REVISED & EXPANDED

Build it with Bales

A Step-by-Step Guide to Straw-Bale Construction

VERSION TWO

Matts Myhrman and **S. O. MacDonald**

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Published by Out On Bale

Library of Congress Cataloging-in-Publication Data

Myhrman, M. A.; MacDonald, S. O.
Build it with bales: a step-by-step guide to straw-bale construction

ISBN 0-9642821-1-9 (paperback)

Version 2.0, second printing, December 1997, 4000 copies

Cover and text printed, respectively, with soy-based ink on 100% (20% post-consumer) and 50% (20% post-consumer) recycled paper by West•Press, Tucson, AZ.

Acknowledgments

We are grateful, above all, to our wives, Judy Knox and Nena I. MacDonald. When we procrastinated, they encouraged us gently to continue the work; when we digressed, they facilitated the necessary course corrections; when we despaired of having enough time to finish the task, they reminded us that we had all the time there was and helped us rearrange our priorities. They were, in fact, our valued partners in this endeavor.

Our thanks go to Orien MacDonald, whose steady pen and three-dimensional vision transformed wavering lines, sometimes scrawled on beer-stained napkins, into the visual viscera of this collaboration. Thanks also to Susan Van Auken, Gila neighbor and proofreader extraodinaire.

In this second edition, we despair of listing by name everyone for whose help, and/or contribution to the revival of bale construction, we are grateful. You know who you are, and even if you don't, we're grateful anyway and will see to it that the good *karma* you have earned is duly recorded. In all cases where specific material has been contributed by others, we have tried to remember to acknowledge this in the text and regret any omissions.

Disclaimer

The authors, Out On Bale, InHabitation Services, and the various individuals who have contributed details to this book make no statement, warranty, claim or representation, either expressed or implied, with respect to the construction details or methods described herein. Neither will they assume any liability for damages, losses or injuries that may arise from use of this publication. The details presented here are based on the best information available, but recent experience with the technique is finite and the information will not be appropriate for all conditions and/or climatic regimes. When in doubt, you are advised to consult with experienced people familiar with your local conditions and building codes.

Dedication

We dedicate this book to all the women and men who, without prior knowledge of the technique, were inspired to create human shelter with bales. The rest of us have, at best, only improved a little on their idea.

> *One thing we do know, that we dare not forget, is that better solutions than ours have at times been made by people with much less information than we have.*
>
> ... Wendell Berry

Matts' Five Bits

1. Honor your partners. Judy Knox continues to be my valued partner where "our dreams bind our work to our play". Whatever contributions we have made individually to the straw-bale revival reflect that partnership. Steve MacDonald continues to be my valued partner in this book. Wherever it encourages the would-be owner-builder with helpful advice and simple, low-cost, low-tech options, you see his influence. Wherever the design of the book deserves applause, you see his creativity.

2. Help with "the work of the commons". Send a tax-deductible contribution to the "DCAT-Straw-bale Testing and Research Fund" (via a check sent to The Development Center for Appropriate Technology, PO Box 41144, Tucson, AZ 85717). Subscribe to, and share your knowledge, experiences and resources with, The Last Straw, an ad-free journal supporting the international revival of straw-bale construction. Work with others, locally and regionally, to eliminate the institutional barriers to straw-bale construction.

3. Accept some "hard truths" and then "invest in the hope". The "green" building being done today is a very pale green, at best. And, as we are reminded by that lovable, "curmudgeon of cob", Ianto Evans, "All construction involves destruction". This said, we can either sign up for euthanasia or pull up our knickers and help each other do better. "Investing in the hope", trying to form "islands of decency" that can serve as examples for each other, doesn't guarantee success, but "investing in despair" almost certainly guarantees failure.

4. Support the whole "natural building " movement. Let's focus on the important commonalities of purpose, rather than the obvious differences in materials. Straw isn't the only "more sustainable" material out there, nor is it always the best one for a given situation. We need to seek joyful marriages of methodologies, selecting our materials from among those which are quickly renewable (e.g., straw), sustainably harvested (e.g., some bamboo and timber) or literally under our feet (e.g., stone, sand, clay). And even with just straw and earth, we can choose from options that form a continuous spectrum from straw alone, through various mixtures of straw and earth, to earth alone. Regenerative architecture is inclusive.

5. Begin to "Just say enough!". There is "no free lunch" when it comes to building. More importantly, the "lunch" that we in the over-developed world are demanding, will be paid for by our grandchildren. We are "eating" their rightful inheritance. Grafting a "more sustainable" technology like straw-bale construction onto the old paradigms creates only the illusion of change.

The "more is better" design syndrome challenges us to:

- create more space than we need.
- use more materials than necessary.
- assume a level of debt that enslaves us.

The "less is more" paradigm challenges us to:

- create the most functionality in the smallest space that actually serves our needs, rather than our egos.
- use no more materials than necessary.
- choose these materials carefully, minimizing the costs to our health, our pocketbooks and our planet.

To paraphrase a Chinese proverb, "If we do not abandon our present path, we will surely, and tragically, end up where this path leads." A better path can begin here, as I write, and you read, these words. The path is steep, but wide enough for all. Walking together, we can share the burdens and the blessings.

... Matts Myhrman, Tucson

SOM's Seven Bits

1. Keep it small. How much space do you really need? Be honest. Be creative with your space. Pretend you're building storage on a ship. Small is easy to heat...and cool. It's easy to keep clean. It takes up fewer of the Earth's resources and takes up less of its space. You finish the job, at a lower cost, so you can devote yourself to more useful work. If your teenagers need distance, have them build their own outbuilding or addition. They need to learn the skills, anyway.

2. Keep it simple. Control your impulses to make your house a complicated "artsy" statement. Simple, small and rectangular houses are beautiful when made of straw and other natural materials. Let form follow function. Let go of the idea of having a perfectly square, flat and sharp-edged building. Again, spend the time and money you saved by building with straw in other ways – restore the river, help a neighbor, play with the kids.

3. Build it yourself. Trust yourself. You can do it, especially if you build with straw. And especially if you follow rules 1 and 2. Read building books and magazines. Ask your builder friends questions. Build it on paper and as a model first. Track the details. Use your common sense. Be creative with your mistakes. Don't be intimidated by the "experts". Get all the stuff together and host a straw-bale "barn raising".

4. Stay out of debt. Pay as you go. Assemble the parts as you have the money...and time. Make your barn raising a "potluck."

5. Use local materials. Use more rock and adobe, less concrete. Use locally-milled lumber and poles. Your neighbor needs the work and you need to know firsthand what demands you're asking of the forests and fields.

6. Be energy conscious. Build to maximize passive heating/cooling strategies. Superinsulate your ceiling. Disconnect from the electric power grid. Use a solar pump. Build a composting toilet. Raise a garden. Throw out the television.

7. Make yourself a home. Don't just build yourself a house, make yourself a home. Stay where you are, if you can. Learn to be at home. Do no harm.

... Stephen O. MacDonald, Gila

Matts Myhrman lives with his life-and-business partner, Judy Knox (who helped proofread this guide), just south of The Little Taj in Tucson, Arizona. He is an extinguished geo-hydrologist who plans to spend his retirement promoting straw-bale and other alternative building methods (so what's new?).

Photo credit Nena MacDonald

Stephen O. MacDonald inhabits the Gila River Valley with wife Nena, along with a host of good neighbors—human and otherwise. Steve, with his love for rats, bats, and other wild creatures, tries to return each summer to his former home in Alaska as a research associate with the University of Alaska Museum.

Contents

Introduction

Why We Wrote the 1st Edition of This Guide

At some point in the yeasty revival of an "alternative" building method, the initial rapid pace of growth and change begins to slow down a little. Experimentation and learning will continue, but there now exists a body of knowledge that has already been validated by experience. Desktop publishing provides an economic way to start sharing such knowledge in printed form. It also allows future revision and expansion on a timely basis. So until someone chooses to publish the official, hard-backed, "complete and unabridged" bible of straw-bale construction, here's grist for the mill from two battle-scarred practitioners.

Why a 2nd Edition, Why Now?

In the three years since the birth of the 1st edition (a.k.a. *Version 1.0*), interest in, and use of, bales for building has increased beyond our wildest dreams. There are now bale structures in nearly all of the 50 states of the USA and in many other countries as well. The homes run the gamut from examples of "enough" (usually owner-built) to classic examples of "eco-over-consumption" (usually professionally designed and built to the client's specifications). The commercial buildings include workshops/studios (for potters, painters, woodworkers, blacksmiths), a counseling center, wineries, churches and bed-and-breakfasts.

From that great teacher, "experience", a great deal has been learned about using bales to make good buildings. Unfortunately, some of the lessons have come from the "school of hard knocks" (e.g., the flammability of loose straw, and even loose bales, under windy conditions). On a more positive note, creative practitioners around the world have come up with new options, new techniques, and new tools, many of which have been shared via *The Last Straw*—the journal of the straw-bale revival. We've been sticking notes about these things in manila folders until they wouldn't hold any more. What clearer message from the universe can two reluctant writers get? So, until the folders get full again, here's our revised, expanded and (hopefully) improved *Version 2.0*.

What's the Same and What's Different

Readers familiar with the first edition will quickly see that **many things are the same**. We haven't tampered with the basic organization of the information, since it reportedly worked well for our readers. We also continue here to devote more pages to the *Loadbearing Option* than to the *Non-Loadbearing Option*. We don't intend this to be a book that will provide detailed information on all the various ways in which you can use materials, other than bales, to support the weight of the roof. There are already good resources out there for this, and we refer you to some of them.

Since many things are basically the same for both approaches (e.g., stacking, pinning, surfacing), we ask that readers who have chosen the non-loadbearing option study first the material about the loadbearing option. Having learned about building straw-bale walls, they can then turn to the material on the non-loadbearing option for information about how to create a bale-superinsulated framework.

This said, let's look at **what's different** about this second edition:

• **Reductions**. We have reduced the coverage of some topics which can now be accessed elsewhere (e.g., testing and building codes).

• **Deletions**. Because each year's Summer Issue of *The Last Straw* will feature an updated, comprehensive directory of straw-bale resources of all kinds, we have eliminated the appendices that provided only a modest amount of such information in the first edition. "How-to" options that have fallen out of general use have also been eliminated.

• **Expansions**. Using all this newly available space, and more, we have added to the coverage of many topics. *Step 7, Surfacing the Walls* has undergone major expansion.

• **Additions**. We have added one totally new item that we hope will be of great use to our readers—an *Index*.

How This Guide is Organized

We've divided the main body of the guide into two parts: *Part One* deals with the things you may want to know, think about or do before you build; *Part Two* takes you through the building process. For both the *Loadbearing Option* and the *Non-Loadbearing Option*, we focus on the "model" structure depicted in the overview drawing placed at the beginning of these two sections.

Each *Step*, in both sections, starts off with our attempt to describe succinctly the generalized *Challenge* the builder faces at this stage in the process. This approach reflects our vision of this guide as a resource for the decision-making process you will step through on the way from your first fantasies to the first (of many) housewarming parties. At each major step in this process, the decision-making context will be unique. The *Challenge* facing you will have many possible solutions. Your shaping of the right solution for your unique situation will reflect many variables which only you can quantify or assess. Consider the following:

• your financial situation;

• your timetable;

• regional and micro-climatic factors and other physical characteristics of your building site;

• your own availability as a worker and your skill level in various areas;

• the availability of additional volunteer or paid labor at various skill levels;

• the depth of your concerns about the sustainability, regional availability, healthiness and life-cycle costs of various materials;

• the degree to which you want to use your time and labor to "buy" materials that have little or no monetary cost;

• your personal comfort level for cost-cutting innovation/greater risk as opposed to typical overbuilding/greater security;

• and, your aesthetic preferences, your willingness to pay for them, and their planetary costs.

The uniqueness of this combination of site, builder and building design suggests to us that a "cookbook" approach will not best serve you, our readers. There is no one "right" way to build a straw-bale structure or even to solve the problems to be faced at any given stage in the process. However, equipped with:

• a modicum of common sense;

• a clear understanding of each *Challenge* and of the unique properties of these big, fuzzy bricks as a building material;

• and, an array of options successfully used by earlier builders.

We can all hope to shape solutions that are uniquely "right" for us. As Amy Klippenstein and Paul Lacinski (1996) put it: "There are only individual solutions, arrived at by the thoughtful synthesis of regional identity and personal need into buildings that work for the inhabitants and the places where we chose to build them."

Each *Challenge* is followed by an arguably chronological *Walk-Through* of the mini-steps that we envision taking you through this stage in the construction of the "model" building. These are highlighted using the symbol "♣". Interspersed with these "model"-related mini-steps are chunks of predominantly non-visual, generic information relevant to the decision-making required during this *Step*.

Following the *Walk-Through* you will find textual and graphic coverage of an array of options that have been used successfully by straw-bale builders. Please note that our drawings are not necessarily "to scale", are not presented as backed by any "engineering", and are intended as general depiction of options, rather than "working drawings".

Throughout the guide we have tried to focus on those aspects of plan development and construction made unique by the decision to "build it with bales". Rather than repeating detailed information from other helpful sources, we provide literature citations (author, year of publication) for them. Complete citations are provided in the *Literature Cited* section near the end of the guide.

As you read this book you will encounter many places in which we refer you to an article in a back issue of *The Last Straw*. We realize that for some readers this may result in frustration, but we could see only three options:

1) lengthy, illustrated coverage that could stand alone;

2) a brief description or small drawing, accompanied by a citation;

3) or, no coverage of the matter at all.

Choosing 1) would have made the book too long and unconscionably expensive, while choosing 3) would have left it unacceptably incomplete. So we chose 2) as the least of the evils, hoping that you will be able to do one of the following:

• Borrow selected issues from a friend;

• find them at your local library or have your library get them through interlibrary loan;

• or, buy the appropriate back issues.

Ways to Use this Book

It's not heavy enough to be a good doorstop and the movie version isn't out yet, so you might as well read it. If you're new to straw-bale, we recommend that you start at the beginning and slog straight on through. Just remember to breathe occasionally and stop to volunteer for wall-raisings. If you already have experience building with bales, you may choose to use the *Table of Contents* and/or the *Index* to go directly to what most interests you, buffet-style.

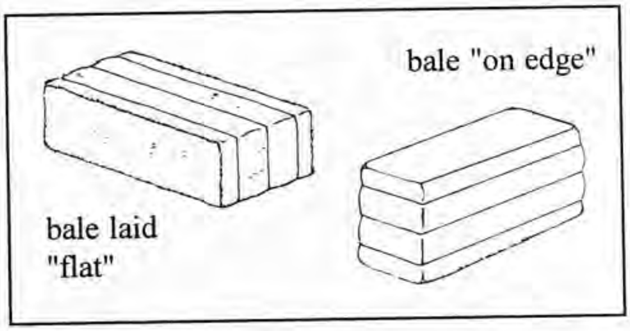
Roots

The saga of building human habitation with rectangular bales of hay or straw begins with the availability of mechanical devices to produce them. Hand-operated hay presses were patented in the United States before 1850, and by 1872 one could purchase a stationary, horse-powered baler. By about 1884, steam-powered balers were available, but the earlier horse-powered versions also continued to be used in the Great Plains at least through the 1920's.

We will probably never know any details of the first "permanent" bale-walled building used to shelter human beings. It seems likely, however, that it's creator was a homesteader, recently arrived on the treeless grasslands of the Great Plains and in desperate need of quick, inexpensive protection from a harsh climate. Although homesteading came to the Sandhills of Nebraska later than other parts of the Plains, it is here that we find the first, documented use of bales in a "permanent" building. The one-room, hay-bale schoolhouse, built in 1896 or 1897 near Scott's Bluff, survived only a few years before being eaten by cows.

The illustration, shown right (adapted from Welsch 1973), provides a visual description of the technique apparently used in many of the early buildings. Although Welsch's diagram doesn't show the ties, we know that bales were used both "flat" and "on edge" (see diagram top right) and that in some cases the bales were laid up with a lime/sand mortar. Of particular importance is the lack of any vertical posts to carry the weight of the light (generally hipped) roof.

Use of the technique in Nebraska, most widespread from about 1915 to 1930, appears to have ended by 1940. Of the approximately



seventy structures from this period documented by Welsch (1970), thirteen were known to still exist in 1993 and all but one of these (the oldest, from 1903) were still being lived in or used for storage.

The demise of the others can almost certainly be attributed to lack of maintenance resulting from abandonment. Once water begins to get through the roof and into the walls, a protracted death is inevitable.

Early Hay-Bale Building Techniques

(adapted from an illustration in Welsch, 1973)

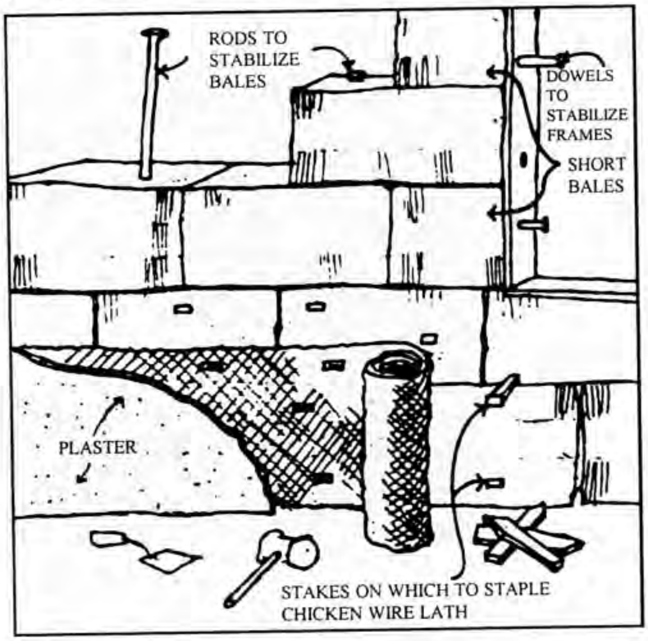


Photo by Matts Myhrman

The Burke House, near Alliance, Nebraska, built in 1903.

Photo by Matts Myhrman

Dr. Burritt's bale-insulated mansion, Huntsville, Alabama, finished in 1938.

... and Revival

After its abandonment in Nebraska by 1940, the idea of bale construction wandered in search of folks motivated to build inexpensive, energy-efficient shelter. Rather than dying out, the method kept popping up in new locations as modern pioneers learned of it or reinvented it.

Welsch's 1973 article in *Shelter* introduced the concept to a readership actively seeking alternatives. Another very important article, which appeared in the mainstream magazine *Fine Homebuilding* (Strang, 1983), described a small, post-and-beam studio designed and built by California architect Jon Hammond. In 1987, New Mexicans Steve and Nena MacDonald, two of the many individuals inspired by Strang's article, finally overcame their fears and built themselves a wonderful home that soon came to the attention of Matts Myhrman and Judy Knox.

Inspired by Steve's and Nena's home and philosophy, and building on the work of straw-bale pioneer David Bainbridge, Matts and Judy researched the historic hay- and straw-bale homes in Nebraska. Encouraged by what they learned, they went on to set up *Out On Bale*, a straw-bale-construction education and resource center and begin publication of *The Last Straw*, the journal of straw-bale construction. Meanwhile, Steve continued to help/teach others to build with bales and, with his son, Orien, developed the straw-bale construction primer that the first edition of this guide expanded on.

Meanwhile, the technique was being used almost exclusively in rural areas, where people could build "without benefit of codes". It became clear that in order for the technique to be legal in more populated areas, structural testing related to wind and seismic forces would have to be carried out. And so, for the first time, the concept of the "straw-bale commons" drew together a group of individuals willing to invest their money, time and energy for the benefit of the whole revival. This testing, begun in Tucson, AZ, has since been continued in other states (especially New Mexico) and other countries (see *The Last Straw*, Issue 15, page 19 for a list of reports on research and testing). Based on the Tucson testing, author Matts and David Eisenberg, began the arduous process of winning code approval for non-loadbearing <u>and</u> loadbearing straw-bale construction in Tucson and Pima County, AZ. Nearly two years later, in January of 1996, after seven drafts and intense negotiating, the document was approved. By that time, it was already being used to develop guidelines for jurisdictions in California, Nevada, and Texas (for details, see *The Last Straw*, Issue No. 15, page 16). Guidelines for the non-loadbearing approach only, have been approved in New Mexico (for a copy of either code, call *Out On Bale—By Mail* at (602) 624-1673, or *The Development Center for Appropriate Technology* at (520) 624-6628. The code phenomenon is slowly developing momentum, as new testing provides additional support for approval.

At the same time, as interest in the technique continued to grow, the need for written and videographic resources became acute. In 1994, two substantive stand-alone books became available (i.e., the first edition of this opus and *The Straw Bale House*). These have been complemented, for the "print-challenged" among us, by several pioneering videos produced by Catherine Wanek & Friends and by Steve Kemble & Carol Escott.

The unique combination of environmental, socioeconomic and natural resource issues facing our species as we approach the 21st century challenge us to expand the choices that will lead us toward more sustainable systems. We see this legacy of bale construction, passed on to us by our homesteading ancestors, as one such choice, a beautiful baby that got thrown out with the bath water, but managed not to go down the drain.

Virginia Carabelli's straw-bale home under construction near Santa Fe, New Mexico, spring 1991.

Photo by Matts Myhrman

Photo by David Eisenberg

Virginia Carabelli's straw-bale home after completion, autumn 1991.

Questions and Answers

Q. What do North American builders mean by the word "bale"?
A. They usually mean a variously-sized, rectangular bundle of plant stems, held together by two or three ties of wire or baling twine and weighing from about 35 to 95 pounds [16 to 43 kg]. Such bales generally consist of "straw", the dry, dead stems that remain after the removal of seed from harvested cereal grains. This is an annually renewable, little-valued byproduct of cereal grain production and great quantities are available for baling in many parts of the world.

Q. If straw-bale construction becomes very widely used (the authors' dream), won't it become difficult to find bales?
A. Basing our answer on the amount of baleable straw that is available every year in North America, we can answer with a resounding "No!". Assuming that about 140 million tons [about 127 metric tonnes] are available to bale each year and that we only use 25% of this, (the remainder being incorporated back into the soil for the uncertain benefits this might provide), we are left with a mere 35 million tons [31.75 million tonnes](Wilson 1995b). If we assume that all of this tonnage is made into 85 pound [about 38.6 kg], three-tie bales, we would have 823,529,411 bales at our disposal. Using the chart on page 20, we can determine that it will take about 260 three-tie bales to build the six-course high walls (about 8 feet, or 2.44 meters) of a modestly rectangular house having an interior square footage of 1500 square feet [about 139 square meters]. A simple division yields a stunning result. Using only one-quarter of the straw available each year in North America, we could build slightly more than 3 million such houses. Now that's a dream that even your authors find hard to assimilate.

Q. What would constitute the ideal "construction grade" bale?
A. It would be very dry, free from seeds, well-compacted, consistent in size and shape, and have a length that is twice the width. More on this on page 15.

Q. Will you always find such bales readily available anywhere?
A. Unfortunately not, but there is usually something grown within reasonable trucking distance that can be baled for building. However, in some areas the only bales available are the big, round ones. We trust that as demand develops globally for "construction grade" bales, entrepreneuring farmers will gladly meet the demand. Sources for bales can often be provided by agricultural extension agents, grain growers associations, tack and feed stores, zoos and race tracks. If you can work directly with a farmer, you have a better chance of getting bales that approach the ideal.

Q. Can a bale be too well-compacted?
A. From a strictly structural standpoint, the answer is no. However, as the bale density increases beyond a certain point, the insulation value per unit of thickness will begin to decrease. This results from a decrease in the amount of trapped air in the

bale, it being this trapped air that actually provides most of the insulating value of baled straw. Another disadvantage of very dense bales is that they become more difficult to penetrate with pins, stakes, dowels, etc., and they become harder to lift and stack (especially noticeable with the larger three-tie bales). Based on the above, the ideal bale for wall-building would have a calculated density no greater than about 8.5 pounds per cubic foot [about 137 kg per cubic meter]. For ceiling insulation, consider using the typically lighter two-tie bales. They will add less to the compressive load on the walls, and will provide more insulation value per unit of thickness.

Q. What are loadbearing versus non-loadbearing straw-bale walls?
A. Loadbearing walls carry a share of the roof loads, both "dead" (i.e., roof/ceiling materials) and "live" (e.g., snow, humans). Non-loadbearing walls, either because of the roof shape or the presence of a complementary framework, carry none of the roof weight. More on this later.

Q. Is straw-bale construction, particularly when done with loadbearing walls (a.k.a. Nebraska-style), inherently less costly?
A. A custom-designed straw-bale house built in mainstream fashion, by a contractor using only paid labor, cannot cost significantly less than a frame or masonry house providing the same interior space. From the standpoint of a cold-blooded, profit-margin-driven cost estimator, this is just an exterior wall system. The cost (labor and materials) attributable to the exterior walls of modest homes generally accounts for only fifteen to twenty percent of the total project cost. Using straw bales to replace insulation, and wood, metal, or masonry, can only affect this already small piece of the pie. The cost increases due to wider foundations and greater required roof area will offset some or all of these savings.

Real savings begin when the eventual owner and friends provide the labor for the wall-raising, wall-surfacing and for interior finishing. Additional savings can result from the use of recycled materials and those that cost little more than the owner's time (*e.g.*, salvaged lumber, locally available stone and earth). Further savings result wherever the owner-builder can substitute his/her own labor for paid labor or reduce costs by assisting a paid tradesperson.

The Straw Bale Workbook (Bolles 1996) contains a wealth of useful information, especially for California builders. In *Chapter 5*, the author provides a quantitative analysis comparing the 30-year and 100-year life-cycle costs for a conventionally built home with three straw-bale homes built with varying levels of both owner-contributed labor and bank financing. Suffice it to say that the bale buildings all had significantly lower costs, for both the 30- and 100-year cycles.

But even if a straw-bale house does end up costing as much as its counterpart, we believe it will still be a better house—quieter, more energy-efficient, more joyful to live in and, if designed with this in mind, less costly to the planet's ecological systems. For a brief look at how straw-bale construction rates ecologically, see Edminster (1997). For a 120-page report entitled *Investigation of Environmental Impacts: Straw-bale Construction* contact Ann Edminster at 115 Angelita Ave., Pacifica, CA 94004 or by e-mail at <74200.746@compuserv.com>.

Q. Okay, but what about termites?
A. A house built of baled straw is at far less risk than a wood-frame building, at least in North America and Canada, since virtually all the termites found there are specifically evolved to tunnel into and eat solid wood. Some builders do use some type of chemical or biological strategy, however, if only to protect wooden door and window frames and furniture. In areas where termites are a severe problem, or where a species of grass-eating termite is found, a metal termite shield should also be included in the foundation design. This is especially true when perimeter insulation is used, since termites use the insulation as an invisible corridor through which to reach the walls.

Q. All right, but what about spontaneous combustion in a baled straw wall?
A. Spontaneous combustion can occur in large, tight stacks of **hay**, baled while still too green and wet. However, we have been able to document no case of this occurring with straw bales stacked in a wall.

Q. Yeah, but what about fire?
A. As long as the bales are covered with plaster, a bale building will be extremely fire-resistant. Exposed bales and loose straw will burn under certain circumstances, however, so **caution is advised** (see page 18).

Q. Then what about vermin (i.e., rodents and insects)? Do the bales need any special chemical treatment to protect against them?
A. As in a frame structure, the secret lies in denying unwanted critters a way to get in and out of your walls. Build so as to isolate the bales (including the tops of the walls) and then regularly check and repair the exterior and interior wall surfacing. A few modern builders have used bales with lime incorporated into them or have dipped or sprayed the bales using a lime slurry or borate solution. Such measures may provide an extra level of insurance if maintenance of the wall surfacings is poor.

Q. Do I need to protect my stacked bales and/or exposed walls from musk oxen, llamas, slow elk (a.k.a. cows), or other roaming ruminants?
A. Yes, you do. Only if very hungry will they actually eat the straw, but the aroma of the straw seems to suggest to them the presence of something tasty just a little further into the bale. They'll use their horns and/or teeth to remove straw and can do major damage, especially at corners. If such critters have access to your building site, you would be well advised to fence it.

Q. Is straw-bale construction suitable for all climates?
A. The only serious enemy of straw is prolonged exposure to water in liquid form, since with sufficient moisture present, fungi produce enzymes which break down the cellulose in stems. High humidity, by itself, does not appear to be a problem, but few historic examples exist from areas characterized by consistently high relative humidity. However, one accessible example is the Burritt Mansion, part of a city park in Huntsville, Alabama. Built in 1930 in a climate characterized by high humidity and a 50 inch [1.26 m] average annual rainfall, it seems to be doing very well. Walls exposed to high humidity from within or without could experience condensation within the walls during periods of extremely cold temperatures. In such situations, moisture barriers (in reality, barriers to the movement

of air and water vapor) are sometimes used. They are most typically placed on, or within, the inner surface of the exterior walls, the ceiling, and the floors. For guidance on building in cold or cold/wet climates, see CMHC (1994), ACHP (1995), and Lstiburek (1997).

Airtight designs for cold climates often require the use of an air exchanger to maintain healthy indoor air quality and humidity levels. The use of exhaust fans to remove humid air from kitchens and bathrooms is typical.

High rainfall can be dealt with by proper design and detailing (e.g., adequate roof overhangs, flashing at window and door openings) and regular maintenance of the roof and wall surfaces. Since thick bale walls are highly insulative, the ideal climate for straw-bale construction may be semi-arid, with hot summers and cold winters, but successful examples exist in a wide range of climates.

Q. What about durability/longevity?
A. The evidence provided by existing hay and straw-bale structures built by Great Plains homesteaders as early as 1903 is irrefutable - bale houses, if properly built and maintained, can have a useful lifespan of at least 90 years, even in areas where high winds are common. Specialists in earthquake-resistant design have predicted that structures with properly pinned bale walls will be unusually resistant to collapse due to earthquake-generated motion.

Q. What keeps the roof of a straw-bale building from being lifted off by high winds?
A. Some straw-bale buildings consist of a "post and beam" framework wrapped (inside or out) or infilled with bales. In this situation, the roof structure is firmly attached to the horizontal beams, which are attached to vertical posts, which are themselves fastened to the foundation. In a loadbearing bale structure, there are no vertical posts. The "beams", in this type of building, can take many forms. When taken together, the "beams" are called a "roof-bearing assembly", or RBA. The roof structure is attached to the RBA, which is itself attached to the foundation.

Q. Does the use of bales impose limitations on the building design?
A. If a framework is used to carry the roof weight, the limitations are very few. One could conceivably build a multi-storied building with straw-bale infill or wrap a huge single-story building with non-loadbearing bale walls.

However, if one wishes to use the walls to carry the roof weight, the unique properties or idiosyncrasies of bales and of bale walls must be given serious consideration. Historic experience and structural testing suggest reasonable limits on the following: 1) the maximum height of walls; 2) the maximum length of wall between buttresses or braces; 3) the individual position and width of, and the total area of, the openings in any one wall, and 4) the maximum compressive load on any square foot of wall-top area. For a detailed treatment of the constraints on the loadbearing approach, see page 31.

Where more space is required than can be comfortably provided by a single-story square or rectangle (of acceptable length), builders have turned to "bent rectangles" (e.g., L-shapes, U-shapes or designs with fully surrounded courtyards). Another strategy is to create additional living space under a "sheltering roof" (e.g., cathedral, gambrel).

The use of bales does not automatically

disqualify any particular roof shape. However, many builders do try to avoid an essentially flat roof surrounded on four sides by parapet walls (a style particularly popular in the southwestern U.S.). Such roofs are notorious for leaking, especially if the drain holes become plugged and the "bathtub" begins to fill up. For those willing to sacrifice the parapet wall on one side, combining three parapets with a shed roof offers a possible compromise (see *Some Standard Roof Shapes* on page 75).

Whether or not they are loadbearing, bale walls are invariably thicker than those resulting from standard frame or masonry construction. In feeling, they more resemble double adobe or rammed earth walls. Unlike earth walls, they cannot practically be left permanently exposed, but a wide choice of coverings can be used (e.g., cement-, lime-, gypsum-, or clay-based plasters, gunite, metal or vinyl siding, wood paneling or sheathing, gypsum-based panels [e.g., sheetrock, drywall]). Many bale buildings have the exterior walls surfaced differently on the inside than on the outside.

Q. What about obtaining construction insurance and a building loan convertible to a mortgage? Do such houses have normal resale value and can potential buyers get financing?

A. The early straw-bale houses were uninsured, pay-as-you-build structures, sometimes by choice, sometimes by necessity. As the technique has gained credibility with building officials, lenders and insurers, it has become easier, generally speaking, to get permits, financing and insurance.

Unfortunately, the attitude toward straw-bale construction can differ greatly from one place to another, from one company to another and within a given company (from one region to another). Ask straw-bale homeowners in your area where they got financing or coverage.

In regard to financing, a written resource that may help you when things are looking bleak is *Empowering the Borrower* by longtime, alternative- construction guru, Eric Black (1996). Regarding insurance, an independent broker can sometimes locate a more adventurous carrier when the big guys wimp out.

The resale value of modern straw-bale homes is difficult to determine since very few have been put on the market. If, as we predict, a strong demand for pre-owned straw-bale houses develops, the hesitancy of insurers and lenders will decrease accordingly. Hot spots like the Santa Fe, New Mexico, area, Tucson, Arizona, and Crestone, Colorado, will be the places to watch.

Q. Will a straw-bale house cost less to heat and cool than a typical frame or masonry house, assuming comparable interior size, shape, ceiling insulation and solar orientation?

A. To provide more than a trivial answer to this question, we need to introduce the concept of R-values (called RSI-values where the metric system is used). These are numerical values which provide a quantitative measure of the resistance of a material or wall system to the transfer of heat through it by conduction (i.e., a measure of the degree of insulation it provides). The R-value per inch of thickness of dry, baled straw, for example, is on the order of 2.5 to 3 [RSI of 0.44 to 0.53], very close to that for fiberglass batts. Since thick house walls of dense materials (e.g., concrete, rammed earth) maintain interior comfort levels much better than their low R-values would suggest, a calculated "effective R-value" is used to predict the actual performance of such walls.

And now, to answer the question. Since typical construction seldom provides wall-system R-values greater than 20 [RSI-3.52], a well-built, straw-bale house with walls providing R-values of from R-40 to R-50 [RSI-7.04 to RSI-8.80] (depending on surface coverings, density of bales, thickness of walls, etc.) will obviously cost less to heat and cool than a typically built home. These energy savings, which will be proportionally greater for smaller designs than for larger ones, will accrue to the owner month after month for the lifespan of the building.

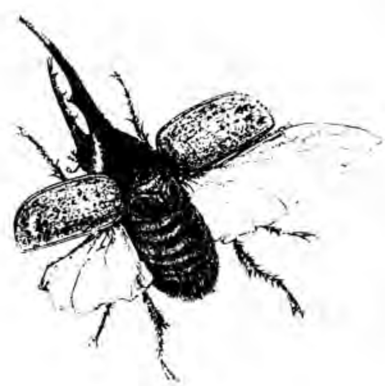
Q. Since straw bales are a relatively low-mass material, will they work well in a passive solar design?

A. The major physical components of an ideal passive solar design would include south-facing glazing, adequate thermal mass (to store and release heat on a 24-hour cycle), and an insulating exterior wrap to reduce heat loss to the outside. In straw-bale construction, proper placement of high-mass materials like plaster, brick, concrete, tile, or earth materials (e.g., adobe, cob*, rammed earth) in the interior of the structure provide the needed thermal mass, while the thick, highly-insulative, straw-bale walls greatly reduce heat loss by conduction. Straw bales on the outside, earth on the inside—we win, the planet wins.

* *A typical cob mixture consists of clay-rich soil, sand, a good deal of straw, and water. A stiff mixture of the above ingredients is formed into bread-loaf sized blobs which are slammed down onto the foundation, and then onto the previous layer, successively, to form a wall. See Bee (1997) or Smith (1997) for comprehensive presentations of the technique.*

Q. Strictly from the standpoint of maximizing the advantages and minimizing the disadvantages of straw-bale exterior walls, is there an ideal size for a simple, rectangular building?

A. This is obviously a very narrow way of looking at how big or small a building should be, but several factors point to dimensions that will provide an interior useable space of about 1200 square feet [111.5 square meters]. This size building has a ceiling area approximately equal to the internal surface area of the outside walls, so the impressive R- or RSI-value you get by stacking the bales is not overshadowed by ceiling area that one needs to insulate. At the same time, by having an interior as large as 1200 square feet [111.5 square meters], we have reached the point where the square footage of the structure's "footprint" is only 16.5% greater than that needed for a house having a 2" X 6" [about 5 cm X 15 cm] frame wall.



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