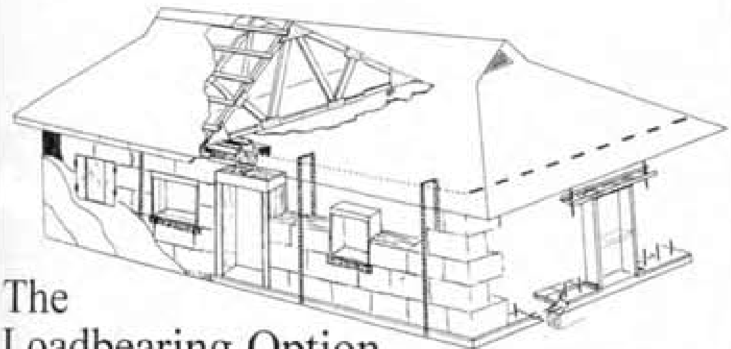
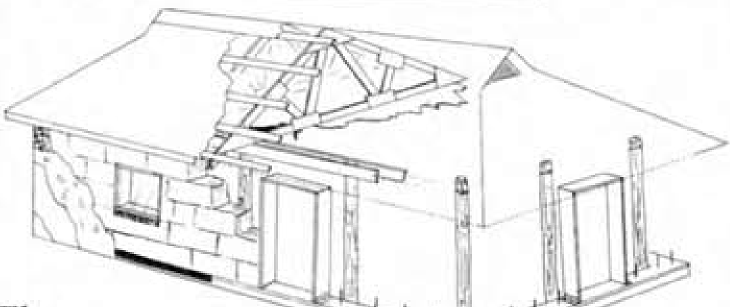
Part Two

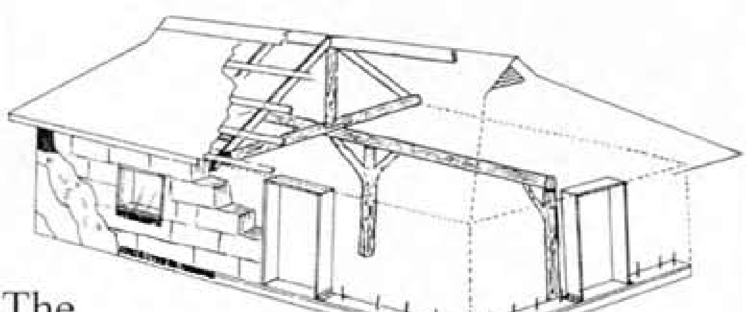
Building At Last!



The Loadbearing Option



The Non-Loadbearing Option



The Hybrid Option

The Loadbearing Option

Step 6 (pages 81-88)

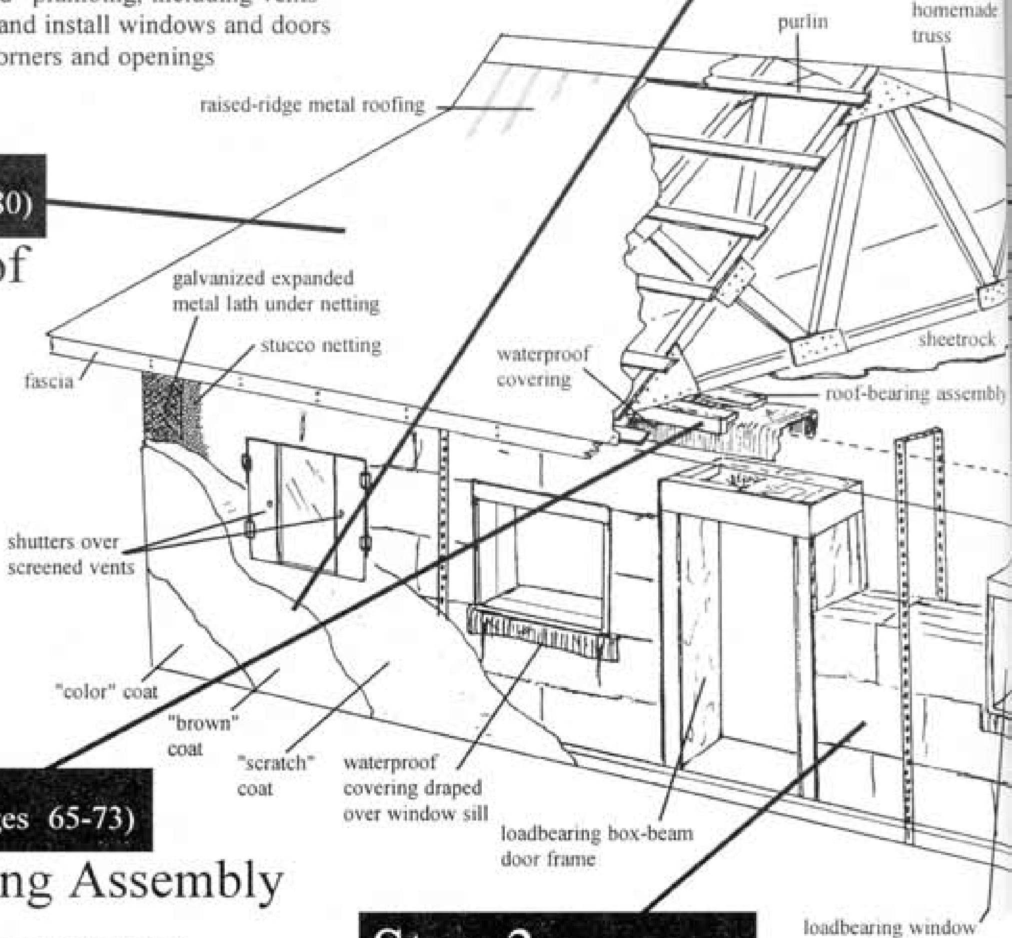
While the Walls Compress

- create the floor/subfloor
- create interior partitions
- install electrical boxes and wiring in bale and partition walls
- install "finished" plumbing, including vents
- secure frames and install windows and doors
- trim bales at corners and openings

Step 5 (pages 74-80)

Adding the Roof

- build roof framework
- surface roof framework
- install electrical boxes and wiring for ceiling fixtures
- install ceiling and insulate



Step 4 (pages 65-73)

Roof-Bearing Assembly

- straighten walls
- install roof bearing assembly (RBA)
- fasten RBA to foundation
- prevent rodent access along top of wall

Step 3 (pages 57-64)

Raising the Walls

- waterproof the foundations and stack the bales
- install window frames over waterproof drape
- install lintels, where necessary
- protect top of walls with waterproof drape

Step 7 (pages 89-117)

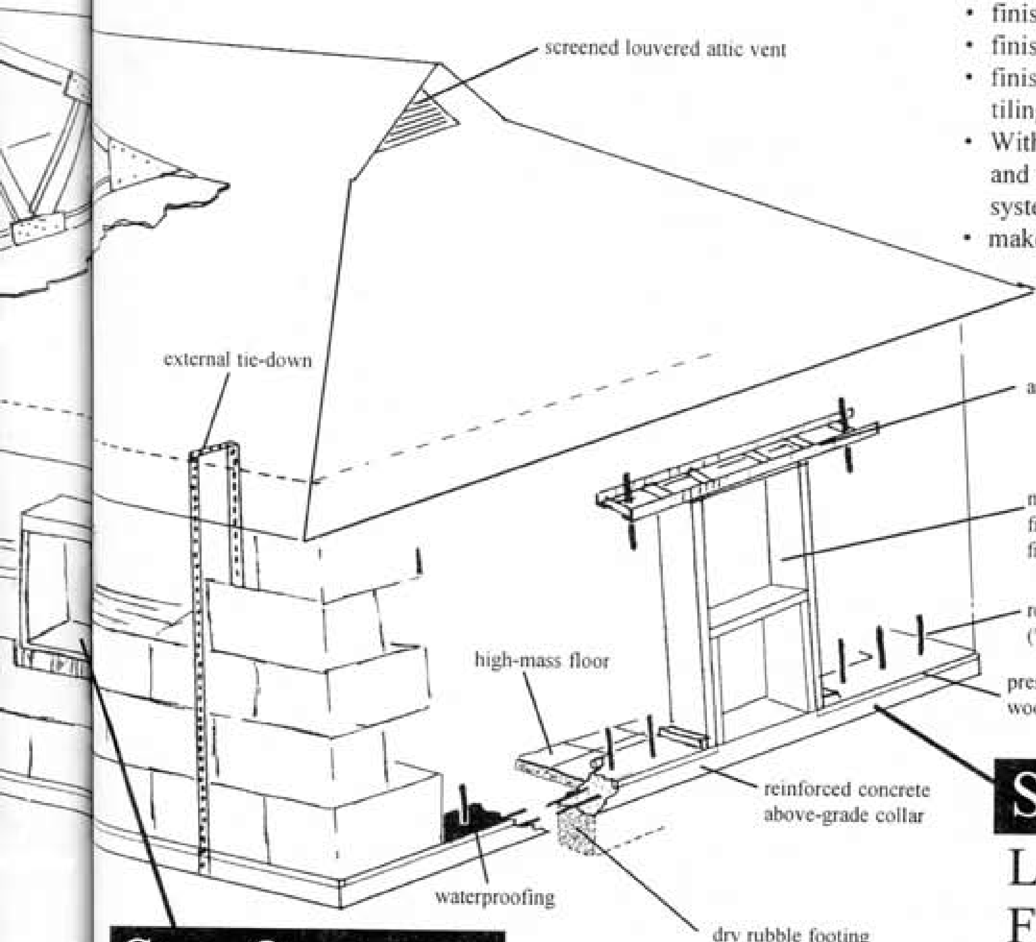
Surfacing the Walls

- install expanded metal lath inside and out
- install stucco netting on outside
- plaster the outside wall surfaces
- cover the interior bale surfaces with earthen (a.k.a. mud or adobe) plaster

Step 8 (pages 118-122)

The Finishing Touches

- finish electrical and plumbing details
- finish carpentry details inside and out
- finish preparation for painting, staining, tiling, etc.
- With safety foremost, install roof jack and stovepipe for backup heating system
- make the house a home



Step 2 (pages 52-56)

Window and Door Frames

- fabricate all frames
- attach door frames to foundation

Step 1 (pages 43-51)

Layout and Foundations

- establish corner locations
- erect batter boards and string lines
- install "rough" plumbing and electrical
- create the foundation for the bale walls with appropriate "hardware" in place

Step 1. Foundations

Challenge: to create a stable, durable base that will minimize the likelihood of water reaching the bales from below and of stress being put on the wall-surfacing materials.

Walk-Through *

• *During the process of finalizing your design, you will have selected a particular foundation system. Your choice would have been influenced by many factors, perhaps including:*
—any unusual conditions you encountered during site preparation (e.g., shallow bedrock);
—soil testing, re: bearing capacities, expansive clays etc.;
—the seismic zone within which you are building;
—the total load created by the proposed structure and whether that load is distributed evenly along a wall or is concentrated at certain points;
—the depth to the frost line or to permafrost;
—and, the relative availability of money vs. owner/ volunteer labor and gatherable materials.

♣ *Having done the site preparation prior to finalizing the design and getting the final drawings prepared, we can now orient the building shape on the site, giving consideration to passive/solar strategies and other concerns.*

♣ *Stake corner positions using 3-4-5 squaring technique or equivalent. Create batter board system, fine tuning for square and level.*

♣ *Mark ground with lime or equivalent to guide excavations. Remove strings and excavate.*

♣ *Fill trenches to the surface with uniform "rubble" material. Compact as needed.*

♣ *Re-install strings. Create level "forms" to contain the poured concrete, giving consideration to rebar placement, waterproof perimeter insulation board, stucco netting attachment, plumbing and other passageways. Wood used to build your forms can be more easily used later (e.g., for framed partition walls) if kept clean during the pour. Kraft paper, plastic sheeting, etc., stapled to "at risk" surfaces, will save you much cleanup time later.*

• *Wet, pourable concrete is very heavy, and while still fluid, exerts pressure against the forms. The deeper the concrete, the greater the outward pressure. Poorly braced and/or cross-tied forms can "blow out"; at best, you get unwanted bulges; at worst, concrete gets wasted and the forms have to be rebuilt. Extra bracing and cross-ties are cheap insurance.*

♣ *Mix, pour, settle and screed concrete, placing any hardware (e.g., "imbalers", foundation bolts, eyebolts) before it becomes too stiff. The "imbalers" are typically 18 inch [46 cm] long, straight pieces of 1/2 inch [1.3 cm] diameter reinforcing bar [a.k.a. rebar). About 6 inches [15.2 cm] are in the concrete, leaving about 12 inches [30.5 cm] sticking up to "imbale" the first course of bales, the purpose being to prevent them from being accidentally bumped out of their desired position. For an expensive but non-metallic, alternative, try fiberglass rebar.*

If possible, place no foundation bolt (for threaded rod tie-downs) closer than 1-1/4 bale lengths from a corner so all corner bales can be placed and adjusted without hassle. For tie-downs closer than 1-1/4 bale lengths, use an external system.

♣ *You'll play hell getting something into concrete or making a hole through concrete once it has set up (i.e., become rocklike). To*

* *You may want to re-read the section on "How This Guide Is Organized" (page 2) before plunging ahead. There is a method to the madness.*

help you remember to place, and to position accurately, all the hardware, use your detailed, scaled, foundation drawing (the plan, or "from above", view), as a guide. Measure carefully and mark on the forms where every item of hardware is to go and as soon as they are in, use the drawing to double check.

♣ *Trowel the area the bales will sit on to a flat, relatively smooth surface, then keep moist for a maximum-strength cure. Any concrete that will remain exposed should be troweled to the desired finish at this time.*

♣ *To provide protection against the sharp edge left by the rebar cutter at the top end of the imbalers, you may want to temporarily cover them with plastic jugs, beverage cans, "dead" tennis balls or the like.*

♣ *After removing the formwork, modify the ground surface to assure good drainage away from the foundation.*

Dimensioning Your Foundation

As discussed earlier under *Finalizing Your Design*, most builders choose not to use foundation dimensions that are arbitrary or based on some non-bale-related module. They do this to avoid having to create many custom-length bales in each course and to avoid having these shortened bales break up the "running bond" (where each bale overlaps the two bales below it by nearly equal amounts).

The preferred approach is to let the chosen bale layout for the first course and the "effective bale length" (see page 35) dictate the length and width measurements for whatever platform the bales will sit on. It's better to have this "foundation" slightly oversized in terms of the length dimensions, since stuffing loose "flakes" of straw into occasional small gaps is much easier than retying bales to shorten them. Since the "effective bale length" of typical 3-tie bales is close to, but very seldom greater than 48 inches [1.22 m], many builders use this as a standard module for calculating the exact dimensions of their foundation. Based on the width of the actual bales you use, the width of any concrete collar or "toe-up" platform will be about 18 in. [45.7 cm] for 2-tie bales and about 23 in. [58.4 cm] for 3-tie bales, including the width of any waterproof perimeter insulation, assuming that the bales are laid "flat".

Building Layout

The purpose of layout is to accurately establish the location of the corners of the outside edge of the element (e.g., slab, grade beam, wooden deck) on which the bottom course of bales will rest (see diagram next page).

The use of batter boards and string lines enables the builder to reestablish these corner points even though corner pins initially placed in the ground have been disturbed or removed. By positioning the horizontal cross-members of the batter boards at the same elevation (using, for example, a commercial hose level kit and a carpenter's level), the strings can then also be used as a "bench mark" from which one can measure down to establish the correct depth of a trench or the correct height of formwork for containing poured concrete. Since small errors can be cumulative during the building process, it make sense to insure that the layout accurately reflects the dimensions and shape shown on your final drawings. However, most straw-bale builders feel comfortable with diagonals (corner-to-corner measurements) that differ by as much as a half inch.

References we can recommend for building layout are Jackson (1979) and Law (1982b).

Concrete

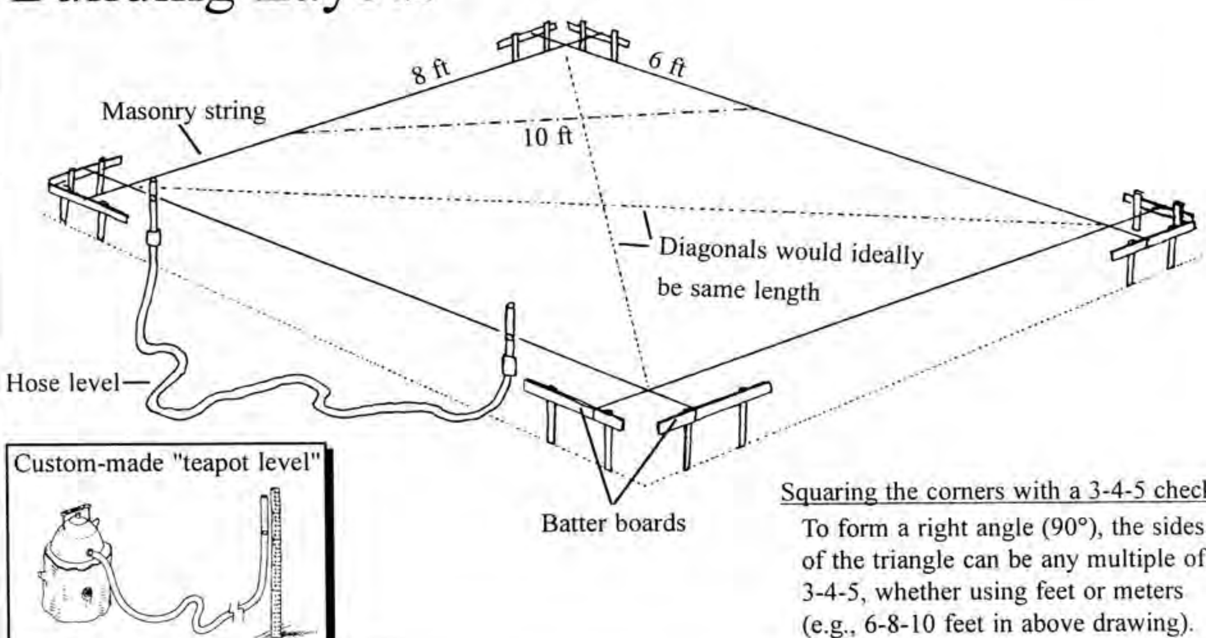
Concrete is a chemically-hardened mixture of cement, sand, gravel and water. A standard mixture is 1 part (by volume) Portland cement, 2 parts sand, and 3 parts gravel.

Make sure that your forming system is level and strong enough to withstand the very considerable outward (and to a lesser extent upward) pressure that will be put on it by the wet concrete. Make sure that any passages through the concrete that will be required for later installation of pipes or electrical wires have been accounted for. Mark your formwork with some easily visible code system that shows where various items of hardware (e.g., rebar stubs, eye-bolts, foundation bolts) need to be inserted into the still-wet concrete.

If using site-mixed concrete, consider equipment, labor and time requirements and local availability of acceptable sand and gravel. If using truck-delivered, already-mixed concrete, consider access for the truck and its chute, helpers and equipment needed to handle a large amount of concrete in a short time. For additional tips, consult Kern (1975), Syvanen (1983), MWPS (1989b) or Loy (1990).

Calculate the cubic yards of concrete needed by multiplying the length by the width by the height of the foundation and/or slab (in feet), then dividing by 27 (the number of cubic feet in a cubic yard). Add 10% to the calculated amount to ensure having enough, and prepare a place to beneficially use any excess.

Building Layout

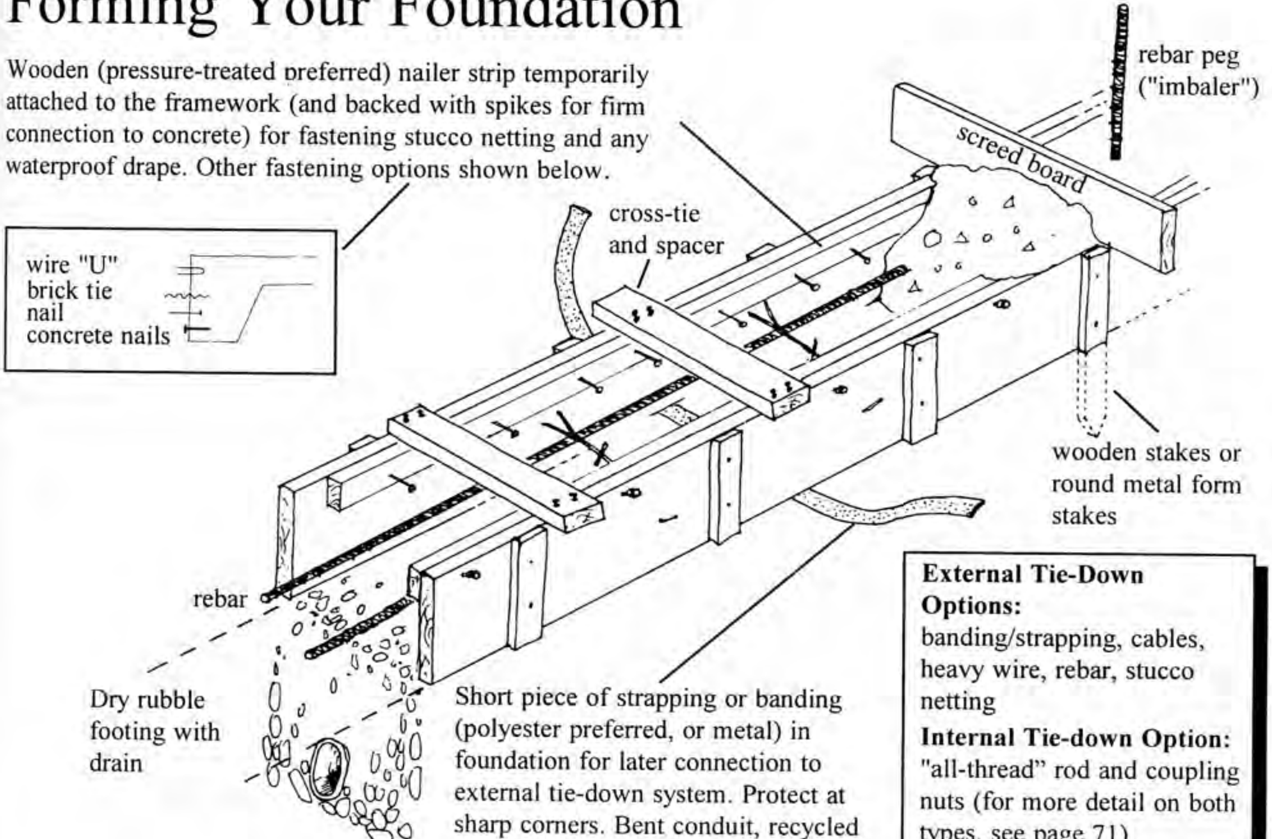


Squaring the corners with a 3-4-5 check:

To form a right angle (90°), the sides of the triangle can be any multiple of 3-4-5, whether using feet or meters (e.g., 6-8-10 feet in above drawing).

Forming Your Foundation

Wooden (pressure-treated preferred) nailer strip temporarily attached to the framework (and backed with spikes for firm connection to concrete) for fastening stucco netting and any waterproof drape. Other fastening options shown below.

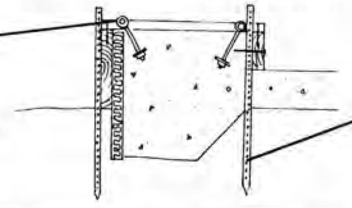


Short piece of strapping or banding (polyester preferred, or metal) in foundation for later connection to external tie-down system. Protect at sharp corners. Bent conduit, recycled garden hose, or drip irrigation tubing can be placed in the concrete as sleeves for later threading of strapping or cable.

External Tie-Down Options:
banding/strapping, cables, heavy wire, rebar, stucco netting

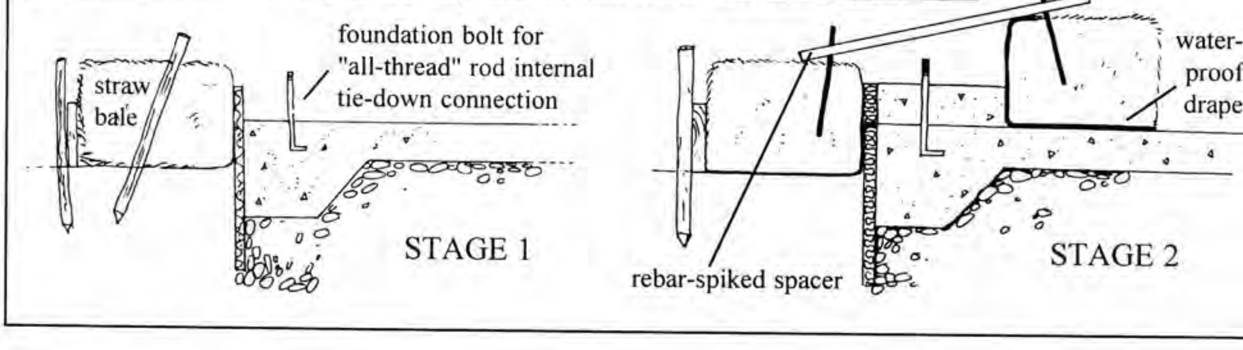
Internal Tie-down Option:
"all-thread" rod and coupling nuts (for more detail on both types, see page 71)

Forming a One-step, Toed-up, Monolithic Foundation and Slab



For information on pouring this type of foundation/slab over bales to provide below-slab insulation, see page 88.

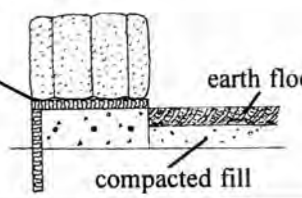
Forming a Two-step, Toed-up Foundation and Slab with Bales

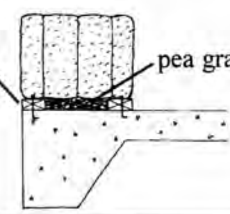


The Argument for Toe-ups

Savvy, modern straw-builders have always created foundations that kept the bales at least 6 inches [15.2 cm] above grade (a.k.a. ground level) on the outside, but often had the bales sitting directly on the waterproofed edge of a slab poured simultaneously with the foundation. Considerable experience (sometimes involving serious anxiety and harsh, retrospective self-criticism) suggests that it is also well worth the trouble to elevate the bales at least 1-1/2 to 2 inches above the slab on the inside. One cloudburst before you get the roof on, or a plumbing disaster that floods the floor for days while you're on vacation, would convince you beyond a doubt that you should have provided a toe-up. Trust us, Just do it!

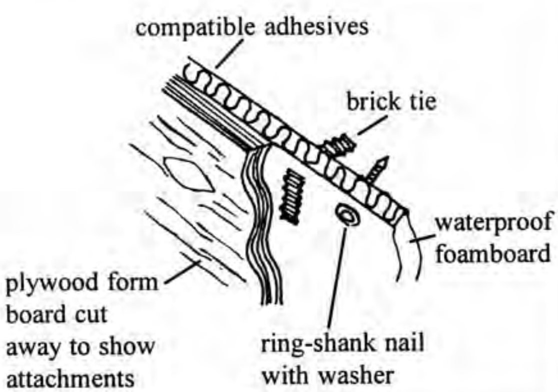
More Options for Toe-ups

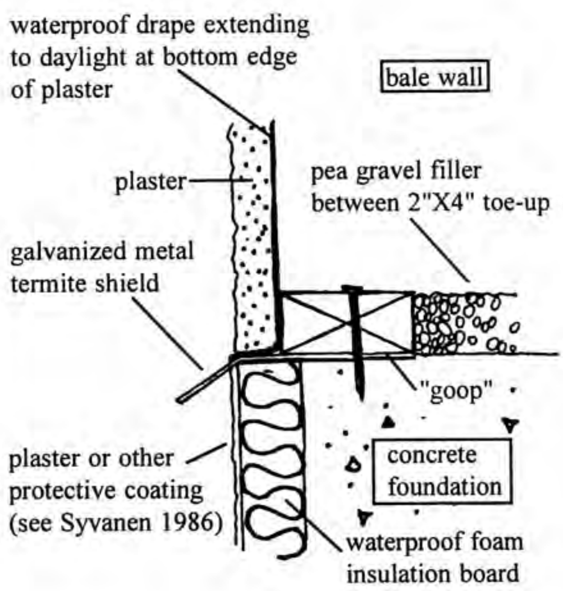




Perimeter Insulation—Some Considerations

Attaching Perimeter Insulation





Perimeter Insulation and Termites

Termites can easily burrow up through foam insulation and bales, gaining access to wooden door and window frames. In areas where termites pose a significant threat, a metal termite shield should be strongly considered. One option for detailing shown above right.

Other Foundation Options

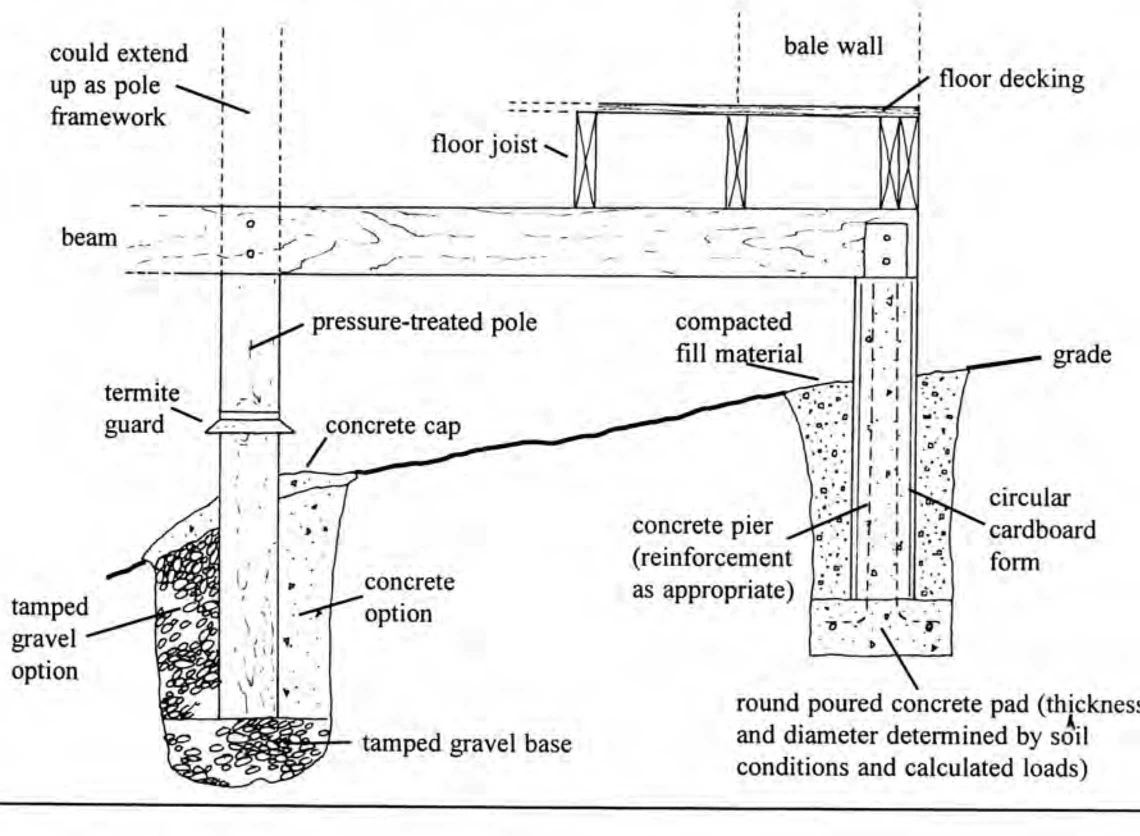
Steeply-Sloped Lots

Sloping building sites present problems to the straw-bale builder. Using the "cut-and-fill" approach may require massive earth moving that results in ugly "cut walls" that need retaining. Step footings have their own problems, especially in load-bearing structures.

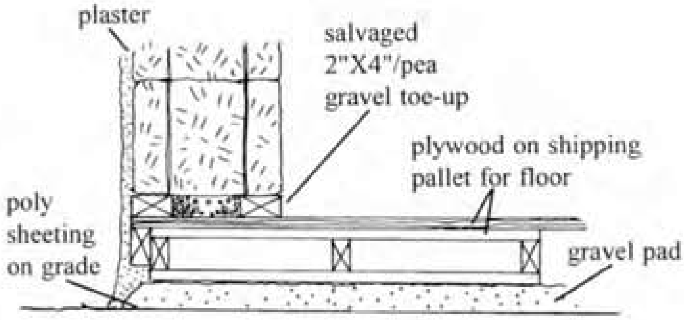
A better solution may be to use a grid of vertical columns or posts to support a wooden deck upon which the straw-bale house can sit. In most climates, the underside of this deck will need to be insulated. Possibilities range from batts (e.g., fiberglass, cotton, or cellulose) to straw bales or flakes (see page 88), to using insulative structural floor panels to create the deck. Such panels usually have a foam core, but Agiboard, Inc. is manufacturing in Texas a panel consisting of compressed straw (for insulation), sandwiched between two layers of oriented strand board (for structure). Access: an Iowa telephone number, (515) 472-0363 or e-mail <agriboard@lisco.com>.

The space under the deck can be closed in with (straw-bale?) skirting, and used for storage (this would be a great place for storing water harvested from the roof). See Levin (1991) regarding further options for sloping sites.

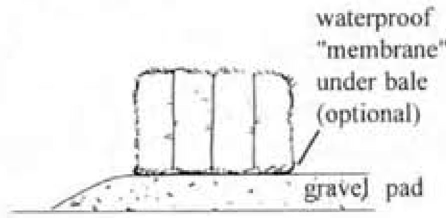
Deck On Pier and Beam



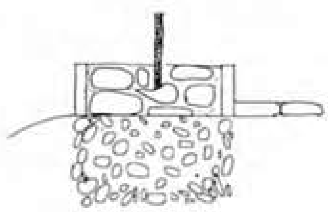
Low-Tech Ideas*



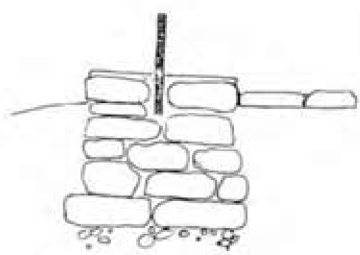
Shipping Pallet on Gravel Pad



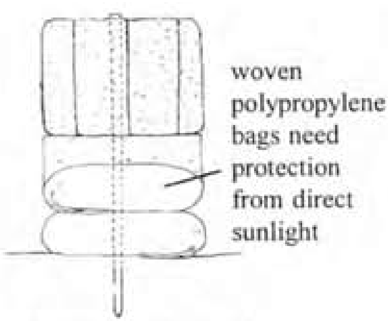
Bale Directly
On Gravel Pad



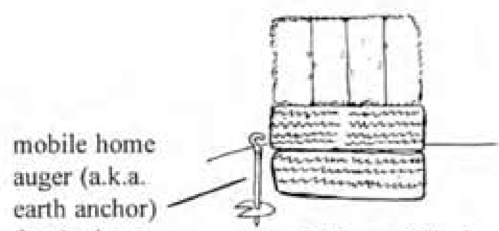
Framed Box
Filled with
Stone and
Concrete



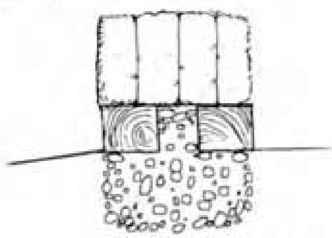
Stabilized Adobe,
Rammed Earth, or
Field Stone



Sandbags Topped
with Cob or
Concrete
(see Kennedy 1996)



Used Tires Filled
with Rammed Earth
(Reynolds 1990)



Railroad Ties and
Gravel Fill

Rock-Filled Gabion
Basket

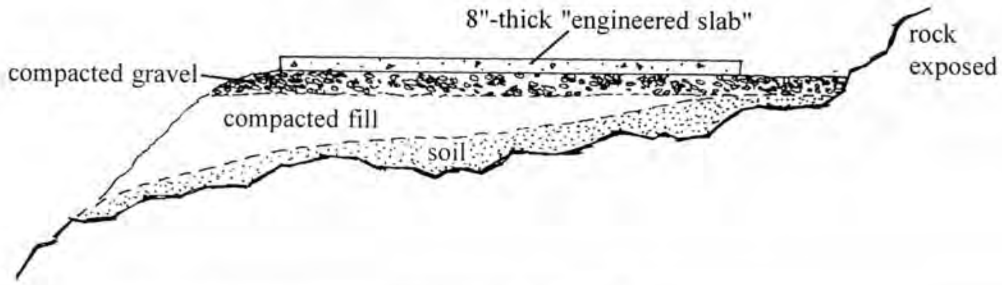
* *For coverage of a variety of low- and high-tech foundation options, see* The Last Straw, *No. 16.*

High Tech Idea For Unusual Conditions*

- Want to do slab-on-grade but shallow bedrock makes excavating for a pad and the integral toed-down foundation prohibitively expensive?
- Have soil conditions (e.g., expansive clays) that are likely to cause cracking in an ordinary slab-on-grade?

The answer (maybe): an 8 inch [20.3 cm] thick, post-tensioned "engineered slab" (see diagram below), with a grid of stainless steel cables that are used to put the slab into compression several days after the pour. Not cheap, but may be the least expensive of the few, working options.

Post-tensioned "Engineered Slab"



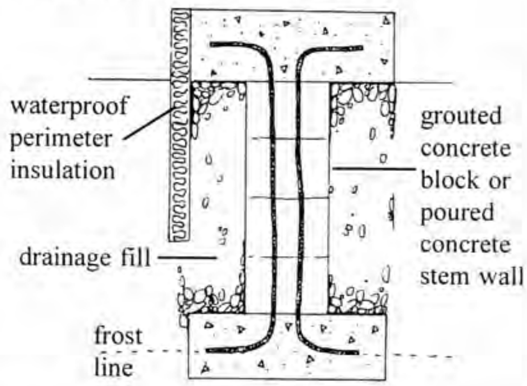
* *Low Tech Idea for Unusual Conditions: accept reality and choose another building site.*

Foundation Strategies for Cold Climates

One downside of our inevitably wide bale walls is that any concrete platform on which they rest must also be wide. In areas where freezing temperatures are encountered at considerable depth, it would require large amounts of concrete to create a uniformly-wide concrete footing extending to below this "frost line". The related costs, both financial and environmental, dictate that we explore alternatives.

One possible solution is the "I-beam" concept, suggested to us by architect Arlen Raikes. The "I" cross-section, being narrower in the middle, requires the use of less cement-based materials.

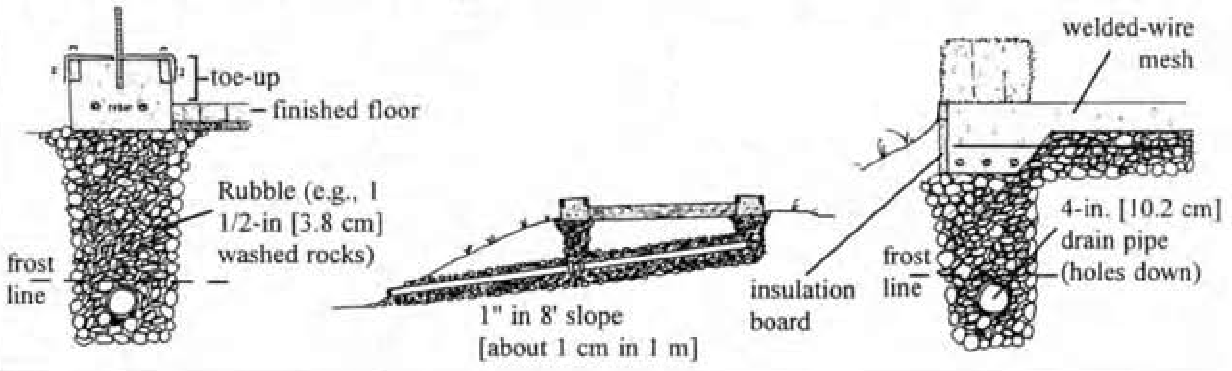
I-Beam Foundation



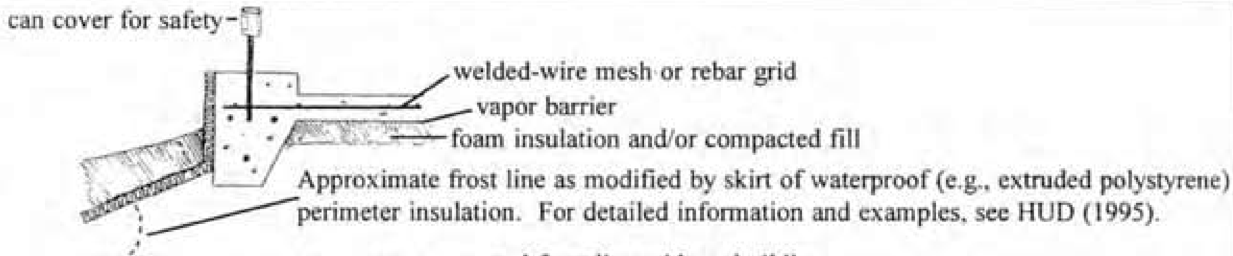
Another approach, suggested to Frank Lloyd Wright (see Wright 1954) by Welsh-born masons in Wisconsin, is the "dry wall footing" (a.k.a. dry rubble footing, rubble trench footing). As Wright used this strategy, trenches were dug only sixteen inches deep to contain "rubble", even though the frost line depth was about four feet below ground surface. He assumed that if the material under the above-grade collar (which in his case, at Taliesen, consisted of linear blocks of limestone laid end to end) could be kept dry, there could be no destructive "frost heaving" even if the soil temperature dropped below freezing. The Taliesen experience was not without problems, and modern users have generally chosen, or been required by building officials, to dig the trenches to below the frost line depth. This requires the use of more "rubble" to fill the trenches to the surface, but "rubble" is less costly to buy and place than concrete. Two useful references on the modern use of this approach are Velonis (1983) and Tom (1996).

The word "rubble", as used in this connection, includes a variety of coarse, quickly-draining materials. Wright used "fist-sized broken rock" in his trenches. Modern builders have used everything from "river run" (rounded pebbles which settle automatically to a stable configuration), to "leach field rock" (angular fragments that should be compacted mechanically).

Rubble-Trench Footings



A third approach (shown below) is the "shallow, frost-protected footing" concept described in a publication prepared by the National Association of Home Builders Research Center for the US Dept. of Housing and Urban Development (HUD 1995). This approach is based on the use of strategically placed waterproof, foam-board perimeter insulation to modify the frost line surface such that a frost-free zone is created under and around the edges of the building "footprint". This enables the builder to safely position the bottom of the footing well above the "normal" frost line. For an excellent summary, see Malin (1995b).



Step 2. Door and Window Frames

Challenge: to create, based on the load they will be carrying, frame/lintel combinations to accommodate each door and window. They should carry this load without deforming, while using no more materials than necessary.

Walk-Through

• *The dimensioning and design of the window and door frames should have been done as part of finalizing your design and preparing a set of plans. Several generic approaches to sizing window openings are shown below. All three could be used in the same building.*

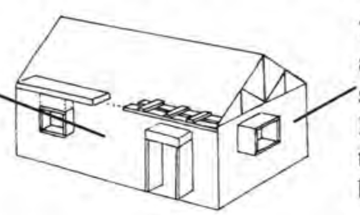
♣ *Using the information from your plans, fabricate the rough frames in advance of the wall-raising. Use sturdy corner or diagonal braces to keep them square until progress requires their removal.*

♣ *Position door and floor-mounted window frames onto the foundation. Once they have been secured, provide temporary bracing to keep them upright and level.*

♣ *Fabricate any separate lintels that you will use above non-loadbearing frames. Lintels, generically, are assemblies, located above openings, that carry any load created by materials above those openings.*

Loadbearing versus Non-Loadbearing Walls

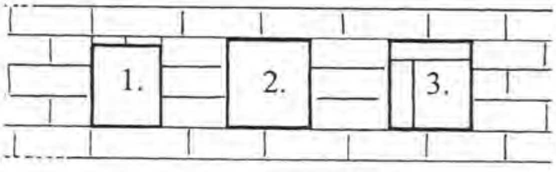
Even in a loadbearing design, the roof load (dead and live) is usually carried entirely by two of the walls. For a rectangular building, the **loadbearing** walls are usually the two longer walls



This means that the other two walls are called **non-loadbearing walls,** since they carry no roof load. Frames or lintels in these walls are thus carrying only the weight of any bales located above these openings.

Sizing Openings

1. Modify bales to fit around the rough frames built for arbitrarily positioned, standard windows or pre-hung doors.
2. Make frames to fit openings dictated by the one-half bale module and the bale height module. Doors and windows will probably have to be custom made if the full opening is to be used.
3. As in # 2, make frames to fit the bale-modular opening. Then, make a second, perhaps lighter, internal frame to fit a standard window or pre-hung door. The space difference between the smaller internal frame and the larger bale-modular opening can be used to create angled openings on the interior or exterior. See the diagram on page 56 (middle right) for details.



Lintel Options

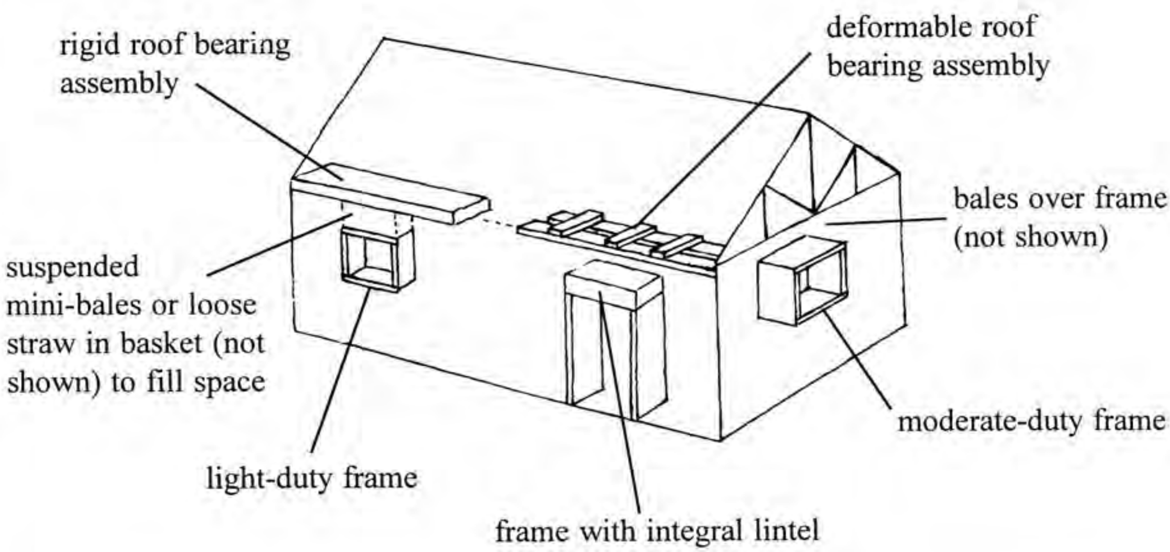
Integral Option

In this option, the upper member of the frame is a built-in (a.k.a. integral) lintel, rigid enough to carry the load from above without deforming (bending). This load is transferred by the side members to the foundation (in the case of a door frame), or to the bottom member, which transfers it to the bales below (in the case of a window frame). In terms of compressive load (load from above), the frame replaces the bales left out to create the opening. Therefore, they cause no increase in the load carried by the columns of bales on either side of the opening. This option is illustrated on page 55, lower left.

Separate Option

Separate lintels are not part of the frame. They extend out on to the bale walls and transfer the load from above, onto the bales on either side of the opening. They can be located at the top of the wall, as in the case where a rigid roof bearing assembly (RBA) acts also as a lintel across openings. They can also be located immediately above the frame, as in the case of an angle-iron lintel (see the diagram for the Non-loadbearing Door Frame and Lintel on page 55, upper right). In such cases, the lintels should extend out onto the walls at least one-half the width of the opening, and no less than 2 feet [61 cm]. They are not commonly used for openings more than 4 feet [1.22 m] wide and are most often used in non-loadbearing walls. Separate lintels always increase the load carried by the bale columns adjacent to the openings they span.

Loadings and Frame Design



Selecting Frame/Lintel Combinations for Openings

Axiom: *Each opening has the potential of being a unique case.*

How sturdy a particular frame needs to be will depend primarily on how much compressive load it will carry. This can vary from a lot (imagine a wide opening in a loadbearing wall that is carrying half the weight of a tile-surfaced roof that sits on a non-rigid roof bearing assembly) to nothing (imagine a non-loadbearing wall with a modest opening spanned by an angle-iron lintel).

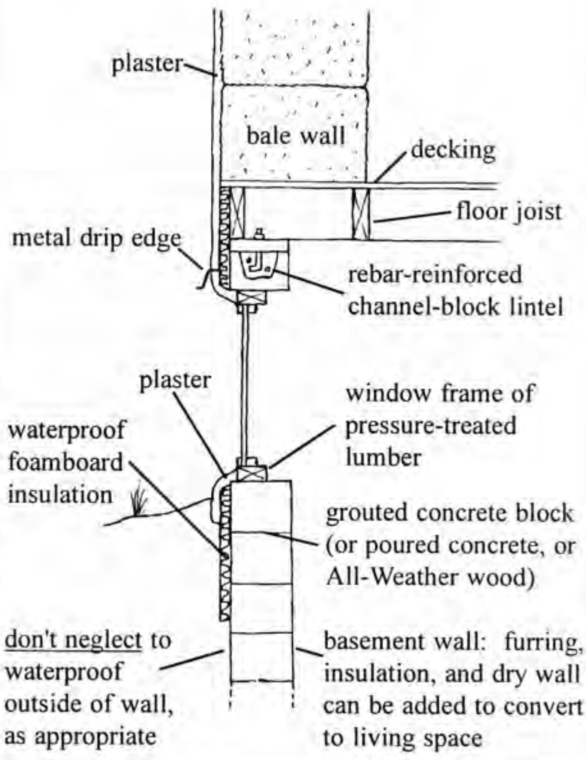
In order to design a frame that can carry its particular load without deforming, while using no more materials than necessary, this load must be calculated or "guesstimated". Engineers and architects use charts which relate both load and span lengths to deformation. Don't hesitate to use their expertise if you are uneasy about making these decisions yourself, particularly if you want wide openings in loadbearing walls.

Another approach is to assess the factors affecting the load at that opening, make a ballpark estimate of the load situation on a scale from 1 (no load) to 10 (really heavy load), and then err on the side of caution. Many successful, simple, loadbearing structures have been built with frame/lintel systems designed this way by their owner-builders.

A list of factors that can affect the load on a given frame would include:

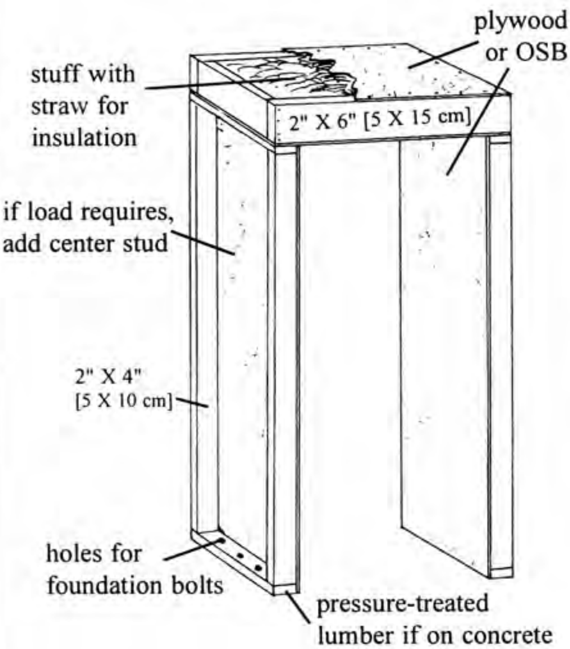
- the width of the opening;
- whether there will be a separate (non-integral) lintel above the frame;
- the number of courses of bales (if any) there are above the frame;
- the relative rigidity of the roof-bearing assembly (RBA) above the opening;
- whether the opening is in a loadbearing or non-loadbearing wall;
- the distance between the loadbearing walls and the weight per square foot of the roof/ceiling/insulation system;
- the weight of the RBA;
- and, maximum anticipated live load (e.g., snow).

Channel-Block Lintel in a Daylighted Basement



Loadbearing Options

Box Beam Door Frame

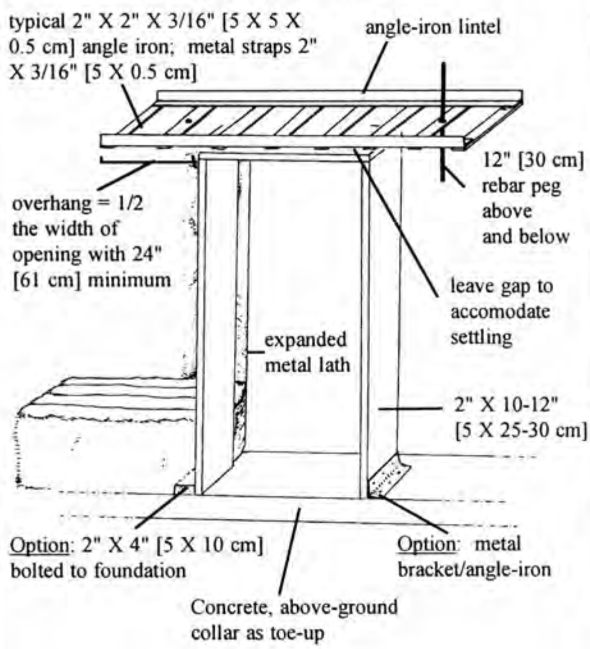


Window Frame with Integral Box Beam Lintel and Bottom

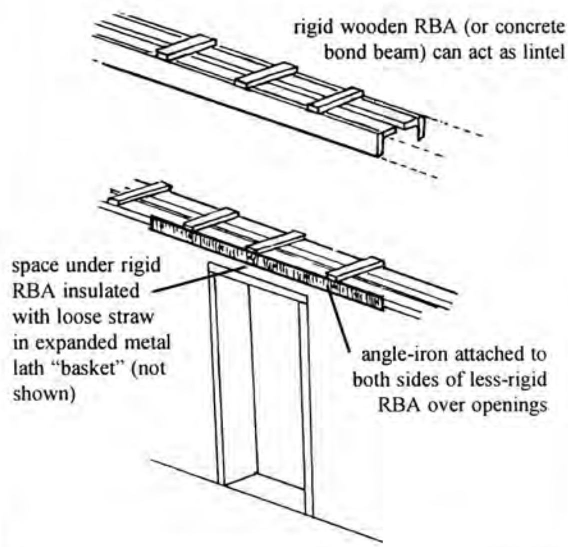
Nominal 2 inch [5 cm] thick lumber. For wider openings (i.e., greater loads) you may also want to use the box beam approach for the sides, as well.

Non-Loadbearing Options

Non-Loadbearing Door Frame and Lintel

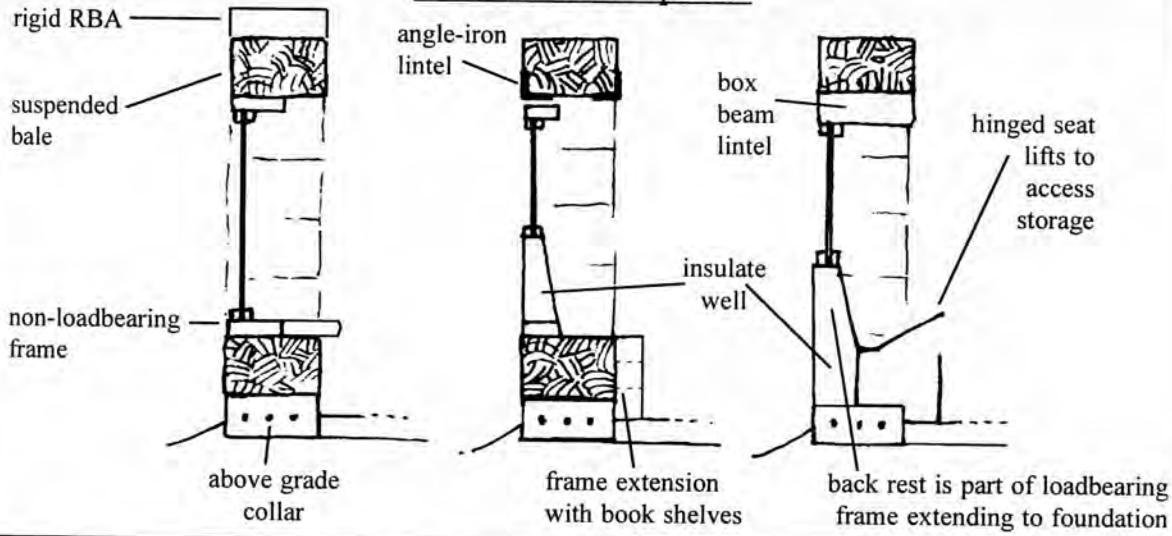


RBA As Lintel

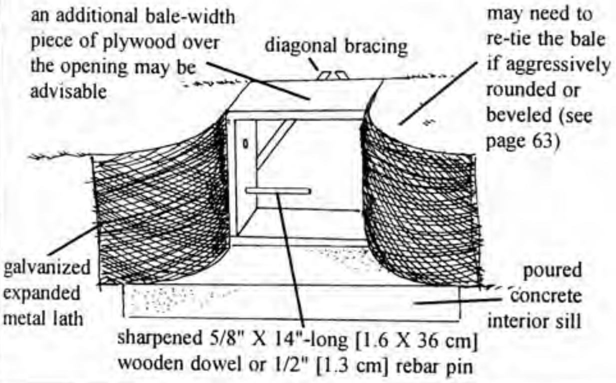


Some Details for Frames

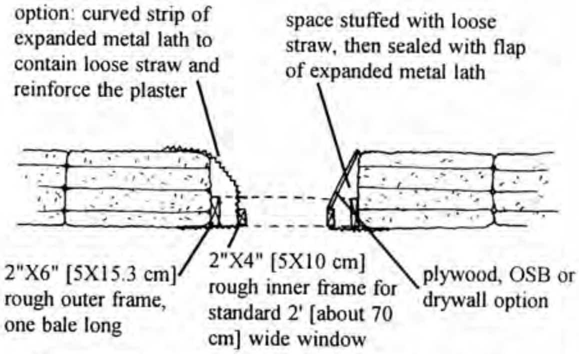
Window Seat Options



Creating Angled Openings by Modifying Bales

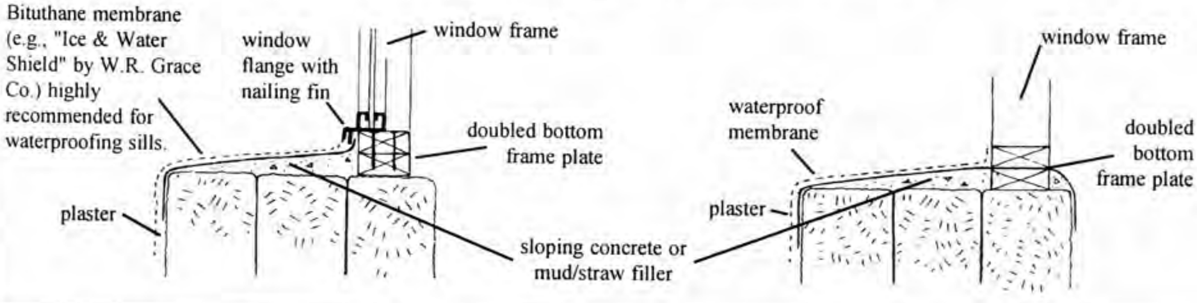


Creating Angled Window Openings via Carpentry*



Horizontal Section Through Window Frame

Creating Waterproof, Sloped Outer Sills**



* *See page 128 for same frame design, different use.* ** *See also page 59.*

Step 3. Raising the Walls

Challenge: to create sound walls that match your expectations for function and form, in a way that reflects your interest in human interaction.

Walk-Through

• *Have all your building materials, hardware, and tools assembled on the site, along with a First Aid Kit and dust masks for your workers. You should also have on hand brooms, rakes and a supply of large, sturdy garbage bags for storing the loose straw that you will periodically want to gather and remove from the working area.* ***Loose straw is a major fire hazard****. Keeping the site cleaned up will greatly reduce the risk of fire, will make the site safer for the workers and will reduce the likelihood that small (but very necessary) tools will disappear when laid on the ground (a bad idea in any case). Cleanup provides an ideal opportunity for even very young and very old volunteers to get meaningfully involved in the excitement. The bagged, loose straw comes in handy for filling cracks and stuffing openings as you build. Also, mixed with a clay-rich soil and water, it can be used to put a fireproof cap over the stuffed openings. Any that still remains will make great mulch for your organic garden. If the weather permits, uncover your bale-storage stacks to give them a final chance to become fully dry.*

♣ *You need to ensure that the bales will not be resting on a surface that becomes moist from water moving up from below. You can do this by having them rest on a material that will not "wick" water upward (e.g., pea gravel) or by sealing the surface they rest on with a waterproofing "membrane"* (e.g., *roofing felt, plastic sheeting, various asphalt-based compounds, or combinations thereof). Be careful to seal around the protruding rebar stubs ("imbalers") and any foundation bolts. As desired—or as required—install a termite barrier* (e.g., *galvanized sheet metal, appropriately bent).*

♣ *Install <u>sturdy</u>, temporary corner guides, as desired. These help keep the corners vertical and, with string lines pulled between them, can help you keep your walls (especially long ones) straight and vertical. When a corner guide gets knocked out of "plumb" (i.e., out of a vertical position), it becomes your enemy. It gives the false impression that the corner is still going up vertically, although it is not.* ***Attach your corner guides very securely and check them often for plumb****. Where two walls meet at a corner that is out of plumb, verticality can be achieved only by dismantling and rebuilding it.*

A building with only curved walls will have no place for corner guides, but similar guides can be erected to ensure that the walls go up vertically. You'll get smoother surfaces if you bend the bales.

• *If a large number of people will be assisting, it will help to break them up into working teams. These can consist of an experienced "wall captain" (for ongoing problem spotting and quality control) and four or five inexperienced members (for bale inspection, carrying, placing and pinning). It also helps to have a several two-person crews set up to make half- and custom-length bales. Be sure to have at least one bale needle for each crew (better yet, two).*

Encourage people to trade jobs occasionally.

• *If you have chosen to have your wall-raising be a "Y'all come!", community-building event, you will probably want to cordon off the work site from the socialization area.*

• *Before any bales are laid, it may be valuable to ask the workers to be mindful of job safety, to review with them the "rules of thumb" for laying bales (see page 63), and to inoculate them against the insidious "bale-laying frenzy".*

If you'll be having a lot of enthusiastic, but inexperienced, people help with the bale-stacking, you might want to ***get the first course of bales in place the previous day****. You'll want the first course "imbaled" such that they are properly lined up relative to the edges of the toe-up. This can be time-consuming and takes care and patience (the opposite of enthusiastic "bale frenzy"). The pre-positioning of the first-course bales also provides a pattern for the volunteers as they start the second course and hides the "imbalers" where people can't trip over them.*

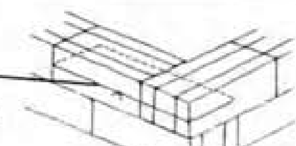
♣ *Start laying bales at corners and on both sides of door frames, lining them up accurately with the edge of the "foundation". At the door (and later, the window) frames, many builders leave a gap of about one-half inch [1.25 cm.] between the frame and the adjacent bales. This prevents the compressing bale walls from exerting enough pressure on the frames to deform them. A narrower gap will suffice in non-loadbearing walls.*

• *If an internal RBA tie-down system is being used, some bales will have to be lowered down over all-thread rods. With practice, and careful measuring and marking of the "insertion spot" on the bottom of the bale, one can generally get the bale to the desired location on the first try.*

♣*The bales in the second course are offset from the pattern set by the first course of bales, overlapping them in order to form a "running bond".*

♣ *You can increase the stability at corners by driving in one or two "staples", bent from short lengths of rebar, where the corner-forming bales butt in each course (see the large drawing on page 61). They can also be used in situations where additional connection between bales is desired (e.g., above a lintel). An alternative is shown below.*

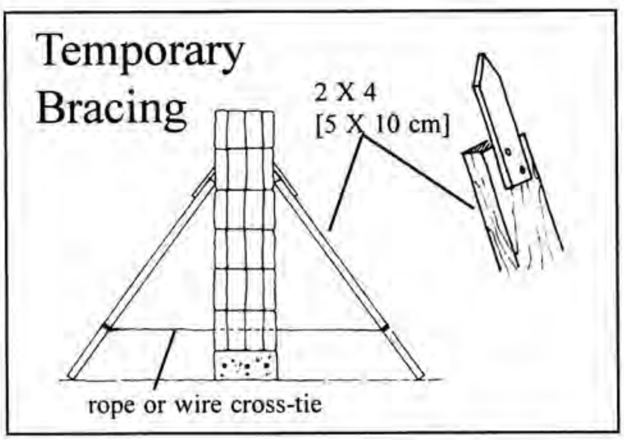
With help of needle tool, tie corner bales together with twine or baling wire



• *The last few bales that will complete a section of wall should be put in place temporarily so that you can measure the size of the gap, if any, or any overlap. If the gap or overlap is very small, you may be able to find and substitute longer or shorter bales. Otherwise, fill the gap (make into two gaps if larger than about 4 inches [1.2 cm]) with a "flake" from a "bad" bale, or adjust for the* *overlap by shortening a bale.*

• *If corner guides are not being used, make diligent use of a carpenter's level (attached to the edge of a straight board) to maintain verticality at the corners, the only part of the walls impossible to mechanically "tweak" (*i.e., *bash, pound, or push into place) after they are finished. Since corners typically end up sloping slightly outward, some builders try to slope the tops of the walls slightly inward at the corners to compensate for this phenomenon.*

• ***Temporarily brace any long, tall walls, especially in windy regions.*** *One simple and effective system for bracing such walls is shown below.*



• *If your design includes long, and/or tall walls, you may also want to incorporate one or more horizontal or vertical elements to stiffen or buttress them. To be effective in a loadbearing wall, horizontal elements must span the entire distance between adjacent, right-angle, buttressing walls and be firmly attached to them. Since such elements are more commonly used in non-loadbearing designs, we have provided more detailed information in* Step 5 *of the* Non-Loadbearing Option.

♣ *The door frames will have been fastened to the foundation before any bales are laid, but window frames, except in the rare case where they will sit on the foundation, cannot be set in place until the proper wall height is reached. After a waterproof covering has been placed over the wall at the correct location along the length of the wall, the frame can be positioned within the wall width as previously determined. Many choose to maximize the interior sill-shelf, and minimize potential water damage, by mounting the windows essentially flush to the outside surface. An exception might be south-facing windows, in a design without roof overhangs, where small windows can be shaded from summer sun by placement to the inside, above a well-sloped and well-waterproofed exterior sill (see the bottom diagram on page 56). Whatever placement is chosen, the frames should then be braced as needed to keep them safely upright. Using a bubble level, check the bottom, horizontal member of each frame to ensure that it is level and stays that way as the wall goes up. Shim under it as needed.*

• ***It's surprisingly easy, if bale frenzy creeps in, to forget to put in a window frame at the right time and/or place.*** *To avoid such embarrassing lapses of attention, post enlarged versions of your wall maps (see page 36, bottom right) in front of each wall, outside the building. One easy option for posting is to stack several bales, put the map on this "table", and cover it with a piece of transparent plastic held down with Roberta Pins (see page 92).*

All members of the wall team, but especially the wall captain, should familiarize themselves with the map of their wall and should refer to it repeatedly. If, however, you still leave out or incorrectly place a frame, the damage can be easily repaired if you catch the error before the roof-bearing assembly (RBA) is on the walls. You just pull out pins *and remove bales as necessary, put the waterproof covering in place, install the frame on it and rebuild the wall. It is possible to retrofit small windows into completed walls, even after they have been surfaced, but it's a lot easier to get them in as the wall goes up.*

• *If aggressively angled or rounded bales are to be used to widen the interior wall opening at doors or windows, they should be customized and placed on either side of the frames as the wall goes up. Minor rounding can be done after the walls are up. An alternative is to make the frame wider than the door or window and use carpentry to create the bevel on the sides of the opening (see the diagram on page 56).*

♣ *Bale pinning normally takes place as the walls are being raised, often starting at the fourth course. At window locations, short pins can be driven into the bales beneath the frame, either before or after it is placed on the wall.*

It might seem rational to pound the pins in until they are out of sight, since this would ensure that no one could trip over them. Experience suggests that this technique has the major disadvantage that you then can't easily tell where you have already pinned. So, we recommend leaving them just barely visible—no tripping, no frustrating searches!

Rebar pins can account for a large percentage of the total embodied energy in the wall, reducing the overall "sustainability" of the design. Consider using bamboo or willow!*

• *Above non-loadbearing frames, some kind of lintel will be needed to bridge across the opening. It distributes the roof and/or wall weight, resulting from materials above the opening, to the bale walls on either side. A generally accepted "rule of thumb" for lintels placed just above a frame in loadbearing walls is that the lintels should extend out onto the walls on both sides for a distance equal to at least half the width of the opening. Increase this distance if the bales at the opening are significantly rounded or angled. Use of the RBA as a lintel over openings is covered in* Step 4.

• *Every few courses, check for level and shim with loose straw if necessary. After each course, stuff gaps and depressions with loose straw. Do not force straw into gaps, as that can push a corner bale out of position.*

• *When the walls have been raised to the desired height, a waterproof covering should be placed along their tops to protect them from rain or snow until the roof has been sheathed. Many builders choose to leave this "cap" in place under the RBA to protect the top of the walls against eventual roof leakage.*

With all the bales in place, now is a good time to mechanically "tweak" (e.g., beat, bash, ram, brace) the walls until they are acceptably smooth (i.e., planar) and vertical. If you tend to be compulsive about such things, remember that part of the charm of a straw-bale house can be the "soft irregularity" of the walls.

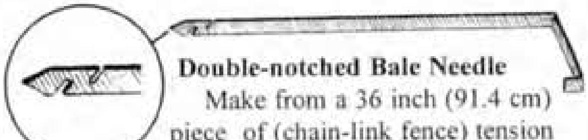
• *Check the walls carefully, inside and out, to make sure that all of the openings are completely stuffed with loose straw. To reduce the risk of fire, some builders go one step further, using a mix of clay-rich soil and straw (use the stuff gathered during your cleanups) to cap all the openings. Should you later surface the walls with a cement-based material, you won't be using an expensive, high-embodied-energy material to fill depressions.*

• *Finally, if you have chosen to spray the walls with a fire-retardant solution, this is a logical time to do it. For additional information, see page 19.*

* "Embodied energy" is defined here as the total amount of non-renewable energy used to create a unit weight of a given material.

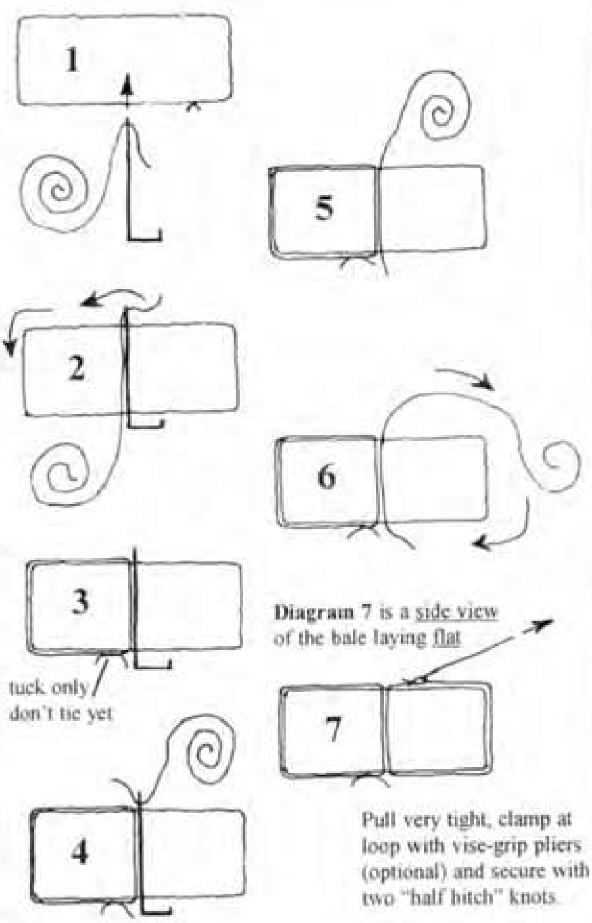
Customizing Bales

Walls stacked in "running bond" require customized, shorter bales where the walls end against door and window frames. As shown below, first create tight new ties to contain the mini-bales. Then cut the original ties, at the knot, to get the maximum reusable length of twine or wire.

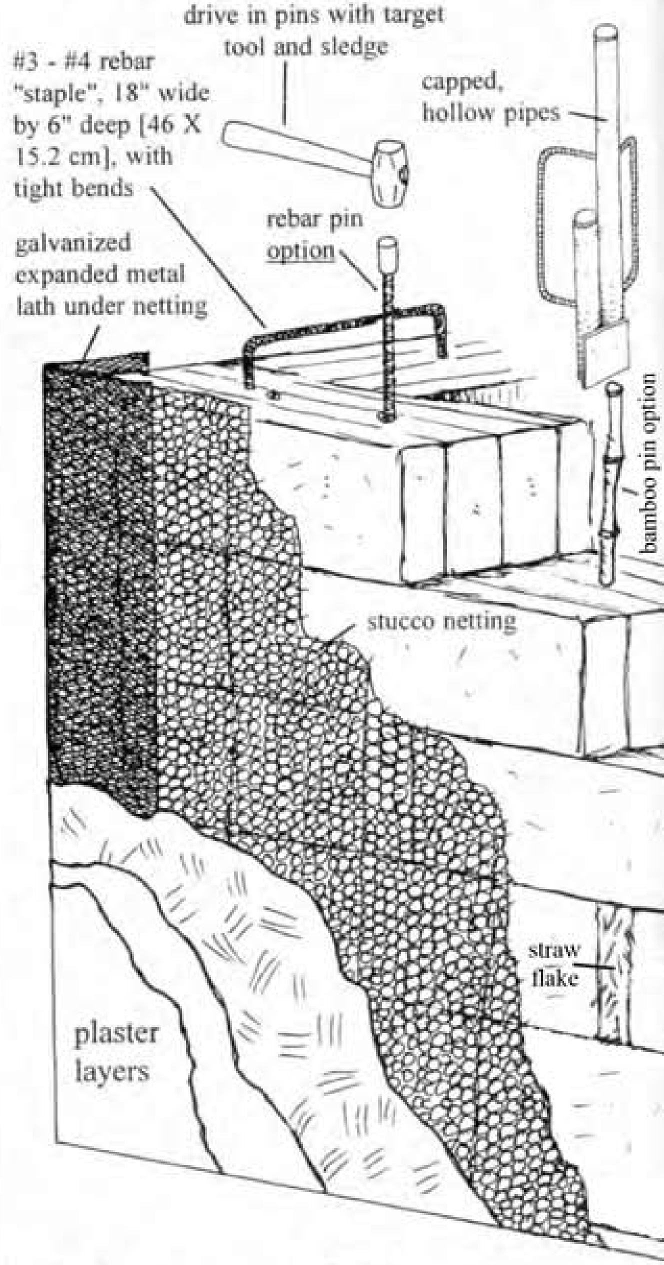


Double-notched Bale Needle
Make from a 36 inch (91.4 cm) piece of (chain-link fence) tension bar or purchase from OOB-By Mail, 1037 E. Linden St., Tucson, AZ 85719.

Diagrams 1 through 6 are views from above of a bale sitting on edge.



Building the Wall



Options for Target Tools

Square or round steel bar with hole. Lifetime guarantee!

Gas pipe nipple. Least durable.

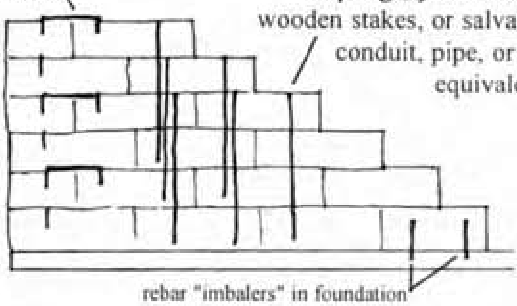
Heavy-wall pipe (even then, cracks eventually at weld).

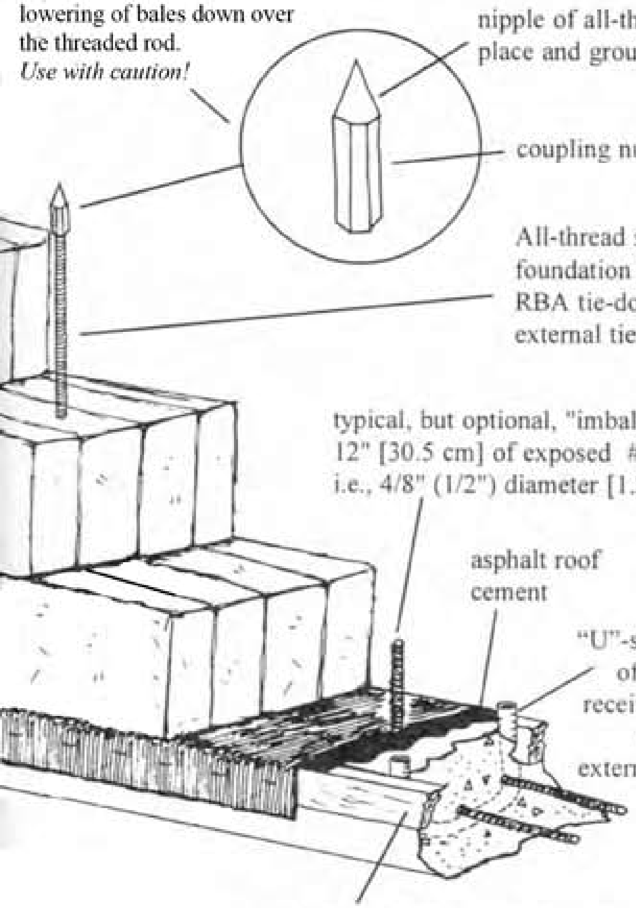
Bale Pinning

Popular Pinning System for Loadbearing Designs with 3-Tie Bales Laid Flat

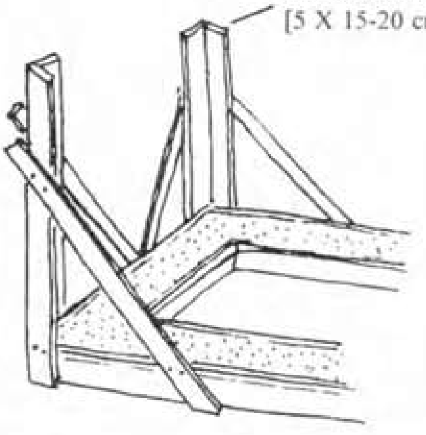
Variations:

1. Short pins, two per bale, penetrating three courses at a time. Start with third course and repeat with all subsequent courses.
2. Eight-ft-long [2.5 m], sharpened "pins" of #5 rebar, two per bale, penetrating the full height of the wall. This technique provides no wall stiffening until the whole wall is up.
3. No pins. In a loadbearing building, once the roof load is on the bales, the pins may not be of much further value for resisting lateral forces. Additional testing is needed here.





Temporary Corner Guides



Rules of Thumb for Laying Bales

1. Start with good bales. **Inspect each bale before placing it on the wall**. Straighten if necessary. Use really "bad" bales for flakes.

2. **Know the details of the wall you are working on**. Consult, often, the wall map posted in front of your wall.

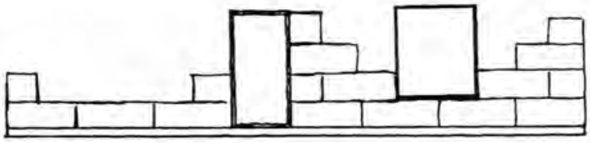
3. **Start laying at corners and door frames; later at window frames**. Leave a small gap between the frame and the adjacent bale. Regularly check frames for level.

4. **Monitor corners carefully to keep them vertical** (or sloping slightly inward). Secure corners with staples or by tying.

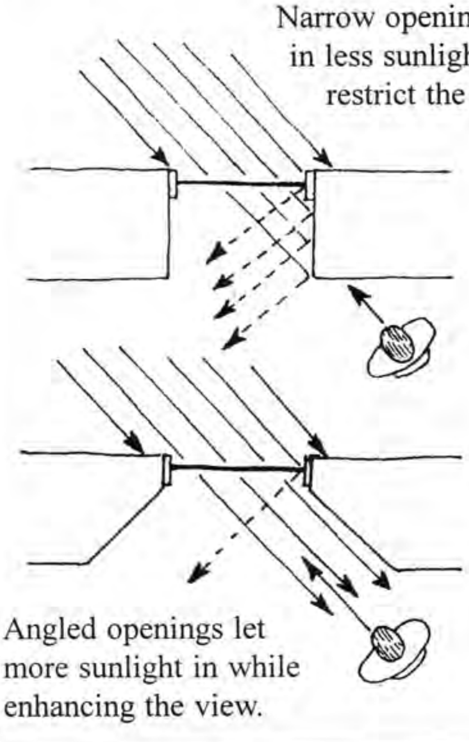
5. **Never cram a bale or a flake into place**; cramming can push corner bales out of position and can bend inward the sides of door and window frames, or push them out of square. **Take your time; pay attention to details.**

7. **When a whole course is finished, stomp the bales down into place.** This gets some of the wall settling done immediately.

8. **Before starting each new course of bales, gently fill with loose straw all gaps or depressions** between bales, and any gaps between bales and frames.

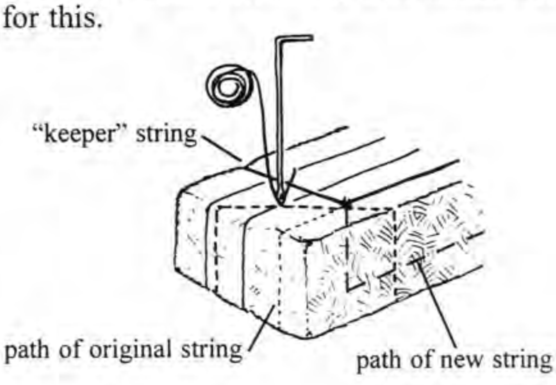


Angled Openings



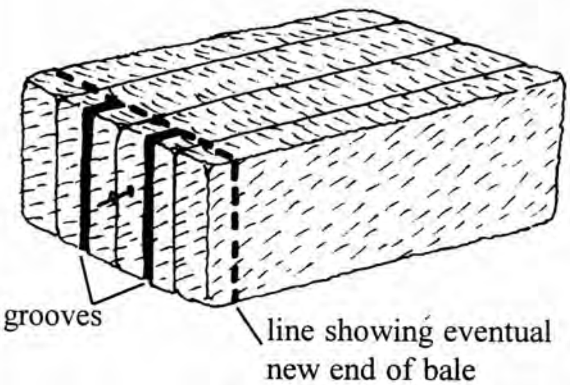
Making Angled Bales

1. Create new shorter ties to allow for the bevel.
2. Add "keeper" strings that run to same new string on underside. These keep the new strings from sliding off the beveled end.
3. Cut original strings at knot and remove.
4. <u>Carefully</u> remove unwanted straw. A chainsaw, bow saw, or hay saw works well for this.



Shortening a Bale Slightly

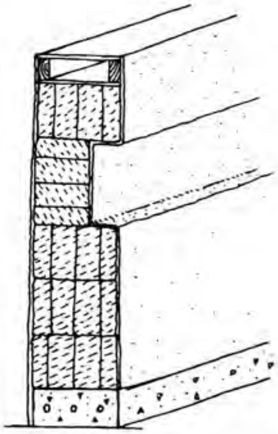
If you need to shorten a bale by only a small amount, try using this technique rather than installing three new strings. You can even shorten the exposed end of a bale that is already part of a wall (e.g., at a corner).



1. Using a saw or grinder-mounted tool (see page 83), cut two grooves, as shown, to the required depth.
2. With the claw of a hammer, or the equivalent, remove the straw that is between the two grooves.
3. Using a large nail, or the equivalent, tighten the middle string, by twisting the nail, until it is as tight as the outside strings. Tie the nail to the string to prevent untwisting.
4. Repeat these steps with one outside string, then the other.

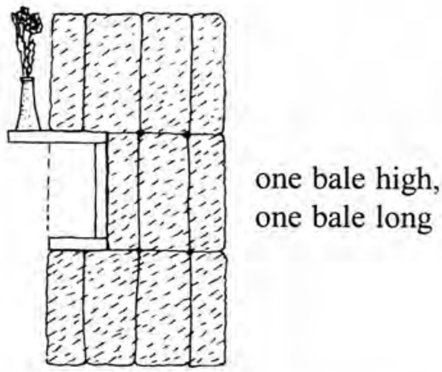
Kinky Bale-Laying Options

Super Shelf



In a loadbearing wall, the on-edge bale should be centered on the bale below.

Instant Niche



Slab of straw cut off with a chainsaw before bale put in place.