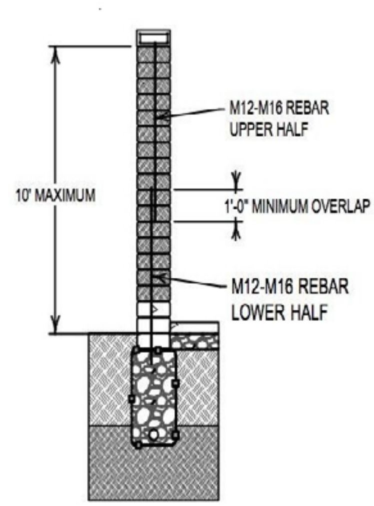
Barbed wire helps to lock the bags together, and forms a matrix within the wall system. Barbed wire resists outward expansion of the wall caused by weight from above, and its tensile strength resists out-plane forces. Barbed wire should be 14 gauge, 4 pointed.

Earthbag structures generally employ a rubble trench foundation, though more traditional types of foundations can be used as well. A rubble trench foundation was first popularized by Frank Lloyd Wright in 1922, and used for his Imperial Hotel design. This hotel survived the great Kanto earthquake, the most devastating in Japanese history.



Earthbag structures, despite being heavy, have great flexibility that makes them highly earthquake resistant. An Earthbag building uses its own weight to anchor itself to the rubble trench foundation. Since the superstructure is not attached to the foundation by bolts or rebars, the foundation and the superstructure are able to move independently, minimizing the shock transfer to the walls. A rubble trench is also built of individual units rather than a continuous beam, further absorbing the shock.

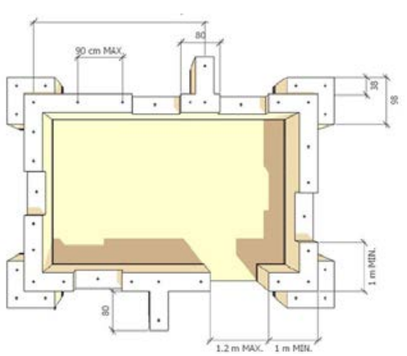
Earthbags are resilient. As per an experimental study on vibration reduction performed by three Chinese universities (Hohai University; Business School of Hohai University; Hefei University of Technology), Earthbags have a relatively high damping ratio, with horizontal as well as well as vertical vibrations effectively reduced.



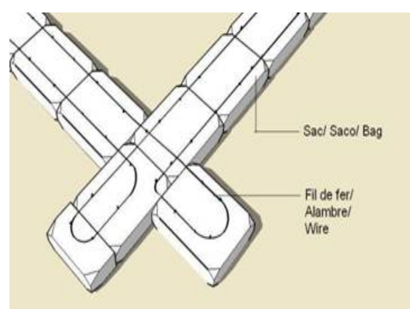
Earthbag walls are generally 14”- 15” thick and provide stability to the structure. The height to thickness ratio of a wall should not be more than 8, and the maximum length of unsupported wall shall not exceed 10X its thickness. Longer walls must be provided with a buttress at intervals not exceeding 10X the wall thickness. Window and door openings must be at least 900 mm from corners, and there should be a minimum of 900mm between two openings. The maximum allowed width of an opening is 150 cm.

Earthquake reinforcement guidelines:

1. *Placement and size of opening and lateral support*

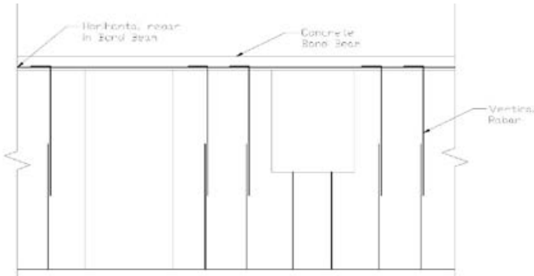


2. *Corner reinforcement*
Increases the in-plane stiffness of the wall



3. *Vertical Reinforcement*
Provides additional shear strength

4. *Bond Beam*
Provides integrity to the structure



5. *Cement render with galvanized or plastic mesh*
   Provides additional strength to the wall to resist in-plane as well as out-plane forces

All of these materials and methods combine to make Earthbag structures *extremely* earthquake-resistant. Tests done in accordance with IBC standards have found that Earthbag construction far exceeds Zone 4 standards, devised to protect against the very highest level of seismic activity. Numerous Earthbag structures have been built in the United States, with Earthbag structures permitted by the California Building Code, due to high seismic activity the toughest in the United States.

CONCLUSION

Earthbag technology offers a safe, simple and sustainable building option. We encourage engineers and building professionals in Nepal and other countries to explore this exciting new technology, and its possible use in those communities most in need.

References and Further Readings:

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