Earthbag construction

Earthbag construction is an inexpensive method to create structures which are both strong and can be quickly built. It is a natural building technique that evolved from historic military bunker construction techniques and temporary flood-control dike building methods. The technique requires very basic construction materials: sturdy sacks, filled with inorganic material usually available on site. Standard earthbag fill material has internal stability. Either moist subsoil that contains enough clay to become cohesive when tamped, or an angular gravel or crushed volcanic rock is used. (Sandbag structures with sand fills are an alternative technology and require very different construction details). Walls are gradually built up by laying the bags in courses — forming a staggered pattern similar to bricklaying.

The walls can be curved or straight, domed with earth or topped with conventional roofs. Curved walls provide good lateral stability, forming round rooms and/ or domed ceilings like an igloo. Buildings with straight walls longer than 5 m (16.4 ft) in length need either intersecting walls or bracing buttresses or piers added. International standards exist for bracing wall size and spacing for earthen construction in different types of seismic risk areas, most notably the performance-based standards of New Zealand[1] recommended by the ASTM International in their Standard Guide for Design of Earthen Wall Building Systems E2392 / E2392M – 10e1). Until more complete structural testing is available to correlate earthbag bracing need and performance to adobe, cement-stabilized buttresses and mortar anchors to hold barbed wire at stress points can be used for public buildings in high seismic risk areas. To improve both friction between each row of bags and finished wall tensile strength barbed wire is often placed between the courses. Twine is also sometimes wrapped around the bags to tie one course to the next, serving to hold the in-progress structure together and add strength. Rebar can easily be hammered into walls to strengthen corners and opening edges and provide more resistance against overturning. The structure is typically finished with plaster, stucco or adobe both to shed water and to prevent any degradation from solar radiation. This construction technique can be used for emergency shelters, temporary or permanent housing and barns. It is frequently chosen for many small-to-medium-sized institutional structures in the developing world.

Earthbag development

Superadobe

While architect and builder Nader Khalili popularized the methods and architecture of earthbag construction (particularly for residential buildings), it was the German professor of earthen architecture, Gernot Minke, who first developed a technique of using bags filled with pumice to build walls.[2]

Nader Khalili called his technique superadobe, because he filled the bags with moistened adobe soil. Many examples of his work can be seen at the Cal Earth Institute in Hesperia, CA, which he established in 1986 to popularize his ideas about natural construction techniques. Khalili pioneered code approval of earthbag domes for high seismic risk regions. Several books and videos have been produced by the institute to demonstrate his methods, however a number of other individuals and groups now offer training workshops. Khalili died at the age of 72 in 2008.

From Superadobe, created by the Iranian Nader Khalili, was developed Hyperadobe by Fernando Pacheco of EcoOca in Brazil. The big difference between the two is that Superadobe uses woven polypropylene bags with barbed wire between the layers, whereas Hyperadobe uses a knit raschel, the same material used in packaging fruit. This leads to less cost compared to the poly bags.

Writers

Although Joseph Kennedy probably invented the term earthbag, Paulina Wojciechowska wrote the first book on the topic of earthbag building in 2001: Building with Earth: A Guide to Flexible-Form Earthbag Construction. Kaki Hunter and Doni Kiffmeyer worked on a variety of projects after studying with Khalili. They aptly called earthbag 'flexible form rammed earth'. Their 2004 book, Earthbag Building : the Tools, Tricks and Techniques is available for purchase as an easy-to-translate ebook.[3]

Free online booklets have been developed by different authors. Owen Geiger and building designer Patti Stouter have written many that address issues of using earthbag for different cultures, climates, and levels of hazard as well as testing soils.[4]

A 2011 e-book by Owen Geiger, Earthbag Building Guide: Vertical Walls Step-by-Step, provides complete photo illustrations of the process and up-to-date discussion of new techniques. This is available through EarthbagBuilding.com.

Promoters

Many like Akio Inoue, from Tenri University in Japan and Scott Howard of Earthen Hand have tested and built buildings. Kelly Hart has shared information freely on his internet sites. With Owen Geiger of GRISB.org he encouraged earthbag's development into different culturally and climatically-appropriate shapes. By early 2010 earthbag buildings had been built in many countries around the world. Special reinforcement techniques are being defined for straight-walled earthbag buildings in medium and high seismic risk regions. Special techniques have been developed and refined by innovators like Dr. John Anderton of South Africa and Fernando Pacheco of Brazil. Anderton has tested a triple channel bag version that reduces the slumping problems inherent in non-cohesive fill material like sand.[5]

Pacheco pioneered the use of lighter HDPE mesh tubing or hyperadobe. This process is less expensive and simpler because the tubes are more pliable and do not require barbed wire to provide friction between courses.

Construction information and plans appropriate for buildings in the developing world are available on the internet. Engineer Nabil Taha has developed and shared general specifications for reinforcement techniques appropriate for the highest seismic risk zones.[6]

Additional engineering tests are needed to further understand and refine reinforcement for different situations. University research programs are more and more attempting to evaluate earthbag construction.

Construction method

The basic construction method usually begins by digging a trench down to undisturbed mineral subsoil. This trench can then be partially filled with cobble stones or gravel to create a rubble trench foundation. In high seismic risk regions a reinforced concrete footing or grade beam may be recommended.

Above that, several rows of doubled woven bags (or tubes) are filled with gravel and placed into the trench and one or two courses above grade to form a water-resistant foundation. Each successive layer will have one or two strands of barbed wire placed on top. This digs into the bag's weave and prevents slippage of subsequent layers, and also resists any tendency for the outward expansion of walls (especially with domes).

The next row of bags is offset by half a bag's width to form a staggered pattern. Bags can be pre-filled with material and hoisted up, or bags or tubes can be more simply filled in place. The weight of this earth-filled layer pushes down on the barbed wire strands, locking the bag in place on the row below. A light tamping of the bags or tubes serves to consolidate the moist clay-containing fill and creates interlocking bags or tubes of a strength between adobe and rammed earth. The same process continues layer upon layer, forming walls. A roof can be formed by gradually sloping the walls inward to construct a dome. Traditional types of roof can also be made.

Bag types

The most popular type of bag is made of solid-weave polypropylene, such as the type often used to transport rice or other grains. Polypropylene is chosen for its low cost and its resistance to water damage, rot, and insects. Organic/natural materials such as hemp, burlap or other natural-fiber bags (like "gunny sacks") can be used; however, since these may rot, they should only be used with fills containing a significant proportion of clay.

Bag-fill materials

Generally inorganic material is used as filler, but some organic material (such as rice hulls) can be used if a strong matrix like wire mesh reinforces the plaster. Filled with soils containing 5- 50% clay, like reject fines, road base, or many subsoils, earthbags tamp into solid structural units but cannot withstand prolonged soaking. Subsoils with clay mold tightly and cure attached around the barbed wire barbs. This may contribute significant and needed tensile strength to walls. Sands, stone dust and gravels can survive prolonged flood conditions, but most require special bracing during construction as well as some form of structural skin. Included chunks of cement mortar between bags may be appropriate to hold barbed wire to bags if clay or cement-stabilized fill is not used. Sand fill may be appropriate for several courses to provide a vibration damping building base, but becomes unstable in ordinary bags above 60 cm- 1m (24- 39") heights. Cement, lime or bitumen stabilization can be used to allow earths with clay to withstand flooding or to allow sands to be used in traditional bags with a non-structural plaster skin, but because earthbag walls are usually 38 cm (15") thick a large amount of stabilizer is needed.

Thermal insulating properties are an important consideration, particularly for climates that experience temperature extremes. The thermal insulating value of a material is directly related to both the porosity of the material and the thickness of the wall. Crushed volcanic rock, pumice or rice hulls yield higher insulation value than clay or sand. Untreated organic materials that could decay should not be used as part of a structural wall mass, but can be used as infill. Scott Howard and others have suggested adding crushed bottles, shredded bags, or other plastic trash as insulating filler in earthbags. Thermal mass properties of the fill material are also an important consideration, particularly for climates that experience high temperature fluctuations from night to day. The thermal flywheel effect can make massive earth walls ideal for mild climates. Materials like clay or sand also have excellent heat retention characteristics and, when properly insulated from the home's exterior, make a logical choice for incorporating a passive solar building design in cool climates. Such a design has the capability of keeping a home's internal temperature stable year-round.

Forming the house

Various types of roofs may be used, including earthbag extensions of the wall which create barrel vaulted or domed roofs, although vaulted roofs of much size are difficult to achieve with earthbags. Earth domes are very inexpensive to build, but waterproofing them is a complex or expensive process for humid regions. Recently rectangular and round buildings are being built with roofs of wood or metal structure to mimic local architectural styles. Windows and doors can be formed with a traditional masonry lintel or with corbeling or brick-arch techniques, usually on temporary forms. Light may also be brought in by skylights, glass-capped pipes, or bottles which are placed between the rows of bags during construction.

Finishing

To prevent damage to the bags from UV rays or moisture, it is necessary to cover the exposed outer surfaces of the bags with an opaque material. There are many possibilities of what material to use, including cement-based stucco, or lime or earthen plaster. This will need to meet any waterproofing requirements, but such requirements can also be met by using additives in the bag-fill material. Some buildings use a planted-earth "living roof" ("green-roof") to top the structure, while others use a more conventional framing and roof placed atop earth-bag walls.

Environment friendly

It's easy to posit that earthbag construction uses the least energy of any durable construction method. Unlike concrete, brick or wood, no energy is needed to produce the necessary materials other than gathering soil. With on-site soil being used, practically no energy is expended on transportation. And unlike rammed earth construction, no energy is required to compact the soil. The energy-intensive materials that *are* used — plastic (for bags & twine), steel wire, and perhaps the outer shell of plaster or stucco — are used in relatively small quantities compared to other types of construction. The buildings last a long time; however, when they are no longer useful they may simply erode with no serious threat to the environment, or even be recycled into new earthbag-constructed buildings.[*citation needed*]

Colonization of the Moon

Khalili proposed using the techniques of earthbag construction for building structures on the Moon or other planets. Currently, it is quite expensive to lift a positive-mass payload from Earth. Thus, Khalili's techniques would seem to be an ideal solution as the requisite supplies would consist of lightweight bags and a few tools to fill them. He specified that such bags would probably have pre-sewn "hook and loop" (i.e. Velcro) fastener strips in lieu of barbed wire.

References

[1] Hugh Morris (2006) New Zealand: Aseismic Performance-Based Standards, Earth Construction, Research, and Opportunities (http://www.getty.edu/conservation/publications/pdf_publications/gsap_part2b.pdf), pp. 52–66
[2] History of Earthbag at (http://www.earthbagbuilding.com/history.htm). Earthbagbuilding.com. Retrieved on 2011-07-27.
[3] Earthbag Building: The Tools, Tricks and Techniques eBook (http://www.ebooks.com/ebooks/book_details.asp?IID=256395). eBooks.com (2004-11-19). Retrieved on 2011-07-27.
[4] Patti Stouter's Documents (http://www.scribd.com/patti_stouter/documents). Scribd. Retrieved on 2011-07-27.
[5] EarthBag Building System (http://www.earthbagbuild.com/earthbagbuild.htm). Earthbagbuild.com. Retrieved on 2011-07-27.
[6] Project Types: Sustainable Building 541-850-6300 (http://www.structure1.com/Earthbag.pdf). (PDF) . Retrieved on 2011-07-27.

External links

General Information

- EarthbagBuilding.com (http://www.earthbagbuilding.com) – Sharing information and promoting all shapes of earthbag building.
- EarthbagStructures.com (http://www.earthbagstructures.com) – Sharing information about culturally and climatically appropriate earthbag buildings for the developing world.
- Geiger Research Institute of Sustainable Building (http://www.grisb.org) – Promoting natural building, and sustainable design and development, through research, training, education and consulting services.
- Cal-Earth (http://www.calearth.org) – *The California Institute of Earth Art and Architecture* has developed a patented system called Superadobe, in which bags filled with stabilized earth are layered with strands of barbed wire to form a structure strong enough to withstand earthquakes, fire and flood. Focuses primarily on domes and vaulted roofs.
- Various Sources (http://www.earthbagbuilding.com/history.htm) - The Cal-Earth patent has since been discovered to be invalid due to the pre-publicity cited in the article attached in the link as well as other public sources. Also due to Nader Khalili's presentation to NASA in the 1980s and the 1995 publication of Adobe Journal #11 in which superadobe is described. This was referenced again in Adobe Journal #12-13 written by Iliona Khalili when she was at CalEarth many years before the application for patent was submitted.

Engineering

- Precision Structural Engineering- all types of stabilized earthbag for seismic risk areas (http://www.structure1.com/earthbag.htm)

Design and Training

- Poland- Earth Hands and Houses building with earthbag (http://www.earthhandsandhouses.org)
- CO, US- ArcheEarth Design (http://www.archearth.com)
- NM, US- Beehive Home Building Course offered by Broken Earth (http://www.brokenearth.org/beehivehome/index.htm)
- OR, US- Earthen Hand Natural Building, Sculpture, and workshops (http://earthenhand.com/)
- KY, US- Homegrown Hideaways training for appropriate technologies and natural building (http://homegrownhideaways.org/workshops.aspx)
- Mexico- Karacadir Earth Builders (http://www.earthbagstructures.com/trainers/karacadir.htm)
- Australia, Japan, South America- Guiding Star (http://guidingstarcreations.blogspot.com/p/international-workshop.html)
- Eccentric Aesthetics: DIY Eco-Friendly Earthbag Homes (http://dornob.com/eccentric-aesthetics-diy-eco-friendly-earthbag-homes/)

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