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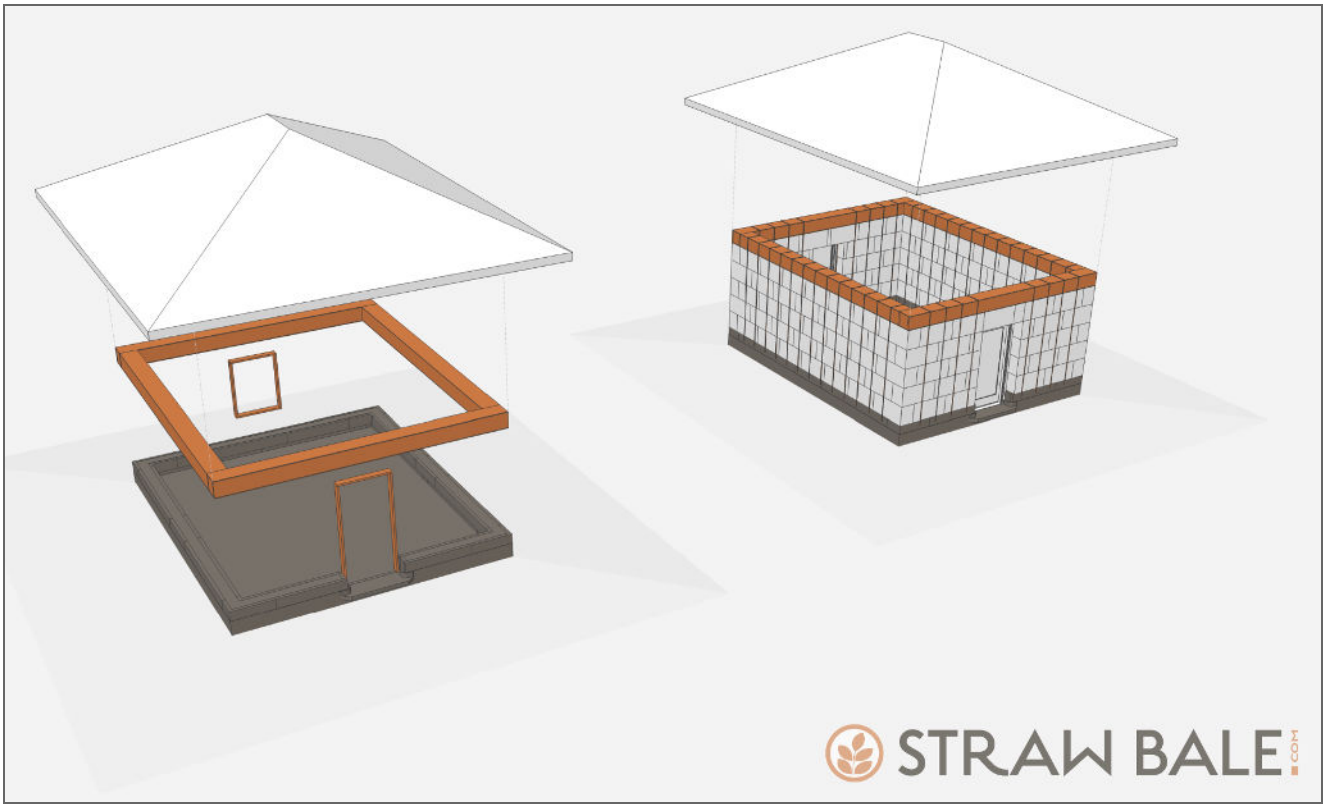

Straw Bale Load Bearing Report

10 Essential Considerations for Designing and Constructing a Load-Bearing Straw Bale Structure

Version 2.0

Thanks for your interest in building your own straw bale structure! We hope this Load Bearing Report proves a valuable reference in your decision-making process. Please visit strawbale.com/blog, as that archive has a wealth of information.

In support,
Timbo & Dainella
Straw Bale Resources LLC

Building Your Straw Bale Structure

You've seen the beautiful photographs, you've read about the health and energy-saving benefits of straw bale homes, and you may have had the opportunity to visit or stay in a bale house. No doubt about it, straw bale building is becoming increasingly popular worldwide, and perhaps you've decided that this is THE way to build your dream home.

At this point, you will need to determine what type of straw bale building you want. The three primary choices are:

1. Load Bearing
2. Infill (Post and Beam, Timber Frame)
3. Buck and Beam, or Hybrid

Load-bearing construction harkens back to the original bale structures in Nebraska and is often referred to as "Nebraska Style."

What's the Difference?

The biggest (and most obvious!) difference between the types is that there is **no structural system used to augment the strength of the bales** in the load-bearing method. The walls, formed primarily of straw bales, are the only structural system used to support the load of the roof assembly.

Advantages of Load Bearing

- The environmental impact of load-bearing structures is less due to the minimized use of wood. The only lumber required for a load-bearing home is found around the windows and doors, roof framing, interior walls, and toe-ups. (Unless, of course, you build on a wood floor system.)
- It tends to be much easier for people with no construction experience! The build process of load-bearing lends itself to the owner builder, who can build this type of structure with limited building skills.

Owner-Builders Can Do It!

Load-bearing construction can be a good fit for owner-builders because **fewer carpentry skills are required**. It is important to have enough skills to construct a simple roof and some window and door bucks, but most of the intricate details of home construction are replaced with **simple block-building techniques. If you ever built with Legos ™ as a kid, you can build a load-bearing straw bale structure!**

Load Bearing is a Fun, Community-Based Build

As opposed to in-fill construction, no notching of the bales is needed because there are no posts or beams to customize around. This speeds up bale stacking dramatically and is ideal for a workshop or bale wall-raising party. Both are fun community-based events that many homeowners appreciate having as a part of the legacy of their build process and story.

10 Essentials to Know Before Building Your Load Bearing Structure

We want to give you a basic understanding of what it takes to build a load bearing structure and the special considerations that go with this building method before you get started on your build. If you haven't ever built before, we recommend you practice on a small structure like a garden shed or studio before tackling a full-size home construction project.

1 - Load Bearing Straw Bale Requires Special Design Considerations

It is critical that you pay attention to these basic design rules before beginning construction. This is especially important when planning out the door and window openings.

Here's what you need to know about the three fundamental ratios of load bearing:

1. Due to the use of bales as the structural component of the home, the openings in the walls are limited to 50% of the wall surface area. Although this sounds harmless, when applied, it means you have to be very precise with the type and placement of your windows.

2. The height of your walls matters - a lot. Because you must factor in the ratio between the wall height and wall thickness. The structure's height is limited by a width-to-height ratio of 5.6:1 under most codes.

   In construction terms, this means that a 23-inch thick wall has a maximum wall height of 10 feet, 8 inches. In addition, load-bearing structures are limited to a single story; however, a loft design may be utilized if the roof pitch is steep enough.

3. The third key ratio is the "unsupported wall length," which cannot exceed a ratio of 13:1 for a 23-inch wide wall. Basically, you cannot have more than 25 feet of unsupported wall length in any direction. This is perfectly acceptable as long as the interior partition walls are spaced appropriately and used to offer perpendicular support to the bale walls.

2 - Foundations

There are three basic foundation options open to you:

1. Slab Foundation
2. Concrete Stem Wall
3. Raised Floor System

Slab Foundation - Very few differences exist between a post and beam and load bearing system if you're building a structure on a slab foundation. But it is worth noting that it is important to create the foundation with enough depth and room to handle the width of the bales and plan for the foundation J-bolts to be placed for the toe-ups.

Stem Wall Foundation - If you are building on a stem wall foundation with a separate slab floor (often the system used when placing an earthen floor), you will have to form the foundation wide enough to support the full width of the bales you use. That can mean a concrete stem wall that is 18 inches to 24 inches wide.

Raised Floor System - Another option is a raised floor system like that used over basements. It should be installed the same way as in a post and beam structure. Be sure to account for the extra weight of the bale walls in the floor joist engineering.

3 - Pay Attention to Your Toe-ups

Toe-ups are used to raise the bales off of the floor as well as to secure the bales to the foundation. By raising the bales off the ground, they are safely excluded from any minor floods caused by leaking appliances or plumbing. The second job of the toe-ups is to provide nailing for the welded wire mesh. 4 x 4-dimensional pressure-treated lumber is typical for toe-up use. Once installed, the toe-up can then be an integral part of the shear system of the building if engineered as such. Once placed, toe-ups are bolted to the concrete floor with preset J bolts.

You must know the width of the bales you will use before installing the toe-ups. Add 1/2 inch of width to the bale width when determining the inner toe-up layout. In other words, if the bales are 18 inches wide, mark the layout so that the interior face of the toe up is 18 1/2 inches from the exterior face of the mudsill. Then snap a chalk line to represent the interior edge of the toe-ups. This yields a straight and precise line for the edge of the toe-up, making installation quick and accurate. Be sure to account for the door openings and swing when laying out the toe-ups!

4 - Bale Compression and Using Compression Straps

Unlike Straw Bale Infill Wall Systems, it is necessary to add special straps underneath the toe-ups before they are tightened to the foundation. The straps are used to secure the bales to the toe-ups and thus to the foundation.

When the straps are tightened, a box beam (more on this later) placed on top of the bales will act as a cinch and to compress them into their final position. If the bales are not pre-compressed, they will tend to sag over time under the weight of the roof assembly. So this step is essential!

Because the straps tend to get in the way of the construction while raising the bales and straightening the walls, you can run a short section under the toe-ups, typically extending about 3 feet up each side of the wall. Roll this strap up and secure it with rubber bands at each location until you are ready to compress the walls. Lay the straps about every 2 feet along the length of the wall, making sure not to lay them in a window or door opening.

Once in place and perpendicular to the toe-ups, tighten down the toe-ups. This will hold the straps securely in position, then add clean gravel or insulation between the toe-ups on top of the foundation.

5 - The Box Beam

A box beam is used on top of the bales to provide a surface to mount the roof assembly and to help evenly compress the bales before the roof is installed. Here's a tip that will make this custom build go much faster and easier: The box beam should be built immediately after the toe-ups are installed. Build the box beam as a mirror image of the toe-ups to the exact dimensions. If you do this, when you place the box beam on top of the bales, it will be easy to find the plumb location of the box beam and ultimately tighten up the walls in a plumb position.

The exception to this is over doors openings. Because the door openings need to be spanned by the box beam, do not stop the box beam construction at the openings created in the toe-ups.

Build the box beams in sections. This makes the beams more easily lifted into position and assembled on top of the bales. Once the bales are in place and checked for plumb, raise the sections of the box beam to their respective locations and nail the sections to each other at every union. Consider using a crane if the beam is too large to lift safely.

Of course, since you have yet to raise the bales, all you can do now is build the box beam with precision, label each piece for its respective location, and place the pieces to the side.

6 - Window and Door Bucks

In a load-bearing building, you will need to build special frames for all your windows and doors. These are called “bucks” and must be created before you begin the baling process. A buck acts as the framing member, firmly anchoring the window or door to the building. Without the buck, there is no way to secure the windows and doors to the bales. The buck must be square to ensure proper window and door operation.

Make it easy on yourself by building the buck deeper than the door or window that they will support so that there is a convenient spot to attach wire mesh to during the shaping phase of construction. A simple 2” x 6” box is often enough to create a window buck, and a 2” x 8”, 3-sided box (no bottom) is adequate for a door buck. Create more elaborate bucks to aid the bale shaping process if so desired.

Be sure to add braces that keep the buck square. You can either use bracing inside the buck itself or plywood scraps nailed to the face of the buck at the corner to hold it in place. Whichever you use, be sure to place the bracing in an area that will not impede the baling process.

The buck should be fully anchored to the building with mesh and dowels before the braces are removed and the window installed. For that reason, install the bracing just inside the exterior plane of the buck where the window or door will eventually sit.

Once your window bucks are built and braced, number them, so you know where they go in the structure and place them around the building in the general area of their final position. The door bucks should be installed at this time. Stand them on the floor system and nail them to the toe-ups. You may need to temporarily brace them until enough bales are installed around them to anchor them firmly in place.

7 - Keeping Your Load-Bearing Structure Plumb

Contrary to popular belief, load-bearing structures need to be built as plumb and square as wood-framed buildings. Consider that the bales are the wall system. Now consider that the wall system, if out of plumb, is not bearing directly on the points below, which have been designed to hold them. Instead, the walls are pushing out to the sides and placing stress on the corners and other supporting areas of the structure like any partition walls, which were never designed to carry such loads.

To build a load-bearing structure plumb, reference must be given. Without it, a series of bales stacked on each other will eventually slip out of plumb. This is because the eye, although very competent at maintaining a plumb or level line, is typically fooled by the odd shape of the bales or the bulges commonly found at the bale ends.

To compensate for this, the eye tends to tell the brain to build out rather than straight. The result is a wall that gradually grows longer and a corner that slowly flares out as you go up in courses. Be sure to plumb your corners with wood braces before stacking bales.

8 - Building Your Walls: Part 1 - Safely Securing the Bales Together

The bales need to be stacked in what is called a running bond. This means that the bales are stacked like bricks so that no two courses have joints that line up with each other (remember the Legos™!)

Start in one corner and work in one direction around the structure or build in 2 directions from the starting corner. If you have several people helping with the bale raising, build out in 2 directions so that more people can actively place bales; however, if your labor force is small, it is best to work in one direction and focus on completing the home in sections.

As you approach another corner or turn in the wall, be sure that a full bale is used on the bottom course. Place the full bale in the corner first, then add the small stuffing behind it towards the bulk of the wall. In that way, the running bond will still apply, and the full bale will maintain the strength and integrity of the corner. Pay attention to the corner braces, so the walls go up plumb from the beginning.

NOTE - DO NOT USE REBAR except in one special area!

Each course of bales needs to be attached to the one below and above. In the past, builders would drive rebar pins into the bales to tie them together. Today, best practices are to secure all the bale courses to each other using welded wire mesh on both sides of the walls once they have been fully raised. The one place that still requires rebar is in the corners. Rebar staples, NOT pins, should still be used to tie the corner and, thus, the walls together.

8, cont. - Building Your Walls: Part 2 - Stacking the Bales

Stacking bales is hugely satisfying. It can be so exciting to see the progress that you might not want to stop, even when you are supposed to install a window buck. Make SURE everyone involved in the bale raising knows the window locations and that the bucks get placed in the wall before the bales get stacked too high.

The easiest way to add bucks is to place them on top of bale courses in the proper location. Once in place, secure them by adding bales on either side of the opening while maintaining the running bond pattern. If the bucks do not stay in place, nailing a wide piece of plywood to the bottom of the sill will help it stand up. The plywood can be left in place once the window buck is secure.

9 - Installing Your Box Beams and Keeping Your Walls Plumb!

The walls may be weak at this stage, especially if they reach the maximum height for bale walls per the width-to-height ratio given earlier. The bracing in the corners will help strengthen the walls, but the major push at this point is to install the box beams on top of the bales.

Because the sections were labeled and properly laid out around the structure, this stage of construction is simply an assembly line. Hoist the box beam sections to the top of the wall and assemble them with nails and plywood. Be sure that you nail them together so that the corners remain square!

Because the box beams mirror the toe-ups below, keeping them square will ensure that the whole building stays square and, ultimately, plumb. Once the box beam is fully assembled, line up the box beam's edge perfectly with the toe-up section directly below it. This is used as the baseline for the building, confirming that the walls, if in line with the toe-ups and box beam, will be plumb.

To make minor wall adjustments, use a soil tamper or homemade ‘persuader’ (large wooden sledgehammer) to hit the bales into position. The weight of the box beam will help secure the wall; however, be careful not to hit the wall too hard and knock it over. It is best to do this in pairs, with one person on the inside of the house and one on the outside. Choose a side representing the perfect plumb line and stick with it. For example, if the person on the outside of the house holds the plumb stick, then all checks for plumb shall happen on the exterior of the building, all the way around. Work the bales from one corner, around the building, and back.

When satisfied with the position of the bales, add the remaining strap material up and over the box beam. Attach it to the small sections previously installed under the toe-ups.

10 - Strapping and Compressing the Bales, Plus Wire Mesh

The strap material serves two purposes. The first is to compress the bales. This is key to reducing cracking in the final plaster and increasing the structure's overall strength. In most cases, the bales will not compress more than a couple of inches. Compress them tightly to prevent further settling.

The other purpose of the straps is to adjust the box beam into a level plane around the structure. If the box beam is not level, the roof framing will be difficult, even for a seasoned carpenter. Therefore, as the straps are tightened, watch the level of the entire box beam system by working from one corner.

After the majority of the compression has been made, the final adjustments can be made incrementally. By starting in one spot and marking it as the baseline for the rest of the house, the box beam can be lowered evenly, creating a perfectly level base for the roof assembly.

The strap material may stretch over time when exposed to direct sun. Therefore, it is vital to check the straps and the box beam for level one last time before the wire mesh is installed. Now is also the time to adjust your bales a final time and have at them with a weed whacker! The smoother your walls are now, by using the weed whacker to trim the loose straw ends off, the easier they will be to plaster.

10, cont. - Attaching the Wire Mesh

Welded wire mesh is a robust and versatile product. It is used as the lateral shear strength of the building, to shape bales, and to attach the bales to the toe-up and the roof. Once the mesh is installed, any adjustments to the strapping will cause the mesh to bow and buckle. This makes the plastering difficult, so it's important to do a final check on the strapping before installing the mesh.

Start installing the mesh on the structure's exterior by nailing it to the box beam and then stretching it to the foundation toe-ups. Be sure to install the mesh tightly running from the top of the building to the bottom. Wrap the mesh around each corner to strengthen the corners. Don't forget to remove any temporary corner bracing you may have used first! After the entire exterior has been installed, adjust the window and door bucks to ensure they are perfectly plumb. Check them for level once again, and then attach the mesh to the face of the bucks.

Once the entire exterior is wrapped in mesh, the focus should turn to the roof assembly. A detailed explanation of roof construction is outside this report's scope. The roof must be installed as soon as possible to fully load the walls and protect the bales from inclement weather.

Finishing Up The Interior!

After the roof is complete, move to the inside and perform any necessary interior work, such as electrical, before adding the interior mesh.

If there are partition walls in the structure, install them at this time. Generally, it is best to support the roof only on the load-bearing walls because the wood partitions will not accept any settling, whereas the bales may continue to settle even if only in minute amounts. The differential settling will cause cracks in the plaster.

With all the interior work complete, the shaping of the bale openings and the interior meshwork is priority number one. Once the mesh and shaping are complete, use bale needles to sew the mesh through the wall to the mesh on the other side.

Tying the two mesh planes together strengthens the walls and ties the entire structure together. This is a vital step for anchoring the bales to one another and for the overall strength of the building. Use baling twine to tie the mesh every 24" on center, in both directions, or more if required by your local inspector. Use a Miller's Knot to tie the twine tight to the bales. After the mesh is fully secured, the structure can be plastered. The sooner the structure is plastered, the sooner it is protected from fire and weather.

That's It!

We hope you found this information useful. Obviously, this report is more of a rough outline than a true end-to-end guide. Our goal is to open your eyes to the possibilities of load-bearing and clear up some of the misinformation we see so much of nowadays. We recommend reviewing the relevant section in the International Residential Code (IRC), Appendix S, for standardized straw bale construction guidelines.

If you want to learn more about building your own load-bearing straw bale structure, please check out our best-selling Step-by-Step How-to Loading Bearing video in our Get Started! Combo Packages.

These videos are structured like a 7-day workshop, with Host Andrew Morrison to guide you through. They take you through every step of the load-bearing build process, from the bare earth of the site to getting the building ready for plaster. Clear and easy to follow in a true step-by-step fashion.

In Support,
Timbo & Team

PS. Remember… This is NOT rocket science. Once you get the techniques down on a small structure, you'll move on to bigger and better buildings before you know it!

PPS. We want to hear from you! Every guide, blog, or eLearning piece we produce has come direct from our straw bale community's questions - That means you too! Please feel free to leave comments or questions on any of our 500+ blogs or email us directly at info@strawbale.com