D Acres of New Hampshire
Organic Farm & Educational Homestead

Alternative Building Weekend Workshop

August 20-22, 2004

featuring:

Field Stone Masonry

Incorporating Adobe Bricks into a Building Project

Cordwood Construction

and a few words about walls!

Compiled by staff and work-traders at D Acres of NH.

Welcome to the weekend alternative building workshop at D Acres! We've been hard at work preparing the foundations of our dual function greenhouse/animal shelter project. Before we get to setting the earthen walls, any earthen building needs a good set of rain "boots" to keep it high and dry from the rain and snow. The **rainy weather** we've had this summer has provided us with a challenge, but such is the nature of **working *with* nature**, and not against! Over the past several weeks we have been working on the animal shelter part of the building, pouring the concrete foundation **and building up a stone wall** several feet high with field stones and cement mortar. We hauled the stones from old walls with our team of oxen, Henri and August. Although we have already used a moderate amount of cement for the foundation and walls, we will use mostly natural materials from here on, and hope that the costs (in terms of finance and embodied energy) will pay off in the long run. To date 179 hours of labor have been put into design, materials acquisition and site preparation, and approximately 250 hours into masonry and foundation work. Out of pocket expenses (including 1 1/2 inch stone, excavation, rebar, poured cement and bag cement) total $1475.65. You can access information about the overall design concepts involved and aspects of foundation laying and adobe brickmaking in last workshop's information packet, which is posted on the D Acres website (www.dacres.org). Those of you with us for this weekend will have the fortune to witness and participate in the **beginning of the earthen walls**! May you take back with you some of the wisdom of the earth and build the future!

Field Stone Masonry

For the base of our animal husbandry building we chose to use stone masonry. It has proven to be cost effective and has created a sturdy base for our building. It also has better water-resistance than some earthen materials, such as cob or adobe. One negative aspect, however, is the massive weight of some of the larger stones. Positioning them can be both laborious and hazardous.

The collection of stone from historic stone walls on the property was a difficult ethical decision. Ultimately it was decided that the construction of stone from old walls would be a tribute to the efforts of farmers from an earlier age. After using our team of oxen to collect a great deal of stone, we began dry setting our first layer. The intensity of this labor made working with a buddy a wise choice! A good eye for picking stones also came in handy, as we wanted at least one side flat enough to be used on the face of the wall. Sometimes, nature's design wasn't quite good enough for us and we chiseled our stones to produce flat sides. We can say with conviction that if you ever have to chose between chiseling granite or slate – go with the slate!

We chose to lay our stone "free-hand", as opposed to using slip-forms, which are sometimes used to help assure the straightness of masonry walls. This meant we were constantly checking the wall with the level as we went. Our goal was to avoid the walls tapering inwards. We laid bigger stones towards the bottom in order to save our backs from breaking and further help the sturdiness of our wall.

We then went about mixing our mortar. Our mix ratio was 2-½ parts sand to 1 part mortar (thoroughly mix the sand and mortar!), plus ½ to ¾ parts water, depending on the humidity. A hoe and wheelbarrow were the preferred tools for this job. Mixing mortar is the type of job best learned by experience. The more you do, the better feel you get for the process. The resulting mix should be runny without hard clumps. Though the formula is based on ratios, it may actually be more of an art than a science. Eventually, you just get a feel for it.

Before we set our stones with the mortar, we made sure to wash them thoroughly, removing all trace of mud and moss. We did this in order to help the mortar and stone adhere together better. A little extra effort at this stage can save you grief later.

To apply mortar we use several tools: large and small pointed masonry trowels and pointers (called bricksets).

When setting the stones we applied ¼ to ½ inch of mortar bedding, trying not to use too much of it. This is because the stone will last much longer than the mortar - and the stone is cheaper! (Our mortar of choice cost us $7.46 per 70 lb. bag, of which we used 20 bags, for a total cost of $149.20)

One of the key ideas in the final setting of the stones was to remember exactly how the rock had been positioned in the dry setting phase. This proved to be tricky, but we got better with experience. It is disadvantageous to be fooling around trying to remember how you wanted the stone set as your mortar begins to dry. For the thicker sections of the wall, we filled the insides with a mix of mortar and one-and-a-half inch gravel.

The wall was built by the long process of dry setting each course, then final setting each course with mortar. Along the way, we always tried to bridge vertical seams, using the rule of thumb that says: "One over two, and two over one." Through lots of hard work, and going through all the steps described above over and over again, we finally reached our desired height.

A word of caution about Portland cement. It is a very popular building material but has drawbacks. Do not breathe the dust while mixing or get the "mud" on your skin. It is very caustic due to its low pH. The tools used in the process must be cleaned at the end of the day or the mortar will bond permanently.

Incorporating Adobe Bricks into a Building Project

Making adobe mortar mix:

The purpose of the mortar is to join the bricks into a solid wall. In addition, it is useful for evening out any uneven portions of the wall due to irregularities in the brick setting or of the bricks themselves. A mortar mix is basically composed of the same materials that the bricks are made of, but without the straw (so clay, sand and water). You want the mortar mix to be sticky, though, so in this case it helps to increase the proportion of clay in the 70-30 percent sand to clay ratio of the bricks. The mortar mix must be wet enough that it oozes a little when you set the brick down onto it.

Making an adobe wall:

Before a brick assumes its final resting spot in your wall, you want to prepare for it a cozy **bed of mortar**. As a general rule when working with earthen materials, it is important to make sure that whatever surface you are adding material to is wet to make sure that a cohesive bond is made with the newly applied material. When you are ready, spread the mortar down thick enough that it will ooze out the sides a little when you lay the brick. If you accidentally put too much down, remember that it is always easier to take away dry material (by chipping away at it) than to add wet material. In order to achieve a snug fit with the adjacent brick, put an excess of mortar against the side of the brick you are laying, set the brick down on the mortar bed beneath and push it into the adjacent brick until the mortar oozes out the top. (See diagram A - Laying a Brick with Mortar)

As mentioned above, laying mortar also allows you **to get rid of unevenness** in the wall. You want to try to keep each course of bricks as flat as possible for maximum strength, but if you notice irregularities they can easily be fixed. For example, if it seems the brick you are laying slants too much in one direction, you can use some small pieces of a broken brick embedded into the mortar to raise that end until the brick is balanced when it is set. Because the project we are working on here at D Acres has a round wall, we will need to fill the gaps created by the straight bricks on the curve with mortar and brick pieces. If however, the curve is sharp enough to leave a very substantial gap, we would need to fill them with a cob mix not unlike the original brick mix. (See Diagram B - Evening out a wall)

With any wall, whether you are working with adobe or cob, it is important to **keep your walls vertical.** Walls that veer from the vertical line are more likely to collapse (unless you plan to taper them slightly toward the top for added strength). Because the human eye is notoriously bad at judging plumb lines, a level or simple plumb bob are good tools to keep you on track. When building with bricks, it is good practice to keep track of your plumbness by one side of the wall, for the sake of consistency. If the building is going to be a space inhabited by people, the interior wall is better since you are eventually looking for a finer finish on the inside. If you find that you are veering too much toward one side, or if there are bulges in your wall, you will have to trim the walls using a machete or a chisel.

It should be noted that once you have laid a brick in mortar, it is best to reapply wet mortar if you choose to reset it, since you will note that the mortar dries substantially in a matter of minutes.

Setting Windows and Door Frames:

The **functions of a window** in your building may include allowing daylight to enter, exchange of air, or for looking out onto a view. In our particular case, we will install windows into the building between the animal shelter and greenhouse interface to give the animals access to light during the day, but also to help manage the exchange of heated air from the greenhouse during the winter. During the summer, when a greenhouse is prone to over heating, we will need windows (or doors) at the interface between the greenhouse and the outside to increase the circulation of fresh air.

There are two basic categories to choose from when setting windows into your earthen walls: fixed and openable. **Fixed windows** are easier to install because they require no frame. For artistic effect, you can use broken shard of glass to create unique openings (but be careful of the edges! Cover them with tape!). If you are working with adobe bricks, simply leave a space slightly larger than the window you plan to install, by supporting the top of the space with a wooden lintel (support beam) that goes at least 4" on either side into the wall. Once you have built up the wall around it, you can snug the window in using a cob mix, first fixing it in place around the bottom, then filling in the rest once it dries. It is a good rule to only set your windows a maximum of ¼" into the cob, since it will be less prone to cracks from the stress of the cob as it dries and so that it is easier to replace. (See Diagram 3 - Fixed Window in Adobe Wall). Make sure that the sill is built sloping away from the window to keep the water from puddling at the sill. For added strength or aesthetic qualities use wood, stone, or tiles for the sill.

Openable windows and doors require wooden frames with heavy lintels. Frames should be reinforced with *cross braces* to make sure that the frames don't move out of square. With doors, it is good practice to brace the frame to the ground, too, to make sure the frame remains in line with the wall. To make sure that the frame is firmly affixed to the wall, it helps to hammer in nails along the sides of the frame to give the cob or adobe a way to key in. You can coincide the nails into the frame with the mortar joints, if you are making an adobe wall. If you are building with cob, it is good practice to build up to the height of the frame, wait until it is dry, and then build the rest of the wall over the frame, or diagonal cracks may occur on the corners as the cob dries and sets along the sides of the frame.

Making an Earthen Top Plate:

A good way to hold together the walls of an adobe building is by uniting them with a monolithic ('one piece') ***top plate***. The top plate is the interface between the roof and the walls where the rafters sit and serves to distribute the weight of the roof evenly over the walls. Slap on a thick layer of mortar (similar to that used for the bricks along the top of the wall) and then work in by hand some handfuls of straw with the grain in the

direction of the wall. After several inches of straw and mortar layers, lay in two ½" branches parallel along the wall and then continue this pattern until the plate is about a foot thick. If it is a curved wall, green (fresh) willow is good because you will be able to bend it to the curve and then it will harden in that orientation when it dries. You can set the rafters on this plate and snug them in with cob around them. (See Diagram 4 - Top Plate)

Running Stove Pipes Through the Wall:

To supplement the passive solar design for the greenhouse/animal shelter complex we will include two stoves. Although they will be in the greenhouse, we will run the pipes through the walls at the interface between the greenhouse and the animal shelter. The idea is not only to heat up both spaces simultaneously, but also to capture as much of the heat escaping out the pipes as possible for storage in the thermal mass of the earthen wall. The pipes will be 6" in diameter, which will allow us 3" either side on a 12" thick wall. The pipe will run vertical in some portions and horizontal in others on its way out through an adobe wall. One technique for the vertical portion is to span two dowels or branches across each mortar joint on either side of the pipe, which will hold the walls together on either side and provide support to fill the rest in with cob. For the horizontal portion in the adobe wall, the pipe will be embedded in cob set onto the adobe wall and then the bricks will continue on top. (See Diagram 5 - Proposed Vertical & Horizontal Portions of Stove Pipe Running Through Adobe Wall.)

Cordwood Construction

Cordwood is a simple and ingenious building technique that has been practiced in various forms since man began burning and collecting wood. The stacked wood naturally became an integral part of living space for non nomadic people. It has many advantages for the modern builder including beauty, cost, ease of construction, and energy efficiency.

The patterns of cordwood walls are natural and pleasing to the eye. The aesthetic is similar to stone. It is unique and can be constructed in patterns and designs. It is said that it is easier to stack cordwood as roundwood instead of split but the possibilities are endless. As an environmentally friendly art, cordwood building is intrinsic beauty visually and mentally.

Cordwood is readily available in New England. Wood is not cheap but can be located locally. If possible the wood should be cut onsite to save the transportation cost. Per wall foot price is comparable to conventional construction especially considering the wood serves as the bearing wall, insulation, interior and exterior finish. Cordwood construction saves the environment by replacing the fiberglass insulation or vinyl siding that might otherwise be used.

This type of construction is fantastic for owner builders. Stacking one log after another is methodical and progress is readily apparent. The walls can be brought up over time as long as they are protected from rain and moisture. The act of construction is as simple as stacking firewood.

Building materials are judged by their ability to support weight, collect thermal energy, insulate, and deter water infiltration. Cordwood is a unique combination of thermal mass and insulation value. The masonry or cob that forms the mortar holds the thermal energy of the sun and releases it passively during cool nights. It moderates high temperature during the intense heat of the summer. Insulation is measured by an R-rating. Wood is rated at .5-1 R per inch. Sawdust is rated at R-3 per inch. The mortar joint is a nominal R-2. Thus a 12 inch cordwood wall with 6 inches of sawdust approaches an R-12-15 nominal value which is comparable to 5 inches of fiberglass insulation in a stick frame wall.

Cordwood can be used in many forms. The wood can be stacked as infill between the posts of a typical post and beam. To build a load bearing corner of cordwood the wood must be "cribbed" or stacked at 90 degree angles to provide stability to the corner. There is also the roundhouse method in which the walls are connected in a circular pattern.

Cordwood is stacked and mortared together one course at time. The mortar is applied on both ends and sawdust is paced in the middle as insulation. The mortar seals out water and air infiltration. Three inches of mortar is sufficient thickness. The sawdust insulation can be augmented with lime to deter pests. The lime to be used is not ag lime but rather construction type labeled "hydrated, type S, or slaked." If the sawdust lime mixture gets wet it will harden and calcify increasing its strength and stability. Sawdust of less than ¼" nominal size can be added to masonry mix to provide extra insulation and reduced shrinkage. Make sure to soak the sawdust in water prior to mixing with cement or it will accelerate drying and shrinkage (cracking).

The art of cordwood is dependent on working towards the strengths and limitations of the material. Light wood such as cedar and pine are the preferred cordwoods because they have higher insulation and rot resistance value. Hardwood can be used but it swells more than less dense woods. Therefore while soft wood should be dried and seasoned for a year before wall building, the hardwood can be stripped and used after a couple weeks. All bark should be removed as it harbors pests and will promote cracks (drafts) in the wall.

Wood rots with moisture. The fungi that eat wood need moisture to survive and thrive. Cordwood will dry through the end grain if exposed to occasional rain so it is crucial to keep the material as dry as possible. To prevent destruction from rain, roof overhangs of at least 16" are recommended. It is also preferable to keep the cordwood well off the ground to prevent splash from rain and absorption of ground moisture.

Sources:
The Sauna by Rob Roy Chelsea Green 1996
Alternative Housebuilding by Mike McClintock Sterling Publishing 1989
The Cob Builders Handbook—You Can Hand-Sculpt Your Own Home by Becky Bee Chelsea Green 1997

Walls

Walls are what hold the roof up and keep the wind out. The walls provide the portals of access for people, air and sunlight. Wall materials are chosen based on the occupants' and builders' criteria. Conventional stick framing is common because it is quick and simple. Large homes are commonly framed with a 3 person framing crew. The system is popular but relies on kiln dried lumber that has been processed into dimensionally consistent pieces. The parts are put together as a system. Components are produced in standardized sizes. The plywood and drywall come in 4*8' sheets, insulation fits snugly into the typical 2*4 wall cavity, and the building is designed to provide uniform 16" spacing between wall studs. Putting together a stick framed building with a nail gun is standard practice and has been institutionalized through industry and building codes. A 3 bedroom house is normally framed in 2-4 weeks.

The walls of earthen structures are different than conventional walls. They are thicker and heavier. In addition, earthen materials serve as the wall structure and the insulation. While conventional home plans and materials are standardized and duplicated, the earthen home is always unique. The earthen home feels different, sounds are less hollow, the walls are solid (not like drywall), and the temperature is moderated from the extremes of the outdoors.

Conventional and earthen buildings require upkeep. The conventional home requires painting and siding maintenance whereas with the earthen building patching and plaster are needed. Both materials will degrade. Conventional construction is resource and petroleum energy dependent. Earthen structures require more human labor. Conventional and earthen buildings are functional based on quality of design and the craftsmanship of the construction.

Earthen walls must be kept dry. That means a good hat and dry boots. The foundation must be well drained and prevent water from permeating the building. A stone base can protect the walls from rain splash and groundwater absorption. The roof needs adequate overhang. This overhang helps prevent rain from directly hitting the walls. It is also a good idea to prevent flora from growing into the walls. Plants harbor moisture and

impede ventilation.

Walls of earth are heavy. As the wall increases in height the thickness should be tapered for increased stability. For the greenhouse the wall tapers about ½ to 1 inch per vertical foot. It is important to plan the thickness needed for the wall. At least 6 inches of earthen material are necessary to form a roof bearing wall.

Windows and doors are the access points for people, air and sunlight. They must be sized and placed according to a thoughtful design. Window glazing can promote passive solar heating but can also be a tremendous heating loss (i.e. skylights). A door can be a graceful entrance or an awkward afterthought. It is necessary to consider location, use and materials to be used for the doors and windows.

Doors are usually large openings that require an operable hinged portal. The frame is usually wood and needs to be firmly secured into the wall. The frame can be "keyed" into the wall by adding strips of wood. The strips are added to the outside of the frame, centered on the existing framework thus locking the frame into the earthen wall It is helpful to square and plum the frame within the wall. This makes building and hanging the door for operation much easier.

Glass windows can be dangerous so please use caution. There are many creative possibilities for glazing. Colored bottles can bring in beautifully diffuse light. Large pieces of broken glass can be tapered into position with cob. Operable window frames can be mounted into the wall by nailing into the frame where the walls can connect and retain the frame. The nails adhere to the earthen wall and prevent the frame from shifting from its placement.

Doors and windows share design and construction specifications. Both need special treatment at the base. Water collects at this point and needs to be directed away from penetrating the building. Sloping rock shelves at the base help keep the water flowing. The head of the opening also needs attention. The head (top) must support the weight of the wall and roof above. Therefore it is necessary to reinforce the area above the opening. Common practice is to use a heavy timber that spans the opening or to construct an arch. Either can be functional but both need to be appropriately engineered depending on the circumstance. For instance a 3 foot wide door might require a 4' piece of 4"*8" but a sliding glass door will need more support. An annoying result of undersized headers could be a door that sticks because of the overhead weight. The best solution is to oversize the installation and preserve the structural integrity of the wall.

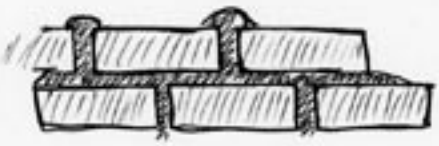
Earthen construction is a labor intensive work that requires no formal training. Basic construction can be accomplished with simple hand-tools. The process and practicality of construction requires thoughtful steps from design through implementation. Careful planning will save time and improve the results. The mission is to make the process less physically demanding while insuring the structure survives and is useful. To accomplish this we must consider the process and outcomes holistically. Search for ways to move the heavy weight less and ease the burden of the work. Strive to mix materials more efficiently and save personal energy. Make sure that the structure is designed and crafted to last the lifetime that was intended.

Good luck and let us know about your earthen building experiences!!!!

— DIAGRAMS —

① Laying A Brick with Mortar

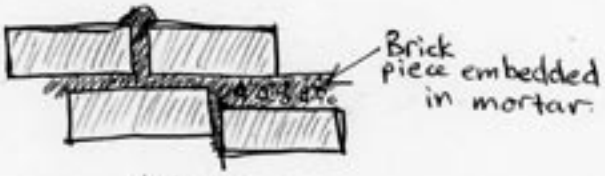
A



B.

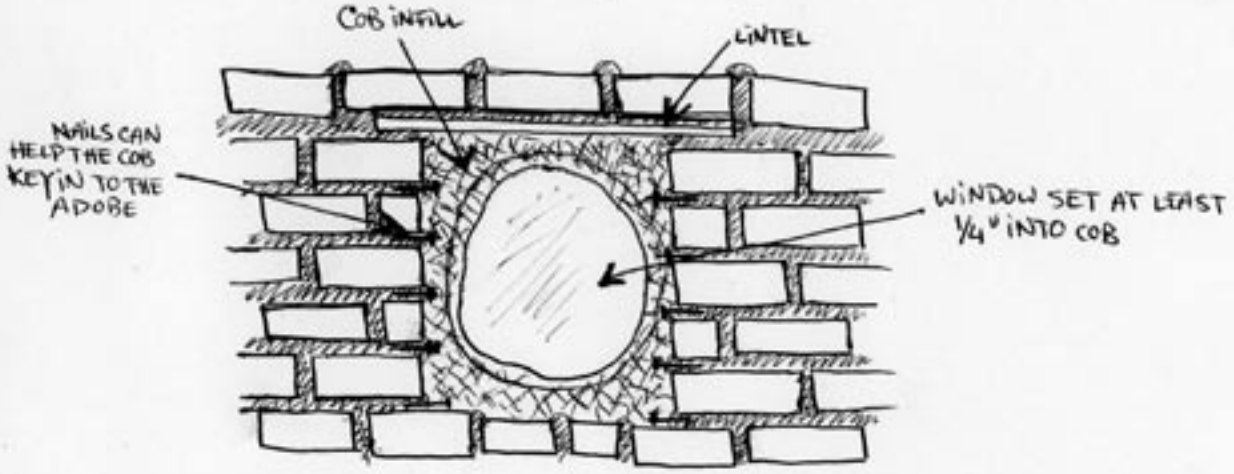
② Evening Out a Wall

NO

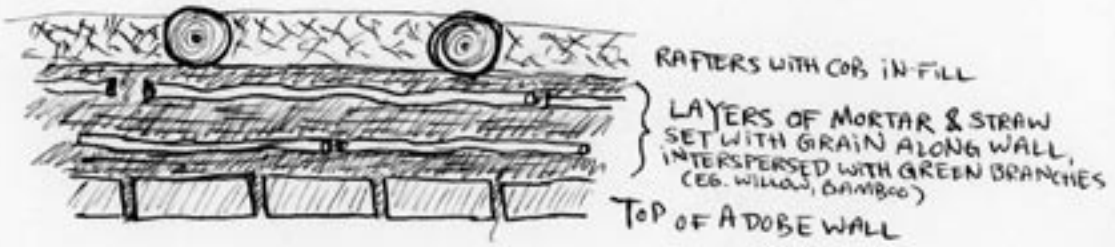


YES.

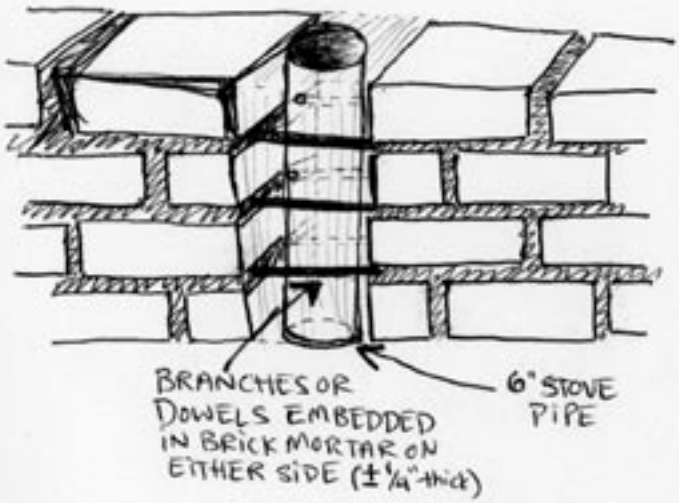
③ Fixed Window in Adobe Wall



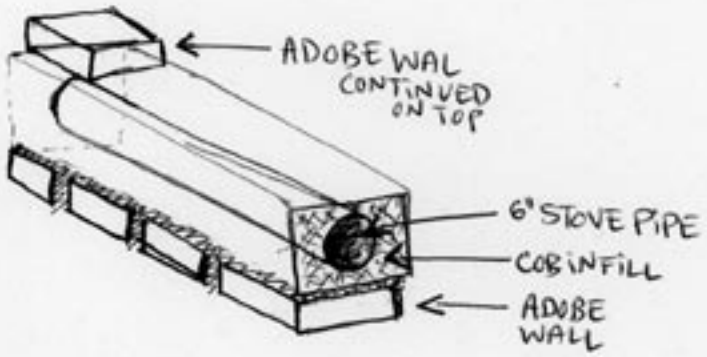
④ Top Plate



(5) Proposed Vertical & Horizontal Portions of Stove Pipe Running Through Adobe Wall.



(A) VERTICAL PIPING WITHOUT COB INFILL



(B) HORIZONTAL PIPING.