Compressed Earth Blocks - Soil & Moisture

By Lawrence Jetter

Everyone in the Earthen Building Business feels that Compressed Earth Blocks (CEBs) are a relatively new thing. But there are early records of CEBs made and used in the 1780's in Bise (be-say), France. The largest area of construction was in the Wajav State, a grape growing region. I suspect that after the vintage season they used the wine presses to make CEBs. After all the world wars and natural disasters, many of the structures are still in use today. In fact Europe is far ahead of the US. in Earthen Construction of both commercial and residential dwellings. Now that we have a little history let's talk dirty.

Let's begin with the idea that we all agree we need to have a quality soil when manufacturing blocks, whether they are Compressed Earth Blocks (CEB) or traditional Adobe. However, I would like to begin with a statement, "Soil is not critical, but is important, moisture in soil is critical when manufacturing CEBs." Please stay with me and I'll try and explain so you won't think I am just talking "Texan". First there are many things that must be looked at here. What are the types of soils (expansive/non-expansive clays, silts, loams, sand) and the composition (the percentage of each type in a particular soil sample)? Will the soil be used for making Soil Only or Stabilized CEBs? Will the machine being used be a manual hand press or hydraulically operated machine? Is the machine a side or end press, top press or bottom press? All these factors figure into the soil equation.

The CEB Code article by Joe Tibbets in "The Adobe Builder", Book #11, addresses some of these differences and the respective machines available in the market place. Also on page 10, column 3, a discussion on Article R1100.5.10 of the New Mexico CEB Code addresses some of the different aspects of manual vs. hydraulic machines.

Let's address soil for a minute. Most soils in New Mexico, Arizona, West Texas, and Old Mexico (along the mountain range and Continental Divide) are very similar in composition. The soil in South and East Texas, Oklahoma, Louisiana, Georgia, Mississippi, and Alabama, for example, are quite different in composition. Soils along rivers and valleys change rapidly and again are different, usually very silty clay sands. We hear a whole lot about "caliche" in our area here. The word "caliche" is a South American Spanish word for Sodium Nitrate. In South Texas, the word is used to describe decaying limestone. South Texas pure "caliche" will not make a CEB in anyone's machine. But most of the time people are calling a mixed yellow/white soil a "caliche" type when actually the soil does have some "caliche" (limestone) in it, but it also has some clay, sand, and silt in its composition and will make CEBs.

Let's address for a minute what happens when we press soil in a CEB. This will help you to understand some of the things we will discuss here. The three components we are to compress are soil, water (moisture) and air. When pressure is applied, what happens? Does the soil go away? No. Does the moisture go away? No! Does the air go away? Yes! The air is pressed out and the soil and water are compressed. If the soil had 6% moisture by volume, the CEB now has 8% to 10% moisture by volume. Volume reduction on a top or bottom press machine is usually from 30% to 45% (6" soil down to 3 1/2" - 3 5/8") depending on the type of machine being used, or type of soils (high aggregate, size, etc.). When pressure is applied to soil you are locking the larger particles together, but they won't stay locked without a binder-- clay/silt are binders. This is why compression machines need more clay than traditional sun dried Adobe and the soil is worked much drier.

Using drier soils with clay will let you work across a wider range of soils and make good strong CEBs. When you have high moisture content in clay soil, it is possible to actually cause a hydro-lock situation. When the pressing device pulls away from the newly pressed CEB, lamination, lifting, or

pulling apart, results in the CEB. This causes a weak or defective CEB. Since this CEB had all the air pressed out, when it tries to dry out and while the clay's molecules are compressed tightly together, the moisture cannot get out until the outer surface dries and shrinks, causing a crack to form. The CEB continues to dry (dehydrate) and the cracks continue to deepen causing a weak block or even failure. Now you are beginning to understand why I said moisture is critical. When you are making a CEB with soil of 5% to 8% moisture, the amount of clay and silt does not have as much effect on the CEB because the soil is so dry. Dry soil cannot have nearly as much air forced out by the moisture and pressure, so the CEB can breathe without cracking. This block will be thicker than the same soil pressed with more moisture of 10% to 15%. Moist soil makes thinner CEBs while drier soil makes thicker CEBs.

In high clay soils we have found that the moisture rate becomes much more critical than with loams or sandier materials. For example, one soil sample that made excellent CEBs at 5% to 6% moisture range was too wet at 7% to 8% moisture and 4% was too dry. So the moisture range on, high clay soils is very narrow compared to other sandier soils. Also you should stay away from expansive clay soils such as Betonite types of soil. If your high clay/silt soils are too high in moisture, coarse-sharp sand will help you stop cracking and let you go ahead and produce CEBs. Always use the sand as it is mined from the ground, since all sands have a minute amount of silt and clay in it (Stay away from the expensive washed sands). We always use what we call dirty sand. Dirty sand helps you to keep working "like" materials, which help the bonding process. Also stay away from salty beach sands. Salty materials tend to attract unwanted moisture and high salinity will effect stabilization. Adding sand to wet high clay soils will lower the compressive strength and modulus of rupture some. But most CEBs are much stronger than 300 PSI Compressive Strength or 50 PSI Modulus of Rupture that is required anyway, so a small drop won't hurt anything.

There is no such thing as a perfect soil, so mixing and blending usually ends up making quality CEBs you can be proud of. The test CEBs, once they are made, should be left to sit and dry to see if they crack or weaken or lose their strength. A good reason for dry testing of CEBs is that back in the 70's and early 80's, when machines were first being developed, a CEB producer traveled to Utah and made good strong green CEBs. He collected his money and went home. The owner/builder was building on the side of a hill overlooking the City of Mohab. As the CEBs dried out in the wall the structure began to crumble with the whole town watching. NOT A PRETTY SCENE. So your testing procedure should always include letting your CEBs dry out thoroughly. Usually CEBs get stronger as they cure out. But there are a few soils that get weaker. Please make this part of your testing procedure.

Many different soils and soil combinations may be used. However, you should field test them before starting your projects. You could use the fruit jar test or the small quarter scale test block machine which is available thru one of the CEB machine manufacturers or both. Information on the fruit jar test can be found in the "Earth Construction Technology manual on Basic Principles of Earth Application", United Nations Centre for Human Settlement's (Habitat) Nairobi 1986. (Peace Corps). Another Source is "BTEC Sustainable Building III Conference, Santa Fe, NM, Oct. 17-18, 2001" on "Soil Block Construction." Dr. Charles W. Graham, PHD, AIA and Dr. Richard Burt, PHD, MCIOB, gave the report on Earthen Construction CEB and in this report discuss one method of fruit jar test, plasticity indexes, etc. Dr. Graham can be reached at the Department of Construction Science, College of Architecture, College Station, Texas 77843-3137 or e-mail address cwgraham@archone.tamu.edu.[1] Dr. Richard Burt can be reached at the same mail address or e-mail address rburt@archone.tamu.edu. You may also contact Lawrence Jetter at 11595 US Highway 181 South, San Antonio, Texas, 78223, (210) 633-3224, Fax (210) 633-3231.

If you have access to a Cinva Ram or to any of the small production type CEB machines such as the AECT "Impact 2001" or the Adobe International "Earth Press V", these CEB machines can be used

also to make your test blocks. These machines make a smaller CEB, so they do not use as much soil. Therefore they lend themselves to working with small amounts of soil mixtures and the CEB are large enough to be tested at a testing lab, if necessary. Many times people want to have a Sieve Soil Analysis performed to find out what is in their soil. I personally feel that this is a waste of money. In the first place if the dirt or soil will make a good block, I don't care what's in it. A standard sieve analysis, doesn't tell you if the clay is expansive, sticky or give you the plasticity index. Also, it does not tell you if the sand is sharp or round. Round sand can actually be detrimental to a CEB structurally. We have seen clay soils (15% - 20%) that would not make a quality CEB because the sand particles were too small (very fine) and round. By adding 1 part coarse sharp sand to 6 parts of the original soil, we fixed the problem and made a good CEB. We also have had soils that were too sandy and added an expansive strong clay (which you really shouldn't do) at the rate of 1 part clay to 5 parts existing high sand soil and fixed the problem and made good CEBs. Here was a case when sand and silt were great enough to offset the expansive clay. But we did mix the soils well. We have also made sticky silty clay soils usuable by adding 1 part sand to 9 parts silty clay. Some times it doesn't take much to make a borderline soil into a good soil.

Anytime you add cement, fly ash, or lime to soil you are going to cut the clay's effectiveness. It actually acts as a lubricant. The Pascua Yaqui Indian Tribe of Arizona was making excellent natural CEBs, testing at 1295 to 1495 PSI Compressive Strength. They decided to make cement stabilized CEBs also, but with 7% cement. The block fell apart using the same soil they were using before with soil only. They found a vein of heavy red clay and added this to their original soil at 1 part clay to 6 parts regular soil and fixed their soil. They have made thousands of cement stabilized CEBs with no problems when tested. If you go through your testing process and are satisfied with the test results, I don't see that any more lab test would be necessary. Just make sure you don't have a high salinity in your soil.

We sent 11 samples of soil to a local university, knowing that 10 of the soil samples would make good CEBs. Sample #11 was a red clay/sand (Baseball Diamond Sand) that we like to use in High Clay Soils and. would not make a CEB by itself. The soils were from Tucson, AZ, Grants and Albuquerque, NM, Tyler, TX and San Antonio, TX area. When the standard sieve analysis was performed, only 3 soil samples passed the standards for Adobe Block Criteria for making Adobe. Yet we had good CEBs, 10 of them and machines were making CEBs in all of those areas. As long as the soils are not too expansive (the fruit jar test will reveal this), I say go with it, save the lab testing money to add to your structure.

Now let's bring the CEB machine into the soil equation. We will start with the manual machine such as the Cinva Ram, etc. Most of these machines require a very moist soil compared to the hydraulic type machine because of lower pressure. This, in turn will narrow down the types of soils available for CEB production, due to the lower pressure provided by your arm strong. These machines will need a screened moist soil with not a lot of clay. As we discussed earlier, high clay or expansive soil cannot be pressed too wet. This is no different than trying to make Adobe's with too high clay content. In fact the manual machine works better with soils that have the high clay content used in traditional Adobes. Again testing and evaluation is important.

When the hydraulic CEB machine people first began operating and developing their machines, they always liked to brag how much pressure they were putting on the blocks (CEB PSI). This writer back in 1989 was probably guilty of some of that too. But folks, pressure *cannot make a bad soil good!!* In other words if your soil is not good, turning the pressure up won't make a good CEB. Each soil has what I call a compaction ratio. Again, the soil has a point that it packs out at or reaches its maximum strength. Adding more pressure only stresses your machine and burns more fuel. Taos, New Mexico area soil packs out at 960-970 PSI on the CEB. Our soil here in San Antonio packs out, at 1000-1050. PSI on the CEB. Jim Hallock of "Earth Block Inc." in Pagosa Springs, Colorado makes cement

stabilized CEBs that packs out at 898 PSI (2500 PSI Hydraulic Pressure on a 8" cylinder and a 10" x 14" Press Plate). True, when using high clay content soil, worked really dry, turning the pressure up helps to make stronger CEBs, but this is the only time were pressure might help. All hydraulic CEB machines manufactured in the US that I know of have enough pressure to get the job done.

The side press or end press machines, press the CEB from the side or end of the block. One machine double presses the block in the press chamber. In these machines usually the soil is worked with more moisture, but not so much as the Cinva Ram or manual machines. So this opens up the field and more soils are available than are with the manual machines. Again, keeping in mind about high clay content and moisture, sticky clay soils tend to stick to the press plate or press foot. Remember, adding sand or drying the soil will correct this problem. Use a less sticky soil or you'll be scraping off the press foot. One manufacturer of CEB machines uses a patented Elastomeric Press Plate which lets you work across a wider range of soils and moisture content, with no sticking. This also works very well when making cement stabilized CEBs. Also turning the pressure down on your machine helps in wet soils. You don't push as much air out of the CEB with the lower pressure. But be careful that you don't affect the structural quality of the CEB.

While we are talking about stabilized CEBs, asphalt emulsion will not work in CEB machines. You'll have to use cement, fly ash or lime. Asphalt emulsion is usually mixed in the water-soil mix in the sun dried Adobes. This lets the asphalt encircle the dirt molecules and stabilize the adobe. Since the CEB soils are worked so dry it is not possible to get the encircling of the molecule thus no stabilization. Jim Hallock of Earth Block, Inc. is working, testing and developing the use of lime as a stabilizer for CEBs at this time with some outstanding results. Jim along with J.O. Stewart, Builder in El Paso and Juarez, Mexico (see Adobe Builder #11, Page 25) are using lime in their CEBs as well as lime plasters with good results.

The last type of hydraulic machine is the top or bottom press machine. These machines press across the width or breadth of the block (flat side) either from the top or the bottom of the molds or breeches. Usually these machines make a more consistent CEB with less hydraulic pressure.

Usually these machines are lighter and give you more options, for example round corners for window openings, different size of CEBs, etc. If you look closely at the Cinva and other hand-operated machines, they also all press across the breadth of the CEBs. One manufacturer of these bottom press hydraulic machines now has 100% control over the thickness, which now means all 3 dimensions are controlled. Things just seem to keep evolving in this CEB business.

In conclusion, you may have noticed, I have not written or discussed the different types of clays (Kaolinite, Smectite, Illite, etc.). I only used Betonite, because everyone knows this is probably the most expansive of all clays and I used it as a reference only. This was done for a reason. You could spend at least a week on defining and covering all of the clays and their different qualities. For the last 15 years, I have not seen a time when this was needed to define good CEB materials. Now, if someone wants to do this, be my guest and spend the next 4-5 years figuring out the many formulas you would need to cover the world. Texas A&M's Department of Construction Sciences under the Direction of Dr. Charles Graham, PHD AIA[1] and Dr. Richard Burt, PHD MCIOB, are teaching Earthen Construction and are doing research on soils and clays with their graduate students. This, in a few years, could really add to the scientific knowledge concerning CEB materials.

During the last 15 or so years many people have brought soil samples for us to test. One of the biggest surprises to us was how many of the samples where actually silty or silty clays not a real pure clay. We only have to look at where and how these silts were generated. I think this could help you understand why this happened. The continuous grinding and movements of the Ice Age Glaciers created many of our silts. Today, rivers flowing, rock slides, flooding, etc. are still generating silts. If

the silt is generated from a high clay area, your silt will usually be a very sticky, clay like material (could be expansive), which sometimes could be used to make good CEBs. If the silts are generated from a high rocky, sandy, silica base material, usually it is a very fine sandy silt and will not make blocks. Nor is it a good additive when blending soil. Also, in some cases, while doing our fruit jar test we have found that the silt ends up on top, not clay, especially the slimy types of silt. The way the tests are being performed, the clays do not have time to dissolve or separate out and become suspended.

As you have learned many things can affect CEBs and CEB Production. My theory is "Keep It Simple", "Test", and use "Common Sense". This works best for us.

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[1]Dr. Graham has since moved to the University of Oklahoma and can be reached at the College of Architecture, Norman, OK or e-mail cwgraham@ou.edu.

ADDENDUM

Since writing the original article for Adobe Builder Magazine we have learned that clay does not stick together because of the platelets being flat as we were taught. Actually, clay has a negative electrical charge and this is what makes silty clay (broken clay particles) stick together. Broken sand and silica particles will not stick together because they have no charge and therefore won't make a block.