Step 7. Surfacing the Walls

Challenge: to provide your straw-bale walls with long-term protection, both inside and out, from the elements, the occupants, infestation by vermin and depredation by curious cattle or vandals.

Walk-Through

♣ *With the settling nearly complete, this is a good time to double-check to ensure that all gaps have been stuffed with some insulating material and, if you wish, capped with a cob mixture. Then make a final inspection of your wall surfaces. This is your last chance to do any final trimming and/or filling of gaps or depressions. Since you will soon be covering the walls, this is also your last chance to add another niche or two, more electrical boxes, more elements related to hanging things on the walls, et cetera.*

• *During the design process, decisions would have been made about how the inside and outside surfaces of the exterior walls would be surfaced. This is the last chance to reconsider those choices. A good review of the most commonly used surfacing materials is provided by Issue 9 of* The Last Straw.

The "flow chart" on page 100 takes you through the series of choices (and options) leading to a completed and maintained surface. Whether the wall surface in question is inside or outside, and whether one chooses a plaster-type surface or one of the non-plaster options, an early decision involves whether to install a barrier against air (and the water vapor it contains), or water in liquid form or both. If you elect to use a barrier, one must then decide whether it will cover the whole wall or only a portion (usually the lower part). The sidebar to the flow chart looks at considerations related to these decisions.

If you do decide to use a plaster-type material, the next major decision involves whether to use some sort of netting as reinforcement. The choice made here has significant implications, which we explore on page 101.

However, even if you chose plaster for most of the straw-bale wall surfaces, you might still consider using drywall, attached to vertical "furring strips", on surfaces against which you plan to attach things like floor-and wall-mounted kitchen cabinets. Drywall is an inexpensive material which, when properly "furred out", will provide you with wonderfully smooth, straight surfaces to mount things against. For more details on attaching "furring strips", see page 131.

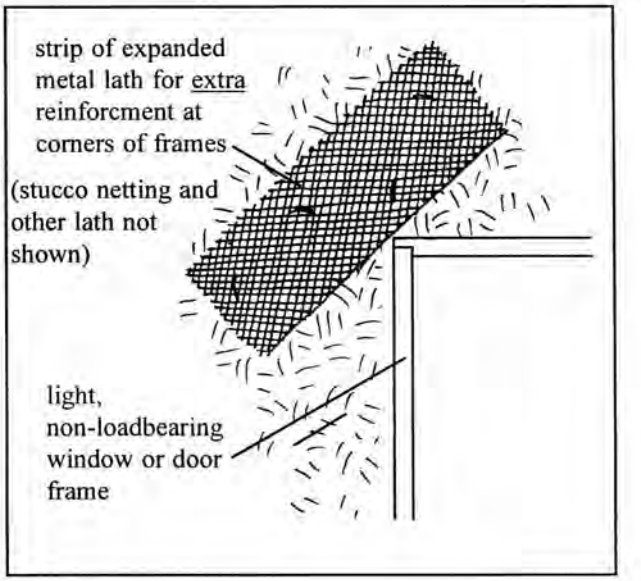
• *Issue 9 of* The Last Straw *includes an article by Jon Ruez (1995) that provides field-tested, detailed information about attaching reinforcement to a straw-bale building. Please note, however, that Jon would now recommend attaching the stucco netting after the expanded metal lath is in place, rather than before. Use Jon's article as a general guide. When it comes to specifics, use his suggestions, those in this and other books and videos, and those gleaned from conversations with other bale builders. Weigh the options in light of your unique situation, and then choose the materials/techniques that are right for you.*

♣ *For our "model" building, we can now wrap the building's corners with galvanized, expanded metal lath (a.k.a. "diamond lath" and "blood lath"), to reinforce the plaster at these often-bumped locations. The same type of reinforcement is recommended at door and window openings. First, as appropriate, protect the edge of the wooden frame with a waterproof material (see below for options). Then attach one edge of an appropriately shaped piece of lath to one edge of the frame. Finally, wrap this piece out onto the wall and secure it with "Roberta" pins (see page 92).*

As part of this process, some builders add a commercially available metal edging strip, called "J-strip", to provide a uniform way to eventually end the plaster against the door and window frames (see diagram at bottom of page). At such openings, many builders take great pains to create corner coverage with no gaps, in hopes of preventing the diagonal cracks that so typically appear in the plaster at these locations. Additional resistance can be provided by attaching an extra strip of lath near each corner as shown in diagram, upper right.

***The cut edges of this lath are like many, tiny razor blades** (therefore, "blood lath"). Gloves are highly recommended.*

♣ *On the outside of the wall, cover all exposed metal and wood with roofing felt or some other waterproof material to isolate them from the damp plaster. A thinner, commonly used alternative to roofing felt is Plaster Kraft Paper (a.k.a. Kraft paper, Grade D paper, or black paper). You may also want (or be required) to protect external, RBA tie-downs from any contact with plaster-type materials by covering them with strips of roofing felt or the equivalent. This will protect them against rusting and corrosion. It may also, as described later in this "walk-through", allow the tie-downs to be retightened after the first coat of plaster has hardened. Expanded metal lath is needed over these waterproof materials to hold the first coat of plaster in place until it cures, and to provide additional reinforcement where the plaster is not keyed into the bale surface.*



Expanded Metal Lath Meets Wood Frame

* For these options attach the expanded metal lath before placing the frames

♣ *For our "model" building, we can now continue the process of surfacing the walls by creating an exterior curtain of stucco netting, securely attached at the top to the RBA and at the bottom to the wooden "nailer" in the side of the grade-beam collar. The toe-up system involving pressure-treated 2"X4"s [5X10 cm] fastened to a slab (see the diagram on page 47) also provides a convenient nailer both outside and in. One-inch mesh poultry netting (a.k.a. "chicken wire") is commonly used as a substitute for stucco netting, but may not meet code.*

• ***For both expanded metal lath and stucco netting, the orientation of the openings in the material is important only where they are placed against something other than straw (e.g., roofing felt or a "barrier" material).*** *For metal lath, in such cases, the longer dimension of the diamond-shaped openings should run horizontally and the narrow strips of metal that form the mesh should slope downward toward the wall. For stucco netting applied over something other than straw, the long dimension of the "diamonds should also be horizontal. In addition, the small, slightly protruding sections of wire, designed to hold the netting away from the underlying material, should be on the inside. When used directly over straw, both materials can be used in any orientation you find most convenient. The crucial thing is that the plaster be applied with enough force to leave the lath or netting completely imbedded in the plaster.*

So, when wrapping the outside corners of a building with "blood lath", we can use a single, full-width strip run vertically. Ah, but what if some or all of the courses are covered with a barrier to exclude liquid water? In such a case, you may also want to use stucco netting (or an equivalent). This, combined with the "improperly" oriented lath, will adequately support the first coat of plaster until it hardens.

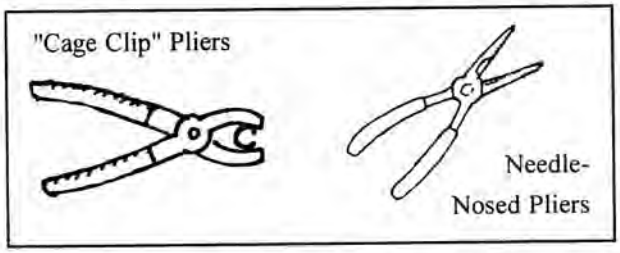
Focusing now on stucco netting, imagine a design in which only the first course of bales has a waterproof drape. ***Which way do we want to orient the strips of netting?*** *Straw-bale builders have usually chosen the* ***horizontal orientation****, perhaps having seen it used this way in mainstream construction. Those building in earthquake-prone areas might be acting on the hunch that wrapping corners with horizontal strips may provide stronger reinforcement at these critical locations than a series of vertical strips connected at a limited number of points along their overlap. Many builders, if orienting the strips horizontally, chose to initially run them right across door and window openings, coming back later to custom cut and make attachments to the frames.*

The ***vertical orientation****, although generally less used so far, seems to have some advantages. A series of strips of equal length can be precut. Given their restricted length and secure attachment to the non-movable RBA, the strips can more easily be pulled taut before the lower end is fastened to the toe-up or the foundation. This removes much of the looseness that would otherwise have to be dealt with as described on the next page. Another possible advantage is that, instead of having to move back and forth along horizontal strips, one can do all the work on each strip from the same general location. This can mean a lot less moving of scaffolding and/or ladders. One case in which you must use the vertical orientation is when you are using the netting as a tie-down system after you have pre-stressed the walls (as described on page 73).*

Considering the way doors and windows

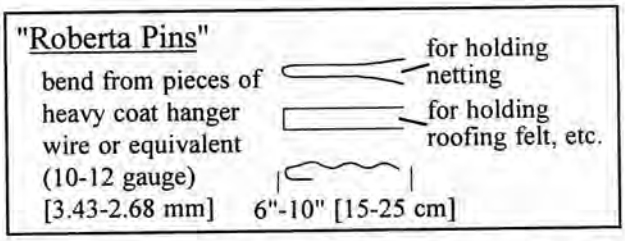
interrupt stretches of wall surface, the most efficient approach might be to use vertical strips in the unbroken areas, while using horizontal strips to fill in the gaps above and below frames.

♣ *Regardless of your of choice of orientation, or whether you use both, you should connect the strips of netting where you have purposely overlapped them by a minimum of two inches [about 10 cm]. One time-honored technique involves binding selected pairs of wires (one from each strip, for greatest effect) together with wire twists or "cage clips" (small, "C"-shaped pieces of galvanized wire). To easily hold and pinch the latter shut, you'll need to buy a special pair of pliers, shown below, or modify a pair of needle nose pliers that you already have by grinding small, cupped grooves near each tip.*

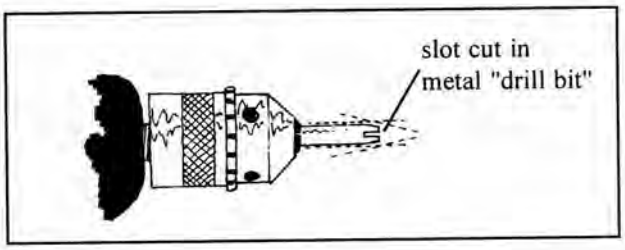


♣ *With the curtain of stucco netting now complete, we can secure it to the bale wall with galvanized wire pushed through the wall with a "bale needle". The diagram on page 102 shows several options. One or two ties per bale is typical, although in very small buildings they have been successfully omitted entirely. Again, only you know how much insurance you want, while guessing at how much insurance any given expenditure of time/labor/money will actually provide. Since our "model" building will have earth plaster, without reinforcement, on the inside surfaces, there will be nothing to which we could fasten the inside end of a wire tie. One option is to fasten one end securely at the midpoint of a short piece of rebar, bamboo, etc., and then push the free end through the wall from the inside to the outside. The loose end can then be twisted around the netting, securing it to the wall.*

Springy areas between these through-ties can be snugged to the bales with long, narrow wire staples (often called "Robert or Roberta pins" to emphasize their size and status relative to "bobby pins"). Square-end "jute net staples", used to hold down erosion control netting, can be purchased as an alternative.



Pronounced springiness/looseness can be dealt with by shortening selected wires in the netting. The low-tech method involves grabbing a wire with a pair of "needle nosed" pliers and twisting. Tim Farrant and John Watt, faced with the daunting task of tightening netting on many hundreds of linear feet of privacy wall in Tucson, came up with a high-tech method that saved time and spared their wrists. As shown below, it uses a homemade, slotted device mounted in a clutch-equipped, battery-operated "screw gun". Slip the tool onto a wire, pull the trigger, pull the tool out of the twist, and proceed to the next location. Enough to make a Luddite twist in her grave, eh?



♣ *Before you lose the opportunity, create one or more "truth windows" on interior (and/or exterior) to provide skeptics with irrefutable evidence that your building really is made of bales. Glass or Plexiglas in a frame works well, as do small, salvaged windows. Consider covering interior "truth windows" with art work in a side-hinged frame.*

♣ *In our model building, cement-based, exterior plaster can now be hand-applied, or blown on by a pumper rig (see page 107). Typically, three coats are applied, with the final, thin "color" coat containing a pigment.*

Blowing a thick, initial coat of plaster onto a wall adds a great deal of weight quickly, and produces some additional compression. This will, in turn, loosen the tie-downs you have so carefully created to hold down the RBA and roof. Not to worry. If you have used the in-the-wall system with threaded rods (and purposely not blocked off access to the nuts), simply tighten them up one last time, after the initial coat has hardened. If you have used an external tie-down system (e.g., polyester strapping), and have prevented the plaster from contacting the tie-downs and have left uncovered the hardware for tightening them, you can now attempt to tighten them one last time. The other, more common, approach is to simply let well enough alone. This leaves the slightly loosened tie-downs to act as a backup. They will function only in the very unlikely case that the weight of the plaster and bale "sandwich" is not enough to resist the uplift created by the Hurricane from Hell.

To achieve maximum strength, each coat of any cement-based plaster must be kept moist until fully cured (about 48 hours). Without this extra moisture, the chemical reaction which hardens the plaster cannot be completed.

Although the "model" building being tracked here has mud plaster only on the interior walls, both stabilized (i.e., water-resistant) and natural mud plasters have been successfully used on the exterior walls of straw-bale walls (the latter needing ample roof overhangs in wetter climates).

♣ *The plans for the building call for un-stabilized mud plaster applied directly to the straw, on the interior surfaces of the straw-bale walls. There will be no stucco netting, but you will still need to attach expanded metal lath over any metal or wood that will be covered by the plaster. Although the building code may not require covering metal or wood within the building with roofing felt, or the equivalent, some builders do it anyway. The rationale for covering metal is that the rust on ungalvanized metals may bleed through and discolor the interior plaster. For wood, the rationale is this—the more you can isolate the wood from water in any form, the less it will undergo cycles of shrinking and swelling that, in turn, can stress the plaster, eventually causing cracks.*

♣ *The earthen (a.k.a. adobe or mud) plaster can now be applied directly onto the bales with a trowel or your hand, taking care to press the mud firmly into all depressions, cracks and crannies. Typically, two or three layers are applied, the last often being a clay slip that provides a surface that is uniform in both smoothness and color. The use of such slips as a decorative technique is covered on page 116. An excellent resource for earthen plasters is Steen and Steen (1997a).*

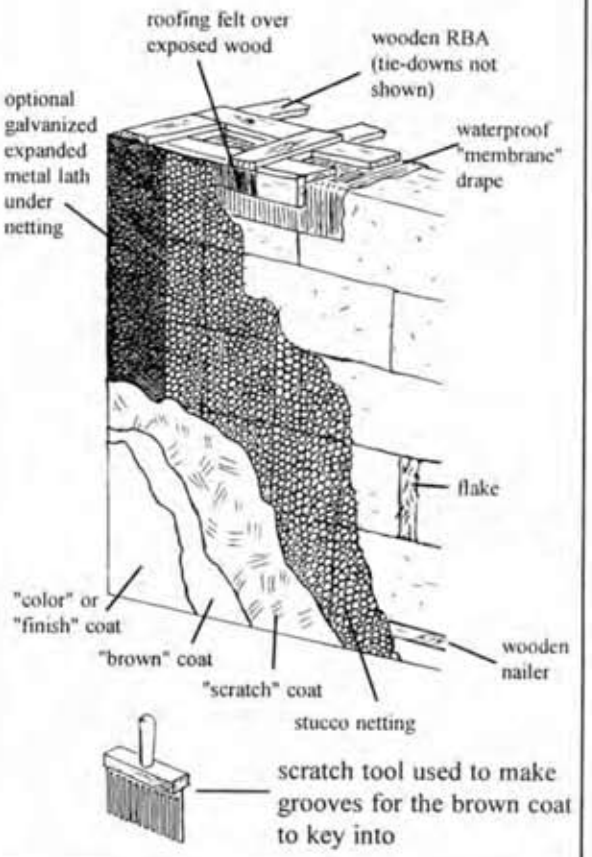
Plasters 101 — The Basics

Hang around the straw-bale revival for a while, and you're bound to hear the bewildering jargon related to surfacing materials. The name used by a manufacturer's technical support person for some material/tool/item-of-hardware, may differ from the name used by the local salesman or tradeswoman, which may, in turn, differ from the name your grandmother taught you. In a different part of the country, someone's grandmother will teach them an entirely different name. It gets even more confusing when you run into things like Keene's Cement—it isn't cement at all, but rather a type of gypsum used in some interior plaster "recipes".

The English have a great, catchall word—render—which comfortably includes a wide variety of mixtures that one might "smear" on a wall to protect it. However, since we, in the U.S. of A., don't really speak English, that isn't much help. The best we can do for a catchall is "plaster", so we'll start off by defining that.

Plaster is a combination of materials which, when mixed with a suitable amount of water (sometimes containing dissolved ingredients), forms a plastic mass which, when applied to a surface, adheres to it and subsequently "sets up" or hardens. The noun "coat", when used in reference to plaster, means an individual thickness, or layer, of plaster applied to a wall surface. With very rare exceptions, two or more coats are used, being numbered consecutively from the inner surface to the outer. For a traditional three-coat plaster application, the first coat is called the "scratch" coat, because it is typically scratched to create horizontal grooves. In straw-bale construction, it is generally applied in a thickness adequate to fully cover the straw and to encompass the wire reinforcement (if any). The attachment of the second, or "brown" coat, is increased by the plaster keying into the grooves in the "scratch" coat. The 'brown" coat, which is typically no less than ¼ inch [about 6 mm] thick, provides a smooth, flat surface onto which the the third, thinner [about 1/8" or 3 mm] "finish" or "color" coat is applied. Lumped together, the first two coats are often referred to as the "base coat".

Cutaway Drawing of a Plastered Bale Wall



It is characteristic of plaster mixes that they contain two sorts of ingredients. The **aggregate**, usually sand, or a lightweight aggregate (e.g., pumice, perlite, vermiculite), provides most of the volume. The **binder(s)**, primarily occupying the spaces between the particles of aggregate, acts as the "glue". By themselves, the "binders" tend to shrink and crack as they cure and/or dry. An important role of the "aggregate" is to reduce or eliminate this cracking, thus preserving the strength and integrity of the hardened plaster. Since the binder(s), more than the aggregate, generally determines the nature and usage of a plaster, it makes sense to categorize plasters by their dominant binder.

Less often, plasters will contain an **admixture**. The term refers to anything, other than aggregate and binder, that is included to modify the plaster mixture in some beneficial way. Two common examples are chopped glass-fibers (for cement-based plasters) and emulsified asphalt (a waterproofer for earthen plasters).

• **Cement-based plasters** are very commonly used on bale buildings for both exterior and (less often) interior surfacing. They generally consist primarily of cement and sand, usually in a ratio of about one part cement (or, cement and lime) to about three to four parts of sand. The lime acts primarily as a "plasticizer", increasing the workability of the plaster. A common, modern addition to the "scratch" and "brown" coats, is small amounts of ½ inch [1.25 cm] long fibers of alkali resistant materials (e.g., polypropylene, glass). By increasing the tensile strength and reducing the shrinkage of the plaster, they (arguably) reduce cracking. When applied to exterior surfaces, cement- based plaster is commonly referred to as "stucco", although in some areas this term refers only to factory-prepared, finish-coat mixtures.

Cement (the binder in these plasters) is not a naturally occurring material. It is usually made by creating a carefully formulated mixture of finely ground limestone, clay, alumina and other naturally occurring mineral materials, and then heating this mixture to high temperatures in large rotating kilns. The resulting balls of "clinker" are then ground up along with a small amount of uncalcined gypsum (which retards the eventual hardening process) to create a powdery material. This powder (which we call cement), when mixed with water and kept moist during the "curing" process, changes chemically and becomes a hard mass.

The mining, transportation, grinding and "burning" required to create cement results in a high "embodied energy" (i.e., it takes a lot of fossil fuel energy to produce it). For this reason, many thoughtful builders use less energy-intensive substitutes where possible. Another disadvantage of cement, when wet, is its somewhat caustic nature. You'll be wise to follow the manufacturers advice regarding its safe use.

Cement does, however, have some attractive properties for use as a binder:

—It is available virtually anywhere.

—There are good written resources (especially, Melander and Isberner 1996) and (often) good, local human resources to help the novice learn its proper use.

—Standard "recipes" are possible, since a given type of cement (e.g., Portland Type I) is the same wherever it's made.

—It produces a plaster that bonds well to straw, is resistant to scratching (i.e., hard), has considerable compressive and shear strength, is seldom affected by repeated freeze/thaw cycles and is unaffected by water.

• **Lime-based plasters** have been used for centuries for both exterior and interior surfacing, and are being used by a small, but growing, number of straw-bale practitioners, mostly for exterior surfacing. Lime is made by "burning" (a.k.a. calcining) limestone (calcium carbonate) . Carbon dioxide gas is driven off, leaving calcium oxide, which we call lime or, more accurately, quicklime. Since quicklime is extremely caustic, it is soaked in water (i.e., slaked), which converts it to hydrated lime (calcium hydroxide). Although much less caustic than quicklime, **bags of hydrated lime do carry cautionary warnings regarding its safe use. Play it safe!**

To further complicate things, hydrated lime comes in two types—S and N. In your area, either one or both types may be available without special order. Having consulted producers, users, and an authority on historical plastering technology, we are convinced that both types can be successfully used as a binder. If an aged, lime putty (see below) is not being used, Type S may be the better choice because it develops plasticity more quickly. Type N, on the other hand, develops its strength more rapidly and may bond more firmly to earthen substrates.

When used in plasters, lime of either type is often soaked in water to form a lime putty. The longer you can soak it, the more "plastic" it will be (we've read that Roman law forbade the use of lime putty less than three years old). When a lime/sand plaster is applied to a wall, the lime begins to slowly change chemically, hardening as it absorbs carbon dioxide and/or carbonic acid gas from the air. For this reason, lime-based plasters were traditionally applied in several thin, successive coats. This provided the material in each coat with more exposure to the atmosphere, and thus with more opportunity to harden.

Despite lime having an embodied energy slightly higher than cement, lime-based plasters offer several possible advantages to the straw-builder. Due to their excellent plasticity, they can be applied without wire reinforcement, although substitutes (e.g., burlap fabric) have occasionally been used. If kept wet, a mix that contains only lime and sand can be stored indefinitely. Lime-based plasters are reputedly much more "breathable" (i.e., more permeable to air and any water vapor in it) than their cement-based counterparts. Finally, micro-cracks in the plaster can be "healed", over time, by deposition of new lime in the crack. Other than the material provided herein, and the booklet published by the Canello Project (Steen and Steen 1997a), there are unfortunately no readily available, modern, written resources providing detailed information about lime-based plasters.

• **Gypsum-based plasters** are used exclusively on interior surfaces because they are subject to deterioration if exposed to water. The naturally occurring mineral called gypsum is hydrous calcium sulfate (i.e., there are attached water molecules). When this form of gypsum is heated (i.e., calcined), most of this water is driven off. The entire process of creating calcined gypsum gives it an embodied energy that is only about one-third that of cement.

When calcined gypsum is mixed with water, it recombines with it, changing chemically and reverting quickly to its hard, crystalline form. We are most familiar with it as the primary ingredient in quick setting "plaster of Paris". When mixed with additives that delay the rate at which it hardens, it can be a useful binder for interior plasters.

Gypsum is usually purchased with the retardants already added. To increase the hardness of finish coat mixes, lime is often included as an additive. Helpful information about commercially available gypsum-based products is often available from the manufacturers (e.g., U. S. Gypsum). Also, check the bag that a product comes in for instructions regarding its proper use. If you want to create relatively hard, extremely smooth interior surfaces, gypsum plasters are the way to go. Be advised, however, that because they generally harden (i.e., set) quickly and require skillful trowel work, you may want to practice in closets, or the like, before tackling more visible surfaces.

• **Clay-based (a.k.a. earthen, adobe, mud) plasters** depend on very small, disc-shaped clay particles, present in many soils, to bind together the larger silt- and sand-sized particles. Particularly in drier regions, they have been used to surface both the interior and exterior of straw-bale buildings. The "binding" properties of clay result not from any chemical reaction with water, but from the adhesion of the platelike clay particles to each other during the drying process that hardens the plaster. Liquid water, when placed in contact with dry, clay-based plaster, is drawn back into the spaces between the platelets of clay, softening the plaster and making it subject to erosion.

The erodability of typical earthen plasters presents a problem in all but very dry climates, unless the walls are protected by large roof overhangs (which often function also as porches). Strategies for reducing the erodability usually involve adding various substances to the plaster itself. Some depend on their physical form, as in the case of chopped straw in mud plaster. To work most effectively, the plaster must be applied in strokes that end with the hand or tool moving horizontally. This leaves the short straws oriented horizontally in the plaster, such that they repeatedly interrupt the flow of water down the wall. Acting as miniature "check dams", they prevent the formation of concentrated rivulets and reduce the erosive power of the water (see Crocker, 1995).

Other additives depend on chemical properties. This include a wide variety of substances ranging from high-tech (e.g., soil stabilizing chemicals and enzymes) to mid-tech (e.g., emulsified asphalt) to low-tech (e.g., exterior grade glue, animal dung). They are usually distributed throughout the plaster, although some have been applied to the dried finish coat as a sealer.

Another minor problem experienced by people using clay-based plasters on interior surfaces is "dusting". This is the tendency for small particles to separate from the surface and fall to the floor, or to rub off on your tuxedo (too much champagne?). For details regarding erodability and dusting, see pages 113-114 and 116, respectively.

Given the above-mentioned problems, why would anyone want to use an earthen plaster? A partial list of reasons, ranging from ecological to esthetic, is provided below.

—The acquisition of clay-rich soils, unless done on a commercial basis, generally leaves scars that are small and (often) temporary. This is usually not true for the other binders.

—Earth plasters can have a very low price tag. Some lucky builders have been able to use the soil from their foundation excavation, perhaps with a little sand added, leaving no scar at all. Fortunately, for those not so lucky, soils with sufficient clay content to bind the plaster can generally be found within a reasonable distance. Even then, however, samples from a number of sources may have

to be experimented with before a satisfactory mix is developed (see page 113).

—Since earthen plasters are usually applied directly to the bales without the use of stucco netting or any substitute, an expensive, labor-intensive step is avoided.

—Mud plasters are more "user-friendly" than the alternatives. The application of mud plaster is easier, especially for the novice plasterer, since a good mix has both sufficient plasticity and excellent adherence to the bale surface. Cleanup of tools and mixing equipment, although more easily done when the residue is still wet, can be done long after an earthen plaster has dried and hardened. With gypsum- and cement-based plasters (and to a lesser extent with lime-based and asphalt-stabilized earthen plasters), one is well advised to do thorough cleanup prior to any pause long enough to allow the plaster to "set up". Since clay-based plasters, even if stabilized with asphalt emulsion, harden only as a result of drying, partially-used batches can be preserved indefinitely for future use simply by keeping the mix wet.

—When earthen plasters are applied without the use of woven wire netting for reinforcement, the integrity of the plaster depends on its attachment to the straw. As opposed to cement-based plaster, it cannot become a disconnected "curtain", hanging from the RBA and hiding water damage that may be taking place behind it. If not firmly attached to "healthy" straw, mud plaster is likely to soon end up on the ground. Not a pretty sight, but better to learn of problems earlier than later.

—And, speaking of pretty sights, it's hard to beat the look and feel of a softly irregular, subtly variegated, earth-plastered wall. Earth not only feels right as a covering for a material that emerged from the earth, but it also feels right to your fingers, or against your cheek—firm but not harsh, inanimate but not dead. MUD, GLORIOUS MUD!

Although our way of grouping the plasters may suggest that each can contain only one binder, many mixes contain several. Cement-based plasters usually also contain lime, which functions there not as a binder, but as an agent to make the wet mix stickier and easier to apply. Lime-based plasters often contain a small amount of cement as an additional, quick-to-harden binder. Although cement appears not to work well, generally, as an additional binder in earthen plasters, a small amount of lime seems to improve their strength (DESIGNER/builder 1996).

Photo by Judy Knox

Don't let a pig do your plastering!

Plasters at a Glance (a very subjective ranking)

Criteria / Property / Characteristic — Type of Plaster	Cement-based	Lime-based	Gypsum-based, Interior Use Only	Clay-based, Natural	Clay-based, Asphalt-stabilized
low embodied energy in binder	◪	◪	◪	■	■
chemically benign binder (non-caustic)	◪	⊞	◪	■	■
availability of binder or pre-packaged mix	■	■	■	⊞ to ■	⊞ to ■
workability (good cohesion and adhesion)	◪	◪	◪	■	■
likelihood of success on straw bales without reinforcement	◪	◪	◪	■	■
resistance to erosion by water	■	◪	◪	⊞	◪
rapid development of strength	◪	⊞	■	◪	◪
eventual hardness	■	◪	◪	◪	◪
breathability	◪	■	◪	◪	◪
low maintenance	◪	◪	■	⊞	◪
no moist curing needed	⊞	■	■	■	■
friendliness to novices, overall	◪	◪	◪	■	◪

■ = best, greatest ⊞ = worst, least

Air & Moisture Barriers

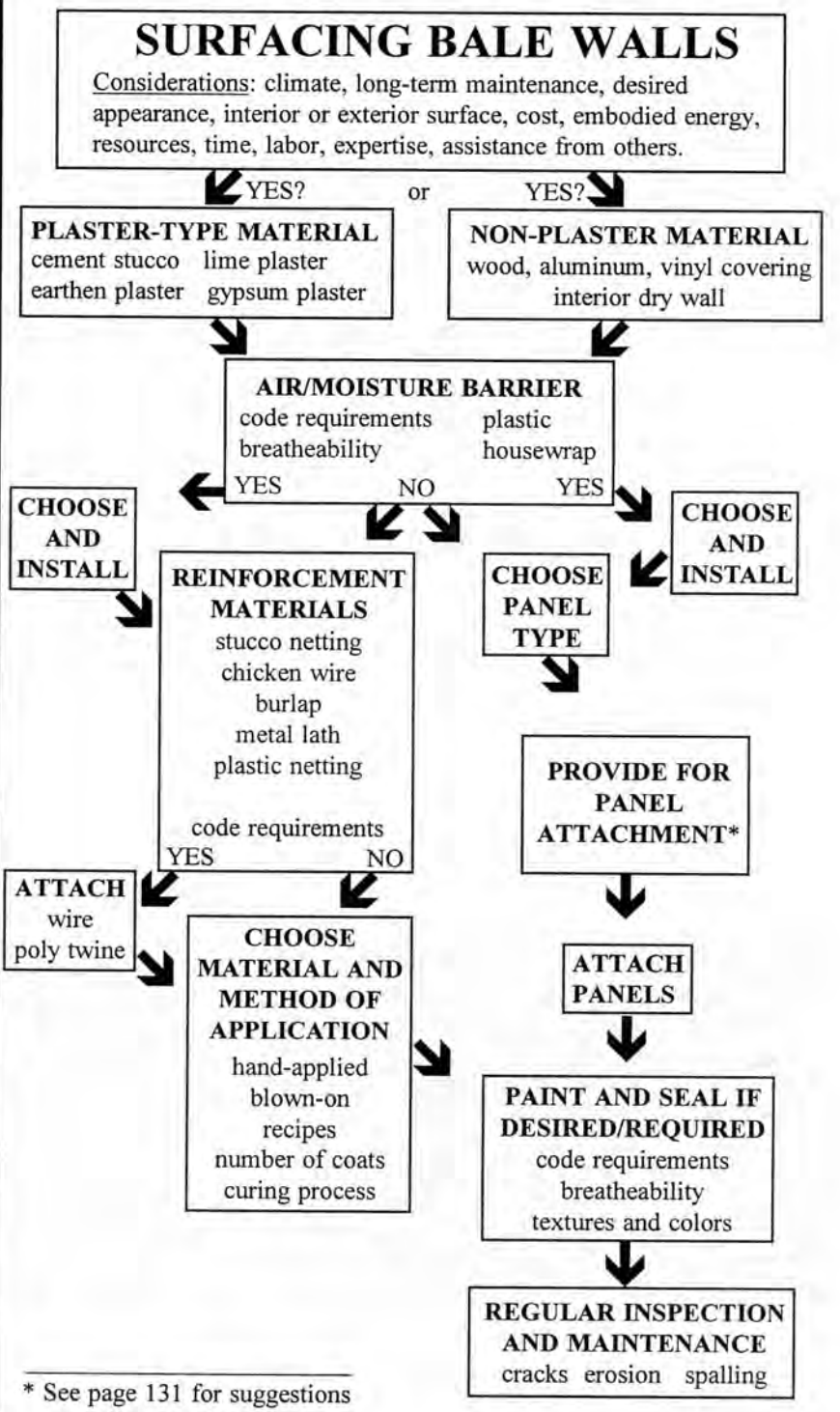
Purpose – to prevent the movement of air (and water vapor), and/or the diffusion of water vapor, and/or the passage of liquid water into the bale walls.

Common Barrier Materials – polyethylene plastic sheeting (barrier to air, water vapor, and water), vapor barrier paints (used as a barrier to water vapor), breathable "house wraps" (barrier to air and water).

Possible Placement – Depending on the strategy, barriers may be placed on the interior surface, on the exterior surface or, occasionally, on both. Breathable "housewraps" are generally used only on the outside surface, and generally only on the lowest courses.

Pros and Cons – Generally not recommended in temperate climates, since they prevent the plaster from "keying" into the roughness of the bales and reduce the wall's ability to "breath". In climates with simultaneous wind and rain or drifting snow, a curtain of "housewrap material" extending part way up the outside of the wall should be considered. In colder climates, air/vapor barriers may be needed on the interior surfaces to prevent water vapor from moving into the wall and condensing. Their use may dictate using a mechanical air exchanger to maintain acceptable indoor air quality. See Gibson (1994) and Lstiburek and Carmody (1993) for more detail.

Flow Chart for Wall-Surfacing Decision-Making



* See page 131 for suggestions regarding panel attachment.

Reinforcement for Plaster

Purpose—It helps to hold the "scratch" coat in place, reduce cracking, tie down the roof plate, sandwich the walls for increased resistance to dislocation by seismic forces, and satisfy code requirements.

Types—The most common types are 1" [2.5 cm] poultry netting, stucco netting (heavier wire than in chicken netting), and galvanized expanded metal lath (a.k.a. diamond lath). Plastic mesh or natural fabic/netting may provide an alternative for those reluctant to use metal netting. In a number of buildings, lime/sand plaster has been applied onto burlap fabric previously attached to the bales and to door and window frames.

Pros and Cons - Many builders use expanded metal lath: 1) where plaster butts up against or covers roofing felt, metal or wood; 2) where interior and exterior wall surfaces curve in at door and window openings; 3) on all outside wall corners.

Covering both surfaces of the bale walls with netting of any kind has considerable costs in time, labor, money and resources. If you plan to use reinforcement in your plaster, build adequate time into the work schedule for the labor-intensive process of attaching it to the walls. If you believe that interference with Earth's natural electromagnetic fields can adversely affect human health, add that as an additional cost of using wire netting (see Pinsky 1995).

You will have to decide, in your particular situation just how much "insurance" you want, and how much you're willing to pay for it. Both cement- and clay-based plasters have been used successfully on bale walls without the benefit of reinforcement. The track record, however, is still being established. The likelihood of success without reinforcement will be enhanced if the plaster is applied to the "cut" edge of the bales, rather than the "folded" edge. Since bales come with one of each, some builders have used a chainsaw to trim about a half inch [1.25 cm] off the folded edge of each bale before stacking them, thus creating bales with two cut edges. Other builders have settled for stacking the bales such that every other bale in each course has the cut edge exposed.

Photo by Hesh Fisk

The Little Taj (a.k.a. Mom's Place) ready for plastering. Note expanded metal lath at corner and black paper over wood and metal.

Photo by Hesh Fisk

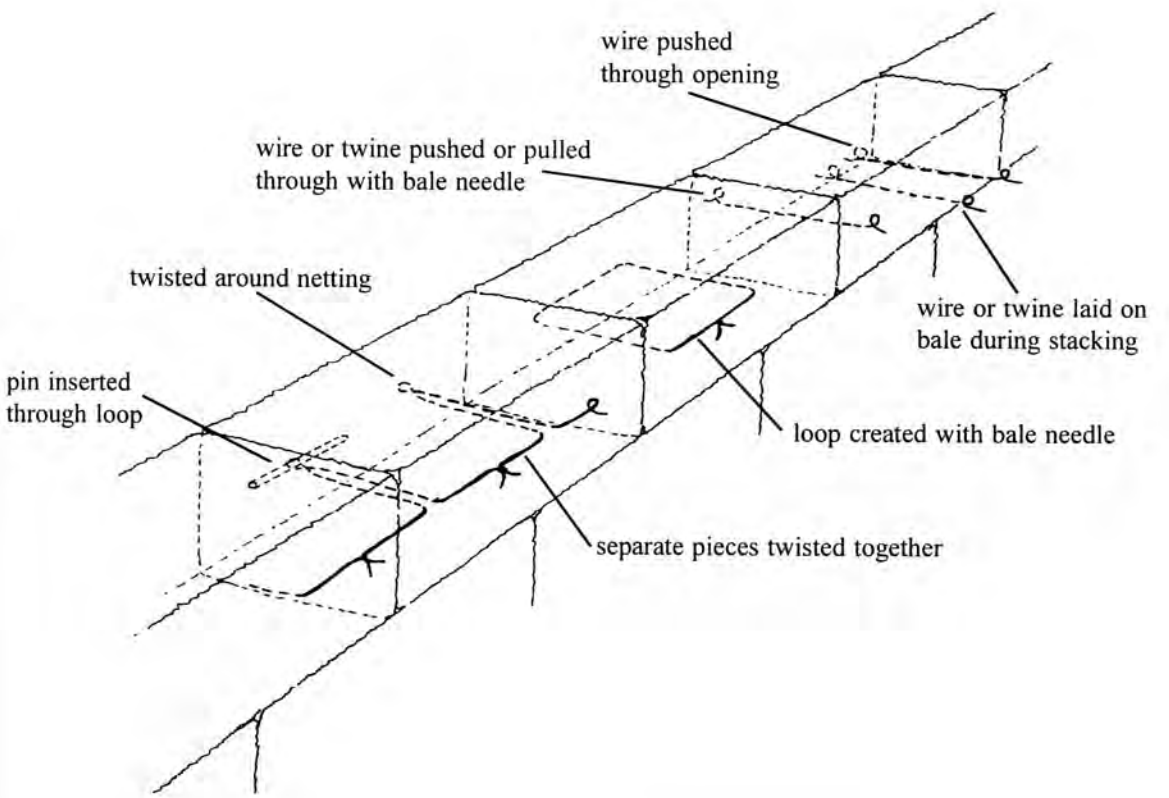
Note 2" x 4" ledgers for hanging cabinets, and seat built into load bearing window frame. Angled opening created with carpentry.

Attaching the Plaster Reinforcement

Polypropylene baling twine has occasionally been used for through-ties. However, galvanized wire is much more commonly used, with 16 gauge [1.59 mm] being typical. A good alternative is the slightly lighter, 17 gauge [1.37 mm] wire used on electric fences. It comes wound on metal spools that can be belt-mounted for convenient dispensing.

In situations where there will be periodic inspections by a building official, you may be required to use some specific type of reinforcement netting (or mesh), and may have to attach it in very specific ways. Some options for attaching stucco netting with through-ties are shown below. Do your homework so that you get it "right" the first time. If you are building "without benefit" of inspections, and the structure is small and the likelihood of earthquakes is even smaller, you do have the option of dispensing with the through-ties altogether. Again, what level of "insurance" are you comfortable with?

Some Options for Through-Ties



Plasters 201 — (some of) The Details

This section contains, for each of our four binders, selected information on "recipes", mixing, application, curing/drying, decorating and, where appropriate, sealing. Please note that for each type of plaster, as with potato salad, every veteran practitioner has their favorite recipe. Many differ only slightly from each other, and produce results so similar that even their "owners" can't tell them apart. We have gathered together, from sources ranging from hard bound to hide-bound, a collection that we hope is generally representative of what people are actually using. For additional options, more specialized or exotic, consult Issue 9 of *The Last Straw*, *Plastering Skills* (Van Den Branden and Hartsell 1984), *The Earthbuilder's Encyclopedia* (Tibbets 1989), *Earth Construction* (Houlen and Guillard 1994), *The Straw Bale House Book* (Steen et al. 1994), and *Earthen and Lime Plasters* (Steen and Steen 1997a).

As usual, we welcome your suggestions for "recipes" you think should be included in the next (Goddess forbid!) version of this opus. All of our recipes use "parts by volume" unless otherwise indicated.

Cement-Based Plasters

Recipes

The Old Standby

This mix can be used for all three coats:

- 1 part cement
- 1 part lime, Type S (if available).
- 5 to 8 parts clean plaster sand (a mix with five parts sand will—arguably—be harder, more expensive per unit volume, and less breathable)

Pumper Mix

This is a recipe regularly used on straw-bale walls by Tucson-based Hansen Kramer Stuccoing, Inc. They mix in large batches and blow the plaster on with a "stucco pump". The bags of cement they use weigh 94 pounds [42.7 kilos]; those of lime weigh 50 pounds [22.7 kilos]; those of silica sand weigh 100 pounds [45.5 kilos].

Scratch Coat

- 2 bags of cement
- 1 bag of lime
- 40 square-end shovels of screened clean, sand

Brown Coat

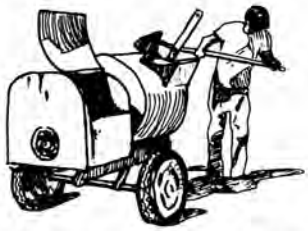
- 2 bags cement
- 1 bag lime
- 40 rounded shovels of screened, clean sand

Finish Coat

- 1 bag cement
- 2 bags lime
- 40 rounded shovels of screened clean sand (use finer silica sand for a smoother finish)

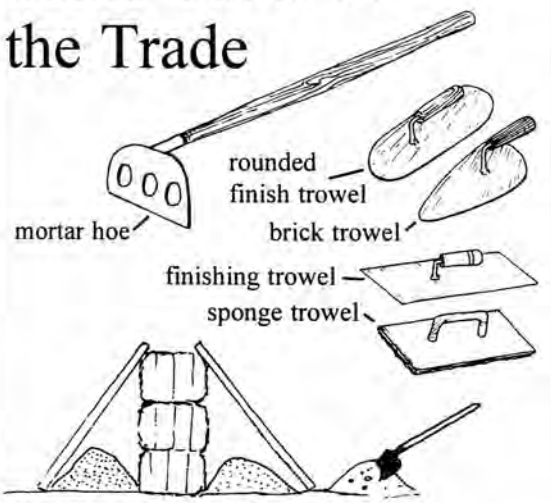
Mixing

Cement-based plasters can be successfully mixed either by hand or by machine. Hand



gasoline-powered plaster mixer

Some Tools of the Trade



Poor Man's Sifter Set-up
fine screens attached to old bed frames, leaning on stack of straw bales

mixing is usually done in a wheelbarrow or in a mixing tub/trough, store-bought or homemade. A mortar hoe (see figure above) will greatly speed up the process of thoroughly mixing all the dry ingredients until a uniform color is achieved. Only then is water added until the desired degree of stiffness/looseness is achieved.

A recommended sequence of steps for effective hand-mixing is as follows:

1) Position about half of the sand near one end of the mixing container.

2) Onto this sand, put all of the cement and lime.

3) Cover the cement and lime with the remaining sand.

4) Add any dry admixture(s) (e.g., fibers).

5) Using a mortar hoe, "chop" and pull the dry materials toward the empty end of the container. Repeat this process, switching ends as needed, until the mix acquires a uniform color.

6) With the homogeneous dry mix at one end, add some of the required water to the empty end.

7) Chop the dry mix into the water, adding more water as needed, until the desired degree of workability has been acheived.

As you approach the desired consistency, (which we could easily show you on a job site, but can't usefully describe in words), very small amounts of additional water cause great reductions in the stiffness. Toward the end, go really slowly! Too little water in the mix may result in an incomplete curing (and reduced strength) and will make it difficult to key the plaster into the roughness of the bales or the scratch coat. Too much water will make the plaster difficult to scoop up and apply with a trowel, reduce the strength of the cured plaster, and increase shrinkage (and cracking). Have a veteran show you what a "good mix" looks and acts like, then try some plastering with their mix to really get a feel for it.

Mixing by machine can make the job a whole lot easier. Concrete mixers, powered either by gasoline or electricity, can do a decent job of mixing your plaster, but a plaster (a.k.a. mortar) mixer can do better, larger batches in less time. When a batch is ready, it is usually dumped into wheelbarrows for transfer to the scene of the action. Whichever type of mixer you use, there is a preferred sequence for adding your materials:

1) Add about 90% of the required water (determined by prior experimentation).

2) Add about 50% of the required sand.

3) Add all of the lime (if any), then all of the cement, then any dry admixtures (e.g., color pigments) or fibers.

4) Add the remaining sand.

5) Mix, adding the remaining water only as needed, until the batch is uniform in color and of the desired consistency.

Cement is formulated to provide adequate time for placement and necessary manipulation of the plaster before it begins to harden. If you mix too big a batch, however, it may begin to harden while still in the wheelbarrow. The hardening process, in this case, cannot be interrupted by covering the mix with plastic sheeting or be reversed by adding more water. Get the stuff out of the wheelbarrow and off your tools, and make a note to adjust the size of the batch to the rate at which it can be applied with the available equipment and work force.

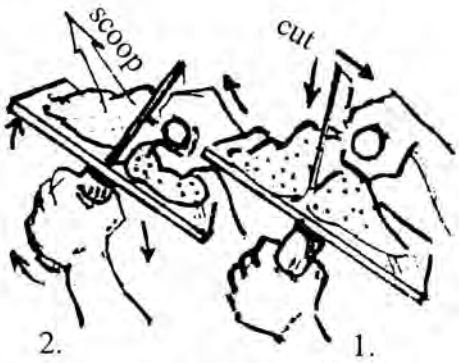
Application

Cement-based plasters are applied either by hand or with aid of some sort of mechanical equipment, either human-powered or otherwise. The only performance advantage that machine applied plaster may have over the hand applied version, is that the scratch coat will probably be more fully keyed into the roughness of the bale-wall surface. Some owner-builder's have the first coat blown on by a plastering contractor, letting them do the heavy work and getting the wall protected quickly. Then, at their own pace, they (and friends!) can do the other coat(s).

Hand application, especially for the scratch coat, could mean just that—a human hand in a rubber glove. Most novice plasterers can exert much more pressure, to push plaster into the roughness of the bale surface with the heel of their hand than with a trowel. And, for them, it may be just as fast. **However, be sure that all the cut ends of wires are tucked away where they cannot jab the unsuspecting plasterer.**

The traditional system, however, involves the use of a **"mortarboard", a "hawk" and a trowel** (see diagram to the left). The plaster is first shoveled onto the "mortarboard", a flat piece of water-saturated or nonabsorbent material placed near the plasterer (often elevated to facilitate use of the trowel to transfer plaster from it to the "hawk"). With several trowel-loads of plaster now on the "hawk", the next step involves getting some plaster onto the trowel, and then onto the wall (see diagram to the left). In the Portland Cement Association's excellent publication (Melander and Isberner,1996), they make the process sound very easy. We quote, "After transferring some of the plaster from the hawk to the trowel, the plasterer lays the plaster on the surface." For a novice, the reality is more likely to be, "While attempting, with an awkward tool called a trowel, to pick up some of the plaster from the demoniacally heavy, plaster-loaded hawk, the frustrated plasterer lays most of the plaster on his or her feet,

Cutting From a Hawk



"It's tricky. You'll drop a lot before you learn. The secret is a certain twist of the hand and wrist, while tilting the hawk with a little motion...The motion of plastering is more like a sweep or arc, while using a pressure...Keep the hawk about one foot from the wall. It will be hard to keep plaster from falling off the hawk at first. Practice makes perfect!" (from Tibbets 1989, page 63)

before laying the flat surface of the trowel up alongside the head of the first person who laughs." In the spirit of "ignorance is the father of invention", the senior author of this guide taught himself how to use a hawk without benefit of knowing how one was supposed to do it. And he unashamedly continues to use his "cheater" method to this day. It's simple. Standing on a ladder or scaffolding, and starting about 16 inches [40 cm] down from the top of the wall, press the further edge of the hawk against the wall. Using the trowel, cut away a slice of plaster from the further edge of the pile. Now, smear this material onto the wall with a graceful upward stroke of the trowel, continuing to press the edge of the hawk against the wall. Any plaster that doesn't stick to the bales will, miraculously, fall back onto the hawk for re-application. Resist the temptation to repeat the stroke with an "empty" trowel, as this will tend to weaken the bond of the wet plaster to the straw. However, you can repeat the "slice and smear" sequence, as necessary, to build up the desired thickness and to leave the reinforcement netting embedded in the plaster. Now, reposition the hawk to either side of your first stroke and repeat the process. As appropriate, drop down about 16 inches, or whatever you have now discovered is comfortable, and repeat the process. They may still laugh at your unprofessional style, but your shoes will probably be a lot cleaner than theirs will.

We were recently shown another novice-friendly technique by the lads at Bowerbird Construction, Dripping Springs, Texas. Their system avoids having to support the weight of several trowel-loads of plaster on the hawk, by dispensing with it. They use the side of a large pointed brick trowel to pick up and transfer plaster directly from the mortarboard, or wheelbarrow, to the trowel. You know the rest.

Hand application is hard work, even for the pros, but "many hands can make lighter work". This is the time to call in your debts, to invite the participation of anyone who could conceivably be made to feel that they owed you a favor. Remind distant relatives of the importance of blood ties. Do whatever it takes to get a lot of help, at least with the scratch coat (the thickest of the three), or plan to be there a long time, painfully developing muscles that are good for little else.

Turning our focus now to **machine application**, we find a wide range of possibilities. The simplest is a hand-powered, hand-held, **"rough-casting" device** available, that we know of, in Mexico and in Europe. By turning a side-mounted handle, one splatters plaster onto the wall. The process leaves a rough surface that reputedly works well for a "scratch" coat. For more information, see *The Last Straw*, Issue 10, page 33, and Issue 11, page 34. Moving toward higher tech, there's the **hopper gun** used to blow texturing mixtures onto drywall. These consist of a pyramidal, plastic hopper to which is attached, at the bottom, a metal pistol grip and trigger, to which, in turn, is attached the hose from an air compressor. The plaster mix, which must be just thick enough so that the sand doesn't sink quickly to the bottom, is poured into the hopper. When the trigger is pulled, compressed air passes through the gun while at the same time an orifice is opened at the base of the hopper, allowing the soupy plaster to fall into the air stream and be blown out of the nozzle onto the wall. Before any pause of more than a couple of minutes, the hopper must be cleaned and the gun flushed out with water. Although this equipment produces

good penetration, it takes a long time to get a significant layer built up. For maximum efficiency, there needs to be one person mixing, one pouring, and one spraying. This method is probably suited only for the scratch coat, where the excellent penetration is an obvious plus. A homemade, larger capacity version of the hopper gun technology is described in *The Last Straw,* Issue 13, page 14. A one-page set of detailed instructions can be obtained by sending a self-addressed, stamped envelope to *The Last Straw*, P.O. Box 42000, Tucson, AZ. 85733-2000.

Moving up to the semi-professional level, you could get yourself a **mini-pumper** such as the "Carrousel Pump", and the associated spraying equipment, made by Quikspray, Inc. of Port Clinton, Ohio, (419-732-2011). Although not capable of putting out as much volume as a full-size stucco pump, this system is safer, more easily portable, and much less expensive. We anticipate that regional straw-bale cooperatives or associations may soon be buying mini-pumpers for use by their members.

Which brings us to the "big toys for big boys", professional **stucco pump** level. They are big, expensive, dangerous to operate and can't be rented, but in the right hands can put a lot of plaster in place in a very short time. If you want good penetration, make sure that your plastering contractor has a rig that ejects the mix from the nozzle at high velocity. Not all pumps are created equal.

Finally, a few straw-bale buildings and privacy walls have been surfaced by professionals using a **"gunite pump"**, which mixes the dry materials (usually a fine-aggregate concrete mix) with water, right at the nozzle. The resulting material can be drier than that blown on with an ordinary stucco pump. This may make it possible to apply the base coat in a single layer, while still not getting an unacceptable amount of cracking.

As a part of "application", whether by hand or machine, decisions must be made about how to finish each successive layer. As the "scratch" coat begins to set up, horizontal scratches should be made in the surface to provide grooves for the "brown" coat to key into. As for the "brown" coat itself, the astute plasterer waits until the plaster has lost sufficient moisture so that the surface sheen has disappeared, but not so long that the plaster has become rigid. A type of trowel called a "float" is used to create a relatively even, open-textured surface. **Floating is considered by some to be the most important part of plastering**, since the consolidation that occurs during floating influences the shrinkage/cracking characteristics of the plaster.

Curing

Decisions must also be made about how quickly each of the first two coats should be followed by the next, and what should be done to ensure that each of the three coats "cures" properly to achieve maximum strength.

Modern practice dictates that the "brown" coat should be applied as soon as the "scratch" is sufficiently rigid to withstand the pressure needed to apply the "brown" without cracking. During this time, the "scratch" coat should be misted periodically to keep the surface damp. The spacing between mistings will be need to reflect the climate and the solar orientation of the wall. In extremely hot, dry, windy situations, it may be worth your trouble to cover the moistened, plaster surfaces with a plastic sheeting.

The "brown" coat should undergo moist curing for three days or more before the

"finish" coat is applied to the moist, but still absorptive, surface. The moisture in the pre-dampened "brown" coat plus the water in the finish plaster itself will be enough to provide for the curing of this thin coat. To prevent variations in the color of this coat, do not apply any water to the finished surface until it has completely hardened.

An alternative to the sequence described above is called "scratch and back". Seattle's own straw-builder/architect, Ted Butchart, recommends this technique for owner-builders who want to use the "stucco party" ploy to get as much of the plastering done as possible in one day. Isn't it strange how few volunteers can be convinced to come back several days later to put on the "brown" coat? Didn't they have fun?

Anyway, the technique involves doing a slightly thinner than normal unscratched first coat. As soon as this has set up enough to withstand normal troweling (i.e., well before it has fully cured), you come back over it with the second coat. With enough mixing capability, tools and volunteers, the two-part base coast is in place at the end of the day.

Decorating

We will use this term to include various techniques one might use to go beyond the smooth, "mortician gray" appearance of the typical "brown" coat, or an unpigmented "finish" coat. We highly recommend that you stack and plaster a freestanding section of wall to use for experiments. Explore various options on this test "canvas" before decorating the real walls.

For the "brown" coat, the most commonly used techniques fall into the following categories:

• Staining—Although technically feasible, using **commercial concrete stains** to color an entire building might be prohibitively expensive. There are, however, several **less expensive alternatives** that have been tried (e.g., copper compounds, ferrous sulfate, ferric nitrate). Ferrous sulfate, used normally as a turf greener on golf courses, can often be purchased at stores selling fertilizers and agricultural chemicals. A saturated solution of ferrous sulfate, minus the yellow precipitate that accumulates on the bottom of the container, is applied to the wall with a brush or roller. It provides a range of colors from an orangy, mustard yellow to a reddish-brown, depending on the number of coats applied. It can also be used to stain concrete slabs. Another chemical, ferric nitrate, provides similar, but perhaps more vibrant colors. Unfortunately, being a strong oxidant, it can only be legally shipped as a hazardous chemical. This makes it harder to find and generally more expensive.

• Painting—Since it requires considerable hand-troweling skill to get a uniformly colored "finish" coat, some builders choose to roll or brush on a coat of **colored cementitious "paint"**. In Washington state, it's called a "fog coat" or "brush coat", and can be purchased, as a dry mix, from suppliers of masonry products. The aforementioned Ted Butchart sent us this simple recipe for a home-brewed version: mix 1 part cement (white cement for lighter tones), 1 part lime, and masonry pigments (or natural oxides), until uniform in color. Measure the ingredients very carefully to ensure color consistency between successive batches. Then add the dry mix to water until a brushable or rollable consistency is reached The plaster surface to which it is applied should be misted such that it is damp but still slightly absorptive. Using a saturated solution of ferrous sulfate as the liquid base of Ted's

recipe might give nice results without additional pigments.

Also in the paint category, are **standard masonry paints** and the stretchy **elastomeric paints and coatings**. Depending on which one of these products is used, and how many coats are applied, you will lose some, or all, of the vapor permeability (breathability) that the plaster would otherwise have had. If you lose it all, no water, or water vapor, will be able to enter the plaster from the outside, an arguable plus. On the down side, no water, or water vapor, that finds its way into the plaster or the bale walls by whatever route, can escape to the outside through the paint layer. Most builders consider this a minus, and perhaps a serious one, especially in cold climates. Proceed with caution!

• Texturing/Sculpting—Textural modification of the "brown" coat itself is seldom seen in the U.S.A., except as an accent feature (e.g., around door and window openings). However, we have seen photos of a Nebraska Sandhills hay-bale house whose plaster was "tooled" to create the appearance of shaped, stone blocks. For accents, possibilities abound. For example, pulling a tool along to create grooves, pressing a "stamp" into the plaster to create repeated patterns., or sculpting to remove and/or add material.

• Accenting with Tiles—Although tiles can be incorporated into the "brown" coat, they are more commonly attached to the cured surface with special adhesives. The right angle formed by the edge of the tiles and the plaster surface is often filled in with some additional plaster, once the adhesive is fully set. If a "finish" coat is to be used, it can be thickened slightly around the tiles, leaving them flush with the final surface.

• Using a Colorant in the "Finish" Coat—This is the most common way to end up with colored walls when using cement-based plaster. Dry mixes can be purchased which already include the pigment(s), or these can be purchased separately and added during the mixing process. To avoid color variations between successive batches, great care must be taken not to vary the amounts of any of the ingredients, including the colorant.

• Modifying an Uncolored "Finish" Coat—Any of the methods described above for staining or painting the "brown" coat can also be used to modify an uncolored "finish" coat. Since this coat is relatively thin, white cement might be used instead of the more economical, gray Portland cement, in order to create a lighter-colored base for a stain or color wash.

Sealing

If rainfall will be repeatedly striking your walls, especially when propelled by high winds, you may want to consider sealing at least the lower portion of your walls with a product that will leave them water-repellent but still breathable. An obvious alternative, i.e.,covering the same part of the walls with a breathable housewrap, should serve the same purpose, but will prevent the plaster applied in those areas from keying into the roughness of the bale walls. Sealers intended for surface application are available from several manufacturers. Among them are Hill Brothers Chemical (Orange, CA, 714-998-8800), the Sinak Corporation (San Diego, CA, 619-231-1771), and El Rey Stucco Co. (505-873-1180).

Lime-Based Plasters

Recipes

Lime Putty Recipe

A lime putty is made by adding hydrated lime (type N or S) to an appropriate volume of water and leaving it undisturbed for at least 24 hours (the longer the better) while it develops "plasticity." Sifting the lime into the water through a window screen will break up any lumps in the dry material and prevent the formation of lumps that may form if the lime is simply dumped directly into the water. Before removing the putty for use in a plaster mix, it is convenient to remove most of the excess water, leaving enough, however, to always keep the top of the putty layer submerged. Steen et al (1994) suggest mixing five, 50 lb [22.7 kilos] bags of Type-N lime with water in a 55 gallon [208 liter] drum. If a good putty requires about seven gallons of water for each 50 lb bag of lime, as indicated by Van Den Branden and Hartsell (1984), you'll want about 35 gallons (160 liters) of water (i.e., a drum that is about two-thirds full).

Lime/Sand Mixes

Historically, lime-based plasters usually consisted of nothing but lime and sand. These plasters are slow to harden and slow to develop maximum strength. Typical mixes contained:

- one part lime putty,
- and, 3 to 4 parts clean plaster sand.

Lime/Sand Plaster with Cement as a Hardener

Because the traditional lime/sand plasters are slow to develop strength and hardness and often develop cracks, modern users often add a small percentage of Keene's cement (a type of gypsum) or Portland cement to provide greater initial strength and hardness. This approach was recently used on a two-story, timber-framed home in Vermont. Based on advice from the innovative folks at ARCHIBIO, in Quebec, the owner-builders (David Shaw and Juliet Cuming of Earth Sweet Home, W. Dumerston, VT) used this general recipe:

- 1 part of "lime/cement blend"
- 3 parts sand

In the first coat, which also contained chopped straw, the cement constituted 25% of the "blend", dropping to about 15% in the second coat and 5% in the final coat. They applied the plaster directly to the bales, using only burlap fabric as reinforcement around door and window openings.

Lime/Sand Plaster with Cactus Mucilage as a Stabilizer

The mucilagenous juice obtained by soaking the chopped up stems of cholla cactus or the chopped-up pads (*nopales*) of prickly pear cactus is traditionally used in Mexico to increase the durability of lime-based plasters. An article from *DESIGNER/builder* magazine (October 1994) describes how a master plasterer from Mexico, Pedro Sanchez, has used this plaster to protect historic adobe churches in New Mexico. He starts the process by soaking an unspecified amount of cholla stems for about six weeks in a covered, sun-warmed, 55-gallon [208 liter] drum filled with water. He then mixes together:

- 100 pounds [45.4 kilos] of lime (the article specifies type N),
- 50 shovels (probably round-nosed) of a coarse sand found locally in a dry streambed,
- and, 10 gallons [about 37.8 liters] of the gooey "cactus water".

The traditional three coats were then applied to the adobe walls, an approach that

should also work directly over bales.

Mixing and Application

These plasters can be mixed either by hand or by machine. In Great Britain, they have traditionally been hand-mixed and then pounded with the end of a tool that resembles a baseball bat. The later process insures that all the sand grains become coated with wet lime. They are typically troweled on by hand, although use has been made of the previously mentioned, hand-powered, "rough-casting" device (see page 106).

As with cement-based plasters, the first coat should be scratched before it becomes too hard. When the "scratch" coat has set, the "brown" coat can be applied onto a slightly dampened surface. Unless compacted it will often crack as the putty shrinks. This is normally done a day after the coat has been applied, with a wooden float (trowel). Some oldtimers would drive a nail through the float, such that the point was barely exposed on the face, so that shallow scratches would be left to enhance the adhesion of the third coat.

The "finish" coat can be compacted either by troweling with a steel trowel, for a smoother finish, or by floating with a sponge float, for a grainy finish.

Curing

Since lime-based plasters cure and harden through contact with the atmosphere, they should be allowed to dry and set up between coats.

Decorating

Many of the techniques for decoration mentioned in the detailed discussion of cement-based plasters can be adapted for use with lime-based plasters, keeping in mind that the latter often have less cohesion. Only limeproof mineral pigments should be used as an admixture for the "finish" coat mix or to color a limewash. A colored limewash used over lime-based plaster by the above-mentioned Pedro Sanchez, consisted of 2 sacks of lime (presumably 50 lb [22.7 kg] bags of Type N) and a 1 lb [0.45 kg] bag of cement-and-mortar colorant. It was applied with a compressor-driven sprayer.

Gypsum-Based Plasters

(Non-)Recipes

Without set-retarding additives, gypsum hardens too quickly to allow for proper finishing. This makes it inconvenient and inefficient to create one's own gypsum plasters from "scratch", especially since time-tested, pre-mixed products are available. It can take considerable practice to acquire the skill needed to get the smooth, flawless surfaces that these products can produce. Start in places where your initial attempts will be least visible.

John Woodin, a respected straw-bale builder from Tucson, has developed a novice-friendly system for using a dual-purpose gypsum plaster for all three coats. The specific product he uses is called Double Duty Hardwall (James Hardy Co.). After installing expanded metal lath and stucco netting, as if for cement-based plaster, he applies a "scratch" coat mixed at a ratio of one bag of Double Duty, weighing 100 lbs [45.4 kilos] to 30 shovels of plaster sand. As soon as this sets, the same mix is used for the second coat. When this has fully cured, a final coat consisting of one bag of Double Duty plus

one bag of 30-mesh silica sand, weighing 100 lbs [45.4 kilos], is troweled onto a slightly dampened surface. Pigment for coloring can be added to this coat. A brush is used to slightly moisten successive areas which are then brought to a smooth finish with a metal trowel.

A two-coat system for application onto adobe walls is described in Tibbets (1989, page 63). It calls for a fibered gypsum mix for the first coat, and an unfibered mix for the second one. For straw-bale walls, one might get good results by first doing an earthen plaster "scratch" coat. This would serve as a base for the two coats of gypsum applied, for example, as described in Servais (1986).

Mixing and Application

Again, mixing can be either by hand or machine, although certain types of finish mixes are traditionally mixed only on a mortarboard. On a residential scale, these plasters are usually applied by hand, although the first two coats are occasionally blown on.

Curing

Since the water that is needed to create a workable consistency is adequate to rehydrate the gypsum, these plasters do not require moist curing as do cement-based plasters. They must, however, be protected from drafts that dry the surface before rehydration is complete. If conditions are hot and windy, you may need to close all doors and windows, or tape cloth or plastic sheeting over their openings.

Decorating

Many of the techniques already described can also be adapted for use with gypsum-based plasters, taking into consideration their tendency to set comparatively rapidly. They are particularly suitable for raised relief sculpting and for treatment with "color washes". These usually consist of one part latex paint diluted with about 5 to 10 parts water. They can be applied in various ways (e.g., brush, mister, sponge, wadded cloth), singly or in combinations, and in one or more layers (see Innes 1992). Experiment on test panels until you get an effect you like, then start on your real walls.

Clay-Based Plasters

(Non-)Recipes

Soils can differ greatly in the amount and type of clay that they contain. For this reason, any specific recipe, whether from a book or from a friend, must be considered suspect, unless you will be using exactly the same materials as were used by the person that developed the recipe. For the same reason, we have chosen to risk your wrath by providing not formulas, but rather a brief guide for creating your own, by systematically experimenting with locally available materials.

Start experimenting early enough, so that you'll have the recipe worked out before the walls are ready to plaster. Your final soil mixture will probably end being about 65 to 80% sand and small pebbles, and 20 to 35% fine material (about half of which should be clay). As a general rule, too high a clay content will cause cracking as the plaster dries, while too little will result in an unacceptably weak final product. In practice, it is generally easier and less expensive to

find and adjust a soil that has too much clay, than to "fix" one that has too little.

A quick method for estimating the clay content of a soil is described in Tibbets (1989, page 48). Another, the so-called "jar test", which gives an idea of the ratio of sand to silt to clay in a soil sample, is described on page 110 of the same source.

A more direct way to assess the plaster-potential of a soil is described below:

• Put your soil sample through a 1/4 inch [about 6 mm] screen to remove twigs, cigar butts, larger pebbles, etc. Mix about a quart [about 1 liter] of this screened soil sample with water.

• Adjust the ratio of soil to water to create a material that can be "smeared" on the side of a bale, with either your hand or a trowel. Create a patch about a foot square [30 by 30 cm], with a thickness of about a half inch [1.25 cm]. If the material won't stay on or doesn't have enough cohesion to maintain itself in a layer of this thickness, it has too little clay. You can chose to add various amounts of clay (either found or purchased) to this soil, but unless this is your last, best hope, eliminate this one and start again with a soil sample from a different location.

• If the material does meet the above requirements, allow the test patch to dry completely and then examine the results. Start by breaking off a chunk from one edge. If it breaks easily and the chunk crushes easily when squeezed between a thumb and forefinger, the clay content is too low. As above, consider eliminating it, at least temporarily.

• Let us assume that the patch offers adequate resistance to breaking and crushing (what degree of resistance is "adequate", only you can decide). Examine the surface for cracking. The spacing and depth of the cracks will suggest how much sand (or sand and straw) must be added. If the cracking is minimal and shallow, try three test mixtures ranging from 1 part soil with 1/2 part sand, to 1 part soil with 1-1/2 parts sand. If the cracking is closely spaced and/or deep, try three mixtures bracketing 1 part soil with 4 parts sand. If the cracking is moderate, try three samples bracketing 1 part soil with 2-1/2 parts sand. You get the idea, eh?

Finding the "ideal" soil mixture often requires considerable trial and error, but it's worth the effort. When water is added to it, the result is a plaster that applies easily and sticks well to straw (has good adhesion) and to itself (has good cohesion). The final result will be a multi-layer coating that is strong, durable, and free from cracks.

Stabilizing

A bewildering array of compounds, both natural and synthetic, have been added to earthen plasters (with varying degrees of success) to reduce their erodability (i.e., increase their resistance to rain that hits and runs down the wall [see Tibbets 1989, pages 80-83]). The purpose of these "stabilizers" is to keep the surface from absorbing water and again becoming "mud", which is easily washed away. The characteristics of an ideal stabilizer would include that it be:

• inexpensive, if not free;

• non-toxic, easy and safe to use;

• low in embodied energy;

• made from something other than petroleum;

• able to "waterproof" the surface without diminishing its vapor permeability (a.k.a. breathability);

• water soluble initially, but insoluble after the plaster has dried.

• natural, rather than synthetic, and usable without extensive processing;

• free from negative effects on the color and appearance of the plaster;
• resistant to solar radiation;
• effective with a wide range of soil types;
• and, regionally available, worldwide.

So there's the challenge. Come up with a stabilizer that meets even most of these criteria and the Nobel Prize for chemistry, or naturalchemy, is yours. In the meantime, the options aren't great. Until something better is found, the most commonly used stabilizer, at least in the overdeveloped world, will be emulsified asphalt (e.g., Chevron CSS-1). Be advised that the asphalt will darken the plaster slightly, chilling the warm earth tones a little. For many sand/soil mixes, the amount of emulsion needed falls in the range of from 3% to 5.5% of the weight of the dry mix. Going higher than 6% can significantly weaken the plaster. Knowing that these emulsions weigh about 8.3 pounds per gallon [1 kg per liter], will enable you to convert from weight required to volume required.

Adobe bricks are considered fully stabilized when they absorb no more than 2.5% of their initial dry weight when they sit on a water-saturated-surface for 7 days. A method for finding the minimum percentage of emulsion needed to achieve this degree of stabilization in bricks is described in Tibbets (1989, page 120). With minor adaptations, it can be used to test plaster samples as well.

A less rigorous approach involves adopting a procedure used successfully by someone else, in hopes that it will also work with your soil. You might try this one, adapted from pages 81 and 82 of the above-mentioned source:

• Use the trial-and-error process described earlier to develop a "proper" mix of clay-rich soil and sand.

• Determine, by experimentation, the amount of water needed to bring 7 shovels of the soil/sand mix to the proper consistency for plastering.

• Multiply this quantity of water by 10 to determine the correct amount for 70 shovels.

• To a plaster mixer (a real labor-saver that can often be rented), add 3/4 of the amount of water as determined immediately above, then add 2-1/2 gallons [9.5 liters] of emulsified asphalt.

• Now add 70 shovels of your mix, or the correct number of shovelfuls of sand and soil that maintain the proper ratio of sand to soil and that add up to 70.

• While continuing to mix, add water in small amounts until the desired consistency is reached.

• Test the "recipe" for erodability by spraying water on dry test patches using a garden hose and pistol-grip nozzle. Spray a patch of unstabilized plaster for comparison.

Clark Sanders of E. Meredith, NY, a veteran of three, owner-built, bale structures, has experimented with linseed oil as a stabilizer. His recipe involved 20 shovels of an earthen plaster mix, 5 gallons [about 19 liters] of chopped straw, 1 quart [about 1 liter] of boiled linseed oil, and water. Test panels were done with the recipe shown above, with this recipe minus the oil, and with this recipe minus both the oil and the straw. Testing indicates that both the oil and the straw help decrease the erodability of plaster and that the straw also helps to reduce cracking. He has concerns, however, about the degree to which the oil, in an amount sufficient to significantly reduce the erodability, will reduce the breathability.

Mixing and Application

Clay-based plasters can be mixed by hand or by machine. Although usually applied by

hand (with either the hand or a trowel), they are occasionally "blown" on, using pumpers adapted especially for this purpose. Variations of this product have been referred to as Ablobe™ and Gun-Earth™. The hopper gun described on page 106 has also been used to blow on a soupy, earthen plaster mix to create a thin, well-integrated "scratch" coat.

In common practice, each coat is allowed to dry completely. This allows any cracking to take place before the surface is dampened and covered with the next coat. The dampening is critical to ensure a good "mud to mud" bond. Any dried coat which contains emulsified asphalt as a stabilizer will not absorb water (and turn to "mud"), so some users prefer to stabilize only the "finish" coat.

Curing

Since earthen plasters harden by drying out, they need no moist curing. However, to reduce cracking of a thick coat, time the application so that it will stay shaded from direct sunlight as long as possible and dry more slowly.

Decorating

• Painting—Standard, water- and oil-based paints do not adhere well to earthen plasters. To provide a paint-friendly surface on interior mud plaster, author Steve has brushed on a thick, creamy mixture of drywall joint compound (a gypsum-based material). It adheres well to earth plaster and interior latex paints are compatible with it. Limewashes (see page 111) have traditionally been used in Mexico as a "paint" for adobe brick and mud-plastered surfaces.

• Texturing/Sculpting—Because of the good cohesion of earthen plasters, and because their "set" can be delayed simply by keeping them moist, they are ideal for this type of decorating. The addition of chopped straw to the plaster will enable more heavily built-up areas and projections to stay attached to the wall. Some practioners have pushed slivers of bamboo into the wall, forming a kind of "armature" onto which the straw-heavy plaster is applied when considerable overhangs are wanted. Photo-illustrated books on international earth architecture (especially that from Africa) provide wonderful inspiration for the builders ready to turn their mud-plastered walls into a riot of color and texture (see Courtney-Clarke 1990).

• Rubbing Pigments onto a Light-Colored Finish Coat—The cover story of Issue 9 of *The Last Straw* describes a technique used by Santa Fe owner-builder Mark Cherry to create some of the most beautiful wall surfaces that author Matts has ever seen. In a nutshell, when his finish coat of buff-colored mud plaster had dried enough to be firm, but was still damp, he used the palm of his hand to rub natural mineral oxides (e.g., red iron oxide) into the drying plaster. Following this up later with a hand applied coat of a Livos brand oil, he sealed the entire surface and then developed a slight sheen in certain areas by applying a second coat of oil. The results are enviable!

• Using a Clay "Slip" on the Finish Coat—For the uninitiated, "slip" might connote a mistake or a piece of lingerie, but for Carole Crews and other aficionados of this technique, it means a creamy suspension of clay and other ingredients in water. Carole's home-based business in Taos, NM, specializes in the enhancement of mud-plastered walls through the use of sculpting and of slips that smooth, seal and brighten/lighten the walls. For ingredients, her slips generally include:

• clay, either found locally or purchased from a supplier of pottery materials (e.g., white kaolin, especially good for making

light-colored slips);

- sand (always fine and generally light-colored);
- wheat paste, as a binder (homemade from flour [see below right], or purchased dry under the alias of wallpaper paste);
- and, fine particles of mica (KMG Minerals, Velarde, NM).

They may also include:

- a bit of chopped straw;
- larger flakes of mica;
- sodium silicate or powdered milk to keep the clay in suspension;
- pigments for coloration;
- and, in humid regions, borax in the wheat paste as a mold-preventer.

She mixes the ingredients in a large container, first filling it about 1/5 full with a thick, but pourable, water-based wheat paste. While stirring, water is then added until the pot is about 3/5 full. While continuing to stir, using a one-quart [one-liter] saucepan or coffee can as a scoop, she then adds about 3 scoops of clay, 1 scoop of fine sand and 1 to 2 scoops of mica. This process is repeated until the mixture has the consistency of "thick cream". If sodium silicate (or powdered milk) and/or straw are added at this point, a little additional water may also be required. At this point the ratio of ingredients may need to be adjusted somewhat. More sand can be added to give a rougher final surface (for a smooth surface, try omitting the sand).

The ideal surface on which to apply slips is one that is smooth and free from significant blemishes. Carole uses the following technique for creating such a surface. When the finish coat has been allowed to set up for just the right length of time (this is art, not science), she smooths out the mud plaster with a round-edged "tile sponge". After the finish coat is completely dry, the slip can then be applied.

Although traditionally applied with a piece of sheepskin, slips are now often painted on with a regular paint brush. Start at the top and work down. When the slip has partially dried, it too should be polished.

Take your tile sponge, dip it in water, wring it out and rub it lightly over the slip, using a circular motion to erase the brush marks. In order to not leave a film of clay over the straw and mica, she recommends rinsing and wringing out the sponge often. The results can be luminous!

Sealing

Sealers are used on **interior walls** primarily to keep the plaster from dusting. A clay slip containing wheat paste constitutes a non-dusting sealer. Wheat paste incorporated into the finish coat of earthen plaster will serve the same purpose. Cedar Rose of CRG Designs—Healthy Homes, in Carbondale, CO, makes her own wheat paste from organic, high gluten, unbleached, white flour. While the water in a big pot, two-thirds full, is coming to a boil, she adds to a gallon [3.8 liters] of cold water, a gallon of flour and two handfulls of vital gluten (available at natural food markets). While stirring, she then pours this mixture into the boiling water, continuing this process only until the blend becomes thick and transparent, at which time it can be added to mud plaster as it is being mixed. An expeditious, if not organic, alternative is dry wallpaper paste, mixed with water and used, just as is, as an additive during mixing.

Instead of incorporating the sealer into the plaster, one can also mist it on with a hand-held spray bottle, or maybe even a paint sprayer. This method has been used successfully with both wheat paste and with a half-and-half mixture of water and cheap white glue. Avoid too thick an application,

unless you want the surface to have a sheen.

Sealers are used on **exterior walls** to water-proof the mud plaster or glue the surface particles together, thus preventing erosion. A waterproofing-type sealer recommended by its manufacturer for use on "earthen structures" is Crown 310 (El Rey Stucco Co. Albuquerque, NM). According to their literature, it "allows substrate to breathe". They also make a gluing-type sealer called "Adobe Protector" that has been sprayed onto the mud plaster covering at least one straw-bale house. Several years after application, the user reported that it seemed to have been effective in preventing erosion, except where water was able to get into cracks and freeze. Since the effectiveness of any sealer may differ from one soil mixture to another, buy a small amount and test it on your plaster before making a big investment.

Photo by David Noble, Photographer, Santa Fe, NM

Step 8. Finishing Touches

Challenge: to create interior and exterior environments that are low-maintenance, low-cost, flexible, practical, healthy, comfortable, visually pleasing, personal and nurturing.

Walk-Through

• *At this point, with the building nearly finished and having learned from your mistakes, you might wish you could go back to* Step 1. *This time you would find an even simpler way to do it—a way that's customized to* <u>*you*</u> *as a builder/inhabiter. You would now have the advantage of knowing a fair amount about straw-bale construction, in addition to knowing much more about your unique situation than any "guide writer" ever could. Really, don't you wish we'd convinced you to start off with a little storage shed or a stand-alone guest bedroom, rather than a complete house? But, you've invested so much time, money, sweat and brain cells into getting to this point that, even though it's not perfect, you might as well finish it.*

♣ *Unless you chose to put interior partitions in before surfacing the interior walls, what you have now is an open space to be divided up according to your original floor plan (or some modification thereof). Consider doing the dividers (*e.g., *walls, screens) in such a way that they can be easily moved at some later time when your spatial needs and/or preferences have changed. Do any appropriate plumbing or electrical work before creating the finished surface on the partition walls.*

• *Most historic and modern bale builders have used thin frame walls, sheathed with gypsum plaster or sheet rock, to divide up their structures. They take up little of the interior floor space, and are cheap, quickly built, and easily moved or removed. If built with 2"X6"s [5X10 cm] they can comfortably accommodate gas and water pipes, drain pipes and plumbing vents. However, whether you use dimension lumber for partition walls or some of the other options listed on page 85, consider filling any voids in the walls with something that will increase their thermal mass and/or reduce the transmission of sound through them (*e.g., *sand, tamped straw, tamped straw coated with a clay slip).*

• *If the natural color of the interior mud plaster is too dark for certain spaces, try a technique that author Steve and his wife, Nena, came up with for their straw-bale home. Mix powdered drywall joint compound with water to reach a consistency just thin enough to paint on with a wide, stiff brush. Be sure to get the mud plaster completely covered. When the joint compound is completely dry, roll or spray on an interior latex paint.*

♣ *Hang any wall-mounted cabinets, bookcases, etc.. If the wooden elements they will attach to are hidden under the plaster, use the map you made earlier (see page 83, upper left) to determine their location. Drill through the plaster to drive in dowels for the hanging of heavy artwork.*

As an alternative to hanging kitchen cabinets on irregular straw-bale walls, some builders have chosen to place against the bale

wall a non-loadbearing, drywall-surfaced "veneer" wall. This provides vertical wooden studs from which the cabinets can be hung, and a smooth plane against which they can snugly fit. For more details on options for hanging and on alternatives to hanging, see the following two pages.

• *Install any floor-standing cabinets, vanities, etc. As an alternative to the "veneer wall" strategy mentioned above, some builders prefer to put all floor-standing units in place after the "scratch" coat is applied, making sure to first patch any cracks in the area to be covered by the units. After you have protected the units with plastic sheeting, the second "brown" coat can then be used to fill any gaps between the back edge of the counter, or splash board, and the wall surface. An obvious disadvantage to this approach relates to future remodeling. If the wall area that has been hidden by the cabinets would then be exposed, considerable skill would be needed to then finish the plastering to match the rest of the wall.*

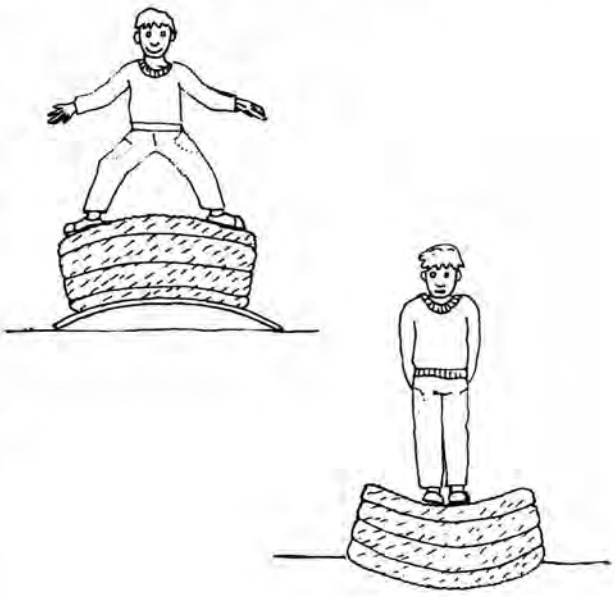
• *Install plumbing-related items and associated fixtures, louvered grilles over air ducts, vent fans, lights, ceiling fans, wood stoves for backup heating, cooling devices, etc. Continue with the seemingly interminable installation of shelves (for options see page 121), and hooks and rods for clothes, and the sanding, puttying, sanding, caulking, priming, sanding, painting, staining, et cetera.*

• *Don't ignore the outside. Get some herbs and a kitchen garden planted. Don't miss the right season to plant landscaping that will give you privacy, beauty, shade, and food (see EPA 1992, Moffat et al. 1995, and Groesbeck and Striefel 1997). Get your trees off to an early start. Add on any shade porches (see* Making Your House a Home *on page 122).*

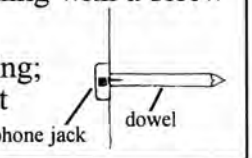
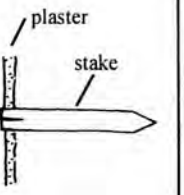
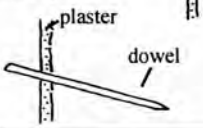
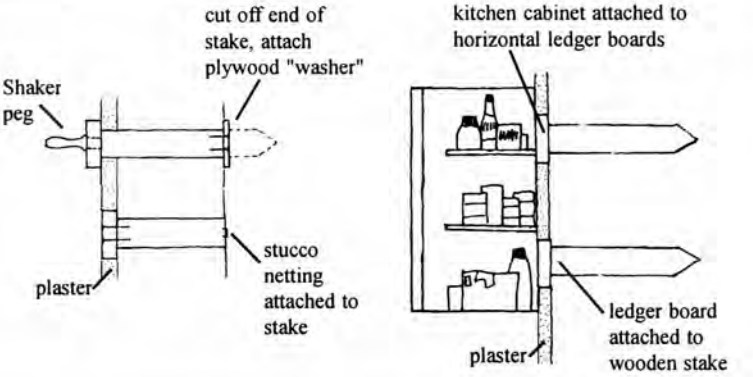
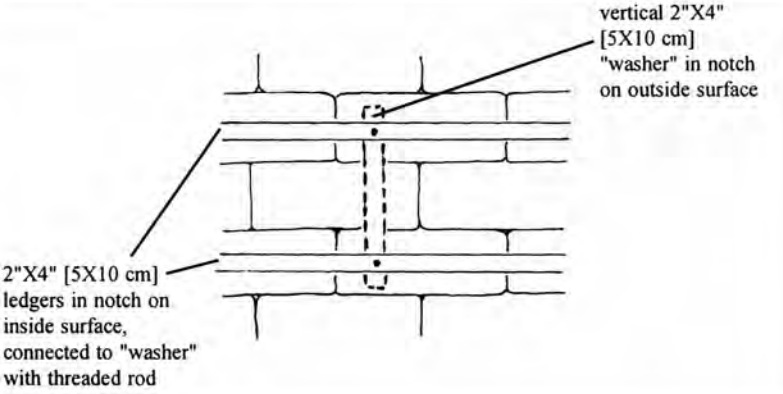
• *Consider using bales to create other things you may want to complement your new home:*

—*a pump house, storage building, shop, studio space, guest house, sauna, etc.;*
—*a root cellar for extremely cold (and hot) regions;*
—*animal shelters;*
—*a solar oven or lumber kiln;*
—*a container for your compost pile;*
—*privacy walls (see Farrant 1996);*
—*and, outdoor seating.*

• *Accept the inevitable truth that* Step 8 *actually never ends—it just continues until you realize that what you are doing would be more honestly called "maintenance". Now you are either ready to avail yourself of the 12-step program that* Straw-bale Builders Anonymous *offers, or to continue with* <u>*our*</u> *8-step program on a new and more elegantly-simple, straw-bale project. Don't be surprised to see one or both of us at the SBBA meetings or lurking around your job site hoping to pick up some tips for the next version of this guide. Bale well and prosper. And don't get too bent out of shape!*



Hanging Things on Straw-Bale Walls

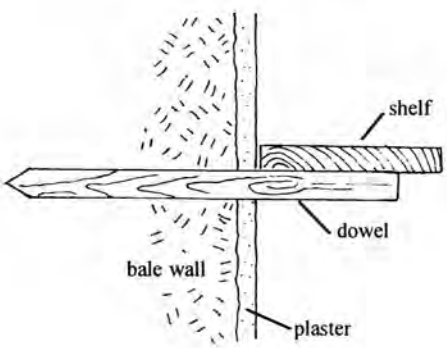
Duty Level	Pre-Plaster Planning?	Description of Option
light	not necessary	• for cement- or gypsum-based plaster, drill hole, insert nail; or drill hole, install plastic insert, attach something with a screw • for clay-based plaster, drill hole for dowel, pound in dowel, add screw on end for hanging; or once dowel in wall, attach something to it (e.g., telephone jack) 
medium	highly advisable advisable not necessary	• Gringo Grip™ (see page 87 for access info) May be O.K. for heavier loads, also. • 2"X4" [5X10 cm] stake with flat side vertical or horizontal, depending on bale density  • drill hole, pound in dowel (not recommended for earth plaster) 
heavy	required	
super-heavy	required	

Alternatives to Hanging Things on Straw-Bale Walls

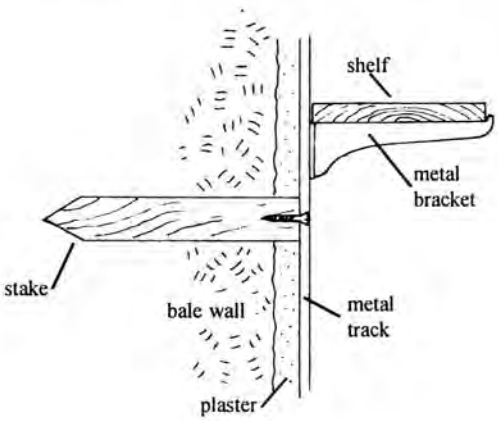
- Hang them from a normal partition wall or from a "veneer" wall (page 118, bottom right).
- Hang them from the roof/ceiling system.
- Have them rest on the floor (e.g., freestanding hutches, bookcases, backward bracket units [see below], storage units).

Special Options for Shelving on Straw-Bale Walls

- Large-diameter (e.g., 1" [2.5 cm]) dowels driven into the bales.

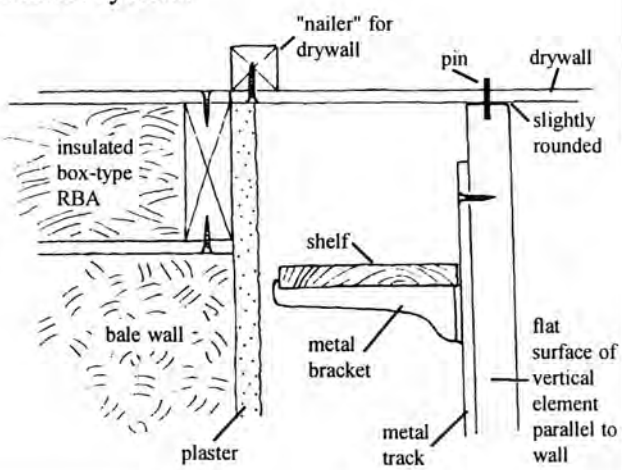


- Metal track and bracket option: normal mounting.

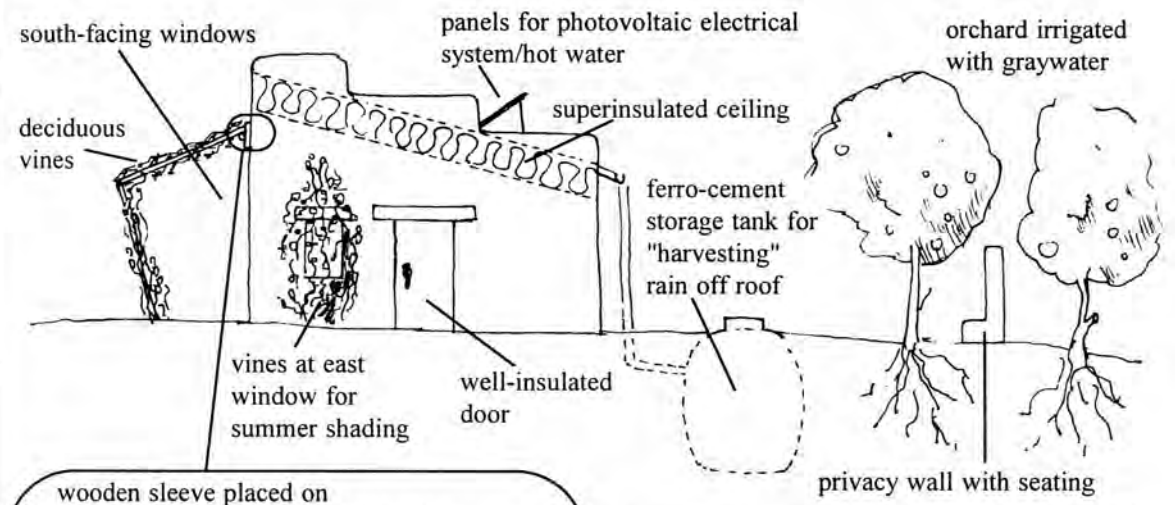


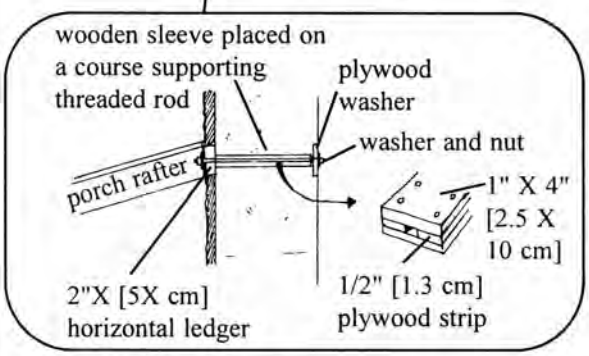
- Metal track and bracket option: backward bracket system.

1. Measure and cut vertical elements (2"X4" [5X10 cm]) for slightly loose fit.
2. Attach metal tracks.
3. Insert pin (e.g., nail with head removed) at top of one vertical element into small hole drilled at measured location in the drywall ceiling.
4. Move bottom end in toward wall until vertical.
5. Repeat steps 3 and 4 for all vertical elements.
6. Add brackets and shelves.



Making Your House a Home

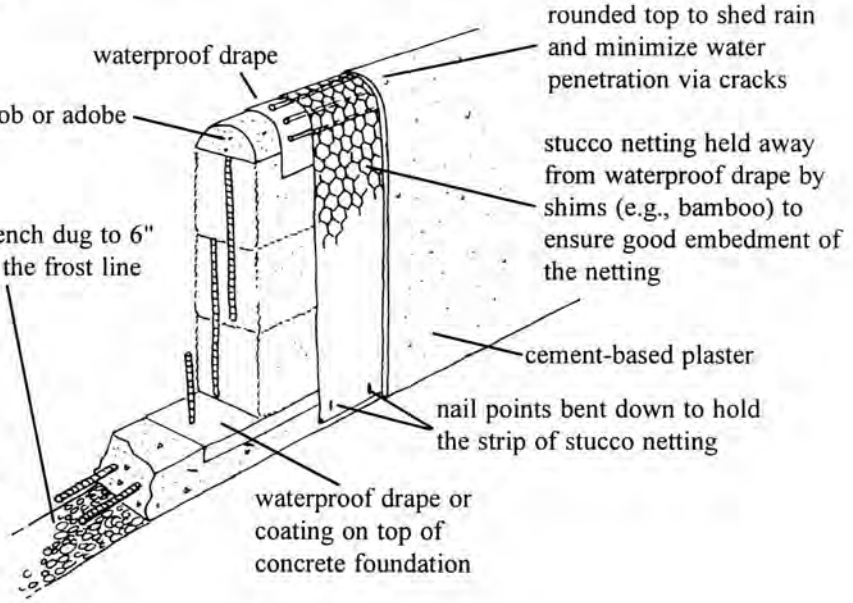




Some Ideas for Attaching a Porch

- Place horizontal plate before plastering (see left).
- Attach to RBA or rafters.
- "Gringo block" stakes driven in to attach ledger for light structures.

Privacy Walls*



* This "Cadillac-of-privacy-walls" design has been approved as part of the straw-bale code in Tucson and Pima counties, Arizona. See Farrant (1996) and *The Last Straw*, Issue No. 7, page 22, for further information on privacy wall construction.