Step 4. Roof-Bearing Assemblies

Challenge: First, to have previously selected, from a wide variety of options, the combination of roof-bearing assembly (RBA) and tie-down system that is "right" for you and for your design. Second, to get the segments of your RBA safely up onto the wall (unless you have chosen to create the RBA in place, on top of the wall) and to make strong connections where they meet. Third, to "tie" this assembly to the foundation in such a way that the maximum expected wind velocity (a.k.a. the design wind load) cannot turn the RBA/roof into an ILFO (identified low-flying object).

Walk-Through

• *During the process of finalizing your design and creating plans, you will have selected the type of RBA to be used. Among the factors that can influence this decision are:*

—whether the RBA will act as a lintel over openings; [This would allow you to use less wood in creating the nonbearing door and window frames, but may bring you to use more wood in the RBA itself. It will guarantee a straight, and probably level, roof line, but may limit the number and size of openings, since the load is concentrated on the bale columns between openings.]

—the distance between the points on the RBA at which the trusses/rafters/vigas/ wooden I-beams concentrate the roof load, the magnitude of the load at each point and whether it is the same for each point;

—the degree of compactness of the bales that the RBA will rest on;

—and, your various concerns about the materials required for the different options (e.g., regional availability for purchase or scavenging, cost [planetary and pecuniary], the tools and skills required to work with them).

You will have also decided whether it will extend continuously around the structure. Every wall carrying any roof load will need an RBA, but modern roof designs for square and rectangular buildings very seldom bear on more than two of the four walls (assuming a square or rectangular building). Even so, one might still choose to have the RBA be a continuous collar, in order to tie the whole building together. A rigid, continuous RBA could also serve as the lintel over all door and window openings in the building, thus enabling all the frames to be similar (lightweight, non-loadbearing). It would also distribute some of the roof load (otherwise carried entirely by the columns of bales between the openings in two of the walls) onto the other two walls.

There are, however, advantages to having the RBA discontinuous (i.e., only on the two loadbearing walls). It saves labor and the cost of materials (both to the planet and the wallet). If the roof design is a gable, and if bales are going to be used to fill in the eaves (the triangular areas formed by the sloping roof surfaces), builders often put in a light-weight horizontal stiffener at the level of the separate RBA's, before stacking bales to fill the triangles. If securely fastened at both ends to the RBA's, it can provide some of the collar-benefit of a continuous RBA. *For more on stiffeners, see page 130.*

• *Before you can fabricate your RBA, you must decide how to dimension it. It is typical to make the width slightly less than the average width of the bales. This ensures that the RBA, which generally acts as the nailer for the stucco netting, does not extend out beyond the edge of the bale wall at any point. Choosing the length dimensions is more complicated. There are two obvious approaches, each with potential advantages:*

1) Use the foundation dimensions, taking into consideration whatever setback you want to have from the edge of the bales. The advantages to this approach are that you can finish building all the segments of the RBA before the wall-raising is finished, that any pre-ordered trusses are guaranteed to fit , as planned, on it; and that you will be mightily motivated to end up with dimensions at the top of the wall that are real close to those at the bottom.

2) Use the actual dimensions of the top of your finished walls as your starting point. The advantage to this approach is that you can customize both the width and length dimensions to accommodate the actual shape and dimensions of your wall top (if this is your first building, you will be lucky not to end up with walls that flare out a little). Possible disadvantages are that you must leave some segments of the RBA unbuilt until the walls are finished, and that you may not be able (depending on their design) to pre-order trusses.

♣ *For the type of RBA on our "model" building, fabricate the roof bearing assembly on the ground in transportable sections. Then move these sections to the top of the wall and connect them, taking care to get strong connections between sections (especially at corners). Make sure that the diagonals are also as nearly equal as possible and that the walls are properly aligned and secured under the RBA. If your system for keeping the top of the wall centered under the RBA involves putting holes in whatever is acting as the waterproof cap, be sure to carefully seal any openings through which water could get down into the bales.*

♣ *Unless your RBA already adequately protects the top of the walls from invasion by rodents, deny them access by utilizing various materials (*e.g., *cement-based mortar, metal lath, sheet metal, plywood scraps, old boards) alone or in combination.*

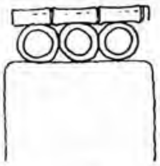
♣ *With your wall tops positioned, as appropriate, under the RBA and with the chosen mechanism in place to keep them in this position, "tie" the RBA securely to the foundation. For our "model", we have chosen an external tie-down system (e.g., polyester cord strapping with buckles or crimped seals). "U"-shaped pieces of "tubing" (e.g., irrigation distribution line, salvaged hose), positioned at a chosen interval in the foundation, provide sleeves for the strapping. You will, hopefully, have taken steps to ensure that no concrete could get into the tubing when you were doing your pour.*

Straight pieces of plastic pipe, passing horizontally through a "collar" type foundation, have also been used for sleeves. However, even with bevels created at the openings where the strapping cord emerges, the right-angle bend may put unwanted, extra stress on the strapping at these points.

Regardless of the type of sleeve used, however, care must also be taken to ensure that sharp corners have been eliminated where the strapping passes over the RBA. Small pieces of sheet metal, bent to make a right angle, work well. Or, you can buy pre-bent metal gizmos (e.g., Simpson A35s) at a construction supply yard.

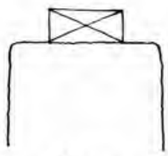
Options for RBA's

Least Rigid

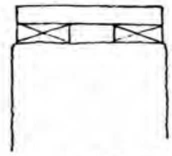


Bamboo

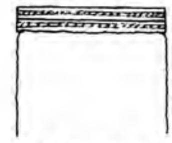
Plank or TJI



Beam



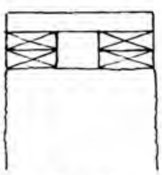
Single 2"X6"* Ladder



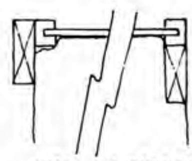
2 Sheets of Plywood or OSB

* Could be used with loadbearing window frames and angle iron to stiffen it over a non-loadbearing door frame.

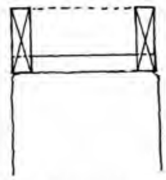
More Rigid



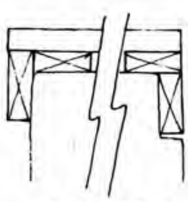
Double 2"X6" Ladder



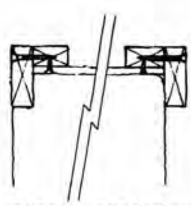
TJI and 2"X6"



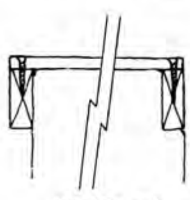
Mongolian (see next page)



Two 2"X6"s w/2"X4" cleats

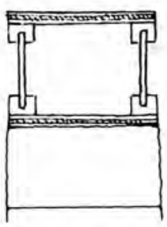


2"X6", 2"X4" w/ continuous plywood "web"

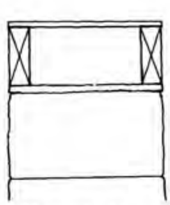


2"X6" w/ plywood

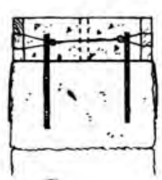
Most Rigid



TJI with plywood (closed box)



2"X6" w/ plywood (closed box)



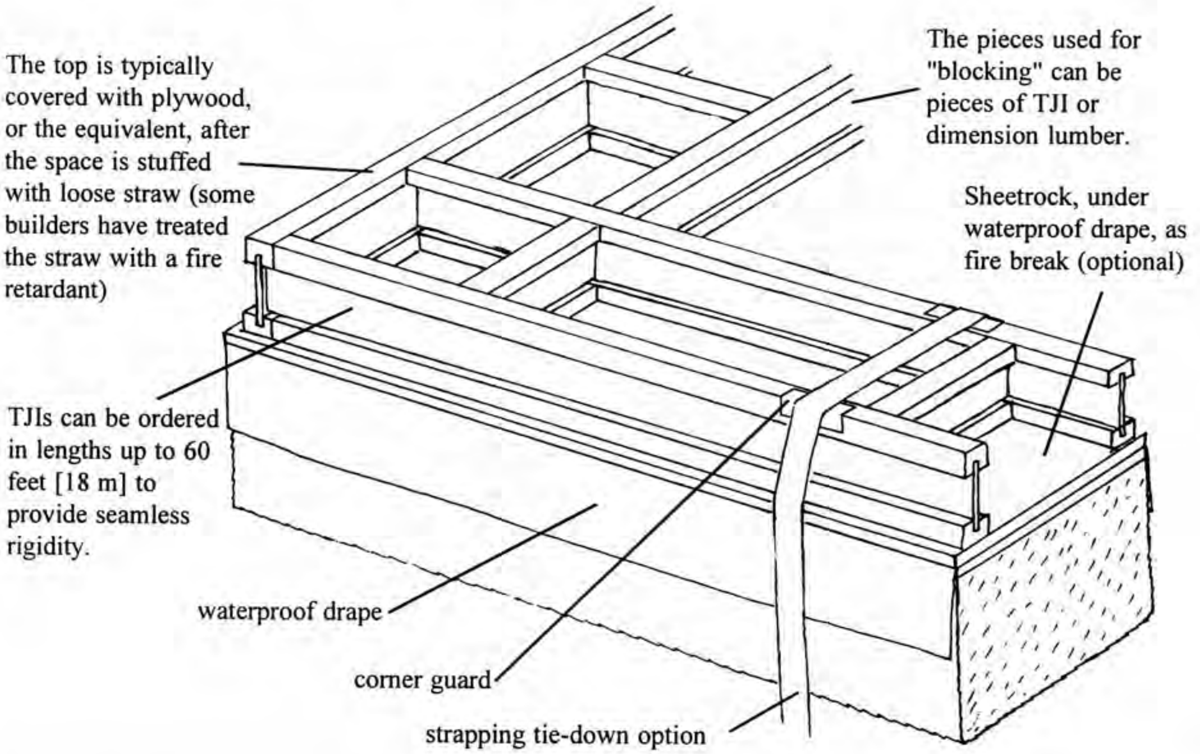
Concrete Bond Beam

(added weight will shorten permissible spans; see page 31)

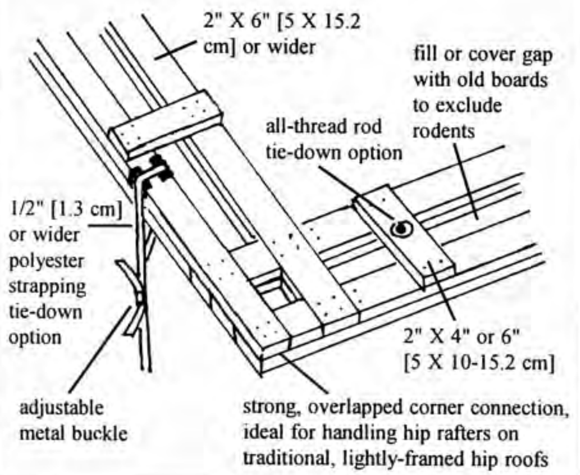
Note: 2" X 4" [5 X 10 cm] and 2" X 6" [5 X 15 cm]

Some Examples of RBAs

Truss Joist I-Beam (TJI) Box

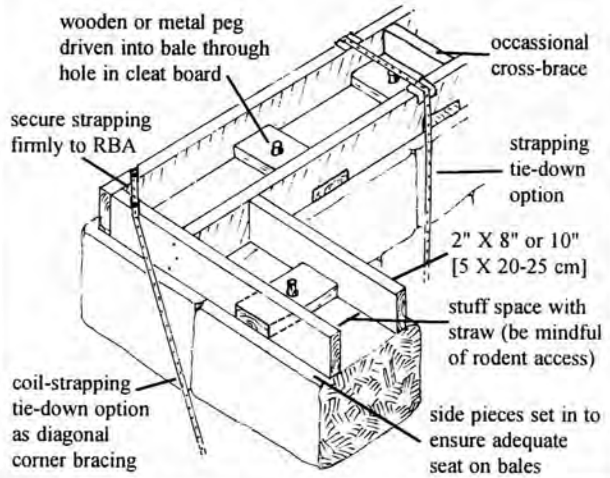


Double-Layer Ladder-Type



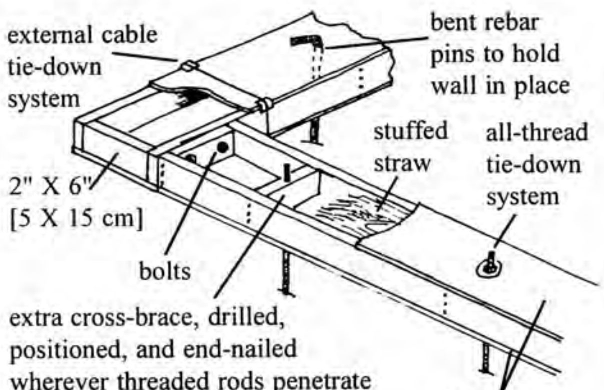
Mongolian Prototype

(suggested by Dan Smith & Associates)

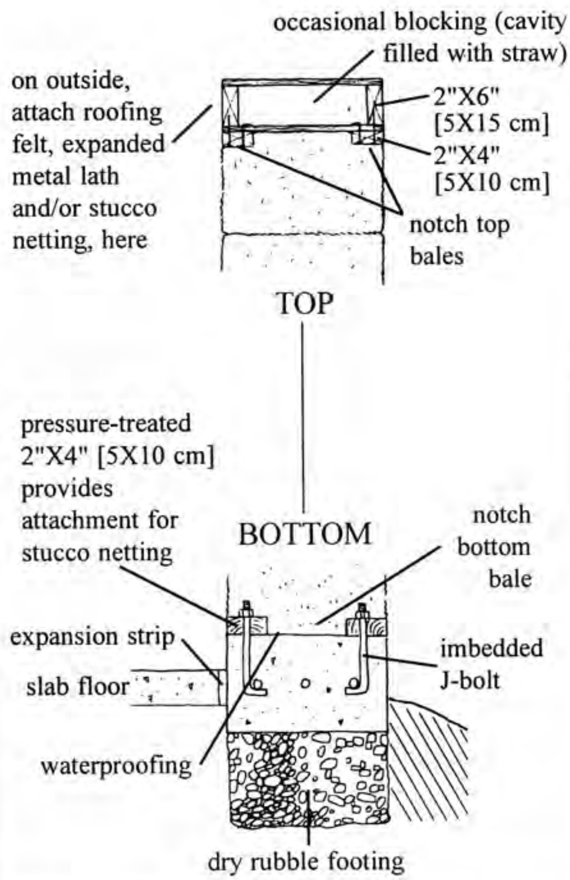


Seismic Considerations

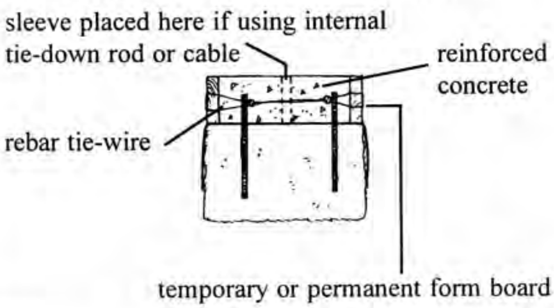
Wooden Box Beam



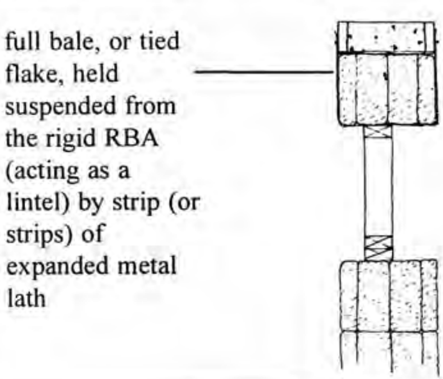
(*suggested by Bob Theis*)

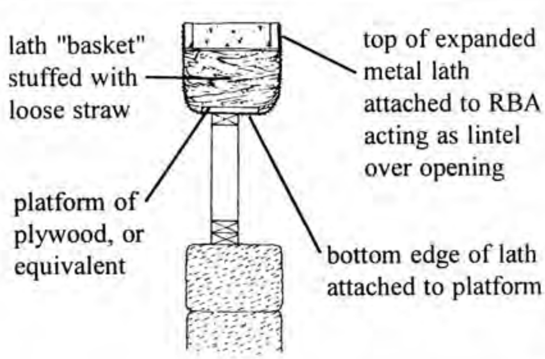


Concrete Bond Beam



Filling the Gap Between Rigid RBA and Frames





Tie-Down Systems: General Considerations

In non-loadbearing designs, the framework that supports the roof load also ties the roof to the foundation, or to the ground, itself. Lacking this framework, loadbearing designs almost always include some mechanism to keep the roof from lifting off. In the historic Nebraska structures, metal or wooden stakes were driven at an angle down into the walls and the fastened to the rudimentary RBA. There is no evidence to indicate that this was not adequate for that situation (hipped roofs with minimal overhangs), but caution (and the concerns of engineers and building officials) have led most modern builders to create ties from the RBA to the foundation.

In a design involving no use of stucco netting, inside or out, the tie-down system (arguably) continues to perform an important function, even after the surface coating is in place. This will be especially true if seismic forces or differential settling of the foundation ever cracked this coating. If, however, cement-based plaster has been applied over stucco netting (especially if applied in vertical strips fastened securely to both the RBA and the foundation), any previously installed tie-down system is then relegated to a strictly backup role. This assumes, of course, that the structural integrity of this plaster-membrane tie-down remains intact for the life-span of the building. For description of a system that uses stucco netting as the only tie-down (Look, Ma, no backup!), see page 73.

Several builders have experimented with placing the tie-down system outside the stucco netting, to hold the curtain of netting against the bales. Through-ties, connecting the inner part to the outer part of a loop of wire, cable or strapping, would further increase the effectiveness of these loops, perhaps making any other tie-throughs unnecessary. One possible chronology for this idea would be as follows:

1) Attach vertically oriented strips of stucco netting to the RBA as soon as it is in place.

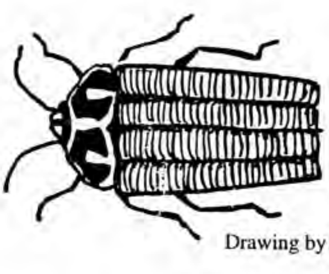
2) Insert lengths of strapping through sleeves in the foundation, passing one end of each length up over the RBA.

3) Fasten the two ends of each length together with a metal buckle, hand-tightening periodically to take the slack out of the strapping as the walls settle under the roof load.

4) When the settling is complete, and just before hand-tightening the strapping for the last time, pull down on the stucco netting and fasten it securely to a wooden nailer attached to the side or top of the foundation.

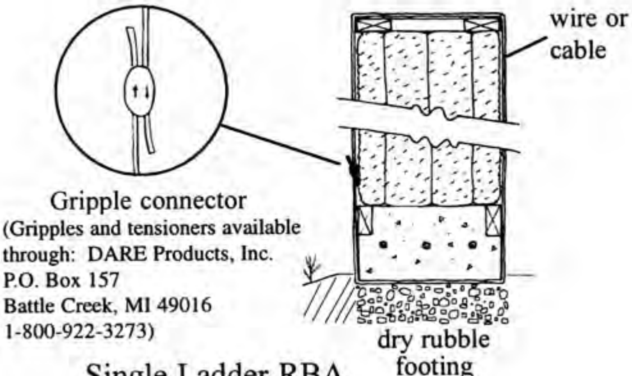
5) Now, hand tighten the strapping one last time.

6) Complete the process by creating some through-ties, to connect the strapping on the inside to that on the outside.

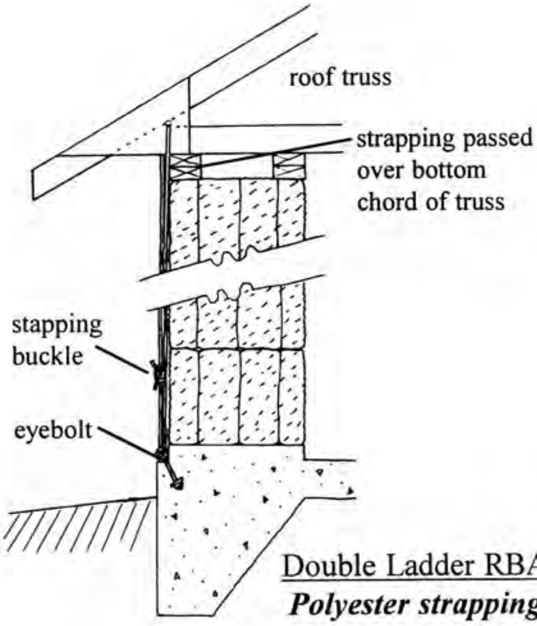


Drawing by Arlen Raikes

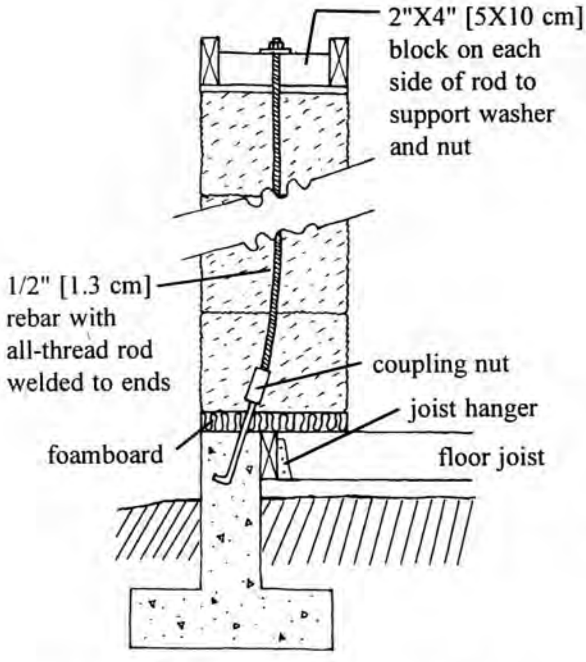
Tie-Down Options



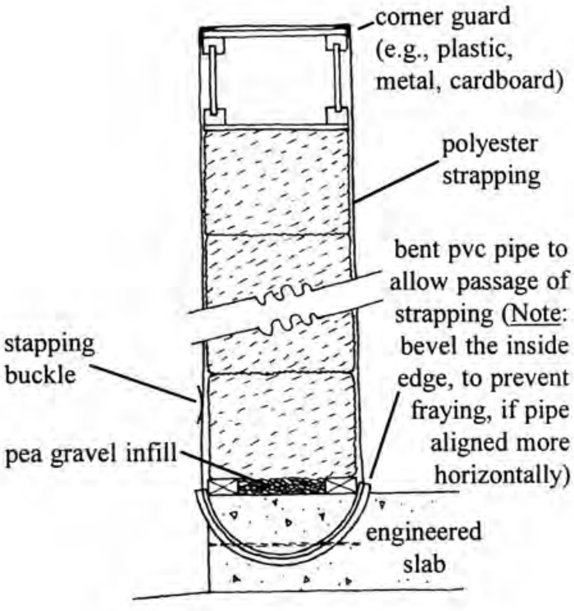
Single Ladder RBA
Heavy Wire or Cable
Under Grade Beam



Double Ladder RBA
Polyester strapping
Eyebolt



Moderately Rigid Open Box RBA
"All-thread" rod/rebar
J-bolt



Rigid TJI RBA
Polyester strapping
PVC pipe in grade beam

Tie-Down Strength and Spacing - Assessing What is Needed

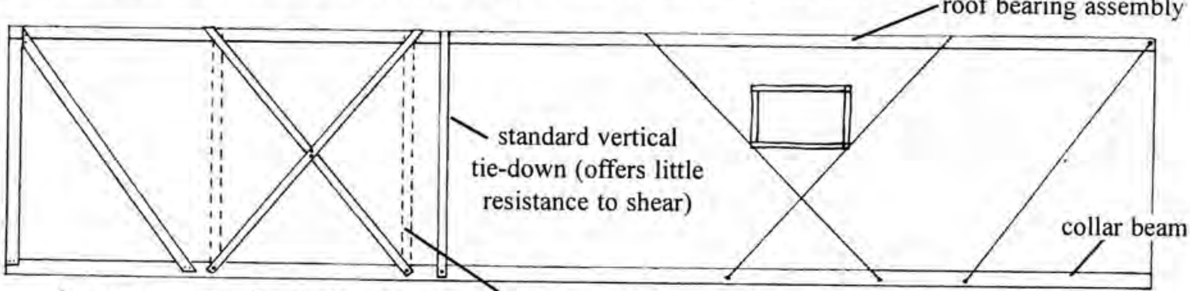
It's easy to guesstimate that a shed roof with no overhangs, on a small building, might need no other tie-down than its own weight. However, given a high profile roof, with large overhangs, on a large building, in an area with a design wind load of 120 mph (3.2 km/second), even the bravest (or most foolhardy) of us all might be reluctant to stake the stability of our roof on a guess.

To start with, we would want to know the maximum uplift that our tie-down system would conceivably have to resist. For a small, simple building, you may choose to do the calculation yourself, using formulas such as those provided in Cole and Wing (1976). Or, regardless of the size of the structure, you can have an engineer or architect do this for you. Once you know the number of pounds of upward force to be resisted by all the tie-downs along a given wall, divide this number by a conservative value for the safe working load for a given type of tie-down, to determine how many such tie-downs should be placed along that wall. Consider arranging the tie-downs in groups of two or three per location along the wall, thus reducing the number of sleeves or pieces of attachment hardware. Remember that one long piece of strapping, passed three times through a sleeve and over the RBA and then fastened, has far less strength than three separate loops fastened individually.

Manufacturers often provide information on the breaking strength (a.k.a. tensile strength) of things like cable and strapping, but seldom say whether it, or the connection (e.g., clamp, seal or buckle), will fail first. Talk to the technical representative at the company, and try to get her/him to provide the safe working load for the product as combined with the connector you wish to use.

Increasing the Wall's Resistance to Shear Forces

(Tie-down systems as backup to the wall surfacing materials)



Tie-Downs as Pre-Stressing Mechanisms

Modern builders, being the impatient souls that we are, have long dreamed of finding a simple way of using the tie-down system to pre-stress (i.e., mechanically compress) the walls, prior to putting the roof on. This would permit immediate application of exterior plaster to protect the walls. Ideally, the compressing mechanism would apply a load in excess of any eventual, combined dead and live loads, further stiffening the walls. Even with mud plaster (and perhaps without pinning) the walls could then withstand heavy wind loads without unacceptable deformation or cracking.

Starting with what was already being used for tie-downs, initial attempts were made to use the in-the-wall, threaded rod system to pull down the RBA, thereby pre-stressing the bales. Unfortunately, it was found that the threads would strip before sufficient compression had been achieved. Then, thanks to the sharp eye of Greenfire Institute's Ted Butchart, along came the Gripple. This small metal disc contains cams that allow a wire or cable to pass through the disc in one direction only. Combined with a tensioning tool, this offered the potential of using a loop of wire or cable to pull down on the RBA with enough force to pre-stress the walls. Unfortunately, at least when used with a rigid RBA, no individual loop can be tensioned enough to pull the whole RBA down significantly.

Hope was fading fast when, in the great tradition of the Royal Canadian Mounted Police, the barking of sled dogs was heard in the distance. Onto the scene, from Ottawa, came engineer Bob Platts and architect Linda Chapman, with an ingenious system that involves inflation.

Here's how it works. After building the walls without pins (but utilizing a system for temporary external bracing), they create a light, wood-frugal RBA, onto which they lay a long, narrow, inflatable tube. On this tube they lay a ladder-like assembly that has the equivalent of hooks sticking out on both sides. Having secured the bottom end of strips of wire netting to the foundation or toe-up, they then push the top end of each strip over the hooks. This is done both inside and out. Now the fun begins, as they slowly inflate the tube. Since the "ladder" can't go up (being held down by the netting), the RBA has to go down, compressing the bales as it does so. This arrangement has the tremendous advantage of applying the downward force both uniformly and simultaneously along the whole length of the RBA. Using numbers derived from the roof design, the live load for the location and structural testing, a target for compression is determined. When this amount of compression has been achieved, the netting is securely fastened to the sides of the RBA before the ladder and tube are removed.

Testing of pin-less walls, pre-stressed with this system, has shown them to be as resistant to wind loading (at right angles to the wall), as similarly pre-stressed walls pinned in the normal fashion (see *The Last Straw*, Issue No. 14, page 14). This suggests that, unless the pins in a pre-stressed wall contribute to the wall's shear strength (i.e., its resistance to being changed from a rectangle to a parallelogram), the pins are serving no structural purpose. Imagine not having to pin! For more information on this intriguing system, contact Bob and Linda at Fibrehouse Limited, 27 Third Ave., Ottawa, Ontario, Canada, K1S 2J5; tel/fax (613) 231-4690; e-mail: <fibre@freenet.carleton.ca>.

Step 5. Adding the Roof

Challenge: to create a sheltering cap (some combination of ceiling, and/or roof, and insulation) that 1) is securely attached to the roof-bearing assembly, 2) protects the tops of your walls and your interior spaces from the elements, 3) adequately retards the movement of heat, and 4) does this efficiently (re: cost, materials, labor).

Walk-Through

• *You will, of course, have chosen a particular roof shape during the design process. Our experience leads us to strongly favor shapes that will allow for overhangs (the wetter the climate, the bigger the overhang) and for guttering, to prevent splash back onto the base of the walls. Should dedication to a regional architectural style, personal preference, or deed restrictions "demand" the use of parapet walls (low extensions of the walls above the roof line), we suggest using a low-pitch, shed roof with parapets on only three sides (as illustrated on the next page). This enables water to move unimpeded off the roof, preferably into a gutter. Even then, very savvy detailing is needed to prevent any water from getting into the base of the parapet, and from there, down into the bales. For one architect's version of a (hopefully) leak proof parapet detail, see* Issue 8, *page 28, of* The Last Straw. *Although bales have sometimes been used to form the parapets, it is more common to frame them, using more wood but less waterproof membrane and plaster.*

♣ *Fabricate the central part of the roof skeleton, using identical homemade or commercial trusses. Complete the end hips, using hip trusses or traditional framing. Double up the two end trusses if your hip system concentrates extra load on them.*

♣ *Brace the roof skeleton as it grows, leaving this bracing permanently in place where appropriate.*

♣ *Securely attach all trusses (and any rafters) to the outside edge of the RBA using the appropriate connectors (a.k.a. hurricane ties or the equivalent). A strong tie-down system for the RBA will mean nothing if these attachments are weak.*

♣ *Attach 2" X 4" [5 X 10 cm] purlin strips, at 2' [0.6 m] intervals, to the roof framework.*

• *Fasten 26-gauge metal roofing to the purlins with special, self-tapping screws equipped with neoprene washers, using standard caulking strips where adjacent panels overlap.*

♣ *Create screened, louvered, attic vents in the gablets at each end of the roof peak, installing proper flashing where the bottom edge of the triangular gablet meets the sloping metal roof.*

If designs with gabled roofs, consider installing a prefabricated ridge vent to provide venting along the entire ridge line. ***Don't underestimate the value of adequate venting****. In hot climates (see Cook 1989), it will keep your house cooler. In cold climates (see Nisson and Dutt 1985; Lenchek et al. 1987), it will prevent problematical moisture buildup.*

♣ *Attach some material to the underside of the overhang created by the ends of the trusses/rafters, leaving adequate, screened vents to allow air movement up into the attic space.*

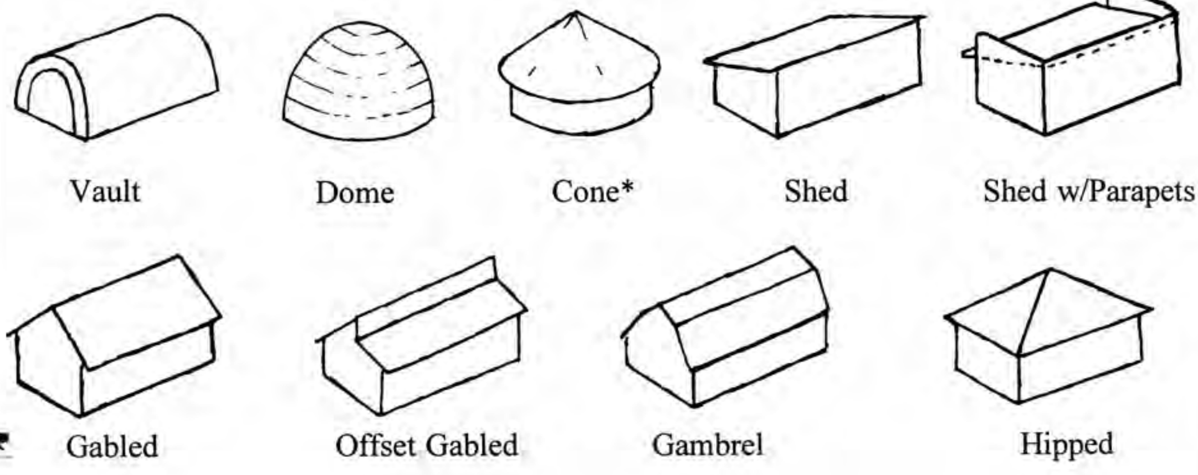
• *With the roof skin now in place, move inside and install any radiant heat barriers following manufacturer's directions. These barriers can be particularly effective in reducing cooling requirements in very hot climates. For an excellent overview of this option, see Nisson (1990).*

♣ *Install all necessary ducting, stove pipe brackets, electrical boxes (e.g., for overhead lights, smoke detectors, fans), wiring and plumbing in the attic space.*

♣ *Install the ceiling material(s) and insulate (or vice versa). Be sure to provide a way to easily gain access to the attic space. If the access is from a space that is heated or cooled, make sure that the removable panel is well-insulated.*

Don't assume that just because your bale walls have a high R- or RSI-value, you can skimp on ceiling/roof insulation and have an energy-efficient building. *The bigger the building, the bigger the ceiling area relative to the total interior surface area of bale walls. For a building with 1200 square feet [111.5 square meters] of usable interior space and eight foot [2.44 m] high walls, the ceiling area is virtually the same as the wall area. For a larger building, the ceiling area will exceed that of the walls. It may not be cost-efficient to create as high an R-value [RSI-value] in the ceiling as you'll have in the walls, but do try to achieve the levels recommended for superinsulated designs for your climatic conditions. For recommendations, consult local architects/ designers that specialize in energy-efficient design, your state Energy Office or selected books (e.g., Nisson and Dutt 1985, Lenchek et al. 1987, Cook 1989, Lstiburek 1997).*

Some Standard Roof Shapes

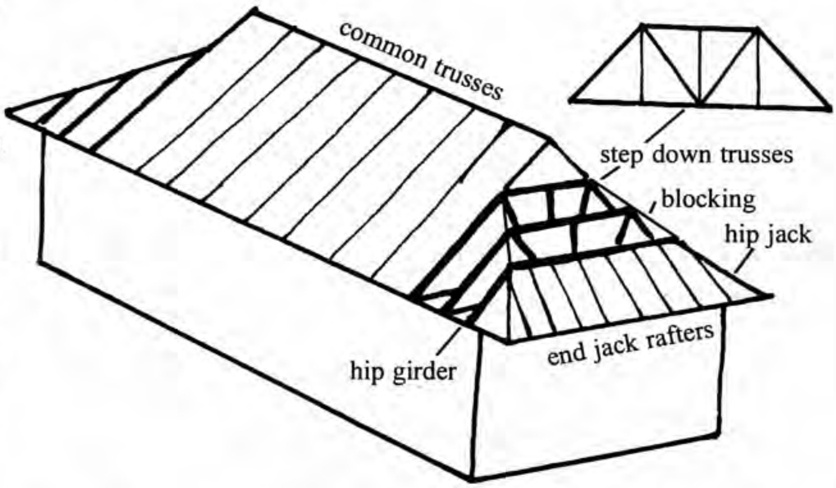


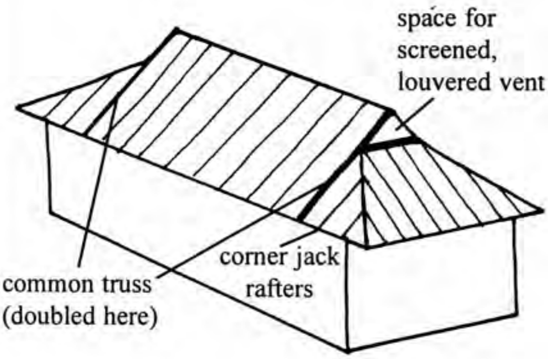
* Prefabricated conical, metal roof kits are available from Butler Mfg. (816-968-6126).

Dutch Hip Framing Options

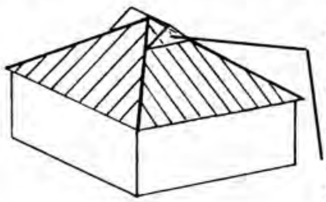
This option is often used on rectangular buildings as a more interesting substitute for a gabled roof.

Depending on the framing system (three possibilities shown here), some roof weight can be distributed to the shorter end walls. This roof shape also overhangs all four walls. For detailed information on roof framing, see Gross (1984).



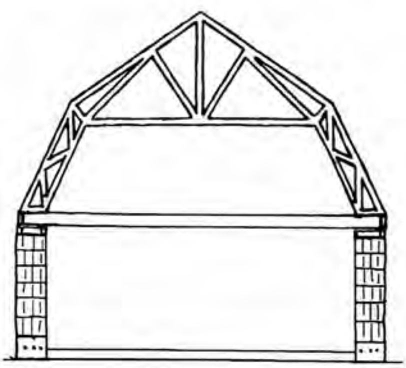


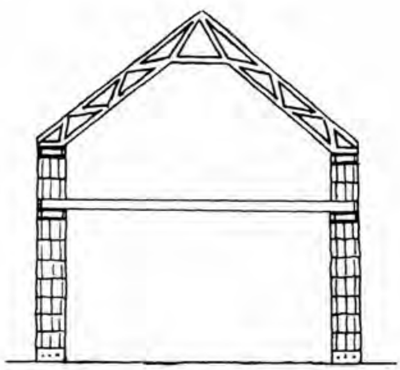
Historically, square or nearly-square bale-walled buildings were covered with a lightly-framed hip roof. The advantage is the nearly equal distribution of roof weight on all four walls.



A short ridge can be scabbed on to modify the pyramidal profile and provide for adequate venting of the attic space (a very important consideration).

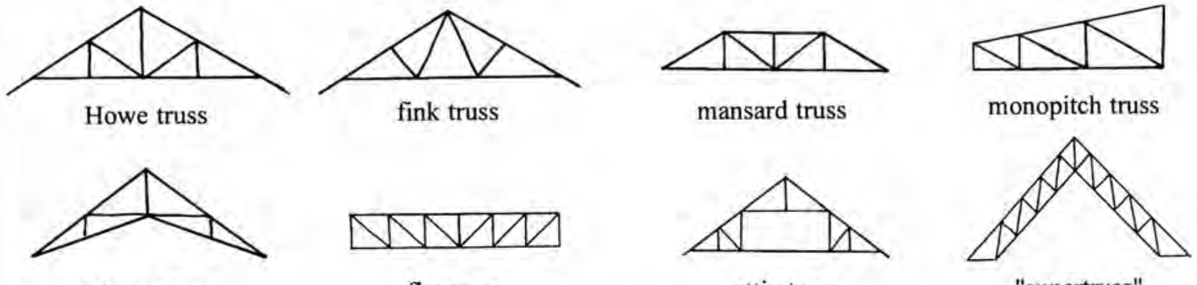
Two-Story, Loadbearing Options Using Super-Trusses™





Some Truss Types*

* For more, see MWPS (1989a), Smulski (1994), and page 80 at bottom.



Roof Surface Options

A secure and durable roof surface is vital for the long-term structural health of your straw-bale home. Periodic maintenance and eventual replacement are also very important. Many historic Nebraska structures died from "roof failure". For roof surfacing options, see Herbert (1989), Kolle (1995), and Malin (1995c).

Among the many roofing surfaces that have been used on bale buildings are:

• Metal (pricey, but easy to install and durable). This typically means standard galvanized or color-coated panels. In dry climates, the shallow-corrugated, cold-rolled steel decking, normally used in high-rise construction as form work for poured concrete floors, provides an interesting alternative. It comes ungalvanized (i.e., without a zinc coating) and quickly attains an attractive, rusted surface. We would not, however, recommend its use in wetter climates, especially those characterized by acid rain. For more information on this option, call The Myers Group at 1-800-729-3325.

• Single-ply membranes (pricey, tricky to install, but effective even on roofs with very little slope, if correctly installed) (see Loomis 1991).

• Asphalt-impregnated roll roofing (inexpensive, easy to install, visually boring).

• Asphalt-impregnated, fake-shingle strips (more work than roll roofing, but less boring).

• Shakes (either wood or composite materials).

• Tile (pricey and **heavy**). Due to their weight, tiles are not normally used in loadbearing designs. Traditionally, "tile" meant fired clay, but tiles made from tires, concrete, and composite materials are now available. The latter can contain considerable amounts of recycled materials.

• Living roofs (ARCHIBIO 1995b, 1995c).

• Thatch (e.g., palm leaves, grass).

• Tarps (especially suited to vaults).

Although requiring periodic replacement, tarps can provide a cost-effective, though none too pretty, option.

Some of the less obvious factors that might influence your choice of roof surfaces may include the following:

• The potability of water harvested off different surfaces. Most types of tile and commercial steel roofing panels are favored over products containing asphalt.

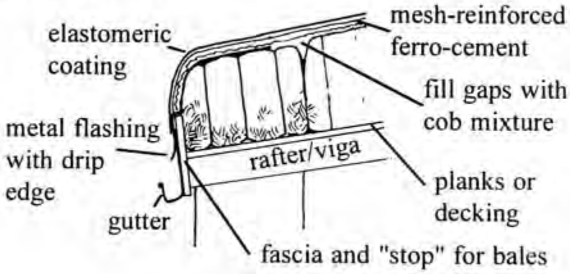
• The weight of the material per unit area. Given some maximum load per square foot of loadbearing wall-top, lighter materials will permit longer spans.

• Degree of flammability. Not generally considered an important factor, but of vital importance in certain areas where the likelihood of brush or forest fires is great.

• The stylistic appropriateness for the neighborhood and/or region.

A Simple Straw-Bale Roof Idea

A long-held desire of many straw-bale aficionados has been to reduce the amount of wood used, while retaining adequate insulation. Vaults and domes can work. Another idea, using ferro-cement and an elastomeric coating, is shown at right.



The Shed Roof Option

Due perhaps to its lack of visual pizazz, the simple, low-pitch, shed roof is generally shunned by both architects and owner-designer-builders. With a few porches, however, this ugly duckling takes on a modest charm. And for the owner-builder, at least in regions where snow loads are minimal, it offers some attractive advantages:

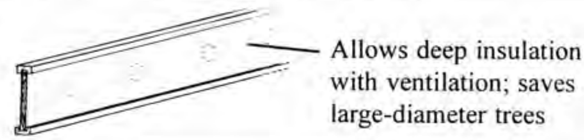
• If we exclude the flat roof (dumb, dumb, dumb) and the very low, gabled roof (why bother?, and few do), it covers a given structure with the minimum square footage of roof surface. Less materials, less labor, less cost.

• With a single gutter and down spout, all the water harvested off the roof can be channeled safely away from the base of the walls onto vegetation, or into a cistern for storage.

• As with a gabled roof constructed with triangular trusses, the whole roof structure is made up of a single, repeated element. Once you've got the first one attached correctly, all the rest are "no-brainers".

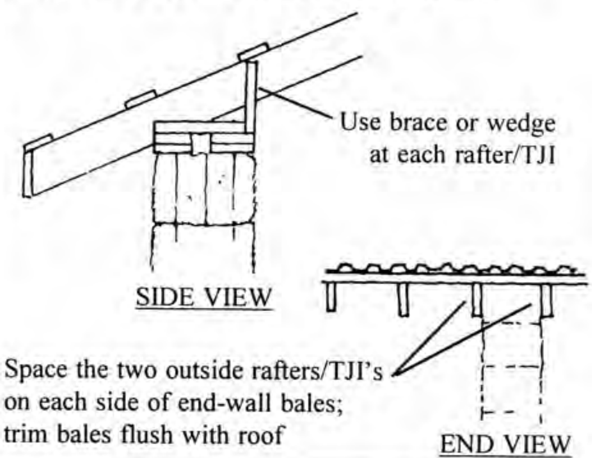
• If 14 inches [35.6 cm], or more, high "truss joist I's" (a.k.a. TJI's, wooden I-beams) are used, long spans are possible, with adequate space available for superinsulation. They can be ordered in various heights and in custom lengths far greater than you'll ever need.

Wooden I-Beam (TJI)



• The necessity of having one end of the TJI's, or rafters, higher than the other, provides the opportunity to insert clerestory windows directly under the roof, where they can be easily shaded by a modest overhang.

Shed Roof Rafter Details



Options for Ceiling Materials

• Sheet rock (a.k.a. drywall, gyp board). This old standard is cheap, relatively non-toxic, and fire-resistant. It is also heavy and cumbersome to install overhead without specialized equipment. For tips on how-to, see Ferguson (1996). To get a continuous, smooth surface, ready for painting, one must fill the joints and sand the filler material smooth. No one we've ever met seems to enjoy the last-mentioned step, and many flat-out hate it. Some builders avoid this step by filling the joints, staining the ceiling with a cheap, dark stain and then stapling rolls of reed or split-bamboo fencing to the ceiling. The long, black-coated staples used for telephone wire installation work well, and are nearly invisible, but do require a special staple gun.

• Wood in various forms. Depending on your design, your wood may be attached to the bottom of something (e.g., a none-too-pretty, pre-engineered truss) or on top of something that you want to see (e.g., a handsome round or squarish beam). People have used:

—Commercial tongue and groove planking

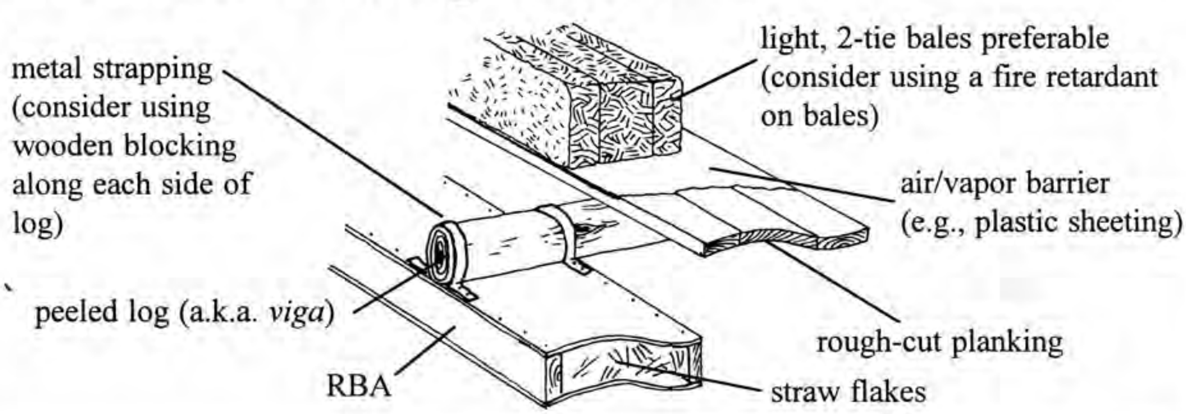
—Stained or singed plywood, or the equivalent. An unusual option here is WheatSheet, a hard, paneling material made by binding wheat straw with a resin. For info, contact Naturall (*sic*) Fiber Board, Box 175, Minneapolis, KS 67467; 913-392-9922.

—Rough cut planks. Something like black plastic sheeting, placed on the upper surface of the planks, will both provide an air/vapor barrier and keep fragments of your insulation from dribbling down through the inevitable cracks into your caviar.

—Peeled saplings (a.k.a. *lattias*), cane, bamboo, etc. Rather than placing them at right angles to the beams , one can angle them and reverse the direction between each consecutive beam to form an attractive "herringbone" pattern.

• PGB3. This unusual product, consisting almost entirely of compressed straw, comes in sheets that are four feet by eight feet by one and a half inches. The surface has a lot of texture and gives the board the properties of an acoustical panel (for info contact BioFab at (916)243-4032 or e-mail them at <info@strawboard.com>).

Straw-Bale Ceiling Insulation

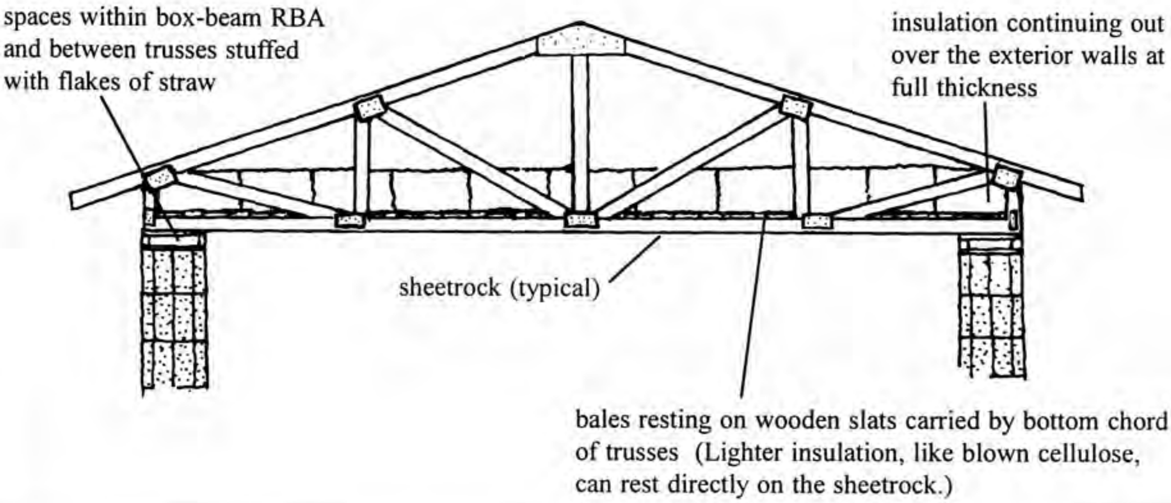


Ceiling Insulation Options

For unbiased articles comparing common types of insulation, see Wilson (1995a; 1996). A wide variety of options have been used, including:

- Fiberglass, in several forms.
- Cellulose, from recycled newspaper, in several forms.
- Cotton fibers, from recycled fabric trimmings, in several forms.
- Foam board
- Structural, insulative panels (for a combined ceiling and roof). Typically these panels have foam sandwiched between two sheets of oriented strand-board (a.k.a., OSB). An interesting alternative, made with straw between the sheets, is being manufacture by Agriboard. Call them at (515) 472-0363 or e-mail them at <agriboard@lisco.com>.
- Loose straw, flakes or bales, including bales used both as the structural roof and the insulation in domes and vaults (see Lerner 1997). Especially when using loose straw, it is advisable to first treat the straw with a fire retardant. For specific information on retardants, see page 19. One approach to treating loose straw has been to first immerse it in the solution and then spread it out on tarps or a concrete slab for drying. If your retardant is water soluble, you must re-treat the straw if it is rained before you get it under roof.
- Surplus sleeping bags containing "fiberfill". Sometimes bought very cheaply (from the U.S. Forest Service), and stacked several high, they are performing well in one small structure in New Mexico. Human ingenuity at its best, we'd say.

Raised-Heel Truss Ceiling



Step 6. Letting the Walls Compress

Challenge: to patiently allow the bale walls to complete their compressional response to the "dead load" exerted by the RBA/roof/ceiling/insulation system, and to use this opportunity to work comfortably inside your building on a variety of tasks.

Walk-Through

♣ *Unless your design includes a tie-down system that enables mechanical compression (see page 73), you must now let the walls gradually compress. Select two, or more, points along each wall at which to periodically measure the distance from the top of the toe-up (or floor surface) to the top of the RBA (or, later, the bottom of the ceiling surface). Number the locations and record the measured distances such that you can compare each set of measurements to the previous set. For two different approaches to measurement, each reflecting for a different degree of anal retentivity, see page 86.*

The initial response to loading is rapid, but then begins to taper off. Experience suggests that complete compression may require anywhere from three to about six weeks. Depending on initial bale compaction and roof weight, total compression will vary from some fraction of an inch (a cm or less) to several inches (about five or six cm). During the settling period, you should occasionally adjust your tie-downs to remove any slack. When all of the measurements in a set show no change from the previous set, you can safely proceed with surfacing the walls, as described in Step 7.

♣ *With the tops of the bale walls now protected by the new roof and the bottom course sitting safely up off the ground on a toed-up, waterproofed foundation and draped with a waterproof membrane, you can catch your breath. Use this respite for things like:*

—recreating and reconnecting with loved ones;

—tweaking any ornery bales into final position;

—adjusting the verticality of door and window frames, as needed, and connecting them securely to the bale walls with dowels or metal pins;

—installing the doors and windows;

—and, creating the floor, if this has not already been done. If the bales have been stacked on a wooden deck carried by basement walls, stem walls or piers/columns, the floor is already in place. Similarly, a slab-on-grade creates the floor and the foundation with a single "pour" of concrete.

Although the floor may end up being created at different points in different buildings, we have chosen to deal with the question of insulation under floors in just two places – right here and on page 88, where we illustrate several options. During the design process, you should have made a decision whether or not to insulate and if so, with what and to what degree. Among the things that you might consider are listed below:

1. The regional climate and the micro-climate at your site.

2. The type, or types, of floor you have chosen.

3. Whether the floor will be heated and/or cooled by pipes through which water or, less commonly, air will be circulated.

4. Whether you are using a frost-protected, shallow foundation, since floor insulation can increase the amount of insulation required at the perimeter (see HUD 1995).

5. The calculated or guesstimated payback time for the investment, and the planetary costs of not doing it.

Our "model" building has a high-mass floor created within the above-grade collar. We are using no insulation around the perimeter of our foundation or under our floor, since our "model" climate requires very little heating or cooling.

The finished floor surface should be at least 1.5" [3.9 cm] below the top of the collar to protect the bales from any interior flooding. We have specified a high-mass floor so that winter sunlight (i.e., solar radiation), entering through south-facing glazing, can hit, and be absorbed by, the floor. This daytime storage of heat will prevent room air temperatures from becoming uncomfortably high during the day. At night, this same heat will "bleed" back out, helping to keep the space from becoming undesirably cool.

—Creating non-loadbearing interior partitions, leaving an adequate gap above them to allow for the settling that may still take place. An alternative approach is to postpone creation of the interior partitions, with any incorporated plumbing and wiring, until the interior surfacing is in place on the exterior bale walls. Then, with all the surfacing materials in place (and all the compressing finished), you no longer needs to guess how much of a gap to leave to allow for settling.

This approach also minimizes the amount of patching required if one eventually relocates a partition wall. See pages 85-87 for options regarding the creation and attachment of partition walls.

—Extending the plumbing into, or up into the interior space. If you do choose to install some, or all, of the partitions at this point, you can also complete any plumbing that belongs in them (see Massey 1994).

There are two obvious ways to get any water lines (cold or hot) into your straw-bale house. The first is to bring any pipes in under your foundation/footings and leave them "stubbed out" at the appropriate locations when you create the floor. If a problem ever develops with one of these buried pipes, you will either destroy part of your floor (if you can pinpoint the leak) or, more likely, abandon all piping under the floor. The logical thing to do then, is to consider using the second option, which you might have been better off using to begin with.

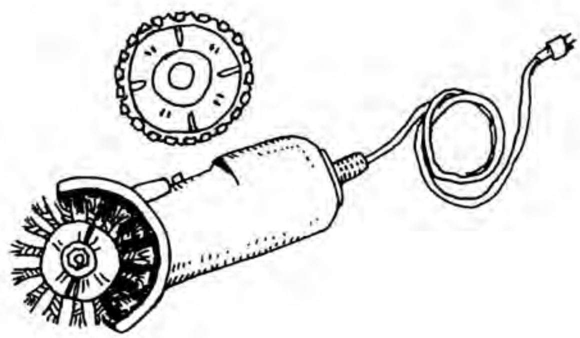
That involves bringing the pipe that provides cold water to the structure up out of the ground outside the wall, at one or more locations opposite a single fixture (e.g., a kitchen sink), or opposite an interior "plumbing wall", preferably framed with 2"X6" [5X15 cm] lumber. Skillful, careful use of the tip of a small chain saw will create a hole, sloped slightly upward toward the inside, for a "sleeve" of plastic pipe. Insert the sleeve and plug any space around it with your cob mixture. The pipe(s) can then be plumbed through the bale wall and into the frame wall. **To safely use this option, you must be able to insulate the pipes to prevent freezing, even during record low temperatures.** In colder climates this may not be economically possible.

If you cannot avoid running water pipes along straw-bale walls, at least isolate them

carefully and completely from the straw.
—Equipping the straw-bale walls with wooden elements to enable the hanging of cabinets, bookcases, etc. If these elements will be hidden by the plaster, map their position precisely on a diagram and save it for later use. We'll cover some of the various options for hanging things on straw-bale walls in Step 8.

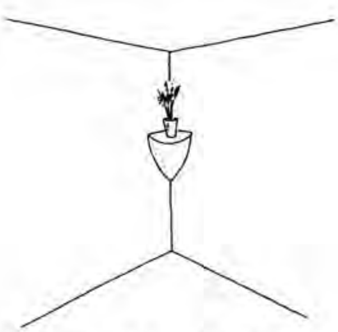
—Installing, in any partitions created at this point and in the exterior walls, any phone jacks, antenna cable, electrical boxes and wiring (see Traister 1994, Cauldwell 1996).

—Rounding/trimming off bales at exterior corners and at door and window openings, as desired, to provide for a "soft-profile" finished appearance. This is also the time to trim off any undesired protrusions on your wall surfaces (a line trimmer/"weed whacker" works beautifully for this). Any niches, notches, alcoves, etc., should all be created at this time using a small chain saw or, better yet, a small electric grinder, equipped with a cable-twist, flat wire wheel or a cutting wheel with chainsaw teeth on the circumference (called the Lancelot*). Both are illustrated below. The wire wheels are cheaper and never require sharpening, but (arguably) cut a little less quickly. They are available from welding supply stores. If none of your local hardware stores, or specialty tool suppliers, carry the* Lancelot*, contact King Arthur Tools at (800) 942-1300.*

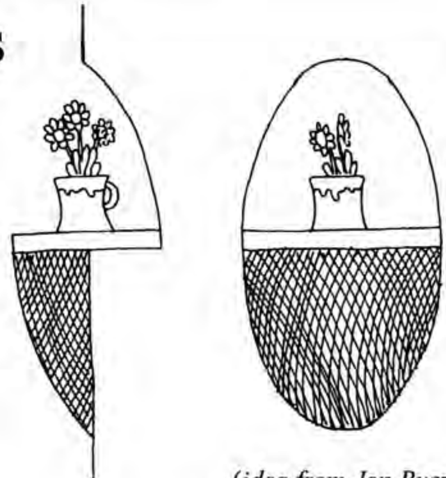


When using any of the above mentioned tools to cut straw, you should always wear safety goggles and a dust mask *(does someone have to die from "yellow-lung disease" before this becomes automatic?). Chainsaws, grinders and even line trimmers are dangerous tools, capable of doing major damage to the operator or those nearby. Use them only with great care.*

Niches and Counter-Niches

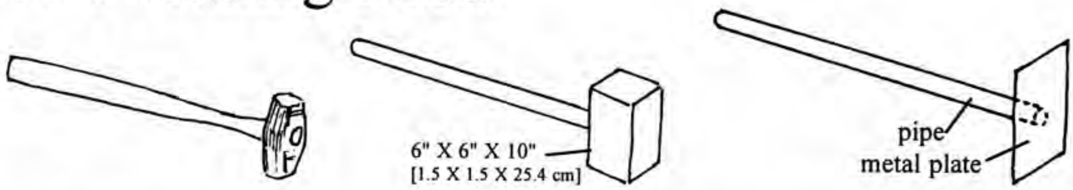


(idea from Bill & Kalla Buchholz)



(idea from Jon Ruez)

Bale Tweaking Tools

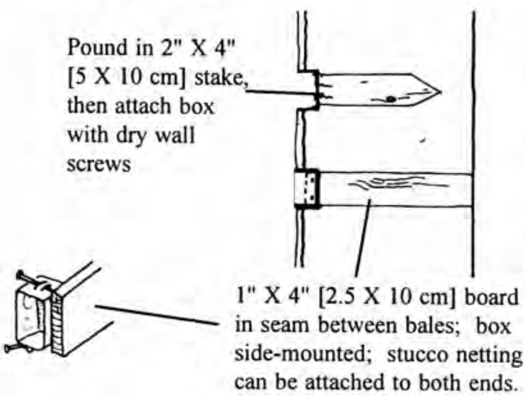


Big Sledge

Wooden Maul
handle mounted in hole or on side

Tamper/"Persuader"

Wiring Options

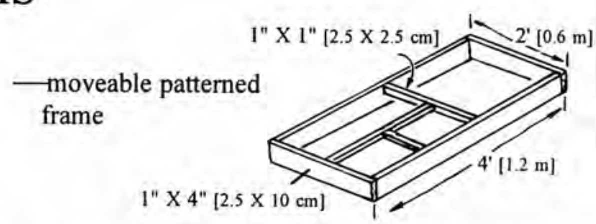


- Wires in metal or flexible plastic conduit on wall surface; or in groove (dug with claw hammer, or cut with tip of chainsaw or circular saw); or run under floor and "popped up" to boxes.
- Wires in surfaced-mounted "decorator" conduit (attached after the wall has been surfaced).
- Plastic-sheathed cable (e.g., Romex 12/2) pushed into 2 1/4" [5.7 cm]-deep groove cut into walls. Hold in place with "Roberta pins" (see page 92).
- Cable run horizontally on a bale course during wall raising. Position wires about 3" [7.6 cm] from the inner edge of the bales to prevent risk of hitting them when pinning).

If doing your own electrical, see Traister (1994) and Cauldwell (1996); Re: EMFs from wiring, see Pinsky (1995).

High-Mass Floor Options

- Bricks or blocks (e.g., fired adobes) on sand (see Ring 1990), stone on earth (Laporte 1993)
- Tiles on slab
- Earth (see Laporte 1993, Steen et al. 1994, Steen and Steen 1997b, and several articles in Issue 17 of *The Last Straw*)
- Compacted soil-cement / rammed earth (see Berglund 1985, McHenry 1989, Easton 1996)
- Concrete
  —regular slab-on-grade
  —regular slab poured over bale insulation (see illustration on page 88)
  —scored or embossed slab (pressed-in pattern)
  —large, thick, poured-in-place "tiles" (frame stays in place)



Coloring Concrete

- Mix dye with the concrete before pouring.
- Sprinkle on and "float" in during final finishing.
- Staining: commercial or homemade (artist pigments, or use ferrous sulphate which is cheap and available from agricultural, chemical, or fertilizer suppliers to get a yellowish, reddish brown).
- Apply special concrete paints.

Options for Interior Partitions

• **Standard frame** (2"X 4" [5X10 cm] or 2"X6" [5X15.2 cm]), covered with sheetrock or some other type of paneling. You may want to use WheatSheet, a thin panel made entirely from straw and a formaldehyde-free, polymer-based binder. For access information, see "Options for Ceiling Materials" on page 79.

• **Infilled standard or widely spaced frame** to which stucco netting has been attached on both sides, creating cavities that are stuffed with straw. Paster is then applied to the resulting surface with hand or trowel, producing an undulating surface reminiscent of the finished bale walls.

Another infill option would involve tamping "light clay/straw" mix into the space between formboards temporarily attached to the frame (see Laporte 1993).

• **Shipping pallets** that have been stuffed with flakes of straw (for sound insulation) before being stacked and connected to form a partition wall. A thick coat of earth plaster, well keyed into the spaces between the boards, will probably stay on just fine without stucco netting. Pallets which would otherwise take up scarce space in a landfill, can usually be acquired without money changing hands. The planet will love you for converting a waste material into a free resource.

• **Wattle and daub**. The "wattle" is a woven framework of saplings, bamboo, reeds, etc., intertwined with smaller twigs or branches. The daub is usually earth plaster, smeared onto both sides of the panel.

• **Hanging dividers**. If the only function of a specific divider is to provide visual privacy, why spend a lot of time and money building a heavy, "permanent" partition that you'll probably end up wanting to move eventually. Consider hanging a fabric partition from those little gizmos that slide along a metal track attached to the ceiling. This system saves space, while providing visual privacy when needed.

• **Furniture walls**. As above, floor standing elements like bookcases and storage units can be used to provide visual privacy without creating a permanent monument to over-building.

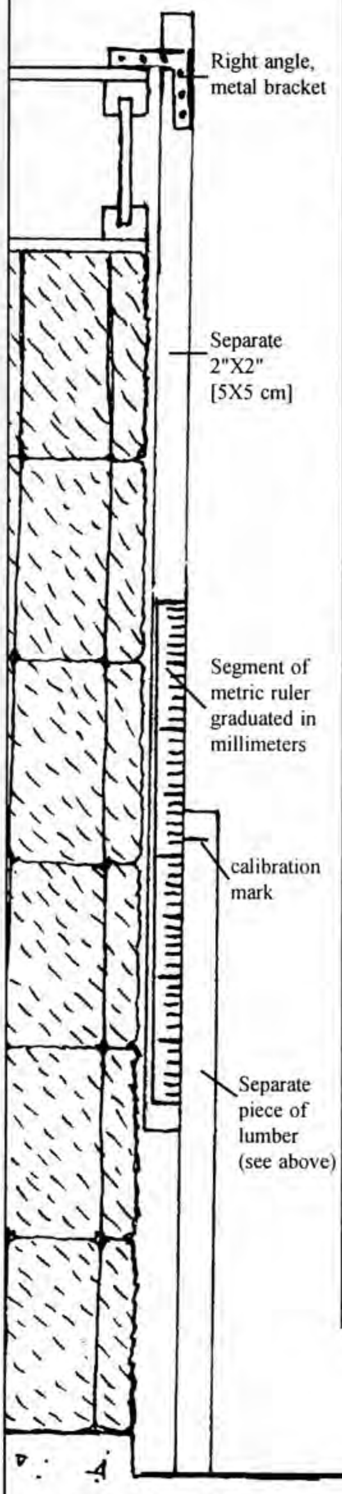
• **Earth materials**.

—*Adobe* (McHenry 1989, Houlen and Guillard 1994) and *Cob* (Bee 1997, Smith 1997) can be used to create handsome, relatively narrow (8" [20.3 cm] is a suggested minimum), sound- dampening walls that also contribute to the thermal mass within the bale envelope. No matter where situated, they will contribute to the effectiveness of passive and active cooling strategies, but are of less benefit in passive solar heating strategies unless they receive direct sunlight for a significant part of the winter day. For specific suggestions on combining earth materials with straw bales in your design, see Issue 17 of *The Last Straw*.

—*Rammed earth* (Easton 1996) is seldom considered for a partition wall unless the wall will also be carrying roof weight, as in the hybrid design with the inverted trusses on page 22, bottom left.

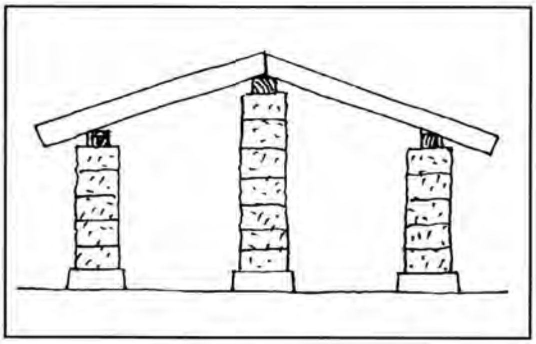
• **Straw bales**. Whole bales, either flat or on edge, have seldom been used for interior partitions, since the resulting walls (ditto for rammed earth) take up lots of precious space. Three-tie bales converted into four-tie bales that are then cut in half, would reduce the straw thickness to about 11" [28 cm]. A wall made from these "straw slabs", perhaps sandwiched between 2"X6" [5X15.2 cm]

Matts' Method



studs spaced about 4' apart, would still provide a good sound barrier and pleasantly thick walls.

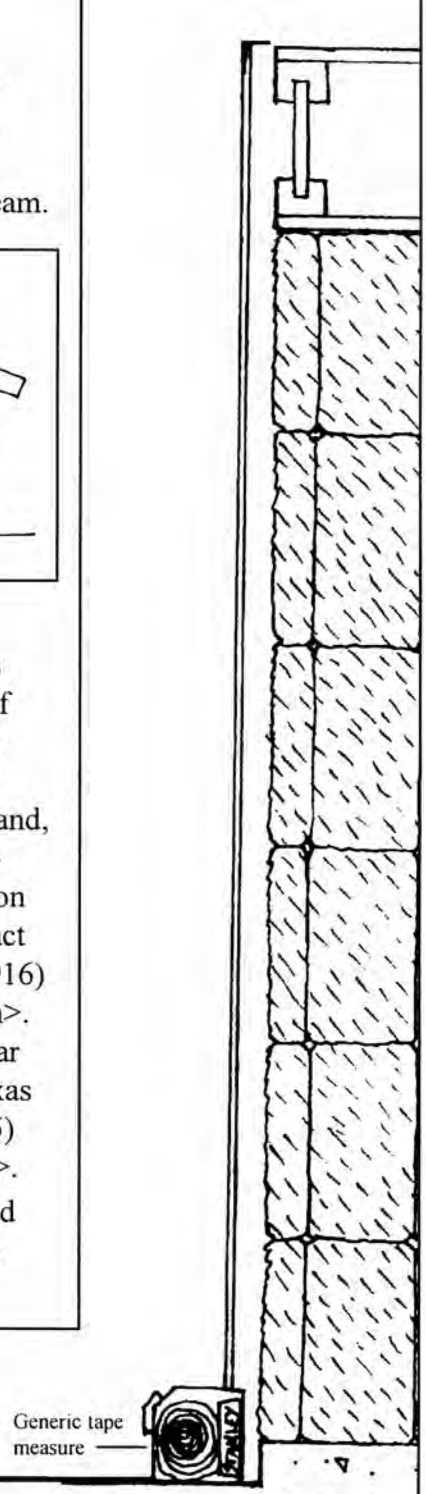
We do know of one building (see below), where a standard bale wall, with doorways in it, was used as a loadbearing substitute for a ridge-beam.



• **Compressed strawboard**. The board typically used for partitions is 2-1/4" [5.7 cm] thick and consists of compressed straw panels with paper glued onto both faces. This type of board has been widely used in England, and elsewhere, to replace sheetrock-covered frame walls. For information on PGB (Pacific Gold Board), contact BioFab, in northern California, at (916) 243-4032 or <info@strawboard.com>. If enough demand develops, a similar product will be manufactured in Texas by Agriboard. Contact them at (515) 472-0363 or <agriboard@lisco.com>.

• **Beverage cans and/or bottles** laid up in earth- or cement-based mortar (see Reynolds 1990).

Steve's Method



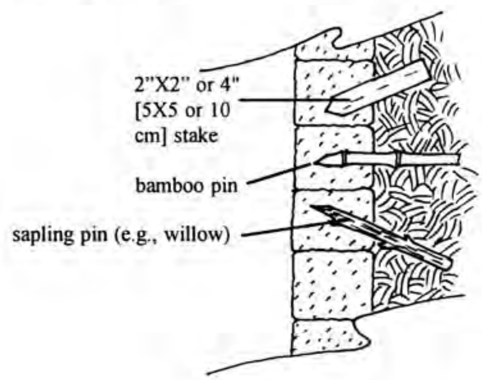
Measuring Compression Progress

Attaching Partition Walls to Bale Walls

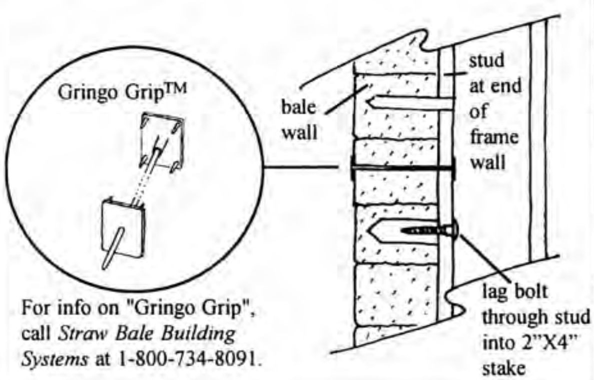
Under certain circumstances (e.g., in areas with minimal seismic risk) and with certain wall types (e.g., frame walls), attachment at the top and bottom of the wall may be judged sufficient. Typically, however, partition walls are attached to exterior bale walls. The technique chosen in a particular case will depend largely on the material(s) used in building the partition wall.

Some options, arranged by partition type, are shown below. Many can also be used (although some adaptation may be needed) to connect the walls of a straw-bale addition to a preexisting structure.

• Cob only — Side View

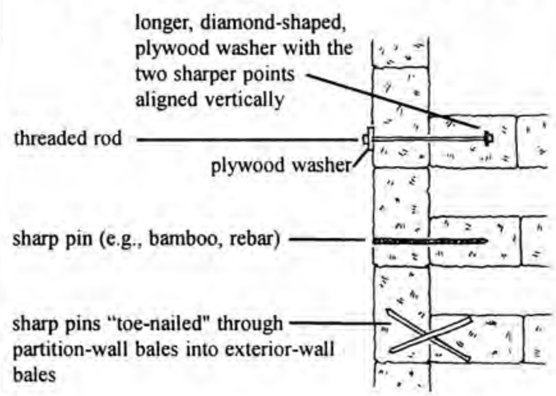


• Frame — Side View

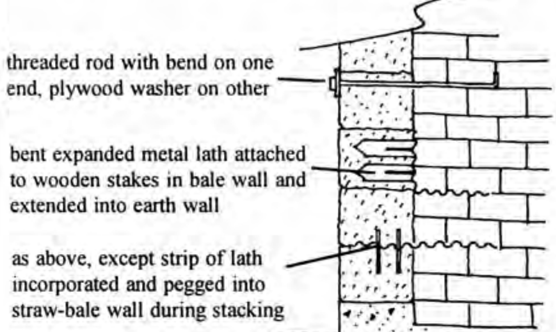


For info on "Gringo Grip", call *Straw Bale Building Systems* at 1-800-734-8091.

• Straw Bale — Top View



• Adobe or Cob — Side View



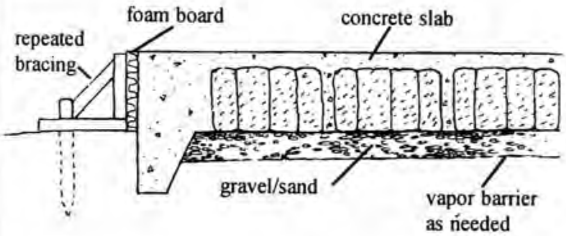
Not illustrated, is the technique of building the straw-bale partition wall and exterior bale wall simultaneously, knitting the two together by having some of the bales in the partition wall extend into the exterior wall. Model it with dominoes, or the equivalent, before doing it!

Insulating Floors

Under Slabs

- foamboard (of a type that can withstand the loading without compressing)
- pumice (provides an R-value of about 2.2 per inch [RSI-value of 15.2 per meter])

• Bales*

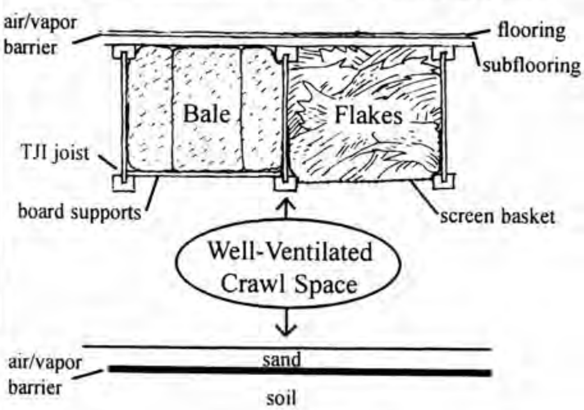


* *See* The Last Straw, *Issue 6, page 14, for photos of a slab being poured over bales, and* ARCHIBIO *(1995d) for how-to.*

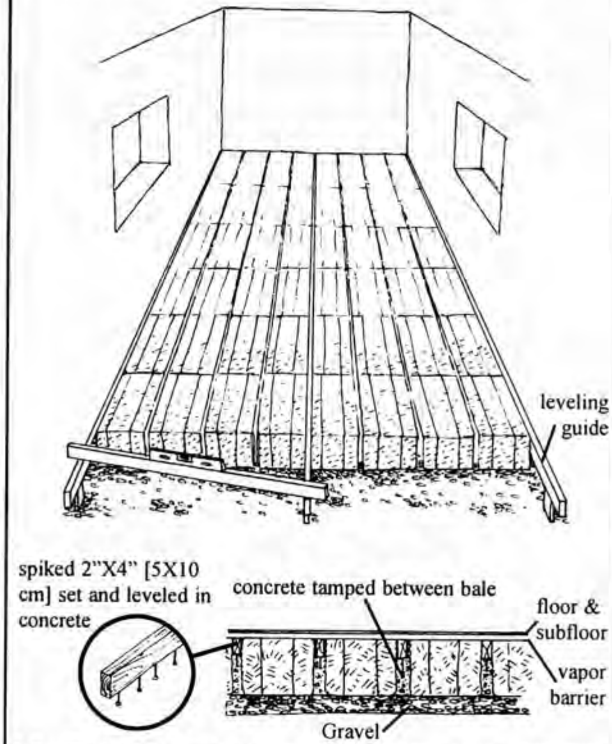
Between Floor Joists/Supports

- fiberglass
- cotton
- cellulose, especially dense-packed
- integral insulation and structural floor (described, with access information for a panel with a strawboard core, on page 80).

• Bales or flakes between raised joists



• Bales on gravel between supports



* *See* The Last Straw, *Issue 12, p. 22, on this example from Mongolia.*

A wet ground surface under a raised floor may contribute to "rising damp" (water vapor in outside air) that could condense within, and lower the R/RSI-value of, the suspended insulation. Strategies to prevent this include providing as much ventilation as possible for the "crawl space" and covering the ground under the building with a layer of plastic sheeting, held down and protected by a layer of sand. Good perimeter drainage is also needed to insure that the sand stays dry.

In cold climates, warm, moist inside air must not be allowed to move downward through the floor materials. (See the diagram to the left, and CMHC 1994.) The danger lies in the possibility that the water vapor will condense, creating liquid water that will damage the floor joists and reduce the R/RSI-value of the insulation.