

COMPRESSED EARTH BLOCKS (CEBS)

History:

Earth construction has existed for over 9000 years. Adobe houses have been uncovered in Russian Turkistan dating from 8000 to 6000 BC as well as homes from 4000 BC in Assyria. Upper Egypt still displays monumental structures that are approximately 3200 years old. The core of Shibam, Yemen was built entirely out of adobe covering 20,000 sq meters.¹

Earth Construction:

Earth can be used for building in a variety of ways. Wet earth can be molded by hand to form walls, often referred to as cob construction. Earth can be formed, thrown, or sprayed over a frame making a wattle-and-daub structure. Earth can also be heavily compressed within a formwork to make rammed earth walls. Unbaked, handmade bricks of earth are referred to as Adobe.

Compressed Earth Blocks:

Blocks produced manually by pouring wet earth into a form and dried are called adobe. A modern adaptation of this building element is the compressed earth block (CEB). CEBs, also called compressed soil blocks, are produced by compacting moist earth in a manual or powered press. The first manually operated soil block press was produced in 1789 by French architect François Cointreaux. More recently, fully automatic presses have been made, producing as many as 1500 to 4000 blocks per day.²

Unfortunately, most CEBs need to be stabilized from erosion with 4% to 8% cement because of the lack of sufficient water or kneading through impact to fully activate the binders. Without stabilization, most CEBs have a lower compressive strength than traditional adobes.³

Construction:

Foundation:

A CEB wall needs a well-constructed foundation. A common foundation is a rubble trench, extended below the frost line, topped with a cast-in-place concrete beam. In areas with excessive ground water a drain line should be installed to divert the water away from the walls. The grade beam should be high enough to ensure the wall is well above the finished grade, approximately 3" – 6". A typical reinforced concrete footing and stem wall can also be used. However, this will involve a significant amount of concrete as the stem wall must be a third thicker than the CEB wall, sometimes as thick as 1.5 feet.

The CEB wall sits directly on top of the stem wall or grade beam and can be connected by simply leaving the top surface of the concrete rough for a strong mechanical bond.

1 Gernot Minke, "Building with Earth: Design and Technology of a Sustainable Architecture" (Basel: Birkhauser-Publishers for Architecture, 2006), 61.

2 Minke, 63.

3 Minke, 64.

Stacking:

CEBs can be stacked much like typical masonry. A double wall or cavity wall can be constructed with a layer of insulation, such as a sawdust lime mixture or perlite insulation, between the interior and exterior CEB walls. Wall ties are used to link the interior and the exterior faces together. A solid masonry wall can also be constructed from CEBs with a layer of rigid insulation applied to the exterior. The exterior will need to be finished with stucco or cladding.

Mortar:

CEBs are laid with an earth mortar or lime mortar or slurry. Midwest Earth Builders, a CEB manufacturing and construction company, uses a thin slurry for unstabilized blocks and a thicker lime mortar for stabilized blocks. Some cement may be added to the mortar but pure cement mortar should not be used as it is too rigid.⁴ Earth blocks may also be dry stacked if the blocks are dipped in water long enough to make the surface of the blocks soft.

Openings, Bond Beam, and the Roof:

Door openings, window openings, and niches can all be formed into the CEB walls using lintels of cast-in place concrete or solid wood. Arches can also be constructed of concrete or earth blocks over doors or windows.

A cast-in-place bond beam or a steel or wood ring beam is built above the CEB walls to tie the walls together and provide a connection for the next floor or the roof. The roof, like the foundation, is necessary in protecting the CEB walls from the sun and rain that cause weathering and erosion.

Finishing:

The exterior walls should be finished with plaster, such as lime, cement, or earth plasters, or cladding to prevent weathering and erosion. Because CEB construction is not monolithic, like rammed earth, it is more susceptible to erosion.

The interior of the CEB walls can be finished with paints, water repellants, plasters, or cladding or left exposed.

Some breathable paints can be used to protect the walls but should be renewed periodically: a pure lime wash dries white and provides weather resistance; a lime-casein wash can be used to make the surface wipe resistant; a borax-casein wash acts like the lime wash but produces a darker finish; a colorless casein coating retains the natural color of the earth while increasing its wipe resistance; and other lime washes using urine, clay, animal glue, and other animal products can also enhance weather and wipe stabilization.⁵

Other colorless liquids can be applied to make the exterior surfaces of the walls water-repellant including silane and siloxanes, silicone resins, siliconates, acrylic resins, silicate ester with hydrophobising additives, and silicates with hydrophobising additives though each can reduce vapor diffusion.⁶

4 Minke, 65.

5 Minke, 98-100.

6 Minke, 101.

Technical Information:

Compressive Strength:

The compressive strength of earth construction depends on the distribution of grain size, the water content, the compaction method of the mixture, and the type of clay mineral used. Generally speaking, the maximum compressive strength of a material is reached if the structural filler, sand and gravel, is distributed for maximum packing volume and the binder, silt and clay, are fully filling the inter-granular spaces of the gravels.

Testing has shown that kneading earth rather than or in addition to compressing earth produces a denser material with a higher compressive strength. An internal electrical reaction of the material structure is triggered by water and movement of the mixture. When compressing material, testing has proven that beating or ramming material, types of dynamic movement that cause vibrations in the structure, produces a higher compressive strength than compacting the material with a static force.

Additives can also increase the compressive strength if necessary. Adding 17% by weight Montmorillonite clay such as Kaolinite and Bentonite or lime and cement will increase the compressive strength. However, additions of minerals in amounts lower than 5% can actually decrease the compressive strength of the material. Other organic additives such as urine containing urea and ammonium acetate, can increase the compressive and binding strength as well. Typically, the addition of fibers to reduce shrinkage, such as straw, can decrease the compressive strength though in small amounts can increase tensile strength.

The maximum compressive strength of earth construction ranges from approximately 284 psi (20 kg/cm²) to 710 psi (50 kg/cm²).⁷ Compressed stabilized earth blocks, with an average of 5-6% cement or lime addition, have an average of **570 psi** (40 kg/cm²) to **850 psi** (60 kg/cm²) at 28 days drying. This strength increases 20% after 2 years.⁸ A Factor of Safety of at least 7 is usually used to determine the allowable compressive force of the material. This means the allowable compressive force ranges from **80 psi to 120 psi**.

Shrinkage and Erosion:

Shrinkage cracks in earth walls should be prevented as increased erosion will occur when exposed to weathering. Shrinkage during drying depends on the mixture's water content, the type of clay and percentage of clay, and the distribution of grain size of the structural filler. Exterior paints, water repellants, plasters, or cladding should be used in conjunction with overhangs to minimize erosion from weather.

Insulation and R-Values:

Earth walls have an average of **R-0.25 per inch** of wall thickness. For a 12 inch wall that is R-2.8 to R-3.0, and for a 24 inch wall that is R-5.6 to R-6.0. If larger aggregates are used to increase the porosity of the wall, thus increasing the insulating qualities of the material, a 12 inch wall could reach **R-4.4** and a 24 inch wall could reach **R-8.7**.

This is hardly sufficient for the weather extremes of the upper Midwest. CEB constructions need added insulation on the exterior of the wall, with stucco or cladding, or buried within the wall, as a cavity wall, to maintain comfortable temperatures year round. Insulation can add R-4 to R-8 per inch to the wall (**4" of insulation buried between two 5 inch layers of CEBs results in R-21 to R-37**).

7 Minke, 43-47.

8 Auroville Earth Institute, "Earth Technologies: Compressed Stabilized Earth Blocks," <http://www.earth-auroville.com/?nav=menu&pg=technologies&id1=9>.

Acoustics:

A 16 inch CEB wall has a Coefficient of acoustic attenuation (tested at 500 Hz) of 40 to 50 dB or an **approximate STC of 45**.⁹

Fire:

CEB walls are said to have “good” fire resistance though no testing has been done to date to confirm this.¹⁰

9 Auroville Earth Institute.

10 Auroville Earth Institute.

Resources:

Books:

The Adobe Story

by Paul G., Jr. McHenry and Helen K. Kerschner

http://www.amazon.com/dp/0826319211/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0826319211&creative=373489&camp=211189

Adobe Houses for Today: Flexible Plans for Your Adobe Home

by Laura Sanchez and Alex Sanchez

http://www.amazon.com/dp/0865346623/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0865346623&creative=373489&camp=211189

Earth Architecture

by Ronald Rael

http://www.amazon.com/dp/1568987676/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=1568987676&creative=373489&camp=211189

Adobe: Build It Yourself, Revised Edition (Paperback)

by Paul G. McHenry Jr.

http://www.amazon.com/dp/0816509484/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0816509484&creative=373489&camp=211189

Earth Construction Handbook: The Building Material Earth in Modern Architecture

by Gernot Minke

http://www.amazon.com/dp/1853128058/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=1853128058&creative=373489&camp=211189

The Good House Book: A Common-Sense Guide to Alternative Homebuilding

by Clarke Snell

http://www.amazon.com/dp/1579902812/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=1579902812&creative=373489&camp=211189

Simone Swan: Adobe Building

by Dennis Dollens

http://www.amazon.com/dp/0930829581/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0930829581&creative=373489&camp=211189

Ageless Adobe

by Jerome Iwa

http://www.amazon.com/dp/086534034X/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=086534034X&creative=373489&camp=211189

Adobe Conservation

by Cornerstones Community Partnerships Staff and Francisco Contreras

http://www.amazon.com/dp/0865345279/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0865345279&creative=373489&camp=211189

Ceramic Houses and Earth Architecture: How to Build Your Own

by Nader Khalili

http://www.amazon.com/dp/1889625019/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=1889625019&creative=373489&camp=211189

Adobe Book

by John F. O'Connor

http://www.amazon.com/dp/094127019X/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=094127019X&creative=373489&camp=211189

Adobe and Rammed Earth Buildings: Design and Construction

by Paul Graham McHenry

http://www.amazon.com/dp/0816511241/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0816511241&creative=373489&camp=211189

The Owner-Built Adobe House

by Duane Newcomb

http://www.amazon.com/dp/0826323235/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0826323235&creative=373489&camp=211189

Casa Adobe

by Karen Witynski and Joe P. Carr

http://www.amazon.com/dp/1586850318/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=1586850318&creative=373489&camp=211189

Adobe Details

by Karen Witynski and Joe P. Carr

http://www.amazon.com/dp/158685030X/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=158685030X&creative=373489&camp=211189

An Architecture for People: The Complete Works of Hassan Fathy

by James Steele

http://www.amazon.com/dp/0756757967/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0756757967&creative=373489&camp=211189

Behind Adobe Walls: The Hidden Homes and Gardens of Santa Fe and Taos by Lis

Dennis and Landt Dennis

http://www.amazon.com/dp/0811811646/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0811811646&creative=373489&camp=211189

Adobe Architecture

by Myrtle Stedman and Wilfred Stedman

http://www.amazon.com/dp/0865341117/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0865341117&creative=373489&camp=211189

Build With Adobe: Revised and Enlarged

by Marcia Southwick

http://www.amazon.com/dp/0804006342/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0804006342&creative=373489&camp=211189

Small Adobe House

by Agnesa Reeve and Robert Reck

http://www.amazon.com/dp/1586850652/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=1586850652&creative=373489&camp=211189

Adobe Houses for Today: Flexible Plans for Your Adobe Home

by Laura Sanchez and Alex Sanchez

http://www.amazon.com/dp/0865343209/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0865343209&creative=373489&camp=211189

Adobe: Remodeling & Fireplaces

by Myrtle Stedman

http://www.amazon.com/dp/0865340862/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0865340862&creative=373489&camp=211189

Pueblo Architecture and Modern Adobes: The Residential Designs of William Lumpkins

by Joseph Traugott and William T. Lumpkins

http://www.amazon.com/dp/0890133670/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0890133670&creative=373489&camp=211189

Building with Earth: Design and Technology of a Sustainable Architecture

by Gernot Minke

http://www.amazon.com/dp/3764374772/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=3764374772&creative=373489&camp=211189

Adobe

by David Larkin and Orlando Romero

http://www.amazon.com/dp/0395566932/ref=nosim?tag=hartworkscom-20&link_code=as3&creativeASIN=0395566932&creative=373489&camp=211189

CEB and CEB Press Information Kits:

Dirt Cheap Housing Building

Adobe & Cinva Ram Earth Block Resource Guide on CD

Contains extensive information on adobe and CEB making.

Cinva Ram Block Press Plans

Contains plans for building your own block press.

Videos:

A Sampler of Alternative Homes: Approaching Sustainable Architecture

Produced by Kelly Hart

<https://www.createspace.com/Workflow/cart.do?action=jump&jump.step=cart>

Products:

Compressed Earth Blocks by Midwest Earth Builders

Midwest Earth Builders' Compressed Earth Blocks were selected as one of the Top 10 Green Building Products of 2008 by Sustainable Industries! Located in Soldiers Grove, Wisconsin, Midwest Earth Builders (MEB) manufactures CEBs as well as builds houses utilizing green materials and sustainable design. MEB use locally available materials mixed onsite and generate the CEBs using an earth block press.

References:

Auroville Earth Institute. "Earth Technologies: Compressed Stabilized Earth Blocks;" <http://www.earth-auroville.com/?nav=menu&pg=technologies&id1=9>.

Minke, Gernot. "Building with Earth: Design and Technology of a Sustainable Architecture." Basel: Birkhauser-Publishers for Architecture, 2006.