Appalachia-Science in the Public Interest
50 Lair St., Mt. Vernon, KY 40445

ASPI TECHNICAL SERIES TP 37

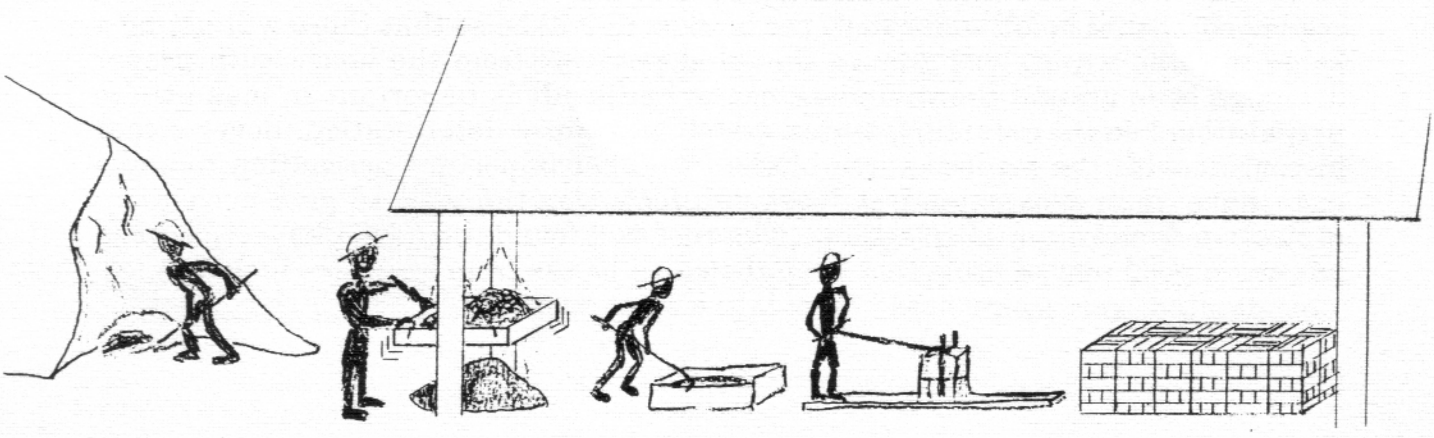
PRESSED EARTH BLOCKS: THE RESPONSIBLE & INEXPENSIVE BUILDING MATERIAL

Introduction

Anyone who has gone to the lumber yard to purchase a 2x4 in recent years will know that prices are high and quality is low for solid wood building products. The reason for this is that we are running out of trees. The lumber industry is cutting smaller trees (it is not unusual to find a 2x4 with the pith on one side, and traces of bark on the other) because the building industry demands extensive quantity. This cannot continue indefinitely. We must reduce the amount of wood used in house construction if our forests are going to have a fighting chance.

To address this environmental emergency we must utilize building materials which (1) use very little energy to manufacture; (2) are native to the area they are used, needing little if any transportation; (3) do not rob the planet of its "vital organs" (trees are our lungs), or cause other environmental degradation; (4) are safe for people to handle and live within; (5) are affordable to the poorer families of the planet; and (6) last for centuries. This does not mean replacing solid wood building products with reconstituted wood—which utilizes clear cutting, chipping, and toxic glues to form the chips into panels and beams—or using steel, concrete, burnt bricks, or synthetic materials—which use vast amounts of energy to manufacture and transport, adding to our pollution problems.

With such high ideals, what material exists that is suitable for construction? Mud! The use of earth to build houses pre-dates written history, and is already commonly used to some extent by the poorer masses of the world in the construction of their homes. Mud is found virtually all over the globe, and it is dirt cheap (sorry). Earth can be made into building products which have greater insulative values than conventional construction, are stronger than burnt bricks, are durable in harsh weather, and last for generations. The trick is to add small amounts of stabilizer to the earth (such as cement or lime) to give it strength and durability, and to compact it so that it will hold together. Adobe, burnt brick, rammed earth, cob construction, and pressed earth block are some of the earth-building techniques. Of these, pressed earth block (PEB) construction is the superior, because of the stabilizers used, and the amount of pressure applied to the blocks which makes them more rugged and durable than the other techniques. This paper will give the basic procedure and some helpful hints for utilizing PEB construction as a means of reducing our impact on the planet.



Advantages

* PEB buildings are better than conventional buildings in extreme temperature climates because they are warmer in the winter and cooler in the summer.

* Material costs for walls are very low.

* For nearly all locales, suitable soil for earth block material is easily found or easily modified, so there is little need for transporting materials.

* PEBs are fireproof.

* There is tremendous satisfaction from digging your house from the earth.

* For Passive Solar designs, PEBs make excellent thermal storage

* The need for many hands can help build community and family relations.

* The environmental cost of building with PEBs is very low, and very few trees are needed. A program in Africa builds PEB houses with a fiber-concrete tile roof, using only half a tree per house, which they compare to the twenty trees worth of energy needed to build the same house from burnt bricks.

* PEBs are twice as strong as burnt bricks.

* PEB walls are very attractive. If desired, colorants can be added to the mixture for various hues.

Disadvantages

* Manufacturing PEBs is time consuming, and labor intensive.

* In earthquake zones PEB houses are not safe unless used as fill for Timber Frame or Poured Concrete Post & Beam construction.

* Because of long cure periods, time must be managed well if efficient use of labor is desired.

* Outside of house needs to be protected from direct impact of rain and splashing from roof.

Technique

This paper will emphasize instruction for making the pressed earth blocks. Though they have varied uses (masonry wood heaters, floors & garden walls) house construction is the use discussed. However, the amateur may need to seek other sources for more information on foundations, roofs, interior structures, and even block laying. A list of resources is given at the end.

1. Preparing the Foundation

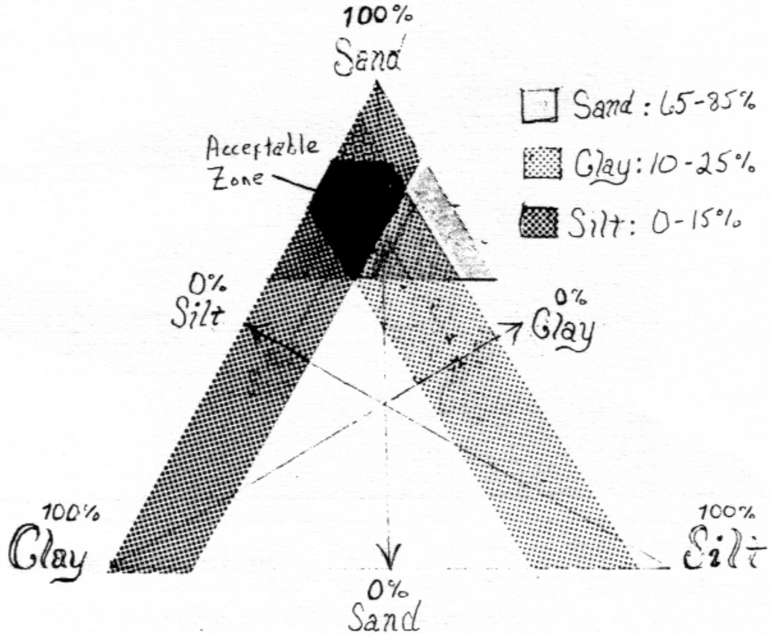
The foundation can be of either cement or stone with mortar. You may find yourself with a lot of stone from digging soil for the blocks, and should look into using it in your foundation. Care should be taken to make it level, and it needs to be at least one foot higher than the grade and as deep as the frost line in your region. It should be no wider than the block wall will be so that there will not be a ledge to catch water. All ground should slope away from the house with proper drainage beds around the perimeter of the house. It is important to make these preparations so that standing water, which will cause deterioration, never comes in contact with the pressed earth blocks. Another important precaution to make is to have your eves extend at least two feet over the wall to give even more protection from rain and splashing. The roof and foundation are like a wide brim hat and a good pair of boots that keep the earth blocks from excessive moisture.

2. Digging the Soil

It is important to remove all organic matter including the topsoil from the subsoil. This is done by simply digging down a foot or so. Save that topsoil, replace it on the excavated site and replant vegetation there so the topsoil won't erode. You will need to sift the subsoil through 1/4 inch wire mesh which can be purchased at most hardware stores. Make a 4' x 4' frame from 2x4s and affix the wire mesh to the frame. The frame can be suspended like a hammock between two trees or posts, and the soil worked through the sifter. Remove any rocks that will not sift through. When there is a sufficient amount of soil sifted for a load to be mixed, the next stages should be executed while more soil is being dug and sifted. Do not allow the sifted or unsifted soil to get rained on.

3. Testing the Soil

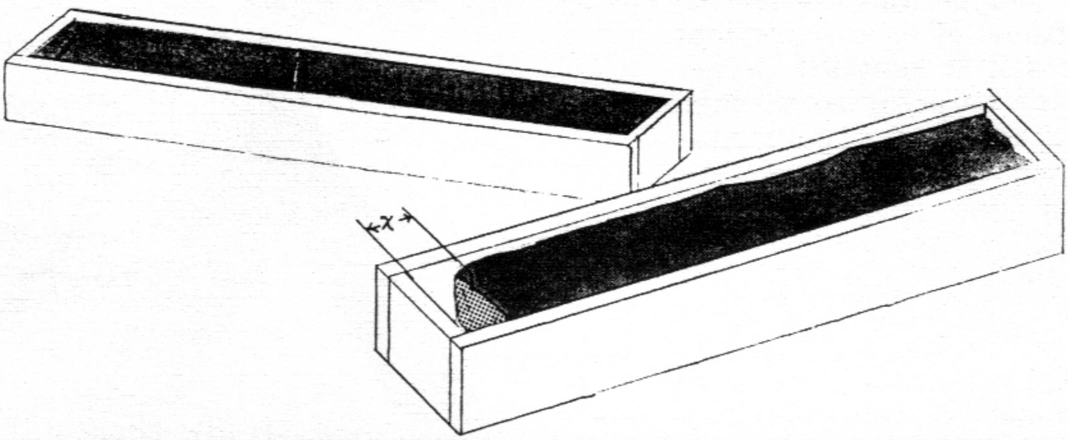
The subsoil is a combination of sand, clay, and silt. It is important to know the proportions of each ingredient in the soil so that the proper ratio can be obtained through adding more of a particular ingredient if it is lacking. The ratio is fairly flexible, but the proportions should be close to 75% sand, 15% clay, and 10% silt [see diagram]. If there is less than 10% silt, more does not need to be added, but there should not be more than 25% clay or the blocks will shrink too much when they dry, and not be as strong. If there is too much silt, sand and clay should be added.



To find out the composition of the soil you will be using, simply take a wide mouth glass jar and fill it half way with the sifted soil. Add a few teaspoons of salt, and fill the jar with water. Place the lid on the jar and shake vigorously for three minutes. Allow to settle overnight. The soil will settle into the three ingredients, which can be measured with a ruler to find the proportions. If there is too much clay, add sand (it is easy to get your own sand from a creek bed). In the rare case that there is not enough clay, you will probably need to purchase it. You can purchase Bentonite clay from most builder's supply stores that handle masonry supplies. This would be your most suitable and economical clay to purchase.

The next test to perform is the shrinkage test. This will tell you how much stabilizer to add to the mix. [See box on "Stabilizers & Mortar.] First, make a wooden trough with the interior dimensions of 1-1/2" x 1-1/2" x 24", leaving one of the long sides open. Take enough moistened soil (of the proper sand/clay/silt content) to pack into the trough, and moisten it enough to hold it together, but not so much that it sticks to your hand when pressed into your palm. When a ball is dropped from shoulder height, it should break into small chunks, but not be pulverized. Fill the trough with properly moistened soil and pack firmly. Allow to dry in a sunny window for three days. Push the dried clay to one end of the trough and measure the length of the gap at the other end. The amount of gap will tell you how much stabilizer needs to be added to the soil for optimum strength and durability:

1/2" or less	1 part stabilizer to 18 parts soil
1/2" to 1"	1 part stabilizer to 16 parts soil
1" to 1-1/2"	1 part stabilizer to 14 parts soil



Stabilizers & Mortar

By far, the greatest cost (in the walls) to your bank account, as well as to the environment, would be the use of pure Portland Cement as a stabilizer. It is the most commonly used stabilizer for pressed earth blocks. However, the problem with cement is that it takes a vast amount of energy to produce, it is made by large corporations in central locations, and it is transported long distances to the consumer. Roughly 5-7% of the PEB mixture is stabilizer, but there is also stabilizer in the mortar to consider, which can increase stabilizer content another 3-5% cement, for a total of 8-12%. Considering that a small house will take several tons of stabilizer for the walls, cement is an expensive choice.

Fortunately, there are several alternative stabilizers to consider. Whatever ingredients you decide on, the first consideration should be the factor of manufacturing impact and local availability. If you live near one of the more efficient cement plants (cement production consumes energy at an exceedingly broad range, with energy consumption rates varying anywhere from 2 to 10 megajoules per kilogram), and if you can get cement for a relatively low cost, then it would be the material to use. However, this will not be the case for most bagged cement that you will likely find. The use of lime as all or part of the stabilizer is one way of reducing the environmental and economic cost.

4. Adding Stabilizer and Water

This step can either be done the quick way or the inexpensive way. The quick way is to rent (or borrow) an electric concrete mixer. The other way is to make a shallow box, 4' x 4' x 6" or get a good wheelbarrow, and use a concrete mixing hoe. Either way, mix all the dry ingredients first. If the mixture is 1:16, put in 1 shovelfull of stabilizer and 16 shovelfulls of soil. It is very important not to add too much water. You will think that it is too dry, but it isn't. The proper moisture content is the same as for the shrinkage test described in step three.

5. Making Blocks

The most important tool for making the blocks is a stabilized soil block press. They are difficult to come by in the U.S. but you can sometimes find them used. International relief organizations such as Habitat for Humanity, in Americus, GA, may be able to help you locate a press. The U.S. distributor of the most common press—called the CINVA-Ram—stopped importing it in the Eighties (they sold for $175), but the manufacturer of the CINVA-Ram is:

Metalibec
Carrera 08B, No. 18-30
AA11798
Bogota, Columbia
Phone: 011-57-12613277

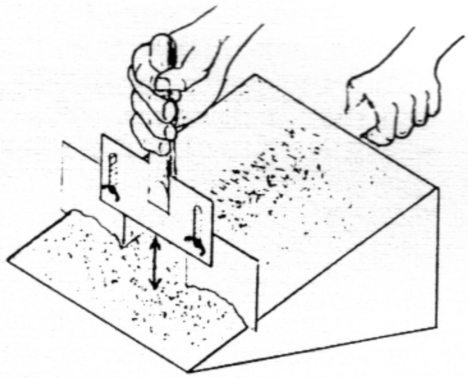
STABILIZERS

Slaked Lime *(calcium hydroxide,* or Agricultural Lime) is limestone that is pulverized and when wetted (or slaked), it expands and reacts thermally (gets hot), breaking back down into a fine powder without the use of additional heat. Lime is the main ingredient in Portland Cement; however, in its unprocessed form, it takes twice as long to cure as cement (**2 weeks wet cure, 2 weeks dry cure, 4 more weeks maximum strength**). Slaked lime mixes better with more clayey soils than cement does, and makes a stronger brick with this type of soil. Simply add 1 shovelfull for every 14, 16, or 18 shovelfulls of soil (depending on the results of the shrinkage test). Once lime and soil are mixed and properly moistened, cover it and let it stand for 1 or 2 days before block making, keeping it moist; break down any remaining lumps and press into blocks. Refer to main text and above figures for specifics on block manufacture.

Portland Cement is made from lime and clay that is mixed, fired at 1450° C, and ground, along with a trace of gypsum, into a fine gray powder. Portland Cement works best with more sandy soil. Mix with soil dry, and add proper amount of water (see shrinkage test). It should be used within about a half hour from being wetted. If it hardens first, discard. Blocks stabilized with cement should **wet cure for 1 week and dry cure for 1 week; they reach maximum strength after 2 more weeks.**

A **Lime/Cement combination** may be a good compromise, lessening the amount of cement used and the amount of time to manufacture the blocks with pure lime. Use

It is very important to fill the press with the proper amount of soil mixture. A scoop can be made from wood or sheet metal that will measure the proper amount for each block [see illustration]. If not enough soil mixture is put into the press, the block will not be pressed enough and will be weak. If too much is put into the press, the block will be too big, or the press will break. The proper amount of force for the CINVA-Ram is 130 pounds on the end of the lever. If water drips from the press when the mixture is being pressed, it is too wet, and should be discarded. To ease in extraction of blocks, a kerosene/oil mixture can be lightly sprayed on the inside of the press before filling.



6. Curing

As the blocks are extracted from the press, they should be inspected for defects, and carefully stacked on a clean, flat, level surface in the shade. You may wish to construct the actual roof for the house first, held up by removable posts (not where the walls will be built) over the foundation, using the floor of the house as your curing area. They should be stacked 3 blocks side by side, 1 inch between the blocks, alternating direction on each layer, with no more than 5 layers per stack. The blocks will need to be covered to hold in moisture, and sprinkled with water once a day for the duration of the wet cure, which depends on the stabilizer used [see section on "Stabilizers"]. After the wet cure, uncover and let stand for the duration of the dry cure. **Never underestimate the importance of careful curing.**

equal parts lime and cement. Add the lime to the soil first, moisten, and keep covered for 1 or 2 days. Break down remaining lumps, add cement, and moisten appropriately. Once blocks are made, they should **wet cure for 10 days and dry cure for 10 days; they reach maximum strength after 20 more days.**

The cure times given are approximations, and may vary depending on the temperature, humidity, and air currents. Walls may be built any time after the dry cure, but take care not to require too much of the blocks before their maximum strength is achieved.

MORTARS

As with the stabilizers, the mortars can use various amounts of cement and/or lime. A good mortar for PEBs is made with **1 part Hydraulic Lime , 4 parts sand** and enough water to make mortar workable.

A pre-packaged mortar, such as BRIXMENT brand type-N Coplary Cement, can be used for a very strong but environmentally and economically costly mortar. You can make your own by mixing **1 part Portland Cement with 6 parts sand** and enough water to make workable.

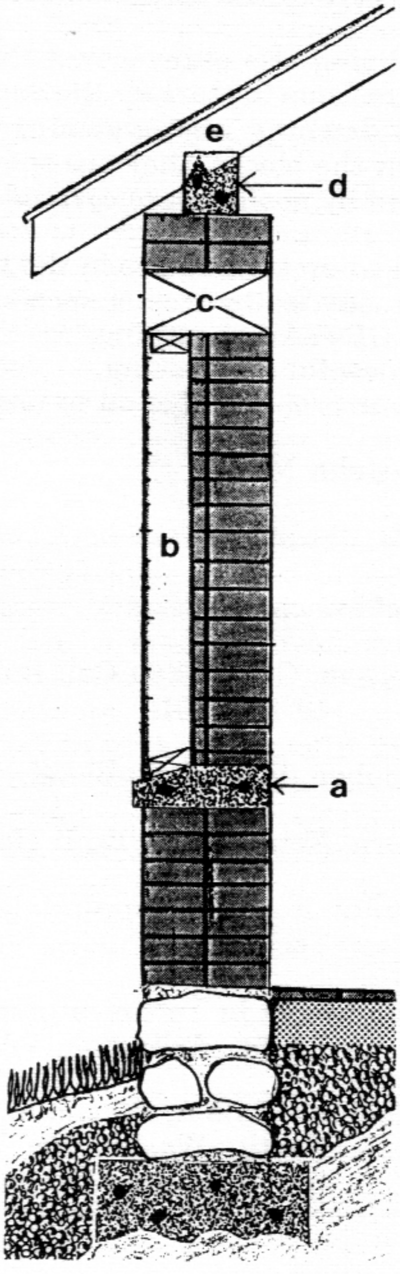
A good strong mortar is a combination of the other mortars using a mixture of **1 part Portland, 4 parts lime, 32 parts sand** and water.

When mixing mortar, mix all dry ingredients thoroughly before adding water. After laying up bricks in mortar, keep the mortar moist for a day or so.

7. Building the Walls

This is the most challenging part of the process, and beginners should familiarize themselves with other sources, such as those listed at the end of the paper. From this point, the building process is virtually the same as with burnt bricks. The blocks themselves measure 3-1/2" x 5-1/2" x 11-1/2" (from the CINVA-Ram), so with 1/2" of mortar, the building units (foundation size, placement of doors & windows) should be in 1 foot increments. You have several options for wall construction: Timber Frame or Poured Concrete Post & Beam using as in-fill a single layer of PEB and rigid foam on outside covered with stucco; a double layer of PEB tied together with brackets and an air space or foam in between; or a double layer of PEB with only mortar in between. You may either use mortar or dry stack the PEBs and use an eighth inch layer of fiberglass bonding cement (Surewall brand) on both sides.

The following is for building walls without the use of Timber Frame or Poured Cement Post & Beam construction. Nail together and brace the door frames in place. Without mortar, lay the first course of bricks around the perimeter of the building to get the proper placement. With 1/2" of mortar under the first course and between each block, lay up the corners and door jams first for several layers, staggering joints. Moisten the blocks before applying mortar (unless you have decided to use Surewall instead of mortar). The corners will act as guides for the rest of the wall. Stretch masons twine across length of wall to keep courses straight. Move the twine up with each course to keep level. Use a 4' level to check for plumb. You can cut the blocks with a brick layer's hammer and good aim, or a masonry chisel.



Once you have gotten up to the window level, pour concrete window sills that will shed the water away from the window [see illustration] (a). Nail together the window frames (b) and brace them in place. Continue laying as before until you get to the top of the windows and doors. Use large timbers for lintels (c) over the windows and doors that are as wide as the wall, as thick as 2 or 3 courses, and that extend past the sides of the opening by at least 1 foot. Fill in between lintels with bricks. Make forms and pour a binder beam of reinforced concrete around the top perimeter of the wall (d). If the roof has been made first, the joists could be notched and integrated into the binder beam (e) and the temporary posts removed once the concrete has cured.

8. Completing Construction

If the roof structure has not been constructed previously, this can be done once the binder beam has cured. It would be environmentally suitable to consider alternatives to plywood and asphalt shingles. Windows, doors and interior finishing are the same as with other types of construction, though you may wish to use single layer pressed earth blocks for the inside walls. For a very durable finish on the outside of the house, you can leave the mortar oozing from the joints and cover the wall with stucco. If you want people to see all of your hard work, you may wish to use a masonry sealer, and recoat the house every couple of years or so. The interior surface treatment can be: plaster, sheetrock on furring strips, or bare. The CINVA-Ram can also make thin tiles for a very durable floor surface.

Ode to a CINVA-Ram

I'll sing you the song of a CINVA:
A simple and portable thing.
Earth pressing—no messing!
A fabulous blessing
When it comes to house constructing

Fill up the box with your shovel,
Then cover and give a big heave.
In compacting it's acting,
The pressure reacting:
Eject, and the brick is achieved.

I'll sing of a shiny new CINVA:
It calls us to start up the day.
At dawning we're yawning
But the blocks, they are spawning,
And by noon we are covered with clay!

So wherever you are in the wilds
Frustrated by lack of success,
A CINVA is soothing,
So useful it's proving,
Your project is bound to impress!

—John Miles (revised by T. F. P.)

Typical Cost (Labor not included)

Here is an example of what you can expect to spend for a 20' x 20' cabin with: pure lime in the stabilizer & mortar, masonry foundation, pressed earth tile floor, and tin roof. The lintels and rafters would be made from some trees felled on the owner's land, and milled with a neighbor's portable bandsaw mill.

Concrete & Rebar (footer, window sills & binder beam)	$300
Slaked Lime	165
Hydraulic Lime	30
Sand (10 tons)	160
Gravel (11 tons)	100
Windows, salvage (6)	60
Doors, salvage (2)	25
Roof	400
Rafters	200
Window & door frames	100
Lintels	75
Insulation	65
Masonry Sealer, caulking	200
Misc. Hardware	100
TOTAL	$1,980

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*Funded by a grant from the **W. Murray Fund***

Text & Illustrations – **T. F. Price**

Printed on Recycled Paper

Project Director – Al Fritsch